**Options and outlook for Phytophthora resistance in peppers and squash**

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## Background

Phytophthora blight, caused by the soilborne oomycete pathogen *Phytophthora capsici*, is a devastating disease in several different vegetable crops, including squash and pepper. Common symptoms include root and crown rot, as well as fruit rot when fruit are laying on the soil or spores are splashed onto above-ground plant parts (Figure 1). Successful management of Phytophthora blight requires an integrated approach with several important components: excluding the pathogen from disease-free fields, using cultural practices that improve soil drainage, and for conventional growers, applying targeted fungicides preventatively.

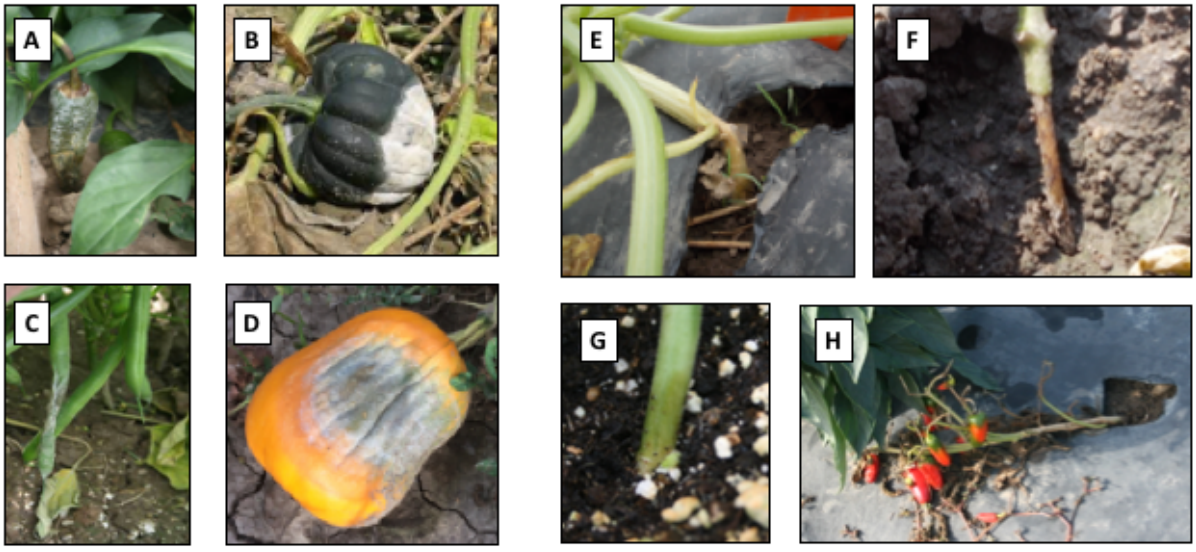


*Figure 1: Examples of fruit rot symptoms in A) pepper, B) acorn squash, C) snap bean, and D) pumpkin, as well as root and crown rot symptoms in E) mature squash, F) pepper seedling, G) squash seedling, and H) mature pepper.*

**Availability of resistant cultivars**

Selecting resistant varieties is another important component of a successful management plan, but options for host resistance to Phytophthora blight are very limited in most crops. In addition, research suggests that resistance in different plant parts is controlled by different genes; for example, a plant with root and crown rot resistance may still have susceptible fruit.

Pepper is currently the only crop that has cultivars commercially available with intermediate resistance (IR) to Phytophthora root and crown rot (usually labeled 'Pc' in seed catalogs). Phytophthora crown and root rot resistance in pepper is controlled by more than one gene, and the level of resistance of IR varieties may vary based on their genetic makeup. Furthermore, plants of even the most resistant varieties may show disease symptoms or die depending on the environmental conditions and pathogen strains present in a field. Currently, intermediate resistance is mostly available in bell pepper cultivars, with a much small number of IR hot pepper cultivars on the market. For information on available IR varieties, see the list compiled by Meg McGrath at: http://vegetablemdonline.ppath.cornell.edu/Tables/TableList.htm.

In squash, there are no cultivars with intermediate or strong root and crown rot resistance commercially available, but the degree of susceptibility of different cultivars varies. Generally, gray zucchini types (ie 'Magda' and 'Hurakan') are the least susceptible to root and crown rot, followed by zucchini and pumpkins, followed by yellow and crookneck squash. Fruit resistance is especially important in pumpkins and winter squash, since their fruit are in greater contact with the soil and remain in the field much longer. Hard-shell decorative pumpkins (ie 'Lil Ironsides' and 'Iron Man') are more fruit-rot resistant than jack-o-lantern types but cannot be carved. In winter squash, a few cultivars, such as Dickinson canning pumpkin, feature age-related fruit resistance: the fruit are susceptible for the first 2 weeks after pollination, then become resistant to fruit rot as they mature.

**Cornell research on resistance in squash and pumpkin**

Several research projects at Cornell are focused on Phytophthora blight resistance in squash and pepper. In 2011, efforts to breed squash with increased root and crown resistance were begun. A gray zucchini landrace from Turkey (called PI 615089 or 'Austrian Bush') with moderate resistance was cross-pollinated with a Cornell zucchini cultivar. The progeny of this cross were then inoculated in the greenhouse as seedlings and the most resistant individuals were self-pollinated and their seed harvested. This selection process was repeated for several generations to develop stable, true-breeding lines.

In 2017 and 2018, we tested three advanced lines from this process in an inoculated field trial along with 3-4 commercial checks and 2 traditional landraces reported to have moderate root and crown rot resistance (Figure 2). The Cornell breeding lines showed significantly less plant death than all of the commercial checks except one, the mini carving pumpkin 'Kandy Korn Plus.' They also displayed equal or superior resistance compared to their gray zucchini parent and were significantly more resistant than PI 181761, a white vegetable marrow landrace from Lebanon being used as a source of resistance at other universities. However, future work is still needed to increase the resistance in these lines to a commercially acceptable level and improve other traits such as growth habit and fruit quality.

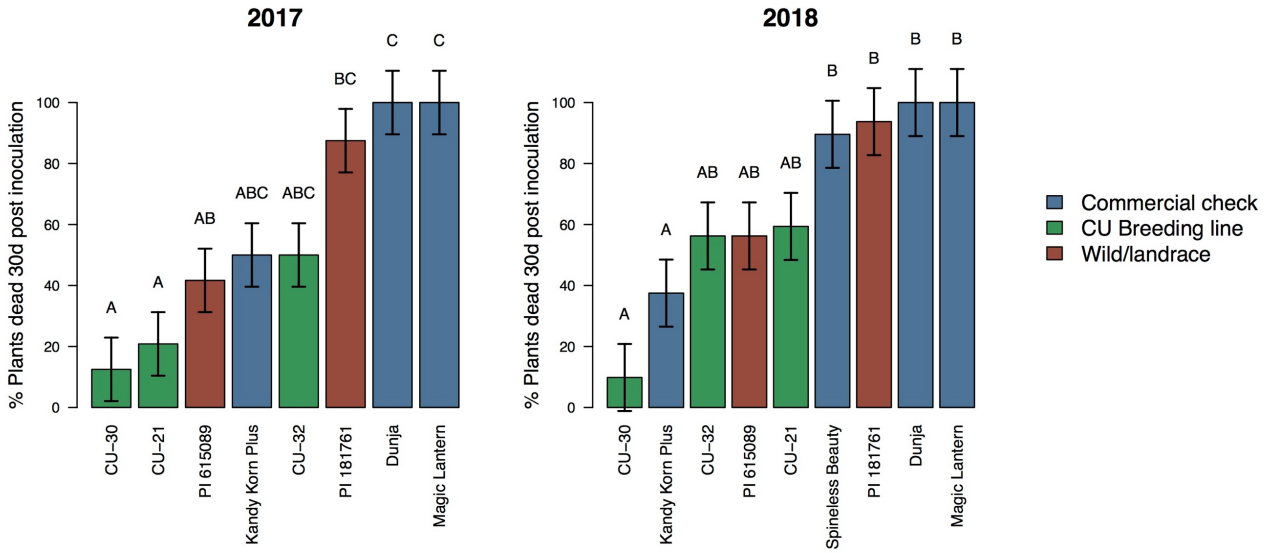


*Figure 2: Results from disease field trials in 2017 and 2018. The plots show the percentage of plants of each variety that were dead 30 days after inoculating with spores of* Phytophthora capsici. *Varieties with the same letter are not significantly different from each other.*

In pepper, we are working to understand why some varieties show strong resistance in certain locations or years but not others. Previous studies suggest that the ability of a pepper cultivar to resist disease is dependent on the pathogen strains, or isolates, that are present in a given field. We collected 117 genetically unique isolates of *Phytophthora capsici*, mainly from farms in New York, and tested their ability in the greenhouse to cause disease on three bell pepper cultivars: Red Knight (susceptible), Aristotle (low level of disease resistance), and Paladin (intermediate resistance) (Figure 3).

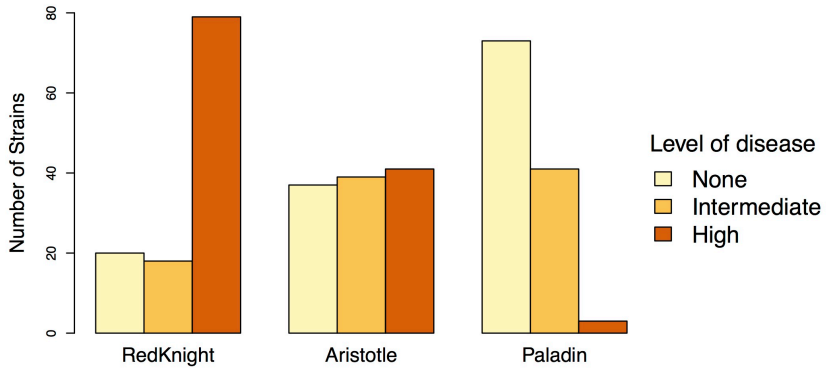


*Figure 3: Results from survey of* Phytophthora capsici *isolates from New York showing their ability to cause disease on bell pepper cultivars Red Knight, Aristotle, and Paladin. Six plants of each bell pepper*

*cultivar were inoculated with each pathogen isolate. The classification of level of disease was determined as follows: none if 0/6 plants killed, intermediate if between 1-5 plants killed, high if 6 plants killed.*

We found that while most of the isolates could cause at least some disease on Red Knight, Aristotle was resistant to about a third of the isolates. Paladin was completely resistant to about 60% of the isolates, and partially resistant to almost all of the rest, with only 3 isolates able to cause a high level of disease. We are currently testing additional pepper varieties and studying the genetic differences among these isolates in order to be able to predict from future pathogen samples which pepper cultivars will be resistant.