RHIZOCTONIA SOLANI: UNDERSTANDING THE TERMINOLOGY

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Rhizoctonia solani can cause seedling damping-off and root rot (Fig. 1) in dry bean (*Phaseolus vulgaris*) (Hagedorn & Hanson 2005) and a number of other major crops including sugarbeet, soybean, cotton, potato, etc. (Sneh et al. 1991). There appears to be an increase in reported incidence in both temperate regions and in tropical areas. As well as a root rot, some strains can cause foliar blights while other strains are non-pathogenic (Sneh et al. 1991) or beneficial to plants (Sneh et al. 1991, Carling et al. 1999). Identification of the type of *R. solani* present in soil or plant tissue is important to determine the risk for a given crop and to monitor changes in where or on what crops different types occur. The type of *R. solani* is an important concern for breeders as resistance to the different forms can be independent (O'Brien et al. 2001).

Rhizoctonia solani is a filamentous fungus in the Basidomycota. It is characterized by production of brown hyphae with right angle branching and a septum near the point of origin in branches, dolipore septa, no clamp connections, and multiple haploid nuclei per cell (Anderson 1982, Ogoshi 1987, Sneh et al. 1991). If a sexual stage is produced, it is *Thanatephorus cucumerimus* (Sneh et al. 1991). It produces no asexual spores and thus a number of different methods have been used to characterize the strains within this species complex.

Figure 1. Root and crown symptoms of Rhizoctonia root rot on dry bean showing sunken, dark lesions.

The most accepted method for characterization of *R. solani* is hyphal anastomosis and vegetative compatibility (Sneh et al. 1991, Carling 1996, Cubeta & Vilgalys 1997). Using this method, isolates are paired on a medium and observed for their interaction. If the two isolates are not closely related, there will be little or no obvious interaction. If the two isolates are very closely related (basically clones), the hyphae will fuse and continue to grow. If isolates are closely related, but not essentially the same isolate, the hyphae will fuse but the fused cells, and often cells around them, will die (Carling 1996). This hyphal incompatibility is used to classify *R. solani* isolates into an anastomosis group (AG). It is a good indication of genetic relatedness in most cases (Sneh et al. 1991, Kuninaga et al. 1997). Different AGs can vary in factors such as host range and types of symptoms produced. Most AGs can be viewed as separate species as they are related but genetically isolated (Anderson 1982, Cubeta & Vilgalys 1997, Gonzalez et al. 2006). Separation of *R. solani* into different species has not been done.

While most AGs show the above characteristics, isolates in a few AGs can have more variable interactions. This is particularly true for "AG 2". Isolates of AG 2-1, AG 2-BI, and AG 2-2 are not closely related, but can undergo hyphal fusion. The rate of anastomosis is lower between than within the same AG (Ogoshi 1987, Sneh et al. 1991). In addition, isolates in some of these can fuse at low rates with AGs outside of "AG 2". The above divisions within "AG 2" are genetically distinct (Liu et al. 1992, Carling et al. 2002) and are not necessarily closely related (e.g. Gonzalez et al. 2006) so it is important to include these distinctions.

The majority of AGs in *R. solani* have been further subdivided. The sub-classification has been done because of characteristics such as variable host range or differences in growth requirements, as well as on morphological characteristics. While these subgroups are not official taxonomic categories, several are phylogenetically supported. For example, within anastomosis group 1, three groups IA, IB, and IC have been identified, with others proposed (e.g. Priyatmojo et al. 2001). The first three were differentiated based on size and shape of the sclerotia, but also vary in that IA causes sheath and leaf blights, IB causes web blights, and IC can cause some damping-off in seedlings rather than damage to aerial parts of plants (Sneh et al. 1991). In AG 4, at least three subgroups have been proposed, including HG-I, HG-II, and HG-III (Sneh 1991). Both HG-I and HG-II occur on beans (Cebi Kilicoglu & Ozkoc 2013) and HG-I is virulent on bean roots (Nerey et al. 2010).

In *R. solani* AG 2-2, several subgroups have been proposed. The first divisions were AG 2-2 IIIB and AG 2-2 IV, based on host range. AG 2-2 IIIB was reported to cause disease on mat rush while AG 2-2 IV caused root rot of sugar beet (Sneh et al. 1991). Subsequently both were found to cause disease of sugar beet, dry bean, and soybean (Engelkes & Windels 1989), but AG 2-2 IIIB was determined to also be pathogenic on grass species like corn (Sumner & Bell 1982). Thus knowledge of which subgroup is present can be an important consideration either for selecting rotation crops or in understanding the potential impact of the existing crop rotation on disease. If the strains present are AG 2-2 IV, corn can be part of rotation for disease management but not if AG 2-2 IIIB is the primary type. Additional subgroups occur on other hosts, and one, AG 2-2 WB, has been proposed based on the ability to cause web blight on dry bean (Godoy-Lutz et al. 2008). The subgroups within AG 2-2 have not been as well supported phylogenetically as those in some other AG and work is ongoing to re-examine AG 2-2 subgroups (Martin et al. 2012).

The types of *R. solani* prevalent on bean can vary depending on the cropping system and/or the location. AG 2-2 is reported commonly associated with bean root rot in some areas of North America (Engelkes & Windels 1989, Muyolo et al. 1993), although more AG 4 is reported in other studies (Papavizas et al. 1975). Other AGs also can damage beans but are less prevalent (Galindo et al. 1982, Muyolo et al. 1993). From Japan, AG 5 was reported as the predominant type on bean, followed by AG 4 (Inoue & Ui, 1974, as reviewed by Ogoshi 1987). In Central and South America, Africa, and parts of the Middle East, AG 4 was reported as the predominant *R. solani* associated with bean root rot (Bolkan & Ribeiro 1985, Diaz & Herrera 2000 as cited by Nerey et al. 2010, Karaca et al. 2002), with AG 1, AG 2-2, and AG 5 also causing damage in some areas (Muyolo et al. 1993, Karace et al. 2002).

For web blight or foliar blight of bean, the most common cause is *R. solani* AG 1 (Bolkan & Ribeiro 1985, Godoy-Lutz et al. 2003). In addition, some strains of AG 2-2 cause web blight (Godoy-Lutz et al. 2008). As stated above, the subgroups within AG 2-2 are debated, and other authors report no web blight with isolates genetically similar to AG 2-2 WB strains (Nerey et al. 2010). This could be due in part to differences in growing conditions in the various experiments as well as variability within the subgroups.

Knowing which AG types are present in a field may be an important factor for selecting resistant material. Varieties can show differential response to AGs (Figure 2). For example, while the cultivar Red Hawk dark red kidney was susceptible to both AG 2-2 and AG 4 with both a seedling and adult plant inoculation, germplasms ADP-629 (H9659-27-10, light red kidney) and ADP-622 (UCD 0701, Jacob's cattle) showed some reduced severity with AG 4 at both the seedling and, for one, at the adult stage. In addition, they showed little resistance to AG 2-2 at the seedling stage but had reduced disease severity as adult plants.

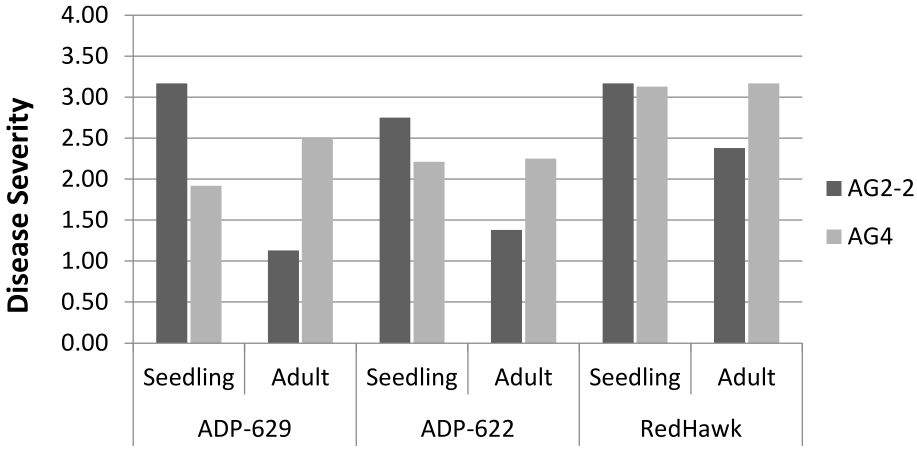

Figure 2. Response of three dry bean lines to *Rhizoctonia solani* isolates, representing two anastomosis groups (AG). Plants were inoculated at planting ("seedling") or 2 weeks after emergence and rated for disease using a 0-6 scale where 0=no symptoms and 6= plant dead.

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