Agronomic Spotlight

Seminis grow forward

Spinach Downy Mildew

- Downy mildew is the most destructive disease of spinach worldwide, with yield losses of up to 100% when severe.
- The development of downy mildew on spinach is favored by cool, wet conditions.
- Strategies for managing spinach downy mildew include the use of resistant varieties, cultural practices, and foliar fungicides.

Downy mildew of spinach occurs worldwide and is considered to be the most destructive disease of spinach in many production areas.[1,2] The disease causes substantial reductions in yield and quality of spinach, and yield losses of up to 100% have been reported.[3] Even low levels of downy mildew can result in the rejection of spinach lots.[4]

An increase in the rate of emergence of new races of the downy mildew pathogen began in the mid-2000s, and these new races have made it more difficult to manage the disease by using downy mildew resistant varieties.[4] The disease has also become more prevalent with the use of high tunnels for spinach production.[5]

Symptoms

Figure 1. Foliar symptoms of spinach downy mildew: (A) irregular, chlorotic lesions form on the upper surface of the leaves, and (B) blue to purple, downy growth develops on the undersides of leaves.

Symptoms of downy mildew usually develop seven to ten days after infection. However, there can be a longer latent period between infection and symptom expression.[1,6] The initial symptoms are dull, yellow, irregular shaped spots on the upper sides of leaves and cotyledons (Figure 1a). Lesions can develop on leaves of any age, and the lesions become bright yellow over time. Blue to purple, downy growth forms on the undersides of leaves (Figure 1b). This growth consists of the spores and spore-forming structures of the pathogen. The lesions enlarge and eventually become tan in color and dry. Severely infected leaves may become curled and distorted, and multiple infections can lead to a blighting of the leaves. Heavily infected plants may be stunted and eventually die.

Latent infections can result in the development of symptoms on leaves after harvest, once the product is packed in bags or cartons.[2,5,6,7]

Cycle and Conditions

There are no known alternate hosts for the pathogen that causes spinach downy mildew. The pathogen most likely overwinters on infested spinach debris and volunteer spinach plants.[1,6,7] The pathogen produces two kinds of spores, asexually produced spores (sporangia) and sexually produced spores (oospores). The sporangia are the spores that form on the undersides of leaves. They are dispersed by wind and splashing water, and they can travel long distances in air currents. The sporangia land on spinach leaves, where they germinate and infect, resulting in new lesions.[1] Spore formation, dispersal, and infection are favored by cool, wet conditions. Optimal temperatures for infection are between 59° and 70°F, but disease can develop over a wide range of temperatures (sub-freezing to 118°F).[6] Infection is favored by the presence of water on leaf surfaces, but leaves do not need to be wet for infection to occur if humidity levels are high. Heavy canopies associated with dense plantings result in humid environments that promote infection and sporulation by the pathogen.[2,7] In the Salinas and Imperial Valleys of California as well as the the desert region near Yuma, Arizona where overlapping crops of spinach are grown from February through November, downy mildew spores have been detected in spore traps throughout the entire growing season, and they may be present at some level year-round.[4]

Oospores form after the fusion of two compatible mating-type strains of the downy mildew pathogen. Sexual reproduction results in genetic recombination and increased genetic variation, including the formation of new races of the pathogen. Oospores have been found in leaf tissue and roots of infected plants, and the oospores in plant tissue and the soil are viable and able to germinate. Oospores have also been found in seed, but seedborne disease is unverified and the role of oospores in the disease cycle is not yet known.[1]

Disease Management

Resistant spinach varieties were first developed in the 1950s and 60s, and resistance has been a primary strategy for

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managing spinach downy mildew ever since. Most of the spinach varieties grown in California and Arizona are hybrids that have some form of resistance against downy mildew.[1] The spinach downy mildew pathogen forms new races that are able to overcome disease resistance. Currently, 17 different races of the pathogen have been identified. Host resistance to races 1 and 2, developed in the 1950s and 60s, were once thought to be conveyed by single, dominant genes, but the resistance to race 1 was later found to be conveyed by two closely linked genes. Now several gene loci (locations of genes on chromosomes) containing downy mildew resistance genes have been characterized. The locus designated as *RPF1* contains genes that are effective against races 1, 7, 9, 11, and 13. Other loci, (*RPF2* and *RPF10*) also contain genes that are effective against multiple races of the pathogen. However, with the ability to reproduce sexually, the pathogen has the ability to quickly adapt and form new races that overcome host resistance genes. Most of the varieties labeled as resistant to downy mildew are not resistant to all races of the pathogen.[2,5] Growers are advised to select varieties that have resistance against the races most likely to be present in their area and to grow several varieties with different forms of resistance.[5,7]

Cultural practices can also be used to help manage downy mildew on spinach. Fall crops of spinach should not be planted near fields where spring spinach crops were grown. Volunteer spinach plants in and around new plantings should be destroyed. Highly infected crops that will not be harvested should be destroyed as soon as possible to reduce the spread of the disease to neighboring fields. Crop residue should be plowed under shortly after harvest, even if the crop showed no symptoms of downy mildew. Rotate away from spinach for at least two to three years if possible.[1,5,6,7] Avoid the use of overhead irrigation or schedule water applications for early in the morning to promote rapid drying and to minimize the number of hours of leaf wetness. Do not place row covers over wet plants.[1,5,6] In high tunnel systems, increase air circulation and reduce humidity levels. Maintain a fallow period of at least two weeks between spinach crops grown in high tunnels.

The application of foliar fungicides is also an important tool for managing spinach downy mildew. Plants should be inspected weekly for symptoms of downy mildew, starting early in the season or as soon as row covers are removed. The fungicides currently registered for use on spinach to control downy mildew are protectants, meaning that they protect plants against new infections but will not eliminate established infections. Therefore, it is best to make the first application before symptoms develop or as soon as the disease is detected. There are many fungicides registered for downy mildew control on spinach. Consult regional production and pest management guides for recommendations on the products that are most effective and registered for use on spinach in your area. Fungicide applications may need to be made regularly throughout the growing season, so it is important to check the REI (reentry intervals) and PHI (pre-harvest intervals) ratings for the products being used. Always consult the product label for application instructions and restrictions.[1,2,5,6,7]

Sources:

[1] Kandel S., Mou, B., Shishkoff, N., Shi, A., Subbarao, K., and Klosterman, K. 2019. Spinach downy mildew: Advances in our understanding of the disease cycle and prospects for disease management. Plant Disease 103:791-803.
[2] UC IPM. Agriculture: Spinach pest management guidelines - downy mildew. https://www2.ipm.ucanr.edu/agriculture/spinach/Downy-Mildew/.
[3] Kandel, S., Hulse-Kemp, A., Stoffel, K., Koike, S., Shi, A., Mou, B., Van Deynze, A., and Klosterman, S. J. 2020. Transcriptional analyses of differential cultivars during resistant and susceptible interactions with ***Peronospora effusa***, the causal agent of spinach downy mildew. ***Sci Rep*** 10, 6719.
[4] Choudhury, R., Koike, S., Fox, A., Anchieta, A., Subbarao, K., Klosterman, S., and McRoberts, N. 2016. Season-long dynamics of spinach downy mildew determined by spore trapping and disease incidence. Phytopathology 106:1311-1318.
[5] Madeiras, A. 2017. Spinach downy mildew. University of Massachusetts Extension, Vegetable Program. https://ag.umass.edu/vegetable/fact-sheets/spinach-downy-mildew.
[6] McGrath, M. 2020. Spinach downy mildew. Cornell Vegetables – Pest Management. https://www.vegetables.cornell.edu/pest-management/disease-factsheets/spinach-downy-mildew/.
[7] Ocamb, C. and du Toit, L. 2020. Spinach (***Spinacia oleracea***) – downy mildew. 2020 Pacific Northwest Plant Disease Management Handbook. https://pnwhandbooks.org/plantdisease/host-disease/spinach-spinacia-oleracea-downy-mildew.
[8] Matheron, M.E., Correll, J.C., Porchas, M. and Feng, C. 2019. Evaluation of fungicides for management of downy mildew of spinach, 2018. Plant Disease Management Reports 13:V044.

Websites verified 8/27/2020.

For additional agronomic information, please contact your local seed representative.

Performance may vary from location to location and from year to year, as local growing, soil and weather conditions may vary. Growers should evaluate data from multiple locations and years whenever possible and should consider the impacts of these conditions on the grower's fields. The recommendations in this article are based upon information obtained from the cited sources and should be used as a quick reference for information about spinach production. The content of this article should not be substituted for the professional opinion of a producer, grower, agronomist, pathologist and similar professional dealing with this specific crop.

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