Supplement to the

JOURNAL OF NEMATOLOGY

VOLUME 30 DECEMBER 1998 NUMBER 4S

Supplement to the Journal of Nematology 30(4S):525–529. 1998.

# VIEWPOINT

## Managing Soybean Resistance to *Heterodera glycines*

LAWRENCE D. YOUNG

*Abstract: Heterodera glycines* is an economically important pest of soybean in the United States. The steps necessary to manage this nematode are to sample for inoculum density, identify the race present, and then select appropriate control measures. Planting resistant cultivars is the most widely used management practice, and this tactic has provided enormous economic benefits. However, the nematode has adapted to each source of resistance deployed. The time required for the nematode to adapt to resistant cultivars is lengthened by including nonhost crops and susceptible cultivars in rotations with resistant cultivars. Searching for new sources of resistance and developing more techniques to prolong the effectiveness of resistance genes are necessary to maintain profitability for soybean producers.

*Key words: Glycine max,* management, nematode, race, resistance, rotation, soybean, soybean cyst nematode, yield loss.

During the past 40 years, the soybean cyst nematode, *Heterodera glycines,* has developed into a nationally important pest from what once was considered a problem only in the southern United States. The nematode is now found in most states where soybean (*Glycine max*) is grown commercially. *H. glycines* may cause nearly as much yield suppression in soybean as all other pathogens combined. The estimated value of this yield suppression in the United States in 1994 was $438.8 million; yield suppression by the nematode worldwide was valued at $667.1 million (Wrather et al., 1997). Producers associate nematode damage with severe stunting and chlorosis of plants. However, Noel (1992) measured 20% to 30% yield losses in fields infested with the nematode when there was an absence of severe stunting and chlorosis. Young (1996) obtained 16% to 32% greater yield in Tennessee with a resistant cultivar than with a susceptible cultivar in absence of visible symptoms of nematode infection in infested fields. Yields of the two cultivars were nearly equal in noninfested fields. Niblack et al. (1992) reported that symptoms were not consistently observed in fields in Iowa with known infestations of the nematode.

The first step in managing *H. glycines* is periodic sampling for nematode infestations. Sampling allows diagnosis of an infestation in the absence of visual symptoms and should become as common as sampling for soil fertility. Currently, an extensive campaign is under way in the midwestern United States to get farmers to sample for the nematode. Renewed extension efforts are probably needed in other states.

The second step in managing the nematode is race identification. The race can change over time, especially if resistant cultivars are frequently planted. Races 3 and 14 were frequently found in Tennessee in the 1970s. Races 2 and 5 have become prevalent in recent years (Young, 1990). Optimum cultivar selection is dependent on knowledge of the race present in a field. Yield of 'Deltapine 415' (resistant to race 3) soybean was significantly less than yield of 'Asgrow 5979' (resistant to races 3 and 14) during a

---

Received for publication 1 October 1998.

[1] USDA ARS, Crop Genetics and Production Research, 605 Airways Blvd., Jackson, TN 38301-3201.

E-mail: youngl@ars.usda.gov.

4-year period in a field infested with race 14 (Young, 1996). Yields of the two cultivars did not significantly differ in a nearby field infested with race 3. Periodic sampling may be substituted for race identification if a history of crops and cultivars planted is known. Once the nematode population approaches the damage threshold after a resistant cultivar has been planted, the race should be identified to determine if a cultivar with an alternate source of resistance can be planted. Although resources are available in most states to process soil samples for nematode population density, resources are currently inadequate to process many samples for race identification. However, a consistent demand for race identification services would likely be met by either university or private laboratories.

Although the race identification scheme (Riggs and Schmitt, 1988) has many flaws, it has provided a practical means of communicating the genetic diversity of *H. glycines* and provided the basis of selecting resistant cultivars for planting. Many cultivars are marketed, in part, by their resistance to specific races. The utility of the race scheme probably resulted from the fortunate selection of the differentials. The differential 'Pickett' was the first resistant cultivar and derived its resistance from another differential, 'Peking' (Dong et al., 1997). Plant Introduction (PI) 88788 was resistant to most populations parasitizing Pickett and was used to develop another group of resistant cultivars. PI 90763 is resistant to many populations parasitizing PI 88788 but has not been widely used in cultivar development, probably due to the identification of PI 437654 as being resistant to most *H. glycines* races (Anand, 1992). Schmitt and Shannon (1992) recommended that PI 437654 be included in race determination tests but not for race identification. If all populations parasitizing PI 437654 are race 4 (Davis et al., 1996; Dias et al., 1998; Young, 1998b), then this race could be divided into PI 437654 positive and negative groups. This system would be simpler than changing to a 25-race scheme. Basing race identification on the source of cultivar resistance will enable an easier transition to a new race scheme based on specific genes present either in the nematode or the plant (Dong et al., 1997). Molecular marker technology holds promise for use of a specific gene scheme (Concibido et al., 1997).

The third step in managing the nematode is selection of control measures. Planting resistant cultivars is the most widely used management practice. This practice is often combined with cultural practices, such as rotation with nonhost crops, planting date manipulation, and conservation tillage. Blends of resistant and susceptible cultivars also have been tried (Wallace et al., 1995; Young and Hartwig, 1992). Nematicides are still available, but they may be expensive and have given inconsistent yield improvements of susceptible cultivars (Epps et al., 1981; Smith et al., 1991). Untreated resistant cultivars often yield more than the nematicide-treated susceptible cultivars.

Planting resistant cultivars has been effective in increasing yields in infested fields. Planting 'Forrest' soybean in seven states during 1975 to 1980 increased yield an estimated $401 million (Bradley and Duffy, 1982). In southern Illinois, a county agent demonstrated a $50 million increase in farm income by planting resistant cultivars (Noel, 1992). However, planting resistant cultivars places intense selection pressure favoring *H. glycines* genotypes that can reproduce on the cultivar. The resistance found in 'Peking' was first utilized commercially when the cultivar Pickett was released in 1966 (Brim and Ross, 1966). It was effective against race 1 commonly found in North Carolina and against race 3 commonly found in other states in the southern United States. Soon after the deployment of 'Pickett', *H. glycines* populations were found parasitizing it. Most of these populations (races 6, 9, or 14) reproduced poorly on PI 88788, the resistant donor for 'Bedford' (Hartwig and Epps, 1978) and many current cultivars. Although races 1 and 3 predominate in the northern United States (Kim et al., 1997), PI 88788 has been used as the resistance source in most cultivars for these maturity zones because it provides resistance to most of the important races. Many *H. glycines* populations that can damage cultivars with the PI 88788 resistance have been found in North Carolina (Koenning and Barker, 1998) and Tennessee (Young, 1990). In these states, race 2 has become prevalent. The Hartwig cultivar is resistant to race 2 and most of the other races. PI 437654 provides the broad resistance found in 'Hartwig' (Anand, 1992). This cultivar has been planted on limited hectarage because its yield potential is much below cultivars with other sources of resistance. In some tests, Hartwig did not yield any better than susceptible cultivars in infested fields (Young, 1996).

The multiple-race resistance found in PI 437654 is controlled by several genes and can be viewed as a natural pyramid of resistance genes. Because early attempts to select *H. glycines* populations that could reproduce on the plant introduction were unsuccessful (Leudders and Anand, 1989), it was hoped that the resistance in PI 437654 would be stable for many years. However, populations have been selected in the greenhouse that can reproduce on 'Hartwig' (Young, 1998b). One population was selected from a field population of *H. glycines*. When the resistance found in PI 437654 is widely deployed in more cultivars, it may be no more stable than the resistance in 'Peking' and PI 88788. The search for new effective resistance must be continued (Boerma and Hussey, 1992; Dong et al., 1997).

Since resistance genes fail to remain effective for many years, practices that extend the durability of the genes have been proposed. Rotation of resistant and susceptible cultivars, often in combination with nonhost crops, and rotation of cultivars with different sources of resistance have been suggested to extend the time that resistance genes are effective.

Planting a susceptible cultivar relieves selection pressure on the nematode population since all nematode genotypes can reproduce on it. It was hypothesized that *H. glycines* genotypes parasitizing resistant cultivars are less fit, in absence of selection pressure. Thus, the wild-type genotypes incapable of parasitizing resistant cultivars may predominate when susceptible cultivars are planted, thereby helping stabilize the race. A series of field experiments (Young, 1998a; Young and Hartwig, 1992) show that planting a susceptible cultivar does not stabilize the race but does lengthen the time required for the shift in gene frequencies. The female index measured on a resistant cultivar increased with each cycle of resistant cultivar, nonhost, and susceptible cultivar rotation through three cycles. The female index on the resistant cultivar (Young, 1998a), after three cycles of the rotation, was approximately that obtained after planting the resistant cultivar for 3 consecutive years. Other studies (Young, 1994; Young and Hartwig, 1988) confirm that planting the susceptible cultivar does not prevent the shift toward greater female index on resistant cultivars. However, using rotations that lessen selection pressure prolongs the effectiveness of each combination of resistance genes and is advantageous. Resistance genes are relatively rare, and their effectiveness should be guarded to the maximum extent possible. Crop rotations may also increase yields by reducing other pathogens.

Rotating cultivars with different sources of resistance was proposed for managing shifts in the nematode by manipulating the selection pressure exerted on the nematode (Leudders and Dropkin, 1983; Young, 1982). Greenhouse studies (McCann et al., 1982; Young, 1984) showed that the resistant germplasm could be divided into two genetic groups. As the female index increased on members of one group, it often decreased on members of the other group. Thus, by alternating cultivars derived from each group, gene frequency changes could be manipulated. When the system was attempted in field studies, selection pressure exerted by one cultivar appeared much stronger than the pressure exerted by cultivars from the other group (Young, 1998a). Even if a more balanced combination of cultivars could be selected, the system would be difficult to maintain in an environment of rapidly changing cultivar availability that is experienced today. Also, less-than-optimum cultivar combinations could be selected if growers placed higher priority on other cultivar traits.

Resistant cultivars are likely to remain the primary means of lessening yield suppression by *H. glycines* in the immediate future. Other sources of resistance may exist in soybean germplasm (Dong et al., 1997). Resistance found in soybean germplasm may be augmented with genes transferred from other crops (Boerma and Hussey, 1992) or perhaps manufactured. The ability of the nematode to adapt to such technologically induced resistance is unknown. Thus, other control measures must be explored. Schmitt (1991) described management schemes based on planting date and cultivar maturity for *H. glycines* control in North Carolina that did not use resistance. Effectiveness of such practices probably will be sensitive to different environmental conditions experienced in various regions; however, these systems are worthy of further study.

In summary, *H. glycines* is an important pest of soybean. Producers need to monitor the infestation levels in their fields and the race present. Resistant cultivars have provided significant economic benefits. However, the nematode has adapted to each source of resistance after it was deployed. Thus, it is imperative that methods to increase the longevity of resistance genes be studied in different regions of the United States, that the search for new resistance genes continues, and that alternatives to use of resistance for suppression of this nematode be developed.

## LITERATURE CITED

Anand, S. C. 1992. Registration of 'Hartwig' soybean. Crop Science 32:1069–1070.

Boerma, H. R., and R. S. Hussey. 1992. Breeding plants for resistance to nematodes. Journal of Nematology 24:242–252.

Bradley, E. B., and M. Duffy. 1982. The value of plant resistance to soybean cyst nematode: A case study of Forrest soybeans. National Resource Economics Staff Report No. AGES820929, USDA, Washington, DC.

Brim, C. A., and J. P. Ross. 1966. Registration of Pickett soybeans. Crop Science 6:305.

Concibido, V. C., D. A. Lange, R. L. Denny, J. H. Orf, and N. D. Young. 1997. Genome mapping of soybean cyst nematode resistance genes in 'Peking', PI 90763, and PI 88788 using DNA markers. Crop Science 37: 258–264.

Davis, E. L., S. R. Koenning, J. W. Burton, and K. R. Barker. 1996. Greenhouse evaluation of selected soybean germplasm for resistance to North Carolina populations of *Heterodera glycines, Rotylenchulus reniformis,* and *Meloidogyne* species. Supplement to the Journal of Nematology 28:590–598.

Dias, W. P., J. F. V. Silva, R. A. S. De Kiihl, D. M. Hiromoto, and R. V. Abdelnoor. 1998. Quebra da resistencia da cv. Hartwig por populacao de campo do nematoide de disto da soja (*Heterodera glycines*). Pesquisa Agropecuaria Brasileira 33:971–974.

Dong, K., K. R. Barker, and C. H. Opperman. 1997. Genetics of soybean-*Heterodera glycines* interactions. Journal of Nematology 29:509–522.

Epps, J. M., L. D. Young, and E. E. Hartwig. 1981. Evaluation of nematicides and resistant cultivar for control of soybean cyst nematode race 4. Plant Disease 65: 665–666.

Hartwig, E. E., and J. M. Epps. 1978. Registration of 'Bedford' soybeans. Crop Science 18:915.

Kim, D. G., R. D. Riggs, R. T. Robbins, and L. Rakes. 1997. Distribution of races of *Heterodera glycines* in the central United States. Journal of Nematology 29:173–179.

Koenning, S. R., and K. R. Barker. 1998. Survey of *Heterodera glycines* races and other plant-parasitic nematodes on soybean in North Carolina and race status of *Heterodera glycines* populations. Supplement to the Journal of Nematology 30:569–576.

Leudders, V. D., and S. C. Anand. 1989. Attempt to select a cyst nematode population on soybean plant introduction 437654. Journal of Nematology 21:264–267.

Leudders, V. D., and V. H. Dropkin. 1983. Effect of secondary selection on cyst nematode reproduction on soybeans. Crop Science 23:263–264.

McCann, J., V. D. Leudders, and V. H. Dropkin. 1982. Selection and reproduction of soybean cyst nematodes on resistant soybeans. Crop Science 22:78–80.

Niblack, T. L., N. K. Baker, and D. C. Norton. 1992. Soybean yield losses due to *Heterodera glycines* in Iowa. Plant Disease 76:943–948.

Noel, G. R. 1992. History, distribution, and economics. Pp. 1–13 *in* R. D. Riggs and J. A. Wrather, eds. Biology and management of the soybean cyst nematode. St. Paul, MN: APS Press.

Riggs, R. D., and D. P. Schmitt. 1988. Complete characterization of the race scheme for *Heterodera glycines.* Journal of Nematology 20:392–395.

Schmitt, D. P. 1991. Management of *Heterodera glycines* by cropping and cultural practices. Journal of Nematology 23:348–352.

Schmitt, D. P., and G. Shannon. 1992. Differentiating soybean responses to *Heterodera glycines* races. Crop Science 32:275–277.

Smith, G. S., T. L. Niblack, and H. C. Minor. 1991. Response of soybean cultivars to aldicarb in *Heterodera glycines*-infested soils in Missouri. Supplement to the Journal of Nematology 23:693–698.

Wallace, M. K., J. H. Orf, and W. C. Stienstra. 1995. Field population dynamics of soybean cyst nematode on resistant and susceptible soybeans and their blends. Crop Science 35:703–707.

Wrather, J. A., T. R. Anderson, D. M. Arsyad, J. Gai, L. D. Ploper, A. Porta-Puglia, H. H. Ram, and J. T. Yorinori. 1997. Soybean disease loss estimates for the top 10 soybean-producing countries in 1994. Plant Disease 81: 107–110.

Young, L. D. 1982. Reproduction of differentially selected soybean cyst nematode populations on soybeans. Crop Science 22:385–388.

Young, L. D. 1984. Changes in the reproduction of *Heterodera glycines* on different lines of *Glycine max*. Journal of Nematology 16:304–309.

Young, L. D. 1990. Survey of soybean cyst nematode races in Tennessee. Supplement to the Journal of Nematology 22:672–675.

Young, L. D. 1994. Changes in the *Heterodera glycines* female index as affected by ten-year cropping sequences. Journal of Nematology 26:505–510.

Young, L. D. 1996. Yield loss in soybean caused by *Heterodera glycines*. Supplement to the Journal of Nematology 28:604–607.

Young, L. D. 1998a. Influence of soybean cropping sequences on seed yield and female index of the soybean cyst nematode. Plant Disease 82:615–619.

Young, L. D. 1998b. *Heterodera glycines* populations selected for reproduction on Hartwig soybean. Journal of Nematology 30:523 (Abstr.).

Young, L. D., and E. E. Hartwig. 1988. Selection pressure on soybean cyst nematode from soybean cropping sequences. Crop Science 28:845–847.

Young, L. D., and E. E. Hartwig. 1992. Cropping sequence effects on soybean and *Heterodera glycines*. Plant Disease 76:78–81.