Infestation of hop seed (*Humulus lupulus*) by chasmothecia of the powdery mildew fungus, *Podosphaera macularis*

B. J. Claassen and **S. N. Wolfenbarger,** Department of Botany and Plant Pathology, Oregon State University, Corvallis 97331; **J. S. Havill** and **A. M. Orshinsky,** Department of Plant Pathology, University of Minnesota, St. Paul 55108; **D. H. Gent**, U.S. Department of Agriculture, Agricultural Research Service, Forage Seed and Cereal Research Unit, and Department of Botany and Plant Pathology, Oregon State University, Corvallis 97331

Powdery mildew of hop (*Humulus lupulus*) is caused by *Podosphaera macularis*. Since, 1997 the disease has frequently caused severe economic loss in production regions in the Pacific Northwestern region of the U.S., the primary area where hops are grown in the country (Gent et al. 2008). *Podosphaera macularis* is heterothallic, but to date only the MAT1-1 mating type has been confirmed in the Pacific Northwest (Wolfenbarger et al. 2015) and ascocarps of the fungus have not been observed in this region (Gent et al. 2006). In the autumn of 2015, seed was collected from wild hop plants at 7 locations in Minnesota for grow out and evaluation of various traits. Prior to planting, seeds were examined under low magnification (30-50×) and in 9 of the 11 seedlots, representing 4 of 7 locations, the seed was found to be externally infested with spherical to flattened, black chasmothecia (syn. cleistothecia). In infested lots, the number of seed bearing chasmothecia averaged 45% (range 5 to 89%; n = 107 to 200 seeds per lot). Scanning electron microscopy indicated chasmothecia had a mean diameter of 82µm and were shriveled with a concaved base. Chasmothecia were easily dislodged from the seed coat despite

the appendages being embedded in a mat of pannose mycelium. Conidiophores and conidia were not observed. The morphological characters were consistent with the genus *Podosphaera* (Braun et al. 2002; Wolfenbarger et al. 2015). Chasmothecia were confirmed as *P. macularis* by extracting DNA from 10 to 15 seeds from each of 6 seedlots using a DNeasy PowerSoil Kit (Qiagen, Carlsbad, CA) and amplifying and sequencing the MAT1-1 and MAT1-2 idiomorphs as described by Wolfenbarger et al. (2015). The sequences obtained for MAT1-1 and MAT1-2 were identical among the extractions of the 6 seedlots. Standard nucleotide BLAST searches in GenBank indicated that the sequences were 97% similar to MAT1-1 (accession KJ922755.1) and 100% similar to MAT1-2 (accession KJ741396.1) sequences of *P. macularis*. To our knowledge, this is the first report of infestation of hop seed by chasmothecia of *P. macularis*. Current quarantine laws that restrict import of planting materials for hop into Idaho, Oregon, and Washington explicitly exempt seed. However, seed infested with chasmothecia may spread the pathogen, potentially introducing novel isolates and mating types of the pathogen. Seed transmission of powdery mildew organisms is scarcely reported (Jarvis et al. 2002), and studies are needed to determine the risk of disseminating *P. macularis* on infested seed. Until such information is available, caution is advised when moving seed from regions where powdery mildew occurs.

References:

Braun et al. 2002. Pages 13 in: The Powdery Mildews: A Comprehensive Treatise, APS Press, St. Paul.

Gent, D. H., et al. Plant Health Progress doi:10.1094/PHP-2008-0314-01-RV.

45 **Gent, D. H.,** et al. Plant Dis. 90:14333, 2006.

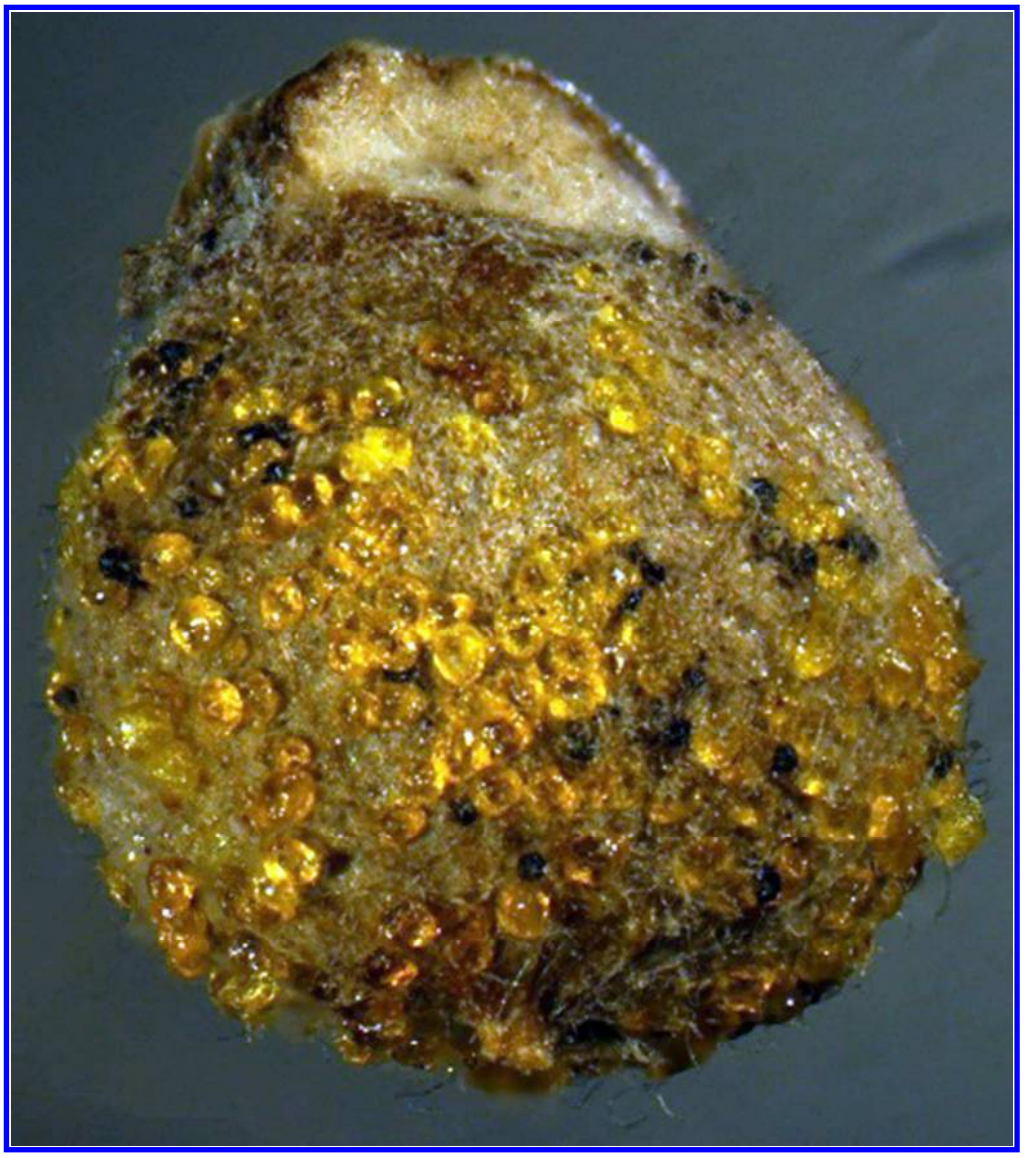
46 **Jarvis et al.** 2002. Pages 169 in: The Powdery Mildews: A Comprehensive Treatise, APS Press,

47 St. Paul.

48 **Wolfenbarger, S. N.,** et al. Plant Pathol. 64:1094, 2015.

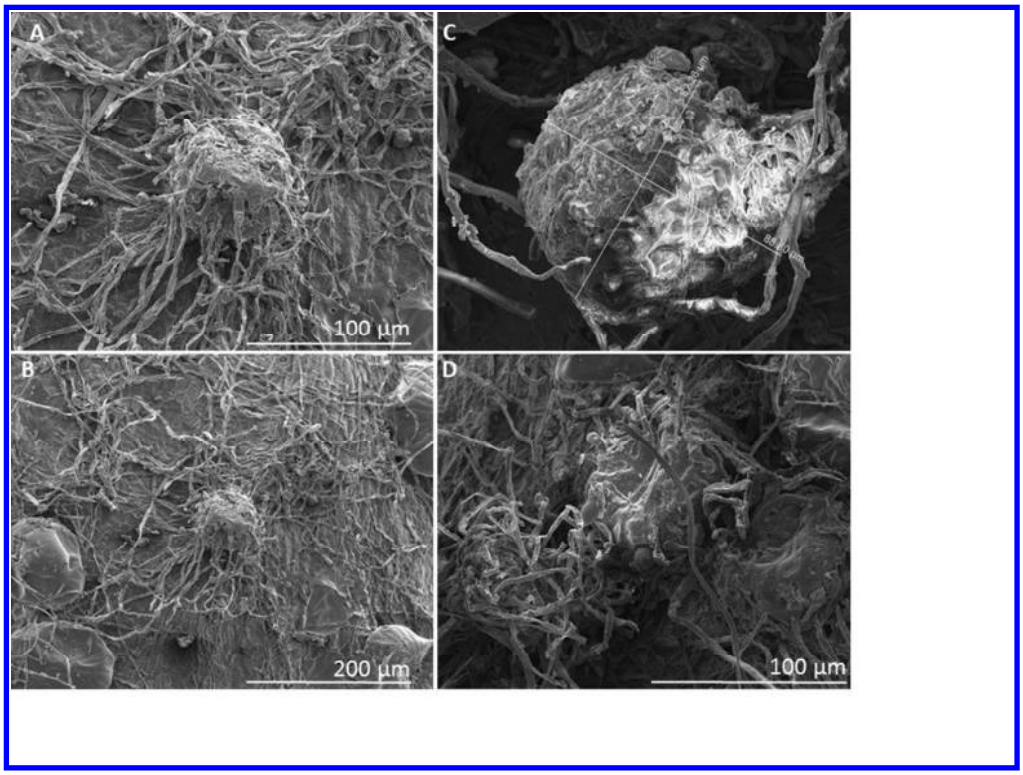
Supplemental Figure 1. Seed from a wild hop plant (*Humulus lupulus*) with numerous, black, spherical chasmothecia of *Podosphaera macularis* and extensive mycelial colonization on the seed coat. The larger yellow structures are lupulin glands. Note the prominent cluster of chasmothecia on the bottom of the seed. Mycelia is most conspicuous on the top half of the seed.

Supplemental Figure 2. Scanning electron micrographs of chasmothecia of *Podosphaera macularis* on hop seed. **A,** Chasmothecium with myceloid appendages on seed coat. **B,** Chasmothecium on seed coat with appendages embedded in pannose mycelium. Larger, non-descript structures are lupulin glands. **C,** Close-up with measurements of the diameter of an ascocarp. **D,** Shriveled ascocarps with concaved basal portions.



Supplemental Figure 1. Seed from a wild hop plant (Humulus lupulus) with numerous, black, spherical chasmothecia of Podosphaera macularis and extensive mycelial colonization on the seed coat. The larger yellow structures are lupulin glands. Note the prominent cluster of chasmothecia on the bottom of the seed. Mycelia is most conspicuous on the top half of the seed.

68x77mm (220 x 220 DPI)



Supplemental Figure 2. Scanning electron micrographs of chasmothecia of Podosphaera macularis on hop seed. A, Chasmothecium with myceloid appendages on seed coat. B, Chasmothecium on seed coat with appendages embedded in pannose mycelium. Larger, non-descript structures are lupulin glands. C, Close-up with measurements of the diameter of an ascocarp. D, Shriveled ascocarps with concaved basal portions.

254x190mm (96 x 96 DPI)