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Prevalence and Epidemiology of Apple Powdery Mildew in Northwest Himalayan Region of Himachal Pradesh

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Abstract

A survey was conducted to assess the incidence and severity of powdery mildew of apples during April to July of 2020 and 2021 at the different locations of Kinnaur district, Himachal Pradesh, India. Assessment scale of Hofer et al. (2019) with slight modification was used for cultivar screening. Apple seedlings were grown in the pots in the polyhouse of the Department of Plant Pathology in order to test the pathogenicity of *Podosphaera leucotricha*. Pathogenicity was confirmed through inoculation tests by gently pressing diseased leaves on young leaves of five asymptomatic, potted one-year-old Gale Gala seedlings of apple. Five non-inoculated plants were used for a control treatment**.** Overall, twenty different apple cultivars were screened against powdery mildew planted under field conditions at Krishi Vigyan Kendra Sharbo, Kinnaur, Himachal Pradesh, India. Out of these cultivars, five cultivars viz. Red Delicious, Royal Delicious, Red Velox, Auvil Early Fuji and Oregon Spur II, were found to be less susceptible to *Podosphaera leucotricha,* causing powdery mildew of apples, while Granny Smith, Golden Delicious, and Gale Gala were found extremely susceptible. Gala series of cultivars were found to be extremely susceptible to the pathogen. Incidence of the disease ranged from 25.42% to 53.80% and severity from 39.75% to 66.25%, respectively. According to the present study the disease initiated during the first week of May and peaked in the month of July in district Kinnaur. Temperatures between 18–24°C and RH between 50–65% were found to be favourable for the disease development. The conditions in the region were found to favourable for disease development and spread.

Keywords: Apple, powdery mildew, disease incidence, epidemiology, pathogenicity

1. Introduction

The most significant and lucrative temperate fruit crops produced in India's North Western Himalayan region is the apple (*Malus×domestica* Borkh.). India's apple orchards are always in danger from a wide range of fungal infections (Singh et al., 2016). Early disease detection is necessary for the appropriate and timely deployment of disease management. Apple scab, powdery mildew, Alternaria leaf spot, Marssonina leaf spot, cankers, root rot, collar rot, and mosaic are the most prevalent diseases that affect apples. Disease has always been one of the main reasons for the decline of apple quality and yield, which directly harms the development of agricultural economy. Therefore, precise diagnosis of apple diseases and correct decision making are important measures to reduce agricultural losses and promote economic growth. The effects of disease infection can range from unpleasant cosmetic appearance, low marketability, and poor fruit quality to decreased production or entire loss of fruit or trees, resulting in enormous economic losses. For effective and timely deployment of disease and pest management strategies, early pest and disease detection is necessary (Delagado et al., 2017; Nazarov et al., 2020). Temperate fruits are of family *Rosaceae* which include Pome and stone fruits like apples, pear, quince, peaqch, plum apricots cherry etc. Their consumption reduces the attack of cardiovascular and cancer diseases (Abrol, 2015). Apple, a global table fruit, is high in lipids, carbohydrates, calcium, phosphorus, and iron (Boyer and Liu, 2004). The plant is cultivated worldwide, especially in New Zealand, Asia, USA, and Europe and southern parts of America and Africa. It is the fourth among globally produced fruits in the world after Oranges, Banana and grapes. In India it is grown in Jammu and Kashmir, Himachal Pradesh and Hills

of Uttrakhand (Muneer et al., 2017).

In H.P. total area under Horticulture (2018–19) is 232139 ha. Apple is grown on an area of 113154 mha with a production of 368603 mt according to the Department of Horticulture, Shimla (Anonymous, 2019). Area under apple cultivation in India has increased tremendously from 241.8 thousand ha in 2001–02 to 306.0 thousand ha in 2017-18. Total area under Apple cultivation in India (2019-20) is 308 thousand ha and production is 2734000 t (Anonymous, 2019). Himachal Pradesh plays an important part in the apple production. According to the Agriculture and Processed Food Products Export Development Authority (APEDA), Himachal Pradesh is also known as the "Fruit Bowl of The Nation".

Modern high density apple orchards are more susceptible to diseases. Often misdiagnosis and repeated faulty spray result in building of resistant pathogen population (Nabi et al., 2017; Sutton et al., 2014; Thapa et al., 2020) Apple powdery mildew, which infects apple trees worldwide (Biggs et al., 2009), is caused by *Podosphaera leucotricha* (Ell. and Ev.) (Grove et al., 2003; Holb, 2009). Powdery mildew disease is one of the most important diseases of Apple, causing severe economic loss to farmers. Powdery mildew can be found in all the world's major apple-growing regions, but is alarming in semiarid areas and in nursery conditions. Apple powdery mildew can easily develop under the congenial weather conditions of apple-producing areas (Jones and Aldwinckle, 1990; Biggs et al., 2009).

The disease can result in fruit russeting, losses of tree growth as well as yield. Moreover, the fungus may survive for many years in a plant material. This makes it so difficult to control (Yoder, 2000). Because of the long-lasting problem of apple powdery mildew, more efforts are required regarding the cultivar susceptibility (Biggs et al., 2009). Keeping these views, the survey was conducted to study the susceptibility of different apple cultivars against the powdery mildew disease.

2. Materials and Methods

The study was done in Department of Plant Pathology, College of Horticulture, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan, India (H.P) and RHR&TS, Sharbo, Kinnaur (31.5365° N, 78.2761° E) while the field trials were laid out in the fields of RHR&TS, Sharbo, Kinnaur Himachal Pradesh.

2.2. Disease incidence and severity

In order to record the incidence and severity of powdery mildew; surveys were conducted between April to August (2020–21) and the disease incidence was calculated by the formula given by Lahlali et al. (2020) as under:

P=D/T, where D=total number of diseased plants, and T=total number of plants

To record disease severity, 25 plants were selected at random and percent disease severity was scored as percentage plant leaf area affected with powdery mildew, evaluated visually on individual leaflets as the percentage of infected area, using a 0 to 4 scale as per Kim et al., 2004. Rating given to leaves during disease severity, 0= Disease free no symptoms, 1=1 to 5% diseased, 2=5.1 to 20% diseased, 3=20.1 to 40% diseased and 4=40.1 to 100% diseased. The disease severity (%) was calculated as under (McKinney, 1923):

Disease severity=Infected area of sample plants/Total area of a sample plant*100

The symptoms were photographed and specimens were brought to the laboratory for further analysis.

2.3. Cultivar screening

Twenty different apple cultivars growing at Krishi Vigyan Kendra (KVK), Sharbo, district Kinnaur, HP were screened against powdery mildew**.** The KVK lies between 31.05°-32.5°North latitude and 77.45°-79.10° East longitudes. Assessment scale of Hofer et al. (2019) with slight modification was used for cultivar screening is as given under.

Scale for mildew: No infection=No visible macroscopic symptoms, Low susceptibility (LS)=Up to 25% of leaves covered with infection, medium susceptibility (MS)=50% leaves covered with infection, High susceptibility (HS)=75% leaves covered with infection and Extreme susceptibility (ES)=100% leaves covered with infection.

2.4. Pathogenicity

In order to test the pathogenicity of *Podosphaera leucotricha*, apple seedlings were grown in the pots (10 cm diameter) in the polyhouse of the Department of Plant Pathology. Pathogenicity was confirmed through inoculation tests by gently pressing diseased leaves on young leaves of five asymptomatic, potted one-year-old Gale Gala seedlings of apple. Five non-inoculated plants were used for a control treatment**.** The surface was first sterilized with 70% ethanol and then thoroughly washed with sterilized distilled water. After inoculation the plants were lightly sprayed with sterilized distilled water to provide humidity for the germination of conidia. The plants were regularly monitored for symptom appearance. Days after dusting till the first symptom appearance were noted and the conidia were microscopically analyzed. The plants were photographed and diseased leaves were detached and preserved in paper bags in the refrigerator at 5+1°C.

2.5. Role of epidemiological parameters on powdery mildew of apple

Sunshine hours, cumulative rainfall, relative humidity, and temperatures were recorded from April to August in the meteorological observatory established at RHR&TS, Sharbo, Kinnaur, H.P. for the 2020 and 2021 growing season to ascertain the role of various epidemiological parameters on the development and spread of powdery mildews of apple. Daily observations on epidemiological parameters were expressed as a mean value for the time between the two

data recording dates, and the data on disease severity was recorded every 7 days. Statistical analytic approaches were used to find simple, partial, and multiple correlations utilizing meteorological data on weekly temperature, average relative humidity, cumulative rainfall, and sunshine hours (Gomez and Gomez, 1984).

3. Results and Discussion

The data presented in Table 1 revealed the presence of disease in all the areas surveyed and incidence varied from 25.42% to 53.80% while the severity varied from 39.75% to 66.25% in district Kinnaur. The data showed that out of two blocks surveyed, Nichar block recorded the highest incidence of 40.99%. However, Pangi village in Kalpa block recorded the highest incidence of 53.80% followed by Chagaon (49.36%) and Sungra (47.44%) villages of Nichar block. In case of disease severity, it was seen that Pangi village had highest severity (66.25%) of powdery mildew closely followed by Chagaon (64.75%) and village Kothi (63.94%) which were statistically at par. Overall high disease severity of 58.34% was recorded in Kalpa Block which was statistically at par with Nichar block with 53.99% severity.

Table 1: Incidence and severity of powdery mildew in apples under field conditions in District Kinnaur

Location/ Villages	Disease incidence (%)	Disease severity (%)
Kalpa block		
Kalpa	36.26(37.78^{c}	62.00(55.91)^{a}
Roghi	29.64(35.13)^{d}	40.49(43.46)^{d}
Pangi	53.80(51.15)^{a}	66.25(59.56)^{a}
Telangi	38.79(39.42)^{c}	59.12(53.37)^{b}
Kothi	38.71(39.17)^{c}	63.94(56.61)^{a}
Mean	39.44(40.53)	58.34(53.78)
Nichar Block		
Nichar	35.08(41.23)^{cd}	56.00(60.91)^{b}
Sungra	47.44(49.91)^{ab}	57.24(62.35)^{b}
Chagaon	49.36(54.26)^{a}	64.75(60.27^{a}
Meeru	47.68(52.21)^{b}	52.25(54.57)^{c}
Bari	25.42(36.79)^{d}	39.75(47.21)^{d}
Mean	40.99(46.88)	53.99(57.06)
Overall mean	40.22(43.71)	56.17(55.42)
CD (p=0.05)	4.56	5.1

3.1. Cultivar screening

The data presented in Table 2 and 3 clearly showed that all the cultivars and pollinizers displayed varied degrees of susceptibility towards the disease.

Although all the cultivars were found to be susceptible, Red Delicious, Royal Delicious, Red Velox, Auveli Early Fuji and Oregon spur II showed low susceptibility towards Powdery mildew disease. Most of the cultivars were moderately susceptible to the disease. Granny smith and Gale Gala pollinizers were extremely susceptible to the powdery mildew infection whereas Redlum Gala was found to be highly susceptible (Table 3). All the delicious group pollinizers were found to be high and extremely susceptible to disease.

Table 2: Screening of apple cultivars against powdery mildew under field conditions of district Kinnaur

Sl. No.	Cultivars	Disease reactions	Disease severity (%)
1.	Rich-a-Red	MS	56.46
2.	Starkrimson Delicious	MS	74.65
3.	Vance Delicious	MS	54.66
4.	Jeromine	MS	72.43
5.	Super Chief	MS	56.89
6.	Red Cap Valted	MS	59.78
7.	Scarlet Spur II	MS	76.22
8.	Top Red	MS	55.78
9.	Red Delicious	LS	19.72
10.	Royal Delicious	LS	21.76
11.	Red Velox	LS	23.56
12.	Oregon Spur II	LS	21.78
13.	Auvil Early Fuji	LS	24.98

ES: Extreme susceptibility; HS: High susceptibility; MS: Moderate susceptibility; LS: Low susceptibility

Table 3: Screening of pollinizer varieties against powdery mildew under field conditions of district Kinnaur

Sl. No.	Cultivars	Disease reactions	Disease severity (%)
1.	Gale gala	ES	92.56
2.	Granny smith	ES	88.02
3.	Golden delicious	ES	77.58
4.	Golden spur delicious	HS	76.44
5.	Redlum gala	HS	88.90
6.	Golden autumn	HS	80.02
7.	Red gold	MS	62.40

ES: Extreme susceptibility; HS: High susceptibility; MS: Moderate susceptibility; LS: Low susceptibility

3.2. Pathogenicity

It was observed that the symptom development occurred 12 days after inoculation. Small, whitish felt-like patches of fungal growth appeared (Figure 1) and quickly covered the entire leaf. Diseased leaves became narrow, crinkled, stunted and brittle. Similar results were observed by Kaspers (1967) and Chauhan (2005) while working on powdery mildew of apples.

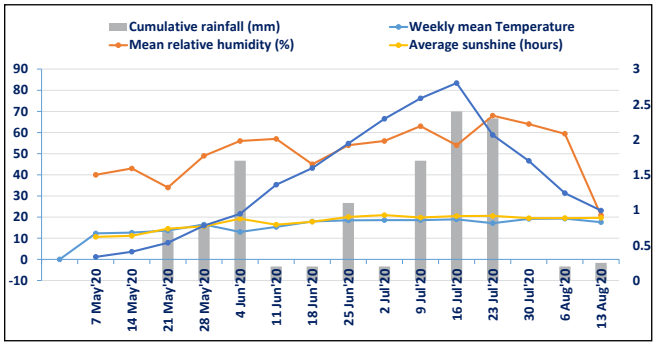

Figure 1: Weather parameters during the study period, 2020

3.3. Effect of epidemiological parameters on powdery mildew of apples

The data (Figure 1 and 2) on meteorological factors and disease development studies revealed that the disease first appeared in first and second week of May in 2020 and 2021 with maximum temperatures at 12.30 and 17.71˚C, relative humidity at 40.00 and 13.84%, cumulative rainfall up to the extent of zero and 0.21 mm and weekly sunshine hours between 10.66 and 11.66 hrs during May 2020 and 2021, respectively. The temperatures varied from 12.30°C to 27.81°C in 2020 and 2021. Similarly mean Relative humidity varied from 13.0 to 68% in both years. Highest rainfall of 2.40 mm was observed in the month of July whereas average sunshine varied from 10.66 to 20.74 hrs in both years. However, highest disease severity (83.41%) was recorded in the month of July 2020 followed by 76.18% in the same month in the year 2020. Similarly, highest disease severity (76.86%) was recorded in the month of July in 2021.

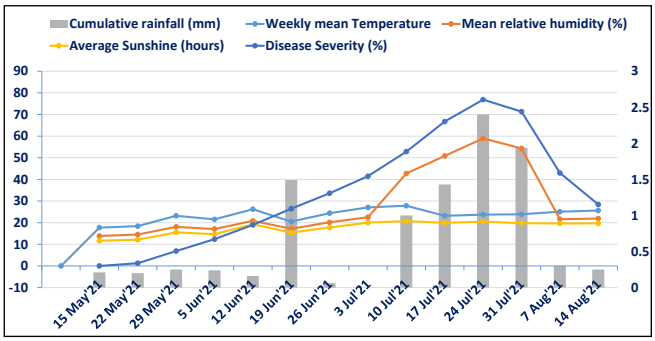

Figure 2: Weather parameters during the study period, 2021

Very low severity was recorded in the month of May during both years. The data presented in Tables 3 clearly show that mean temperature between 18–24°C and Relative humidity levels between 50–60% were favourable for disease development. The present study clearly indicated that relative humidity and temperature played a significant role and offered congenial atmospheric condition for the maximum development of powdery mildew of apple in dry temperate agro- climatic conditions of district Kinnaur. The present study also suggested that powdery mildew disease severity and development in apple orchards of Kinnaur can be determined through weather factors. The present results can be used for better decision making well in advance to check the incidence and disease development in accordance with the weather. The present findings are corroborated by the works done by Gupta and Sharma (2009), Gupta and Sharma (2005) and Bana et al. (2020).

3.4. Correlation of disease severity with meteorological factors

The information on weather parameters and disease development revealed that the disease appeared in the first and second week of May 2020–21. The disease assumed serious proportions in July. The progress of the disease is dependent on weather parameters such as mean maximum temperature, relative humidity and cumulative rainfall. Therefore, simple, partial and multiple correlations were worked out to establish relative contribution of these dependent variables on disease severity and spread.

The data presented in Table 4 revealed that the value of simple correlation coefficient between disease severity and relative humidity (0.673) was highly significant and positive indicating consistent effect of relative humidity on disease severity. However the increase in relative humidity levels above 60 percent was found to be unfavourable for the disease development. The results are in conformity with the work done by Gupta and Sharma (2009). Similarly, correlation coefficient between mean air temperature and disease severity was found significant and negative (-0.544). Temperature between 18–25°C was found to be optimum for the disease development. The temperature above 25°C had a deleterious effect on the disease development. The effect of rainfall was found to be non-significant and positive (0.431). Temperature and humidity were considered as an important factor for appearance and development of powdery mildew diseases. The results to a greater extent corroborate the findings of various workers (Monlar, 1971; Grushin, 1988; Gupta and Sharma, 2009; Tang et al., 2017) who reported high disease development under humidity conditions ranging from 20 to 65%. Data further indicated that partial correlation between disease severity and relative humidity (0.662) was highly significant and positive whereas with temperature and rainfall it was positive but not significant.

Table 4: Simple and partial correlation coefficient between disease severity and weather parameters

Meteorological factors	Disease severity	
	Simple correlation	Partial correlation
Temperature	-0.544	0.412
RH	0.673	0.662*
Cumulative rainfall	0.431	0.459

*Significant at p<0.05% level of significance

Stepwise multiple regression analysis was performed using the following equation:

y =bo+b1×1+b2×2+b3×3+bnxn

Where, Y_1=Disease severity (%), X_1=Mean temperature (˚C), X_2= Mean relative humidity (%), X_3=Cumulative rainfall (mm)

Statistical analytic approaches were used to find simple, partial, and multiple correlations utilizing meteorological data on weekly temperature, average relative humidity, cumulative rainfall, and sunshine hours (Gomez and Gomez, 1984). The multiple correlation coefficient (Table 5) between disease severity and group of independent variables *viz*., Relative humidity, temperature and cumulative rainfall, was found to be 0.693, which indicated that 69.30% change in disease severity could be attributed to the cumulative effect of these independent variables, whereas, the rest of the variation was due to unexplained factors like wind speed, cloud cover and error variations and those factors were not included in the study. It was reported by various workers that at 10–25°C (optimum 20–22°C) and relative humidity ranged between 70 to 100%. Germination of conidia of powdery mildew was slow at temperatures below 4–10°C and above 28–30°C (Covey, 1969, Hickey and Yoder, 1990, Holb, 2013). The present study is in concurrence with the work done by various workers (Gupta and Sharma, 2009, Tang et al., 2017) who reported that temperature between 18–25°C and relative humidity between 50–70% favoured the disease development but high rainfall and temperatures above 25°C were deterrent to the disease development.

Table 5: Multiple correlation and regression equation between disease severity and weather parameters

Sl. No.	Regression equation	F-value	Standard error	R^2
1	- 279.80+0.314 x1*+- 0.146X2*+4.3076x3	7.290	15.98	Y_1=0.693

N: 10; *p=0.05

4. Conclusion

Powdery mildew of apple caused by *Podosphaera leucotricha* posed a serious threat of Kinnaur district of Himachal Pradesh. The disease severity ranged from 39.75% to 66.25%. The pollinizers and Gala series of cultivars found to be more susceptible to this disease. Granny Smith, Golden Delicio uss and Gale Gala pollinizers were extremely susceptible to the powdery mildew infection in district Kinnaur. Temperatures between 18–24°C and RH between 50–65% were favourable for the disease development.

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