

## Crop Water Deficit Index at Phenophases and Yield of Kharif Crops in Gujarat

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**Abstract** Aridity index is derived in relation with individual growth phases of *Kharif* crops and designated as crop water deficit index (CWDI). Weekly indices were cumulated from sowing to maturity to get 'seasonal' CWDI. Yield and phenophasic CWDI were found to be negatively correlated while the CWDI during flowering and grainfilling stages of crops were significantly correlated with yield. The impact of seasonal and phenophasic crop water deficit is reflected in the crop productivity and its variability at different stations in Gujarat.

**Key words** Phenophasic crop water deficit index, Seasonal crop water deficit index, productivity, Yield variability, Kharif crops.

Low productivity and large yield fluctuations are two problems in dryland areas of Gujarat. In major portion of the Gujarat which falls under arid and semi-arid climates spread over in eight agroclimatic zones, rainfall is the most important factor limiting the crop production. As agriculture is mainly practised in *kharif* season, the crop water deficit index computed for the *kharif* season assumes significance in characterising drought than a single annual aridity index without reference to growth phases of crops. Hence, it is felt that a study of the weekly distribution of the index computed with reference to phenophases of crops during the crop growing period is more important than that for the whole season, which is considered from 22nd to 44th standard weeks.

## Materials and Methods

Drought can be defined in terms of aridity index, which is the ratio of moisture deficit (PET-AET) and water need (PET) expressed in percentage where the AET and PET values were derived by the Thornthwaite and Mather (1955) through the water balance technique. Weekly climatic water balance for each year from 1958 to 1989 at Anand, from 1976 to 1989 at Jamnagar, 1957 to 1989 at Junagadh, 1977 to 1989 at Navsari, 1971 to 1989 at Rajkot, 1979 to 1989 at Sardarkrushinagar and 1968 to 1988 at Surat was computed by using weekly meteorological data recorded at the res-pective agrometeorological observatories.

Table 1 Duration (in weeks) of phenophases of crops

Phenophases	Duration
Pearl millet (PM)	
I Sowing and Establishment	2
II Tillering	4
III Flowering and earhead emergence	2
IV Grain filling and maturity	5
Sorghum (SG)	
I Sowing and germination	2
II Panicle initiation	3
III Flowering and earhead emergence	4
IV Grain filling and maturity	5
Groundnut (GN)	
I Germination and flowering	5
II Pegging	4
III Pod development	3
IV Pod filling and maturity	4
Cotton (CT)	
I Establishment	3
II Vegetative	4
III Flowering	9
IV Boll formation	4
V Boll bursting and ripening	2
Rice (RC)	
I Vegetative	10
II Reproductive	2

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**Table 2** Correlation between yield and phenophasic crop water deficit index (CWDI)

Station	Crop	Phenophases			
		I	II	III	IV
Anand	PM	-.089	-.115	-.587**	-.069
	CT	-.414*	-.234	-.021	-.261
	RC	-.575**	-.110	-.212	
Jamnagar	GN	-.393	-.941*	-.999**	-.933*
Junagadh	PM	-.285	-.367	-.636**	-.536*
	GN	-.075	-.190	-.335	-.424
Navsari	SG	-.561	-.205	-.426	-.744*
Rajkot	PM	-.269	-.433	-.794*	-.934*
	SG	-.350	-.483	-.880*	-.795
	GN	-1.91	-.788	-.977**	-.892**
SK Nagar	SG	-.791*	-.554	-.355	-.735*
	GN	-.402	-.824*	-.724*	-.792*
	CT	-.033	-.323	-.472	-.764*

\* Significant at 5 % level, \*\* at 1 % level.

The duration of crop growth stages (Phenophases) for five major *kharif* crops grown in the region are presented in table 1. Weekly values of aridity index were summed over each growth stage to provide an accumulated aridity index for the particular stage of the crop. Since this index reflects climatic water deficit in the season with reference to the crop growth phases and duration, it is named as 'Crop Water Deficit Index' (CWDI). The weekly values were also accumulated from sowing to harvest of each crop individually to provide a seasonal CWDI. Thus, the CWDI values of different magnitudes were obtained depending upon the growth duration of individual crops at each station as well as the intensity of drought for each crop at the different stations. Standard deviation (SD) and median of these values were used to categorise individual *kharif* seasons by following the procedure adopted by Subrahmanyam and Sastri (1969). This method was also adopted to estimate yield levels for the corresponding categories of seasons. The seasonal CWDI values were also correlated with the district wise yield data of crops which were collected from the Agricultural situation in India and Department of Agriculture,

Gujarat, publications for the period from 1965-66 to 1987-88. The mean and coefficient of variation were calculated for each crop for all the districts corresponding to the stations under study.

## Results and Discussion

*Crop water deficit index at phenophases and yield* : Yield are significantly correlated with CWDI at flowering stage of pearl millet at Annad, Junagadh and Rajkot stations, for peg development stage of

**Table 3** Correlation of yield with progressive accumulative CWDI in phenophases and at the end of the season

Station	Crop	CU-2	CU-3	Seasonal
Anand	RC	-.560*	-	-.471*
Jamnagar	GN	-.751	-.898	-.951*
Junagadh	PM	-.366	-.487	-.545*
	GN	-.486*	-.654**	-.690*
Rajkot	PM	-.373	-.533	-.785*
	SG	-.572	-.799	-.844*
	GN	-.589	-.886**	-.671*
SK Nagar	GN	-.710*	-.724*	-.748*

\* significant at 5 % level, \*\* at 1 % level.

CU-2 = PhI + PhII, CU-3 = CU 2 + PhIII, Seasonal = CU2 + CU 3 + PhIV, ph - phenophase

groundnut crop at Jamnagar, Rajkot and SK Nagar stations and for sorghum at Rajkot station (Table 2). It is also revealed that drought occurrence during grainfilling and maturity stages of pearl millet at Junagadh and Rajkot, for sorghum at Navsari and SK Nagar, for pod filling and maturity stages of groundnut at Rajkot and SK Nagar and at boll formation stage of cotton at SK Nagar significantly influenced yield (Table 2).

It is interesting to note that in general the CWDI during phases III and IV that is, the flowering and grainfilling phases respectively and significantly correlated with yield, indicating that the drought at these stages has a significant impact on the yield.

*Cumulative CWDI in phenophases and yield*: The results (Table 3) indicate that cumulative CWDI in phenophases and yield are negatively correlated for the crops at all the stations. However, significant correlation is observed at selected stations for specific crops such as rice at Annad, groundnut at Jamnagar, pearl millet and groundnut at

Junagadh, pearl millet and sorghum at Rajkot and groundnut at SK Nagar. Cumulative and seasonal CWDI however reveals significant correlation with crop yield. This is attributable to the time lag in crop response to prevailing weather conditions in the individual phases.

*Levels of CWDI and yield*: The limits of CWDI and yield levels obtained by employing the relationship of SD and median values in respect of different crops at various stations are shown in table 4. A lower value of the index signifies 'no drought' condition and hence the yield levels are higher, while at the higher values of CWDI, the yield levels reduce moderately or severely depending on the nature of the drought intensity. The level of CWDI for safe yield levels of crops are seen to be different because of different climatic conditions at a locality. The CWDI value of 356 is minimum for getting more than 900 kg ha<sup>-1</sup> yield of groundnut at Junagadh as compared to 315 and 700 kg ha<sup>-1</sup> respectively at Annad and so on.

Table 4 Levels of crop water deficit index (CWDI) and yield (kg ha<sup>-1</sup>) of kharif crops in Gujarat

Drought	Pearl millet		Sorghum		Groundnut		Cotton	
	CWDI	Yield	CWDI	Yield	CWDI	Yield	CWDI	Yield
				Anand				
No drought	262	950	265	600	315	700	851	175
Moderate	263-441	950-600	266-457	600-300	316-551	700-400	852-1167	175-150
Severe	442	600	458	300	552	500	1168	150
				SK Nagar				
No drought	399	600	477	450	654	700		
Moderate	400-687	600-400	478-758	450-200	655-963	700-400		
Severe	688	400	759	200	064	400		
				Jamnagar				
No drought	571	600	700	190	869	500	1385	190
Moderate	572-882	600-400	701-1032	190-130	870-1251	500-300	1386-1844	190-120
Severe	883	400	1033	130	1252	300	1845	120
				Junagadh				
No drought	242	950	279	600	356	900	730	200
Moderate	243-487	950-600	280-550	600-400	347-669	900-600	731-1157	200-140
Severe	488	600	551	400	670	600	1158	140
				Rajkot				
No drought	403	600	447	400	418	500	1053	190
Moderate	304-653	600-400	447-731	400-200	419-782	500-300	1054-1528	190-130
Severe	654	400	732	200	783	300	1529	130

