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Influence of dew on the growth and yield of wheat crop

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सार — इस शोध पत्र में भारत के छः चुने हुए गेहूँ-उत्पादक क्षेत्रों-अर्थात्, हिसार, ग्वालियर, वाराणसी, जबलपुर, रायपुर और पुणे में गेहूँ की फसल की बढ़वार तथा इसके उत्पादन पर पड़ने वाले ओस के प्रभाव का अध्ययन किया गया है। इसमें 12 से 15 वर्षों तक के आंकड़ों का प्रयोग किया गया है। फिशर्स तकनीक के अनुसार आंकड़ों का प्रयोग किया गया है और ओस पड़ने के अनुकूल व प्रतिकूल प्रभाव की अवधि का पता लगाया गया है। अध्ययन से पता चलता है कि सामान्यतः ओस गेहूँ के पौधों की बढ़वार में सहायक होती है। गेहूँ के उगने से लेकर पौधों में और दाने उत्पन्न होने तक ओस पौधों के समुचित विकास तथा फसल की पैदावार बढ़ाने में सहायक सिद्ध होती है। आंकड़ों के गहन विश्लेषण से ज्ञात हुआ है कि सापेक्ष आर्द्रता और फसल के उत्पादन के बीच गहरा संबंध है। विश्लेषण से यह भी पता चला है कि गेहूँ की पैदावार को बढ़ाने में ओस प्रत्यक्ष या परोक्ष रूप में काफी हद तक सहायक होती है।

ABSTRACT. In this study effect of dew deposits on the growth cycle of wheat and its yield have been examined for six selected wheat growing locations in India, *viz.*, Hisar, Gwalior, Varanasi, Jabalpur, Raipur and Pune. The data set varied from 12 to 15 years. The data were subjected to Fisher's technique and periods when dew exerted beneficial or baneful effect, identified. The study indicates that dew generally helps the emergence of wheat. Dewfall from jointing to flowering/dough stage helps in proper development of the plant and increase in yield. Subjecting the data to path analysis brought out high association between relative humidity and yield. It also revealed that, by and large, dew directly or indirectly contributes to increase wheat yield.

Key words — Path analysis, Orthogonal polynomial, Response curve, Dew deposition, Crown root initiation, Pathogenic fungi.

1. Introduction

Overall effect of dew as a moisture contributor and as a factor for exchange of heat and water in the agro-system cannot be neglected. The present study examines the extent to which the dew amount and its distribution contributes to the growth and development of wheat crop in India. This has been done by subjecting the data to Fisher's response curve analysis. Path analysis has also been done to seperate out effect of dew on yield from other meteorological factors.

2. Data

Six agricultural meteorological observatories, *viz.*, Hisar (29° 10'N, 75° 44'E), Gwalior (26° 14'N, 78° 15'E), Varanasi (25° 18'N, 83° 01'E), Jabalpur (23° 10'N, 79° 57'E), Raipur (21° 16'N, 81° 36'E) and Pune (18° 32'N, 73° 51'E) have been chosen for the study. The dewfall at these stations are measured daily by Duvdevani dew gauge. From the daily values weekly totals were obtained from the date of sowing till harvesting.

The dewfall and yield series were subjected to Fisher's (1924) response curve technique. Gangopadhyay and Sarker (1965), Sreenivasan and Banerjee (1972, 1978), Chowdhury and Dandekar (1991) etc have examined crop weather relationships applying this technique to field crops in India.

The weekly dew accumulation values were first subjected to orthogonal polynomial analysis. Since the polynomial fitted was of fifth degree, six constants called "dew distribution constants", were obtained as shown below :

$$D = a' + b'\xi_1 + c'\xi_2 + d'\xi_3 + e'\xi_4 + f'\xi_5 \qquad (1)$$

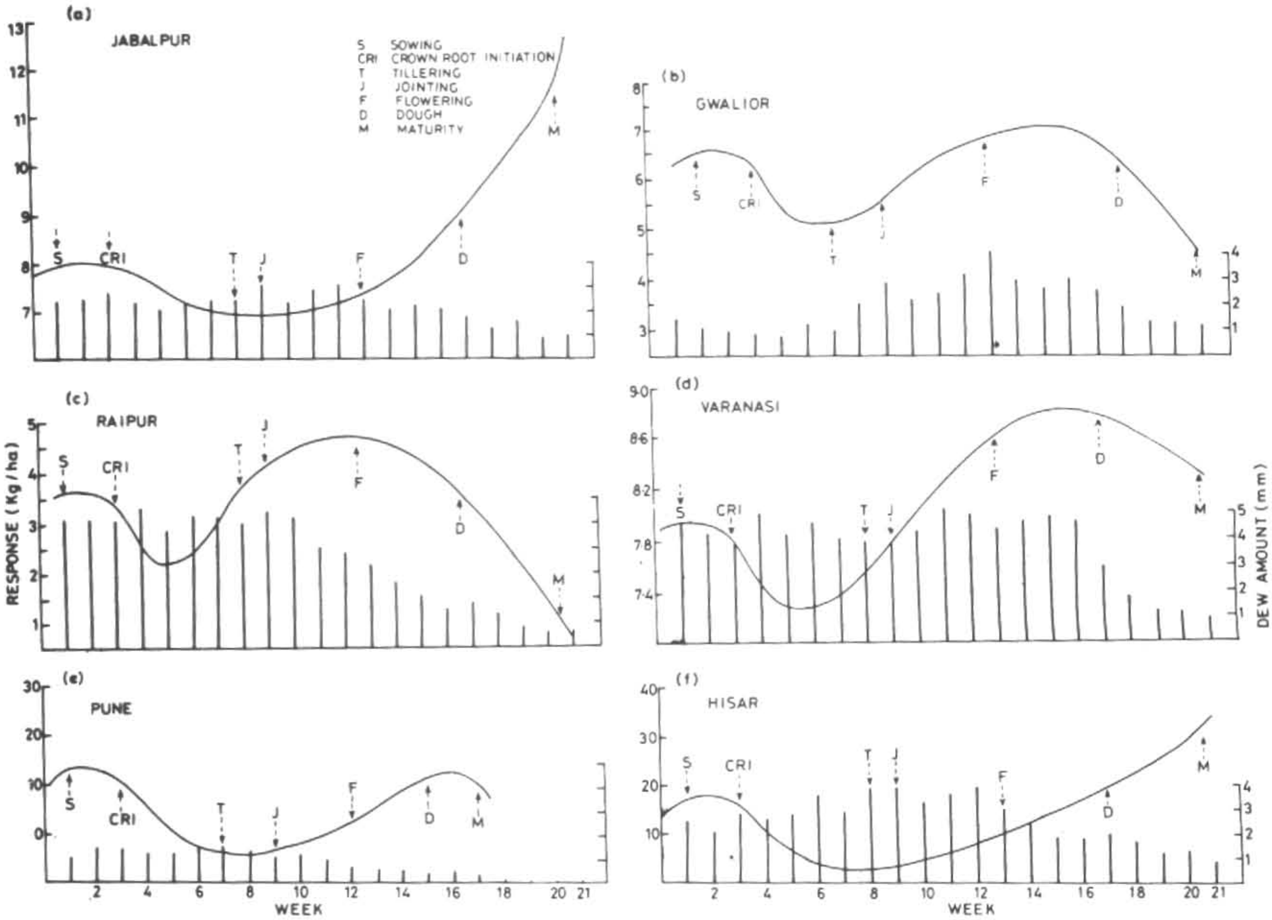
In the above equation D is the amount of dew deposition. a', b', c', d', e', and f' are dew deposition constants obtained for each year for each observatory and ξ_i (i = 1,..........5) are the constants given in statistical table by Fisher and Yates (1938).

The yields were then correlated with the distribution constants for each of the stations to examine effect of dew on wheat yield. The results are given in Table 1. The correlation coefficients, in majority of the cases, were large and statistically significant, varying from 0.01 to 0.92. That the dew deposit effects the wheat yield is, thus, clearly established.

Taking yield deviation from mean as dependent variable and deviations (from their respective means) of dew distribution constants as independent variable, a multiple regression was fitted to the data. The following equations could be obtained :

Hisar

$$Y = 304.31a' + 132.67b' + 177.95c' - 313.31d' + 217.31e' + 75.79f'$$
$$R^2 = 0.58 \qquad (2)$$



Gwalior

$$Y = 127.14a' + 1.85b' - 5.045c' - 38.92d' - 54.02e' + 67.17f' \quad R^2 = 0.70 \quad (3)$$

Varanasi

$$Y = 171.81a' + 12.01b' + 1.64c' - 37.30d' + 22.74e' + 0.99f' \quad R^2 = 0.88 \quad (4)$$

Jabalpur

$$Y = 164.19a' + 26.71b' + 21.18c' + 47.62d' + 17.67e' + 27.21f' \quad R^2 = 0.50 \quad (5)$$

Raipur

$$Y = 263.60a' + 7.43b' - 22.18c' - 28.07d' + 19.69e' - 2.83f' \quad R^2 = 0.53 \quad (6)$$

Pune

$$Y = 92.38a' - 83.63b' + 343.87c' - 226.38d' + 18.32e' - 305.35f' \quad R^2 = 0.56 \quad (7)$$

The multiple correlation coefficients at Gwalior and Varanasi were found significant at 1% level, at Hisar, Jabalpur and Raipur at 5% level and at Pune nearly at 5% level. In Varanasi, the MCC was nearly 1, bringing out the importance of dew to wheat crop in the Gangetic plains. Dew explains 58 to 88 per cent variations in yield in the present study.

The regression coefficients no doubt have different magnitudes for different stations. They also vary in sign from location to location.

The yield expected from equations above were then calculated. The Root Mean Square Error (RMSE) is included in Table 1. Least RMSE was observed at Varanasi (*i.e.*, 103 kg/hec) followed by Gwalior (*i.e.*, 198 kg/hec). At the remaining stations RMSE values were quite high with largest value of 611 kg/hec seen at Raipur.

The smallness of RMSE is an additional proof that dew significantly affects wheat yield.

The response *(P)*, *i.e.*, the quantitative effect of dew as the crop development progress can be obtained as follows :

$$P = A + B\xi'_1 + C\xi'_2 + E\xi'_3 + F\xi'_4 + G\xi'_5$$

where, *A, B, C, E, F* and *G* are constants,

TABLE 1

Correlation coefficients of wheat yield with dew distribution constants and root mean square error (RMSE)

Correlation coefficient	Hisar	Gwalior	Varanasi	Jabalpur	Raipur	Pune
a'	0.15	0.57	0.92	0.61	0.08	−0.42
b'	0.60	0.39	−0.51	−0.19	0.44	0.44
c'	0.09	−0.29	−0.58	−0.08	−0.39	0.68
d'	−0.45	−0.52	−0.75	−0.13	−0.10	−0.26
e'	0.39	−0.56	0.50	−0.01	0.62	−0.15
f'	0.01	0.56	0.29	0.24	−0.24	−0.10
RMSE of yield (kg/hec)	524	198	103	503	611	410

$\lambda\xi_i = \xi'_i$ (i = 1, 2, 3, 4, 5), and λ represents progressive week number starting from sowing. The ξ'_is are obtained from Fisher and Yate's tables for different λs.

The response curves showing effect of dew on yield are given in Fig. 1. The changes shown in the figure are the average effect corresponding to an additional unit of dew deposit above the average at any point of time during the growth cycle. The results obtained are discussed below :

> Dew is influenced by high relative humidity, clear sky and moderate wind speed. Therefore, impact of dew has to be separated out from these other variables through the path analysis. This has also been attempted.

3. Discussion

3.1. *Fisher's response integral*

3.1.1. *Hisar* — Hisar is situated in the northern belt where maximum dew deposition of over 30 mm occurs (Chowdhury *et al.* 1990). At this station dew between sowing & nearly crown root initiation provides moisture for seedling establishment and is thus helpful to the crop. Subsequently till tillering, dew affects the wheat crop adversely at this station [Fig. 1 (f)]. According to Mehta (1952), after two to three months of sowing, conditions are favourable for outbreak of rust. The uredospores of the rust germinate readily after their release, if environmental conditions, such as, heavy dew and a temperature ranging from about 13° to 24° C are available (Pal 1966) which is generally the case at Hisar. Thus plants remain stunted as a result of reduction in the elongation of the internodes and twisting of culms considerably reducing the number of tillers. Dew deposition after tillering helps increase in wheat yield.

3.1.2. *Gwalior* — The response pattern at Gwalior [Fig. 1 (b)] is similar to that at Hisar till nearly soft dough stage, *i.e.*, 2 weeks after flowering. However, amplitude of the response is much lower than that at Hisar, presumably because the amount of dew deposit till beginning of flowering is much less at Gwalior compared to Hisar. After 16th week of sowing onwards, *i.e.*, in the post flowering period, dewfall brings down the yield. Heavy dew during this period, leads to fungus formation, shrivilling of the grains and hence less yield. It may be mentioned that in this period, dew deposit at Gwalior are higher than at Hisar.

3.1.3. *Varanasi* — The response curve at this station is similar to that at Gwalior and brings out the effect of dew as a moisture contributor from tillering to soft dough stage. Studies by Venketaraman *et al.* (1976) and Battawar *et al.* (1993) revealed that maximum water demand of wheat occurs around flowering. After soft dough stage dew affects adversely as has been observed in case of Gwalior [Fig. 1(d)].

3.1.4. *Jabalpur* — The wheat yield at Jabalpur responds to dew in a manner identical to that at Hisar. It affects negatively between CRI to tillering [Fig. 1(a)]. According to Yarwood (1958) a water film on plant surface is essential for infection of many plant pathogenic fungi. The heavy dew deposit from CRI to the begining of tillering probably promoted heavy rust infection (Johnston *et al.* 1936) and finally led to fall in yield. Subsequently, dew helps to increase the yield as in case of Hisar.

3.1.5. *Raipur* — The pattern of Raipur nearly resembles that at Gwalior and Varanasi. After 1½ month of sowing till flowering, dew deposition helps to increase the wheat yield. Subsequently the dew contributes negatively to the yield [Fig. 1(c)].

3.1.6. *Pune* — Dew as moisture contributor exerts detrimental effect on wheat yield from sowing till tillering at Pune [Fig. 1(e)]. Gangopadhyay & Sarker (1965) also observed that rainfall during this period at two Deccan Plateau stations of Parbhani & Dharwad, exert negative influence on the wheat yield. Subsequently dew deposition helps to increase the yield till about hard dough stage.

TABLE 2

Correlation coefficient between yield, dew deposition, minimum temperature, wind speed and relative humidity

	Yield X_1	Dew deposition X_2	Min. temp. X_3	Wind speed X_4	Relative humidity X_5
		1. Hisar			
X_1		.28	.51	.11	.18
X_2			—.29	—.02	—.49
X_3				—.51	.78**
X_4					—.70**
		2. Gwalior			
X_1		.56	—.63**	—.33	.60**
X_2			—.38	—.34	.71**
X_3				.17	—.25
X_4					—.07
		3. Varanasi			
X_1		.39	.63**	—.62**	.51*
X_2			.79**	.04	.73**
X_3				.14	.97**
X_4					.26
		4. Jabalpur			
X_1		.55*	—.27	.38	.11
X_2			—.03	—.10	.26
X_3				.35	.39
X_4					.40
		5. Raipur			
X_1		.07	.36	.36	.50*
X_2			—.23	—.37	.06
X_3				.31	.37
X_4					—.16
		6. Pune			
X_1		.63*	.23	—.31	.10
X_2			.13	.39	.32
X_3				—.18	.84**
X_4					.14

* Significant at 5% level. ** Significant at 1% level

3.2. *Path analysis* — In correlation analysis, values of correlation coefficients are generally dependent on the choice of individual parameters. Dew formation is mainly influenced by relative humidity, wind-speed and the sky cover. On the other hand sky cover generally determines the magnitude of minimum temperature. As such impact of dew on wheat yield cannot be studied in isolation and the effect has to be separated from the effect of these variables. This has been achieved through path analysis (Dewey and Lu 1959). The correlation coefficients for each of the stations are given in Table 2 and discussed below :

3.2.1. *Hisar* — Dew deposition is weakly correlated with relative humidity (r = —0.49). Correlation of minimum temperature and wind speed each with dew is also weak, though each of them are significantly correlated (at 1% level) to relative humidity (r = 0.78 and r = —0.70 respectively) and also with one another (r = —0.51). Yield has, among the three weather factors, a maximum correlation of r = 0.51 with only minimum temperature which, however, is not significant at 5% level. Since minimum temperature depends largely on relative humidity and with wind speed as observed above, the latter two parameters, indirectly influence the yield through minimum temperature. Directly dew exert very insignificant influence on yield (r = 0.28).

3.2.2. *Gwalior* — Dew formation at this station is influenced by relative humidity, minimum temperature and wind speed in that order with r = 0.71, —0.34, —0.34 respectively. The inter-correlation among the three weather factors is, however, very weak and does not exceed 0.25. Since relative humidity is also significantly correlated with yield (r = 0.60 significant at 1% level), it means, it affects the wheat growth and yield indirectly through dew.

On the other hand, minimum temperature, compared to relative humidity, has a larger correlation with yield (r = —0.63) which is significant at 1% level but is poorly correlated with dew. Hence its effect on yield could be termed as direct.

Dew thus bears a correlation r = 0.56 (significant at 5% level) and explains 31% of the yield variations.

3.2.3. *Varanasi* — At Varanasi dew amount is highly dependent on minimum temperature (r = 0.79) and relative humidity (r = 0.73), both correlations being significant at 1% level. Both these parameters are highly dependent on each other (r=0.97). In view of such a high inter-correlation, and large correlations (significant at 5% level) which minimum temperature and relative humidity each bear with wheat yield (r = 0.53 and r = 0.51 respectively), both these parameters affect dew formation and hence the yield through mutual interaction.

Dew amount though positively influencing the yield, explain about 15% of the variations in wheat yield.

3.2.4. *Jabalpur* — Dew at this location is poorly correlated with each of the three weather factors, the highest being r = 0.26 with relative humidity. These weather parameters also do not bear large or significant correlation with yield. Dew has a moderately large correlation with yield (r = 0.55, significant at 5% level) and explain 30% of variations. Dew thus affects the yield directly.

3.2.5. *Raipur* — None of the weather parameters considered in this study significantly influence dew formation at Raipur. Among themselves also they appear to be independent of each other. Dew does not appear to have any influence on the yield. The rather large (r = 0.50 significant at 5% level) correlation yield bears is, with relative humidity. Thus dew affects the yield indirectly through relative humidity only.

3.2.6. *Pune* — Dew formation in Deccan Plateau, as represented by Pune, is influenced to a limited extent, by wind speed (r = 0.39) and relative humidity (r = 0.32). Wind speed, however, compared to other weather factors, affect the wheat yield, though statistically insignificantly (r = —0.31). Because of moderate relationship between dew and wind speed, it could be inferred that the latter's influence on the yield is indirect through dew. Dew bears a statistically significant (at 5% level) relationship (r = 0.63) with yield and explains nearly 40% of yield variations.

It is clear from above that dew does exert positive influence on wheat crop yield though the degree of influence differs from location to location. Dew as such, can contribute as much as about 40% of yield variations except Raipur where its effect on yield was negligible. In the north Indian plains, relative humidity mainly contributes to dew depositions and hence indirectly helps in increasing the yield. South of Satpura maintain range, dew formation appears to be less dependent on weather factors.

4. Conclusions

The following conclusions emerge from the analysis :

(i) Large scale dew formation prior to sowing and up to initial stage of crown root initiation helps in proper growth of wheat.

(ii) From tillering to flowering high dewfall help better crop growth.

(iii) Relative humidity, in general, contributes to dew formation in northern Gangetic plains only and hence indirectly to wheat yield.

(iv) When considered in association with other environmental factors through path analysis, the dew appears to contribute 0.5 to 40% only to wheat yield.

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