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Preliminary studies on Crop-Weather relationships —Cotton

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1. Introduction

Under the All India Crop-Weather Scheme —Cotton, quantitative observations, on a uniform basis, are being recorded at a network of selected experimental farms in India, regarding the growth and yield and the incidence of diseases and pests of cotton crop, side by side with the weather factors experienced by the crop during its life-cycle. The object of the scheme is to formulate, in quantitative terms, the effects of the different weather factors on the growth and yield and the incidence of diseases and pests of the cotton crop. However, a study of the data using standard statistical techniques can be undertaken only after these have been collected for a sufficiently long period, *i.e.*, 25 to 30 years. Meanwhile, a tentative study of the data collected up to the year 1955-56 was made, to obtain indications, though of a strictly tentative nature, of crop-weather relationships pertaining to the cotton crop. An account of these studies was included in the *Report of the Co-ordinated Crop-Weather Scheme relating to Cotton, for the year 1956-57*, by the Director, Agriculture Meteorology, Poona. It is considered that the results obtained are of sufficient general interest to the scientific public and hence these are described in this paper.

The name of the stations and the number of years for which data for each of them were available for study, are given in Table 1.

It will be seen from the above, that data available from individual stations are for too short a period for stationwise treatment. It, therefore, became necessary to pool together data from a few stations, located in more or less similar climatological areas, thus substituting replication in space for replication in time.

TABLE 1

Station	Period of data (yrs)	Station	Period of data (yrs)
Nagpur	7	Viramgam	6
Akola	7	Hagari	8
Jalgaon	7	Coimbatore	8
Parbhani	9	Kovilpatti	8
Dharwar	7	Babbur	2
Surat	7	Hansi	3

2. Grouping of stations

With the object of grouping the stations together for the pooling of data the amount and distribution of rainfall during the crop period, at each station, were examined as rainfall is by far the most important single meteorological factor in the case of rainfed crops in India (at all the stations except Hansi, cotton for crop-weather observations is grown as a rainfed crop).

The varieties of cotton under observation, the average yield, as well as the normal values of rainfall and the number of rainy days during the average vegetative and the reproductive periods, for each station (except Hansi where the crop is irrigated), are given in Table 2.

It will be seen from the figures in Table 2 that the normal rainfall during the average

TABLE 2

Normal rainfall and number of rainy days during average crop-growth phases

Station	Name of varieties under observation	Average yield (all picking) of kapas (lbs per acre)	Rainfall in inches and the number of rainy days	
			Vegetative period (sowing to flowering)	Reproductive period (flowering to first picking)
Nagpur	Local Jadi	807	28·31(33·4)	6·95(9·4)
	H·420			
Akola	Local Jadi	760	18·46(23·8)	5·73(9·1)
	H·420			
Jalgaon	197–3	561	15·99(25·9)	8·23(10·0)
	Jarilla			
Parbhani	G 6	327	14·63(22·8)	10·18(12·3)
	G_{12} F_2			
Dharwar	Jayawant	573	13·16(22·8)	0·55(1·0)
	Jayadhar			
Surat	Suyog	301	32·05(39·8)	0·54(0·8)
	2087			
Viramgam	Local Waged	681	8·56(11·2)	0·36(0·9)
	Kalyan			
Hagari	H_1	275	9·04(12·1)	0·42(1·6)
Coimbatore	K_2	290	12·58(19·0)	1·17(2·4)
	K_5			
Kovilpatti	Local	421	10·84(15·6)	2·02(3·6)
	K_2			
Babbur	Jayadhar	142	8·62(11·3)	1·00(1·8)
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reproductive period is 5″ or more at Nagpur, Akola, Jalgaon and Parbhani, while at all the other stations the corresponding value of rainfall is about 2″ or less. Accordingly, the stations were divided into two groups—Group (a) consisting of Nagpur, Akola, Jalgaon and Parbhani, and Group (b) consisting of Dharwar, Hagari, Coimbatore and Kovilpatti. On considerations of other climatic and soil conditions it was not considered desirable to include Surat and Viramgam in any of the above two groups, Hansi was excluded as the crop is rainfed and Babbur was excluded because data for only 2 years were available.

3. Meteorological factors and crop-growth features included for examination

This study was confined to the following weather elements and crop-growth features.

(*i*) *Weather elements*—Total rainfall, total number of rainy days, mean daily values of maximum and minimum temperatures, total sunshine, total evaporation and mean daily values of soil temperature at 15 cm depth at maximum and minimum temperature epochs.

(*ii*) *Crop-growth features*—Germination percentage in the field, number of branches, height, number of flowers and number of bolls, picked at the first picking only.

As the growth of crops is affected not only by the concurrent weather prevailing during a particular growth phase but also by past weather, the meteorclogical conditions during a *4-week* period immediately preceding (the choice of 4-week period is arbitrary and cannot be helped in the absence of any knowledge on the subject at present), as well as those prevailing during the duration of the different growth phases, were taken into account.

For pooling together the data from the stations under each of the two groups mentioned above, the average of the yearly values was obtained, separately for each variety and for each station. The departures of each year's values from the corresponding averages were then expressed as percentages of the averages. The station to station variability was eliminated by dealing with the percentage departures, for obtaining correlation coefficients.

4. Correlation between different growth features and yield

The correlation coefficients between different growth features and yield, separately for group (a) and group (b) stations, are given in Table 3.

However, even though many of the values are significant even at 1 per cent level of probability, in view of the relatively small percentage of variabilities accounted for, when the correlation coefficients are less than 0·5 in magnitude, the only inference which can be drawn with any degree of confidence is that, both for group (a) and group (b) stations, higher the number of flowers, greater the number of bolls and greater the number of bolls, higher the yield; while for group (b) stations only, higher number of plants and greater height at the time of picking are associated with higher yield.

Broadly speaking there also appears to be an indication that vegetative growth influences yield to a greater extent at stations, situated in southern parts than at the stations in the central parts of India.

The multiple correlation coefficients of yield with germination percentage, number of branches, height, number of plants at the time of picking and the number of flowers work out to 0·752 and 0·833 for group (a) and group (b) stations respectively. If the number of bolls picked is taken into account in place of the number of flowers these values rise up to 0·925 and 0·922 for group (a) and group (b) stations respectively. The values of the correlation coefficients are no doubt quite promising.

5. Correlation between meteorological factors and some important crop-growth features

The correlation coefficients between the meteorological factors and a few crop-growth features are given in Tables 4(a) and 4(b) for group (a) and group (b) stations respectively. In these tables the values against P represent the correlation with the past weather (during a period of 4 weeks immediately before the commencement of the particular growth phase) while those against C represent the correlation with the prevailing weather (during the particular growth phase). The indications and suggestions so far as these can be judged from the values of these correlation coefficients are discussed below—

Although some of the values in Tables 4(a) and 4(b) are significant even at 1 per cent level, in view of their small magnitude, most of them have been ignored and it was

TABLE 3

Values of the coefficients of correlation (r)

Correlate with	Germination per cent (g)	Number of plants at first picking (p)	Height of plants at first picking (h)	Number of branches at first picking (b)	Total number of flowers (f)	Number of bolls picked at first picking (b_1)
	Group (a) stations (Nagpur, Akola, Jalgaon and Parbhani)					
(p)	+ 0·187					
(h)	— 0·222	+ 0·165				
(b)	+ 0·007	— 0·079	+ 0·331*			
(f)	+ 0·149	+ 0·011	+ 0·428*	+ 0·043		
(b_1)	— 0·059	+ 0·279	+ 0·213	— 0·159	+ 0·592**	
Yield	+ 0·020	+ 0·122	+ 0·140	— 0·203	+ 0·680**	+0·903**
	Multiple C.C. for regression equation connecting (*i*) Yield with (g), (p), (h), (b) and (f) = 0·752 (*ii*) Yield with (g), (p), (h), (b) and (b_1) = 0·925					
	Group (b) stations (Dharwar, Hagari, Coimbatore and Kovilpatti)					
(p)	+ 0·484**					
(h)	+ 0·454*	+ 0·414*				
(b)	— 0·126	+ 0·057	+ 0·496**			
(f)	+ 0·333*	+ 0·437*	+ 0·345*	+ 0·171		
(b_1)	+ 0·146	+ 0·573**	+ 0·597**	+ 0·316	+ 0·564**	
Yield	+ 0·077	+ 0·547**	+ 0·600**	+ 0·330*	+ 0·496**	+ 0·887**
	Multiple C.C. for regression equation connecting (*i*) Yield with (g), (p), (h), (b) and (f) = 0·833 (*ii*) Yield with (g), (p), (h), (b) and (b_1) = 0·922					

* C.C. significant at the 5 per cent level of probability **C.C. significant at the 1 per cent level of probability

assumed that a real connection has been shown to exist only when the coefficient of correlation is 0·5 or more. On this basis the following inferences can be drawn.

For group (a) stations—(*i*) Greater rainfall during four weeks immediately before branching period as well as during the period and more rainy days during the period of branching, tend to increase the number of branches; (*ii*) Greater rainfall and more rainy days during the boll formation period tend to reduce the number of bolls available for picking, and (*iii*) Higher maximum temperature during the boll formation period tends to increase the number of bolls for picking.

For group (b) stations—Greater sunshine during the period of boll formation, tends to reduce the number of bolls available for picking.

It would be well to bear in mind that for obtaining the above correlation coefficients, data from different stations have been pooled together; therefore, the indications mentioned above should be considered to be of

TABLE 4(a)

Values of the coefficients of correlation (r) for Group (a) stations

(Nagpur, Akola, Jalgaon and Parbhani)

Meteorological factors	Period to which the meteorological factors refer to	Crop-growth features			
		Germination percentage on the field	No. of branches at the time of 1st picking	Total No. of flowers	No. of bolls picked at 1st picking
Total rainfall	P	+·321*	+·559**	+·040	—·123
	C	—·204	+·636**	—·134	—·567**
Number of rainy days	P	+·329**	+·459**	+·098	—·167
	C	+·071	+·646**	—·123	—·533**
Total evaporation	P	—·057	—·186	+·157	+·083
	C	+·085	—·188	+·146	+·365**
Total number of hours of bright sunshine	P	—·280*	+·446**	+·133	—·009
	C	—·077	+·013	+·480**	+·324
Mean daily maximum temperature	P	—·231	+·411**	+·207	+·366**
	C	+·099	—·307*	+·451**	+·739**
Mean daily minimum temperature	P	—·327**	+·207	+·073	+·257*
	C	—·244	—·267	+·196	+·366**
Mean daily soil temperature at 15 cm depth at maximum temperature epoch	P	—·396**	+·248	+·036	+·016
	C	—·315*	—·267	+·197	+·323*
Mean daily soil temperature at 15 cm depth at minimum temperature epoch	P	—·371**	+·043	+·040	+·119
	C	—·392**	—·374**	+·333**	+·327*

* Significant at 5 per cent level of probability

**Significant at 1 per cent level of probability

a tentative nature, to be confirmed or otherwise, for each station, in due course.

6. Conclusion

It may be added in conclusion that in the case of crop-weather relationships the correlation coefficients of very low values is not necessarily an indication that there is no connection. Hence, when we find no correlation between the weather and a crop, it, by no means, follows that the crop is indifferent to the weather.

In considering the question of correlation between the weather and crop, it may be well to remember that the weather factors are themselves correlated in nature; for example rainfall and number of rainy days are negatively correlated with sunshine. So that, if the correlations of a crop-growth feature with rainfall and sunshine are in opposing directions the total observed effect will be very insignificant and may even be nil. It will, therefore, be necessary to calculate the partial correlation coefficients. Further the distribution of the meteorological factors, within shorter periods of time (week by week), will also have to be taken into account somewhat on the lines used by Kalamkar and Satakopan (1940). However, for adoption of these techniques it will be necessary to deal with the data stationwise and not pool together data from 2 or more different stations. Therefore, for a correct appreciation of the crop-weather relationships, it will be necessary to accumulate reliable crop-weather data, for each station, for quite a long period. Hooker (1907) was satisfied that 21 years is much too short a period for obtaining the deductions about correlation between crop and weather.

TABLE 4(b)

Values of the coefficients of correlation (r) for Group (b) stations (Coimbatore, Kovilpatti, Dharwar and Hagari)

Meteorological factors	Period to which the meteorological factors refer to	Crop-growth features			
		Germination percentage on the field	No. of branches at the time of 1st picking	Total No. of flowers	No. of bolls picked at 1st picking
Total rainfall	P	—·141	—·296*	+·307*	+·103
	C	+·281*	+·092	+·096	+·172
Number of rainy days	P	+·087	—·192	+·153	+·193
	C	+·145	+·091	+·160	+·100
Total evaporation	P	—·019	—·105	—·137	—·322*
	C	—·228	—·198	+·042	—·225
Total number of hours of bright sunshine	P	+·499**	+·197	—·268	—·328*
	C	—·214	+·225	—·215	—·533**
Mean daily maximum temperature	P	+·082	—·154	—·296*	—·316*
	C	—·359**	—·195	—·102	—·319*
Mean daily minimum temperature	P	—·275*	—·055	—·051	+·004
	C	+·220	—·039	—·047	—·040
Mean daily soil temperature at 15 cm depth at maximum temperature epoch	P	+·077	+·046	—·239	—·070
	C	—·369**	—·203	—·208	—·171
Mean daily soil temperature at 15 cm depth at minimum temperature epoch	P	+·072	+·123	—·227	—·156
	C	—·010	—·099	—·039	—·123

*Significant at 5 per cent level of probability **Significant at 1 per cent level of probability

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