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Crop growth as an indicator of the final yield — Wheat Crop

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1. Introduction

Systematic observations are being recorded on important crops of India under the Co-ordinated Crop-Weather Scheme. Wheat is one such crop under crop-weather studies and information on the behaviour of this crop is available for a few years from a small network of six crop-weather stations in India. An attempt has been made in this paper to relate the growth characteristics to the final yields to see which of them is more important from the point of view of the yield of the crop.

Strictly speaking, a long series of yield data for a single station recorded under comparable conditions, is essential before we can get a valid estimate of the regressions of the crop growth characteristics on the yield of the crop so that it may be useful for a crop yield forecasting. While the purpose of crop-weather observations is to accumulate such series of data for different crops, interim studies with these observations, though not capable of yielding valid estimates of the regression characteristics, would still enable us to get some indications of the nature of relationships involved and may bring out the relative importance of the different crop growth characteristics to the ultimate yields. The aim of this note is to present the results of such an interim study of wheat yields of six farms for eight seasons together with the growth observations of the crop.

2. Material and method

For the purpose of this study, the data on wheat crop collected at the following crop-weather stations, situated in the region of black soil, have been made use of— Dharwar, Parbhani, Niphad, Jalgaon, Nagpur and Powerkhera. In all the above stations except Parbhani, wheat was grown under dry conditions and Pusa 4 (N.P.4) was one of the two varieties under observation. At Parbhani, the crop was given one irrigation in the years 1949-50, 1950-51 and 1951-52. Wheat crop at these centres was grown year after year according to the local practice with mean distance of 10 to 13 inches between rows and the following crop characters were recorded at suitable intervals by means of sampling technique (*Agrimet Tech. Circ.*, 1953).

(*i*) Daily germination count,

(*ii*) Number of shoots and plants per sample at weekly intervals,

(*iii*) Ear-emergence and number of ear-heads per sample at daily interval during the 'grand period of ear-emergence' and at weekly or fortnightly interval thereafter,

(*iv*) Elongation at weekly interval during the 'grand period of elongation' and

(*v*) Yield of the produce at the time of harvest.

The sampling unit is a four-foot length of row made up of four parallel foot lengths on adjacent rows. There are six replications of each variety and six samples are selected at random from each replication. Thus the percentage of crop sampled works out to 3·5 to 4·6 per cent.

As the crop grown at Dharwar failed completely in 1948-49 due to severe attack of rust, this year's data were not included in this study. There were in all 46 stations-cumyears data. As the fertility as well as the weather conditions at those stations were different, the data were reduced in the first instance to a common base. This was accomplished by the artifice of expressing the individual yearly values as the percentage of the station mean. Thus (*i*) the germination percentage, (*ii*) maximum number of shoots per sample, (*iii*) time taken from sowing to commencement of elongation, (*iv*) maximum height, (*v*) maximum number of earheads per sample and (*vi*) actual yield of grains from the periodical growth observation block and a few other crop observations were initially expressed as the percentage of the station mean.

With the data so processed, the amount of variability present in the various crop characters and the simple as well as multiple correlation coefficients and regressions between the various characters and actual yield were evaluated.

There are two main limitations in the technique of analysis adopted here—(*i*) The mean yield of the crop of a small number of years has been taken as the normal yield for that station and the yields of individual years expressed as a percentage. Thus the percentage departures of different seasons become the dependent variate in the regression analysis instead of the absolute yields. (*ii*) The percentage departures of yield of the same season for different stations have been considered as independent observations whereas actually they may not be. It is, therefore, considered that the tests of significance of the regression coefficients etc discussed in this paper are not strictly valid but should only be taken to give indications of relative importance of the growth characteristics on the yield only in a qualitative manner.

3. Results

3.1. *Magnitude of variation present in the various crop characters*

Since the actual data from the various stations have been reduced to a common base and expressed as a percentage of the station mean, the mean for any crop character will be 100. Table 1 gives the coefficient of variation, the highest and the lowest percentage and their difference for the various crop features.

TABLE 1

Crop feature	Coefficient of variation	Highest (%)	Lowest (%)	(3)—(4)
(1)	(2)	(3)	(4)	(5)
Germination % (x_1)	31·7	199·2	46·4	152·8
Maximum No. of shoots per sample (x_2)	37·6	238·2	36·6	201·6
No. of days from sowing to commencement of elongation (x_3)	12·7	139·0	79·1	59·9
Height (x_4)	17·2	146·4	71·9	74·5
No. of earheads per sample (x_5)	32·2	212·2	31·1	181·1
Actual yield of grain (Y)	40·3	231·8	62·2	169·6

In the above table the yield shows the greatest coefficient of variation. Height and duration of early growth phase show rather low coefficients of variations.

3.2. *Simple correlations*

The correlation coefficients between the various crop characters as well as yield Y (all expressed as percentage of the station mean) are given in Table 2.

The germination percentage was found to have a highly significant coefficient of correlation with the final yield, this value being 0·4926. Thus a good germination may be expected to lead to a good harvest.

Soon after germination the crop enters the tillering stage and in the course of two to three weeks the maximum number of shoots per sample is usually attained. This maximum number of shoots is highly significantly correlated with the final yield, the magnitude of positive correlation coefficient being

TABLE 2

	x_2	x_3	x_4	x_5	Y
x_1	0·6986	—0·4131	0·2518	0·7427	0·4926
x_2		—0·6371	0·2687	0·8387	0·6035
x_3			0·3233	—0·5448	—0·3412
x_4				0·2490	0·4046
x_5					0·7971

0·6035. Also it was found that better germination percentage leads in general to a better tillering, correlation coefficient between germination percentage and maximum number of shoots per sample being 0·6986.

There is a certain amount of interval between the time of sowing and the commencement of elongation. Longer this interval, lesser is the yield and *vice versa*, the order of negative correlation being — 0·3412. This correlation coefficient is significant.

Elongation, which may be considered as an index of growth, is highly significantly correlated with yield, correlation coefficient being 0·4046 and positive in sign.

Finally, the maximum number of earheads per sample was found to have the best of correlation coefficients with final yield, being as high as 0·7971. Thus all the five above referred crop attributes were significantly correlated with the final yield but with varying magnitudes of correlation. Most of them are also correlated among themselves. Therefore, one may expect to find greater multiple correlations between the final yield and two or more crop attributes put together. These multiple correlations and regressions have been presented in the next section.

3.3. *Multiple correlation coefficients and regressions between the various crop characters and the final yield*

The coefficient of correlation between the germination percentage and yield is 0·4926 and is highly significant (Fisher 1950, Snedecor 1946, and Fisher and Yates 1948). When the germination percentage as well as the maximum number of shoots are taken together, the multiple correlation of these two and the yield is 0·6116 only (Fisher 1950, Snedecor 1946, Fisher and Yates 1948). Hence there is very little gain by including germination percentage with maximum number of shoots which by itself has a simple correlation coefficient of 0·6035 with the final yield.

The improvement in the multiple correlation by the inclusion of the number of days from sowing to commencement of elongation is again negligible, the value being only 0·6137. Thus at the very early stages of the crop growth, the data on the maximum number of shoots alone, yield practically all the information that could be obtained about the final yield.

At a later stage when the crop has completed the elongation the multiple correlation coefficient between the previously mentioned three crop factors along with the maximum height and the final yield of grain works out to 0·6748. With the completion of earemergence the crop finishes practically all the important phases of its growth. The number of earheads along with the earlier mentioned few crop characters give rise to a multiple correlation coefficient of 0·8567 which is very highly significant.

Table 3 gives the multiple regression formulae for predicting the yield Y (expressed as percentage of the station mean) with the completion of the various phases of the crop growth.

TABLE 3

$$Y = 100 + 0.1765\, x_1 + 0.5431\, x_2$$

$$Y = 100 + 0.1713\, x_1 + 0.5911\, x_2 + 0.2089\, x_3$$

$$Y = 100 + 0.1345\, x_1 + 0.2778\, x_2 - 0.8240\, x_3 + 0.9203\, x_4$$

$$Y = 100 - 0.2780\, x_1 - 0.3719\, x_2 - 0.5951\, x_3 + 0.8194\, x_4 + 1.3297\, x_5$$

In Table 3, x_1 the germination percentage, x_2 the maximum number of shoots per sample, x_3 the time taken from sowing to commencement of elongation, x_4 the height and x_5 the number of earheads are expressed as the percentage deviation from the station mean.

3.4. *The efficiency of the regression formulae to predict the yield*

Earlier in the paper it was pointed out that the germination percentage and the time taken from sowing to commencement of elongation do not appear to contribute substantially to the multiple correlation coefficient. Hence, the multiple correlation coefficient omitting these two factors were worked out. The multiple correlation coefficient between maximum number of shoots, maximum height and the number of earheads and the final yield works out to 0·8376 as against 0·8567 which was obtained by including the other two crop factors also. The corresponding regression expression is $Y=100-0\cdot2864\, x_2 + 0\cdot5291\, x_4 + 1\cdot2057\, x_5$ where, as before, x_2 the maximum number of shoots, x_4 the height and x_5 the number of earheads are expressed as percentage deviation from the station mean.

Using the regression expression involving Y, x_2, x_4 and x_5, the 46 yield values were estimated and it was found that they accounted for 70 per cent of the total variance in the actual yield recorded at these stations on various years (Sanderson 1954). Also, it was noticed that out of the six stations, Parbhani and Powerkhera contributed the least to minimise the variation in yield after adjustment by the regression formula. In other words the regression formula failed partially at these two stations. The linear correlation between the estimated and the actual yield which was only +0·8374 increased to +0·9252 when Parbhani station was dropped and increased further to +0·9602 when Powerkhera also was omitted.

4. Discussion and Conclusion

Cochran (1938) found that the most important factor is shoot height. Also the yield and plant number are negatively correlated, indicating that inter-plant competition plays an important part. However, the data collected under the Co-ordinated Crop-Weather Scheme in India on wheat grown in the black soil of central and south India under dry winter conditions show that the yield and the maximum number of shoots as well as the number of earheads are highly correlated and positive in sign. The correlation of yield and maximum height are not so high as that of yield with maximum number of shoots and earheads. This may mean that (*i*) the inter-plant competition is not perhaps noticeably present under our conditions and (*ii*) the crop height has not such a profound effect on the yield.

Since the correlation coefficients were evaluated after reducing the station yields to a common level, namely, the percentage basis, it will be interesting to find out the magnitude of correlation coefficients between the actual and estimated yields given in Table 5. These correlation coefficients were 0·964 for the stations other than Powerkhera and Parbhani, 0·963 for stations other than Parbhani and 0·890 for all stations taken together as against 0·960, 0·925 and 0·837 respectively, obtained earlier between the actual and estimated yields expressed as percentage of the station mean.

From Table 5, it may also be noticed that on certain occasions, the estimate has failed especially for Parbhani station. The reasons for such failures may be attributed to differential agronomic practices such as irrigation and manures, pests diseases and attack by wild animals and some of these are given as foot-note to Table 5.

It is very encouraging to find that the correlation between the actual yield and estimated yield is very high. Hence, it should be possible to evolve in due course, a more precise and efficient multiple regression formula for each station or locus and thereby fulfil one of the aims of the Co-ordinated Crop-Weather Scheme, namely, to use the crop itself as an indicator of its final yield.

TABLE 5

Actual and the estimated yield in lbs per acre along with the discrepancy

Year	Name of Crop-Weather Station								
	DHARWAR			JALGAON			NIPHAD		
	A.Y.	E.Y.	Dp.	A.Y.	E.Y.	Dp.	A.Y.	E.Y.	Dp.
1947-48	907	1104	21·7	380	395	4·2	597	578	—3·2
1948-49	—	—	—	491	498	1·4	649	664	2·3
1949-50	970	803	—17·2	1209	1113	— 7·9	332	421	26·8
1950-51	764	615	—19·5	582	536	— 7·9	258	251	—2·7
1951-52	873	962	10·3	293	405	38·2	634	575	—9·3
1952-53	929	921	— 0·9	247	217	—12·1	84	93	10·7
1953-54	655	743	13·6	470	482	2·6	485	491	1·2
1954-55	1233	1184	— 4·0	501	527	5·2	339	307	—9·4
Station Mean	904	—	—	522	—	—	422	—	—
	PARBHANI			NAGPUR			POWERKHERA		
1947-48	611	416	—31·9	—	—	—	269	248	—7·8
1948-49	461	736	59·7	1248	1377	10·3	620*	481	—22·4
1949-50	1249§	847	—32·2	629	730	16·1	243	350	44·0
1950-51	719§	495	—31·2	857	876	2·2	403	302	—25·1
1951-52	766§	662	—13·6	729	644	—11·7	368	378	2·7
1952-53	319	794	148·9	608	532	—12·5	142†	252	77·5
1953-54	407‡	588	44·5	909	863	—5·1	413	381	—7·6
1954-55	795	791	—0·5	488	445	—8·8	237	303	27·8
Station Mean	666	—	—	781	—	—	337	—	—

Mean yield in lbs per acre for the year

	1947-48	1948-49	1949-50	1950-51	1951-52	1952-53	1953-54	1954-55	Station Mean
A.Y.	553	694	772	597	611	388	557	599	596
E.Y.	548	751	711	513	604	468	591	593	597
Dp.	—3·4	8·2	7·9	—14·1	—1·1	20·6	6·1	—1·0	9·9

A.Y.—Actual Yield; E.Y.—Estimated Yield; Dp.—Discrepancy, which is the difference between the estimated and the actual expressed as percentage of the actual

§Crop was irrigated ‡ Crop attacked by rat *Attacked by shoot borer

† Attacked by wild animals at late stage

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