The Soybean Resistance Gene Rag1 Does Not Protect Against Soybean Cyst and Root-knot Nematodes

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Abstract
The soybean cyst nematode (SCN), Heterodera glycines, is the main soybean (Glycine max) pest in the United States (3); in addition, root-knot nematodes (RKN), Meloidogyne spp., also cause substantial yield losses. Currently, the most feasible option for nematode management is the use of resistant soybean cultivars; however, only a few different sources of resistance to SCN have been identified and introduced in commercial cultivars (3).

Disciplines
Agricultural Science | Biochemistry, Biophysics, and Structural Biology | Plant Breeding and Genetics | Plant Pathology

Comments
The Soybean Resistance Gene \textit{Rag1} Does Not Protect Against Soybean Cyst and Root-knot Nematodes

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The soybean cyst nematode (SCN), \textit{Heterodera glycines}, is the main soybean (\textit{Glycine max}) pest in the United States (3); in addition, root-knot nematodes (RKN), \textit{Meloidogyne} spp., also cause substantial yield losses. Currently, the most feasible option for nematode management is the use of resistant soybean cultivars; however, only a few different sources of resistance to SCN have been identified and introduced in commercial cultivars (3).

Another important pest of soybean is the soybean aphid (SBA), \textit{Aphis glycines}. SBA causes decreases in yield that can reach up to 40%. Aphid management relies on the use of insecticides, although resistant soybean cultivars are currently being tested. The aphid resistance present in the soybean cultivar Dowling is the best characterized (1) and is controlled by \textit{Rag1}, a single dominant gene that produces a strong antibiosis-type resistance. This gene may belong to the NBS-LRR type of resistance genes (2), but it has not yet been cloned.

The only well-characterized gene controlling aphid resistance is \textit{Mi-1.2}, a tomato gene that confers resistance not only to aphids but also to RKN (4). \textit{Mi-1.2} belongs to the NBS-LRR family and functions as a single dominant gene. Based on these similarities between \textit{Mi-1.2} and \textit{Rag1}, we hypothesized that \textit{Rag1} could also provide resistance to nematodes. Thus, we evaluated two related soybean lines, LD16060 and SD01-76R (provided by Dr. Brian Diers, University of Illinois), that carry the \textit{Rag1} gene or no resistance gene, respectively, for susceptibility or resistance to SCN and RKN.

For SCN, the soybean cultivars were planted in soil infested with SCN. The soybean cultivar Jack was used as a nematode-resistant control and the cultivar Kenwood 94 was a susceptible control. The number of SCN females that developed on SD01-76R and LD16060 were not significantly different (Fig. 1A), indicating that \textit{Rag1} does not affect susceptibility to SCN. A similar experiment was conducted with RKN. Two tomato cultivars, susceptible or resistant to RKN, were used as controls to verify that RKN infection was occurring normally. The tomatoes and the two soybean lines, with or without \textit{Rag1}, were grown in soil infested with \textit{Meloidogynes incognita}. There was no significant difference in the number of galls on roots (Fig. 1B) of the soybean plants with or without \textit{Rag1}. 
Fig. 1. Effect of Rag1 on nematode infections. (A) Two related soybean lines, LD16060 and SD01-76R, that carry the Rag1 gene or no resistance gene respectively, were sowed in soil infested with the soybean cyst nematode (SCN). Plants were collected after 45 days, and SCN females were removed from roots and counted. The soybean varieties Kenwood 94 and Jack were used as susceptible and resistant controls, respectively. (B) A soybean line carrying the Rag1 gene (LD16060) and a related line without Rag1 (SD01-76R) were sowed in soil infested with the root-knot nematode (RKN, *Meloidogyne incognita*). Plants were collected after 45 days of growth, roots were stained, and galls were quantified. RKN susceptible (Early Girl hybrid) and resistant (Beefmaster hybrid) tomato plants were used as controls. In both experiments ten plants of each line were used, and the experiment was repeated three times with similar results. Results from a representative experiment are shown. Means with the same letter were not significantly different (Fisher’s least-significant-difference test, a = 0.05). * Data were normalized by root volume.
Finally, to confirm that \textit{Rag1} provided efficient protection against SBA in the soybean line tested, we performed a non-choice growth chamber experiment. The line carrying \textit{Rag1} was very poorly colonized by SBA, whereas there were high numbers of SBA on the susceptible line, which lacked \textit{Rag1} (Fig. 2). This result confirmed that \textit{Rag1} provides strong antibiosis-type resistance against SBA.

Our results suggest that \textit{Rag1} will not be useful as protection against SCN or RKN, although it provides good protection against SBA. However, we cannot discard other effects of \textit{Rag1} when both nematodes and SBA are present on the plant simultaneously. Our results also suggest that \textit{Rag1} confers resistance to SBA by a mechanism that differs from that of \textit{Mi-1.2}. Thus, it will be important to dissect such mechanism to understand soybean resistance to SBA.

\textbf{Literature Cited}