'BeltGlade RR-1', 'BeltGlade RR-2', and 'BeltGlade RR-3': Rust-resistant Snap Bean Breeding Lines with the *Ur-4* and *Ur-11* Genes

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Bean rust, incited by the fungus *Uromyces appendiculatus* (Pers.) Unger var. *appendiculatus* [formerly *U. phaseoli* (Ruben) Wint.] is a common disease of *Phaseolus vulgaris* L. It has the potential to cause serious crop losses, and is particularly troublesome in warm, humid production regions such as Florida (Stavelly, 1999a, 1999b; Stavelly and Pastor-Corrales, 1989). Currently, the Florida snap bean industry is valued at over \$100 million annually, and generally relies on just over a half-dozen cultivars. The major source of rust resistance in these popular cultivars is the *Ur-4* gene (Kelly et al., 1996), previously identified in 'Early Gallatin' as *Up-2* (Christ and Groth, 1982). Unfortunately, this gene is not completely effective against the races that now infect snap beans in Florida, and growers must routinely apply fungicides to control bean rust and a number of other foliar diseases. In the past few years, 90 of the estimated 150 worldwide bean rust races have been identified and are curated at Beltsville, Md. (Stavelly, 1998a, 1999b). To date, 11

dominant resistant genes have been identified to control these pathogenic races. They confer various host plant resistance reactions, including immunity, hypersensitivity, and/or reduced uredina size (Stavelly, 1998a). The *Ur-4* gene confers a hypersensitive type resistance, with necrotic lesions of 0.3–1.0 mm in diameter, to 30 of these races (Stavelly, 1998a). Another gene, the dominant *Ur-11* allele, confers hypersensitive or reduced uredinium (≤ 0.3 mm) type resistance to 89 of these races (Stavelly, 1998a). The *Ur-11* gene was previously identified as *Ur-3*² and later found to be linked in repulsion phase with the *Ur-3* locus (Stavelly, 1998b). The *Ur-11* allele is not protective against Race 108 from Honduras (= H951, Steadman, pers. comm.), but *Ur-4* is effective. When combined, the *Ur-4* and *Ur-11* genes concurrently provide either immunity, chlorotic or necrotic hypersensitive, or tiny uredinium resistance to all of the 90 races, with duplicate resistance to 29 of these races (Stavelly, 1998b). Given the dynamic epidemiology of bean rust, more races will likely arise in the United States, Central America, and the Caribbean basin. A prudent strategy for the management of this disease is the deployment of different genes that confer resistance to a wide array of races, thereby diversifying the genetic basis of resistance.

The primary objective of this breeding effort was to generate broad-spectrum bean rust resistance in subtropically adapted, fresh market, snap bean germplasm. To accomplish this objective, the *Ur-11* gene was introgressed into snap bean germplasm with existing resistance based on the *Ur-4* gene. Additional emphasis was placed on the reten-

tion of resistance to bean common mosaic virus as conferred by the *I* gene (Drijfhout, 1978) and presently deployed in many of the important cultivars grown in Florida. These breeding lines are intended for use as a combined source of rust resistance based on *Ur-11* and *Ur-4* genes.

Origin

'BeltGlade RR-1' (BG-RR-1), 'BeltGlade RR-2' (BG-RR-2), and 'BeltGlade RR-3' (BG-RR-3), previously coded as 5-1815, 5-1853, and 5-1858, respectively, were developed using a modified backcross and pedigree method. In this crossing scheme, PI 181996 was the male donor of the *Ur-11* gene (Stavelly, 1988). PI 181996 was introduced from Guatemala in 1949 and is a typical Mesoamerican accession with an indeterminate growth habit, photoperiod sensitivity and black seeds (Stavelly, 1990). A series of snap beans with bush growth habits were used as female parents recurrently, but not sequentially (Fig. 1). These included 'Eagle' and 'Opus', each used in one cross, 'Sprite' and 'Podsquad', each used twice and three times, respectively. 'Eagle', a processor snap bean, was the primary source of the *Ur-4* gene and the unprotected *I* gene. 'Opus', 'Podsquad', and 'Sprite' are fresh-market snap bean cultivars, which have been commonly grown in Florida. All of these cultivars also carry the *Ur-4* gene, as well as the *I* gene without any recessive modifiers.

From the first cross between 'Eagle' and PI 181996, an F_3 individual was selected for snap bean horticultural quality, along with *Ur-4* and *Ur-11* based resistance to bean rust, and BCMV resistance as conferred by the *I* gene. This plant was subsequently crossed as a male to 'Sprite' with the F_1 again tested for rust resistance. The progeny were subsequently crossed and backcrossed to 'Podsquad', with a rust resistant BC_1 individual crossed again to 'Sprite'. After this last cross with 'Sprite', 'Podsquad' was used as a female parent in the sixth cross. An F_2 progeny set was generated and tested for rust resistance, with a desirable individual used in the last cross to 'Opus'. Progeny from each of the seven crosses were selected for rust resistance following the inoculation technique of Stavelly (1983), where 12 indicator races and Race 108 (Stavelly, 1998a), were used to differentiate *Ur-4*- and *Ur-11*-based resistance (Stavelly et al., 1983). Because each of the named snap bean cultivars and the F_3 individual in the first cross were homozygous for the *I* gene, testing for BCMV resistance was delayed until near the end of the breeding program. With completion of the final cross, progeny were increased and the F_2 selected for rust resistance and snap bean quality in Beltsville, Md. Subsequent selection for yield, plant type, pod, and seed confirmation was conducted at three sites in Belle Glade and Homestead, Fla., from the F_3 to F_5 generations. Individual field selections in the F_5 generation were bulk increased in the greenhouse to produce the F_6 progeny,

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for 'Opus', 'Pod Squad', and the three breeding lines averaged 28.5–30 g/100 seed.

Availability

These three breeding lines are released without restriction. Small samples of seed may be obtained either from BTS or JRS. Seed has also been deposited in the U.S. Dept. of Agriculture (USDA) germplasm repository at Pullman, Wash.

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