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Root Water Uptake of Sesame under Various Irrigation Regimes in New Alluvial Zone of West Bengal

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ABSTRACT

A field investigation was carried out on a sandy loam soil (Series, Gayeshpur, Great Group : Typic Ustockrept) at the Regional Research Station, Bidhan Chandra Krishi Viswavidyalaya, Gayeshpur, West Bengal to study the root water uptake by sesame (*Sesame indicum* L.) from various soil layers in the rhizosphere and its dynamics during the crop growth period under three different moisture regimes which were created by various irrigation scheduling, namely irrigation at 1.0 IW/CPE ratio, irrigation at 0.03 MPa at 15 cm depth and irrigation at critical growth stages.

During the crop growth stages, various rooting parameters like root length density, root distribution function were measured of the total rhizosphere under any regimes which gradually increased with the growth of the crop and became maximum at pod development stage and then gradually decreased. Variation in rooting density resulted in different root water uptake from various soil layers. In all the irrigation regimes, the uptake by the roots were always maximum in 0-15 cm layer contributing around 59% of the total uptake during the study period. However, the uptake was decreased with the soil depth. Within an irrigation cycle, the variation in root water uptake in any soil layer associated with the available moisture present in that particular zone.

Specific root water uptake of each soil depth during the study period varied due to difference in water uptake and root length density within an irrigation cycle, the values were decreased with time in the upper layer and increased in the lower layers due to redistribution of moisture within the profile and presence of active non suberised roots in the lower layer to meet the transpiration pool.

Not much significant variation in rooting parameters, root water uptake and specific root water uptake was observed among the irrigation treatments as all the irrigation treatments resulted similar moisture regimes due to optimum rainfall during the study period. However, maximum root water uptake of 19.35 cm duringthe study period was obtained when crop was irrigated at IW/CPE, 1.0, which contributed 68% of the actual evapotranspiration.

Introduction

Proper irrigation scheduling is one of the key factors for obtaining optimum crop yield in irrigated agriculture. The timely and adequate supply of water in the cropped field maintains favourable moisture regime in the rhizosphere within the soil profile and minimizes avoidable water losses and results optimum water use by the crop. Actual water use which is equivalent to actual evapotranspiration of any crop is sum of the total water extraction by the roots and soil evaporation and its dynamic nature during the crop growth period depends on the ability of roots to absorb soil water, capacity of soil to supply water to the root surface and on crop water demand. The crop water use may be obtained by measuring various components of field water balance and many researchers determined the same and its efficacy for number of crops under various inputs. However, information about the water uptake by roots in the rhizosphere under various soil moisture regimes for field crops is meager although it is useful to evaluate the ability of the roots to extract water and nutrient from different soil layers and helps in irrigation and nutrient management.

Sesame is an important oil seed crop of the country and attains its maximum potential yield under irrigated condition. The information regarding its actual water use as well as root water uptake is scanty, particularly for Eastern India.

It is therefore, considered to study the actual water use, root extraction pattern of various soil layers and yield of sesame crop under various irrigation schedulings.

Materials and methods

A field experiment was conducted with sesame (*Sesame indicum* L.) cv. Rama as a test crop during the *pre kharif* season of 2001 at the Regional Research Station of Bidhan Chandra Krishi Viswavidyalaya located at Gayeshpur, Nadia, West Bengal. The soil of the experimental field was sandy loam in texture (Typic Ustochrept) and the soil reaction is slightly acidic (pH - 6.7). Seven treatments of irrigation scheduling such as 1) Rainfed (T_1); 2) Irrigated at IW/CPE-0.6 (T_2); 3) Irrigation at IW/CPE-0.8 (T_3); 4) Irrigation at IW/CPE-2.0 (T_4); 5) Irrigation when ψ reach 0.03 MPa at 15 cm soil depth; 6) Irrigation when ψ reach 0.05 MPa at 15 cm soil depth; 7) Irrigation at critical growth stages (tillering + flowering + pod development). The trial was laid out on randomized block design with 3 replications. Irrigation of 5 cm were measured by a Parshall flume cumulative pan evaporation were monitored by a class A pan evaporimeter installed in the Research Station. Crop received 19.61 cm of rainfall during its growth period and the water table remains below 3 metre during the period of experimentation.

Soil moisture content of each irrigation treatments were measured gravimetrically up to 75 cm at 15 cm depth interval weekly and next day after rainfall. Mercury manometer type tensiometers in duplicate were installed in each treatment plot at 75 and 85 cm soil depth to monitor the hydraulic gradients at 75 cm for calculation of deep drainage of capillary contribution within the 75 cm soil profile. Unsaturated hydraulic conductivity of the experimental site was determined in a bare soil following the method described by Watson (1966). Actual evapotranspiration (AET) was determined by using the equation as

$$AET = P + DS \pm \int_{t_1}^{t_2} V_z \, dt$$

where P is the effective rainfall, ΔS is the soilmoisture depletion and V_z is the vertical flux across the lower boundry of the soil profile considered as rhizosphere.

In the present investigation, root water uptake of the sesame was estimated only for three wetter moisture regimes namely T_4, T_5 and T_7 for which tensiometer upto 75 cm soil depth at 15 cm depth intervals were installed and tensiometer readings were monitored daily. From these treatment plots, root samples were obtained at 15 cm depth interval on 45, 61, 76 and 91 days after sowing and its length were measured following the method of Tennant (1975). Interpolated values of root length during the study period were used to estimate the rate and pattern of root water uptake (r_z) at any given depth and time which was computed from the equation.

$$r_z = (d\theta/dt) \pm (\partial v_z/\partial z)$$

where θ is the soil wetness (m^3m^{-3}), t is the time (days) V_z is the vertical flux ($mmday^{-1}$) and z is the depth (cm) directed positively upward. Total water uptake from the root zone profile may be obtained by integrating the value of r_z for total rhizosphere.

Specific root water uptake for each soil layer were also estimated as

$$Q = r_z / L_v$$

where L_v is root length densityi.e. root length per unit volume of soil.

Results and Discussion

Actual evapotranspiration

Various hydrophysical properties of the experimental site were determined to calculate different components of field water balance for computation of actual evapotranspiration of the cropped soil (Table 1). During the study period (28-94 DAS) soil moisture depletion responded well with the soil moisture regime maintained in the profile due to differential irrigation schedulings. Depletion values were always more in wetter moisture regime and the maximum moisture depletion of 145.9 mm was obtained under T_4 treatment which received 4 irrigations while the

Table 1. Hydro-physical characteristics of the experimental field

Parameters	Soil depth (cm)				
	0-15	15-30	30-45	45-60	60-75
Bulk density (Mgm^{-3})	1.53	1.61	1.62	1.57	1.60
Particle size (%):					
Sand	69.7	78.2	80.1	70.3	80.3
Silt	20.2	14.3	11.2	18.2	10.2
Soil moisture retained (m^3m^3) at:					
0.01 MPa	0.32	0.30	0.29	0.32	0.30
1.5 MPa	0.13	0.11	0.10	0.12	0.10

Table 2. Field water balance of sesame under various irrigation regimes during the study period (28-94 DAS)

Irrigation regimes	No. of irrigation	Profile moisture change (mm)	Effective rainfall (mm)	Deep drainage (mm)	Capillary contribution (mm)	Ae $mmday^{-1}$
Rainfed	-	24.9	196.1	18.4	14.6	217.2
Irrigation at IW/CPE : 0.6	2	77.2	196.1	50.6	26.6	249.3
Irrigation at IW/CPE : 0.8	3	103.4	19.61	73.2	32.4	258.7
Irrigation at IW/CPE : 1.0	4	145.9	19.61	108.8	36.4	281.4
Irrigation at Ψ soul reached 0.03 MPa at 15 cm soil depth	3	91.6	196.1	63.2	37.6	264.5
Irrigation at Ψ soil reached 0.05 MPa at 15 cm soil depth	1	41.7	196.1	32.1	26.0	232.7
Irrigation at critical growth stages	3	119.9	196.1	81.3	38.7	265.4

lowest amount of 24.9 mm was recorded in rainfed plots (T_1). Treatments like T_3, T_5, and T_7, which received 3 irrigation each, depleted more or less equal amount of moisture. The influence of irrigation on soil moisture depletion may be ascribed to the increase in root proliferation and more vegetative growth. The results are in tune with the findings of Mitra and Pal (1999).

The amount of capillary contribution and deep drainage during the study period reveals more amount of water losses through deep drainage from the rhizosphere (0-75 cm) compared to the capillary contribution under all irrigation levels (Table 2). The predominance of deep drainage in this study was due to more rainfall received during the cropping period in addition to the irrigation water added to soil profile. Bandopadhyay and Mallick (2002) also obtained similar results in case of wheat crop. The highest amount of deep drainage amounting 108.8 mm was observed under T_4 treatment while it was only 18.4 mm under rainfed condition. Singh *et al.* (1999) also obtained similar results of crop fields in vertic inceptisol.

Similar to the deep drainage capillary contribution within the rhizosphere mostly at the end of any irrigation cycle responded to the soil moistures. Wetter moisture regimes always promoted more capillary contribution when the rhizosphere to meet the crop evaporative demand.

Among the different irrigation treatments, total amount of water lost through actual evapotranspiration during the studyperiod was highest (281.4 mm) under T_4 treatment while the lowest value of 217.2 mm was obtained under T_1 treatment and was 22% lesser compared to the wettest moisture regime. The amount of total evapotranspiration of the crop followed the irrigation treatment sequences as $T_4>T_7>T_5>T_3>T_2>T_6>T_1$ which corresponded to the time and amount of irrigation during the cropping period. Dutta and Das (2001) also found dependence of actual evapotranspiration or water use of some crops to the moisture regime of the profile.

Table 3. Root length density (cm root cm^{-3} soil) of sesame as a function of depth and time under various irrigation regimes

Soil depth	Days after sowing (DAS)			
	45	61	76	91
	Irrigation at $IW/CPE^{-1.0}$			
0-15	0.205	1.007	1.407	1.232
15-30	0.057	0.094	0.135	0.127
30-45	-	0.067	0.095	0.097
45-60	-	-	0.043	0.042
	Irrigation when ysoil reached 0.03 MPa at 15 and 08			
0-15	0.223	0.721	1.383	1.213
15-30	0.065	0.077	0.118	0.112
30-45	-	0.060	0.113	0.107
45-60	-	-	0.059	0.054
	Irrigation at critical growth stage			
0-15	0.180	0.601	1.616	1.442
15-30	0.050	0.072	1.142	0.136
30-45	-	0.064	0.064	0.110
45-60	-	-	0.052	0.052

Table 4. Root water uptake (cm^3 water cm^{-3} soil day^{-1}) of Sesame during the study period (44-94 DAS) under various irrigation regimes

Irrigation regimes	No. of irrigation	DAS when irrigated	Soil depth (cm)				
			0-15	15-30	30-45	45-60	Total
Irrigation at IW/CPE 1.0	4	33,52,64,79	0.753 (58.4)	0.342 (26.5)	0.141 (10.9)	0.052 (4.2)	1.290
Irrigation when Ψ soil reached 0.03 MPa at 15 cm soil depth	3	33,59,79	0.735 (58.9)	0.322 (25.8)	0.128 (10.9)	0.061 (4.90)	1.247
Irrigation at critical growth stages (Branching + Flowering + Pod development stage	3	45,60,72	0.760 (59.3)	0.308 (24.0)	0.106 (11.4)	0.067 (5.3)	1.281

Figures in parenthesis refer the percentage contribution of the layer.

Root length density

In the present investigation for determining root water uptake from various soil layers of the rhizosphere, layer wise roots were collected for determining root length density (L_v) and are given in Table 3.

The data of root length density reveals that on 45 DAS no roots was present below 30 cm which was found up to 45 cm depth on 61 DAS. However, roots were found upto 60 cm on 76 and 91 DAS. In general root length density values were always more in surface soil in all the irrigation treatments studied, which gradually decreased with depth. Among the irrigation treatments, T_4 showed higher root length density on 61 DAS compared to other two treatments which is attributed to the effect of irrigation to T_4 on 52 DAS which maintained wetter moisture regime while other two treatments subjected to relative soil moisture stress and later received irrigation around 60 DAS. Subsequently Lv values were similar on 7% and 91 DAS among the irrigation treatments although at all depth Lv values on 76 and 91 DAS among the irrigation treatments although at all depth Lv values on 76 DAS were more compared to 91 DAS because 76 DAS was under active flowering stage.

Root water uptake

Root water uptake pattern of various soil layers under different irrigation treatments followed similar trend as manifested by root length density (Table 4). In general, water withdrawal by the roots from 0-15 cm soil layer contributes 59% of the total withdrawal while it was only 5% from the bottom most layer (45-60). The roots of the other two layers namely 15-30, and 30-45 cm contributed around 25.5 and 11.0% respectively towards the transpiration pool. The data suggested that the magnitude of root water uptake from any soil layer is related to quantity of roots and moisture regimes present in that layer. Sarkar and Kar (1992) and Bandyopadhyay and Mallick (2000) also reported similar nature of root water uptake of some field crops. The overall differences of uptake values among the irrigation treatments were negligible due to adequate rainfall and similar moisture regimes created by irrigation scheduling.

Table 5. Specific root water uptake (cm^{-3} water cm^{-3} of soil cm^{-1} of root day^{-1}) of sesame as a function of depth and time

Days after sowing	Depth of soil (cm)			
	0-15	15-30	30-45	45-60
A. Irrigation at IW/CPE = 1.0(T_4)				
44-47	0.066	0.127		
50-56*	0.029	0.127		
57-63	0.013	0.066	0.049	
64-71*	0.015	0.074	0.050	
72-78	0.011	0.043	0.035	0.049
79-85*	0.012	0.044	0.043	0.066
86-94	0.009	0.038	0.036	0.048
B. Irrigation at 0.03 MPa ($_5$)				
44-47	0.038	0.106		
50-56	1.079	0.090		
57-63*	0.028	0.106	0.068	
64-71	0.017	0.0080	0.049	
72-78	0.0104	0.041	0.025	0.038
79-85*	0.012	0.047	0.033	0.051
86-94	0.009	0.043	0.026	0.048
C. Irrigation at critical growth stage (T_7)				
44-47	0.073	0.134		
59-56	0.050	0.134		
57-63*	0.032	0.0108	0.059	
64-71	0.015	0.058	0.044	
72-78	0.0087	0.031	0.031	0.054
79-85*	0.010	0.034	0.038	0.061
86-94	0.086	0.033	0.044	0.054

*Irrigation given

From the specific root uptake values (Table 5) it was found that the activity of the roots in 0-15 cm soil layer gradually decreased with time during the crop period inspite the profile was recharged with irrigation or rainfall. During the vegetative to flowering stage of the crop the activity of the roots in 15-30 cm layer was more and had capacity to draw more moisture from the rhizosphere. However, since the maturity stage (72 DAS onwards) root activities were increased in bottom most layer (45-60). From the data it was indicated that at later stage of the crop growth fewer younger roots present in the deeper layers were more active and capable of extracting more moisture from the surrounding soil by reducing its own root water potential while at the same time, roots of the surface layer although older were incapable of extracting sufficient moisture even after irrigation. Katayrma *et al.* (2000) also reported similar variation of specific root water uptake of number of cereals and legumes.

Seed yield and water use efficiency

Seed yield of sesame significantly responded to the soil moisture regimes created by irrigation application. The irrigation treatments, which received three irrigation produced, significantly higher yield compared to the treatments received one irrigation only during crop growth period. However, no significant improvement in seed yield was noticed due to addition of 4th irrigation over the treatments received 3 irrigations (Table 6). Highest seed yield of 9.61 qha^{-1} was obtained when 3 irrigations were applied at critical growth stage while minimum yield was recorded under rainfed condition. Variation in seed yield inspite of the same number of irrigations applied at different dates after sowing following a different approaches of irrigation scheduling is mainly attributed to differential moisture environment existed during the growth period.

Table 6. Effect of pod yield, total water use and water use efficiency of sesame under various irrigation regimes

Irrigation regimes	Pod yield (Kg ha^{-1})	Total water use (mm)	Water use efficiency kg ha^{-1} mm^{-1}
Rainfed	628	23.12	2.64
Irrigation at IW/CPE=0.6	749	26.33	2.85
Irrigation at IW/CPE=0.8	814	27.27	2.98
Irrigation at IW/CPE=1.0	917	29.54	3.10
Irrigation at Ψ soil 0.03 MPa	833	27.85	2.99
Irrigation at Ψ soil 0.05 MPa	651	24.67	2.64
irrigation at critical growth style	961	27.94	3.44
C.D. at (0.05)	89.4		

The data of water use efficiency pointed out that frequent irrigation not always effectively utilized by the crop, which was reflected in yield, and water use efficiency. In the present investigation, three irrigations at critical growth stages, found more efficient for optimum yield expensing minimum water. The findinds were in accordance with the work of Mitra and Pal (1999).

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Use of Hydrus-2D Model for Predicting Moisture Distributions and Evaporation Losses from Different Amount and Frequency of Drip Irrigation

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ABSTRACT

Drip irrigation is an efficient irrigation system for supplying water to crops and its managements rely on knowledge of water distribution within the wetted soil volume. Computer simulated models would be valuable to partially acquire this knowledge. In present study, numerical simulations of variably saturated flow using Richards equation-based Hydrus-2D model was carried out to evaluate the effects of different amounts and frequencies of drip irrigation on water distribution and evaporation losses in sandy soil under bare field condition. The experiment was conducted at Regional Research Station Balsamand of C C S Haryana Agricultural University, Hisar, India. It consisted of three treatments of different irrigation amounts (156, 124 and 77 litres per plot) and three treatments of irrigation frequencies (after 1, 2 and 5 days). A drip lateral was placed in the centre of each plot. Unsaturated soil hydraulic properties were described using van Genuchten-Mualem approach. Measured hydraulic properties were used to obtain model parameters. Simulated horizontal and vertical wetting fronts agreed well with those of experimentally measured wetting fronts. Moisture contents were measured at 0.1 m distance from centre of the dripper. Simulated moisture distribution agreed well to the measured values and hence, verified the applicability of the model in drip irrigated sandy soil. After verification, the model simulations were used to project the effect of different frequencies and amounts of drip irrigation on soil evaporation and water storage. The evaporation of the applied irrigation was 35.4% when irrigation was applied after 5 days and was 56.1% when irrigation was applied after 1 day interval. Soil water storage also increased with decrease in irrigation frequency. The percentage of soil water storage was maximum for applied irrigation of 124 litres in the present study. It implied that drip irrigation system may be made portable for high valued crops by keeping appropriate irrigation frequency.

Key words: Drip irrigation, irrigation frequency, modeling, water flow.

Introduction

Scheduling irrigation with limited water is big challenge to agricultural scientists to ensure crop productivity and sustained irrigation agriculture. Drip irrigation offers a great potential for meeting these needs because water is applied to a small surface area. However, a saturated or nearly saturated soil surface generally exists beneath each dripper. In arid climates, evaporation from the soil surface beneath drippers can be considerable due to hot and dry air blowing across the wetted surface (Bresler, 1975). Matthias *et al.* (1986) reported that evaporation accounted for about 35-40% of applied water over the week following the drip irrigation. Meshkat *et al.* (1999) observed increase in evaporation with increase in drip irrigation frequency. The optimum frequency of the drip irrigation depends on crop, soil type and water quality. Several studies reported increase in crop yield with frequency of drip irrigation with good quality water whereas, others suggested no significant increase or even decrease in crop yield as irrigation frequency increased (Buck *et al.*, 1982; Posternak and Malach, 1995). Hence, drip irrigation management scheme rely on the water information in the wetted soil volume. Part of the information can be obtained from computer models to partially replace expensive field experiments. Therefore, present study was carried out to 1) verify the applicability of Richards equation-based Hydrus-2D model to evaluate the moisture distribution pattern in drip irrigated soil and 2) predict the effects of different amounts and