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Effect of epidemiological factors on percent disease index of rose powdery mildew caused by *Podosphaera pannosa* (Wallr.) de Bary

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ABSRACT

The effect of epidemiological factors was studies on severity (disease index) of rose powdery mildew in cultivar Lutin during the years 2015 and 2016. The disease was first noticed in 2nd week of April in both the years and the disease index ranged from 6.92 to 48.76 per cent and 4.77 to 47.93 per cent in the year 2015 and 2016. respectively. There was a progressive increase in the disease severity upto 2nd week of June and was recorded maximum at this period during both years of study when the temperature remained 24.6 °C, cumulative rainfall (25.5 mm), mean relative humidity (61.5%) and total sunshine (4.6 hrs). Simple correlation between per cent disease index, temperature was 0.910, cumulative rainfall (-0.545), average relative humidity (0.616) and total sunshine hours (-0.760). While the partial correlation between per cent disease index, temperature was 0.475, cumulative rainfall (-0.872), average relative humidity (0.072) and total sunshine hours (-0.273). However, multiple regression equation indicated powdery mildew severity was dependent upon meteorological factors about 97.2 per cent for the disease development during both years i.e. 2015 and 2016.

***Keywords*:** Correlation, multiple regressions, powdery mildew, rose

Rose (*Rosa hybrid* L.), the top ranking cut flower of today, belongs to the subfamily Rosideae within the family Rosaceae. The beauty, fragrance and multiple uses of roses as cut flowers or landscape plants have made roses an appreciated crop since ancient times (Hummer and Janick, 2009). It cures dry and patchy skin and its herbal tea use has an advantage of treating cold and cough. Rose water and rose vinegar are also prepared from it and are also considered as major flowers for the perfume industry, medicinal and culinary qualities (Gudin, 1999).

Now a days the success of flower trades, both in domestic and international markets, depends upon the quality. But flower grown in open fields are subjected to various biotic and abiotic stresses due to which their quality deteriorates because of blemishes and losses due to insect pests and diseases etc. Both pot plants and cut roses either planted outdoors or in glasshouses are susceptible to many phytopathogens. Among the most serious foliar diseases, it is worth mentioning powdery mildew, downy mildew, black spot, grey mould, leaf spot and rust (Linde and Shishkoff, 2003) causes heavy losses to roses.

The minimum, optimum and maximum temperatures for the rose powdery mildew fungal growth are 3±5°C, 21°C and 33°C, respectively (Longree, 1939). The fungus is believed to perennate as mycelium in buds (Yarwood, 1944; Howden, 1968; Price, 1969 and Price, 1970). On rose leaves, conidial germination is not affected greatly by relative humidity (Rogers, 1959; Pathak and Chorin, 1969) but is reduced signiûcantly by the presence of free water (Sivapalan, 1993). Mycelial growth on leaves is apparently not affected by relative humidity (Rogers, 1959) but is affected by temperature (Price, 1970), as has been conûrmed for apple powdery mildew (Xu and Butt, 1998). Germination of conidia and subsequent colonization can take place in relative humidity as low as 50 per cent (Rogers, 1959; Pathak and Chorin, 1969). Price (1970) however, showed that conidia can withstand long periods at 0°C without loss of viability, provided they are incubated in moist conditions. In spring, mycelium that over wintered in buds formed during the previous season infects newly emerging leaves, resulting in 'primary' mildew. Conidia produced from 'primary' mildew colonies initiate an epidemic of 'secondary' mildew cycles on new host tissues. Within a season, many cycles of inoculums multiplication are possible. Conidia are dispersed in air with a diurnal periodicity (Pady, 1972; Tammen, 1973; Leu and Kao, 1975). An infection can begin whenever an ascospore or conidium lands on a susceptible host, germinates, and forms a germ tube that develops to form a hypha with appressoria, penetration pegs and haustoria. Appressoria are short, lateral hyphal outgrowths or swellings and create penetration pegs to infect host cells (Kunoh *et al.*, 1977; Green *et al.,* 2002). Maximum infection of powdery mildew was observed in the cool and humid months of year. Multiple linear regression analysis indicated that 1°C increase in maximum temperature, disease will be increased by 1.75 per cent and 1°C decrease in minimum

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temperature, disease will be increased by 2.75 per cent. An increase in 1 per cent maximum and minimum RH will give 0.26 and 0.29 per cent increase in disease (Kumar *et al.*, 2010). The present study was carried out to know the effect of meteorological factors on the powdery mildew disease development under Himachal Pradesh natural field conditions and developing the strategies for management of disease by understanding the epidemiological conditions the disease.

MATERIALS AND METHODS

The experiment was conducted at DR. M. R. Thakur, Rose Garden, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP). Data on disease severity were recorded at weekly intervals with the first appearance of disease under field conditions with effect from the end of March to its disappearance in end of June for two consecutive years 2015 and 2016. The data on the weather parameters were obtained from the Meteorological Observatory, Department of Environment Science, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) to find out their effect on disease initiation and subsequent spread. Further, correlation and regression coefficients were also calculated by following the procedures as described by Gomez and Gomez (1984) and regression lines were developed. The per cent disease index of each interval was also calculated. The per cent disease index (PDI) was calculated by using the formula given by McKinney (1923) as follows :

$$\text{Disease index } (\%) = \frac{\text{Sum of all the disease ratings}}{\text{Total number of samples observed} \times \text{Maximum disease grade}} \times 100$$

The data on disease severity was recorded by following a disease rating based on 0-6 scale developed for the estimation of rose powdery mildew by Sahni (1987) with slight modifications.

Numerical rating	Description
0	No symptom of powdery mildew
1	Small scattered specks covering <1% leaf area
2	Small scattered specks covering 2-5% leaf area
3	Small powdery lesions covering about 6-20% of leaf area
4	Powdery lesions enlarging covering 21-40% of leaf area
5	Powdery lesion coalesces to form big patches covering 41-80% of leaf area
6	Powdery patches covering the entire leaf and stem (>80%)

RESULTS AND DISCUSSION

Role of meteorological factors on disease development under field conditions

In order to study the effect of meteorological factors on the progress of disease under field conditions, experiment was conducted at Dr M R Thakur rose garden, Department of Floriculture and Landscaping Architecture, Dr Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) under natural epiphytotic conditions during the years 2015 and 2016. The data on severity of the disease was recorded at weekly intervals commencing from 9th April to 11th June and are presented in the table 1, 2 and 3 (pooled).

The data on weather parameters and disease development revealed that the disease appeared in the 2nd week of April with the prevalence of congenial weather conditions such as 17.7 and 20.4 °C mean temperature; 4.00 and 0.00 mm cumulative rainfall, 55 and 41 per cent mean relative humidity; total sun shine (hrs) 10.6 and 12.6 in 2015 and 2016 crop seasons, respectively. The disease was first noticed in 2nd week of April and the per cent disease index ranged from 6.92 to 48.76 and 4.77 to 47.93 per cent till the 2nd week of June in both the years. There was a progressive increase in the disease severity upto 2nd week of June and was recorded maximum at this period during the years of study as mentioned in the pooled data (Table 3) when the temperature remained 24.6 °C, cumulative rainfall, mean relative humidity, total sunshine (hrs), as 25.5 mm, 61.5 per cent and 4.6 hours, respectively. These results to a greater extent also corroborate the findings of various workers (Longree, 1939; Price, 1970; Horst, 1983; Howard *et al*., 1994; Xu, 1999 and Agrios, 2005) who reported relative humidity as low as 50 per cent and temperature ranges of 20-25°C (22°C optimum) for the spread of powdery mildew disease.

Correlation and regression analysis

Simple, partial and multiple correlations were worked out between per cent disease index (PDI) and meteorological factors (mean temperature, cumulative rainfall, average relative humidity and total sunshine hours) for the years 2015 and 2016.

Simple correlation

Simple correlation coefficients were determined using all the combinations of per cent disease index (PDI) with temperature, relative humidity, rainfall and total sunshine hours, and are presented in table 4. It is evident from the correlation matrix that simple correlation coefficients between PDI and mean temperature was positive (0.901, 0.791) in both the years (2015 and 2016) and non significant. Their pooled correlation coefficient

Table 1: Effect of meteorological factors on powdery mildew disease of rose during 2015

Date of observation	Mean temperature (ºC)	Cumulative rainfall (mm)	Average RH (%)	Total sunshine hours	Disease index (%)
09 April-15April	17.7	4.0	55.0	10.6	6.92
16 April-22April	20.6	31.8	45.0	13.1	9.78
23 April-29April	20.6	0.0	53.0	9.4	20.68
30 April-06 May	21.5	1.7	48.0	5.3	24.66
07 May -13 May	23.6	6.0	56.0	5.4	27.67
14 May -20 May	22.8	8.4	53.0	8.9	30.86
21 May -27 May	25.6	0.0	42.0	6.3	37.87
28 May -03 June	22.8	8.4	53.0	6.9	39.57
04 June -10 June	25.6	0.0	47.0	5.8	45.00
11 June -17 June	24.8	5.0	55.0	4.9	48.76

Table 2: Effect of meteorological factors on powdery mildew disease of rose during 2016

Date of observation	Mean temperature (ºC)	Cumulative rainfall (mm)	Average RH (%)	Total sunshine hours	Disease index (%)
09 April-15April	20.4	0.0	41.0	12.6	4.77
16 April-22April	23.5	1.6	48.0	14.1	15.91
23 April-29April	21.2	1.6	37.0	9.4	21.00
30 April-06 May	23.1	18.8	44.0	6.5	23.18
07 May -13 May	22.3	54.0	58.0	5.7	24.98
14 May -20 May	25.4	24.4	45.0	9.7	38.93
21 May -27 May	24.0	17.8	50.0	7.2	39.55
28 May -03 June	24.3	17.8	51.0	7.8	43.04
04 June -10 June	23.6	55.2	67.0	5.5	45.87
11 June -17 June	24.3	46.0	68.0	4.2	47.93

Table 3: Effect of meteorological factors on powdery mildew disease of rose during 2015-2016 (pooled)

Date of Observation	Mean temperature (ºC)	Cumulative rainfall (mm)	Average RH (%)	Total sunshine hours	Disease index (%)
09 April-15April	19.0	2.0	48.0	11.6	5.85
16 April-22April	22.0	16.7	46.5	13.6	12.85
23 April-29April	20.9	0.8	45.0	9.4	20.84
30 April-06 May	22.3	10.3	46.0	5.9	23.92
07 May -13 May	22.9	30.0	57.0	5.6	26.33
14 May -20 May	24.1	16.4	49.0	9.3	34.90
21 May -27 May	24.8	8.9	46.0	6.8	38.71
28 May -03 June	23.5	13.1	52.0	7.4	41.31
04 June -10 June	24.6	27.6	57.0	5.7	45.44
11 June -17 June	24.6	25.5	61.5	4.6	48.35

Table 4: Simple correlation coefficients between PDI and meteorological factors

Meteorological factors	2015	2016	Pooled data
Mean temperature (°C) x PDI	0.901	0.791	0.910
Cumulative rainfall (mm) x PDI	-0.436	-0.636*	-0.545
Average relative humidity (%) x PDI	0.372	0.479*	0.616
Total sunshine hours (hrs) x PDI	-0.789	-0.713*	-0.760*

*Note: *Significant at 5% level*

Table 5: Partial correlation coefficients between PDI and meteorological factors

Meteorological factors	2015	2016	Pooled data
Mean temperature (°C) x PDI	0.615	0.481	0.475
Cumulative rainfall (mm) x PDI	-0.780	-0.899	-0.872
Average relative humidity (%) x PDI	0.118	0.451	0.172
Total sunshine hours (hrs) x PDI	-0.381	-0.191	-0.273

Table 6: Multiple regression equations and coefficient of determination of disease development based on meteorological factors

Year	Regression equation	R^2
2015	$Y = -96.655 + 5.607X_1 + 0.462X_2 - 0.221X_3 - 2.564X_4$	0.886
2016	$Y = -104.825 + 4.849X_1 + 0.576X_2 - 0.128X_3 - 0.461X_4$	0.885
Pooled	$Y = -193.519 + 7.207X_1 + 1.479X_2 - 0.851X_3 - 0.462X_4$	0.972

Note: Where, Y = Disease index (%); X_1 = Mean temperature (°C); X_2 = Cumulative rainfall (mm); X_3 = Average relative humidity (%) and X_4 = Total sunshine hours (hr)

was also highly positive and non significant. Simple correlation coefficient of PDI with cumulative rainfall was negative (-0.436, -0.636) in both the years (2015 and 2016) and significant during 2016. Simple correlation coefficient of PDI with average relative humidity was positive (0.372, 0479) during years 2015 and 2016 and significant during 2016. Simple correlation coefficients of PDI and sunshine hours were negative (-0.789, -0.713) in both years and significant in 2016 and their pooled correlation coefficient was negative (-0.760) and significant. The minimum, optimum and maximum temperatures for the fungal growth are 3±5°C, 21°C and 33°C, respectively (Longree, 1939). On rose leaves, conidial germination is not affected greatly by relative humidity (Rogers, 1959; Pathak and Chorin, 1969) but was reduced significantly by the presence of free water (Sivapalan, 1993). Mycelial growth on leaves was apparently not affected by relative humidity (Rogers, 1959) but is affected by temperature (Price, 1970), as has been confirmed for apple powdery mildew (Xu and Butt, 1998). Germination of conidia and subsequent colonization can take place in relative humidity as low as 50 per cent (Rogers, 1959; Pathak and Chorin, 1969). Similar results were found by the Gupta *et al.* (2004) in respect of powdery mildew in rose. They reported that the simple correlation coefficient between the per cent disease index (PDI) and average relative humidity was highly significant (0.873) and positive showing thereby consistent effect of relative humidity on disease development. However, correlation coefficients between disease severity and temperature (-0.737) and light (-0.623) were found to be significant and negative.

Partial correlation

Partial correlation coefficients were worked out using all the combinations of PDI with mean temperature, cumulative rainfall, average relative humidity and total sunshine hours, and are presented in table 5. During 2015 and 2016, the partial correlation between PDI and mean temperature was positive and negative (0.615, 0.481), respectively and non significant. The partial correlation between PDI and the cumulative rainfall was negative (-0.780, -0.899) during the both years but non-significant. Partial correlation between PDI and total sunshine hours was negative (-0.381, -0.191) during the both years (2015, 2016) but non-significant. Partial correlation coefficient between per cent disease index (PDI) and average relative humidity (0.743) was significant and positive (Gupta *et al.*, 2004). Pathania (2015) reported the negative partial correlation between severity and temperature, humidity and sunshine however cumulative rainfall was found positive while studying the powdery mildew of bhindi. Partial correlation in mango powdery mildew studied by the Kaur (2015) found the positive correlation between severity and rainfall, relative humidity and sunshine hours while negative with temperature.

Multiple regression

The multiple coefficient of determination (R^2) was calculated to measure the contribution of linear function of independent variables, such as mean temperature (T), cumulative rainfall (CF), Average relative humidity (RH) and total sunshine hours (SH) on dependent variable i.e. PDI and is presented in table- 6.

The coefficient of determination (Table 6) between PDI and group of independent variables was found to be 0.886 and 0.885 which indicated that the powdery mildew severity was dependent upon mean temperature, cumulative rainfall, average relative humidity and total sunshine hours collectively upto 88.8 per cent and 88.5 per cent during the both years of investigations, respectively. Rest of the variation was due to unexplained (error variation) factors or on the factors not included in the investigations. Therefore, it could be concluded that the meteorological factors taken under the present study contributed up to the extent of 97.2 per cent in development of powdery mildew in the field when pooled data of two years were considered for the study of multiple correlation.

Moreover, partial correlations and regression equation between disease severity and environmental factors have further elaborated the role of mean temperature for the disease development. These results corroborate the findings of Yarwood (1957) who attributed higher incidence of powdery mildews to be due to low temperature ranges (18-28°C). Coefficient of determination between disease severity and environmental factors contribute about 80.34 per cent change in the results was due to environmental factors (Gupta *et al.*, 2004) investigated under control conditions. In powdery mildew of mango, the coefficient of determination between disease severity and environmental factors contribute about 95.5 per cent effect (Kaur, 2015). Similarly, Pathania (2015) reported the contribution of environmental factors in development of powdery mildew of bhindi upto the extent of 84.88 per cent.

From the meteorological parameters like average temperature between 19.0 to 24.6°C, cumulative rainfall (2 to 30.0 mm), average relative humidity (46.0 to 61.5%) and total sunshine hours

(4.6 to 11.6 hours) were proved to be critical parameters for the development of rose powdery mildew. Meteorological factors contributed upto 97.20 per cent in powdery mildew development.

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