

Consumptive use and water use efficiency in cropping systems as influenced by irrigation levels

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ABSTRACT

An experiment was conducted during *kharif* and *rabi* season to find out consumptive use of water and water use efficiency as influenced by irrigation levels and different cropping systems. Consumptive use and water use efficiency was increased when irrigations given at all critical growth stages closely followed by irrigation skipped at one critical growth stage and the lowest when irrigations skipped at two critical growth stage during both the years. Total consumptive use and consumptive use per day was recorded maximum in sorghum-wheat followed by pearl millet + pigeonpea and groundnut + pigeonpea. The maximum water use efficiency (WUE) was recorded in soybean – chickpea cropping system followed by pearl millet – chickpea and sorghum – chickpea.

Key words: consumptive use, water use efficiency, critical growth stage, irrigation levels, cropping systems.

INTRODUCTION

Climate, Soil and Water are three basic natural resources that decide the nature, scope and extent of successful growing of crops. The main concern of productive agriculture is the effective and efficient supply of water to crop fields. Farming accounts for around 70% of water used in the world today and competition for water is increasing due to pressure from urbanization, industrialization and climate change. Sustainable management of water in agriculture is critical to increase agricultural production, maintain the environmental and social benefits of water. Economic use of water helps to improve water use efficiency in crop production. The scope of sustainable management of water in agriculture, one of the concerns is use water efficiently with beneficial outcome, especially irrigation to smooth water supply throughout the production seasons (OECD, 2010).

Availability of adequate irrigation water ensures adoption of suitable cropping systems comprising high value, high yielding and remunerative crops. There are some crucial stages of a crop plant and allowing water stress beyond a certain limit during these stages causes an adverse effect on plant growth processes and yield.

These stages are referred as the critical growth stages of water requirement. Water use efficiency (WUE) is the measure of a cropping systems capacity to convert water into plant biomass or grain. Hence it is important to know consumptive use and water use efficiency as influenced due to irrigation levels on different cropping system.

MATERIALS AND METHODS

A field experiment was conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. The soil was clayey with pH 8.2 and EC 0.29 dSm⁻¹, low in available nitrogen (168.41 kg ha⁻¹), medium in available phosphorus (15.69 kg ha⁻¹) and high in available potassium (497.15 kg ha⁻¹). The field capacity, permanent wilting point and bulk density of soil are 38.23, 18.42 per cent and 1.28 Mg m⁻³, respectively. The total rainfall received was during 2002-03 was 367.7 mm in 18 rainy days and 302.4 mm in 21 rainy days in 2003-04. The treatment comprised three levels of irrigation *viz.*, as main plot treatment and eight cropping systems as sub-plot treatment. The experiment was laid out in split plot design with four replications.

The field trials were conducted during both the seasons in the same field without changing randomization and site of main and sub treatments in a split plot design with four replications.

In all twenty four treatments comprised of three levels of irrigation *viz.*, Optimal (Irrigations at all critical growth stages- I₁), Irrigation skipped at one critical growth stage- I₂, Irrigations skipped at two critical growth stages- I₃ and eight cropping systems *viz.*, Pearl millet-wheat- CS₁, Sorghum-wheat- CS₂, Pearl millet-*Rabi* sorghum- CS₃, Pearl millet-chickpea- CS₄, Sorghum-chickpea – CS₅, Pearl millet + pigeonpea (2 : 2) intercropping- CS₆, Groundnut + pigeonpea (2 : 2) intercropping – CS₇, Soybean-chickpea – CS₈. The allocation of treatments was done by random method. Other recommended cultural practices were followed in all the treatments.

Consumptive use were monitored in 15-60 cm soil layer before sowing and at 20 days interval by gravimetric method for soil samples taken periodically. The moisture use was calculated from the change in the successive samples from the following relationship (Dastane, 1972 and Michael, 1978) and for total moisture use the summation of moisture use between two sampling dates.

$$MU = \sum_{i=1}^n E U_j$$

Where,

MU = Moisture use from ith between two successive sampling
 N = Number of sampling

Whenever, rains received in between the two periodical successive observations. Evapotranspiration of the crop for the particular period is calculated by the following formula.

$$ET_c = PE \times K_{pan} \times K_c \times \text{Number of days}$$

Where,

ET_c = Evapotranspiration of the crop
 PE = Pan evaporation (Average)
 K_c = Crop coefficient
 K_{pan} = Pan factor

The ground water contribution (GWC) was not considered as the depth of water table was more than three meters.

The WUE was worked out by the following formula.

$$\text{WUE} = \frac{Y}{\text{ET}} \text{ kg ha}^{-1} \text{ mm}^{-1}$$

Where,

Y = Yield (q ha^{-1})
ET = Evapotranspiration (mm)

RESULTS AND DISCUSSION

A. Consumptive use of water

Effect of irrigation levels

Total consumptive use of water (Table 1) was 855.46 and 814.47 mm during 2002-03 and 2003-04, respectively when irrigation given at all critical growth stages of crop growth. The less quantity of water (797.98 and 768.66 mm) was consumed when irrigations were skipped at two critical growth stages during both the years of experiment. These estimation of water consumed revealed that more of water was extracted when irrigations were given at all critical growth stages as compared to other levels of irrigation. Maity and Jana (1987) were reported that seasonal consumptive use of water of pulses increased with the increase in the levels of irrigation.

Effect of cropping systems

The total consumptive use of water (Table 1) was more in sorghum (625.34 and 627.27 mm and 626.82 and 630.13 mm) in *kharif* season and in *rabi* season in pigeonpea (411.65 and 431.93 mm and 382.64 and 476.67 mm) followed by wheat during 2002-03 and 2003-04. The cumulative consumptive use of cropping system was more in sorghum – wheat followed by groundnut + pigeonpea intercropping.

This might be due to longer duration crops. Almost similar trend was observed in daily consumptive use of water by *kharif*, *rabi* crops and altogether in the cropping system. Maliwal *et al.* (1988) and Mallick *et al.* (1993) reported the similar results. Intercropping system used more water compared to sole pearl millet reported by Singh and Joshi (1997).

B. Water use efficiency

Effect of irrigation levels

The water use efficiency (Table 2) was maximum in *kharif* crops, *rabi* crops and in cropping system (14.35 and $15.90 \text{ kg ha}^{-1} \text{ mm}^{-1}$) during 2002-03 and 2003-04 due to irrigation given at all critical growth stages of crop growth. It was closely followed by irrigation skipped at one critical growth stage which recorded 12.94 and $14.60 \text{ kg ha}^{-1} \text{ mm}^{-1}$ during 2002-03 and 2003-04, respectively. Similar results were reported by Bhatia *et al.* (1982), Singh and Sharma (1982).

Effect of cropping systems

Amongst different *kharif* crops (Table 2) soybean was most efficient in utilizing the soil moisture towards growth and pod yield by recording higher water use efficiency (17.92 and $19.82 \text{ kg ha}^{-1} \text{ mm}^{-1}$) than the other crops. Pearl millet was equally efficient in utilizing soil moisture towards economic yield. Intercropping system used more water compared to sole pearl millet reported by Singh and Joshi (1997). The lowest water use

efficiency recorded by groundnut in *kharif* season as groundnut was suppressed in pigeonpea intercropping.

During *rabi* season the highest water use efficiency was recorded by chickpea (6.43 and 12.54 kg ha⁻¹mm⁻¹) during 2002-03 and 2003-04, respectively. In cropping system, the highest water use efficiency was recorded by soybean-chickpea (17.86 and 26.24 kg ha⁻¹mm⁻¹) followed by pearl millet – chickpea and sorghum – chickpea during both the years. This may be attributed to the higher efficiency of these cropping systems in diverting the used soil moisture towards production of economic yield. Mallick *et al.* (1993), Singh and Joshi (1997), Rashid and Islam (1999) and reported the similar results.

Table 1.Total and daily consumptive use of *kharif* crops, *rabi* crops and cropping systems as influenced by different treatments

Treatment	Total consumptive use (Kharif crops) (mm)		Total consumptive use (Rabi crops) (mm)		Total consumptive use (Cropping systems) (mm)		Daily consumptive use (kharif crops) (mm)		Daily consumptive use (rabi crops) (mm)		Daily consumptive use (Cropping systems) (mm)	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Irrigation levels												
I ₁ : Irrigation at all critical growth stages	500.45	456.34	355.01	358.13	855.46	814.47	5.20	4.99	2.53	3.67	3.45	3.44
I ₂ : Irrigation skipped at one critical growth stage	491.90	446.45	336.70	347.32	828.59	793.77	5.11	4.88	2.46	3.65	3.56	3.41
I ₃ : Irrigations skipped at two critical growth stages	483.97	440.93	314.01	327.74	797.98	768.66	5.02	4.82	2.29	3.56	3.45	3.33
Cropping systems												
CS ₁ : Pearlmillet – Wheat	448.07	377.08	406.47	425.01	854.54	802.08	5.03	4.71	3.23	4.20	4.00	3.92
CS ₂ : Sorghum – Wheat	625.34	627.27	405.28	423.67	1030.61	1050.94	5.85	6.15	3.22	4.68	3.98	4.64
CS ₃ : Pearlmillet – Rabi sorghum	442.58	377.80	326.06	325.40	768.64	703.20	4.97	4.72	2.30	3.41	3.33	3.15
CS ₄ : Pearlmillet – Chickpea	440.57	378.79	250.74	224.10	691.32	602.89	4.95	4.74	2.11	3.36	3.33	3.06
CS ₅ : Sorghum – Chickpea	626.82	630.13	248.73	224.08	875.55	854.21	5.86	6.18	2.09	3.95	3.88	3.90

CS ₆ : Pearlmillet + Pigeonpea	442.20	374.90	411.65	431.93	853.85	806.84	4.97	4.69	2.26	3.14	3.15	2.92
CS ₇ : Groundnut + Pigeonpea	482.18	436.46	382.64	476.67	864.82	913.13	4.55	3.93	2.10	3.17	3.00	2.97
CS ₈ : Soybean – Chickpea	429.08	380.82	250.33	224.30	679.41	605.12	4.66	3.93	2.11	3.10	3.22	2.83
General mean	492. 11	447. 91	335. 24	344. 40	827. 34	792. 30	5.11	4.90	2.43	3.63	3.49	3.39

Table 2. Water use efficiency ($\text{kg ha}^{-1}\text{mm}^{-1}$) of *kharif* crops, *rabi* crops and cropping systems as influenced by different treatments

Treatment	Water use efficiency ($\text{kg ha}^{-1}\text{mm}^{-1}$) (<i>kharif</i> crops)		Water use efficiency ($\text{kg ha}^{-1}\text{mm}^{-1}$) (<i>Rabi</i> crops)		Water use efficiency ($\text{kg ha}^{-1}\text{mm}^{-1}$) (Cropping systems)	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Irrigation levels						
I ₁ : Irrigation at all critical growth stages	12.59	11.70	5.61	7.56	14.35	15.90
I ₂ : Irrigation skipped at one critical growth stage	10.01	9.31	5.42	7.53	12.94	14.60
I ₃ : Irrigations skipped at two critical growth stages	7.66	7.62	4.22	6.24	10.06	11.87
Cropping systems						
CS ₁ : Pearlmillet – Wheat	11.06	10.67	3.85	7.70	10.80	15.44
CS ₂ : Sorghum – Wheat	10.14	8.32	3.65	7.72	10.11	13.70
CS ₃ : Pearlmillet – <i>Rabi</i> sorghum	10.04	10.12	2.59	2.91	8.21	8.59
CS ₄ : Pearlmillet – Chickpea	10.43	9.15	7.26	9.27	16.06	16.88
CS ₅ : Sorghum – Chickpea	9.54	8.57	6.64	9.01	14.26	15.48
CS ₆ : Pearlmillet + Pigeonpea	11.15	8.79	5.06	3.21	13.09	8.50
CS ₇ : Groundnut + Pigeonpea	0.39	0.90	5.17	4.52	9.23	8.15
CS ₈ : Soybean – Chickpea	17.92	19.82	6.43	12.54	17.86	26.24
General mean	10.09	9.54	5.08	7.11	12.45	14.12

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