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EXPLORING CONSUMPTIVE USE AND MOISTURE USE EFFICIENCY VARIATIONS OF *KHARIF* PEARL MILLET IN RESPONSE TO DIVERSE SOWING WINDOWS IN THE WATER-SCARCE REGION OF MAHARASHTRA, INDIA

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ABSTRACT

A field experiment was conducted during *kharif* seasons of 2021 and 2022 at the Zonal Agricultural Research Station in Solapur, Maharashtra, India. The study aimed to assess the impact of different sowing times and cultivars on the yield, consumptive use (CU), and water use efficiency (MUE) of *kharif* pearl millet cultivars, namely ICTP-8203, Mahyco hybrid, and Adishakti. The experimental treatments involved three sowing times designated as S_1 (26th June – 01st July), S_2 (23rd July - 29th July), and S_3 (27th Aug – 02nd Sep.), treated as main plots, and three pearl millet cultivars ICTP-8203, Mahyco hybrid, and Adishakti as sub-plots. The experiment was arranged in a split plot design with three replications. Results revealed that the Adishakti variety exhibited the highest consumptive moisture use when sown in the 26 MW sowing window (S_1), reaching 372.5 mm, while the ICTP-8203 variety showed the lowest consumption at 314 mm in the 35 MW windows (S_3). The MUE for Adishakti was highest in the 26 MW windows (S1) at 4.07 Kg ha^{-1} mm, whereas the ICTP-8203 variety had the lowest MUE in the 35 MW windows (S_3) at 3.14 Kg ha^{-1} mm. The study concludes that sowing Adishakti in the 26 MW (S_1) windows optimizes consumptive moisture use, leading to higher yields.

***Key words*:** Pearl millet, yield, Consumptive use (CU), Moisture use efficiency (MUE), Sowing windows, variety

Introduction

Pearl millet (*Pennisetum glaucum*) ranked as the fourth most widely cultivated food crop in India, trails behind rice, wheat, and maize. It spans an extensive area of 6.93 million hectares, producing an average of 8.61 million tons and boasting a productivity rate of 1,243 kg/ha (Anonymous 2021). Specifically in the state of Maharashtra, pearl millet covers 0.70 million hectares, contributing to an average production of 0.63 million tons (Anonymous 2020). As the fourth most extensively grown food crop in India, pearl millet holds significant economic and nutritional importance. However, the challenges posed by water scarcity underscore the necessity for precise estimations of consumptive use and water use efficiency in pearl millet cultivation. In this context, understanding the dynamics of water consumption and efficiency becomes paramount for sustainable agricultural practices. This research endeavours to delve into the complexities of consumptive use and water use efficiency estimation, specifically tailored to the scarcity zones where pearl millet thrives. The study aims to contribute valuable in sights that can inform resource-efficient strategies for pearl millet cultivation in regions confronted by water scarcity challenges.

Material and Methods

A field experiment was conducted during two *kharif* seasons of 2021 and 2022 at the Zonal Agricultural Research Station in Solapur, Maharashtra, India positioned at latitude of approximately 17°41' N and longitude of approximately 75°56' E.

Treatment details:

I. Main Treatment: (3 sowing windows)

1. S_1 = Second fortnight of June. 26 MW (25th June – 01st July)
2. S_2 = Second fortnight of July. 30 MW (23rd July - 29th July)
3. S_3= Second fortnight of August. 35 MW (27th Aug – 02nd Sep.)

II. Sub plot treatment: (3 Varieties)

1. V_1 = ICTP – 8203
2. V_2 = Mahyco hybrid
3. V_3 = Adishakti

Layout of the experiment field

The layout of experimental field was laid out with 9 treatment combinations in 3 replications. Gross plot size was 15.0 x 6.3 m^2 and net plot size was 10.0 x 4.5 m^2. A distance of 1.5 m was kept between the plots.

Consumptive-use of water

CU (mm) = PET (mm) of 48 hours immediately rainfall + soil moisture depletion (per cent) from the effective root zone (i.e. soil moisture-use by the crop from the profile) + effective rainfall (mm)

The quantification of field consumptive water use by the pearl millet crop is achieved through the application of a specified formula, outlined as follows:

$$CU\ (mm)=\sum_{i=1}^{n}(Eox0.8) + \frac{M_1i\text{-}M_2i(ASi\times Di)}{100} + GWC + ER$$

Where,

CU = Consumptive use of water in mm

n = Number of soil layers in the root zone

i = Time instant of the respective rainfall

Eo = Actual evaporation recorded by U.S.A.'class A' pan evaporimeter for the period of 48 hours from the respective rain fall

M_1i = Moisture content at the first sampling in the i^{th} layer (percent)

M_2i = Moisture content at the second sampling in the i^{th} layer (percent)

AS i = Bulk density of the i^{th} layer (Mgm^{-3})

Di = Depth of soil in the i^{th} layer (cm) GWC=Ground water contribution (mm) ER= Effective rainfall (mm)

Soil moisture-extraction pattern:

Soil moisture extraction pattern for each treatment were determined in pearl millet during bothyears. The soil moisture depletion in mm and percentage extraction of moisture from different soil layers for the period between each successive rainfall in each treatment were calculated by summing up the values of depletion of soil moisture from different profiles during the entire crop season. The values of potential evaporation for 48 hours after rainfall were added to the depletion of first layer and the total loss of moisture in each layer were calculated on percentage basis. The ground water-table during the course of investigation remained beyond 4m each; indicating no possibility of ground water contribution.

Moisture use efficiency

The calculation of Moisture use efficiency (MUE), denoted as the yield of dry pearl millet grains (in kilograms) per unit of water (in millimeters) per hectare, for each irrigation treatment is determined utilizing the subsequent formula:

$$MUE = \frac{Y}{CU}$$

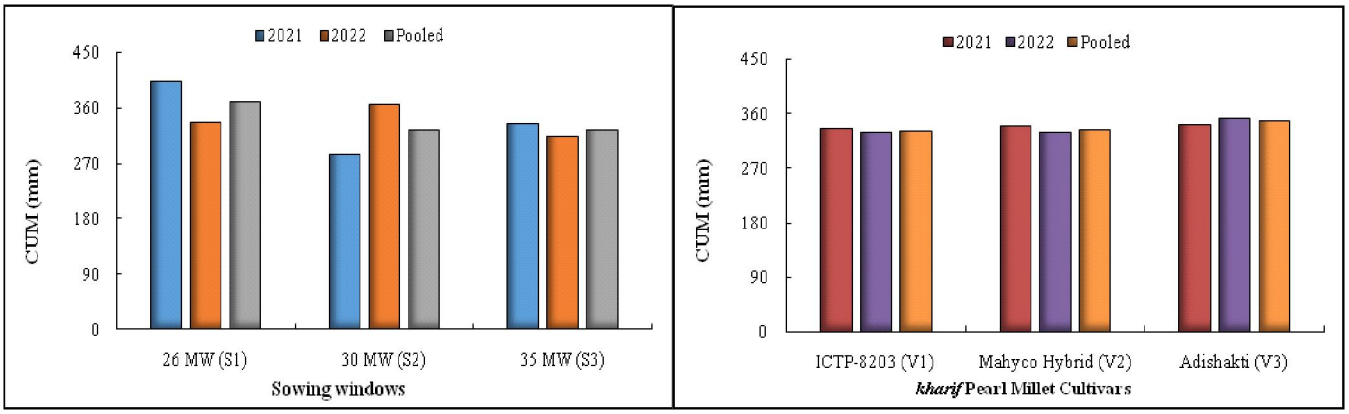

Fig. 1: Mean Consumptive use as influenced by sowing windows and varieties in *kharif* pearl millet in 2021 and 2022

Table 1: Mean Consumptive use as influenced by sowing windows and varieties in *Kharif* pearl millet in 2021 and 2022.

Treatments		2021		2022		Pooled
Sowing window	Varieties	MUE (Kgha^{-1} mm)	Grain yield	MUE (Kg ha^{-1} mm)	Grain yield	MUE (Kg ha^{-1} mm)
S_1: 26 MW	V_1: ICTP-8203	396	1490.07	337.0	1036.9	366.5
	V_2: Mahyco Hybrid	403	1517.53	333.0	1098.7	368
	V_3: Adishakti	410	1702.93	335.0	1288.2	372.5
S_2: 30 MW	V_1: ICTP-8203	276	830.87	360.0	1341.7	318
	V_2: Mahyco Hybrid	283	878.93	355.0	1352.7	319
	V_3: Adishakti	289	947.60	380.0	1483.2	334.5
S_3: 35 MW	V_1: ICTP-8203	337	1084.93	291.0	892.7	314
	V_2: Mahyco Hybrid	333	1126.13	300.0	940.7	316.5
	V_3: Adishakti	328	1345.87	345.0	1167.3	336.5
General mean		**339.4**	**1213.9**	**337.3**	**1178.0**	**338.4**

Table 2: Mean moisture use efficiency as influenced by sowing windows and varieties in *Kharif* pearl millet in 2021 and 2022.

Treatments		2021		2022		Pooled
Sowing window	Varieties	MUE (Kg ha^{-1} mm)	Grain yield	MUE (Kg ha^{-1} mm)	Grain yield	MUE (Kg ha^{-1} mm)
S_1: 26 MW	V_1: ICTP-8203	3.63	1490.07	3.08	1036.9	3.35
	V_2: Mahyco Hybrid	3.77	1517.53	3.3	1098.7	3.53
	V_3: Adishakti	4.31	1702.93	3.84	1288.2	4.07
S_2: 30 MW	V_1: ICTP-8203	2.87	830.87	3.73	1341.7	3.30
	V_2: Mahyco Hybrid	3.11	878.93	3.81	1352.7	3.46
	V_3: Adishakti	3.51	947.6	3.9	1483.2	3.70
S_3: 35 MW	V_1: ICTP-8203	3.22	1084.93	3.06	892.7	3.14
	V_2: Mahyco Hybrid	3.38	1126.13	3.14	940.7	3.26
	V_3: Adishakti	4.1	1345.87	3.38	1167.3	3.74
General mean		**3.54**	**1213.87**	**3.47**	**1178.01**	**3.51**

Where,

MUE=Moisture use efficiency (kg of grains ha^{-1} mm^{-1})

Y = Grain yield (kg ha^{-1})

CU =Total seasonal consumptive- use of water (mm)

Results and Discussion

Consumptive use (CU)

The mean consumptive use of water was 339.4 mm and 337.3 mm during the years 2021 and 2022, respectively. While the mean pooled consumptive use of water was found 338.4 mm. The study examined the varying levels of moisture consumption in relation to different sowing windows and pearl millet varieties.

In the case of the Adishakti variety, the highest levels of consumptive moisture use were observed when the crop was sown within the 26 MW sowing window (S_1), resulting in a recorded consumption of 410 mm. Similarly, for the 30 MW sowing window (S_2), which occurred

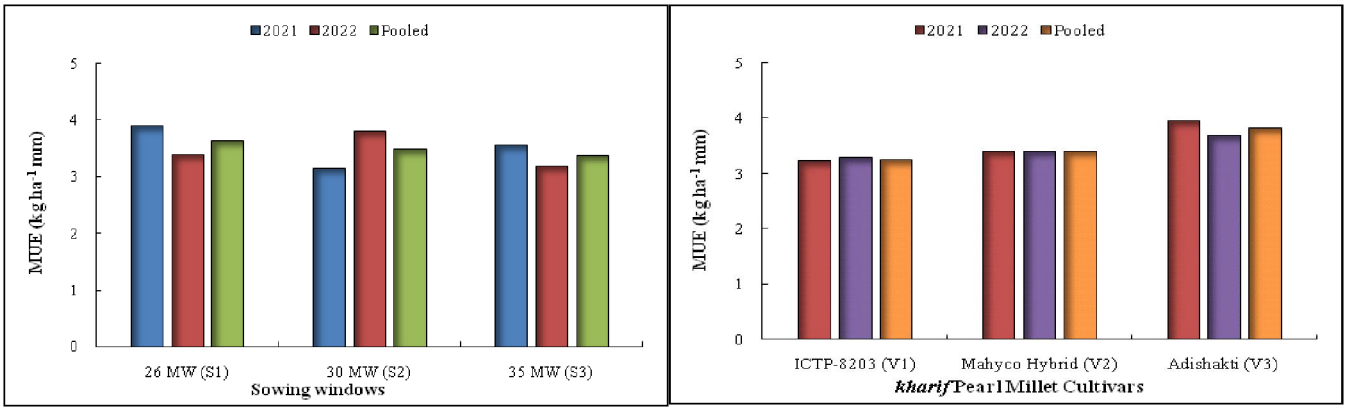

Fig. 2: Mean Moisture use efficiency as influenced by sowing windows and varieties in *kharif* pearl millet in 2021 and 2022

later, the moisture consumption remained relatively high at 380 mm. Conversely, for the ICTP-8203 variety, the lowest levels of consumptive moisture use were noted when the crop was sown within the 30 MW sowing window, leading to a consumption of 276 mm. Another low consumption value was observed for the 35 MW sowing window, amounting to 291 mm during the years 2021 and 2022 respectively. These findings were in close confirmation with Shinde (2011).

When pooling the results, the 26 MW sowing window (S_1) in conjunction with the Adishakti variety demonstrated the highest consumptive moisture use, reached 372.5 mm and lowest consumptive moisture use, reached in 35 MW sowing window (S_3) 314 mm in ICTP-8203. This synthesis underscores the discernible impact of sowing windows and cultivars on consumptive moisture patterns. Significant improvement in pearl millet grain yield owing to favourable microclimate, rainfall and low temperature under former sowing window and significant decrease in pearl millet grain yield under later sowing window with owing to adverse microclimate, increased temperature and low rainfall. The highest consumptive use of moisture in sowing window (S_1) and variety Adishakti could be attributed to the synchronized interaction between favourable rainfall patterns, optimal soil moisture content, low amount of temperature, plant development stages, and plant characteristics.

Moisture use efficiency (MUE)

The mean moisture use efficiency (MUE) of water was 3.54 kg ha^{-1} mm and 3.47 kg ha^{-1} mm during the years 2021 and 2022, respectively. While the mean pooled moisture use efficiency of water was found 3.51 Kg ha^{-1} mm. The study examined the varying levels of moisture use efficiency in relation to different sowing windows and pearl millet varieties.

Among the various sowing windows, the 26 MW sowing window (S_1) exhibited the highest MUE for the Adishakti variety, recording a value of 4.31 Kg ha^{-1} mm. Similarly, the 30 MW sowing window (S_2) showed a relatively high MUE of 3.9 Kg ha^{-1} mm for the same variety. In contrast, for the ICTP-8203 variety, the 30 MW sowing window (S_2) had the lowest MUE at 2.87 kg ha^{-1} mm, followed by the 35 MW window (S_3) with a value of 3.06 Kg ha^{-1} mm in the experimental years 2021 and 2022. These results are in accordance with those reported by Vyas *et al.*, (1994). When the data from both years were combined, the Adishakti variety sown in the 26 MW windows (S_1) demonstrated the highest overall MUE of 4.07 Kg ha^{-1} mm. Conversely, the ICTP-8203 variety sown in the 35 MW windows (S_3) exhibited the lowest pooled MUE value of 3.14 Kg ha^{-1} mm.

The increased grain yield during the former sowing window was attributed to the advantageous interplay between synchronized factors, including beneficial patterns of rainfall, optimal soil moisture levels, favourable microclimate, low temperature, developmental stages of the plants, and inherent plant characteristics. This harmonious synergy among these factors contributed to the heigh consumptive utilization of moisture in the designated sowing window (S_1) 26 MW for the Adishakti variety. While in later sowing window (S_3) 35 MW for ICTP-8203 variety there was significant decrease in MUE because of adverse microclimate, increased temperature, low rainfall and abnormal inherent plant characteristics.

Conclusion

The outcomes of this investigation serve as a crucial resource for decision-makers and cultivators operating in regions facing water scarcity. The grain yield, consumptive use (CU), and moisture use efficiency (MUE) of *Kharif* pearl millet are notably influenced by the availability of soil moisture. It is concluded that from above results, crop sown in 26 MW sowing window (S_1) 26th June - 01st July in conjunction with the Adishakti variety demonstrated the highest consumptive moisture use, reached 372.5 mm and lowest consumptive moisture use, reached in 35 MW sowing window (S_3) 27th Aug - 02nd Sep. *i.e.*, 314 mm in variety ICTP-8203. Similarly, highest moisture use efficiency (MUE) was found in 26 MW sowing window (S_1) 26th June - 01st July in conjunction with the Adishakti 4.07 Kg ha^{-1} mm and lowest consumptive moisture use, reached in 35 MW sowing window (S_3)27th Aug - 02nd Sep. *i.e.*, 3.14 Kg ha^{-1} mm.

Thus, sowing the pearl millet variety Adishakti in the *Kharif* season is best performed within S_1 (26th June - 01st July) *i.e.*, 26 MW. This timing optimizes soil moisture utilization, leading to higher yields.

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