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RESEARCH ARTICLE

Water requirement satisfaction index of rainfed sown groundnut cultivars (*Arachis hypogaea* L.) during two individual precipitation years in middle Gujarat Agroclimatic zone

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SUMMARY : A field experiment for the two years was conducted during the *Kharif* seasons of 2009 and 2010 with six sowing window combinations with the first sowing done at the onset of monsoon followed by successive sowings at an interval of 15 days along with the varieties namely V_1-M 335 (Virginia spreading type), V_2-GG 20 (Virginia semi-spreading type) and V_3-GG 5 (Spanish bunch type) to study the crop water requirement satisfaction index (CWRSI) for assessing the sufficiency of rainfall *vis-a-vis* the crop water requirements and its effect on pod yield. The performance of groundnut crop in terms of pod yield from the present study suggested that, sowing of groundnut should be taken up for variety V_1 between 26th to 27th week, as a good rainfall amount and distribution of 823 to 852 mm under early/normal onset of monsoon as observed during 2010 which resulted in commercial production of groundnut. Whereas, sowing of groundnut should be taken up for variety V_2 between 26th to 27th, because reasonably a good crop can be produced on as little as 269 to 298 mm of rainfall under late onset of monsoon as observed during 2009 crop growing season as the rainfall amount and distribution had determined the crop performance due to the crop water requirements were actually met by the available water vis-a-vis soil moisture content, actual evapotranspiration (AET) resulting in improved CWRSI of the crop. The correlation and regression studies revealed that the CWRSI, soil moisture content, AET and rainfall were having highly significant positive correlation during pod development phase and for the entire crop duration. However, the stepwise regression revealed that the CWRSI during pod development phase determined 93% variation in the pod yield. Whereas, rainfall and AET together had resulted in determining 89% variation in the pod yield for the entire crop duration.

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Water management in arid and semi-arid region, is of very complex nature as the crop yield is the culmination of many temporal plant processes which is affected by various external factors related to soil and weather, as the climate or weather of a region or locality which fall under rainfed regions have limited access to irrigation as rainfall is highly unreliable, both in time and space, with strong risks of dry spells at critical growth stages even during good rainfall years has a great influence on available water use which is linked to crop transpiration affecting the crop growth and yield. Therefore, water requirement satisfaction varies with the type of crop and environmental conditions as water is indispensible for crop growth and rainfall is the most important source of water for crop production. Better utilization of water which includes rainfall, surface water and ground water on the crop water requirement for

maximum yield production of a crop is essential as the accurate information concerning potential water available and crop water requirement may facilitate water savings in irrigation practice, improve crop management and increase crop production. However, it is also important to determine appropriate planting dates and cultivars in order to take full advantage of limited soil moisture availability in a shortened crop growing season. Therefore the main objective of the present study was to investigate the usefulness of critical crop water availability for maximum yield of groundnut cultivars and the average planting date on the knowledge of rainfall distribution and onset to avoid crop water stress over the groundnut growing season to maximise the pod yield.

EXPERIMENTAL METHODOLOGY

The field experiments were conducted on sandy loam soils of Agronomy farm, B. A. College of Agriculture, AAU, Anand (22°35" N lat. and 72°55" E long. at an elevation of 45.1 m) during the *Kharif* seasons of 2009 and 2010 with the first sowing done at the onset of monsoon followed by successive interval gap of 15 days as of 2nd July *i.e.*, 27th week (D_1: Normal onset of monsoon), 17th July *i.e.*, 29th week (D_2: Very late onset of monsoon), 1st August *i.e.*, 31st week (D_3: Very very late onset of monsoon) in 2009 and 15th June *i.e.*, 24th week (D_1: Early onset of monsoon), 30th June *i.e.*, 26th week (D_2: Normal onset of monsoon), 14th July *i.e.*, 28th week (D_3: Late onset of monsoon) in 2010 with the varieties as sub plot treatments namely V_1- M 335 (Virginia spreading type), V_2- GG 20 (Virginia semi-spreading bunch type) and V_3- GG 5 (Spanish bunch type). The experiment was laid out in Split Plot Design. Size of the gross plot was 21 m^2 and net plot was 12 m^2. Spacing adopted was 30 x 10 cm. Recommended dose of fertilizers (12.5 N, 25 P_2O_5, 0 K_2O kg ha^{-1}) were applied to the crop as basal. Weather data for the experimental period was recorded at meteorological observatory, Anad Agricultural University, Anand. The data on pod yield and dry matter produced were determined for net plot and were worked out for kg ha^{-1}. Water requirement satisfaction index (WRSI) was used for assessing the sufficiency of rainfall *vis-a-vis* the crop water requirements which was determined by running CROPWAT v. 8.0 model to determine the water supply and demand a crop experiences during a growing season which was calculated as the ratio of seasonal actual evapotranspiration (AET) to the seasonal potential (PET) water available and expressed as percentage. The estimates of the actual and potential evapotranspiration were based on the Penmen-Monteith approach, using crop co-efficient (Kc) of 0.65, 1.15, 0.85 and 0.55, respectively, during emergence to flowering, pegging, pod development and physiological maturity stages given by (Chaudhary *et al.*, 1999) for groundnut crop at Anand conditions. Correlation and regression analysis were also used to discuss the yield response to optimum groundnut water requirement under different stages of plant growth. The integrated soil moisture content from soil surface to a depth of 45 cm below the surface was determined by gravimetric soil sampling and was expressed as percentage.

EXPERIMENTAL FINDINGS AND DISCUSSION

The data pertaining to crop water requirement satisfaction index for the dates of sowing and varieties is presented in Table 1. The differences in the CWRSI were found significantly higher for D_2 (*i.e.*, 27th week) date of sowing only during 2010. Whereas, among the varieties the differences in the CWRSI were found significantly higher for variety V_2 and V_1, respectively during 2009 and for the pooled data over years. These significant differences in the CWRSI had significantly influenced the pod yield in comparison to rest of the sowing dates and varietal combinations. The observed differences in the CWRSI was mainly due to significantly higher soil moisture content which had resulted in higher actual evapotranspiration for D_2 (*i.e.*, 27th week) date of sowing during 2010. Similarly, among the varieties significantly higher soil moisture content with significantly higher actual evapotranspiration for variety V_2 (GG 20) during 2009 and significantly higher soil moisture content resulting in higher actual evapotranspiration for V_1 (M 335) for the pooled data over years had resulted in significantly higher CWRSI.

However, the overall performance of groundnut crop in terms of pod yield over the years revealed that, sowing of groundnut variety V_1 between 26th to 27th week resulted in commercial production of groundnut indicating that the crop water requirements was satisfied due to rainfall amount and distribution was found optimum to have significantly influenced higher soil moisture content with higher actual evapotranspiration to the water availability resulting in an increased CWRSI. The above results are in confirmation to the findings of Cox (1979), Nigam *et al.* (1994); Bapuji Rao *et al.* (2011); Patel *et al.* (2010) and Caliskan *et al.* (2008).

Effect of water requirement satisfaction index on pod yield of groundnut :

In investigating the stage at which the crop experienced moisture sufficiency, correlation and regression studies were performed between pod yield of groundnut and weather derived indices at respective phenophases which is presented in Table 2 and depicted in Fig. 1 and 2. The correlation and regression studies revealed that the CWRSI, soil moisture content, AET and rainfall were having highly significant positive correlation during pod development phase and also for the entire crop duration. However, the stepwise regression

revealed that the CWRSI during pod development phase had determined 93% variation in the pod yield as depicted in Fig 1. Whereas, rainfall and AET together had resulted in determining 89% variation in the pod yield for the entire crop duration as depicted in Fig. 2. The above presented results were in confirmation with the findings of Cox (1979), Nigam *et al.* (1994), Bapuji Rao *et al.* (2011), Patel *et al.* (2010) and Caliskan *et al.* (2008).

This fall of the index below 50 per cent signifies a crop failure as the water requirements were not met, an index ranging between 50 per cent and 75 per cent signifies the yield would be mediocre while an index above 75 per cent is an indicator of a good harvest. On the other hand, some appreciable yields were expected for the other years under study. This was confirmed with the actual yields obtained for that season; Livingstone had a yield of 0.01 metric tons per hectare. This season was characterized with low rainfall amounts which resulted into some water deficits. In investigating the stage at which the crop experienced moisture deficits, the water balance calculation indicated that for Livingstone district, the total water deficits amounted to 220mm for the 2001/02 season which is significantly high compared to Choma and Kafue which had deficits of 115mm and 89mm, respectively. On analysis of the spatial distribution of the water deficits at different stages of growth, it was found that the groundnut crop experienced more water deficits at vegetative and flowering stages of their growth.

Better utilization of water which includes rainfall, surface water and ground water on the strategy to investigate on crop water requirement for maximum yield production of a crop is essential. The major contributors to the observed yield were the water excess and actual evapotranspiration at different stages of growth for the different districts. Significant rainfall deficits at critical stages of crop growth have frequently led to a serious shortfall in crop production. In short, changes in the supply of rainfall, whether in the total volume or in its distribution within a season, have enormous consequences for agricultural production in Zambia. Major factors contributing to this low yield have been the long dry spells within a season and the shorter rainfall seasons which have been experienced by the country in the past years. We often emphasize on the importance of well documented onset and cessation dates of seasonal rainfall as well as monitoring of the phenological stages of crops for crop yield

Table 1: Average pod yield, crop water requirement satisfaction index (CWRSI), soil moisture content (SMC) and actual evapotranspiration (AET) of groundnut under different dates of sowing and varieties during *kharif* seasons of 2009 and 2010

Treatment	Pod yield (kg ha^{-1})			CWRSI (%)			SMC (%)			AET (mm)		
	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled
Mean for dates of sowing												
D_1	1838	2650	2244	42	63	52	66	79	72	260	315	287
D_2	813	2866	1840	43	65	54	56	85	70	261	318	289
D_3	471	2799	1635	42	60	51	56	81	68	259	315	287
Overall mean												
S.E. ±	53.82	52.48	403.86	0.4	0.6	0.7	0.81	0.98	0.63	1.51	1.81	1.18
C.D. (P=0.05)	169.58	165.36	NS	NS	2.0	NS	2.55	3.07	1.87	NS	NS	NS
C.V. %	21.94	8.03	11.83	3.60	4.43	4.25	5.42	5.08	5.25	2.46	2.43	2.45
Mean for variety												
V_1	903	3035	1969	43	63	53	62	86	74	215	327	271
V_2	1157	2590	1873	45	57	51	67	76	70	290	306	313
V_3	1063	2691	1877	40	60	50	61	75	68	224	316	270
Overall mean												
S.E. ±	38.89	110.00	180.26	1.0	1.4	0.8	0.77	1.63	0.90	22.14	5.54	20.40
C.D. (P=0.05)	112.31	317.65	NS	2.9	NS	2.4	2.23	4.72	2.56	63.92	15.99	NS
C.V. %	15.85	16.84	18.36	10.09	9.37	9.77	5.15	8.51	7.48	36.16	7.43	23.77

NS=Non-significant

Table 2: Correlation coefficients between pod yield and weather and weather derived indices during different phenophases of groundnut crop

Phase	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	LC
CWRSI	0.65	0.36	0.12	0.40	0.27	0.72*	0.62	0.59	0.77*
SMC	-0.49	0.41	-0.34	0.42	0.35	0.74*	0.74	0.66	0.68*
AET	-0.53	-0.06	0.28	0.22	0.12	0.67*	0.66	-0.64	0.87**
Rainfall	0.75*	-0.46	-0.56	0.04	-0.30	0.82**	-0.16	-0.41	0.85**

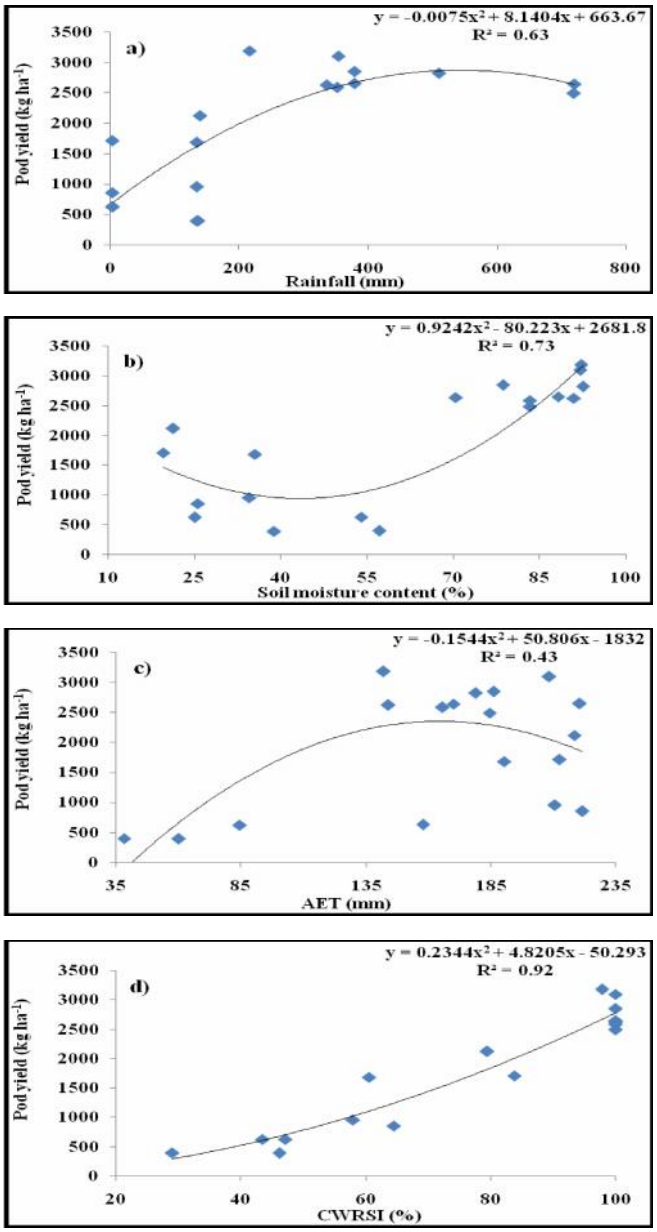

Fig. 1 : Relationship between pod yield and rainfall (a), soil moisture content (b), actual evapotranspiration (c) and crop water requirement satisfaction index (d) of groundnut crop during pod development stage during *Kharif* seasons of 2009 and 2010

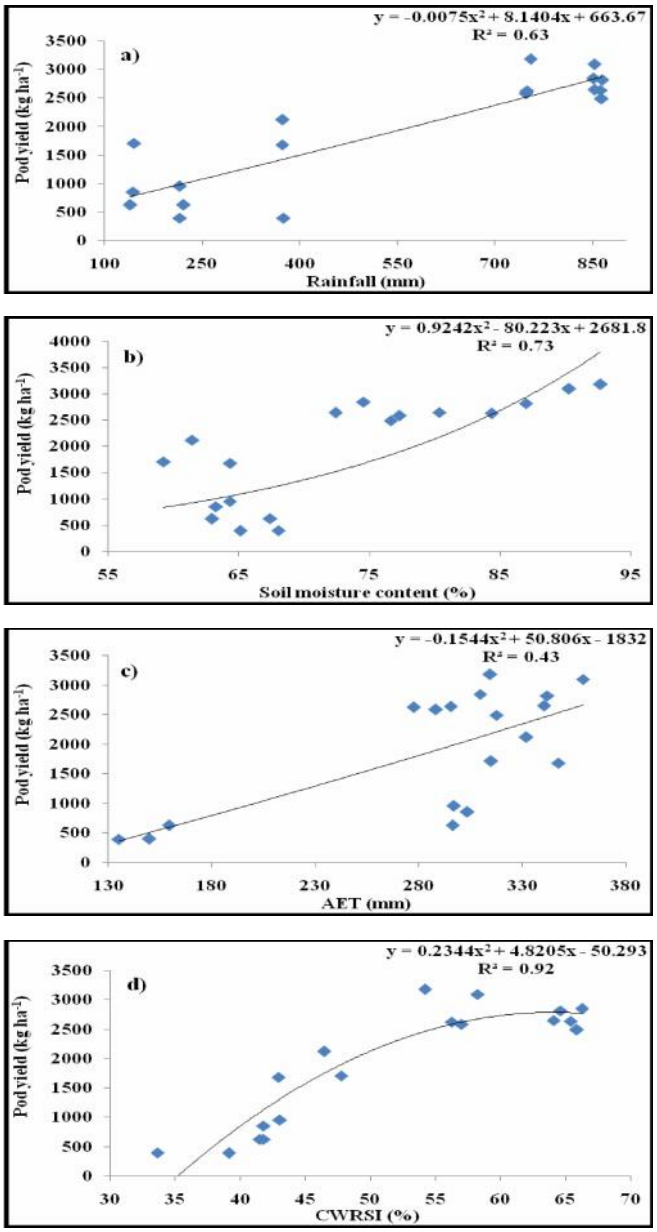

Fig. 2 : Relationship between pod yield and rainfall (a), soil moisture content (b), actual evapotranspiration (c) and crop water requirement satisfaction index (d) of groundnut crop for the entire crop duration during *Kharif* seasons of 2009 and 2010

assessments in our country. However, it is also important to carry out cost benefit analysis on determination and applications of appropriate planting dates in order to take full advantage of limited soil moisture availability in a shortened crop growing season. In this section, we discuss the various methods used in this scheme *i.e.* calculation of water requirement (WR), available water amount (AvW), soil water (SW), deficits or surpluses and finally the water satisfaction index (WRSI) summarizes, up to a specific growth stage or the end of its development, the degree to which cumulative crop water requirements have been met. The water requirement satisfaction index (WRSI) is a crop performance indicator based on the availability of water to the crop during a growing season. It expresses which percentages of the crop's water requirements were actually met.

The working rainfall amount reflects the effective water received by the crop, in this case, the rainfall amount received during the dekad is considered to be 100% effective. The figures below indicate the water requirements (WR) of the crop, the actual decadal rainfall (ACT) and the water requirement satisfaction index (WRSI). This index is a crop performance indicator and was used to give a general view of the expected yields. An index of 100% indicates expected good yield while an index of 50% or below indicates total crop failure. From the water requirement satisfaction index alone indicated that for the 3 stations, poor yields were likely to be observed if no other parameters come into play except rain in 2002 and 2005 where we had the index falling below 100 by a substantial margin. In investigating the crop water requirement for maximum yield production of groundnut, the water balance calculation indicated that for most stations, the crop water requirement was satisfied except for Livingstone district in the 2001/02 season where the index fell below 50%.

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