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Consumptive Use, Water Use Efficiency and Moisture Extraction Pattern of Summer Pearl Millet in Western Maharashtra as Influenced by Sowing Times and Irrigation Regimes

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Abstract

A field experiment was conducted during summer 2010 and 2011 at Water Management Project Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahemadnagar, Maharashtra, India to find out appropriate sowing times and irrigation regimes for summer pearl millet. Twelve treatment combinations were investigated in this study: four with sowing times including D_1 - 6th MW (5th - 11th February), D_2 - 8th MW (19th - 25th February), D_3 - 10th MW (5th - 11th March) and D_4 - 12th MW (19th - 25th March) and the remaining three treatments were of irrigation regimes I_1 - 100 mm CPE, I_2 - 125 mm CPE and I_3 - 150 mm CPE. Irrigation water for all treatments was precisely supplied using Replouge flume. The consumptive use of water was more in 8th MW (394.2 mm) followed by 6th MW (391.0 mm) and 10th MW (382.2 mm). The consumptive use of water was more in 100 mm CPE irrigation regime (443.47 mm), followed by 125 mm (379.67 mm) and 150 mm CPE (321.0 mm) irrigation regime. Whereas, reverse trend was noticed for water use efficiency was more in 150 mm CPE (8.16 kg ha^{-1} mm^{-1}) irrigation regime. The soil moisture extraction was more from middle soil moisture layer of 15-30 cm in 6th MW followed by sowing of crop in 8th, 10th and 12th MW during both the years. The soil moisture extraction from surface layer of 0-15 cm was more with 100 mm CPE irrigation regime owing to adequate moisture supply followed 125 mm CPE and 150 mm CPE irrigation regime during both the years. The sowing of summer pearl millet in 8th MW increased grain yield (30.09 q ha^{-1}), consumptive use (394.16 mm) and net monetary returns (Rs. 25742 ha^{-1}) while the 100 mm CPE irrigation regimes increased grain yield (29.48 q ha^{-1}), consumptive use (443.47 mm) and net monetary returns (Rs. 23784 ha^{-1}). Results indicated that 100 mm CPE irrigation treatment gave the highest crop yield, followed by 125 mm CPE and 150 mm CPE irrigation regimes treatments. Increasing water stress sharply decreased biomass production. Water use efficiency (WUE) was increased as inadequate water is supplied to crop (150 mm CPE irrigation regime). Results also proved that summer pearl millet sowing in 8th MW (19-25th February) and irrigating with 100 mm CPE irrigation regime treatment is a practical tool to harvest maximum crop yield, monetary benefits and water use efficiency.

Key words : Pearl millet, yield, consumptive use, Water use efficiency, soil moisture extraction pattern.

Maharashtra ranks second in area and production of pearl millet (Pennisetum glaucum) in India. However, average productivity is relatively low as pearl millet is mostly grown under rainfed condition. Because of high productivity under assured irrigation, pearl millet cultivation in summer season is gaining popularity. Drought is the most important abiotic stress that limits plant productivity and will only worsen in the future when constraints on water resources increase. Plant coping strategies under water deficit are limited and revolve around the need to use water in an efficient way, ensure that water is available for the grain filling period, and maximise water capture from the soil profile. In irrigation scheduling, a climatological approach based on IW/CPE ratio (IW –irrigation water, CPE – cumulative pan evaporation) has been found most appropriate. This approach integrates all the weather parameters that determine water use by the crop and is likely to increase production by at least 15–20% (Dastane 1972). Optimum scheduling of irrigation led to increase

in grain yield and water use efficiency. Pearl millet is a potentially productive, high-quality grain or silage crop that appears superior to sorghum concerning establishment and production under limited soil moisture (Serraj and Sinclair, 2002; Purcell *et al*., 2002; Dakheel *et al*., 2009). Due to these changing environmental conditions, pearl millet is considered to be a good option to grow as a grain crop. The current research tries to achieve the greatest aboveground biomass production per unit of water by two methods. First is the evaluation of optimum time of sowing and second is application of precision irrigation to add the required amount of water when and where needed. Precision irrigation means applying irrigation water in the right place with the right amount at the right time (Almarshadi and Ismail, 2011).

The present experiment was therefore, undertaken to find out suitable sowing time and irrigation regime for summer pearl millet with following objectives.

1. To study the microclimatic conditions of summer pearl millet under different environmental conditions.
2. To study the effect of sowing times and irrigation regimes on growth, yield, nutrient uptake, water requirement, water use efficiency and economics of pearl millet.
3. To study the interaction effects between sowing times and irrigation regimes on growth, yield, nutrient uptake and economics of pearl millet.

Material and methods

A field experiment was conducted during summer 2010 and 2011 at Rahuri (Western Maharashtra) to investigate the effect of sowing times and irrigation regimes on yield, CU, WUE and moisture extraction pattern of summer pearl millet variety Shanti. The treatments were comprised of four sowing times (D_1 - 6th MW (5th - 11th February), D_2 - 8th MW (19th - 25th February), D_3 - 10th MW (5th - 11th March) and D_4 - 12th MW (19th - 25th March)) as the main plots and irrigation regimes (I_1 - 100 mm CPE, I_2 - 125 mm CPE and I_3 - 150 mm CPE) as sub-plots. The experiment was laid out in strip plot design and replicated three times. The soil was sandy clay loam in texture, well drained with high moisture retention capacity (field capacity 32.2%, permanent wilting point 16.0, bulk density 1.38 g cc^{-1}). The soil of experimental plot was low in and N (142 kg ha^{-1}) and medium in available P and high in K. The seeds were sown as per the sowing times during both the years. Common dose of 40 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} was applied in the form of urea, SSP and MOP respectively, as basal and After 30 DAS, top dressing of 40 kg N ha^{-1} was done through urea in between the two rows of crop. Irrigations were scheduled based on CPE values of 100, 125 and 150 mm in respective plots. Daily evaporation data were recorded from the evaporimeter installed in the plot. In all, one common irrigation was applied immediately after sowing for proper germination and establishment of the plants. Remaining irrigations were given as per treatments when CPE reached at respective level and the quantity of water was measured with the help of Replouge flume. Soil moisture studies were started right from sowing and continued up to final harvest of pearl millet crop. The soil samples for soil moisture studies were taken just before irrigation and 24 hours after irrigation from 0-15, 15-30 and 30-45 cm soil depth with the help of screw auger from net plot area of each treatment. Immediately the samples were transferred to aluminium soil moisture boxes and covered with moist gunny bag to avoid moisture losses from soil samples. The moisture boxes containing soil samples were shifted immediately

to laboratory for weighing and drying the soil samples. The soil samples were dried at 1050C for 8 to 10 hours till constant weight was obtained. The loss in moisture was expressed in percentage on oven dry weight basis as suggested by Dastane (1972). Soil moisture studies were also taken up with the help of 'Troxler Model 4302 moisture gauge with Neutron Probe'. The data obtained on moisture percentage as above for each depth were used for calculating consumptive use (CU) of water, water use efficiency and the moisture extraction pattern of pearl millet crop.

The field consumptive use of water by summer pearl millet crop in mm, respectively, is computed by the formula, as given below:

$$CU\ (mm) = \sum_{i=1}^{n}(Eo \times 0.8) + \frac{M_1i - M_2i}{100}(ASi \times Di) + GWC + ER$$

Where, CU = Consumptive use of water in mm, n = Number of soil layers in the root zone, i = Time instant of the respective irrigation schedule (1, 2, 3,...n), Eo= Actual evaporation recorded by U.S.A. 'class A' pan evaporimeter for the period of 48 hours from the respective scheduling of irrigation, M_1i = Moisture content at the first sampling in the ith layer (per cent), M_2i = Moisture content at the second sampling in the ith layer (per cent), ASi= Bulk density of the ith layer (Mg m^{-3}), Di = Depth of soil in the ith layer (cm), GWC = Ground water contribution (mm) and ER = Effective rainfall (mm)

Moreover, from the data on consumptive use of water, the daily water use rates (mm day-1) were also computed for respective schedule of irrigation.

Water use efficiency (WUE) i.e. kg of pearl millet grains (dry) produced mm^{-1} of water hectare-1 in each irrigation treatment and is worked out by the following formula:

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

Where, WUE = Water use efficiency (kg of grains ha^{-1} mm^{-1}), Y = Grain yield (kg ha^{-1}) and CU = Total seasonal consumptive-use of water (mm).

Result and discussion

Effect of sowing times on consumptive use of water and water use efficiency : Consumptive use of water and water use

Table 1. The yield, consumptive use of water, daily water use and water use efficiency as influenced by different treatments

Treatments	2010			2011		
	Yield (q ha^{-1})	CU (mm)	WUE (kg ha^{-1} mm^{-1})	Yield (q ha^{-1})	CU (mm)	WUE (kg ha^{-1} mm^{-1})
Sowing times						
6^{th} MW	29.07	355.90	8.17	28.17	426.10	6.61
8^{th} MW	30.50	358.04	8.52	30.10	430.28	7.00
10^{th} MW	26.69	348.36	7.66	26.82	416.04	6.45
12^{th} MW	25.32	333.86	7.58	25.47	380.02	6.70
Irrigation regimes						
100 mm CPE	30.11	424.83	7.09	29.51	460.12	6.41
125 mm CPE	27.89	348.28	8.01	27.71	411.06	6.79
150 mm CPE	25.69	274.85	9.35	25.69	368.16	6.98
General mean	27.90	349.16	7.99	27.64	413.11	6.69

efficiency were more when the crop was sown in 8th MW (358.04 mm and 8.52 kg ha mm^{-1}) (Table 1), whereas, these values were lower when crop was sown in 12th MW (333.86 mm and 7.58 kg ha mm^{-1}) because of significant improvement in pearl millet grain yield owing to favourable microclimate under former sowing time and significant decrease in pearl millet grain yield under later sowing time owing to adverse microclimate. Similar results were reported by Shinde (2011) and Waghmode (2012).

Effect of Irrigation regimes times on consumptive use of water and water use efficiency : The consumptive use of water was more *viz*., 424.83 and 460.12 mm with 100 mm CPE irrigation regime during the year 2010 and 2011, respectively, followed by 125 and 150 mm CPE irrigation regimes, because of supply of adequate quantity of water under former irrigation regime and inadequate supply of irrigation water under later irrigation regime. Whereas, reverse trend was noticed for water use efficiency where it was more *viz*., 9.35 and 6.98 kg ha^{-1} mm^{-1} under 150 mm CPE irrigation regime during the year 2010 and 2011, respectively followed by 125 and 100 mm CPE irrigation regime owing to efficient utilization of available soil moisture under inadequate water supply of 150 mm CPE irrigation regimes. These results are in the line of Tomar *et al*. (1992), Vyas *et al*. (1994), Gargi and Gautam (2003), Patel and Singh (2004), Sonawane *et al*. (2010), Shinde (2011) and Waghmode (2012).

Effect of sowing times on soil moisture extraction pattern : The soil moisture extraction from the surface layer of 0-15 cm was more when crop was sown in 8th MW followed by sowing of pearl millet in 6th, 10th and 12th MW during both the years. The soil moisture extraction was more from middle soil moisture layer of 15-30 cm in 6th MW followed by sowing of crop in 8th, 10th and 12th MW during both the years. However, soil moisture extraction was more from lower depth of 30-45 cm soil layer with each successive delay in sowing during both the years.

Effect of irrigation regimes on soil moisture extraction pattern : The soil moisture extraction from surface layer of 0-15 cm was more with 100 mm CPE irrigation regime owing to adequate moisture supply followed 125 mm CPE and 150 mm CPE irrigation regime during both the years. Whereas, the soil moisture extraction was more with 150 mm CPE irrigation regime from deep soil layer of 30-45 cm followed by 125 and 100 mm CPE irrigation regimes during both the years of experimentation because of moisture stress condition. This could be due to enhancement of moisture availability in the surface layer with frequent irrigations under 100 mm CPE irrigation regimes. Lack of sufficient soil moisture in the surface layers at 150 mm CPE irrigation regime might have forced the plants for vertical movement to meet water requirement from deeper layers. The maximum configuration of pearl millet roots in the top 30

Table 2. The soil moisture extraction pattern from different soil layers as influenced by different treatments

Treatments	Soil moisture extraction pattern (%)					
	2010			2011		
	Soil layer (cm)			Soil layer (cm)		
	0-15	15-30	30-45	0-15	15-30	30-45
Sowing times						
6th MW	46.78	35.23	17.99	45.85	35.00	19.15
8th MW	48.56	33.46	17.98	47.03	34.18	18.79
10th MW	45.68	33.12	21.20	44.35	34.61	21.04
12th MW	44.68	32.87	22.45	43.80	33.79	22.41
Irrigation regimes						
100 mm CPE	47.30	35.26	17.44	47.68	35.06	17.26
125 mm CPE	45.33	36.02	18.65	45.81	34.98	19.21
150 mm CPE	44.51	36.28	19.21	44.64	34.36	21.00
General mean	46.12	34.61	19.27	45.59	34.57	19.84

cm soil profile explained the moisture extraction pattern by the crop. Similar findings have been reported by Gulati *et al*. (2001).

Conclusion and Recommendation

The findings of this study are very important for decision makers and growers of semi-arid regions. Moisture affected the grain yield, consumptive use, water use efficiency (WUE) and soil moisture extraction pattern of summer pearl millet tested significantly. It can be summarized from above results that summer pearl millet be sown in 8th MW (19-25 February) and irrigated with 100 mm CPE irrigation regimes with an average irrigation interval of 12 days for higher consumptive use, water use efficiency, productivity and better monetary benefits. There is need for further work on the extent to which WUE contribute to drought tolerance in summer pearl millet under field conditions.

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