White Mold

White mold caused by *Sclerotinia sclerotiorum* (Lib.) de Bary has a worldwide distribution. Cultural practices, fungicides and plant resistance are used to manage the disease (Schwartz and Steadman, 1989). Resistance to white mold is partial and is considered a complexly inherited trait. There are both physiological and avoidance components to resistance in common bean and bean ideotypes have been proposed that combine morphological, phenological and physiological resistance mechanisms (Kolkman and Kelly, 2002; Park, 1993). The prevalence of plant avoidance mechanisms in the field poses a challenge to breeders interested in breeding for the physiological components of resistance. In order to differentiate between avoidance and physiological resistance, several greenhouse screening methods have been developed to complement field evaluations.

Lyons et al (1985) developed a laboratory technique to screen beans for physiological resistance to white mold using ascospore inoculation. Open bean blossoms were inoculated with ascospores at a concentration of 1×10^4 spores/ml. Inoculated plants were placed in a chamber for 5 days at 100% RH and a temperature of 20^0 C. Severity of infection was evaluated at 14 d after inoculation using a 1-9 scale where 1 = no disease symptoms and 9 = high level of disease. Hauf and Grafton (2001) found results of the ascospore inoculations to be correlated with results from field trials whereas the detached-leaf and oxalate assay were not correlated with field results. Hauf and Grafton (2001) also reported that the straw test does not detect the white mold resistance found in the cultivar ‘Bunsi’. Boosalis et al. (2000) described new methods for the production, recovery, delivery and storage of ascospores of *S. sclerotiorum*.

Kolkman and Kelly (2000) used an oxalate assay to screen bean lines for physiological resistance to white mold. Twenty-day-old plants were cut at the surface of the soil and the cut stems were placed in plastic tubes containing a 20 mM solution of oxalic acid. The tubes were kept in the greenhouse with no light at 21^0 C for 12 h (overnight). Plants were evaluated the following morning using a 1-6 scale where 1= no wilting and 6 = the collapse of the main stem.

Steadman et al. (1997) used a detached leaf technique to evaluate the physiological resistance of bean lines to white mold. The assay was conducted by removing the second trifoliolate leaf from twenty-day-old plants and placing an agar plug of *S. sclerotiorum* mycelia on the center leaflet on either side of the mid-vein. The leaves were placed in orchid tubes containing distilled water to maintain turgidity. The leaves were placed on top of a petri dish in an aluminum baking pan containing 300 ml of distilled water. The pan was covered with plastic wrap to maintain humidity. The size of the lesion was measured after allowing the mycelium to colonize the leaf tissue for 48 h at 22^0 C.

Petzoldt and Dickson (1996) developed the straw test. Inoculum was prepared by growing *S. sclerotiorum* on PDA in Petri plates for 3 days at 23^o C. The fungus was transferred at least once from storage to ensure the inoculum has an actively growing culture. Petri plates ready to use as inoculum have overgrown plates and have a fuzzy appearance, but have not initiated the formation of sclerotia. Plastic drinking straws (6 mm in diameter) were cut into 3 cm lengths. One end was stapled closed and the other end was used as a cork borer to cut a disk of agar from the plate. The growing point of the main stem of the plant to be tested was removed and the end of the straw with agar was placed over the cut end. The bean plants were tested 3-5 weeks after planting in a greenhouse at 20-27^o C. Plants were evaluated 8 days after inoculation using a 1-9 scale (Table 1).

Table 1. Rating scale (1-9) used to evaluate beans for white mold using the straw test.

White mold score	**Plant symptoms at 8 days after inoculation using the straw test.**
1	No sign of disease, but stem infected adjacent to agar inoculant when the straw was removed for inspection
3	Invasion of the stem for several inches or to first node, but no further.
5	Invasion past the first node, but progressing slowly.
7	Invasion to 2^{nd} node or further, but not a total collapse of the plant.
9	Total plant collapse

Source: Petzoldt and Dickson (1996).

Kull et al. (2003) evaluated cotyledon, cut stem and detached leaf inoculations with six variable *S. sclerotiorum* isolates on soybean and dry bean. There was an isolate by inoculation method interaction for identification of partial resistance in dry bean. Overall, the cut stem method was the best for evaluating resistance. There are sources of partial resistance in most seed classes of dry bean and snap bean (Table 2).

To screen for white mold tolerance, Hauf and Grafton (2001) used narrow row spacing (46 cm) to favor disease development in the field. A row of the susceptible cultivar Othello was planted between each experimental unit as a spreader. The test rows were inoculated at full bloom (R~~6~~1) with ascospores of *S. sclerotiorum* at a concentration of 1 x 10^6 spores/L. White mold severity was evaluated near physiological maturity (R9) using a 1-9 scale where 1 = no disease symptoms and 9 = high level of disease. The use of a susceptible cultivar as a disease spreader in border rows of experimental plots is common practice in field experiments (Kolkman and Kelly, 2002).

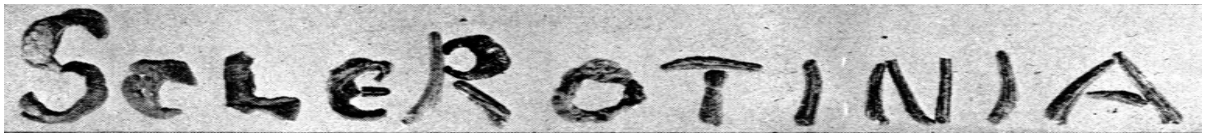
Steadman and Eskridge (2002) compared multi-location field screening and straw tests for white mold reaction. Randomized blocks with three replications were used for the field test. Experimental units consisted of 2 rows of each entry and 1 row of a common susceptible check. All fields used for screening had a previous history of white mold. White mold severity was recorded as percent of above ground plant canopy with signs/symptoms at R9. All straw tests produced similar rankings of the nine putative resistant lines and were highly correlated even though different *S. sclerotiorum* isolates were used by each investigator.

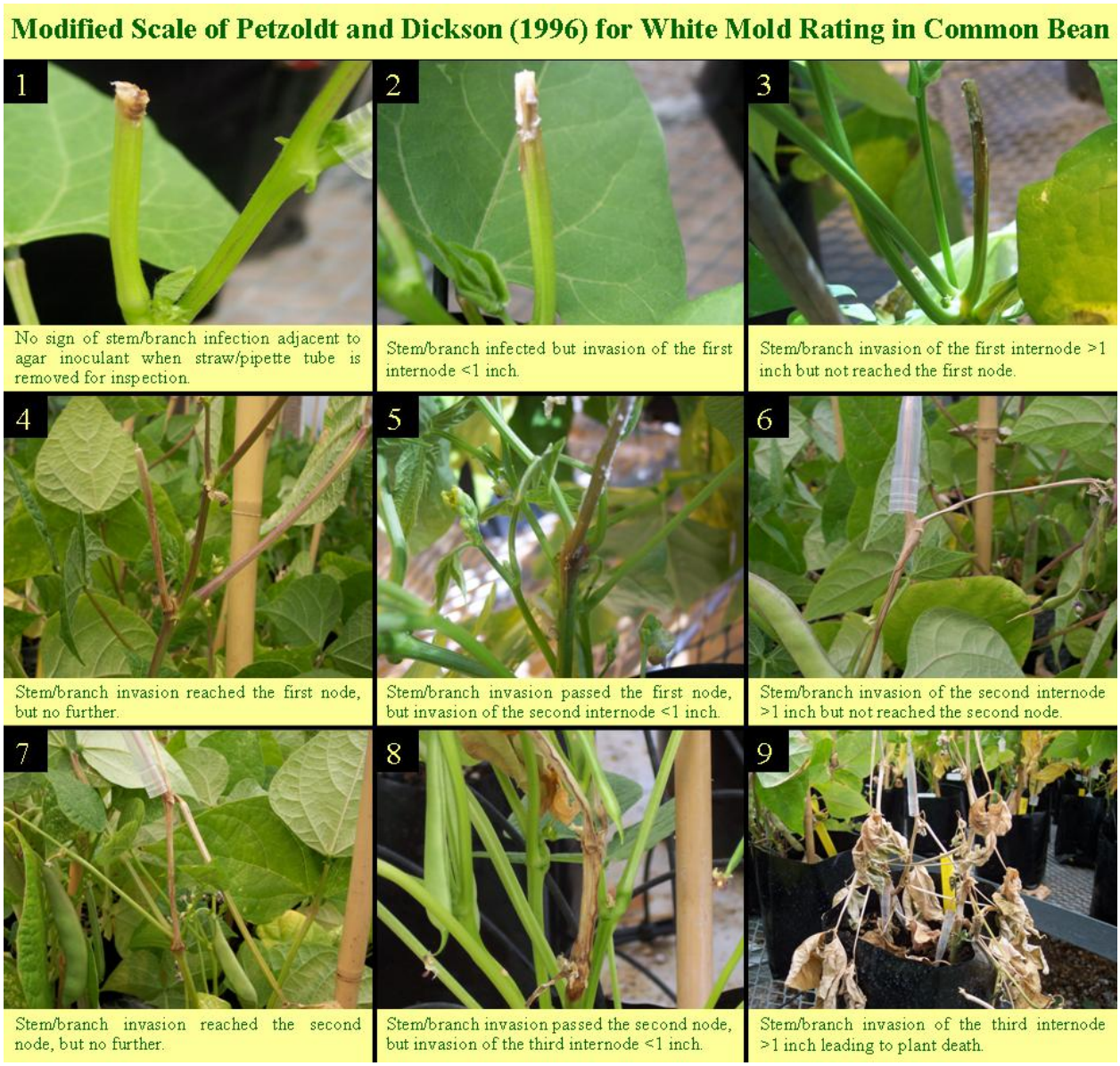
Quantitative Trait Loci (QTL) mapping has been conducted for a number of partial resistance sources including Bunsi navy, Bunsi derived line ND88-106-04, Andean cranberry G122, red mottled pompadour PC 50, and snap bean NY-6020-4. Table 2 shows linkage groups where QTL for white mold resistance have been detected. The amount of variation accounted by individual QTL varies greatly. In field studies physiological resistance can be confounded by plant avoidance mechanisms resulting in the identification of QTL for both resistance and avoidance. Depending on the environmental factors in a given location across the time of the study, the variation accounted for by a QTL for avoidance can be highly variable. In certain instances, QTL identified in Bunsi on B2 and B7 were confirmed in a marker-assisted study (Ender et al., 2007). However, in other instances QTL map to different regions of B7 in the Bunsi navy sources as compared to the Andean G 122 and PC 50 sources, perhaps indicating different genes underlie the respective QTL. Future work involves integration of resistance from wild and exotic landrace bean sources using the inbred backcross method.

Table 2. Sources of partial resistance to white mold in different bean seed classes.

Name or Number	Seed color / type	Linkage Group*	Reference
Tacaragua I9365-31; 92BG-7	9 / Black		Fuller, et al. (1984) Miklas, et al. (1998)
Seahawk I9365-19	1 / White		Kelly et al. (2003) Miklas, et al. (1998)
PI 169787	1/ Small White		Dickson and Hunter (1982)
Ex Rico 23 ICA Bunsi	1/ Small White	B2, B7 B2, B5, B7, B8	Tu and Beversdorf (1982) Kolkman and Kelly (2003) Ender and Kelly (2005) Ender et al. (2007)
ND88-106-04	1/ Small White		Miklas et al. (2004, 2007)
USPT-WM-1 (AN 37)	4M / Pinto		Miklas et al. (2005, 2006)
USPT-WM-2 (AN 69)	4M / Pinto		Miklas et al. (2005)
AN 1	1/Great Northern		Miklas et al. (2004)
I9365-5;I9365-25	5 / Pink		Miklas et al. (1998)
I9365-3	6 / Small red		Miklas et al. (1998)
G 122	2R / Cranberry	B1, B7	Miklas et al. (2001)
PC 50	6M / Red mottled	B4, B7, B8, B11	Park, et al. (2001)
Cornell 601	5K / Light red kidney		Griffiths (in press)
Cornell 501	1 / Snap		Griffiths et al. (2004)
NY-6020-4	1/Snap	B6, B8	Miklas et al. (2003)
6 lines	1 / Snap		Dickson and Hunter (1989)
Plant Introductions	Various		Hunter et al. (1982)
P. coccineus			Dickson et al. (1981)

* Indicates the Linkage Group where QTL conferring partial resistance to white mold were detected





Photograph and scale provided by Shree Singh
University of Idaho

References

Boosalis, M.G., J.R. Steadman, K. Powers and B. Higgins. 2000. New methods for production, recovery, delivery and storage of ascospores of *Sclerotinia sclerotiorum* and other fungal propagules. Annu. Rep. Bean Improv. Coop. 43:156-157.

Dickson, M.H., J.F. Hunter, J.A. Gigna and M.A. Boettger. 1981. Resistance to white mold. Annu. Rep. Bean Improv. Coop. 24:126-128.

Dickson, M.H. and J.F. Hunter, 1982. Sources of white mold resistance and breeding for resistance. Annu. Rep. Bean Improv. Coop. 25:104-105.

Dickson, M.H. and J.F. Hunter. 1989. Release of six snap beans with resistance to white mold and gray mold. Ann. Rep. Bean Improv. Coop. 32:139.

Ender, M. and J.D. Kelly, 2005. Identification of QTL associated with white mold resistance in common bean. Crop Sci. 45:2482-2490.

Ender, M., K. Terpstra, and J.D. Kelly. 2007. Marker-assisted selection for white mold resistance in common bean. Mol. Breed. (on line:10.1007/s11032-007-9115-9).

Fuller, P.A., D.P. Coyne and J.R. Steadman. 1984. Inheritance of resistance to white mold disease in a diallel cross of dry beans. Crop Sci. 24:929-933.

Hauf, D.C. and K.F. Grafton.2001. Evaluating non-field screening techniques for white mold reaction of common bean. Annu. Rep. Bean Improv. Coop. 44:91-92.

Hunter, J.E. M.H. Dickson, M.A. Boettger and J.A. Cigna. 1982. Evaluation of plant introductions of *Phaseolus spp*. for resistance to white mold. Plant Disease. 66:320-322.

Kelly, J.D. 2003. Notice of naming and release of ‘Seahawk’, a new mid season, upright, white mold tolerant navy bean cultivar for Michigan and the Great Lakes region. Annu. Rep. Bean Improv. Coop. 46:245-246.

Kolkman, J.M. and J.D. Kelly. 2000. An indirect test using oxalate to determine physiological resistance to white mold in common bean. Crop Sci. 40:281-285.

Kolkman, J.M. and J.D. Kelly. 2002. Agronomic traits affecting resistance to white mold in common bean Crop Sci. 42:693-699.

Kolkman, J.M. and J.D. Kelly. 2003. QTL conferring resistance and avoidance to white mold in common bean. Crop Sci. 43:539-548.

Kull, L.S., T.D. Vuong, K.S. Powers, K.M. Eskridge, J.R. Steadman and G.L. Hartman. 2003. Evaluation of resistance screening methods for Sclerotinia stem rot of soybean and dry bean. Plant Disease 87:1471-1476.

Miklas, P.N., R. Delorme, and R. Riley. 2003. Identification of QTL conditioning resistance to white mold in snap bean. J. Amer. Soc. Hort. Sci. 128(4):564-570.

Miklas, P. N., K. F. Grafton, J. D. Kelly, J. R. Steadman, and M. J. Silbernagel. 1998. Registration of four white mold resistant dry bean germplasm lines: I9365-3, I9365-5, I9365-31, and 92BG-7. Crop Sci. 38:1728.

Miklas, P.N., D.C. Hauf, R.A. Henson and K.F. Grafton. 2004. Inheritance of ICA Bunsi-Derived Resistance to White Mold in a Navy X Pinto Bean Cross. Crop Sci. 44:1584-1588.

Miklas, P., K. Grafton, D. Hauf, and J. Kelly. 2005. Release of Partial White Mold Resistant Pinto Bean Germplasm Lines USPT-WM-1 and USPT-WM-2. Annu. Rep. Bean Improv Coop. 48:190-191.

Miklas, P.N. K.F. Grafton, D. Hauf, and J. D. Kelly. 2006. Registration of partial white mold resistant pinto bean germplasm line USPT-WM-1. Crop Sci. 46: 2339.

Miklas PN, Larsen KM, Terpstra KA, Hauf DC, Grafton KF, Kelly JD.2007. QTL analysis of ICA Bunsi-derived resistance to white mold in a pinto x navy bean cross. Crop Sci 47:174-179.

Park, S.J. 1993. Response of bush and upright plant type selections to white mold and seed yield of common beans grown in various row widths in southern Ontario. Can. J. Plant Sci. 73:265-272.

Park, S.O., D.P. Coyne, J.R. Steadman, and P.W. Skroch. 2001. Mapping of QTL for resistance to white mold disease in common bean. Crop Sci. 41:1253-1262.

Petzoldt, R. and M.H. Dickson. 1996. Straw test for white mold in beans. Ann. Rep. Bean Improv. Coop. 39:142-143.

Schwartz, H.F. and J.R. Steadman. 1989. White mold. p. 211-230 . *In* H.F. Schwartz and M.A. Pastor-Corrales (eds.). Bean production problems in the tropics. Centro Internacional de Agricultura Tropical (CIAT). Cali, Colombia.

Steadman, J.R. and K.M. Eskridge. 2002. Comparison of screening methods for identification of sources of resistance to *Sclerotinia sclerotiorum* in common bean. Ann. Rep. of the Bean Improv. Coop. 45:158-159.

Steadman, J.R., K. Powers and B. Higgins. 1997. Screening common bean for resistance using detached leaves. Ann. Rep. Bean Improv. Coop. 40:140-141.

Tu, J.C. and W.D. Beversdorf. 1982. Tolerance to white mold (*Sclerotinia sclerotiorum* (Lib.) de Bary) in Ex Rico 23, a cultivar of white bean (*Phaseolus vulgaris* L.). Can. J. Plant Sci. 62:65-69.