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PREDICTION OF FOG OCCURRENCE AND ITS IMPACT ON MUSTARD PRODUCTION IN ARID ZONE OF HARYANA

1. Oilseed crops constitute important components of agricultural economy of India amongst which the genus *Brassica* is important as major source of edible oil. Rapeseed and mustard occupy a prestigious position and rank second after groundnut in India. Mustard is one of the important *rabi* crop of the arid zone of Haryana State which constitutes an important component of agricultural economy of the State. Haryana occupies an important place as major rapeseed and mustard growing State of the country having an area of 0.535 million hectare with production of 0.796 million tonnes of oilseed (Anonymous 2002). Weather phenomena *viz.*, fog, frost, cold waves, heat waves etc. have a pronounced effect on growth and development of plants. Early morning fog is most common in January and less common in February, December (Golder and Banerjee 1989). Its effect on the plants is similar to the effect of rain and dew. Occurrence of fog also depends upon the previous days weather. Cloud cover, wind speed and dew point depression were most significant variables for explaining 64.7 per cent of variance in differences in temperature between shelter and grass minimum thermometers (Goldsworthy and Shulman 1984). Golder and Banerjee, (1989) studied the relationship between duration of fog and minimum temperature and found that duration of fog depends upon the minimum temperature during foggy nights. The information available on fog studies in relation with mustard productivity is very scanty. Therefore a study was conducted on fog occurrence and prediction and its impact on mustard productivity in arid zone of Haryana.

2. The daily meteorological data of winter seasons (December, January and February) of past 20 years from 1982 to 2002 of Hisar representing the arid zone of Haryana were taken from the Agrometeorological observatory, Chaudhary Charan Singh Haryana Agricultural University, Hisar on the following parameters as follows.

Grass minimum temperature (°C), morning and evening actual vapour pressure (mm of Hg), morning and evening relative humidity (%), wind speed (km/hr.), sunshine (hrs.), evaporation (mm) and fog occurrence. Data on mustard productivity from 1982 to 2002 were taken from Statistical Abstract of Haryana. Data on

TABLE 1(a)

No. of days of fog occurrence in winter season of 1982-2002

Year	Dec	Jan	Feb	Total
1982-83	4	1	0	5
1983-84	0	0	0	0
1984-85	0	3	0	3
1985-86	0	1	0	1
1986-87	0	6	0	6
1987-88	4	3	0	7
1988-89	8	2	3	13
1989-90	12	10	5	27
1990-91	3	4	3	10
1991-92	12	6	4	22
1992-93	3	6	5	14
1993-94	3	6	1	10
1994-95	3	10	3	16
1995-96	0	8	5	13
1996-97	0	15	5	20
1997-98	9	3	3	15
1998-99	19	14	6	39
1999-2000	11	10	6	27
2000-01	3	17	2	22
2001-02	14	14	2	30
Mean	5.4	6.9	2.7	15.0
CV (%)	101.8	71.0	80.7	70.5

TABLE 1(b)

Probability of daily fog occurrence in winter season

Day of the month	Dec	Jan	Feb	Day of the month	Dec	Jan	Feb
1	0.00	0.30	0.10	17	0.25	0.20	0.05
2	0.05	0.00	0.15	18	0.20	0.25	0.10
3	0.05	0.30	0.10	19	0.15	0.20	0.00
4	0.10	0.30	0.15	20	0.20	0.15	0.05
5	0.15	0.35	0.00	21	0.10	0.10	0.10
6	0.00	0.35	0.05	22	0.25	0.15	0.05
7	0.00	0.45	0.05	23	0.20	0.15	0.10
8	0.05	0.50	0.05	24	0.35	0.00	0.00
9	0.10	0.30	0.10	25	0.30	0.05	0.05
10	0.05	0.25	0.10	26	0.25	0.05	0.15
11	0.20	0.30	0.25	27	0.40	0.05	0.25
12	0.20	0.25	0.20	28	0.30	0.10	0.00
13	0.25	0.30	0.15	29	0.35	0.10	0.00
14	0.05	0.30	0.15	30	0.25	0.10	-----
15	0.10	0.35	0.05	31	0.25	0.10	-----
16	0.20	0.15	0.10				

TABLE 2(a)

Regression equations for the prediction of fog with weather parameters of (n-1) and (n-2)th days

Equation	R^2	Equation	R^2
$y = 11.888\ x_1 - 68.317$	0.67	$y = 81.644$ Ln $(x) - 143.67$	0.65
$y = 7.9273\ x_2 - 47.03$	0.82	$y = 61.464$ Ln $(x) - 110.97$	0.79
$y = 0.9253\ x_3 - 25.117$	0.72	$y = 42.374$ Ln $(x) - 144.19$	0.71
$y = -23.062\ x_4 + 64.35$	0.63	$y = -48.058$ Ln $(x) - 51.143$	0.64

y = Foggy days in winter season,
x_1 = Morning actual vapour pressure (mm of Hg),
x_2 = Evening actual vapour pressure (mm of Hg),
x_3 = Evening relative humidity (%),
x_4 = Evaporation (mm)

TABLE 2(b)

Multiple regression equations for the prediction of fog with weather parameters of (n-1) and (n-2)th days

Equation	R^2
$y = -40.95 + 7.61x_1 - 1.67x_2$	0.82
$y = -50.34 + 8.12x_1 - 4.93x_2 + 1.80x_3$	0.83
$y = -50.50 + 9.93x_1 - 6.19x_2 + 1.88x_3 - 27.0x_4$	0.84

y = Foggy days in winter season,
x_1 = Evening actual vapour pressure (mm of Hg),
x_2 = Evaporation (mm),
x_3 = Sunshine (hours) and
x_4 = Evening relative humidity (%)

meteorological parameters and mustard productivity were analyzed using the methods given below :

2.1. *Fog occurrence probability* - Daily probability of fog occurrence was determined using the formula :

$$\text{Probablity} = \frac{\text{Fog events occurred}}{\text{Total number of observations}}$$

2.2. *Coefficient of variation* - Coefficient of variation (CV) of meteorological data was computed using the formula :

$$\text{CV}(\%) = \frac{\text{SD}}{\text{Mean}} \times 100$$

Where, SD is standard deviation.

2.3. *Correlation and regression* - Correlation and regression analysis was carried out to study the relationship of fog occurrence with previous (n-1)th day and previous to previous (n-2)th day weather parameters. Relationship of fog occurrence with weather parameters and the impact of foggy days on mustard productivity were also quantified using the stepwise regression analysis. The following equations were fitted by least square method

(*i*) *Straight line*

$$y = a + bx$$

(*ii*) *Multiple regression*

$$y = a + b_1x_1 + b_2x_2$$

$$y = a + b_1x_1 + b_2x_2 + b_3x_3$$

$$y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4$$

(*iii*) *Exponential*

$$y = ae^{-bx}$$

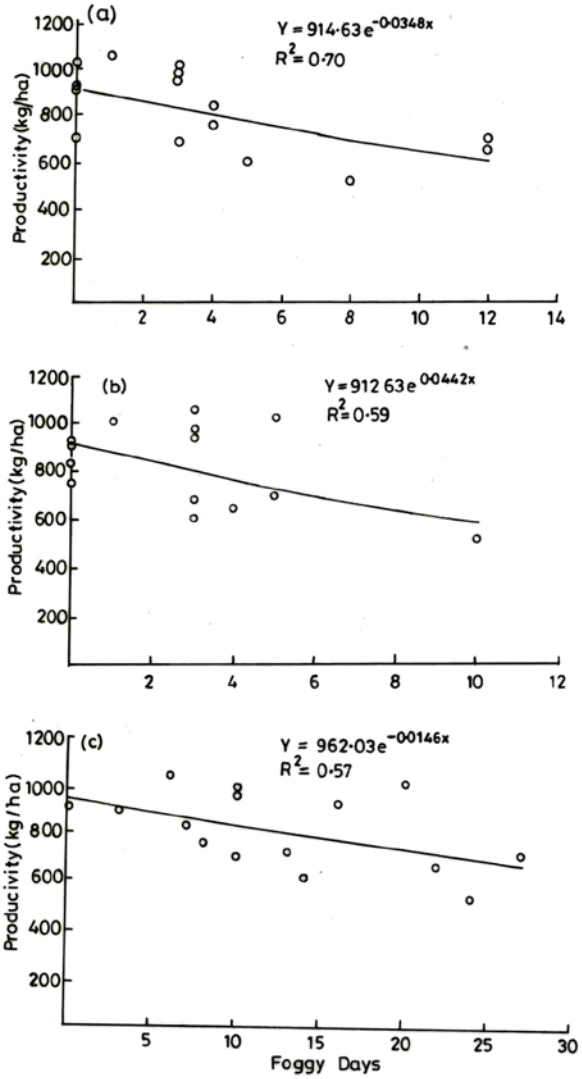
(*iv*) *Logarithmic*

$$y = a + b \ln (x)$$

3. The results of the study conducted on quantification and prediction of fog occurrence and its impact on mustard production in arid zone of Haryana are presented here and discussed with the help of suitable available literature in the following sub headings :

3.1. *Foggy days* - Foggy days in winter months (December to February) at Hisar station from 1982 to 2002 are presented in Table 1(a). Mean foggy days were the maximum in January (6.9), followed by December (5.4) and February (2.7). The mean value of total foggy days during winter season was 15.0. The value of coefficient of variation was less in January as compared to December and February. Golder and Banerjee (1989) reported that early morning fog is most common at Calcutta in January and less frequent in December and February. In past 20 years, total foggy days were highest in 1998-99 (39) and no fog was occurred in 1983-84. In February from 1982-83 to 1987-88, no fog was occurred. Same trend was observed in December from 1983-84 to 1986-87 and in 1995-96 and 1996-97. Yang (1995) reported that fog occurrence was increasing in recent years in Taiwan.

3.2. *Probability of daily fog occurrence* - Probability of daily fog occurrence during winter season is presented in Table 1(b). Probability of fog occurrence in December was more in 2nd fortnight as compared to 1st fortnight. During January, it was higher in 1st fortnight or



Figs. 1(a-c). Relationship of mustard productivity with foggy days in (a) December, (b) February and (c) whole winter season

during a spell of eighteen days from 3rd to 20th January, it ranged between 0.15 and 0.50, but after 1st fortnight or this spell it was very less in rest of January and whole of February. Maximum daily probability of fog occurrence was 0.50 on 8th January and minimum probability was zero on 1st, 6th and 7th December, 2nd and 24th January and 5th, 19th, 24th and 29th February. Maximum continuous foggy days were observed during 1998-99 (21) from 13th December to 2nd January and no continue spell was observed from 1983-84 to 1987-88 and in 1995-96 and 1996-97 in December and in January from 1982-83 to 1985-86 and 1999-2000. Similarly in February no continuous spell of foggy days was observed from 1982-83 to 1988-89and in 1993-94, 1994-95, 2000-2001 and 2001-2002.

3.3. *Relationship of foggy days with weather parameters* - The foggy days were correlated with different weather parameters and they were significantly correlated with morning and evening actual vapour pressure, morning and evening relative humidity and evaporation. Among the weather parameters, evening actual vapour pressure was best associated with foggy days. The significant weather parameters were selected for developing relationship with foggy days. A significant linear relationship was observed between foggy days and weather parameters (morning and evening actual vapour pressure, evening relative humidity and evaporation). The required mathematical equations were also developed and presented in the figure with R^2 values. Evening actual vapour pressure and evening relative humidity individually explained the variability in foggy days upto 82 and 72 per cent respectively. However, the variability in foggy days was less explained by morning actual vapour pressure and evaporation.

A logarithmic relationship was also observed between foggy days and weather parameters. However, R^2 values of linear relationship were higher as compared to R^2 values in case of logarithmic relationship [Table 2(a)]. Multiple regression equations for prediction of fog using weather parameters as input parameters are presented in Table 2(b). The weather parameters such as evening actual vapour pressure, evaporation, sunshine, evening relative humidity collectively explained the variability in foggy days upto 84 per cent.

3.4. *Relationship of mustard productivity with fog* - Productivity of mustard crop was negatively and exponentially associated with fog occurrence. The required exponential regression equation is given in Figs. 1(a-c). Foggy days in December explained more variability in mustard productivity upto 70 per cent as compared to the January and February. Only upto 59 and 57 per cent variability is explained in mustard productivity by foggy days in February and whole winter season, respectively. Mustard productivity was negatively associated with fog occurrence. This might be due to the reason that foggy weather is congenial for white rust disease spread in *Brassica* which might caused reduction in seed yield. Saifuzzaman and Meisner (1996) studied the wheat sterility in Bangladesh and they reported that the probable cause of wheat sterility was low light due to foggy weather.

4. Based on the above results, the following conclusions are drawn :

(*i*) Mean foggy days were maximum in January (6.9) followed by December (5.4) and February (2.7) and mean foggy days during winter season were 15.0.

(*ii*) Maximum probability of fog occurrence was 0.50 on 8th January and minimum probability was zero on 1st, 6th and 7th December, 2nd and 24th January and 5th, 19th, 24th and 29th February.

(*iii*) Actual vapour pressure and relative humidity during evening, individually explained the variability in foggy days upto 82 and 72 per cent, respectively.

(*iv*) Productivity of mustard crop was negatively and exponentially associated with fog occurrence. Foggy days in December alone explained the variability in mustard productivity upto 70 per cent.

References

Anonymous, 2002, "Statistical abstract of Haryana".

Golder, R. N. and Banerjee, J., 1989, "On lifting of fog at Calcutta airport", *Mausam*, **40**, 2, 230-232.

Goldsworthy, W. J. and Shulman, M. D., 1984, "A statistical evaluation of near ground fog processes", *Agril. Forest Met*., **31**, 59-68.

Saifuzzaman, M. and Meisner, C. A., 1996, "Wheat sterility in Bangladesh : an overview of the problem, research and possible solutions", In Proceeding a workshop on sterility in wheat in sub-tropical Asia: extent, causes and solutions held at ACIAR Canberra on 18-21 September, 104-108.

Yang, C., 1995, "A mini review of the effects of acid precipitation on crops", *Chinese J. Agromet*., **2**, 2, 47-52.

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