Indian J. Met. Geophys. (1972), 23, 3, 385-392

551. 509. 314 : 551. 5 : 633

Fisher's regression integral *versus* regression function of selected weather factors in crop-weather analysis*

P. S. SREENIVASAN

Meteorological Office, Poona

(Received 14 April 1971)

ABSTRACT. The paper deals with the relative performance of the two statistical methods, namely, (*i*) Fisher's 'regression integral' which brings out the slow continuous change in the response of crop to the weather pattern experienced by the cultivated soil and crop and (*ii*) regression function in which 'weather pattern' is subjected to continuous screening to yield a few well-defined weather periods of significance to the soil and crop. In the case of wheat crop at Jalgaon and Niphad the regression function has given better multiple correlation coefficient than the regression integral. This may be due to the differential response of some of the adjacent phytophases of crop and the changing soil characteristics to the weather factors. By and large, this inference was found to be true as seen from the physiological and pedological considerations.

1. Introduction

In his classical paper on "The influence of rainfall on the yield of wheat at Rothamsted" Prof. R. A. Fisher (1924) has stated the following in the introductory section on "General Problem of evaluating the effects of Weather on Crops".

"At the present time very little can be claimed to be known as to the effects of weather upon farm crops. The obscurity of the subject, inspite of its immense importance to a great national industry, may be ascribed partly to the inherent complexity of the problem which it presents and more especially to the lack of quantitative data obtained either under experimental or under industrial conditions, by the study of which accurate knowledge alone can be acquired".

"The inherent complexity of the relationships which it is sought to elucidate, between the yields of farm crops, and the previous weather which largely control those yields, arises primarily from the complexity on the problem of specifying the weather itself".

"The complete aim of agricultural meteorology should, however, be emphasised, for it is only by its substantial achievement that other causes of crop variation can be freed from much obscurity."

Agriculture being the greatest national industry of India, the All India Co-ordinated Crop-Weather Scheme was instituted in 1945 with the object of understanding the direct and indirect effects of weather on the five main farm crops of India. In this paper an attempt has been made to study the relative performance of two statistical methods, *viz.*, Fisher's Regression Integral and the Regression Function of selected weather factors.

2. Material

Wheat is one of the five crops under crop weather study and most of the systematic periodical observations on the crop and its environment with its contemporary weather factors have been recorded systematically at the two crop-weather stations, namely, Jalgaon and Niphad in central Maharashtra for more than two decades. Details of the scheme of crop weather observations are given by Ramdas (1960) in the Indian Council of Agricultural Research Monograph on "Crop and weather in India" and it will suffice for our purpose in mentioning that various phytophases of the crop in each year is arrived at by taking observations on thirty-six samples located at random on each occasion while actual yield is also recorded after harvest. Meteorological and micro-climatic observations are recorded twice daily corresponding roughly to the minimum and maximum epochs except rainfall which is recorded at 0830 IST. The data discussed in this paper were collected at Jalgaon and Niphad in central Maharashtra since 1947.

3. Statistical techniques under study

Fisher's technique in brief consists of generating the distribution constants A_0, A_1 etc to each year's or season's meteorological data by fitting an orthogonal polynomial. Then the regression of the distribution values on yield, with

*Paper originally presented at the 24th Annual Conference of the Indian Society of Agricultural Statistics held at Madras from 31 Dec 1970 to 2 Jan 1971.

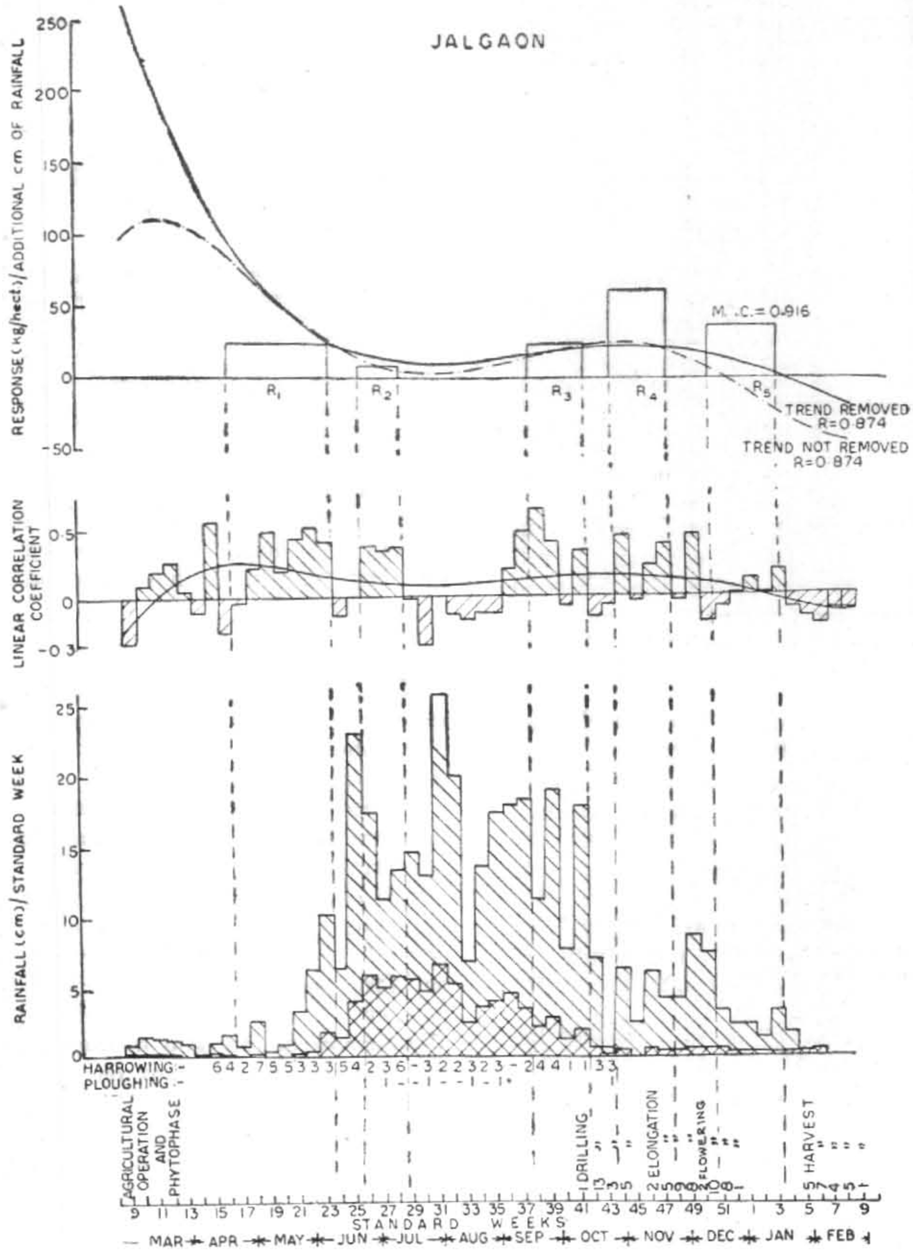

Fig. 1

Rainfall amount; Distribution and influence on wheat yield, N.P. 4

TABLE 1

Multiple correlation coefficients 'R' obtained by Fisher's Technique

Row/ Col.	No. of years	No. of weeks in the period	Weeks included from		Weeks included to		Degree of the polynomial	Multiple C.C. (R) with the trend			
								Not removed		Removed	
			Jalgaon	Niphad	Jalgoan	Niphad		Jolgoan	Niphad	Jalgoan	Niphad
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	22	13	40		52		5	0·570	0·609	0·547	0·668
2	22	26	27		52		5	0·827**	0·666	0·840*	0·697
3	22	35	18		52		5	0·891**	0·655	0·889**	0·844*
4	22	39	14		52		5	0·874**	0·642	0·861*	0·827*
5	22	52	1		52		5	0·806*	0·698	0·864*	0·839*
6	22	52	9	10	8	9	5	0·874**	0·806**	0·874*	0·832*
7	22	52	9	10	8	9	3	0·848**	0·604	0·873**	0·642
8	21	52	9	10	8	9	5	—	—	0·887*	0·832*
9	21	52	9	10	8	9	7	—	—	0·941**	0·866
10	21	52	9	10	3	9	9	—	—	0·974*	0·898

*Significant at 5% level **Significant at 1% level of probability

or without the elimination of trend, if any, is found out. From this regression equation it is possible to generate the response of the crop to the weather element at any time falling within the period under investigation. In the practical application of the method of the regression integral, Fisher in his historical paper (1924) has specifically stated that it is not necessary that the rainfall record should be strictly continuous. He used 6-day subdivision whereas in the present paper 7-day subdivision is made use of.

In the second method the critical rainfall periods were arrived at by working out systematically the correlation coefficient (C.C.) between yield and rainfall during periods continuouly increasing from one week to ten weeks (Sreenivasan 1970). Thus 52 C.C. were found out between yield and rainfall in 52 weeks, then 51 C.C. were obtained between yield and 51 periods, each period consisting of 2 weeks. In this manner, periods were increased to 10 weeks yielding 43 C.C. From a critical examination of these C.Cs, those which are statistically significant were selected as factors for working out the regression equation. In addition to these significant factors, factors such as rainfall during some of the critical crop phases like 'grain formation' were also taken into account purely on physiological considerations.

4. Result obtained by Fisherian technique

The result obtained by subjecting the weekly rainfall and wheat yield data recorded at the two Government Experimental Farms, Jalgaon and Niphad for the 22 years, to Fisherian technique is presented in Table 1.

4.1. From the rows 1 to 5 and columns 9, 10, 11 and 12 it appears that by and large, at both the stations the multiple correlation coefficients (M.C.C.) increases with the inclusion of more weeks.

4.2. Among the two periods of 52 weeks rainfall data given in rows 5 and 6 the M.C.Cs for the period ending with the harvest of the crop, namely, standard week No. 8 in Jalgaon and 9 in Niphad have yielded consistently significant values than that period corresponding to calendar year.

4.3. For this optimum interval of 52 weeks ending with the week of harvest polynomials of 3rd, 5th, 7th and 9th degree were fitted and the M.C.Cs obtained are given in rows 6 to 10. The fifth degree appears to be the most appropriate especially in Niphad.

Taking both the stations together it may be seen that employing Fisher's technique of fitting fifth degree polynomial without removal of trend to all the 52 weeks of the harvest year has yielded the best result (row 6 of Table 1). The M.C.C. is 0·874 for Jalgaon and 0·806 for Niphad which are highly significant. Therefore, using this period the response of crop yield to the progress of rainfall for 52 weeks is graphically represented in Fig. 1 for Jalgaon and in Fig. 2 for Niphad.

TABLE 2

Weeks	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
JALGAON																											
1	.198	.255	.035	-.117	.137	-.229	.184	.175	.475	.181	.416	.494	.399	-.145	.008	.349	.319	.332	-.227	-.359	.004	-.147	-.173	-.136	-.136	.184	.439
2		.247	.164	.026	.531	.031	-.216	.188	.246	.339	.427	.482	.562	.297	-.046	.244	.440	.429	.235	-.284	-.209	-.067	-.208	-.159	-.160	.025	.451
3		'89	.158	.336	.027	.045	-.033	.253	.305	.475	.488	.317	.465	.168	.196	.328	.523	.344	-.046	-.136	-.122	-.102	-.225	-.179	-.036	.251	.516
4			.188	.382	.034	.041	.183	.019	.316	.315	.504	.525	.576	.276	.347	.279	.428	.461	.101	-.041	-.317	-.264	-.184	-.241	-.066	.173	.430
5			.308	.119	.045	.161	.218	.075	.517	.543	.629	.540	.323	.40[illegible]	.413	[illegible]	.408	.307	.097	-.101	-.253	-.314	-.209	-.125	.143	.340	.465
6				.139	.120	.15[illegible]	.216	.273	.347	.546	.556	.544	.321	.419	.464	.509	.355	.276	.266	.008	-.139	-.238	-.330	-.119	.083	.306	.411
7				.147	.212	.201	.272	.441	.485	.656	.574	.327	.419	.479	.545	.432	.226	.236	.186	-.085	-.194	-.337	-.245	.085	.242	.387	.389
8					.225	.257	.256	.341	.510	.632	.532	.347	.422	.472	.555	.512	.356	.196	.166	.157	-.081	-.230	-.246	-.040	.247	.329	.365
9					.261	.311	.440	.409	.466	.560	.349	.436	.481	.552	.531	.403	.308	.155	.139	.102	-.133	-.153	-.046	.129	.329	.307	.428
10						.306	.485	.513	.646	.580	.331	.437	.497	.535	.530	.421	.349	.335	.111	.093	.048	-.081	-.054	.113	.241	.310	.378
Average rainfall	.11	.10	.15	.00	.08	.13	.03	.13	.02	.10	.27	.39	1.81	1.46	3.94	5.87	4.35	5.61	5.41	4.54	6.48	5.02	2.36	3.55	5.80	4.54	5.37
										(A)							(B)										
NIPHAD																											
1	.002	-.131	.287	-.027	.340	-.065	-.029	.224	.009	-.121	.163	.227	.255	-.001	.051	.278	.231	.170	-.089	-.598	-.088	.245	.478	-.007	.080	-.275	-.164
2		-.131	.237	.281	.316	.152	-.066	.067	.230	-.116	.103	.294	.883	.731	.042	.218	.256	.234	.078	-.461	-.605	.131	.465	.321	.045	-.134	-.309
3		.238	.253	.433	.146	.061	.019	.068	-.009	.102	.219	.386	.328	.192	.189	.319	.283	.156	-.221	-.518	-.560	.361	.379	.317	.130	-.165	-.092
4			.234	.398	.223	.058	.120	.019	-.050	.182	.220	.329	.356	.263	.291	.294	.303	.200	-.114	-.259	-.346	-.063	.312	.410	.137	-.184	-.040
5			.399	.295	.197	.119	.122	-.065	.115	.259	.370	.319	.321	.348	.380	.296	.244	-.019	-.149	-.159	-.033	-.058	.246	.269	.074	-.043	-.079
6				.296	.177	.246	.121	.475	.096	.233	.364	.340	.316	.373	.429	.374	.236	-.003	-.039	-.152	.026	-.094	-.004	-.224	.212	.168	.082
7				.178	.229	.246	.045	.143	.215	.357	.372	.216	.371	.413	.417	.316	-.005	-.023	.068	.115	.020	-.027	-.167	.173	.289	.049	.061
8					.230	.231	.167	.142	.248	.334	.339	.349	.370	.411	.398	.365	.073	-.022	.080	.191	.08[illegible]	[illegible]	-.177	-.273	.231	.120	.186
9					.232	.151	.221	.247	.360	.321	.313	.292	.410	.390	.350	.115	.057	.056	.212	.108	.113	-.046	-.232	-.105	.097	.243	.176
10						.151	.212	.293	.362	.347	.307	.354	.435	.390	.342	.125	.092	.127	.129	.130	.178	.029	-.068	-.131	-.119	.214	.237
Average rainfall	0.	.07	.17	.07	.25	.17	.46	.27	.023	1.063	1.04	.69	1.61	1.04	2.58	2.27	2.92	3.87	3.74	3.45 (A)	2.33	2.87	2.45 (B)	1.45	2.55	2.04	1.51

TABLE 2 (*contd*)

Weeks	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12
JALGAON																											
1	.515	.365	-.076	.311	-.160	-.070	.413	-.057	-.307	.341	-.048	.414	-.207	-.106	-.000	.110	-.003	.162	-.124	-.171	-.238	.000	-.141	.024	-.350	.256	.199
2	.536	.596	.287	.254	.244	-.165	.408	.370	.183	.392	.209	.232	-.006	-.202	-.099	.080	.084	.149	.084	-.127	-.245	-.224	-.141	.071	-.151	-.071	.287
3	.622	.544	.430	.181	.243	.157	.365	.423	.346	.295	.365	-.029	-.049	-.201	-.042	.069	.165	.080	.081	-.186	-.245	-.242	.071	-.171	.044	.045	
4	.622	.587	.650	.370	.160	.366	.122	.421	.649	.269	.479	.150	-.060	-.049	-.175	-.065	-.159	.127	.077	-.052	-.186	-.254	.009	-.171	-.005	.121	
5	.598	.633	.594	.389	.291	.368	.343	.549	.464	.400	.353	.093	-.067	-.028	-.127	.360	.118	.174	.049	.062	-.235	.008	-.220	-.006	.014		
6	.458	.620	.604	.595	.452	.289	.405	.388	.464	.508	.236	.200	.093	-.044	-.225	-.132	.014	.118	.100	-.049	-.002	-.087	-.226	-.045	.074		
7	.516	.601	.503	.427	.461	.338	.474	.309	.502	.376	.187	.203	.117	-.045	.024	-.136	.012	.094	.100	.020	.081	-.271	-.049	.042			
8	.472	.492	.600	-.241	.642	.502	.404	.447	.376	.376	.333	.190	.213	.119	.004	.004	-.135	-.003	.094	.075	.079	-.042	-.115	.039			
9	.433	.497	.636	.642	.695	.565	[illegible]	.498	.269	.333	.338	.201	.217	.148	-.014	.003	-.146	-.003	.071	.127	-.044	.043	-.023				
10	.413	.438	.554	.656	.663	.745	.560	.440	.444	.230	.330	.345	.205	.238	.130	-.015	-.000	-.148	-.019	.121	.018	.045	.100				
Average rainfall	2.00	2.35	1.02	1.86	.57	.03	.29	.12	.48	.43	.31	.16	.40	.36	.09	.10	.11	.15	.10	0	.09	0	.05	.07	.07	.11	.00
		(C)						(D)																			
NIPHAD																											
1	.206	-.169	.399	-.018	.378	.125	.221	.402	-.142	.580	.504	.098	-.162	.027	-.244	-.233	-.064	.246	.248	.083	.200	.135	.000	-.143	.266	-.061	.039
2	.089	.012	.138	.296	.219	.299	.178	.428	.237	.493	.599	.287	-.135	-.153	.007	-.273	-.192	-.227	.246	.253	.063	.135	.186	-.113	-.114	.222	.035
3	-.050	.179	.121	.423	.230	.312	.348	.306	.507	.549	.551	-.064	-.127	-.157	-.101	-.219	.179	.232	.249	.259	.153	.155	-.177	-.114	-.116	.087	
4	.127	.148	.164	.228	.408	.250	.422	.288	.513	.551	.574	.390	-.058	-.130	-.178	-.126	.171	.191	.233	.249	.296	.153	-.107	-.078	-.116	-.087	
5	.055	.132	.250	.246	.401	.342	.394	.493	.554	.570	.343	.395	-.061	-.151	-.164	.143	.185	.195	.233	.266	.296	-.102	-.078	-.080	-.087		
6	.061	.045	.221	.264	.255	.458	.325	.444	.530	.564	.425	.351	.393	-.082	-.158	-.071	.150	.187	.193	.251	.268	-.030	-.373	-.080	-.055		
7	.054	.120	.236	.270	.308	.451	.469	.461	.542	.450	.434	.348	.380	-.069	-.049	-.049	.161	.127	.211	.251	.174	.007	-.275	-.255			
8	.054	.122	.148	.243	.312	.304	.515	.485	.373	.453	.481	.436	.333	.381	.014	-.028	-.046	.161	.204	.211	.163	.179	.005	-.049			
9	.124	.137	.160	.266	.308	.379	.530	.494	.521	.494	.459	.424	.334	.441	.033	-.027	-.048	.176	.204	.127	.168	.178	.022				
10	.248	.138	.147	.204	.283	.369	.390	.538	.461	.532	.463	.449	.427	.401	.448	.034	-.027	-.40	.176	.121	.134	.168	.165				
Average rainfall	2.35	4.43	2.47	2.29	1.30	.51	.43	53	.34	.81	.09	.10	.45	.13	.0	.03	.07	.17	.03	0	.02	.00	.00	.10	.01	.00	.07
				(C)							(D)																

N.B : C.C. values statistically significant at 5% level (more than 0.422) are underlined with broken line and significant at 1% level (more than .556) are underlined by a continuous one.

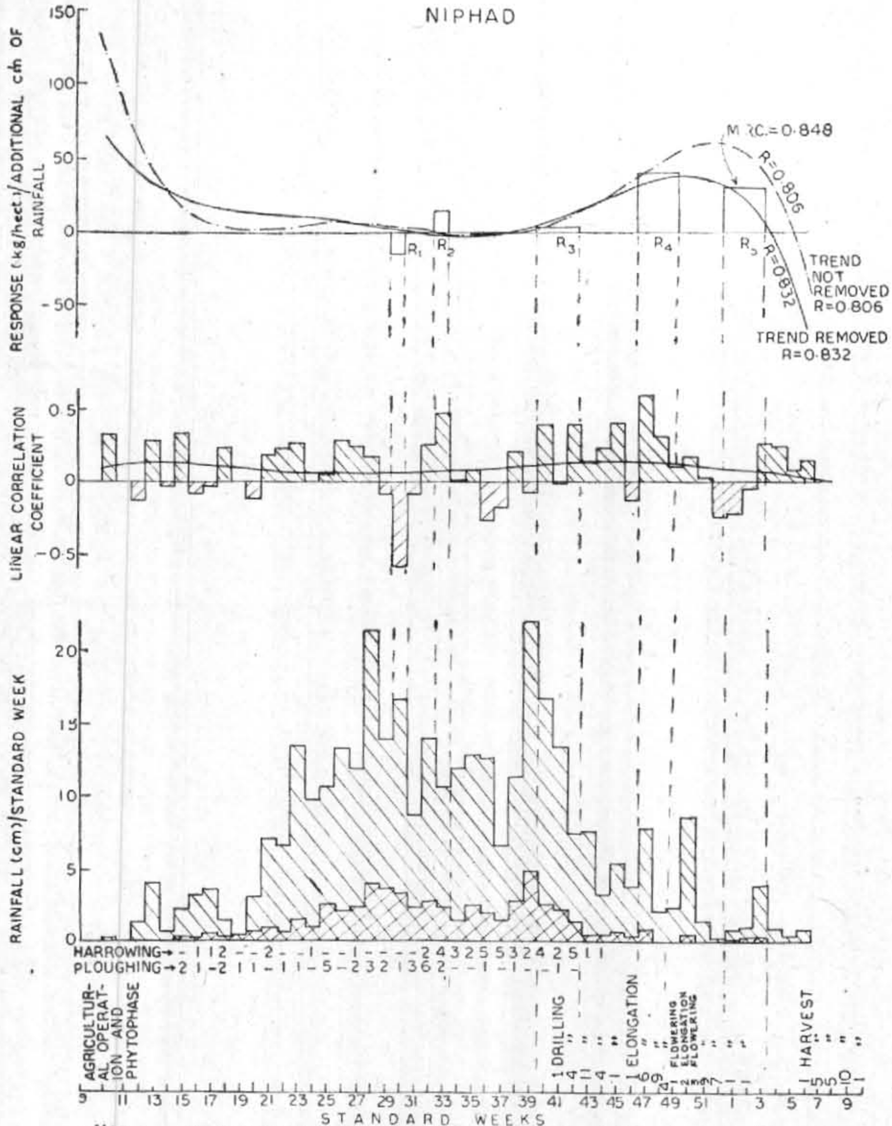

Fig. 2

Rainfall amount: Distribution and influence on wheat yield N.P. 4

5. Regression function of selected weather factors

For the period commencing from week No. 10 and ending with week No. 9 (52 weeks) when the wheat is harvested, correlation coefficients (C.Cs) between each week and 22 yearly yield values were worked out. Similarly C. Cs between rainfall in the 51 overlapping two-week periods and yield, were found out. This process is continued for 50 overlapping three-week periods and so on, upto 43 overlapping ten-week periods. These C. Cs along with the mean rainfall are tabulated for Jalgaon and Niphad in Table 2.

From an examination of all the C.Cs one can locate 4 areas which show significant correlations. The mean rainfall values in these 4 periods are underlined and marked as A, B, C and D for Jalgaon and A′, B′, C′ and D′ for Niphad. The selected rainfall periods are —

Period	Rainfall during week Nos.	C.Cs with yield	Remarks
		JALGAON	
A	17-23	0·658	Pre-monsoon thundershowers
B	26-28	0·523	Monsoon rains
C	38-41	0·650	Pre-sowing rains
D	44-47	0·549	Crown-root initiation period
		NIPHAD	
A′	30	—0·596	Week of very heavy rains
B′	33	0·478	Mid-August with an usual lull in the monsoon
C′	40-42	0·422	Pre-sowing rains
D′	47-49	0·651	Crown-root initiation period

In addition to these four periods, from crop physiological considerations, the occasional rain which may fall during the critical phase of grain formation (standard weeks 51 to 3) is also taken as an independent factor.

The inter-correlation between these five independent factors as well as the degree of correlation with the dependent factor, namely yield are given in Table 3 in rows A—1 to 5 for Jalgaon and B—1 to 5 for Niphad. Row 6 gives the linear regression equation, row 7 the multiple regression equation and row 8, the average values along with their standard deviations.

5.1. All the inter-correlations between rainfall in different periods except one are not significant.

5.2. Rainfall in all the four selected periods are significantly correlated with yield, correlation being positive for all periods in Jalgaon and three of the four for Niphad.

5.3. The multiple regression given in row 7 shows that for Jalgaon, the influence of rainfall for the period (26-28) is not significant while for Niphad the pre-sowing rainfall in the period (40-42) is not significant.

5.4. There is some improvement in the significance of partial regression over linear regression for the periods R-3, R-4 and R-5 for Jalgaon and R-5 for Niphad as seen from the ratio of regression coefficient to its standard error (S.E).

The multiple correlation coefficients by this method are 0·916 for Jalgaon and 0·848 for Niphad and these are statistically significant even at 1% level of probability.

6. A comparative study of these two methods

Thus the multiple correlation coefficients by these methods are —

Multiple correlation coefficients with	(a) Fisherian Technique		(b) Selected periods
	Before removal of trend	After removal of trend	
Degree of freedom	15	10	16
For Jalgaon	0·874	0·874	0·916
For Niphad	0·806	0·832	0·848

The method (b), namely, selected periods with 16 degrees of freedom gives better M.C.C. than the method (a). To bring out the magnitude of response, the responses in the selected periods are also super-imposed as histogram over the Fisher's "Response Curves" given in the figures referred to already. By and large, the direction of responses by these two methods is the same except in the periods (30) and (33) for Niphad. But the magnitudes are somewhat different. At this stage, we should try to give physical interpretation to these responses and this is attempted in the next section.

7. Physical interpretation of the responses by the two methods

An examination of the response curves by Fisherian technique and the response during selected periods given in the figures brings out the following —

7.1. The response to any additional rainfall is practically always favourable at both the stations except during weeks of 33 to 37 at Niphad, when it shows slight negative response.

7.2. During the pre-sowing period, for Jalgaon station both the methods indicate that the premonsoon showers benefit the post monsoon wheat perhaps by improving the soil texture or the soil aeration or the soil fertility thiou h the soil microbes present in this heavy soil. This is not so in the case of Niphad which has somewhat lighter soil.

TABLE 3

Total correlations, regressions with yield, mean and standard deviation

Row No.	Details	Rainfall during the period consisting of standard week				
		@(17-23) : R-1	(26-28) : R-2	(38-41) : R-3	(44-47) : R-4	(51-3) : R-5
(1)	(2)	(3)	(4)	(5)	(6)	(7)
				A—JALGAON		
1	Rainfall in (26-28)@	0·27				
2	Rainfall in (38-41)	0·42*	0·32			
3	Rainfall in (44-47)	0·40	0·21	0·05		
4	Rainfall in (51-3)	—0·25	0·20	0·11	—0·02	
5	Yield of grain 'Y'	0·66**	0·52*	0·65**	0·55**	0·11
6	Linear regression on 'Y' (with S.E.)	488·2+58·94** R1 (15·06)	309·1+0·89* R2 (7·70)	425·8+29·74** R3 (7·78)	544·9+81·16**R4 (27·64)	631·6+35·44 R5 (70·12)
7	Multiple regression on 'Y' (with S.E.)	189·7+23·61*R1 (11·95)	+7·12 R2 (4·49)	+23·12** R3 (5·46)	+62·00**R4 (17·39)	37·44 R5 (34·87)
8	Average of Y : 652·3 kg/hect. (with S.D.)	2·78 cm (3·51)	16·42 cm (7·87)	7·61 cm (7·87)	1·32 cm (2·12)	0·58 cm (0·99)
				B—NIPHAD		
		@(30) : R-1	(33): R-2	(40-42) R-3	(47-49) : R-4	(52-3) : R-5
1	Rainfall in (33)@	—0·23				
2	Rainfall in (40-42)	—0·35	0·00			
3	Rainfall in (47-49)	—0·25	0·11	0·46*		
4	Rainfall in (52-3)	—0·19	0·29	—0·10	—0·12	
5	Yield of grain 'Y'	—0·60**	0·48*	0·42*	0·62**	0·24
6	Linear regression on 'Y' (with S.E.)	568·4—25·95** R1 (7·79)	411·4+27·44* R2 (11·31)	404·1+12·26* R3 (5·87)	418·4+55·82**R4 (15·80)	466·2+50·37 : R5 (46·14)
7	Multiple regression 'Y' (with S.E.)	418·4—15·13* R1 (6·50)	+17·27* R2 (8·20)	+2·69 R3 (4·57)	42·67** R4 (13·78)	+31·54 R5 (30·48)
8	Average of Y : 478·6kg/hect. (with S. D.)	3·45 cm (3·89)	2·45 cm (2·93)	6·08 cm (5·83)	1·07 cm (1·87)	0·24 cm (0·79)

*Significant at 5% level of probability (C.C.—0·423 or more); S.E.—Standard error of the regression value

** Significant at 10% level of probability (C.C.—0·537 or more) S.D.—Standard deviation

@ Figures within bracket refers to standard week

7.3. In the monsoon months of June to September the Fisherian response curve suggests that the heavy black soil of Jalgaon benefits by additional rain whereas the soil of Niphad is indifferent. The selective period method, however, shows significant negative response to the rainfall in the 30th week and positive response to that in 33rd week. As the influence of pre-sowing rainfall is through soil the change in the fertility status of this soil during these critical periods due to additional rainfall is to be investigated in detail.

7.4. For better germination which may mean better yield, there should be sufficient moisture and temperature at the depth of sowing. The average maximum temperature during this critical period is of the order of 33°C at Jalgaon while at Niphad it is only 31°C. Therefore any rainfall at Jalgaon at this period brings down the maximum temperature nearer to the optimum temperature for germination. Thus the beneficial influence of rainfall at Jalgaon is more through lowering the maximum temperature (Sreeniinvasan, *see* Ref.).

7.5. After establishing themselves, the seedlings enter the active phase of crown-root formation and the amount of adventitious roots formed, depends on soil depth, texture and the availability of moisture at shallow depths. The magnitude of response of the crop by the multiple regression function for the rainfall period (R-4) is more than double the response for this period by Fisherian technique at Jalgaon. Whereas the responses by the two methods are of the same order at Niphad.

7.6. Another critical crop phase is at the time of grain formation. Here again the remarks on the magnitude of responses at these two stations by the two methods given in the previous paragraph of 7·5 holds good.

8. General remarks

Fisher in his paper under reference has developed a sophisticated method with the premise that (a) the meteorological variates to be employed must be chosen without reference to the actual crop record and (b) relationship of a complicated character should be sought only when long series of crop data are available. Referring to 52 weekly partial regression coefficients, Fisher opines that such a calculation would leave out of consideration the all-important fact that the effect of weather on crop may be expected to change continuously during the year (p. 96). He warned against the common practice to search for the so-called critical periods as a preliminary to the study of crop weather correlations (p. 94).

The second method, namely, the multiple regression is based on locating the critical periods, as seen from the simple regression of rainfall for one week, overlapping two weeks, three weeks etc on yield. The question arises whether there are any critical periods in different seasons of the year which determine the fertility status of the soil influencing the crop. Also are there any sharp, well-defined important physiological periods of the crop say 'germination', 'crown-root initiation', 'primodial differentiation' or 'grain formation' which are more sensitive to changes in weather and with differential requirement from other phytophases of the crop. These are questions which await further study by pedologists, crop physiologists, ecologists, and agricultural meteorologists. Meanwhile it may be stated here that if there is such a differential effect of weather during certain critical seasons or phytophases from a continuous general effect visualised by Fisher, then the search for these critical phases lasting for a few days or weeks by this technique of continuously overlapping periods of varying lengths say from a day or week to a few days or weeks (depending upon the duration and variation in the occurrence of these critical phases), is justified. In the present study an attempt has been made to examine these critical phases from the pedological and physiological aspects.

Acknowledgement — The author is grateful to Shri K. N. Rao, Deputy Director General of Observatories (Climatology & Geophysics) for his helpful suggestions. He also wishes to record his indebtedness to the authorities of the Maharashtra State Agricultural Department at Jalgaon and Niphad for recording crop and weather data systematically.

REFERENCES

Fisher, R. A. 1924 "The influence of rainfall on the yield of wheat at Rothamsted". Lond. *Phil. Trans. Roy Soc.* CCXIII—B404, pp. 89-142.

Ramdas, L. A. 1960 "Crop and Weather in India". I.C.A.R. Mongr. New Delhi, pp. 1-127.

Sreenivasan, P. S. 1970 "Studies in Agricultural Meteorology of some field crops of India. (Ph. D. Thesis).

"Studies in Agricultural Meteorology of Wheat Crops at Jalgaon and Niphad" (unpublished).