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Quantification of Rainfall Effects on Grain Yield of Sorghum Genotypes in Dryland Alfisols

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Summary

Regression analysis of yield of three sorghum genotypes with rainfall received during 6 phenological stages was performed using 10 years data from 1972 to 1981 generated in alfisols. A comparison of three types of regression models viz., natural, square root and logarithmic scales has been made and suitability of regression coefficients for yield prediction is discussed. The study indicated that the rainfall had a negative effect in vegetative state, while it had positive effect in primordial initiation and boot leaf stages. The study also suggested the necessity of conserving moisture for meeting the dry spells likely to occur in different stages of crop growth.

Key Words : Rainfall effects, Prediction, Regression coefficients, Model-building, Crop growth stages.

Introduction

In rainfed agriculture, the amount of rainfall and its distribution at different stages of crop growth is more important than any other input variable. The grain yields of a crop fluctuate from season to season due to variation in rainfall distribution. The effects of rainfall and its distribution on high yielding varieties, hybrids and locally grown varieties are similar although organic and chemical fertilizer variables play an important role in attaining significantly higher yields with high yielding varieties. An effort is made to develop suitable statistical prediction models for kharif sorghum grain yield in terms of amount of rainfall as received and observed under six different stages of crop growth during 10 years from 1972 to 1981 in dryland alfisols.

2.0. *Materials and Methods*

2.1. *Experimental Data*

Field experiments on kharif sorghum (Sorghum bicolor (L.) with two high yielding popular hybrids 'CSH-6' and 'CSH-5' and a local variety 'PJ (8)K' were conducted at Hayathnagar Research Farm of Central Research Institute for Dryland Agriculture, Hyderabad from 1972 to 1981 under rained conditions. The soils are light and shallow with varying depths from 10 to 50 cms, and were found to hold moisture by 15% on volume basis which is just sufficient for 10 days of crop growth (Vittal et al., [5]. The normal rainfall in this region is about 773 mm from 52 rainy days which is bimodal in distribution (Singh, [2]). A basal N dose of 10 kg and P dose of 40 kg/ha was applied at the time of sowing, and a level of 25 kg N/ha was top-dressed when the crop was of about 25 days duration. The test entries were sown after the soils were fully saturated with the early monsoon rains which resulted in good emergence and optimum population. All the crop management and plant protection measures were adopted. The observations on amount of rainfall received on each day were recorded. The three genotypes of sorghum were harvested separately and grain yields recorded.

2.2. *Grouping of rainfall data*

The entire crop duration starting from sowing to harvest has been classified into 6 periods viz., P1 to P6. Each period was of three week duration which broadly coincided with important phenological stages of genotypes tested as detailed below.

Period	Duration (days)	Phenological stages of sorghum		
		CSH-6	CSH-5	PJ(8) K
P 1	1-21	Vegetative	Vegetative	Vegetative
P 2	22-42	Primordial initiation	Vegetative/ Primordial initiation	Vegetative
P 3	43-63	Flowering	Primordial initiation/ flowering	Primordial initiation
P 4	64-85	Milk	Flowering/ Milk	Flowering
P 5	86-105	Dough	Milk/Dough	Milk
P 6	106-124	-	Dough	Dough

The grain yield prediction models are calibrated by regressing yield on rainfall as received in each of the six periods with the following objectives:

(i) for reliably predicting sorghum grain yield in terms of rainfall and its distribution;

(ii) for testing significance of rainfall effects as received and recorded on different stages of crop growth.

2.3. *Model-building of yield and rainfall variables*

Multiple regression models of yield of each genotype by using total and mean rainfall received under P1, P2, P3, P4, P5 and P6 periods can be given as

$$Y = A + B1\ P1 + B2\ P2 + B3\ P3 + B4\ P4 + B5\ P5 + B6\ P6 \quad (1)$$

This model can be compared with squareroot and logarithmic models which can be given respectively as

$$\sqrt{Y} = C + D1\sqrt{P1} + D2\sqrt{P2} + D3\sqrt{P3} + D4\sqrt{P4} + D5\sqrt{P5} + D6\sqrt{P6} \quad (2)$$

$$Y = E + F1\log(P1) + F2\log(P2) + F3\log(P3) + F4\log(P4) + F5\log(P5) + F5\log(P6) \quad (3)$$

In models (1), (2) and (3), A, C and E are intercepts; B1 to B6, D1 to D6, and F1 to F6 are statistical estimates of regression coefficients of rainfall in different periods. The models are screened by comparing estimates of coefficient of predictability (R^2), experimental error (σ) and percent coefficient of variation. One can select a model with maximum R^2, and minimum experimental error and coefficient of variation. One can also screen rainfall variables representing different periods based on their significance for predicting yield under different models. Finally, a model suitable for making precise yield prediction in terms of significant regression variables of rainfall and provides estimates of critical amounts of rainfall that is required for crop growth in each of the six periods with an acceptable confidance bounds can be selected.

3.0. *Results and Discussion*

The season wise distribution of rainfall in six different periods along with harvested grain yields of three varieties of sorghum in 10 years is given in Table 1. In subnormal years like 1972, the grain yield of hybrids was found to be marginally higher over local variety. In normal and above normal years, the hybrid yields were found to be significantly higher when compared to local variety, due to high genetic yield potential and efficient moisture utilisation as given in Fig. 1.

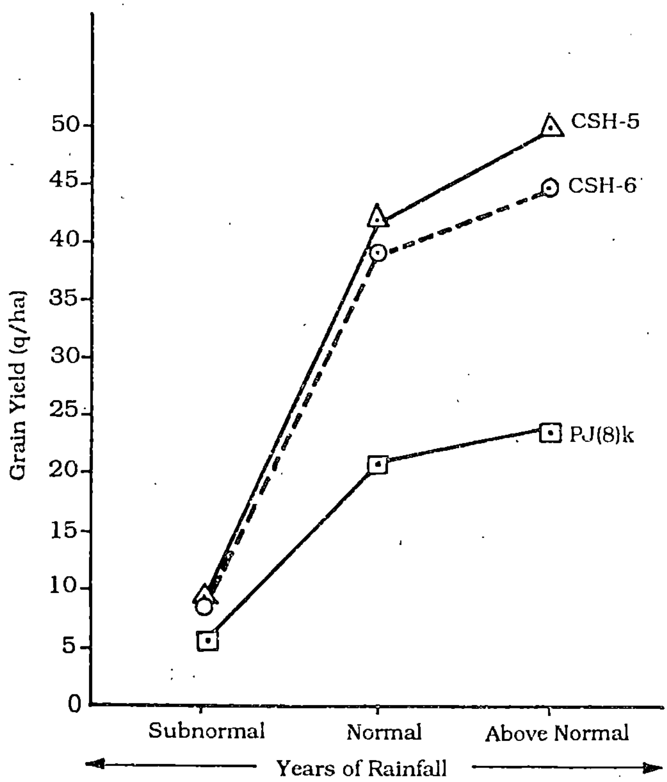

Fig. 1. The grain yield of sorghum genotypes under varying rainfall situations.

Regression models of sorghum yield were calibrated by regressing yield separately on natural, squareroot and logarithmic scales of rainfall variables. The estimated regression coefficients of rainfall, R^2, σ, percent coefficient of variation and expected yields of sorghum are given in Table 2. The regression coefficient of rainfall

Table 1. Distribution of rainfall in different period and yield of three sorghum genotypes in 10 seasons

Year	Seeding week	Rainfall during different periods (mm)						Total	Grain yield (q/ha)		
		P1	P2	P3	P4	P5	P6		CSH-6	CSH-5	PJ (8) K
1972	27	59.3	10.7	12.0	96.7	59.0	36.1	273.1	7.34	3.44	3.26
1973	23	93.7	180.3	101.6	112.5	14.5	212.5	714.4	45.19	40.07	34.13
1974	25	80.1	89.9	124.8	34.0	166.8	98.9	594.5	33.57	42.17	22.17
1975	24	42.5	105.8	163.7	76.5	258.5	183.9	830.9	58.95	62.41	21.95
1976	26	128.3	199.6	76.0	68.7	15.7	25.4	513.5	30.10	46.69	18.38
1977	25	41.2	125.2	79.8	109.2	1.4	56.0	412.8	49.62	44.85	24.61
1978	25	163.2	63.2	225.6	56.9	174.2	3.0	686.1	35.23	39.85	14.97
1979	24	90.6	4.3	126.9	33.0	44.5	51.4	350.7	9.62	15.42	8.24
1980	24	70.3	47.1	78.4	55.6	48.8	2.6	303.3	42.33	32.02	28.60
1981	25	206.8	9.8	151.7	129.8	247.3	88.4	769.3	33.35	34.26	12.60
Mean		97.6	83.5	114.1	77.3	103.1	75.8	544.9	34.53	36.11	18.89
S.D.		53.7	69.8	58.8	33.6	99.0	72.1	203.2	16.26	16.54	9.38
C.V.(%)		55.0	83.5	51.5	43.5	96.1	95.1	37.3	47.10	45.79	49.67

Table 2. Estimates of regression coefficients, experimental error and R^2 values of three sorghum varieties in terms of rainfall distribution in six stages

Variety		Regression coefficients of rainfall periods							σ	R^2	EY	CV
		Inter cept	P1	P2	P3	P4	P5	P6				
CSH6	(a)	4.88	-0.14	0.13	0.10	0.19	0.10	-0.06	15.6	0.70*	34.5	45.0
	(b)	-20.21	-3.84*	-2.05*	3.58*	4.46*	0.71	-0.87	9.6	0.88**	34.5	27.7
	(c)	-50.56	-16.97**	5.41**	14.15**	17.52**	1.90	-1.74	5.7	0.96**	34.5	16.6
CSH-5	(a)	10.51	-0.10	0.22**	0.07	0.01	0.12*	-0.06	10.1	0.88**	36.1	27.8
	(b)	-18.61	-1.86	2.93**	2.70*	1.70	1.05	-0.40	8.0	0.92**	36.1	22.2
	(c)	-54.22	-7.58	7.71**	12.18**	6.84	2.01	0.59	7.6	0.93**	36.1	21.0
PJ (8)	(a)	12.36	-0.05	0.07	0.05	-0.07	-0.01	0.02	10.8	0.56*	18.9	56.9
	(b)	2.65	-0.88	1.20	1.21	0.58	-0.37	0.10	9.9	0.63*	18.9	52.6
	(c)	-5.63	-3.28	4.06	4.22	1.92	-0.83	-0.17	-9.3	0.67*	18.9	49.1

(a) Natural Scale (b) Squareroot Scale (c) Logarithmic Scale

* and ** are 5% and 1% levels of significance

of both early and late vegetative period (P1) was found negative for all the three varieties under all models, but significant only for CSH-6 under logarithmic model. Siva Kumar et al., [3]) observed that any rainless period for 20 days or less duration was found to have no effect either on plant stand or grain yield. On the other hand, excess rainfall in this period effected weeding operations and also in leaching of weeds during the first 20 days of seeding appeared crucial in reducing yields.

The estimates of regression coefficients of rainfall in both P2 and P3 periods were found positive for all varieties and significant for hybrids under logarithmic regression models. During these two periods, the leaf area was found increasing followed by physiological phenomena like panicle initiation, fixing of grain number and stem elongation which competed for photosynthesis. Venkateswarlu and Tata Rao [4] and Eastin et al., [1] observed that as moisture requirement by crop was maximum during these two periods, any moisture deficiency will lead to drying of leaves resulting in reduced rate of photosynthesis and grain yields.

Although positive association was recorded between rainfall in P4 stage and grain yield of all genotypes, only in case of hybrids it was statistically significant. Further, occurrence of rainfall in P5 and P6 periods did not influence yield of genotypes significantly. Thus logarithmic models of all varieties were found preferable to both natural and squareroot scale models because of high predictability of yield and also significance of regression coefficients of rainfall variable under different stages. The study has thus indicated that primordial initiation and flowering stages appeared crucial for all genotypes. In addition to these two stages, the stage was found crucial for CSH-6 genotype. During this period, the genotypes were at either flowering or milk stage and the demand for water was found to be high. In another study, a life saving irrigation of 2 cm/ha given to CSH-6 at flowering stage was found to increase grain yield from 8.7 q/ha (control) to 15.4 q/ha. Further, conservation of soil moisture during early periods of crop growth and harvested water due to excess rainfall can be used for giving supplemental irrigation at crucial stages.

Thus the study suggests that conservation of moisture by removal of weeds and dust mulching is beneficial to preserve moisture in soil to tide over dry periods likely to occur during P2, P3, and P4 stages of the crops. In cases water harvesting technology is adopted, a life saving irrigation will significantly boost the yield of sorghum genotypes.

Table 3. Estimates of regression coefficients, experimental error and R^2 values of three sorghum varieties in terms of rainfall distribution in first five stages

Variety		Regression coefficients of rainfall periods						σ	R^2	EY	CV
		Intercept	P1	P2	P3	P4	P5				
CSH-6	(a)	2.94	-0.17	0.12	0.16	0.20	0.04	12.36	0.74*	34.5	35.8
	(b)	-19.15	-3.22*	1.85*	3.30*	3.61*	0.50	9.43	0.85**	34.5	27.3
	(c)	-52.82	-14.99**	5.61**	13.31**	15.37**	1.73	6.11	0.94**	34.5	17.7
CSH-5	(a)	5.78	-0.08	0.19**	0.11	0.03	0.08	8.68	0.88**	36.1	24.0
	(b)	-18.13	-1.58	2.83**	2.57*	1.32	0.95	7.25	0.91**	36.1	20.1
	(c)	-53.45	-8.25	7.64**	12.47**	7.57*	2.06	6.70	0.93**	36.1	18.5
PJ (8)	(a)	8.46	-0.06	0.08	0.07	0.05	-0.02	9.60	0.53*	18.9	50.8
	(b)	2.52	-0.96	1.22	1.24	0.68	-0.35	8.63	0.62*	18.9	45.7
	(c)	-5.84	-3.09	4.08	4.14	1.71	-0.84	8.03	0.67*	18.9	42.5

(a) Natural Scale (b) Squareroot Scale (c) Logarithmic Scale

* and ** are 5% and 1% levels of significance

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