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Height and yield of Kharif Jowar in relation to rainfall during vegetative growth

A. K. MALLIK

Meteorological Office, Poona

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1. Introduction

'Kharif' Jowar is grown during the south-west monsoon season generally as a rain-fed crop. During this season, extremes of temperature are uncommon so that rainfall assumes great importance in the case of Kharif Jowar crop. It was, therefore, considered worthwhile to examine the effects of rainfall during the vegetative growth period on the growth in height and the yield of grain for this crop.

For this purpose, the data collected under the *All India Co-ordinated Crop-Weather Scheme* was utilised. Under this scheme, systematic observations regarding the growth and yield of Kharif Jowar crop (among other crops) as well as the meteorological factors experienced by the crop during its life cycle are being recorded on a uniform basis at a few selected experimental farms in India. The names of the experimental farms and the number of years' data on Kharif Jowar, available for each station are as follows —

Dharwar	10 years	
Parbhani	10 years	(9 only for height)
Jalgaon	10 years	
Akola	10 years	
Nagpur	8 years	

Total 48 station-years
(47 only for height)

The sampling technique followed under the *All-India Co-ordinated Crop-Weather Scheme* is briefly described as below—

At each station, two varieties of the crop, under observations, are grown according to the following layout plan, with 6 plots under each variety—

V_1	V_2	V_2	V_1	V_1	V_2
V_1	V_2	V_2	V_1	V_1	V_2

V_1 = I Variety
V_2 = II Variety

The size of the plot is 1/40 acre. The sampling unit is 8 ft length made up of two parallel 4 ft lengths (ultimate units), in adjacent rows. Three such samples are selected by randomization from each half of the plot, giving 36 samples or 72 ultimate units, for each variety. The two end plants of each ultimate unit come under measurement.

The height measurements are thus made on 144 plants in all, for each variety, selected by randomization. The height is measured from the ground upto the base (junctura) of the topmost fully opened leaf. The height values, under consideration in the paper, represent the average of the heights, from the ground to the junctura of the topmost fully opened leaf, based on the measurements made on 144 plants of each variety selected by randomization, at a time when the height of the crop has reached the maximum. The yield values, however, are based on the yield of all the six plots of each variety, pooled together.

As has been mentioned above, there are two varieties under observations at each station, but these varieties differ from station to station and, therefore, for the purpose

TABLE 1

Height (cm) attained by Jowar crop

Year	Dharwar	Parbhani	Jalgaon	Nagpur	Akola
1946-47	255		123		227
1947-48	295	237	235*		278
1948-49	299*	209	132	195	174
1949-50	273	197	182	241	175
1950-51	199	109	175	237	160
1951-52	263	161	160	259	250
1952-53	271	236	128	211	213
1953-54	216	317*	212	293*	285*
1954-55	275	222	205	179	269
1955-56	283	176	155	101	217
Average	263	207	171	214·5	225

* Maximum height

of this study, for height and yield, average values of the two varieties at each station in each year have been taken to represent the height and yield values. These average values of height and yield are given in Tables 1 and 2 respectively along with the averages over the year for each station.

A preliminary examination of the crop data showed that the vegetative growth period (*i.e.*, sowing to ear-emergence) varies from 12 to 15 weeks from station to station and from year to year. Therefore, for the sake of uniformity at all the stations and for all the years, a period of 12 weeks immediately preceding ear-emergence was taken to represent the vegetative growth period.

It is generally agreed that either too much or too little rain as well as too long wet or dry spells during the vegetative growth are injurious to Kharif Jowar. In other words, both for amount and distribution of rainfall, there is an 'optimum', any deviation from which tends to damage the crop. It is also reasonable to expect that the optimum conditions will differ from station to station being particularly dependent on soil conditions. However, with the limited data available at present, it is not possible to fix up precisely the optimum conditions for each station. Hence for the purpose of this study, the year, in which the height or the yield of grain at a particular station was highest, was assumed to be an optimum year for rainfall also for that station. Judged on this basis, from the values given in Tables 1 and 2, it would be seen that the optimum years for height are — Dharwar 1948-49, Parbhani 1953-54, Jalgaon 1947-48, Nagpur 1953-54 and Akola 1947-48. However, it will be seen from Table 1 that for Dharwar, the difference in the height values, between the years 1946-47 and 1947-48, is negligible. Therefore, for the sake of uniformity over large areas, the year 1947-48 was considered to be the optimum year for height at Dharwar also. On the same consideration, and also because yield is highest in 1947-48, the optimum year for Akola, for purposes of height, was fixed as 1947-48. The optimum years for the purpose of the yield were similarly fixed up. The optimum years thus fixed up, for considerations of height and yield are as follows—

Height

Dharwar, Jalgaon and Akola	1947-48
Parbhani and Nagpur	1953-54

Yield

Dharwar and Parbhani	1952-53
Jalgaon and Akola	1947-48
Nagpur	1953-54

TABLE 2

Yield of grain of Jowar in lbs per acre

Year	Dharwar	Parbhani	Jalgaon	Nagpur	Akola
1946-47	1688	1270	668		1262
1947-48	2711	1355	1333*		2059
1948-49	1796	759	879	665	832
1949-50	2203	1117	645	642	749
1950-51	961	433	953	1637	64
1951-52	1985	857	1001	2117	1014
1952-53	2826*	1988*	461	1774	1509
1953-54	1308	561	894	2169*	1735
1954-55	2164	1664	1017	1172	1425
1955-56	2135	967	386	533	1220
Average	1978	1097	824	1339	1187

* Maximum yield

TABLE 3

Rainfall (inches) in the optimum years

No. of weeks immediately preceding ear-emergence	Dharwar		Parbhani		Jalgaon	Nagpur	Akola
	for height (1947-48)	for yield (1952-53)	for height (1953-54)	for yield (1952-53)	for height and yield (1947-48)	for height and yield (1953-54)	for height and yield (1947-48)
12	2·88	1·85	3·62	1·73	3·51	2·24	1·26
11	0·53	0·85	0	2·91	1·36	10·54	0·64
10	0·10	0·72	0·65	1·72	0·02	2·32	0·21
9	1·43	0·68	3·17	0·49	0·63	1·50	1·11
8	3·37	0·04	0·41	1·41	0·58	0·01	0·52
7	0·98	0·09	1·65	1·02	1·19	1·30	2·73
6	1·85	0	3·90	0·08	3·23	1·07	3·47
5	0·88	0	0·29	3·01	4·44	4·07	2·60
4	0·05	0·66	2·26	0	3·53	0·29	0·02
3	2·60	2·51	0·03	0·67	0	1·09	1·62
2	0·34	1·13	0·18	0·02	0·91	1·59	2·98
1	0·10	0·09	2·61	2·98	2·60	0	0·04
Total for the whole vegetative growth period	15·11	8·62	18·79	16·04	22·00	26·02	17·20

The actual amounts of rainfall, week by week, during the vegetative growth period (12 weeks immediately preceding ear-emergence) in the above optimum years, for each station, are given in Table 3. The correlations between height and yield as well as between the deviations of rainfall from optimum and these two crop features were next examined. The procedure adopted is described below.

(*A*) *Height and Yield*—As will be seen from Tables 1 and 2, the number of years for which data for each individual station are

TABLE 4

Station : Dharwar Crop character : Height
Year : 1946-47 Optimum year : 1947-48

No. of week before ear-emergence (1)	Rainfall during 1946-47 (inches) (2)	Rainfall during 1947-48 (optimum) (inches) (3)	Departure from optimum (Col. 2—Col. 3) (inches) (4)	Departure expressed as % of optimum or 0·50″, whichever is greater (Col. 4— Col. 3) or (0·50×100) (5)
12	0·67	2·88	— 2·21	— 77
11	4·21	0·53	+ 3·68	+ 694
10	1·56	0·10	+ 1·46	+ 292
9	1·01	1·43	— 0·42	— 29
8	0·84	3·37	— 2·53	— 75
7	0·60	0·98	— 0·38	— 39
6	0·17	1·85	— 1·68	— 91
5	2·28	0·88	+ 1·40	+ 159
4	0·02	0·05	— 0·03	— 6
3	1·69	2·60	— 0·91	— 35
2	4·26	0·34	+ 3·92	+ 784
1	4·97	0·10	+ 4·87	+ 974
			Arithmetic sum of % departures =	3255

available, is too small for working out the correlation coefficients according to standard statistical techniques. Therefore, the data from all the stations, for all the years, have been pooled together by expressing the values of height and yield at each station in each year as the percentage departures from the averages of the respective stations. These percentage departures were then utilised for calculating the correlation coefficients. In the procedure adopted, a replication in space has been substituted for a replication in time and to that extent the conclusions arrived at will be tentative, to be confirmed or otherwise when a sufficiently long series have been built up for each station. The correlation coefficient between the height attained by the crop and the yield of grain was then calculated using the percentage departures.

(*B*) *Rainfall*—For this purpose, the departure of the actual rainfall from that during the optimum year, was expressed as a percentage of the rainfall during the optimum year, week by week (weekly percentage departures from the optimum), for each of the 12 weeks of the vegetative growth period. The arithmetical (irrespective of positive or negative) sum of these percentage departures were then computed for each year, for each station, which was taken to represent the index of rainfall deviations. However, according to this procedure, when the rainfall in any particular week of the optimum year is very small, the percentage departure value gets very much exaggerated and in the extreme case becomes infinity for 0 rainfall. This was got over by computing the departure as a percentage of 0·50″ or the actual rainfall, whichever is greater. Perhaps the example given in Table 4 may help to clarify the procedure adopted.

The index of rainfall deviation for Dharwar for the purpose of height, during the year

TABLE 5

Index of rainfall deviation

Year	Sum of weekly percentage departures of rainfall from that of the optimum year at						
	Dharwar		Parbhani		Jalgaon	Nagpur	Akola
	for height	for yield	for height	for yield	for height and yield	for height and yield	for height and yield
1946-47	3255	2760	†	2510	926		1971
1947-48	0*	1848	1239	1810	0*		0*
1948-49	1228	1324	993	1362	1268	1463	1334
1949-50	790	933	1681	2126	2840	1491	2273
1950-51	1729	1849	3067	2602	935	773	**
1951-52	1087	517	2206	1425	1049	988	1335
1952-53	948	0*	2038	0*	1728	1110	1537
1953-54	2288	1798	0*	2387	1649	0*	1836
1954-55	1434	1257	2784	1153	1200	1288	1952
1955-56	1328	898	1725	3374	1353	940	2802

* These are optimum years, hence no departure

† Height value not available, hence index of rainfall deviation not calculated

** This is the year of crop failure, hence data for this year are excluded

1946-47 is, therefore, 3255. Similarly the index of rainfall deviation for each year for each station and separately for purposes of height and yield wherever necessary, was computed and these values are given in Table 5.

The correlation coefficients between index of rainfall deviation and (*a*) height (% departures) and (*b*) yield (% departures) were calculated.

3. Results

The following values of the correlation coefficients (r) between height (H), yield (Y) and rainfall deviation (R) were obtained.

$$r_{HY} = +\cdot 5913$$
$$r_{RH} = -\cdot 4247$$
$$r_{RY} = -\cdot 5092$$

All the above values of r are significant at 1 per cent level of probability.

In order to find out whether the rainfall deviation has any effect on yield independently of height, the partial correlation of yield and rainfall on height (r_{YR-H}) was calculated and the following value was obtained—

$$r_{YR-H} = -\cdot 3534$$

This is significant at 5 per cent but not at 1 per cent level of probability.

4. Inferences

(*i*) The strong positive correlation between height and yield indicates that the height of the crop is a good precurser of the yield. Thus the general belief that taller the crop, greater the yield is confirmed.

(*ii*) Considering the total rainfall and yield, during the optimum years for yield, the yield in lbs per inch of rain for the different stations are as follows— Dharwar 328, Parbhani 124, Jalgaon 61, Nagpur 83 and Akola 120.

This shows that during optimum year, the utilisation of water for the production of grain is much more efficient at Dharwar than at the other stations.

(*iii*) The highly significant correlations of height and yield with rainfall deviations show that greater the deviations of the rainfall from the optimum, shorter the crop and lower the yield. The prevalent idea that either too much or too little rainfall is detrimental to the crop is thus corroborated,

Further, the highly significant correlations appear to indicate that the optimum values given in Table 3 may not be very different from the actual optimum values to be determined statistically in due course.

(*iv*) The significant partial correlation of yield and rainfall deviation on height appears to suggest that rainfall may have some additional effects on the yield independently of height.

In this paper attention has been confined to only rainfall and that too during the vegetative growth alone. There is no doubt that other meteorological factors like sunshine, humidity, rainfall during the reproductive period (ear-emergence to harvest) etc also exert some influence on the yield of the crop. When these factors are taken into account, the correlations, it is hoped, will definitely improve. Therefore, no attempt has been made to work out regression equations for forecasting the yield at the present stage.

In view of the procedure adopted in this paper, *i.e.*, substituting replication in space for replication in time, the inferences drawn should be regarded as tentative, to be confirmed or otherwise when data for a sufficiently long period for each station become available.

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