



Lettuce Downy Mildew in Hawai'i

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In 2016, lettuce (*Lactuca sativa* L.) ranked as the eleventh most valuable crop in Hawai'i, with a production value in excess of \$9.2 million. Farmers grow and market fresh lettuce each week to grocery stores and local markets and to restaurants in urban and resort settings. In addition, many home gardeners cultivate lettuce crops continually throughout the year in Hawai'i. These lettuce crops are grown outdoors or hydroponically under shade or plastic covers. Regardless of the farming method, the crops are subject to damage and economic losses caused by insect pests and plant diseases.

Globally important epidemics of downy mildew afflict lettuce crops grown in cool, wet locations. Such regions in Hawai'i tend to be associated with upper elevations, such as Waimea and Volcano (Island of Hawai'i) and Kula (Maui). Within these areas, the downy mildew epidemics tend to become most severe during the cool and rainy winter months of the year.

In this article we discuss downy mildew of lettuce, its pathogen, the disease occurrence, and the typical symptoms and disease diagnosis. We also describe a set of integrated management practices designed to mitigate losses due to downy mildew.



Figure 1. A young lettuce plant growing in a plug tray in a nursery already infected by downy mildew.

Pathogen

Bremia lactucae Regel, Bot. Ztg.: 666 (1843), the causal agent of downy mildew of lettuce, is an oomycete, one of a group of fungus-like organisms also known as “water molds.” Although the fungus can infect some plant genera and other species related to lettuce, the pathogen strains tend to infect only a narrow range of hosts. This pathogen’s DNA can mutate readily, resulting in new races capable of overcoming the downy mildew resistance in lettuce varieties. Furthermore, these mutant strains of the pathogen can develop resistance to some

important fungicides. Research has not yet been done on the pathogen strains and variability among pathogen isolates in Hawai'i.

Hosts

The hosts of *B. lactucae* include lettuce (*Lactuca sativa* L.) and some other related plant genera and species.

Environment

The environment most conducive to downy mildew epidemics on lettuce in Hawai'i is cool and wet weather, with high relative humidity (> 88% RH) and air temperatures around 55°F (13°C).

Infection and Symptoms

Lettuce plants are susceptible to infection at all ages and stages of plant development. Symptoms appear first on older, outer leaves as angular, light green or yellow spots that tend to be delimited by leaf veins. The leaf spots often have a white, powdery mass of pathogen conidiophores and conidia on the undersides of infected leaves (Figure 1), especially during periods of high relative humidity. The lesions quickly turn brown to black in two or three days as the infected tissues die (Figure 2), leading to the destruction of entire leaves. Plants may be stunted and unmarketable. Downy mildew can kill young seedlings.

Disease Cycle and Epidemiology

Dispersal and inoculation: Spores are spread from conidiophores or sporangia by wind and splashing rain or irrigation water and are deposited on susceptible leaves.

Infection: Conidia (asexual spores) germinate on leaves during periods when water droplets (from dew, fog, rain, or irrigation) persist on leaves for at least 5 hours. After germinating, they penetrate directly through epidermal cells. Oospores, produced sexually within infected leaves, may germinate to produce zoosporangia to initiate additional cycles of infection. Zoosporangia release zoospores, which encyst, germinate, and infect through epidermal cells of the leaf.

Survival: The pathogen survives on lettuce plant debris in soils and on infected weedy hosts.

Integrated Disease Management Recommendations for Downy Mildew of Lettuce

Downy mildew on lettuce can be managed using a combination of cultural and chemical approaches.

- **Crop rotation:** Do not plant lettuce continually at the same location. At the very least, rotate crops among different lettuce varieties if possible.
- **Polycropping:** Grow non-susceptible hosts between beds of lettuce
- Plant **downy mildew-resistant cultivars** (Table 1). This is one of the most effective ways to manage this disease.
- **Fungicides:** See Table 2 for acceptable fungicides. When weather conditions are conducive to the downy mildew disease, begin fungicidal spray applications early in crop development and continue at 7- to 14-day intervals, depending on



Figure 2. Lower leaves of romaine lettuce damaged by downy mildew.

conditions (shorter intervals when disease pressure is high). It is important to obtain good spray coverage. Use a good-quality surfactant. Follow label rates and avoid over-diluting the spray mixture. Manage the risk of resistance selection by adopting a spray program that alternates between fungicides from different mode-of-action groups. Alternate after every two applications unless fungicide label specifies alternating after one application—always read and follow the label.

- **Sanitation:** Remove symptomatic leaves; sterilize soils or growing media by steam if reused between crops as crop debris bearing the pathogen can fall and lodge in soils
- Spatial **separation** of sequential plantings is recommended, but this is often not possible in commercial operations.
- Use **drip or subsurface irrigation** to minimize the duration of leaf wetness and relative humidity.
- Grow lettuce under **cover** in cool regions prone to disease outbreaks, such as Waimea on the Big Island.
- Identify and **destroy weed hosts** of *Bremia lactucae* near or at the lettuce-growing location.
- **Scout** crops regularly for symptoms and initiate management promptly. Do not allow epidemics to progress unabated.
- Promptly **destroy any remaining crop** after harvest has been completed.

Table 1. Lettuce varieties resistant to downy mildew

Green	S	Red Leaf	S	Boston	S
'Aerostar' (Romaine)	OP	'Annapolis' (Romaine)	H	'Gondar'	OP
'Arroyo' (Romaine)	FM	'Antonet' (Lolla)	H	'Raider'	H
'Auvona' (Romaine)	H	'Blade' (Oakleaf)	OP	'Butterhead'	S
'Bambi' (Bibb)	H	'Breen' (Romaine)	OP	'Adriana'	H
'Bellezia' (wild arugula)	H	'Buckley' (One-cut Oakleaf)	OP	'Alkindus' (red)	H
'Bergam's Green' (Batavian)	OP	'Calshot' (Red-Romaine)	H	'Australe'	OP
'Black Seeded Simpson' (Heirloom)	HG	'Cantarix' (Red-Oakleaf)	H	'Avicenna'	OP
'Bolsachica' (Oakleaf)	OP	'Cegolaine' (Bibb)	H	'Butterhead' Blend	H
'Capulin' (Batavian)	H	'Cherokee' (Batavian)	H	'Chicama'	H
'Celinet'	H	'Dark Lolla Rossa'	OP	'Harmony'	H
'Defender' (Romaine)	OP	'Five Star Mix'	H	'Kweik'	OP
'Dragoon' (Romaine)	H	'Fossey' (Lolla Rossa)	H	'Mirlo'	OP
'Encino' (Oakleaf)	OP	'Galactic'	OP	'Newham' (Bibb)	OP
'Ezrilla' (one-cut Tango)	OP	'Galatea RZ'	H	'Optima'	OP
'Fenberg' (Romaine)	H	'Garrison' (Oakleaf)	H	'Pirat' (Heirloom)	H
Foundation Collection (Salanova)	H	'Hyper Red Rumble Waved'	H	'Red Cross' (red)	H
'Gaviota' (Oakleaf)	OP	'Jeanine' (Batavian)	H	'Rex'	H
'Green Butter' (Salanova)	H	'Lovelock' (Batavian)	OP	'Rhapsody'	H
'Green Incised' (Salanova)	H	'Magenta' (Batavian)	OP	'Roxy' (red)	OP
'Green Oakleaf' (Salanova)	OP	'Merlot'	OP	'Skyphos' (red)	P
'Green Star'	OP	'Merlox Red Oak'	H	'Sylvesta' (Bibb)	H
'Green Sweet Crisp' (Salanova)	H	'Mottistone' (Batavian)	H		
'Hampton' (One-cut Oakleaf)	OP	'New Red Fire'	FM	Specifics: H = Hybrid OP = Open Pollinated FM = Fresh Market HG = Home Garden	
'Holon' (Romaine)	H	'Oscarde' (Oakleaf)	OP		
'Ilema' (Lollo)	H	'Pomegrante Crunch' (Romaine)	OP		
'Jericho' (Romaine)	OP	Premier Collection (Salanova)	H		
'Lettony'	OP	'Red Butter' (Salanova)	H		
'Livigna' (Lollo)	H	'Red Deer Tongue'	H		
'Loma' (French crisp)	OP	'Red Incised' (Salanova)	H		
Mini Romaine Blend	H	'Red Oakleaf' (Salanova)	OP		
'Muir' (Batavian)	H	'Red Rosie' (Romaine)	H		
'Nevada' (Batavian)	OP	'Red Sweet Crisp' (Salanova)	H		
'Newham' (Romaine)	H	'Rhazes' (Romaine)	OP		

Table 1. Lettuce varieties resistant to downy mildew, cont'd.

Green	S	Red Leaf	S	Boston	S
'Panisse' (Oakleaf)	H	'Rosaine'	H		
'Plato II' (Romaine)	H	'Rouxai' (Oakleaf)	H		
'Ragol RZ' (Romaine)	H	'Ruby Sky'	H		
'Salvius' (Romaine)	H	'Sierra' (Batavian)	FM		
'Sparx' (Romaine)	H	'Spock' (Romaine)	OP		
'Spretnak' (Romaine)	OP	'Spritzer' (Oakleaf)	H		
'Starfighter' (Green-leaf)	H	'Tamarindo' (Red-romaine)	H		
'Stryker' (Romaine)	H	'Thurinus' (Romaine)	H		
'Sulu' (Oakleaf)	OP	'Truchas' (Romaine)	OP		
'Super Jericho' (Romaine)	H				
'Valmaine' (Romaine)	OP				

Source of information: <http://vegetablemdonline.ppath.cornell.edu/Tables/TableList.htm>

Lettuce Varieties

CTAHR has several publications on lettuce farming and lettuce varieties (examples: "Lettuce for the Home Garden," <https://www.ctahr.hawaii.edu/oc/freepubs/pdf/hgv-2.pdf>, and "Lettuce Production Guidelines for Hawai'i," <https://www.ctahr.hawaii.edu/oc/freepubs/pdf/res-164.pdf>). But we do not have current resistance information for these older varieties. Therefore, we advise that the reader refer to Table 1 for disease-resistant lettuce varieties.

References

- Hawaii Annual Statistics Bulletin (2016). United States Department of Agriculture National Agricultural Statistics Service Hawaii Field Office Cooperating with Hawaii State Department of Agriculture.
- Sakuoka, R., R.T. Hamasaki, R. Shimabuku, and A. Arakaki. 2000. Lettuce for the Home Garden. <https://www.ctahr.hawaii.edu/oc/freepubs/pdf/hgv-2.pdf>

Pesticide label searches were conducted using the National Pesticide Information Retrieval System (NPIRS)

State Public website at Purdue University and the Hawaii Department of Agriculture Pesticides Branch.

Disclaimer

The pesticide label is a legal document; therefore, before purchasing a pesticide, you should carefully read the label to determine if the product suits your needs and if it is legal for use. Not all products with the same active ingredient are registered for use in the same crops.

Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the University of Hawai'i and does not imply its approval to the exclusion of other products that may also be suitable or that may inadvertently not have been listed.

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Table 2. Fungicides registered in Hawai'i for management of downy mildew of lettuce

Product Name (Active ingredient)	Mode-of-Action Subgroup(s)	Amount per Acre/ Restrictions	PHI (Days)
Ridomil Gold® SL (mefenoxam)	4	0.125–0.25 pints	7
Azure™ Agricultural Fungicide (azoxystrobin)	11	12.0–15.5 fluid ounces Do not exceed 92.3 fluid ounces of this product per acre per season. Do not exceed the equivalent of 1.5 pounds a.i. per acre per season from any azoxystrobin-containing products.	0
Heritage® Fungicide (azoxystrobin)	11	No more than one application of Heritage Fungicide or other Group 11 fungicides before alternation with a fungicide that is not in Group 11	0
Reason® 500 SC Fungicide (fenamidone)	11	5.5–8.2 fluid ounces Do not apply more than 24.6 fluid ounces of Reason 500 SC Fungicide per growing season. No more than one application of Reason 500 SC Fungicide before alternating with a fungicide from a different resistance-management group.	2
Quadris® Flowable Fungicide (azoxystrobin)	11	12.0–15.5 fluid ounces Do not apply more than 92.3 fluid ounces of product per acre per season Do not apply more than 1.5 pounds a.i. per acre per season of azoxystrobin-containing products.	0
DuPont™ Tanos® (famoxadone/cymoxanil)	11/27	8–10 ounces	1
OSO™ 5%SC Fungicide (polyoxin D zinc salt)	19	3.75–13 fluid ounces No more than 6 applications at max. rate	0
Actigard® 50WG (acibenzolar-S-methyl)	21	0.75–1 ounces No more than 4 applications per crop.	
Ranman® (cyazofamid)	21	2.75 fluid ounces No more than 3 consecutive applications No more than 6 applications per crop	0
Previcur® Flex (propamocarb hydrochloride, carbamate monohydrochloride)	28	2.0 pints No more than 8.0 pints per season	2
Aliette® WDG Fungicide (aluminum tris)	33	2.0–5.0 pounds Do not exceed seven applications per season	3
Fosphite® (phosphorous acid)	33	1–3 quarts	0
Forum® (dimethomorph)	40	6 fluid ounces No more than 3 applications per season (18 fluid oz)	0

Table 2. Fungicides registered in Hawai'i for management of downy mildew of lettuce, cont'd.

Product Name (Active ingredient)	Mode-of-Action Subgroup(s)	Amount per Acre/ Restrictions	PHI (Days)
Micora™ Fungicide (mandipropamid)	40	5.5–8.0 fluid ounces Apply no more than two applications per crop Always apply Micora with an effective non-Group 40 fungicide labeled for downy mildew control Do not apply consecutive applications containing Micora. Alternate applications containing Micora with an application of an effective non-Group 40 fungicide labeled for this use.	
Orondis® Ultra (oxathiapiprolin, mandipropamid)	U15, 40	5.5–8.0 fluid ounces Maximum annual rate 32.0 fluid ounces per acre per year	1
Revus® Fungicide (mandipropamid)	40	8.0 fluid ounces Do not apply more than 32 fluid ounces of product per acre per season	1
Zampro® Fungicide (ametoctrandin, dimethomorph)	45/40	14 fluid ounces Maximum of 42 fluid ounces per year No more than 2 sequential applications	0
Serenade® Max (QST 713 strain of <i>Bacillus subtilis</i>)	F6	1–3 pounds/acre	0
Serenade® ASO (QST 713 strain of <i>Bacillus subtilis</i>)	F6	2–6 quarts/acre	0
Sonata® (<i>Bacillus pumilus</i> strain QST 2808)		2–4 quarts/acre	0
Copper-based fungicides Various brands	M1	Labeled rates	0
Carb-O-Nator™ (potassium bicarbonate)	NC	2.5–5.0 pounds per 100 gallons of water	0
MilStop® Broad Spectrum Foliar Fungicide (potassium bicarbonate)	NC	Field: 2.0–5.0 pounds per acre Greenhouse: 1.25–5.0 lbs. per 100 gallons of water.	0
MilStop® SP (potassium bicarbonate)	NC	Field: 2.0–5.0 pounds per acre Greenhouse: 1.25–5.0 pounds per 100 gallons of water	0
Rendition® Bactericide/Fungicide (hydrogen peroxide, peroxyacetic acid)	NC	Curative: 3 pints per 100 gallons of water Preventive: 1 pint per 100 gallons of water	0

Subgroup numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action. Fungicides with a different group number are suitable to alternate in a resistance-management program. Preharvest interval (PHI) is the number of days from treatment to harvest.