

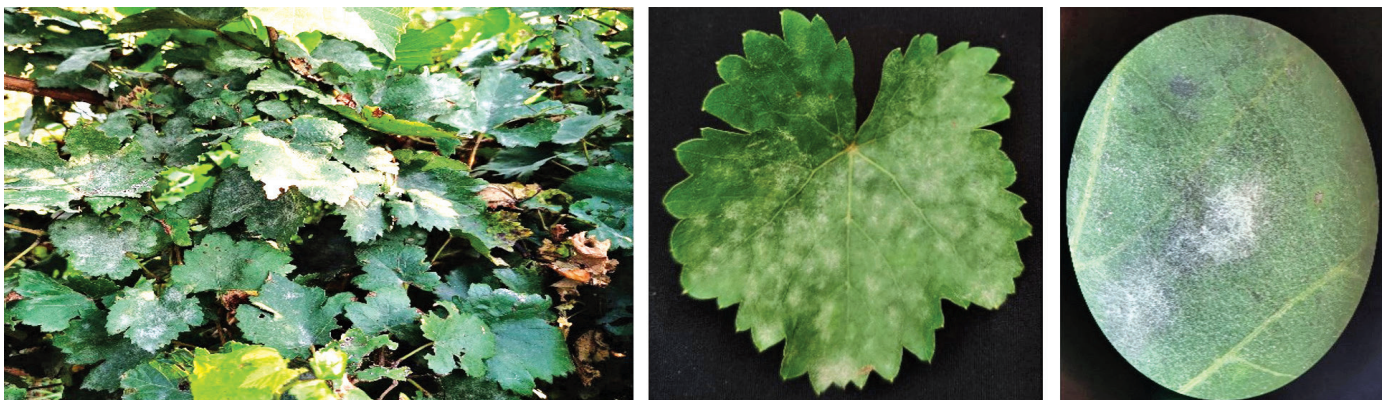
Integrated and eco-friendly management of powdery mildew disease in commercial viticulture

Grapevine is one of the major fruit crops grown worldwide. In India, the major grape-growing states are Maharashtra, Karnataka, Tamil Nadu, and Mizoram. The production of grapes is limited due to several pests and diseases infestations among which powdery mildew is the second most important endemic disease, causing huge economic losses, i.e., upto 40% reduction in yield every year. At present, its management is largely dependent upon the use of chemical fungicides. The best alternative strategy is by using eco-friendly management practices to reduce crop loss and disease severity. The integrated disease management (IDM) modules are the other safe options that need to be popularized amongst growers for producing residue-free grapes that would fetch higher market price and also boost the export.

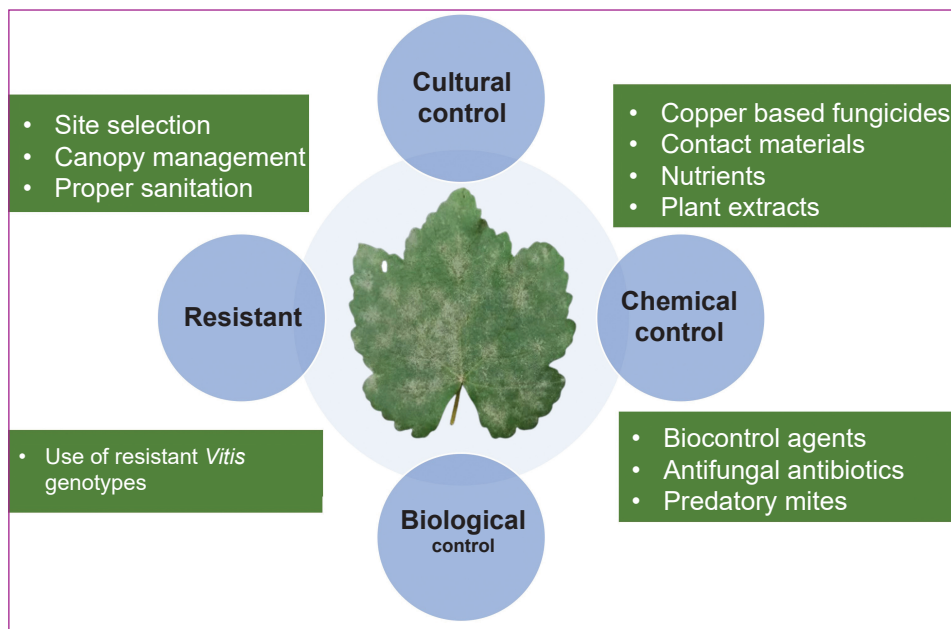
THE grapevine is one of the world's most cultivated horticultural crops worldwide. The origin of the cultivated grape (*V. vinifera*) is southern Caucasia, now occupied by northern Iraq, north-west Turkey, Azerbaijan and Georgia. The grape is used for making many value-added products ranging from juice, wine, raisins and preserves. Grape is one of the major cash crops in India and is also exported. However, several diseases like powdery mildew, downy mildew, anthracnose etc. attack grapevines and cause severe loss in yield, and berry quality and thus deplete the economy. Commercial viticulture is practiced in over 1,43,000 ha area spread in three distinct agro-climatic regions, i.e., tropical, sub-tropical and temperate. Accordingly, we are suggesting different safe alternatives to produce residue-free grapes in these regions so that they are fit for local consumption and also boost the exports from these regions owing to

the distinct harvest seasons.

The pathogen causing powdery mildew, i.e. *Erysiphe necator* Schw. is an obligate biotrophic fungus on members of Vitaceae, including *Vitis*, *Cissus*, *Parthenocissus* and *Ampelopsis*. The European grape - *V. vinifera*, which is highly susceptible to powdery mildew, is the major disease occurring worldwide. All green tissues of the grapevine are infected. It causes curling and senescence of leaves, inhibition of bud sprouting and berry cracking, which results in high economic loss. Powdery mildew leads to reduction in yield up to 40%. Inflorescences and berries are most susceptible at early stages and can become completely coated with whitish-cottony growth. Worldwide, an average of 35% of all pesticides produced are used in viticulture. In India, a total of 1,814 MT of pesticides were used on fruit crop production during 2020-2021, of which major was only on grapes. The current



Powdery mildew infection on whole vine, leaf and macro-view on leaf surface



Integrated management of powdery mildew disease in grape

management practices are using repeated heavy-dose applications of chemical fungicides that develop pathogen resistance, besides environmental contamination and cause adverse effects on humans and the environment. Therefore, the optimization of the usage of pesticides in grape cultivation is of utmost importance. The best alternative to a chemical control strategy includes using eco-friendly management practices to reduce the disease severity caused by powdery mildew. Therefore, alternative practices like organic or biocontrol agents besides IDM strategies is widely recommended.

Integrated Disease Management Strategies

The safe components, i.e. cultural practices, biological control, botanicals, and safe chemicals used at different stages of grapevine growth are essential for achieving complete powdery mildew management. By implementing IDM strategies, grape growers can minimize the disease intensity, optimize yield and also improve the berry quality.

Resistance varieties and rootstocks: Choose resistant grape scion varieties for planting whenever possible based on the prevailing agro-climatic conditions, i.e. tropical, sub-tropical or temperate. Resistant varieties having inherent resistance can thus reduce the chances or intensity of fungal infection thereby minimizing plant

application of protection chemicals. The use of rootstocks like Dog Ridge, 110 R and 1103P have shown minimal powdery mildew intensity.

Management of PM in tropical conditions

This region covers Nashik, Sangli, Solapur, Pune, Satara, Latur and Osmanabad districts of Maharashtra; Hyderabad, Rangareddy, Mehbubnagar and Medak districts of Telangana; Anantapur and Chittoor districts of Andhra Pradesh; Bijapur, Bagalkot, Belgaum, Gulbarga and Bengaluru districts of Karnataka; Krishnagiri, Theni, Dharmapuri, Madurai, Dindigul, Tirunelveli and Coimbatore districts of Tamil Nadu; Mandsour and Ratlam

districts of Madhya Pradesh. These areas are the major viticulture region in the country accounting for 90% of the total area under grapes in the country. Vines do not undergo dormancy and double pruning and a single harvest is the general practice. The major cultivation problems in this region are diseases like powdery mildew, downy mildew and anthracnose, hailstorms, extreme drought *etc.*

After April Pruning (April to October)

- Spray wettable sulphur 2.0 g/L or potassium bicarbonate 5.0 g/L when PM is noticed during the last week of May. Sulphur is not recommended in high temperatures ranging from 35-40°C as it leads to phyto-toxicity.
- Another spray of wettable sulphur (2.0 g/L) or Dinocap (0.25 ml/L) or potassium bicarbonate (10.0 g/L) is recommended when the weather is dry and without rains (more than 2 mm) or when cloudy weather prevails for 3 to 5 days during June to August.
- The foliar application of the potassium and phosphate fertilizer Top-KP + (1-50-33 NPK) reduced disease incidence on leaves and the developing bunches by 15–65% and severity by 75–90%. The simple compound Top KP+, which contains potassium (K)

Table 1. Response of different *Vitis vinifera* genotypes to powdery mildew infection

Response	Variety(ies)		
	Sub-tropical	Tropical	Temperate
Resistant	Pusa Navrang, Chardonnay, Merlot	Bangalore Blue, Gulabi, Sharad Seedless, Kali Sahebi, Kishmish Beli, Tas-A-Ganesh, Manjari Medika, Crimson Seedless	Rangspay, Sholtu Red, Sholtu White
Moderately resistant	Beauty Seedless, Banqui Abyad, Pusa Urvashi, Cardinal, Bharat Early, MACS Punjab Purple	Manjari Naveen, Bhokri, Anab-e-Shahi, Red Globe	Hussaini Sahebi, Himrod, Gulabi
Moderately susceptible	Pearl-of-Csaba, Fakhri, Cabernet Sauvignon	Flame Seedless, Thompson Seedless	Abshari



Healthy vineyard after forward pruning

and phosphorus (P), or Top KP+ combined with ready mixtures of micronutrients [zinc (Zn), boron (B), copper (Cu), iron (Fe), manganese (Mn) and molybdenum (Mo)] are highly effective in controlling powdery mildew on grapevines by inhibiting conidial germination causing mildew.

- Application of microbial-agent(s)/ microbial consortia based fungicides/ fungistatic agents containing beneficial bacteria or fungi to vines before pruning as a preventive measure against powdery mildew. These products induce protective barriers against fungal pathogens. Milastin K @ 1 ml/L, a formulation containing *Bacillus subtilis* (KTBS) gives effective control powdery mildew on leaves and bunches in grapevines and thus sustain the yield and maintain the acceptable berry quality. Further, *B. subtilis* is not affected by other fungicide sprays.
- Use of bioagents is particularly beneficial as they are safe and do not give pesticide residues. Microbe-based technologies, such as Eco-pesticide® (2.75×10^8 /mL), Bio-Pulse® (*T. asperellum*: 2.25×10^7 /g, and *B. amyloliquefaciens*: 2.50×10^8 /g), and Bio-Care 24® (3.50×10^8 /mL) developed at ICAR-NBAIM, Uttar Pradesh, has emerged as the promising biopesticides for managing powdery mildew at all stage of grapevine growth, which can be further maintained by cooperatively combining with liquid sulphur spray under severe infections.

After Forward Pruning (October to April)

- Removing and destroying the infected foliage and pruned vines during October to prevent the spread of disease to healthy vines during the vegetative and bearing stage.
- Spraying of wettable sulphur (2.0 g/L) is highly recommended at this stage (80% canopy volume) with power sprayers.
- A broad-spectrum antifungal antibiotic called Aureofungin-sol™ has been very beneficial. It is an improved formulation containing 46.15% aureofungin technical and 53.85% solubilizing agent that controls PM even at a lower dose (0.1 g/L).
- The petroleum-derived spray oils such as JMS Stylet-oil (97.1% paraffin oil) can also be applied, i.e., as wash spraying, sole fungicide treatment or in combination with other contact molecules for minimizing powdery mildew disease.
- In organic farms, cow-based products like milk and whey are also used as potential organic replacements for synthetic fungicides and sulphur to control powdery mildew. Application of milk or whey solutions during early phase growth periods reduce disease pressure or work as preventive treatments before actual symptoms appear. This spray is applied at regular intervals as the disease stage or weather conditions.
- A spray of *Bacillus subtilis* (strain DR-39) at 2.5 g/L ($> 10^8$ cfu/g) is recommended on bunches at about 20 days before harvest to reduce the residues.

Tropical Regions	Subtropical Regions
Before Backward pruning (April): Soil application of <i>Trichoderma</i> @ 2.0 L or kg/acre	Before pruning (December): Soil application of <i>Trichoderma</i> @ 2.0 L or kg/acre
May: Spray wettable sulfur (2.0 g/L) or potassium bicarbonate (5.0 g/L)	After winter pruning (January): Neem oil (10 ml/L) or Bordeaux mixture (1%) foliar spray
June to August: Another spray of wettable sulfur (2.0 g/L) or Dinocap (0.25 ml/L) or potassium bicarbonate (10.0 g/L)	Cane maturity & FBD (Feb-March): Sprays of <i>Trichoderma</i> & <i>Bacillus amyloliquefaciens</i> (2.0 g/L)
September to October: Bioagents sprays of Eco-pesticide, Bio-Pulse and Bio-Care 24 under severe disease conditions	April: Copper fungicide or Copper oxychloride or Bavistin or Ridomil Gold @ 2.0 g/L
After Forward pruning: Spraying of wettable sulphur (2.0 g/L) or Aureofungin-sol™ (0.1 g/L) or potassium sulphate (2-3 g/L) at timely intervals whenever disease symptoms are observed	May: Sprays of Bordeaux mixture or CoC is recommended
30 days before harvest: Grape spray oil 5.0 to 7.0 ml/L or Tricure® (5.0 ml/L) or <i>Bacillus subtilis</i> @ 2.5 g/L	Pre-harvest (last week of May): Spray neem oil (10 ml/L) or potassium bicarbonate (4.0 g/L)
10 days before harvest: Spray of Chitosan (2.0 ml/L) in combination with <i>Ampelomyces quisqualis</i> (5.0 g/L)	

IPM strategies for managing powdery mildew disease in vineyards

Before Harvest

- Spray of HP Grape spray oil 5 to 7 ml/L or Tricure® (Azadirachtin 0.03%) 5 ml/L at 30 days before harvesting if any visible symptoms are noted.
- ICAR-NRC for Grapes, Pune has promoted bio-intensive management package for powdery mildew of grapes using Chitosan (2 ml/L) in combination with *Ampelomyces quisqualis* (5 g/L) to produce residue-compliant quality grapes.

Management of PM in Sub-tropical regions

This region covers Delhi, Meerut and Muzaffarnagar districts of Uttar Pradesh; Hisar, Sirsa and Jind districts of Haryana; Bhatinda, Ferozepur, Amritsar, Gurdaspur and Ludhiana districts of Punjab; Kota, Udaipur, Hanumangarh and Bharatpur of Rajasthan; Purulia & Bankura districts in West Bengal; Raipur in Chhattisgarh; Champhai district of Mizoram; Dimapur district of Nagaland; and Imphal district of Manipur. The occurrence

Table 2. General practices for minimizing the incidence of powdery mildew disease in grape

Particular	Suggestions
Site selection	Select cultivation sites with good air-circulation and adequate sunlight penetration in canopy to minimize high humidity accumulation.
Vineyard sanitation	Regularly remove old fallen leaves and vine biomass to reduce the potential inoculum sources.
Canopy management	Follow proper pruning intensity to provide better aeration and light penetration for quality bunch development.
Biological control	Soil application of 0.05% <i>Trichoderma asperelloides</i> (strain 5R) and <i>B. amyloliquefaciens</i> (strain TL-171).
Botanicals	Spray Tagatose (0.5 to 5.0%), <i>Reynoutria sachalinensis</i> (5%) or neem oil (1%) on leaves and developing bunches.
Irrigation management	Adopt drip irrigation over overhead sprinkler irrigation to avoid relative humidity build-up.
Nutrition management	Spray of potassium (monopotassium phosphate/ potassium nitrate/ potassium sulphate @ 2-3 g/L) to overcome its deficiency and minimize disease intensity.
Physical & Mechanical Control	Sulphur spray (2.0 g/L) as a prophylactic fungicide.
Safe chemical control	Use of copper-oxychloride, carbendazim @ 2 g/L
Bio-pesticides	Foliar spray of <i>Trichoderma afroharzianum</i> (NAIMCCF-01938 strain) and <i>Bacillus amyloliquefaciens</i> (TL-171 strain) @ 0.2 g/L.
Bio-agents	Release of mycophagous mite <i>Orthotydes lambi</i> (10-20 mites/ leaf).
Bio-fungicide	Aureofungin-Sol (0.1 g/L) at a lower dose is very effective as systemic fungicide.
Monitoring & Forecasting	Register and follow ICT-based DSS like ICAR-NRCG-SKAI PM Expert software for timely guidance and effective management.

of pre-monsoon showers provides conducive conditions for the occurrence of powdery mildew, thereby causing large-scale berry cracking, rotting and defacing of berries. An integrated strategy, which farmers can adopt to either escape or efficiently manage the powdery mildew disease. Sub-tropical grape offers advantage over tropical grape cultivation in terms of off-season harvesting (May to June). In this region, pruning is done at the end of December-January when the vines are dormant. The early maturing cultivars like Perlette, Beauty Seedless, Pusa Urvashi, Pusa Navrang, Pusa Aditi, Flame Seedless *etc.* are cultivated, which escapes the pre-monsoon shower damage. To minimise the effect of powdery mildew and to maintain the quality of the crop, following strategies should be adopted.

- Spray of 1.5 *a.i.* Hydrogen cyanamide (Dormax, Dorbreak) immediately after pruning to hasten uniform and early bud break. This treatment leads to about 15-day early maturity of the crop too. Thiourea 2% can also be applied, which gives about a week earliness.
- Application of natural plant extracts such as neem oil (10 ml/L) or Bordeaux mixture (5:5:50 L, 1%) as foliar spray after winter pruning to protect the vines from natural infection by PM due to erratic or late winter rains/ cloudy weather.
- One prophylactic spray of copper fungicide or copper oxychloride (COC) or Bavistin or Ridomil Gold @ 2 g/L in April, *i.e.* after berry set.
- In case of fluctuating or cloudy weather conditions, another spray of Bordeaux mixture or COC in May as a prophylactic spray to minimise the occurrence of PM disease affecting berry quality and bunch maturity due to pre-monsoon shower.
- Another spray of any of the above-mentioned fungicides is recommended after monsoon rains, *i.e.* after harvest so that the foliar and stem portions are maintained healthy without heavy infection.
- Alternative to chemical fungicides, the sulphur tolerant

strains of *Trichoderma afroharzianum* (NAIMCCF-01938 strain) and *Bacillus amyloliquefaciens* (TL-171 strain) @ 0.2 g/L are recommended as spray for effective management of powdery mildew at cane maturity and flower bud differentiation phase under sub-tropical conditions.

Management of PM in temperate regions

This region covers Kangra, Una and Solan districts of Himachal Pradesh; Pulwama, Baramulla, Udhampur, Kathua & Kupwara districts of Jammu and Kashmir; Nainital, Dehradun, Haridwar & Udham Singh Nagar districts of Uttarakhand. For managing powdery mildew, the management strategies under sub-tropical region are suggested to be followed. The only difference is that the crop maturity is late and accordingly needs to be monitored.

SUMMARY

Grapevine powdery mildew is one of the most important fungal diseases in commercial viticulture worldwide. Despite the frequent application of fungicides, powdery mildew is often poorly managed primarily due to fluctuating weather conditions. Different IDM strategies/modules suggested above can be adopted by the grape growers, which would increase production and fetch higher returns due to safe production and also reduce the cost of plant protection chemicals. Eco-friendly management practices like canopy management, cultural practices, use of resistant genotypes, biocontrol agents, nutrients, plant extracts/ botanicals, contact materials, predatory mites and bioremediation can effectively be used to produce pesticide-free bunches for consumption.

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Vertical expansion of nursery under protected conditions using soilless rooting medium

An efficient technology for multiplication of clonal rootstock (M-9, MM-106, MM-111, P-22, B-9, M-27) of apple under greenhouse conditions was standardized. The technique involves wounding/incision on branches with diameter of 5 mm at 30 cm above ground level using sharp knife/blade to remove the bark followed by application of 2,500 ppm IBA as rooting hormone. The treatment starts from the second week of June till the last week of August. Small polybags (filled with rooting medium) are fastened at the points where rooting needs to be initiated. A lightweight substrate (cocopeat) having high moisture holding capacity is used as rooting medium. Staking is accomplished with the help of bamboo poles to hold the bags in a proper position and to keep the plants straight. This technology is very useful in promoting the vertical expansion of the nursery in greenhouse conditions and the multiplication of number of plants per unit area has increased by three to four times with minimum utilization of extra inputs and area. One more additional benefit of this technology is that under the greenhouse conditions, the rootstocks attain sufficient girth (> 6 mm) and all the plants are suitable for budding. The technology not only produced the additional 3-4 rootstocks but also the budded plants which have added advantage to this technology.



Source: ICAR Annual Report 2022-23