Vol XIX
No. 3 & 4

ISSN 0019-5014

SILVER JUBILEE
NUMBER

INDIAN JOURNAL OF AGRICULTURAL ECONOMICS

JULY-
DECEMBER
1964

INDIAN SOCIETY OF
AGRICULTURAL ECONOMICS,
BOMBAY

INDIAN JOURNAL OF AGRICULTURAL ECONOMICS

Silver Jubilee Number

INDIAN SOCIETY OF AGRICULTURAL ECONOMICS
BOMBAY-1.

Rs. 8.00

A STUDY OF THE EFFECTS OF SOME WEATHER FACTORS ON THE YIELD OF WHEAT IN LUDHIANA DISTRICT PUNJAB

B. M. RAO*

INTRODUCTION

THE hold of weather on agricultural production, though somewhat loosened in some countries through various methods, is still a force to be reckoned with. In countries like India, it is still a major factor in the agricultural production. To define or to study such a factor in its entirety is a complicated one. Because of its complex behaviour, only some components of it are taken to study their effect on the yield of wheat. The selection of these components is not arbitrary but followed by a certain logic which will be explained later. A linear multiple regression analysis has been done by the well-known method of least squares on the yields obtained from irrigated and unirrigated fields and a comparison is made with the agronomic conclusions to stress the importance in corroborating these two types of results.

Some Soil Features of Ludhiana

The district is a part of the Western Indo-Gangetic plain with the soil variation from hard clay to the lightest sand. It is classified into three physiographic regions, namely, *Bet*, lower *Dhaya* and upper *Dhaya*. The *Bet* area has light textured soil and at some places soil erosion takes place and is subjected to floods. The soil in lower *Dhaya* area is very light sand but heavier in sub-soil and is

* The author wishes to thank Dr. U. K. Bose, Meteorologist, Publication and Information, New Delhi ; Indian Agricultural Research Institute authorities for their assistance in collecting the data ; the IADP authorities at Ludhiana and the Director of the Agricultural Meteorological Department at Poona and Dr. R. K. Misra, Assistant Meteorologist, also at Poona for their assistance in picking out the variables and also to Dr. W. David Hopper in initiating this study.

generally low in fertility. The upper *Dhaya* soil is heavier in texture and more fertile. Sand dunes and alkaline patches are found in some places.[1]

Cultivation of Wheat

The crop is grown under irrigated and rainfed (unirrigated) conditions. In irrigated areas the normal sowing time is middle of October to middle of November and three to four irrigations are given. If there is no pre-sowing precipitation, one irrigation is given before a week of sowing. One irrigation should be given four to six weeks after the germination and another one may be given in the month of January. Further irrigations are given as and when needed.

In unirrigated areas the sowing is done mostly by the end of October. The sowing is done in rows by implements except in *Bet* area where it is done by broadcast.[2]

SELECTION OF VARIABLES

For the two types of cultivation mentioned above, yields and acreage were copied from the "Seasonal Crop Reports" published by Punjab Government covering a period of twenty-five years (1919-20 to 1943-44). This period is chosen because : (i) the World War I came to an end by 1919 ; (ii) depression started and so the cultivators had no incentive to grow more by adopting new techniques ; (iii) even though World War II started at about 1940 the depression continued till 1942 and Grow More Food Campaign started only later when the Britishers lost the cereal-growing countries under their empire ; (iv) by the time the cultivators came to know the use of artificial fertilizers they became scarce; and (v) in 1945, communal riots broke out and in 1947 India got the independence at the cost of partition. Because of causes (ii), (iii) and (iv) crops were grown at the mercy of weather.

Having established the importance of the period selected we can now consider the weather factors. No one can deny the fact that every component of weather has its influence individually or combined with other ones. But one may not be in a position to take all those into consideration because of unavailability of such data or lack of time or because of some other causes. In such a situation, one has to be satisfied with the selection of some important factors for which the knowledge of the physiology of the crop is essential if one wants to avoid the difficulties that would otherwise arise. In the present case, as the knowledge of physiology is absent, consultations have taken place with the Agronomist, IADP, Ludhiana and Agricultural Meteorologist of Poona in picking out the important components of weather with respect to wheat. Unfortunately, in India, it seems no serious attempt has been made to study the crop-weather relation.

From these consultations the three factors, namely, rainfall, temperature and humidity have emerged out as the important ones. Even though the distribution

1. Package Programme Districts—Facts and Figures, Ludhiana District, Punjab, Farm Information Unit, Directorate of Extension, Ministry of Food & Agriculture, New Delhi.

2. Cultivation of Wheat in the Punjab, Agricultural Information Service, Department of Agriculture, Punjab.

of rainfall is of much importance in assessing its proper impact on the crop, practical difficulties have restricted the selection to the months of August, September, October, December, January, February and March. The first three months (August, September and October) have been clubbed and treated as one variable—pre-sowing rainfall, (one may wish to call it as pre-sowing precipitation but pre-sowing rainfall is preferable because the amount of rainfall does not equate itself to the amount of precipitation) and the others as individual variables. November rainfall is not taken into account since generally there won't be rains and in the data considered here there was no rain in eighteen years out of twenty-five years. As the analysis progressed some of these variables have been dropped, the explanation of which will be given along with the functions to be presented later.

Temperature can be considered in any one of the forms, namely : (i) Maximum minus Minimum, (ii) Maximum, (iii) Minimum, (iv) $\frac{\text{Maximum} + \text{Minimum}}{2}$ and (v) some index of (i) . With all its importance, the first one cannot be considered as it has an inherent defect of being constant at times even though changes occur in Maximum and Minimum. By any sense, form (iv) is meaningless and with all probability it might lie within the limits that are conducive to the crop, thereby giving absurd results. Two types of form (v)—range as a percentage of Maximum and also Minimum—were tried ; but found to be not worth the trouble as could be seen from the Table I (First order correlation). At the same time it can be said that a proper index can be of much value rather than any of the other four types mentioned above. With the rejection of (i), (iv) and (v) two forms, Maximum and Minimum are left. The selection of one of them depends on the climatic conditions of the region. In cold countries Minimum is important and in tropical countries Maximum is important. These are so because of little effect on the crop from the other end. For the present study the Maximum temperature has been considered and the months chosen are November, December, February and March. January temperature has been excluded in favour of humidity because of the correlation of order —0.6228 in-between them. The statements "Quite severe ground frosts in December and early January have little or no effect,"[3] and "Low temperature is necessary for the normal growth and yield of Indian wheats,"[4] leave no doubts in any mind about the justification of the selection of Maximum Temperature.

During earing and before or after flowering moisture is essential to the crop. This means that atmospheric moisture is required which also helps in preserving the ground moisture. Humidity is such a one and to be on safe side January and February have been considered which are the months during earing and before flowering.

In addition to the above factors some other factors, namely, Minimum Temperature of certain months, April Maximum Temperature, Wind Velocity × Rainfall of March and April also have been considered.

Because of limited data, all the variables mentioned above could not be fitted in one function. Average yield per acre in tons is the dependent variable and

3. A Textbook of Punjab Agriculture, Sir W. Roberts and S.B.S. Kartar Singh, Lahore Civil and Military Gazette Ltd. (1951).

4. Annual Reports, Indian Agricultural Research Institute, New Delhi.

TABLE I—FIRST ORDER CORRELATION BETWEEN THE YIELD (IRRIGATED) AND TEMPERATURE OF DIFFERENT MONTHS

Months	Temperature			
	Maximum	Minimum	$\frac{\text{Maximum—Minimum}}{\text{Maximum}} \times 100$	$\frac{\text{Maximum—Minimum}}{\text{Minimum}} \times 100$
November ..	—0·2497	—0·1606	0·0052	0·0063
December ..	—0·2576	—0·0583	—0·0962	—0·0745
January ..	—0·1106	0·1323	—0·1978	—0·1678
February ..	—0·3607	—0·0458	—0·2822	—0·2957
March ..	—0·1584	—0·2236	0·0420	0·0677
April ..	—0·3470	—0·2502	—0·1042	—0·1169

average rainfall, humidity and temperature are independent variables. A comparative study of irrigated and unirrigated results is also given. Agronomic conclusions follow the results. The scale of measurement is Rainfall: inches ; Temperature: Fahrenheit and Humidity: Percentage.

The contribution of each independent variable to the R^2 is given under the heading R^2. This split up is valid only in the order the variables occur. If the order is changed there is no guarantee that the above breakdown holds good. Where the order of the independent variables is fixed this type of breakdown of R^2 greatly helps in picking out the independent variables which have substantial influence on the dependent variable and also helps in determining the relative importance of the independent variables.

RESULTS AND CONCLUSIONS

There is one point worth mentioning before presenting the regression results. Whereas estimated variances of irrigated (0.10430074/24) and unirrigated (0.08516651/24) yields do not differ statistically from one another the means (irrigated : 0.521044 ; unirrigated : 0.229716) diffe- significantly. This may be interpreted as that the irrigated fields are high in fertility.

(i) *Rainfall* : X_1: Pre-sowing (August+September+October) ; X_2: December ; X_3: January ; X_4: February and X_5: March.

F(i)	Irrigated			Unirrigated		
Variable	Coefficient (lbs. per acre)	Standard Error of the Coefficient	R^2	Coefficient (lbs. per acre)	Standard Error of the Coefficient	R^2
X_1	0·02262	0·0481	0·00004	0·01158	0·0463	0·0032
X_2	0·02761	0·0347	0·1312	0·0462^	0·0333	0·1490
X_3	0·06438	0·0556	0·0091	0·05725	0·0535	0·0119
X_4	0·09567*	0·0432	0·1577	0·09649*	0·0415	0·1857
X_5	—0·07091	0·0340	0·1307	—0·01059	0·0327	0·0036
Total			0·4287			0·3534
Constant term a :	0·45338			0·14593		

* Significant at 5 per cent level ; ** Significant at 1 per cent level.

In both the cases the signs of the coefficients are the same, *i.e.*, the direction of the influence of rainfall is independent of irrigation. The magnitudinal difference can be explained in the following way:

Pre-sowing Rainfall (X_1): The greater influence of pre-sowing rainfall over irrigated when compared to unirrigated may look somewhat anomalous but it is not untrue because the *Bet* area of which explanation is given already is unirrigated area and does not require much rain as compared with irrigated where sufficient precipitation bars the pre-sowing irrigation. And also there is no evidence to substantiate the belief that pre-sowing rainfall has substantial influence on the crop. This may be due to the floods in *Bet* area which is unirrigated and may be due to irrigation before sowing in the case of irrigated.

December Rainfall (X_2) : Winter drought sets in at this time. It is counteracted through irrigation in the case of irrigated but in the case of unirrigated only rainfall can arrest the drought effect. That is why the December rainfall is more essential to unirrigated rather than irrigated and the coefficients give weight to this conclusion.

January (X_3) *and February Rainfall* (X_4) *:* Not much difference can be found in the coefficients because rainfall is essential in February (earing state) and January rainfall also is helpful.

The signs of above months in both the cases are positive. This means crop favours the rainfall during these months. No explanation need be given in the case of pre-sowing rainfall as anybody can understand its good effect on the crop. With respect to others, the following quotes can explain the signs : "Rainfall has its greatest value during the growing season." "February rainfall is essential. December and January rainfall also help."[5]

March Rainfall (X_5) : The wide disparity in the coefficients can be due to greater ear weight and late maturity of irrigated crop as compared to the rain-fed crop. Because of heavier ears the possibility of lodging and thereby increased damage is more. Many of the diseases attack the crop around March and the infection of some of them is severe under moist conditions following rain. Hence in late maturing material loss due to diseases is likely to be more. Therefore, the sign of this partial regression coefficient is negative in both. It may be proper to mention the causes of lodging which may help in better understanding of the magnitudinal impact of March rainfall that "Lodging may be attributed to wet soil due to water-logging, irrigation or rainfall followed by strong wind and attack by pests and diseases."[6]

(ii) *Rainfall, Humidity and Maximum Temperature*: X_1 : November temperature ; X_2 : December rainfall ; X_3: December temperature ; X_4: January humidity ; X_5 : February rainfall ; X_6: February temperature ; X_7: February humidity ; X_8 : March rainfall ; X_9 : March temperature ; and X_{10}: April temperature.

5. Annual Reports, Indian Agricultural Research Institute, New Delhi.
6. *Ibid.*

Because of very little contribution from pre-sowing rainfall and January rainfall to R^2 (multiple correlation) and because of the limited data of yields no further consideration of these two variables has been undertaken.

F(ii)	Irrigated			Unirrigated		
Variable	Coefficient (lbs. per acre)	Standard Error of the Coefficient	R^2	Coefficient (lbs. per acre)	Standard Error of the Coefficient	R^2
X_1	—0·01478	0·0087	0·0624	—0·01627*	0·0058	0·0246
X_2	0·03709	0·0317	0·0866	0·05366*	0·0210	0·1266
X_3	0·00626	0·0051	0·0035	—0·00071	0·0034	0·0111
X_4	0·00068	0·0027	0·0260	—0·00245	0·0018	0·0971
X_5	0·05112	0·0517	0·1538	0·00440	0·0341.	0·1742
X_6	0·00301	0·0054	0·0049	0·00786*	0·0035	0·0117
X_7	0·00327	0·0028	0·0857	0·00836**	0·0018	0·2765
X_8	—0·09210*	0·0402	0·1964	—0·03485	0·0265	0·0160
X_9	0·00167	0·0060	0·0005	—0·00508	0·0039	0·0001
X_{10}	—0·00339	0·0047	0·0137	0·00676*	0·0031	0·0665
Total			0·6335			0·8044
Constant terms a :	0·95064			0·38054		

* Significant at 5 per cent level. **Significant at 1 per cent level.

November Temperature (X_1) : In irrigated as well as unirrigated, the sign of the coefficient is negative. This can be due to the following causes : (a) germination and early seedling growth are adversely affected with high November temperature, due to loss of moisture in the upper layers of soil ; (b) "Early sown crop is sometimes attacked by cut worms, which is a very destructive insect" for which the control measure is use of insecticides. Milder season also reduces the incidence of this pest[7] and (c) "Early sown *barani* (unirrigated) crop, if the temperature is usually high, is attacked by white ants which kill the young seedlings" for which the control measure is either light irrigation or use of gammexane.[8] Incidentally, the last cause explains the difference in magnitude of the two coefficients.

December Rainfall (X_2) : Explanation is given in function (i). Note the increase in values of the coefficients and the statistical significance of the coefficient in the case of unirrigated in contrast to the function (i).

December Temperature (X_3) : The coefficients have opposite signs : positive in irrigated and very low negative in unirrigated. The negative sign is inexplicable and in the function (iii) which will be discussed later, one can see this coefficient changing its sign to positive. Generally, December temperature helps the crop in its vegetative growth and the data considered in this example lies within the range of temperature favourable to the crop. Any slight increase within this range (65.8°F—77.3°F) accelerates growth. This positive effect is, however, small

7. Cultivation of Wheat in the Punjab, Agricultural Information Service, Department of Agriculture, Punjab.
8. *Ibid.*

January Humidity (X_4) : Humidity indirectly helps in preserving the soil moisture and reduces the adverse effect of winter drought on the crop. This advantageous condition is utilized by the irrigated crop as one can see from the positive sign of the coefficient. However in the unirrigated crop this turns out to be bane (the sign of the coefficient is negative). One may be able to explain this oddity by connecting the favourable conditions for the incidence of yellow ear rot and the general conditions that prevail at this time in *Bet* area and other unirrigated area. These factors may also explain the magnitudinal difference in the coefficients.

February Rainfall (X_5) : Note the decrease in magnitude of the coefficients and statistical non-significance as compared to those in function (i).

February Temperature (X_6) *and Humidity* (X_7) : Depending upon the date of sowing partly or completely the period of flowering and grain formation falls in this month. During this period an optimum range of temperature and certain percentage of humidity are required for proper development of the embryo. The positive signs of these two factors in irrigated and unirrigated not only affirm the above statement but also gives an idea of the ranges (66.6°F—77.8° F ; 59—93%) that are conducive to the crop. In the case of unirrigated both the coefficients are statistically significant, the temperature being at 5 per cent and the humidity at 1 per cent level.

March Rainfall (X_8) : Note the statistical significance of the coefficient in irrigated and the increase in absolute value in irrigated and unirrigated in comparison with those of function (i).

March (X_9) *and April Temperature* (X_{10}) : At this time hot weather is harmful to the crop as "shrivelling of grain takes place and the quality is affected."[9] But the signs of the coefficients of March in irrigated and April in unirrigated being positive, do not lend support to the above statement and why these are so is inexplicable with the available knowledge. Also it is interesting to note that April temperature in unirrigated has an explanatory power of 6 per cent and is statistically significant at 5 per cent level.

As the harvest is completed around second week of April, the variable April Maximum temperature has been dropped and the new function with the remaining variables is presented below :

(iii) *Rainfall, Humidity, and Maximum Temperature* : Variables are the same as in function (ii) except the variable April temperature (X_{10}) which is omitted (page 229).

Note the change of signs of December Maximum temperature (X_3) in unirrigated and March Maximum temperature (X_9) in irrigated and also the statistical non-significance of December rainfall (X_2) and February Maximum temperature (X_6) in unirrigated as compared to the coefficients in function (ii) above. Except January humidity (X_4) which has opposite signs in irrigated (positive) and unirrigated (negative) the rest have the same signs in both the cases.

9. A Textbook of Punjab Agriculture, Sir W. Roberts and S.B.S. Kartar Singh, *Op. cit.*

F(iii)	Irrigated			Unirrigated		
Variable	Coefficient (lbs. per acre)	Standard Error of the Coefficient	R^2	Coefficient (lbs. per acre)	Standard Error of the Coefficient	R^2
X_1	—0·01619	0·0084	0·0624	—0·01346*	0·0063	0·0246
X_2	0·03958	0·0311	0·0866	0·04870	0·0233	0·1266
X_3	0·00555	0·0050	0·0035	0·00069	0·0037	0·0111
X_4	0·00005	0·0025	0·0260	—0·00118	0·0019	0·0971
X_5	0·04540	0·0503	0·1538	0·01580	0·0377	0·1742
X_6	0·00463	0·0048	0·0049	0·00464	0·0036	0·0117
X_7	0·00422	0·0024	0·0857	0·00648**	0·0018	0·2765
X_8	—0·09683*	0·0390	0·1964	—0·02543	0·0293	0·0160
X_9	—0·00072	0·0049	0·0005	—0·00030	0·0037	0·0001
Total			0·6198			0·7379
Constant term a :	0·85807			0·56494		

* Significant at 5 per cent level. **Significant at 1 per cent level.

(iv) *Rainfall, Humidity, Temperature and Rain × Wind Velocity* : X_1 : November Maximum Temperature ; X_2 : December Rainfall ; X_3 : December Minimum Temperature ; X_4 : January Minimum Temperature ; X_5 : January Humidity ; X_6 : February Rainfall ; X_7 : February Humidity ; X_8 : March Maximum Temperature ; X_9 : March Rain × Wind Velocity ; and X_{10} : April Rain × Wind Velocity (page 230).

The last two variables X_9 and X_{10} are included because of the opinion that the damage caused by the combination of rain and wind velocity is more than that of rain itself. The inclusion of the variables X_3 and X_4 (December minimum temperature and January minimum temperature respectively) is done in order to examine the validity of the belief among some that the effect of these two count more rather than the effect of maximum temperature in those two months.

The signs of the coefficients of January minimum temperature (X_4, sign positive in irrigated and unirrigated), January humidity (X_5, negative sign in both the cases) and April rain × wind velocity (X_{10}, positive sign in both the cases) in irrigated and unirrigated and the sign (positive) of the coefficient of March maximum temperature in irrigated do not stand the scrutiny from agronomical point of view. They are supposed to have negative, positive, negative and negative signs respectively. None of the coefficients in irrigated and except February humidity (X_4), no other coefficient in unirrigated are significant in statistical sense.

F(iv)	Irrigated			Unirrigated		
Variable	Coefficient (lbs. per acre)	Standard Error of the Coefficient	R^2	Coefficient (lbs. per acre)	Standard Error of the Coefficient	R^2
X_1	—0·01188	0·0066	0·0624	—0·01084	0·0054	0· 0246
X_2	0·03950	0·0318	0·0866	0·05101	0·0256	0· 1266
X_3	—0·00438	0·0051	0·0052	—0·00039	0·0041	0· 0011
X_4	0·00663	0·0072	0·0315	0·00493	0·0058	0· 0022
X_5	—0·00091	0·0028	0·0162	—0·00182	0·0023	0· 1279
X_6	0·04850	0·0520	0·1875	0·01283	0·0419	0· 1756
X_7	0·00289	0·0024	0·1219	0·00591**	0·0019	0· 2637
X_8	0·00013	0·0049	0·0167	—0·00018	0·0039	0·00002
X_9	—0·02291	0·0152	0·1089	—0·00081	0·0122	0· 0003
X_{10}	0·01669	0·0228	0·0134	0·00146	0·0183	0· 0001
Total			0·6503			0· 7221
Constant term a :	1·23131			0·62102		

**Significant at 1 per cent level.

As in functions (i) and (iii) here also the coefficients have the same signs in irrigated as well as unirrigated except the coefficient of March maximum temperature which has positive sign in irrigated and negative sign in unirrigated.

Conclusions

From this study, rainfall of December, February and March and humidity of January and February have emerged as the most important weather factors that influence the crop yield. March rainfall has more destructive effect on irrigated crop than on unirrigated and February humidity is more essential to unirrigated crop than to irrigated crop. The temperature also has some effect on the crop.

Comparing the signs of the coefficients of irrigated and unirrigated in functions (i), (iii) and (iv) one can confidently say that the directional influence of the weather factors considered in this study is independent of irrigation and irrigation alone has no capacity either to take full advantage of favourable weather factors or counteract fully the adverse weather factors.[10] Also, it appears that weather factors have such a profound effect on yield that even irrigation cannot offset their effects. Since the two most important factors emerging from this study

10. The author is indebted to Dr. B. R. Murty, Biometrical Genetist, Indian Agricultural Research Institute, for his suggestion.

are rainfall and humidity, it appears that adequate soil moisture cannot compensate for the poor grain development due to limited atmospheric moisture in arid regions. It will be worthwhile to undertake a study of the mechanisms by which atmosphere precipitation has greater influence on crop yield than adequate soil moisture.

One may also note that an improper selection and combination of variables would vitiate the results and putting undue emphasis on the statistical significance of the coefficients is undesirable as is evident from function (iv). It can also be concluded that in selecting variables any *a priori* knowledge of such variables, if available, should be taken into consideration.