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Water Flux into the Root Zone of Wheat vs Irrigation Amount under Shallow Water Table

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ABSTRACT

Field experiments were conducted to study the relationship between seasonal water flux into the root zone (0.5 m) vs irrigation amount with wheat (c.v. WH 283) under shallow water table conditions (<1.6 m) in sandy loam soil (Typic camborthid) at Hisar in *rabi* seasons of 1992-93 and 1993-94. The wheat crop was subjected to 5 post sowing irrigation treatments viz; I_0- no irrigation, I_1-one irrigation at CRI stage, I_2- two irrigations at CRI + IW/CPE = 0.3, I_3- three irrigations at CRI + IW/CPE = 0.6 and I_4- five irrigations at CRI + IW/CPE = 0.9 ratio. Water flux was calculated using predetermined hydraulic conductivity function calculated from moisture retention vs matric potential relationship using Darcy's equation of water flow. Capillary contribution of water from groundwater decreased with the increase in irrigation frequency. Under no post sowing irrigation condition, the average capillary contribution of water was equal to 1.68×10^{-9} m s^{-1} which decreased to 1.27×10^{-9} m s^{-1} under five post sowing irrigation treatment. Contrary to capillary contribution, rate of water loss due to total evapotranspiration increased from 35.07 to 55.97×10^{-2} m under five post sowing irrigation, over no post sowing irrigation treatment. Significantly higher yields were obtained up to two post sowing irrigation treatment in both the years of study.

Introduction

Capillary rise is known to be a major source of meeting the water requirement of crops in shallow water table conditions. The contribution of groundwater towards the crop evapotranspiration requirement in areas having fresh ground water proves to be a boon. In areas where canal irrigation has been introduced, the rise of water table is a regular phenomenon. Shallow water table at less than critical depth may reduce growth and yield of crops due to decreased rooting volume and insufficient oxygen availability. On the other hand, with deep water table, the growth is reduced because of the decreased water availability at relatively deeper water table. Thus, where the water table is deep, there is need of irrigation for optimum crop production while the shallow water table can supplement irrigation through water movement to the root-zone (Jat and Das, 1978). Little information is available on the response of wheat crop to irrigation in the presence of shallow water table depth (<3.0 m). The present study was, therefore, undertaken to determine the relationship between seasonal water flux into the root-zone (0.5 m) and irrigation amount in wheat production under shallow water table depth condition.

Materials and Methods

Field experiments were conducted during rabi seasons of 1992-93 and 1993-94 with wheat (c.v. WH-283) at CCS Haryana Agricultural University, Hisar. The mean monthly temperature is more than 34°C during 8 months in the year and less than 15°C in January. The average annual rainfall is about 400 mm which is highly erratic, most of which is received during rainy season from July to September. The mean daily evaporation ranges from 2.4 mm in December to 13.4 mm in June. The soil of the experimental site (Table 1) was sandy loam in texture (Typic Camborthid), very deep with some nodules of $CaCO_3$ approximately 1m below the soil surface. It was low in N, medium in P and rich in K content. The crop was subjected to five post sowing irrigation treatments viz: I_0- no post sowing irrigation, I_1-one post sowing irrigation at crown root initiation (CRI) stage, I_2- two post sowing irrigation at CRI + IW/CPE ratio of 0.3, I_3- three post sowing irrigation at CRI + IW/CPE ratio of 0.6 and I_4- five post sowing irrigation at CRI + IW/CPE ratio of 0.9. The variation of the groundwater table depth from soil surface in the area was measured by installing piezometers. The groundwater table depth varied from 1.10 to 1.65 and 0.85 to 1.40 m during rabi crop season of 1992-93 and 1993-94, respectively (Table 2). The sowing of wheat was done on 8th December and 6th November in 1992 and 1993, respectively, at a row spacing of 0.22 m. The soil moisture content was monitored regularly at an interval of a fortnight from 0 to 1.2 m soil depth at an interval of 0.2 m.

The groundwater contribution towards the water requirement of wheat was calculated from the flux density entering into the root-zone. It was assumed that the flux entering the lower boundary of the root-zone is the potential contribution of the groundwater to the crop requirement. For estimating

Table 1. Physico-chemical properties of soil

Property	Soil profile depth (m)					
	0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	1.0-1.2
Sand (%)	62.50	60.90	58.80	57.50	56.50	56.40
Silt (%)	18.90	20.10	21.10	22.10	22.00	22.90
Clay (%)	18.50	18.90	20.10	21.40	20.50	20.50
EC dsm^{-1}	0.17	0.15	0.20	0.25	0.25	0.24
pH (1:2)	7.80	7.80	7.80	7.90	8.00	8.00
O.C. (%)	0.34	0.28	0.25	0.20	0.10	0.10
Moisture retained (m^3 m^{-3}) at different suctions (MPa)						
0.0000	0.460	0.470	0.480	0.490	0.500	0.490
0.0001	0.360	0.365	0.370	0.380	0.385	0.390
0.0300	0.272	0.279	0.275	0.280	0.280	0.285
0.0750	0.230	0.230	0.235	0.240	0.242	0.242
0.2000	0.194	0.195	0.195	0.196	0.198	0.200
0.7500	0.140	0.142	0.144	0.145	0.146	0.150
1.0000	0.126	0.127	0.128	0.128	0.129	0.129

Table 2. Water table depth (m), different crop growth stages and days after sowing (DAS)

Growth stage	1992-93			1993-94		
	Depth	Date	DAS	Depth	Date	DAS
Sowing	1.10	08-12-92	0	0.85	06-11-93	0
CRI	1.15	02-01-93	26	1.00	30-11-93	24
Late tillering	1.05	20-01-93	44	1.05	19-12-93	43
Heading	1.13	07-02-93	62	1.05	07-01-94	61
Flowering	1.20	21-02-93	76	1.00	20-01-94	74
Milk ripe	1.27	12-03-93	95	1.15	15-02-94	100
Dough ripe	1.30	26-03-93	109	1.20	07-03-94	120
Ripe	1.58	08-04-93	122	1.35	17-03-94	130
Harvesting	1.65	28-04-93	142	1.40	08-04-94	150

the lower boundary of root-zone, it was assumed that the maximum root penetration for wheat is 1 m which is achieved in 90 days after sowing. For others, say 15, 30, 45 DAS the lower boundary of the root-zone was estimated with the help of following equation:

$$L = RD_m$$

where L stands for root-zone depth, R is the ratio of days after emergence to the total days required to achieve D_m i.e. maximum root-zone depth.

Results and Discussion

Soil moisture depletion and capillary contribution

The calculated average groundwater flux values of the profile at different times under different irrigation levels have been given in Table 3. These results indicate that, in general, after irrigating the crop at CRI stage, there was a constant decrease in water flux values with increase in irrigation frequency at all the stages of crop

Table 3 Calculated flux values (10^{-9} m s^{-1}) at different irrigation levels (average of two years)

DAS	Irrigation levels				
	I_0	I_1	I_2	I_3	I_4
0-14	0.407	0.405	0.405	0.405	0.407
14-28	0.567	0.568	0.567	0.566	0.556
28-42	1.075	1.058	0.943	0.933	0.932
42-56	1.654	1.611	1.487	1.470	1.464
56-70	2.149	2.139	2.130	2.095	1.852
70-84	2.811	2.760	2.621	2.477	2.184
84-98	3.341	3.111	2.894	2.662	2.475
98-112	2.557	2.544	2.477	2.407	1.557
112-126	1.736	1.409	1.409	1.163	0.926
126-140	0.513	0.405	0.404	0.406	0.359

growth. However, under no post sowing irrigation condition, these flux values were higher as compared to those where post sowing irrigation were given, because of prevalence of higher water content in the root-zone in the latter. The average upward flow rate of 1.68x 10^{-9} m s^{-1} up to active root-zone (about 0.5 m) was observed under no post sowing irrigation treatment. Under all the irrigation treatments, the flux values were less than 0.6x10^{-9} m s^{-1} up to 35 DAS. It increased to about 3.34x10^{-9} m s^{-1} i.e. peak flow rate, around 95 DAS. This may be due to the fact that the plants might have attained their maximum root proliferation at this growth stage leading to higher rate of moisture utilization from soil profile and thus, from groundwater. Flux density decreased with the increase in irrigation frequency. The average seasonal flux density values under nil, one, two, three and five post sown irrigation levels were observed as 1.68, 1.60, 1.58, 1.45 and 1.27x 10^{-9} m s^{-1}, respectively. These results are in close conformity with the results obtained by Williamson and Carrekar (1970), Ghildyal and Chaudhary (1977) and Jat and Das (1983). The soil moisture depletion was estimated during crop growth period using soil water content in the crop root-zone from the sowing to the harvest of the crop. The seasonal soil moisture depletion was highest under I_0 as compared to that of post sown irrigated plots (Table 4). However, least seasonal moisture depletion was observed under I_4.

Evapotranpiration and yields

As shown in Table 4, the ET rate increased with increase in post sowing irrigation frequencies. Seasonal ET varied from 35.07 to 55.97x10^{-2} m. Under five post sowing irrigation conditions the increase in ET was about 37 per cent higher over no post sowing irrigation treatment. The corresponding increase for one, two and three post sowing irrigation levels were about 28, 22 and 14 per cent, respectively. The variation in crop ET rate was influenced by the irrigation scheduling under present study. These observations are similar with the observations of Rajput and Yadav (1974), Ghosh *et al.* (1975), Lal and Sharma (1976) and Jat and Das (1978).

A significant increase in grain yield (Table 4) was observed up to two post sowing irrigation treatments and beyond this, the yield did not increase significantly. It may be concluded from the study that near maximum wheat grain yield in semi-arid tract of northern India (Hisar tract) under shallow water table depth condition (<1.6 m) can be achieved with only two post sowing irrigation.

Table 4. Evapotranspiration and grain yield under different irrigation levels

Irrigation level	Moisture depletion	Rainfall (m)	Irrigation (m)	Total flux (m)	ET (m)	Grain yield (kg ha^{-1})
I_0	0.1052	0.0422	0.00	0.2033	0.3507	2783
I_1	0.0966	0.0422	0.06	0.1936	0.3924	4294
I_2	0.0881	0.0422	0.12	0.1854	0.4357	5364
I_3	0.0810	0.0422	0.18	0.1764	0.4796	5475
I_4	0.0638	0.0422	0.30	0.1537	0.5597	5581
CD (P=0.05)						0938

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