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Short communication

Estimating crop water requirements for irrigation scheduling in different crops in humid subtropical agro-climate of Western Himalayas

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Deficiency of water in the rhizospheric area of soil results in reduced crop growth adversely affecting crop yield. Thus, the objective of irrigation is to maintain the adequate moisture content in the root zone, such that the crop yield is not adversely affected (Kumar *et al*. 2012; Kumar *et al*. 2020). However, in the current scenario of climate change, rapid industrialization and population increase, there is tremendous pressure on water resources both quantitatively and qualitatively (Rao and Poonia 2011). Hence, precise allocation of water resources considering the crop water requirement and proper knowledge of soil composition is essential to attain optimum yield, and maximum water use efficiency (Mehta and Pandey 2016). The crop water requirement is generally crop evapotranspiration (ET_c) considering atmospheric water loss through plant transpiration and soil evaporation simultaneously (Kumar 2017; Poddar *et al*. 2021). There are several methods for direct estimation of ET_c which includes energy balance, microclimatological methods, field water balance and Lysimeters. However, the indirect methods includes measurement of reference evapotranspiration and crop coefficients (Chaudhari *et al*. 1999). Estimating water balance in the Lysimeter is the most reliable and useful approach for determining actual ET_c under field conditions (Kashyap and Panda, 2001). Hence, the present study was undertaken for *rabi* (Wheat, Indian mustard, Potato) and kharif (Maize, Sorghum, Guar) crops grown in a humid subtropical agro-climate of western Himalayas with a specific objective to estimate the ET_c using the lysimeter water balance approach.

Description of the field experiments

An experiment was conducted in the campus of National Institute of Technology Hamirpur, Himachal Pradesh, India situated at 3162.8‘68°’’ N latitude and 7613.3‘52°’’ E longitude, and 895 m amsl altitude. The field trials were conducted during the 2017 – 2019 crop growing seasons. The crops considered in the experimental study were wheat (*Triticum aestivum*), Indian mustard (*Brassica Juncea*), potato (*Solanum tuberosum L.*), maize (*Zea mays*), sorghum (*Sorghum bicolor L. Moench*) and guar (*Cyamopsistetragonoloba L.*). The details of the crop type, crop duration, growth stages, and irrigation events for the present study are illustrated in Table 1. Local agronomic practices (i.e., land preparation, manuring, fertilization) were followed while conducting experiments on different crops.

Water balance method

Two drainage type lysimeters (1.5×1.5×2 m) were installed separately and rim of the lysimeter was kept 0.1 m above ground level to prevent surface runoff. A land gravel filter (0.3m) was provided at the bottom of the lysimeter to facilitate drainage to a calibrated collector. A soil moisture capacitance probe was used to measure soil moisture content at 0.1 m interval till 1.6 m in the soil profile on daily basis. The applied irrigation was measured using a discharge meter installed at the outlet of the water tank. The daily rainfall was recorded using a tipping bucket rainfall.

The water balance method assesses the incoming and outgoing water flux into the crop root zone. Since drainage type lysimeters were used, ET_c was obtained for long periods. The ET_c was determined using the water balance equation (Bandyopadhyay and Mallick, 2003) as:

$$P + I = D + ETc + RO \pm \Delta S \quad (1)$$

where, P = precipitation (mm), I = irrigation (mm), D = Drainage from lysimeter (mm), RO = runoff (mm), and ΔS = change in soil moisture storage (mm). ΔS for a specific depth (d_z) for a specific time period is computed as:

Table 1: Details of the crop duration, growth stages, and irrigation days pertaining to *Rabi* and *Kharif* crops grown in the field

Crop	Variety	Date of sowing	Date of harvesting	Duration	Growth stages (Days)				Irrigation provided (DAS)	Spacing (cm)
					I	II	III	IV		
Rabi Crops										
Wheat (*Triticum aestivum*)	Super (6776/PB)	3rd Jan,2017	15th May, 2017	133	25	36	45	28	26th, 44th, 56th,80th, 96th, 116th	20x5
Indian mustard (*Brassica juncea*)	VL-804	22nd Jan, 2018	14th May, 2018	113	19	32	38	25	11th, 25th, 37th, 59th, 91st	40x15
Potato (*Solanum tuberosum L.)*	Kufri Himsona	7th Jan, 2019	6th May, 2019	120	22	32	38	29	21st,40th, 52nd, 64th,87th, 104th	45x15
***Kharif* Crops**										
Maize (*Zea mays*)	Maize 7074 (HYBRID)	20th May, 2017	10th Sept, 2017	114	20	34	36	24	22nd,36th, 48th, 64th	50x20
Sorghum (*Sorghum bicolor L. Moench*)	TX 610	16th May, 2018	22nd Sept, 2018	130	21	35	39	35	22nd, 48th, 75th, 93rd	30x15
Guar (*Cyamopsistetr-agonoloba L.*)	Agaita Guara - 112	28th May 2019	1st Sept, 2019	97	20	26	28	23	26th, 53rd, 81st	25x15

$$(\Delta Sz) = (\theta z,final - \theta z,initial)\times dz \tag{2}$$

where $\theta_{z,\ final}$ and $\theta_{z,\ initial}$ is the final and initial moisture content, respectively in the soil profile in a discrete-time interval.

ET_c variation in rabi crops

The seasonal ET_c of *rabi* crops, i.e., Indian mustard, wheat, and potato, was 165.8 mm, 242.7 mm, and 308.7 mm, respectively (Table 2). The precipitation received during the crop period of wheat, Indian mustard, and potato was 112.4 mm, 114.5 mm, and 108.5 mm, respectively. The amount of irrigation required for wheat, Indian mustard, and potato, was 195.0, 140.0, and 240.0 mm, respectively. This indicated that the irrigation requirements of *rabi* crops are higher than the precipitation received during the crop period. In the case of wheat and potato, the irrigation supplied was almost twice the precipitation, indicating that nearly two-thirds of the crop water requirements were fulfilled by irrigation. The contribution to the groundwater during the *rabi* crop season was quite low as compared to the amount of water received. The variation of stage-wise ET_c for *rabi* crops considered has been shown in Table. 2. It is evident from the table that the ET_c during the initial and mid-season stage for *rabi* crops was quite similar. However, during the crop development stage, the ET_c for potato was significantly higher than wheat and Indian mustard. During the late season, the ET_C for wheat was higher as compared to the other two crops.

ET_c variation in kharif crops

The seasonal ET_c of *kharif* crops, i.e., maize, sorghum, and guar, was 502.9 mm, 518.9 mm, and 494.7 mm, respectively (Table 2). The amount of precipitation obtained during the crop period of maize, sorghum, and gaur, was 1052.5, 1059.3, and 1124.3 mm, respectively, which is comparatively much higher than the *rabi* crops. The total amount of irrigation required for maize, sorghum, and gaur, were 10.0, 31.4, and 20.0 mm, respectively, which is substantially less than the irrigation required for *rabi* crops. This also indicates that the irrigation requirements of *kharif* crops were very low as compared to the received precipitation. More than 95 per cent of the crop water requirements were fulfilled by the precipitation alone. The groundwater contribution during the *kharif* crop season was substantially high. The variation of stage-wise ET_c for *kharif* crops considered has been shown in Table 2. The ET_c for *kharif* crops during the initial and late-season stages was nearly the same. The ET_c for sorghum was significantly low during the crop

Table 2: Crop growth stage-wise water balance components for *Rab*i and *Kharif* crops

Water balance component	Initial	Development	Mid-season	Late-season	Total (mm)	Initial	Development	Mid-season	Late-season	Total (mm)
			Wheat					**Indian mustard**		
P	0.0	6.8	104.6	1.0	112.4	6.0	10.5	11.5	77.0	105.0
Ir	20.0	70.0	35.0	70.0	195.0	20.0	60.0	70.0	20.0	170.0
Dr	8.9	17.5	39.5	4.0	69.9	6.2	7.9	5.4	51.1	70.6
ΔS	-7.6	21.2	-10.5	-8.3	-5.2	-1.6	4.7	-9.7	24.4	17.8
ET_c	18.7	38.1	110.6	75.3	242.7	21.4	57.9	85.8	21.5	186.6
			Potato					**Maize**		
P	0.0	6.8	4.7	97.0	108.5	152.4	385.7	241.4	273	1052.5
Ir	20.0	140.0	80.0	0.0	240.0	0.0	10.0	0.0	0.0	10.0
Dr	4.5	6.0	5.4	42.0	57.9	101.2	176.4	88.4	187.6	553.6
ΔS	-10.6	-11.4	-21.7	15.6	-28.1	30.0	-16.4	-18.3	10.7	6.0
ET_c	26.1	152.2	101.0	39.4	318.7	21.2	235.7	171.3	74.7	502.9
			Sorghum					**Guar**		
P	61.5	203.5	552.8	241.5	1059.3	132.6	485.7	280.4	225.6	1124.3
Ir	31.1	0.0	0.0	0.0	31.1	20.0	0.0	0.0	0.0	20.0
Dr	39.2	96.2	284.2	129.5	549.1	95.2	252.3	165.2	161.5	674.2
ΔS	-2.0	12.3	10.2	1.8	22.3	25.0	8.4	-29.3	-28.7	-24.6
ET_c	55.4	95.0	258.3	110.2	519.0	32.4	225.0	144.5	92.8	494.7

Note: P - Precipitation, I_r-Irrigation, D_r- Percolation to groundwater, ΔS - Change in soil moisture storage, and ET_c - Crop evapotranspiration

development and significantly high during the mid-season stage when compared to maize and guar crops. The ET_c variation of maize and guar crops was similar during all stages of crop growth.

The seasonal ET_c in the case of *rabi* crops was highly variable, but for *kharif* crops, it was nearly similar. The stage-wise ET_c variation was different for each *rabi* crop considered. For *kharif* crops, maize and guar followed similar stage-wise ET_c, whereas sorghum followed a different pattern. The estimated ET_c of different crops may further help in planning of optimal irrigation schedules in the humid sub-tropical agro-climate of the western Himalayas.

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