

RUST



Photograph provided by H. F. Schwartz
AglImage - Colorado State University

Bean rust, caused by *Uromyces appendiculatus* (Pers.) Unger, is an important disease in both temperate and tropical bean production regions. Ideal conditions for rust are cool to moderate temperatures, concurrent with high humidity (>95%) for periods of at least 7-8 h, interspersed with dryer, windy periods that favor dispersal (Harter et al., 1935). The pathogen is not seed borne. *U. appendiculatus* is an obligate parasite, and macrocyclic, completing its entire life cycle on the common bean (*Phaseolus vulgaris* L.) (Harter & Zaumeyer, 1941).

Due to the variability of the pathogen, pyramiding of rust resistance genes is recommended (Ballantyne, 1974; Coyne & Schuster, 1975; Araya, 2003 and Araya, 1996). At the Third International Rust Workshop, a new set of 12 differential lines for the characterization of rust races was proposed (Table 1) (Steadman et al., 2002b). A binary value is assigned to each differential so that a unique number can be generated for each rust race.

Table 1. Bean rust differentials proposed at the Third International Bean Rust Workshop held in South Africa in 2002 (Steadman et al., 2002b).

Gene pool	Name	Seed type	Binary value	Resistance gene(s)	Rating for race 6:27 (MA:A)
Middle American	GN 1114	1	1	<i>Ur-7</i>	-
	Aurora	1	2	<i>Ur-3</i>	+
	Mexico 309	9	4	<i>Ur-5</i>	+
	Mexico 235	5	8	<i>Ur-3+</i>	-
	CNC	9	16	<i>Ur-CNC</i>	-
	PI 181996	9	32	<i>Ur-11</i>	-
	<i>Sum of binary values for Middle American lines for race 6:27</i>			2+4=6	
Andean	Early Gallatin	1K	1	<i>Ur-4</i>	+
	Redlands	4K	2	<i>Ur-13</i>	+
	Pioneer				
	Montcalm	6K	4		-
	PC 50	6M	8	<i>Ur-9, Ur-12</i>	+
	Golden Gate	4K	16	<i>Ur-6</i>	+
	Wax				
	PI 260418	3R	32	<i>Ur-260</i>	-
<i>Sum of binary values for Andean lines for race 6:27</i>			1+2+8+16=27		

Stavely et al. (1983) proposed a rust evaluation scale that considers pustule size and intensity of infection (Table 2). Pustule size is evaluated on a 1-6 scale. When several pustule grades are present, they are recorded in order of predominance with the most prevalent type listed first. "C" indicates the presence of a chlorotic halo around the pustule. The modified Cobb scale (1 – 7) or the CIAT 1 – 9 scale (Van Schoonhoven & Pastor-Corrales, 1987) can be used to estimate intensity of infection. Bean breeding lines in the field are usually evaluated for rust reaction during pod fill.

Table 2. Scale for the evaluation of bean rust pustule size and intensity of infection

Type of reaction (1-6 scale) ^{1/}	Pustule size	Intensity of infection ^{2/}
1 - Immune	No visible symptoms	Use the 1 – 7 modified Cobb scale for estimating percent leaf area infected (including the area occupied by the halos), or the CIAT 1 – 9 intensity scale ^{3/} [where 1 = minimum and 7 (Cobb) or 9 (CIAT) = maximum infection]
2 - Resistant (hypersensitive)	Necrotic spots without sporulation	
3 - Resistant	Pustules < 300 µm in diameter	
4 - Susceptible	Pustules 300-500 µm in diameter	
5 - Susceptible	Pustules 500-800 µm in diameter	
6 - Susceptible	Pustules > 800 µm in diameter	

^{1/} Stavely et al., 1983.

^{2/} Stavely, 1985.

^{3/} Van Schoonhoven & Pastor-Corrales, 1987.

Steadman et al. (2002a) recommended a mobile nursery of bean lines with different rust resistance genes to determine which combination of rust resistance genes would be effective when incorporated into widely grown cultivars (Table 3).

Table 3. Procedures for conducting the bean rust mobile nursery (Steadman et al., 2002a)

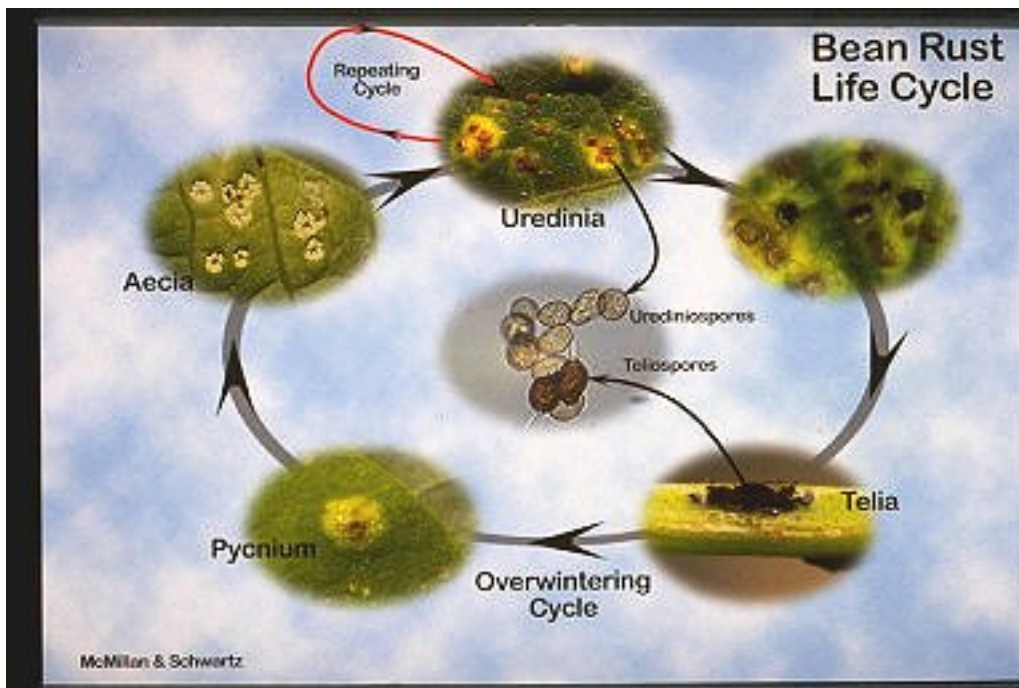
1. The bean rust differentials (Table 1) and other sources of rust resistance can be used for the mobile nursery.
2. Because the state of development of the leaf affects the size of the pustule, all of the plants in the nursery should have the same degree of leaf expansion. The seed of lines which take longer to emerge should be pre-germinated in order to obtain a more uniform germination. The seed should be placed in wet paper towels for 2-3 days at a temperature of 25-29° C. Scarification of the testa can also be used to promote germination. Two seeds of each line should be planted in small pots. Extra pots should be planted to allow for poor or late germination.
3. The seedlings should be ready to take to the field approximately one week after planting, when the primary leaves are approximately $\frac{1}{2}$ to $\frac{2}{3}$ expanded.
4. The pots containing the bean rust differentials and other sources of resistance are placed in a tray and taken to a bean field infected with rust. The tray should be placed near the focus of infection, i.e. bean plants with fresh urediniospores (masses of brown spores inside the uredinia) for 3 to 4 h. Dry and windy conditions favor spore dispersal to the seedlings.
5. After removing the mobile nursery from the field, the plants should be placed in a mist chamber (>95% humidity) for 15 h at 18-24 ° C. It is important to avoid temperatures > 30° C. The plants can then be placed in a greenhouse maintained at 18/24 ° C night/day.
6. Scoring should be done 14 days after the plants were exposed to rust, using the scale established at the First International Bean Rust Workshop (Table 2).

An effective field screening technique was developed at the Escuela Agrícola Panamericana. Bean lines growing in benches are inoculated with a mixture of virulent pathotypes of bean rust, followed by frequent moistening of the leaf canopy using micro-irrigation (Beaver et al., 2003).

Table 4. Sources of resistance to bean rust in different seed classes.

Line/Cultivar	Seed color / type	Resistance genes	Reference
Ouro Negro	9 / Black	<i>Ur-Ouro-Negro</i>	Corrêa et al., 2000
BelMiDak-RMR-10-12	1 / Navy	<i>Ur-4, Ur-11</i>	Pastor-Corrales (2003)
BelDakMi-RMR-19-23	2M / Pinto	<i>Ur-3, Ur-4, Ur-6, Ur-11</i>	Pastor-Corrales (2003)
BelMiNeb-RMR-9-13	1 / Great Northern	<i>Ur-3, Ur-6, Ur-11</i>	Pastor-Corrales (2003)
BelNeb-RR-1	1 / Great Northern	<i>Ur-5, Ur-6, Ur-7</i>	Stavely et al., 1989
Merlot	7 / Red Mexican	<i>Ur-3</i>	Hosfield et al. (2004)
	6 / Small red		
Rosada Nativa	5 / Pink	<i>Ur-5</i>	Beaver et. al. (1999)
	2R / Cranberry		
PC-50	6M / Red mottled	<i>Ur-9, Ur-12</i>	Saladin et al. (2000)
	6K / Dark red kidney		
BelDade-RGMR-4-6	1 / Snap	<i>Ur-3+, Ur-4</i>	Stavely et al. (1997)

Other effective control measures include crop rotation, removal of volunteer plants, deep plowing to remove bean debris from the soil surface and encourage rotting, avoidance by choice of planting time, and fungicide treatment. Effective fungicides include protectants such as chlorothalonil and dithiocarbamates, and systemic chemicals such as triazoles and carboxins.



Photograph provided by H. F. Schwartz
AglImage - Colorado State University

References

- Araya, C.M. 2003. Coevolución de interacciones hospedante-patógeno en frijol común. *Fitopatol. Bras.* 28:221-228.
- Araya, C.M. 1996. Pathogenic and molecular variability and telia production of *Uromyces appendiculatus* isolates from Andean and Middle American centers of domestication of common bean. Ph.D. dissertation. University of Nebraska –Lincoln.
- Ballantyne, B. 1974. Resistance to rust in beans. *Annu. Rep Bean Improv. Coop.* 17:19-20.
- Beaver, J.S., J.C. Rosas, J. Myers, J. Acosta, J.D. Kelly, N. Nchimbi-Msolla, R. Misangu, J. Bokosi, S. Temple, E. Arnaud-Santana and D.P. Coyne. 2003. Contributions of the Bean/Cowpea CRSP to cultivar and germplasm development in common bean. *Field Crops Research* 82:87-102.
- Beaver, J.S., P.N. Miklas and R. Echavez-Badel. 1999. Registration of Rosada Nativa pink bean. *Crop Sci.* 39:1257.
- Coyne, D.P., Schuster, M.L. Genetic and breeding strategy for resistance to rust (*Uromyces phaseoli* (Reben) Wint) in beans (*Phaseolus vulgaris* L.).
- Harter, L.L., Andrus, C.F. and Zaumeyer, W.J. 1935. Studies on bean rust caused by *Uromyces phaseoli typica*. *J. Agric. Res.* 50:737-759.
- Harter, L.L. and Zaumeyer, W.J. 1941. Differentiation of physiologic races of *Uromyces phaseoli typica* on bean. *J. Agric. Res.* 62:717-731.
- Hosfield, G.L., G.V. Varner, M.A. Ubersax and J.D. Kelly. 2004. Registration of 'Merlot' small red bean. *Crop Sci.* 44:351-352.
- Pastor-Corrales, M.A. 2003. Sources, genes for resistance and pedigrees of 52 rust and mosaic resistant dry bean germplasm lines released by the USDA Beltsville bean project in collaboration with Michigan, Nebraska and North Dakota Agricultural Experiment Stations. *Ann. Rep. of the Bean Improv. Coop.* 46:235-241.
- Saladin, F., E. Arnaud-Santana, J.C. Nin, G. Godoy-Lutz, J.S. Beaver, D.P. Coyne and J.R. Steadman. 2000. *Crop Sci.* 43:430-431.
- Stavelly, J.R. 1985. The Modified Cobb Scale for estimating bean rust intensity. *Annu. Rep. Bean Improv. Coop.* 28:31-32.

- Stavely, J.R. 1990. Genetics of rust resistance in *Phaseolus vulgaris* plant introduction 181996. (Abstr.) Phytopathology 80:1056.
- Stavely, J.R., Steadman, J.R., Coyne, D.P. and Lindgren, D.T. 1989a. BelNeb Rust Resistant-1 and -2 Great Northern dry bean germplasm. HortScience 24:400-401.
- Stavely, J.R., Freytag, G.F., Steadman, J.R., Schwartz, H.F. 1993. The 1983 Bean Rust Workshop. Annu. Rep. Bean Improv. Coop. 26:iv-vi.
- Stavely, J.R., Kelly, J.D., Grafton, K.F., Mullins, C.A., Straw, A., McMillan, Jr., R.T., Beaver, J.S., Miklas, P.N., Steinke, J., Steadman, J.R., Coyne, D.P., Lindgren, D.T. and Silbernagel, M.J. 1997. Rust resistant bean germplasm releases, 1994-1996. Annu. Rep. Bean Improv. Coop. 40:120-121.
- Steadman, J.R., G. Godoy-Lutz, J.C. Rosas and J.S. Beaver. 2002a. Uso de un vivero móvil para obtener patrones de virulencia de la roya del frijol común. Agronomía Mesoamericana 13:37-39.
- Steadman, J.R., M.A. Pastor-Corrales and J.S. Beaver. 2002b. An overview of the 3rd bean rust and 2nd bean common bacterial blight international workshops, March 4-8, 2002, Pietermaritzburg, South Africa. Annu Rpt Bean Improv Coop 45:120-124.
- Van Schoonhoven, A, Pastor-Corrales, M.A. 1987. Rust. Pages 24-27 in; Standard System for the Evaluation of Bean Germplasm. CIAT, Cali, Colombia.