Journal of Agrometeorology

ISSN : 0972-1665 (print), 2583-2980 (online)
Vol. No. 25 (4) : 610-612(December - 2023)
https://doi.org/10.54386/jam.v25i4.2063
https://journal.agrimetassociation.org/index.php/jam

Short Communication

Effect of weather parameters on the growth and development of downy mildew of grape caused by *Plasmopara viticola*

M. P. KHATAL*[1], T. K. NARUTE[1], R. B. SONAWANE[2] and V. K. BHALERAO[3]

[1]*Department of Plant Pathology and Agricultural Microbiology, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India*
[2]*Onion and Grape Research Station, Pimpalgaon Baswant (Mahatma Phule Krishi Vidyapeeth), Nashik, Maharashtra, India*
[3]*All India Co-ordinated Research Project on Grape, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India*
**Corresponding author email: mahadevkhatal123@gmail.com*

Grapes (*Vitis vinifera* L.) are a pleasant fruit that are high in carbohydrates and vitamins, particularly vitamin C. It is abundant in glucose, protein, vitamins, amino acids, lecithin, and minerals, as well as flavonoids, which act as antioxidants, neutralise free radicals, and slow the ageing process (Choudhary *et al*., 2014). Grapes are grown in India under two distinct climatic conditions: (i) the sub-tropical climatic conditions of the north, where winter temperatures rarely reach the freezing point and vines go dormant in the winter, and (ii) the tropical climatic conditions of the peninsular India, where winters are mild and vines do not go dormant and remain evergreen all year. During their growth and fruiting phases, grapes like a hot, dry atmosphere. It thrives in climates with a wide range of temperatures. It is best to live in an area where annual rainfall does not exceed 900 mm and is evenly spread throughout the year. Grapes can be grown on sandy loams, sandy clay loams, red sandy soils, shallow to medium black soils, and red loams, among other soil types. The soil should be well drained and have a high-water holding capacity, however soils with a pH range of 6.5-8.0 are optimal.

In India, the grape is grown an area of 150 thousand hectares with production of 3181 thousand ton and a productivity of 21.21-ton ha^{-1}. It is grown on 105.50 thousand hectares in Maharashtra, with a yield of 2286.44 thousand ton and a productivity of 21.67-ton ha^{-1} (Anonymous, 2019). Nashik is the leading district in area and production of grape in Maharashtra which having an area of 58.37 thousand ha and production of 16897.59 thousand tons having productivity of 25.00 ton.

During poor climatic conditions, the pathogen can live in many forms, and the development and progression of disease varies by region. The downy mildew disease's progression is influenced by environmental factors. Temperature, humidity, rainfall, sunshine, wind speed, and the number of wet days are the most important environmental variables because they affect the pathogen, host, or host pathogen interaction during pathogenesis. Weather variables have been established in numerous host pathogen systems for disease development. However, nothing is known about the impact of this environmental element on the development of grape downy mildew. As a result, research into the relationship between climatic conditions and illness severity, which determine disease propagation in time and space, is critical. Downy mildew is one of the most harmful diseases to grapevines in India's wine-growing regions. During damp and warm weather, the disease affects flower buds, young shoots, leaves, and berries. If rainfall happens throughout the early growth to fruit set stages of the fruiting season, crop losses can range from 30% to 100%. Infections on clusters can arise even if there is no rain because dew forms at night (Sawant and Sawant, 2010).

Field studies were carried out at Onion and Grape Research Station Pimpalgaon Baswant, Nashik to access the downy mildew disease severity after October pruning of both years 2020 and 2021. The observations were scored on 0 to 4 scale where 0 = Nil; 1=Trace to 25 per cent leaf area infected; 2= 26 to 50 leaf area infected; 3= 51 to 75 leaf area infected and 4 = More than 75 leaf area infected (Horsfall and Barrate, 1945), at weekly intervals and expressed as per cent disease index (PDI) using Wheeler's formula (1969);

$$\text{Per cent disease index (PDI)} = \frac{\text{Sum of all numerical rating}}{\text{Number of leaves examined x Maximum grade}} \times 100$$

Article info - DOI: *https://doi.org/10.54386/jam.v25i4.2063*
Received: 9 January 2023; Accepted: 25 October 2023; Published online : 30 November, 2023

Table 1: Development of downy mildew disease of grape (Cumulative and periodical increment in PDI) with correlation coefficient (Pooled data of 2020-21 and 2021-22.)

Month	Standard week no.	Max. temp (^{0}C)	Min. temp. (^{0}C)	RH-I (%)	RH-II (%)	Rainfall (mm)	No. of rainy days	Sunshine (h)	Wind velocity (km/h)	Evapora-tion (mm)	Disease severity (%)
Oct.	40	30	22.1	91.1	69.5	49.1	3	3.6	4.4	2.7	0.00
	41	30.5	22.4	88.3	66.0	20.4	2	2.0	2.9	3.0	0.00
	42	30.7	21.6	84.9	63.3	69.4	4	5.1	3.7	4.0	24.33
	43	30.8	19.5	91.7	68.5	5.0	1	8.2	1.9	5.1	57.08
	44	30.7	16.7	87.5	54.0	0.0	0.0	7.9	1.1	5.3	60.66
Nov.	45	30.1	13.6	87.0	55.0	0.0	0.0	8.2	1.5	5.2	65.25
	46	30.3	15.3	83.5	47.5	0.0	0.0	8.0	2.0	5.3	61.65
	47	30.1	17.3	88.0	60.0	3.4	0	7.0	1.7	3.8	58.50
	48	28.6	15.8	84.0	50.0	40.2	0.5	6.1	3.3	3.9	56.00
Dec.	49	28.5	13.4	85.5	52.0	6.0	0.5	7.2	2.1	3.2	52.16
	50	26.9	15.1	87.5	46.5	0.0	0.0	7.3	2.1	3.3	50.50
	51	27.2	25.7	87.0	43.0	0.0	0.0	7.8	1.9	3.9	47.50
	52	28	29.1	84.0	44.5	0.0	0.0	7.8	2.3	3.2	46.96
Jan.	1	27.9	13.7	83.0	50.5	0.0	0.0	5.8	2.8	3.2	43.83
	2	27.6	12.9	84.5	51.5	0.0	0.0	7.3	2.5	1.9	41.83
	3	28.7	11.6	86.0	49.0	0.0	0.0	8.7	2.1	3.5	38.58
	4	27.3	8.0	83.0	42.5	0.0	0.0	8.9	2.8	3.5	35.25
Feb.	5	29	7.4	81.5	34.0	0.0	0.0	9.0	2.0	4.1	34.25
	6	29.1	7.4	81.5	37.0	0.0	0.0	8.5	1.7	3.4	31.67
	7	29.4	9.5	83.0	42.5	0.0	0.0	9.0	2.0	3.4	28.83
	8	30.6	11.4	84.0	34.5	0.0	0.0	9.1	2.3	4.1	24.66
March	9	33.6	11.3	83.6	28.0	0.0	0.0	8.7	1.0	4.5	22.75
	10	32.8	11.5	88.8	42.4	0.0	0.0	8.7	1.4	5.0	19.00
	11	32.3	12.5	84.8	40.4	0.0	0.0	9.0	1.9	5.0	15.50
Correlation coefficient (r)		0.014	0.484*	0.485*	0.664**	0.278	0.184	-0.323	-0.019	0.415	-

Significant level at 5 per cent = **0.423** and Significant level at 1 per cent = **0.537**

The weather parameters *viz*. maximum temperature (T_{max}), minimum temperature (T_{min}), mean temperature, morning relative humidity (RH I), evening relative humidity (RH II), average rainfall, rainy days, Sunshine, wind velocity and evaporation were recorded daily and weekly average values collected from metrological observatory of Onion and Grape Research Station, Pimaplgaon (Baswant).The mean of weather parameters were considered for correlating of downy mildew disease intensity.

Correlation analysis was carried out by following the standard statistical method. An attempt was made to study the effect of weather factor in relation to disease incidence by subjecting the data to regression analysis. The weather parameter was correlated to per cent disease index taken at seven days interval by calculating the correlation coefficient (r). The goodness of fit of multiple regression models was evaluated by the correlation coefficient (r) as suggested by Cornell and Berger (1987).

The pooled data presented in Table 1 revealed that, disease development and spread was observed from 42nd SMW to 11th SMW and maximum per cent disease index was recorded during 45th SMW. During first 30 days after October pruning, downy mildew development and spread was recorded maximum and reached relative humidity – I (85-91%), average maximum temperature (30^{0}C) and rainfall. Similar results reported by Ghosh *et. al.,* (2015) and revealed that the correlation between various meteorological parameter and increase in downy mildew in cucumber revealed that the high humidity (RH more than 94%) and average temperature (24-30^{0}C) along with leaf wetness not less than 8 hours was reported to trigger the development of downy mildew and positive correlation between increasing downy mildew intensity and temperature and relative humidity. Atri and Singh 2019 reported that maximum temperature (32.8^{0}C to 36.9^{0}C), minimum temperature (17.2^{0}C to 27.8^{0}C) and relative humidity more than 73 per cent are crucial weather factors for disease development of downy mildew in pearl millet.

Correlation analysis of pooled data (After October pruning 2020-21 and 2021-22) revealed that, minimum temperature and morning relative humidity- RH I had positive significant with correlation coefficient 0.484 and 0.485 respectively. The evening relative humidity- RH II had positive highly significant with correlation coefficient 0.664. However, sunshine hours and wind velocity had negatively and non-significant with correlation coefficient -0.323 and -0.019 respectively. The maximum temperature, evaporation, rainfall and number of rainy days had positive non-significant with correlation coefficient is 0.014, 0.415, 0.278 and 0.184 respectively (Table 1). Similar results in respect of weather parameter and downy mildew disease severity were reported by Daunde *et al.,* (2017) reported downy mildew of cucumber caused by *P. cubensis* studied the rate of disease increase was dependent on weather factors, weather-based forewarning system enable to guide farmers to take protection measures timely. The correlation of their study revealed that cucumber downy mildew disease intensity showed significantly negative correlations with minimum temperature (-0.721) and wind velocity (-0.690). Further the best fit linear regression equation, intensity of downy mildew decreased with rise in Min temperature (-4.163) and evaporation (0.882). Co-efficient of determination R^2 value (0.63) represented 63 per cent influence on the intensity of downy mildew by two independent variables *viz*., minimum temperature and evaporation. Atri and Singh (2019) reported that correlation of their study revealed that pearl millet downy mildew disease intensity showed significantly negative correlations with maximum temperature (r= -0.665*), minimum temperature (r = -0.776**), wind speed (r = -0.898**), and rainfall (r = -0.625**) and non-significant negative correlation with morning relative humidity (r = -0.523) with downy mildew incidence.

The regression analysis revealed that minimum temperature, relative humidity-II, number of rainy days, and evaporation rate were positively correlated with the disease, while maximum temperature, relative humidity-I, Rainfall, Sunshine and wind velocity were negatively correlated with disease severity with R2 value of 0.94. Among the meteorological factors' minimum temperature, relative humidity-I, relative humidity-II and rainfall plays an important role in development of downy mildew disease of grape. The farmers are adviced to take up preventive or protective measures with recommended label claim fungicides. While spraying of fungicides, farmers should take consideration of PHI, label claim of fungicides and recommended dose of fungicides and stage of grape orchard for avoiding the residue detection for export of grapes.

ACKNOWLEDGMENT

The authors are thankful to the Dean, Faculty of Agriculture, MPKV., Rahuri and the Director of Research MPKV, Rahuri for providing field facilities for grape orchards and weather station facilities at MPKV., Rahuri.

***Conflict of interest*:** Authors declare that there is no conflict of interest with this work.

***Authors contribution*: KMP**: Execution of the experiment, data collection and interpretation, **NTK**: Conceptualizing, technical program and interpretation, **SRB**: Execution of the experiment, data collection and interpretation, writing, **BVK**: Designing the experiment, writing and editing the manuscript.

***Data availability*:** The data supporting the findings of this study are available from the corresponding author upon reasonable request. Access to the data is subject to approval by the institutional review board and compliance with data use agreements.

***An ethical approval**:* This article does not contain any studies with human participants or animals performed by any of the authors.

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