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Consumptive water footprints and water use efficiency of two potato cultivars under different planting dates with different irrigation frequencies

Amit Biswas, Subhrajyoti Chatterjee, M Viswanath, Anindita Roy and Suprajit Roy

Abstract
A farm level research study was conducted with two different potato cultivars (i.e. *Ashoka* and *Jyoti*) at research farm of Bidhan Chandra Krishi Vishwavidyalaya during the period of November-March to assess the impact of different irrigation frequencies on consumptive water footprints (CWF) and crop water use efficiency (CWUE) of those varieties. The total experiment was conducted under two different planting dates (20th and 29th November) during the above period. The soil was sandy-loam with medium land situation. The plot size was 4.5 m × 3.7 m. The maximum yield recorded under 20th November was 50.56 t ha^{-1} and under 29th November was 63.65 t ha^{-1}. Irrespective of irrigation level and cultivar, the highest average seasonal CWF was estimated at 37.43 m^3 t^{-1}under 2nd planting date (29th November); whereas, the first planting date exhibited 11% lower CWF. But, the CWUE was found to be maximum (41.10 kg m^{-3}) under 1st planting date; whereas, the second planting date presented about 7% lower WUE. Hence, the study recommended early planting of potato at the study region to obtain better CWUE with comparatively lower CWF.

Keywords: Consumptive water footprint, irrigation, potato, water use efficiency

Introduction
With global total output of 368 M metric tonnes per year, potato is one of the major crops feeding the global population and is the most important ration composition in India. It also accounted for 20-30 M metric tonnes rise in potato demand by 2030 (Scott *et al.* 2019) [13] in India. A majority of potato in the cou0 ntry is cultivated during dry season and total water demand of potato production is fulfilled mainly by irrigation water (Brar *et al.* 2019) [1]. But, the limitation and shortage of water resources have become key constraints in the development of irrigation (Kumar *et al.* 2018) [6]. This problem is particularly serious in India, an important developing country with the 2nd largest population (Sun *et al.* 2012, Cao *et al.* 2017) [14, 2] after China. Objective evaluation of real water consumption during crop production is reliable way to promote an efficient and sustainable use of water resources in agriculture (Rathinavel *et al.* 2020) [10]. Consumptive water footprint (CWF) is a comprehensive measure of water consumption by human activities and can be used to evaluate the effect on water volume (Pellicer-Martínez and Martínez-Paz 2016, Scherer and Pfister 2016) [9, 12]. The CWF of crop production is the volume of fresh water that is consumed during the crop growing period (Cao *et al.* 2018). Considering the advantages of CWF, the research on CWF of agricultural crop production has become a burning research area. The evaluation of CWF was conducted before in multiple regional scales from an irrigation district (Suttayakul *et al.* 2016) [15], a city level region (Chu *et al.* 2017) [3], a river basin (Roux *et al.* 2017) [11], a country (Zhuo *et al.* 2016b) [18] to the global perspective (Hoekstra and Mekonnen 2012, Lovarelli *et al.* 2016) [4, 7]. The CWF values for 126 crops and derived crop products at provincial level of the world during 1996 to 2005 can be easily gained according to Mekonnen and Hoekstra (2010) [8]. However, almost all reported value of the WF of crop production in the previous studies was obtained through models of many types, including hydrological model, water balance model and crop water productivity model. They were all more or less based on assumptions on inputs that resulted in uncertainties across different models as well as among certain individual estimations (Tuninetti *et al.* 2015) [16]. Although modelling is efficient in time and economy to measure costs for large scale WF assessment, field or farm level measurement is the real-time measurement of CWF related parameter and it is clearly more accurate than the model

simulation results and can provide more practical reference for individual farmers (Johannessen *et al.* 2015) [5]. In this paper, irrigated potato was studied with different irrigation scheduling, and a field measurement based method was introduced for CWF assessment of two different potato cultivars under different planting dates.

Material and Methods

The experiment was carried out at "C" block research farm (lat - 22.5^0 N, long - 89^0 E and altitude 9.75 m above msl) of Bidhan Chandra Krishi Vishwavidyalaya at Kalyani during the period of November-March. The soil of the study site was sandy-loam type with medium land situation.

Experimental design and treatments: The treatments were distributed in a split plot design, where the date of planting was considered as the main plot treatment, the irrigation levels as sub plot treatment and varieties as sub-sub plot.

The treatment combinations were as follows

Main plot treatment (Date of planting; D)

D_1 – 20th November

D_2 – 29th November

Sub plot treatment (Irrigation level; I)

		IW/CPE
I_1	=	1.40
I_2	=	1.20
I_3	=	1.00

Total plot size was 4.5 m × 3.7 m. In a particular plot, the spacing is 45 cm × 15 cm.

Sub-sub plot treatment (Potato variety; V)

V_1 – *Ashoka*

V_2 – *Jyoti*

Methods and Observation

Soil moisture content: Gravimetric soil moisture was measured before and after irrigation and also at the initial and harvest time of potato crop.

Yield and yield attributes: The crop was harvested on two phases. In the first phase, crops were harvested on 16th February. It was 88 dates after planting (DAP). In the other phase, crops were harvested on 3rd March. It was 95 DAP.

Consumptive water footprint (CWF): Consumptive water footprint (CWF) refers to the ET_C during the crop growth period (Xinchun *et al.* 2018) [17]. The CWF was estimated by the following equation:

$$\text{CWF}\ (\text{m}^3/\text{t}) = \frac{\text{ET}\ (\text{m}^3/\text{ha})}{\text{Yield}\ (\text{t/ha})} \qquad (1)$$

Water use efficiency (WUE): The seasonal WUE of potato was estimated by the following equation

$$\text{WUE}\ (\text{kg/m}^3) = \frac{\text{Yield}\ (\text{kg/ha})}{\text{Irrigation+Rainfall}\ (\text{m}^3/\text{ha})} \qquad (2)$$

Results and Discussion

Estimation and analysis of seasonal evapotranspiration (ET) by soil water balance method: It was observed from Table 1 that the variation in SWS (change in soil moisture storage) value was more in case of D_1 than D_2. The maximum values of SWS were 52.14 under I_3 V_1 and 77.77 under I_1 V_1 for D_1 and D_2 respectively. The results again revealed that the maximum ET values were 162.14 mm under I_3 V_1 and 229.17 under I_1 V_1 for respective D_1 and D_2.

For SWS value the decreasing order is

In case D_1: $I_3 V_1 > I_1 V_2 > I_2 V_2 > I_3 V_2 > I_2 V_1 > I_1 V_1$

In case D_2: $I_1 V_1 > I_3 V_1 > I_2 V_2 > I_2 V_1 > I_1 V_2 > I_3 V_2$

For ET value the decreasing order is

In case D_1: $I_3 V_1 > I_1 V_2 > I_2 V_2 > I_3 V_2 > I_2 V_1 > I_1 V_1$

In case D_2: $I_1 V_1 > I_1 V_2 > I_3 V_1 > I_2 V_2 > I_2 V_1 > I_3 V_2$

Thus the values of SWS and ET varied from one treatment to another.

Table 1: Estimation of seasonal evapotranspiration (ET) by soil water balance method

Treatment	SWS	Irrigation (mm)	Rainfall (mm)	ET (mm)
$D_1 I_1 V_1$	28.78	110	0	138.78
$D_1 I_1 V_2$	48.12	110	0	158.12
$D_1 I_2 V_1$	33.24	110	0	143.24
$D_1 I_2 V_2$	45.80	110	0	155.80
$D_1 I_3 V_1$	52.14	110	0	162.14
$D_1 I_3 V_2$	39.64	110	0	149.64
$D_2 I_1 V_1$	77.77	150	1.40	229.17
$D_2 I_1 V_2$	44.20	150	1.40	195.60
$D_2 I_2 V_1$	47.48	120	1.40	168.88
$D_2 I_2 V_2$	61.99	120	1.40	183.39
$D_2 I_3 V_1$	65.82	120	1.40	187.22
$D_2 I_3 V_2$	40.62	120	1.40	162.02

Yield, CWF and WUE of Potato crop: In the present study, it was observed that average potato yield was at the highest level (50.15 t ha^{-1}) under 2nd planting date (D_2: 29th November) irrespective of variety and irrigation level and it declined by 5 t ha^{-1} (on an average) when the crop was planted 9 days earlier (Table 2).

Table 2: Yield, CWF and WUE of Potato crop

Treatment	Yield (t ha^{-1})	CWF (m^3 t^{-1})	WUE (kg m^{-3})
$D_1 I_1 V_1$	45.17	30.72	41.06
$D_1 I_1 V_2$	50.28	31.45	45.71
$D_1 I_2 V_1$	44.27	32.36	40.25
$D_1 I_2 V_2$	48.97	31.82	44.52
$D_1 I_3 V_1$	50.56	32.07	45.96
$D_1 I_3 V_2$	31.98	46.79	29.07
Average	45.21	33.46	41.10
$D_2 I_1 V_1$	63.65	36.00	42.04
$D_2 I_1 V_2$	55.26	35.40	36.50
$D_2 I_2 V_1$	41.52	40.67	34.20
$D_2 I_2 V_2$	52.34	35.04	43.11
$D_2 I_3 V_1$	50.24	37.27	41.38
$D_2 I_3 V_2$	37.90	42.75	31.22
Average	50.15	37.43	38.08

Irrespective of date of planting and variety, the highest average yield (53.59 t ha^{-1}) was attained under I_1 treatment, which declined by 13% under I_2 treatment. The same was at its lowest peak (42.67 t ha^{-1}) under I_3 treatment. Among two cultivars, *Ashoka* variety produced the highest average yield (49.23 t ha^{-1}) and it declined by 6% under Jyoti variety.

Irrespective of variety and irrigation level, the highest average ET (187.71 mm) was recorded under 2nd planting date (D_2: 29th November) and it was around 36.32 mm lower when the crop was planted 9 days earlier (Table 1). Irrespective of date of planting and variety, the highest average ET (180.42 mm) was attained under I_1 treatment, which declined by 10% and 8% under I_2 and I_3 treatment respectively. Among two cultivars, the ET value of *Ashoka* variety was at the highest level (171.57 mm) and it declined by only 4 mm under *Jyoti* variety. Table 2 depicted that irrespective of variety and irrigation level, the CWF was 33.46 m^3 t^{-1} under 1st planting date (D_1: 20th November) and it increased by 3.97 m^3 t^{-1} (on an average) when the crop was planted 9 days later (Table 2). Irrespective of date of planting and variety, the highest average CWF (39.72 m^3 t^{-1}) was attained under I_3 treatment, which declined by 12% under I_2 treatment and 16% under I_1 treatment. Among two cultivars, the average CWF of *Jyoti* variety was at the highest level (37.20 m^3 t^{-1}) and it declined by 6% under *Ashoka* variety.

Table 2 also indicated that irrespective of variety and irrigation level, the WUE was at the highest level (41.10 kg m^{-3}) under 1st planting date (D_1: 20th November) and it declined by 3.02 kg m^{-3} (on an average 7.34%) when the crop was planted 9 days later (Table 2). Irrespective of date of planting and variety, the highest average WUE (41.33 kg m^{-3}) was attained under I_1 treatment, which declined by 2% under I_2 treatment and 11% under I_3 treatment. Among two cultivars, the WUE of *Ashoka* variety was at the highest level (40.82 kg m^{-3}) and it declined by about 6% under *Jyoti* variety.

Conclusions

The varieties of a crop may require different amount of water for their maximum productivity and variety selection should be such that minimum water can produce maximum, making the slogan ‘more crop per drop’. The annual requirement of potato in West Bengal is much higher. Potato is sown in the month of November and harvest to March. In the light of the fact that in the present global scenario there is increasing deficit in the supply of irrigation water, this study concentrated on the determination of seasonal consumptive water footprints and water use efficiencies of two potato cultivars. The results of investigation indicated that the average potato yield was at the highest level (50.15 t ha^{-1}) under late planting irrespective of variety and irrigation level and it declined by about 10% when the crop was planted 9 days earlier. The CWF was at the highest level (37.43 m^3 t^{-1}) under late planting and it declined by around 11% when the crop was planted 9 days earlier. The WUE was at the highest level (41.10 kg m^{-3}) under early planting and it declined by 7% when the crop was planted 9 days later. Among two cultivars, the WUE of *Ashoka* variety was at the highest level (40.82 kg m^{-3}) and it declined by about 6% under *Jyoti* variety.

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