Annals of Arid Zone 46(2): 151-156, 2007

Rainfall Characteristics and Crop Production in Churu District of Western Rajasthan

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Abstract: The rainfall characteristics, frequency of meteorological and agricultural drought, water-use yield relationships of pearl millet and kharif pulses of arid Churu District were studied. The meteorological droughts prevailed in 28 out of 101 years (1906-2006) whereas, agricultural drought occurred in 18 out of 33 years (1971-2003). The actual evapotranspiration during reproductive stage of pearl millet and kharif pulses gave significant correlation with grain yields. Regression relationships of grain yield of pearl millet with rainfall explained 68% of the yield and with actual evapotranspiration 72-74%. Kharif pulses were less susceptible to drought than pearl millet attributed to difference in growth duration.

Key words: Rainfall characteristics, weekly water balance, drought, pearl millet and kharif pulses, Churu District.

Churu District, located in the arid western Rajasthan, is highly vulnerable to extreme climatic conditions and drought compared to other arid regions of the country. Out of 11.4 lakh ha of cropped area, only 5.1% area is under irrigation. Some of the principal crops grown in the district are pearl millet on 37.04% and pulses on 18.7% in kharif and rapeseed and mustard on 1.54% of the area in rabi (DES, 2002). An attempt is made in this paper, to analyze the rainfall characteristics, weekly water balance for identifying the meteorological and agricultural droughts and to find out the relationships between actual water-use and productivity of pearl millet and kharif pulses.

Materials and Methods

The daily rainfall data for the period 1906 to 2006 of Churu District, located in western Rajasthan (27°14′-29°00′N and 73° 44′-75° 41′E), were collected. The district-wise pearl millet and kharif pulses (mung bean, cowpea and moth bean) grain yield data (1971-2001) were also collected to analyze water use productivity relationship.

The frequency of different categories of meteorological droughts were made according to a classification of India Meteorological Department (Table 1). The agricultural droughts are classified based on moisture adequacy index obtained from weekly water balance studies (Sastri *et al.*, 1981; Ramana Rao *et al.*, 1981).

The 1-day maximum rainfall for different return periods were estimated using

Table 1. Classification of meteorological drought

Drought category	Departure from normal (%)
Excess or flood	>+51
Above normal	+26 to +50
Normal	+25 to -25
Below normal	-26 to -50
Drought	<-51

Weibull's formula (Chow, 1964) based on daily rainfall events at six locations of Churu District. The following equation was used to estimate the probable maximum precipitation;

$$X_m = X_{mean} + \sigma K_m$$

where,

X_m = estimate of PMP

X_{mean} = mean of rainfall

σ = standard deviation of rainfall

K_m = frequency factor

where,

$K_m = X_L - X_{meanN-1})/\sigma_{N-1}$

L = largest value of the rainfall series

$X_{meanN-1}$ = mean of the rainfall excluding X_L value

σ_{N-1} = standard deviation of rainfall excluding X_L value

The annual rainfall trends were obtained by using linear regression technique based on the annual rainfall totals for each *tehsil*. The weekly water balance of Churu District was computed using Thornthwaite and Mather (1955) book-keeping procedure. The water holding capacity of the sandy to loamy sand soils of Churu District was assumed as 125 mm m^{-1} depth.

Results and Discussion

Climatic characteristics

Churu District in the Indian arid region experiences temperatures as low as -3.0°C (1978) in winter to as high as 49.4°C (1993) in summer. The mean annual rainfall (1906-2006) in the district varied from 312.6 mm in 18.5 rainy days to 390.3 mm in 21.4 rainy days with an average of 353.5 mm in 20.4 rainy days (Table 2). The southwest monsoon rainfall had contributed up to 77-89% to the annual total, whereas the winter rains form 4-7% and summer rains will account 6-7% of the total. The coefficient of variation in annual rainfall for these locations was between 43% at Churu to 48% at Sardarsahar.

Table 2. Mean monthly rainfall (mm) and rainy days in Churu District

Station		Winter (Dec-Feb)	Summer (Mar-May)	Monsoon (Jun-Sept)	Post-monsoon (Oct-Nov)	Total
Churu	Rainfall	19.4	23.4	321.3	10.8	360.5
	Rainy days	1.8	2.3	16.3	0.7	21.1
Rajgarh	Rainfall	23.3	24.7	315.6	10.7	374.2
	Rainy days	2.2	2.2	16.5	0.8	21.7
Ratangarh	Rainfall	14.5	25.5	308.3	10.2	358.6
	Rainy days	1.4	2.1	16.5	0.8	20.8
Sardarsahar	Rainfall	14.7	19.3	239.6	8.9	312.6
	Rainy days	1.5	1.8	16.5	0.5	18.5
Sujangarh	Rainfall	15.4	28.0	337.0	10.0	390.3
	Rainy days	1.5	2.6	16.9	0.7	21.4
Taranagar	Rainfall	17.8	21.3	277.2	8.8	325.0
	Rainy days	1.7	2.0	14.8	0.7	19.0
Distt. average	Rainfall	17.5	23.6	302.4	9.9	353.5
	Rainy days	1.7	2.1	16.0	0.7	20.4

Table 3. Extreme 1-day rainfall events in Churu District

Stations	Highest	Date	PMP (K=9)
Churu	210.0	21-07-1993	334.3
Ratangarh	170.2	22-07-1929	353.5
Rajgarh	223.0	06-09-1977	412.1
Sardarshahar	226.1	09-07-1960	415.8
Sujangarh	209.5	23-07-1957	397.7
Taranagar	319.0	22-07-1978	415.2

Annual rainfall in the district varied from 20.3 mm in 1918 to 1036.0 mm in 1978. Extreme rainfall events recorded in Churu District showed that 1-day highest rainfall was between 170.2 mm at Ratangarh to 319.0 mm at Taranagar (Table 3).

The 1-day rainfall in Churu District for different return periods of 5, 10, 25, 50 and 100 years (Table 4) was the lowest at Churu and highest at Sujangarh for all the return periods.

Long-term trends in the annual rainfall (1906-2006) at different locations showed either normal or marginal increase in rainfall in the district. The rate of increase in the annual rainfall over a hundred year period was thus 45 mm at Churu, 66 mm at Rajgarh, 18 mm at Ratangarh, 98 mm at Sardarsahar and 69 mm at Sujangarh and 94 mm at Taranagar with an average increase of 65 mm for the district as a whole.

Meteorological droughts

The frequency of meteorological droughts in Churu District, computed as per IMD classification are given in Table 5. Churu experienced highest number of drought-free years of 77 out of 101 years, and drought in 24 years. Taranagar experienced highest number of moderate to severe drought conditions (36 out of 101 years). Overall, the average frequency of meteorological drought in Churu District varied from once in 4.2 years at Churu to 2.8 years at Taranagar.

Agricultural droughts

The frequency of agricultural drought in Churu District (1971 to 2003) is shown in Fig. 1. Pearl millet was free from drought only in 7 years compared to 11 years in case of kharif pulses. Thus, kharif pulses can escape drought compared to pearl millet due to short growing season of the respective

Table 4. Return period of 1-day rainfall (mm) in Churu District

Station	Return period (years)				
	5	10	25	50	100
Churu	89.9	106.8	127.9	143.6	159.7
Rajgarh	96.9	118.7	145.9	166.2	186.9
Ratangarh	89.3	107.6	130.4	147.4	164.8
Sardarshahar	94.0	116.3	144.1	164.8	185.9
Sujangarh	101.4	121.9	147.5	166.6	186.0
Taranagar	92.6	114.9	142.8	163.5	184.7

Table 5. Meteorological drought in Churu District (number of years; 1906-2006)

Category	Tehsils						Churu District
	Churu	Rajgarh	Ratangarh	Sardarshahar	Sujangarh	Taranagar	
No drought	77	68	68	71	73	65	73
Moderate drought	18	21	19	17	19	20	24
Severe drought	6	12	14	13	9	16	4
Total	101	101	101	101	101	101	101

crops. Thus, the optimum sowing time for pearl millet as well as for kharif pulses to escape from drought is found to be 28th standard week (9-15th July).

Grain yield water-use relationships

The relationships between seasonal rainfall or accumulated seasonal actual evapotranspiration estimated from water balance studies and productivity of pearl millet (Fig. 2) showed that the actual evapotranspiration and seasonal rainfall closely followed the productivity of pearl millet. The productivity of pearl millet has increased due to improved technology and use of short duration HYV adopted in the region. The correlation coefficients (Table 6) between crop yield and rainfall or AE showed that the AE correlated with yield better than with rainfall in all pheno-phases of the pearl millet and kharif pulses. The rainfall/AE gave the highest correlation at vegetative/reproductive stage for pearl millet and at reproductive stage for pulses showing the importance of rainfall at these stages for higher productivity.

The regression relationships between grain yield of pearl millet and kharif pulses with seasonal as well as for different pheno-phases of the crop are given below:

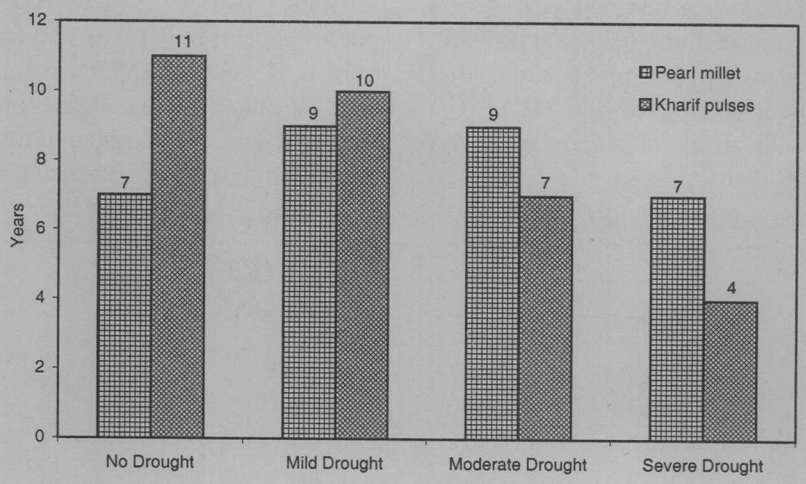

Fig. 1. Frequency of agricultural droughts in Churu District.

Pearl millet vs. rainfall

Y_{pm} = 0.5097Rs+0.4600Rv+0.5605Rr+87.3634 (r^2=0.68; SE_{est}=38.35) ---(1)

Y_{pm} = 0.4996 RT+87.6826 (r^2=0.68; SE_{est}=36.98) ---(2)

Pearl millet vs. AE

Y_{pm} = 0.7218 AEs+0.4887AEv+0.9124AEr+58.4992 (r^2=0.74; SEest=34.62) ---(3)

Y_{pm} = 0.6723AET+60.3865 (r^2=0.72; SEest=34.29) ---(4)

Kharif pulses vs. rainfall

Y_{kp} = 0.4454 Rs-0.0410 Rv+1.2721 Rv +1.2721 Rr+32.8174 (r^2=0.55; SEest=51.80) ---(5)

Y_{kp} = 0.3162RT+59.6445 (r^2=0.26; SEest=63.72) ---(6)

Kharif pulses vs. AE

Y_{kp} = 0.1771AEs+0.0212AEv+1.5922AEr+36.4356 (r^2=0.52; SEest=52.97) ---(7)

Y_{kp} = 0.7667 AET-11.7384 (r^2=0.43; SEest=55.93) ---(8)

where,

Y_{pm} is grain yield of pearl millet, kg ha^{-1}

Y_{kp} is grain yield of kharif pulses, kg ha^{-1}

Rs, Rv and Rr are rainfall (mm) and AEs, AEv and AEr are AE (mm) during seedling, vegetative and reproductive stages of the crop.

Regressions (1-4) for pearl millet showed that the seasonal rainfall could explain 68% of the grain yield, whereas, AE explained 72-74%. Thus, the actual evapotranspiration (AE) obtained from weekly water balance calculations predicted the yield better than rainfall alone. However, the reduction in crop yield due to floods or pests and diseases were not considered before regression analysis due to lack of such historical records at district level which might have given lower estimates from the above equations.

The regression equations (5-8) for kharif pulses showed that the seasonal rainfall explained only 25% of the yield, whereas,

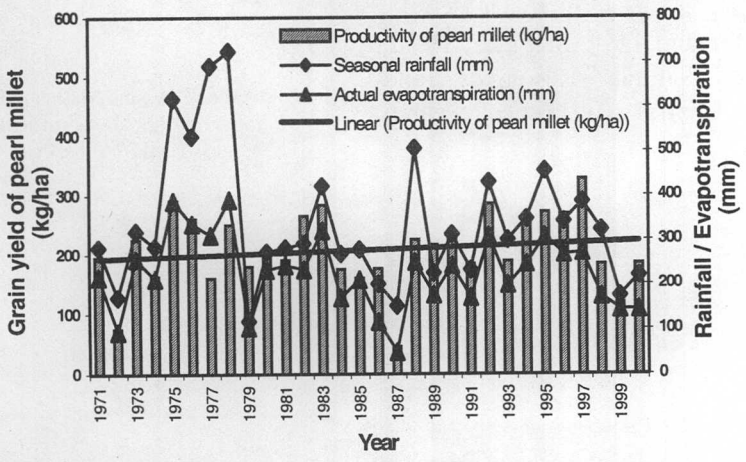

Fig. 2. Relationship between seasonal rainfall, evapotranspiration and pearl millet yield in Churu District.

Table 6. Correlation coefficients between crop yield vs rainfall/AE in Churu District

Parameter	Pearl millet	Kharif pulses
Rainfall (mm)		
Seasonal total	0.82**	0.51**
Seedling stage	0.44*	0.24
Vegetative stage	0.66**	0.26
Reproductive stage	0.58**	0.70**
Actual evapotranspiration (mm)		
Seasonal total	0.85**	0.65**
Seedling stage	0.48**	0.17
Vegetative stage	0.76**	0.38*
Reproductive stage	0.76**	0.72**

**Significant at 1% level; * Significant at 5% level.

the rainfall during different pheno-phases explained 55% of the yield. The seasonal AE explained 42% of the yield and AE in different pheno-phases 52% of the yield. The low r^2 values for the regression equations of kharif pulses as compared to pearl millet showed that in the Churu District, the rainfall has relatively higher impact on pearl millet compared to kharif pulses, which differ in crop duration.

Acknowledgements

The authors are grateful to Dr. K.P.R. Vittal, Director and Dr. Amal Kar, Head, Division of Natural Resources and Environment, Central Arid Zone Research Institute for facilities.

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