First Report of Quinoa Downy Mildew in the United States: Implications for Global Quinoa Production

Anna L. Testen and Paul A. Backman
Department of Plant Pathology, The Pennsylvania State University

What is quinoa?

-Quinoa, *Chenopodium quinoa*, is an Amaranthaceous pseudo-grain native to the Andean region of South America.
-Quinoa was prized by the Inca as their sacred, mother grain.
-Quinoa's seed is a complete protein and is highly nutritious (United Nations FAO).
-Quinoa is drought and saline tolerant.
-Consumption of quinoa in North America and Europe has increased greatly in recent years.
-Bolivia, Peru and Ecuador produce the vast majority of quinoa in the world.
-Production of quinoa has expanded to other areas of the world including Denmark, India, Canada and the United States.

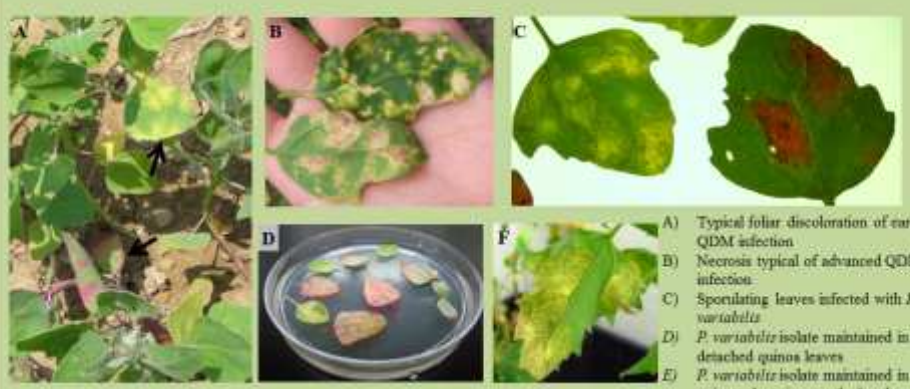
What is quinoa downy mildew?

-Quinoa downy mildew, the key disease of quinoa, reduces quinoa yield and seed quality.
-*Peronospora variabilis, (*formerly *Peronospora farinosa* f. sp. *chenopodii*) is the causal agent of quinoa downy mildew (QDM).
-*P. variabilis* is an obligate, heterothallic oomycete pathogen.
-Quinoa downy mildew is indigenous in quinoa's native range and has also been reported in Denmark, India, Canada and the United States. Downy mildew-like symptoms were concurrently noted on native *Chenopodium* weeds, except in the United States.

First Report in United States

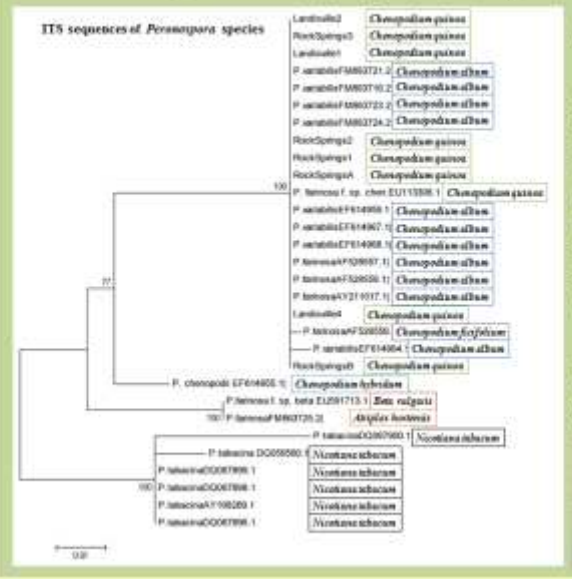
-Quinoa plots were established in Centre Co. and Lancaster Co. during summer of 2011.
-Seeds were from domestic, organic seed producers ('Faro') or from foreign grown, consumable, grocery store sources.
-Quinoa downy mildew was noted at both Pennsylvania locations in July and disease persisted through the remainder of the growing season.

Signs and Symptoms of Quinoa Downy Mildew



A) Typical foliar discoloration of early QDM infection
B) Necrosis typical of advanced QDM infection
C) Sporulating leaves infected with *P. variabilis*
D) *P. variabilis* isolate maintained in detached quinoa leaves
E) *P. variabilis* isolate maintained in quinoa plants in growth chamber

Peronospora variabilis is the causal agent of quinoa downy mildew



-Koch's postulates were verified in detached quinoa leaves and plants.

Molecular Characterization

-DNA isolated from *Peronospora* infected leaves was amplified using ITS specific primers and sequenced.
-The Pennsylvania isolates (RockSprings and Landisville) appear to be comparable to known *P. variabilis* isolates from GenBank.
-*P. variabilis* appears to infect only *Chenopodium* species.

Morphological Characterization

-A vouchered accession of *P. variabilis* from Pennsylvania quinoa has been deposited in the U.S. National Fungus Collections (BPI 882064).

What are the global implications of quinoa downy mildew?

-Quinoa downy mildew reduces quinoa yield.
-*P. variabilis* can survive as oospores on quinoa seeds.
-The primary inoculum is likely seedborne oospores.
-Increased cultivation of quinoa in other countries may require seed treatments to reduce yield loss from quinoa downy mildew.
-The host range of *P. variabilis* must still be determined.
-Seeds sold for human consumption can serve as sources of plant diseases and may be a possible gap in agricultural biosecurity.
-Rapid screening methods are required to determine if seed is free of *P. variabilis* oospores.
-More intensive screening of viable seed sources may be required if quinoa production expands further.

References

1. Testen, AL. et al. 2011. First report of quinoa downy mildew caused by *Peronospora variabilis* in the United States. Plant Disease. DOI: 10.1094/PDIS-09-11-0723
2. Choi, YJ. et al. 2010. Morphological and molecular characterization of the causal agent of downy mildew on quinoa. Mycopathologia. 169:403-412.
3. Ochoa, J. et al. 1999. Postulation of virulence groups and resistance factors in the quinoa downy mildew pathosystem using material from Ecuador. Plant Pathology 48:425-430.
4.Cooke, DL. et al. 2000. A molecular phylogeny of *Phytophthora* and related oomycetes. Fungal Genetics and Biology. 30:17-32.

Acknowledgements

We would like to thank Dr. John McKemy, USDA APHIS-PPQ, for his assistance in confirming the morphological identity of our *Peronospora variabilis*. We would also like to thank Jill Pollok, Khahn Nguyen, and Dawn Zhao for assisting Anna Testen in her research. This research was funded by the United States Agency for International Development.