

Structure and regional differences in U.S. *Blumeria graminis* f. sp. *tritici* populations: divergence, migration, fungicide sensitivity, and virulence patterns

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Several aspects of the biology of USA populations of wheat powdery mildew (*Blumeria graminis* f. sp. *tritici*, or *Bgt*) have been investigated for their importance to the integrated management of this widespread and potentially damaging pathogen. For example, the virulence profiles of U.S. *Bgt* populations have been surveyed at approximately decade intervals starting in 1993. Most recently, over 580 *Bgt* isolates were collected from unsprayed commercial wheat fields in 11 U.S. states in 2013 and tested for virulence to single-*Pm*-gene differentials. *Pm1a*, *1b*, *4b*, *16*, and *36* are still widely effective, although they are not widely utilized in the U.S. for various reasons. Most other *Pm* genes with numbers lower than *Pm25* are widely defeated. Based on field and laboratory data, several resistance sources from wild relatives that were recently introgressed -- *MLG12*, *Pm25*, *Pm34*, *Pm35*, and *Pm37* -- are highly effective. They are available in soft red winter wheat backgrounds adapted to the Mid-Atlantic and Southeastern USA. Approximately 600 more *Bgt* isolates were obtained from commercial fields in 12 U.S. states in 2014, and their virulence profiles are currently being determined.

Interestingly, some widely used *Pm* genes are not universally defeated in the USA. Although ineffective along the Atlantic coast, *Pm3a* and *Pm3b* remain somewhat or very effective in several areas west of the Appalachian Mountains (Kentucky, Nebraska, Oklahoma and Texas). This discrepancy may persist due to newly illuminated migration patterns in the U.S. *Bgt* population. Between 2003 and 2010, 238 *Bgt* isolates were collected from 12 U.S. states and evaluated for local and regional population differences, linkage disequilibrium, and migration. Isolates from the Southeast, Mid-Atlantic, and Great Lakes regions comprised a single large cluster, and they were separated genetically from the populations in Kentucky, Oklahoma and Texas. Moderate isolation by distance was detected ($R^2 = 0.19$, $P = 0.003$). One-way migration was estimated at the rate of approximately six individuals per generation from the Kentucky/Texas/Oklahoma populations toward the north and east. Altogether, the evidence suggested annual re-establishment primarily from local sources, resulting in a large-scale mosaic of overlapping local populations, but with some long-distance dispersal in a west-to-east direction. This suggests that novel virulences or fungicide resistance traits that arise anywhere in the eastern U.S. are likely to become widespread in that region, but unlikely to migrate west across the Appalachian Mountains.

In the USA, use of several fungicides on wheat is estimated to have increased, especially since 2007 when wheat prices began rising. *Bgt* is considered a high-risk pathogen for development of reduced fungicide sensitivity. We are acquiring the first comprehensive dataset on regional U.S. differences in *Bgt* sensitivity to commonly applied fungicides. From the 2013 isolate collection mentioned above, a set was chosen that originated from 11 fields in eight states grouped into four regions (Deep South, Mid-Atlantic, Great Lakes, and Plains). The sensitivity of over 150 single-spored isolates was evaluated on susceptible detached wheat leaves previously sprayed with fungicides. Five fungicides (tebuconazole, prothioconazole, pyraclostrobin, picoxystrobin, and fluxapyroxad) were evaluated at 12 rates each. Significant regional differences were found for all fungicides, although to the smallest degree for pyraclostrobin and fluxapyroxad. Isolates from the Plains were the most sensitive to all products. The experiment is being repeated with 2014 isolates. The existence of regional differences may indicate uneven emergence and development of reduced sensitivity.

Overall, the results underscore the importance of (1) accelerating the incorporation of new *Pm* genes, if possible in pyramids, into quantitatively resistant, adapted wheat backgrounds; and (2) restricting unnecessary use of fungicides on wheat in order to slow the emergence and spread of reduced sensitivity in the *Bgt* population.