RAINFALL FLUCTUATIONS AND CROP YIELDS

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IN recent years, there has been growing interest in possible weather changes and their influence on crop yields. The year 1972–73, during which widespread drought occurred in India and several other regions of the world, is often cited as an important case study.

While the limits of rainy season and consequently the crop growing period in a given region could reasonably be well defined, rainfall fluctuations within the seasons are less definable; statistical probabilities of droughts do not provide for prediction of the behaviour of the current crop season. On the other hand, crop production strategies selected on the basis of performance in the most droughty years might provide built-in safeguards for unforeseen low and/or fluctuating rains encountered during a crop season.

Sorghum popularly known as *Jowar* constitutes the major food crop of the semi-arid tropics almost wholly grown under rainfed conditions. Traditional sorghums grown in black soil areas of the Deccan and Central Indian plateaus are of 5–5½ month duration while the rainy season is of about 100–110 days duration commencing towards the later half of June and terminating before the end of September or middle of October in most parts.

During 1972–73, the long duration traditional sorghums suffered during flowering and thereafter. The *rabi* (October-February) sorghums, which grow and mature primarily on stored profile moisture, either could not be sown in time or failed to yield for want of adequate reserve soil moisture. However, the early maturing hybrids and high yielding varieties of sorghum of 95–110 days duration, as against 150-day locals, when planted in time, and well managed, gave satisfactory yields during *kharif*. Similarly an early maturing hybrid CSH-1, when planted earlier in *rabi* season under proper management, also returned very satisfactory yields. It appears, therefore, that years like 1972–73 need not create a scare for rainfed agriculture and a choice of suitable genotypes, together with appropriate management practices, could still return average yields several times higher than all-India averages which are presently very low for most rainfed crops. The purpose of this paper is to analyse the rainfall-yield relationships of some superior sorghum 'hybrids' and 'varieties' grown under good management, during 1972–73 *kharif* and *rabi* seasons with focus on the controllable and manageable part of the variation in yield so as to realise satisfactory agricultural yields in spite of rainfall fluctuations.

1972–73 KHARIF SEASON

Multiple regression analysis utilising: (1) total rainfall during the year, (2) the number of rainy days and (3) the coefficient of variation in the monthly rainfall at each of the locations, as auxiliary variates, was attempted to study the relationship between rainfall attributes and grain yields. The set of 29 locations, from which data were available provided a reasonably representative sample of the environments, in which the sorghum crop is being grown and will continue to be grown in the country. The regression analysis has been carried out separately, for each of the high yielding hybrids and varieties. In the case of hybrids and varieties, where regression coefficients associated with rainfall attributes were significant, the coefficients have been recalculated, after deleting the less important auxiliary variates. If the proportion of variation attributable to the rainfall characteristics is small, the capacity of the genotype to withstand drought will be greater.

The mean yields, the total rainfall, the number of rainy days and the coefficient of variation in the monthly rainfall are presented in Table I. The analysis of variance and the values of the regression coefficients are presented in Tables II and III, respectively.

The genotypes 302 and 604 among the varieties, and CSH-1, CSH-3 and CSH-5 among the hybrids seem to be less dependent on the vagaries of rain as compared with the rest of the varieties and hybrids, *Swarna*, CS-3541, CSH-2 and CSH-4. The contributions of the number of rainy days (x_2) and the coefficient of variation in the monthly rainfall (x_3) to the variation in the yield of sorghum is larger than that of total rainfall (x_1) as could be seen from the significant values of b_2 and/or b_3 in the case of *Swarna*, CS-3541, CSH-2 and CSH-4. In other words, the analysis suggests that yield of sorghum is influenced more by the number of rainy days and the distribution of monthly rainfall rather than the total rainfall. The negative values of b_3 or b_3' indicate that larger values of coefficients of variation adversely affect yields.

The percentage of variation, ascribable to rainfall attributes, is shown in Table IV. The amount of

TABLE I

Mean yields (kg/ha) of varieties and hybrids during 1972–73 kharif, *total rainfall, number of rainy days and coefficient of variation(%) in the monthly rainfall*

Sl. No.	Location	Varieties				S.E.$_m$ (kg/ha)	Hybrids					S.E.$_m$ (kg/ha)	Total rainfall mm (x_1)	No. of rainy days (x_2)	c.v. (%) of monthly rainfall (x_3)
		Swarna	CS 3541	302	604		CSH-1	CSH-2	CSH-3	CSH-4	CSH-5				
1	Parbhani	4592	30·3	6326	3322	239	5701	4163	4133	5550	5171	342	524·9	44	126
2	Jalgaon	3322	3032	3148	3811	353	2621	3040	3471	2994	3699	425	650·0	38	135
3	Karad	3179	3640	2635	2345	313	4316	4053	3662	4374	4233	309	367 8	55	152
4	Kolhapur	3356	3356	3761	4398	215	3868	5102	4115	3292	4444	446	439·4	63	147
5	Buldhana	2511	2751	3796	2426	398	3860	1853	3486	4008	4754	440	463·4	35	148
6	Nagpur	3329	3570	4398	3358	283	3309	2551	2990	3309	3022	262	546·4	54	147
7	Yeotmal	3655	3402	4349	2619	128	4862	2593	3921	4994	4860	308	699·1	59	129
8	Dharwar	4467	3378	3176	3880	397	6057	5400	5615	4995	6737	448	722·44	73	97
9	Bagalkot	1555	1540	1514	1808	168	2125	1052	773	2073	2335	185	491·5	40	113
10	Arbhavi	3543	3271	3938	3210	295	4230	4576	3934	4181	4675	326	429·2	32	99
11	Gangavati	5069	3102	5683	5752	420	5426	5426	6645	7346	6340	477	313·5	41	114
12	Rajendranagar	4485	4898	5142	3079	279	5023	2421	4107	4902	[illegible]185	445	419·9	36	102
13	Anantapur	674	75	447	1075	1151	1037	1057	800	810	706	157	557·3	37	138
14	Yemmiganur	3746	2439	3573	5576	331	7201	4688	5374	6574	9029	833	394·4	27	100
15	Navsari	4080	3358	3857	3065	266	4166	3663	4300	2650	5521	281	963·9	59	172
16	Surat	2095	2196	2111	1973	233	2200	2097	2353	2395	2727	226	791·7	35	173
17	Deesa	1828	818	1147	444	240	2104	1963	2629	2172	1622	239	366·0	18	205
18	Gwalior	1943	2978	2886	2587	259	4831	2264	3651	282	4624	426	864·0	31	234
19	Khargoan	1974	2110	1721	1936	265	1691	1535	1217	2547	2412	230	392·5	33	164
20	Chindwara	2731	3339	2951	243	309	3251	1284	2609	3539	3284	420	671·1	37	209
21	Indore	4492	3620	5021	3486	312	5860	5464	5788	5942	7144	383	679·0	52	216
22	Powerkheda	1594	2025	1661	2523	150	2942	2269	2592	2707	3109	245	908·4	44	226
23	Coimbatore	4010	3847	2551	5166	320	4736	5218	4792	4361	3347	408	962·0	48	127
24	Bhavanisagar	4525	3390	3760	3258	243	4816	5334	5405	4959	6219	300	1384·2	49	160
25	Tindivanam	1910	1426	973	957	202	2571	2278	2194	2998	2386	307	839·2	46	131
26	Pudukottai	4339	3753	4305	3108	160	5304	5147	5476	5500	5342	276	1014·0	58	102
27	Vallabhnagar	3330	2555	3879	2480	293	3018	2405	2416	2338	2778	352	311·8	27	166
28	Jhansi	2693	2372	2519	2694	212	2921	2158	1677	1252	3582	291	743·5	31	225
29	Kanpur	822	864	598	1478	144	2665	1456	2224	2050	2286	227	475·4	27	182
	Mean	3098	2765	3166	2830	130	3886	3224	3530	3710	4268	111	634 0	42·4	153·1

TABLE II

Regression analysis

Source	d.f.	Mean sum of squares								
		Varieties				Hybrids				
		Swarna	CS 3541	302	604	CSH-1	CSH-2	CHS-3	CSH-4	CSH-5
Regression	3	4568929*	2763627*	3619974 (NS)	4049214 (NS)	4327697 (NS)	8597944†	5772548 (NS)	64[illegible]1259*	5653567 (NS)
Deviation from regression	25	1106086	915198	2085786	1580066	1983491	1595692	1953846	2102004	3793649

* Significant at 5% level. † Significant at 1%. NS Not significant.

TABLE III

Regression coefficients

Regression coefficient	Varieties				Hybrids				
	Swarna	CS 3541	302	604	CSH-1	CSH-2	CSH-3	CSH-4	CSH-5
b_1	−0·51 (NS)	0·11 (NS)	−0·88 (NS)	0·05 (NS)	0·40 (NS)	0·72 (NS)	0·84 (NS)	−0·05 (NS)	0·50 (NS)
b_2	42·83*	57·91*	38·99 (NS)	22·73 (NS)	32·79 (NS)	53·17*	39·16 (NS)	28·73 (NS)	31·12 (NS)
b_3	−7·69 (NS)	−2·88 (NS)	−6·35 (NS)	−12·17 (NS)	−9·53 (NS)	−10·21 (NS)	−9·36 (NS)	−15·33*	−12·86 (NS)
b_2'	46 09†	41·31†	..	..	..	68·25†	..	..	..
b_3'	..	..	..	..	..	..	..	−18·02†	..

* Significant at 5% level. † Significant at 1% leavl. NS=Not significant.

Note: b_1, b_2 and b_3 represent the coefficients of regression associated with total rainfall. number of rainy days, and the coefficient of variation (c.v.%) in the monthly rainfall respectively.

b_2' Coefficient of regression associated with the number of rainy days after deletion of the total rainfall and coefficient of variation in the monthly rainfall.

b_3' Coefficient of regression associated with coefficient of variation in the monthly rainfall after deletion of total rainfall and number of rainy days.

TABLE IV

Percentage of variation accounted for by regression

Percentage of variation	Varieties				Hybrids				
	Swarna	CS 3541	302	604	CSH-1	CSH-2	CSH-3	CSH-4	CSH-5
With variables x_1, x_2 and x_3	33·1	26·6	17·2	23·5	20·7	39·3	26·2	26·9	15·2
With x_2 alone (after deleting x_1 and x_3)	23·8	25·4	..	..	..	32·9	..	..	..
With x_3 alone (after deleting x_1 and x_2)	..	..	..	..	..	..	..	22·2	..

Note: x_1=Total rainfall, x_2=Number of rainy days, x_3=The coefficient of variation in the monthly rainfall (c.v. %).

variation in yield ascribable to rainfall is mostly determined by the number of rainy days and/or the coefficient of variation in the monthly rainfall within the limits of rainfall received. What is more important is that in none of the cases studied, the variation ascribable to rainfall characteristics exceeds 40% of the total variation. This shows that still a large proportion of the total variation in yield, upto 85% over the locations, is attributable to causes other than fluctuations in rainfall as discussed later.

1972–73 RABI SEASON

In view of the low rainfall received during the early months of June, July and August and the anticipated low production of sorghum during *kharif* season, it was thought that possibilities of compensating for *kharif* losses may be explored in the *rabi* sorghum belt.

The low rainfall preceding the *rabi* season resulted in low levels of profile moisture which was apt to adversely influence the *rabi* production. Keeping this in mind a *rabi Jowar* production campaign based on the following principles was suggested: (1) Advancing dates of planting well into early September, without waiting for the traditional sowing dates in October so that the crop has a chance of getting some rain during early growth period; (2) Growing early maturing 100-day hybrids in place of 120–135 day locals; (3) All basal fertilization; (4) Full crop stands and (5) Seed treatment with a chemical, carbofuran, to prevent damage by sorghum shoot fly, a seedling pest. The whole programme was oriented towards earliness, so that the crop was raised during the period September–mid December instead of the traditional October–February.

A well directed programme of this type in one District of Andhra Pradesh, Khammam, over about 50,000 acres undertaken by the Department of Agriculture was an unqualified success. This was partly due to the somewhat favourable rains received during early crop growth period. While weather

TABLE V

Number of crop cutting experiments and mean grain yield in different Samithies of Khammam District, Andhra Pradesh—Rabi *1972–73*

S. No.	Samithi	No. of experiments conducted CSH-1	Local	Grain yield (kg/ha) CSH-1	Local	% over local
1.	Wyra	3	3	4490	1318	340
2.	Khammam	3	3	4983	2109	236
3.	Burgampad	2	..	4457	..	..
4.	Kothagudam	6	6	4915	1233	398
5.	Yellandu	5	4	2683	1297	207
6.	Bhadrachalam	1	1	4571	1186	385
7.	Tirumalayapalem	8	4	4235	1742	243
	Mean			4239	1477	287

analysis of this region is not available, yield data obtained by the Department of Agriculture from crop cutting experiments (Table V), speak for the efficacy of the programme.

Besides, there is considerable experimental evidence accumulated over years in the *rabi Jowar* belt, that advancing dates of planting, during *rabi* enables certain genotypes (varieties or hybrids) respond better to higher seed rates and all basal fertilization, thereby, providing insurance against drought and also result in much higher levels of production.

Planning for Rainfed Agriculture

Rainfall analysis by itself does not provide for prediction about the behaviour of the immediate cropping season. On the other hand, analyses based on more successful experiments and profitable farmer experience during the worst years encountered is more positive and could provide for development of cropping plans which could be least risky if the rains are subnormal and highly profitable if rains are normal. The current analysis is an attempt in this direction.

Genotype alterations involving reduction of duration, reduction of total dry matter and its more efficient distribution between stalk and ear (economic product), adjustments in times of sowing, maintenance of optimum plant populations, use of fertilizer, plant protection measures and practice of suitable systems of cropping, ratooning, etc., all of which are in the realm of human control could enhance productivity levels and impart stability to production in rainfed agriculture. During 1972–73, sorghum yield levels in well managed experiments and with several farmers were of the order of 25–30 q/ha against the national average of 5 q/ha in normal years and near total failure during 1972–73.

A point of significance in planning for rainfed agriculture emerges here. Attempts at enhancing agricultural productivity do realise the role of environmental barriers and the need to transgress 'error' (environmental) limits. Yet, the targetted yield increases planned more particularly for rainfed agriculture are frequently within the limits of environmental error and do not provide for the much needed increments of a larger magnitude. A breakthrough in rainfed agriculture can, therefore, be expected only by planning for large quantum jumps rather than for slow and graded annual targets which are within the realm of environmental fluctuations. This approach may all the more be necessary, in the initial years since the present all-India averages for most rainfed crops are less than 500 kg/ha and the available know-how has the potential to elevate the national averages several fold.

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