

## Effects of Continuous Cropping of Resistant and Susceptible Cultivars on Reproduction Potentials of *Heterodera glycines* and *Globodera tabacum solanacearum*<sup>1</sup>

A. P. ELLIOTT,<sup>2</sup> P. M. PHIPPS,<sup>3</sup> AND R. TERRILL<sup>3</sup>

**Abstract:** The reproductive potentials of *Heterodera glycines* (mixture of races 3 and 4 and unidentified races) and a tobacco cyst nematode *Globodera tabacum solanacearum* were studied in the field. The experiments involved four cultivars of soybean *Glycine max* and four cultivars of *Nicotiana tabacum*. The reproductive potential of the *H. glycines* population was high on Essex and Lee 74 soybean but low on Forrest and Bedford over the 3 years (1982-84) of continuous cropping. The reproductive potential of *H. glycines* was 12% on Forrest and 6% on Bedford in 1982 but increased to 37 and 35% in 1983 and to 71 and 41% in 1984, respectively, on these two cultivars. The reproductive potential of *G. tabacum solanacearum* was high on McNair 944 and Coker 319 tobacco cultivars and low on VA 81 and PD 4 over the 3 years of cropping. The reproductive potential of *G. tabacum solanacearum* on VA 81 and PD 4 was 18 and 17% in 1982, 7 and 16% in 1983, and 5 and 5% in 1984, respectively. The changes in reproductive potentials of *H. glycines* and *G. tabacum solanacearum* may be related to inherent genetic variability in the systems that control reproduction of the two cyst nematodes and nature of resistance incorporated in the soybean and tobacco cultivars.

**Key words:** *Glycine max*, *Nicotiana tabacum*, soybean cyst nematode, tobacco cyst nematode, plant resistance, population dynamics.

The soybean cyst nematode (SCN) *Heterodera glycines* Ichinohe (8) is an economic pest in 22 states in the United States including seven counties in Virginia (2,17). A tobacco cyst nematode (TCN) *Globodera tabacum solanacearum* (Miller and Gray) (14), Stone (21) occurs in 10 counties in Virginia (4,10). Several races of *H. glycines* have been identified from field populations (6,12,13,17,19,22). Reports on the biotype status of *G. tabacum solanacearum* are limited to differences in reproductive potentials on tobacco cultivars with resistance to this nematode (5,7,15,20).

Planting resistant cultivars is one method of managing nematodes (1,11,17). However, several researchers have found that continuous cropping of resistant cultivars results in development of new nematode biotypes adapted to these cultivars (16-18,22,23).

Our objective was to examine the pop-

ulation dynamics and reproductive potentials of *H. glycines* and *G. tabacum solanacearum* under continuous cropping systems of susceptible and resistant cultivars.

### MATERIALS AND METHODS

Field experiments were conducted during 1982-84 with a population of *H. glycines* consisting of predominantly race 3, some race 4, and an unidentified race. Experiments were conducted on an Emporia fine sandy loam soil in Southampton County, Virginia, in a randomized block design of four replicates of four *Glycine max* (L.) Merr cultivars (Essex and Lee 74, susceptible to all races of *H. glycines*, and Forrest and Bedford, resistant to races 1 and 3 and races 3 and 4, respectively) (1). Four-row plots were 7.6 m long with 0.9 m between rows. Soybean cultivars were planted on 10 June 1982, 8 June 1983, and 6 June 1984; the same cultivars were located in the same plots each year.

Field experiments with *G. tabacum solanacearum* were conducted on a Wedowee clay loam soil during 1982-84 at the Southern Piedmont Research Center in Blackstone, Virginia, with *Nicotiana tabacum* L. cultivars McNair 944 and Coker 319 (susceptible) and VA 81 and PD 4 (resistant) (7,11). Four-row plots were 6.1 m long with 1.22 m between rows. Tobacco

Received for publication 31 July 1985.

<sup>1</sup> This research was funded by the Virginia Soybean Commission and Virginia Polytechnic Institute and State University Experiment Station Regional Research Project (S-154).

<sup>2</sup> Assistant Professor, Division of Nematology, University of California, Davis, CA 95616.

<sup>3</sup> Associate Professors, Tidewater Research Center, and Southern Piedmont Research Center, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.

The authors thank the staff of the VPI&SU Nematology Laboratory for their technical assistance.

TABLE 1. Population densities (cysts/500 cm<sup>3</sup> soil) of *Heterodera glycines* and *Globodera tabacum solanacearum* on four soybean and four tobacco cultivars (1982).

| Soybean cultivar | <i>Heterodera glycines</i> |      |        |        |      |       |       | Tobacco cultivar | <i>Globodera tabacum solanacearum</i> |      |       |        |
|------------------|----------------------------|------|--------|--------|------|-------|-------|------------------|---------------------------------------|------|-------|--------|
|                  | Sampling date              |      |        |        |      |       |       |                  | Sampling date                         |      |       |        |
|                  | 6/10                       | 7/1  | 8/3    | 8/24   | 9/13 | 10/6  | 11/18 |                  | 5/17                                  | 6/10 | 8/2   | 8/24   |
| Essex            | 73 a                       | 18 a | 324 a  | 110 ab | 19 a | 201 a | 319 a | McNair 944       | 13 a                                  | 13 a | 40 a  | 130 ab |
| Lee 74           | 98 a                       | 22 a | 135 ab | 129 a  | 19 a | 188 a | 359 a | Coker 319        | 9 a                                   | 8 a  | 2 b   | 185 a  |
| Forrest          | 89 a                       | 18 a | 29 b   | 73 b   | 13 a | 43 b  | 42 b  | VA 81            | 20 a                                  | 8 a  | 15 ab | 34 b   |
| Bedford          | 73 a                       | 25 a | 69 b   | 60 b   | 15 a | 43 b  | 20 b  | PD 4             | 8 a                                   | 4 a  | 2 b   | 32 b   |

Column means followed by the same letter(s) are not significantly ( $P = 0.05$ ) different according to the Duncan's multiple-range test.

transplants were planted on 7 May 1982, 10 May 1983, and 15 May 1984; the same cultivars were located in the same plots each year.

Soil samples for nematode analyses were taken from soybean and tobacco plots at planting and at harvest. The two center rows of each soybean plot were harvested on 27 November 1982 and 14 November 1983 for yield data but not in 1984 because of poor growth and yield. Leaves from tobacco plants in the two center rows of each plot were harvested on 12 August 1982, 24 August 1983, and 24 August 1984 in three pullings, with the first one-third of the leaves being pulled during the second week of August; two additional leaf harvests were taken 2 and 4 weeks after the initial harvest. Cysts were extracted from 500 cm<sup>3</sup> soil by elutriation (3) and collected on a 250- $\mu$ m-pore sieve. After cysts were counted, they were blended for 1 minute in a Waring blender to release eggs which were collected on a 25- $\mu$ m-pore sieve. Vermiform nematodes including second-stage juveniles (J2) of *H. glycines* were extracted from 500 cm<sup>3</sup> soil by elutriation (3) and centrifugal-flotation (9). An index of reproduction (IR) was calculated as (number

of cysts recovered from a test cultivar/number of cysts recovered from a standard susceptible cultivar)  $\times$  100. Nematode population densities were determined as numbers of nematodes per 500 cm<sup>3</sup> soil. Statistical analysis systems (SAS) programs were used to compute analyses of variance and provide graphic representation of data.

## RESULTS

*H. glycines*: Population dynamics in 1982 indicated that greater cyst population densities were associated with Essex and Lee 74 than with Forrest and Bedford (Table 1). Large final population densities of cysts, eggs within cysts, and J2 of *H. glycines* were associated with Essex and Lee 74 soybeans, whereas significantly ( $P = 0.05$ ) lower densities of all stages were associated with Forrest and Bedford over the 3 years (Fig. 1A-C). Lee 74 was selected as the standard susceptible cultivar with an IR of 100. The IR for *H. glycines* on Essex was slightly below that for Lee 74 in 1982 and 1983 but increased to 235% in 1984 (Table 2). The IR for Forrest was only 12% in 1982 but increased to 71% by 1984. Bedford had the lowest IR, 6%, in 1982; this increased to 35% in 1983 and was only slightly higher, 41%, in 1984. In 1982, Essex and Lee 74 yields were significantly ( $P = 0.05$ ) lower than those from Forrest but not from Bedford (Fig. 2). Essex yield was significantly ( $P = 0.05$ ) lower than Lee 74 in 1983 but not different from the other cultivars (Fig. 2).

*G. tabacum solanacearum*: Final population densities of *G. tabacum solanacearum* cysts, eggs within cysts in 1982 and 1984, and J2 in 1983 and 1984 were significantly greater ( $P = 0.05$ ) on McNair 944 and Coker 319 than densities associated with VA

TABLE 2. Influence of 3-year continuous cropping of four soybean cultivars on indices of reproduction (IR) of *Heterodera glycines*.

| Cultivar | IR   |      |      |
|----------|------|------|------|
|          | 1982 | 1983 | 1984 |
| Essex    | 89   | 92   | 235  |
| Forrest  | 12   | 37   | 71   |
| Bedford  | 6    | 35   | 41   |

IR is based on 100 for Lee 74 as the standard susceptible cultivar = no. of cysts recovered from test cultivar/no. of cysts recovered from Lee 74  $\times$  100.

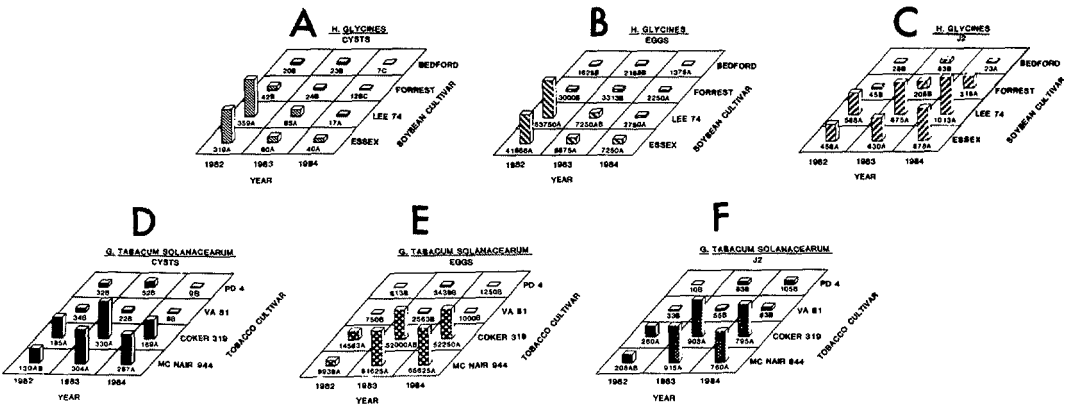


FIG. 1. Effect of continuous cropping of soybean cultivars on (A) cysts, (B) eggs within cysts, and (C) second-stage juveniles (J2) of *Heterodera glycines* associated with four soybean cultivars; (D) cysts, (E) eggs within cysts, and (F) J2 of *Globodera tabacum solanacearum* associated with four tobacco cultivars. Vertical bars represent final mean nematode population densities at harvest expressed as cysts, eggs within cysts, and second-stage juveniles. Numbers below vertical bars represent final mean nematode population densities of cysts, eggs within cysts, and second-stage juveniles at harvest per 500 cm<sup>3</sup> soil. Mean densities within each year followed by the same letter(s) are not significantly ( $P = 0.05$ ) different.

81 and PD 4 (Table 1, Fig. 1D-F). Coker 319 was selected as the standard susceptible cultivar with an IR of 100. The IR of McNair 944 was somewhat below that of Coker 319 in 1982 and 1983, but higher (158%) in 1984 (Table 3). The IR of VA 81 and PD 4 remained low throughout the 3 years of testing. VA 81 yielded more than Coker 319 and PD 4 in 1983 and more than any other cultivar in 1984 (Fig. 3).

DISCUSSION

Results from these studies indicated that the reproductive potentials of *H. glycines* and *G. tabacum solanacearum* differed under continuous cropping of resistant and susceptible soybean and tobacco cultivars.

The lower reproductive potentials on Forrest and Bedford cultivars and higher yields obtained in 1982 indicate that these cultivars were offering some resistance to this population of *H. glycines* in 1982. The increases in indices of reproduction associated with Forrest and Bedford indicate the development of *H. glycines* biotypes capable of reproducing on these cultivars. Although cyst population densities associated with susceptible cultivars were lower in 1984, the J2 densities were high on susceptible cultivars but low on cultivars with some resistance. The low cyst population densities could be related to time of sampling which corresponded to hatching of second-stage juveniles. The higher yields associated in 1982 with Lee 74 (which has resistance to *M. incognita*) and lower yields associated with other cultivars may be re-

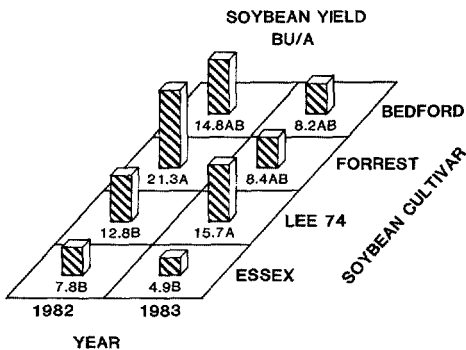


FIG. 2. Soybean yield as affected by continuous cropping of soybean cultivars associated with *Heterodera glycines*.

TABLE 3. Indices of reproduction (IR) of *Globodera tabacum solanacearum* on four tobacco cultivars, over a 3-year continuous cropping sequence.

| Cultivar   | IR   |      |      |
|------------|------|------|------|
|            | 1982 | 1983 | 1984 |
| McNair 944 | 70   | 92   | 158  |
| VA 81      | 18   | 7    | 5    |
| PD 4       | 17   | 16   | 5    |

IR is based on 100 for Coker 319 as the standard susceptible cultivar = no. of cysts recovered from test cultivar/no. of cysts associated with Coker 319 × 100.

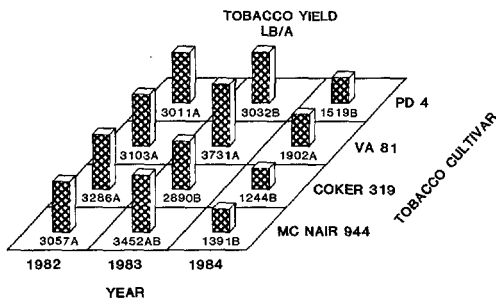


FIG. 3. Tobacco yield as affected by continuous cropping of tobacco cultivars associated with *Globodera tabacum solanacearum*.

lated to the population of *Meloidogyne* spp. at the field test site. The general decrease in cyst population densities over the 3 years could be related to competition from the concomitant *Meloidogyne* population. The low IR maintained on VA 81 and PD 4 indicated that resistance to *G. tabacum solanacearum* was maintained over the 3 years of continuous cropping. The maintenance of resistance against *G. tabacum solanacearum* may be related to the multigenic nature of resistance incorporated into VA 81 and PD 4 (15,20).

The differences in reproductive potentials of the two cyst nematodes could be related to inherent reproductive potential variability resulting from differences in their genetic systems controlling reproduction and the nature of the resistance incorporated into the resistant cultivars. Continuous cropping of VA 81 and PD 4 tobacco cultivars, with multigenic resistance to *G. tabacum solanacearum*, may be recommended since loss of resistance was not demonstrated.

#### LITERATURE CITED

1. Anonymous. 1984. The soybean cyst nematode. W. F. Moore, chairman. The American Soybean Association and the Southern Soybean District Workers, Mississippi State University.
2. Brewer, F. L. 1982. Special assessment of the soybean cyst nematode (*Heterodera glycines*) problem. Joint planning and evaluation staff paper. United States Department of Agriculture, Washington, D.C.
3. Byrd, D. W., K. R. Barker, H. Ferris, C. J. Nusbaum, W. E. Griffin, R. H. Small, and C. A. Stone. 1976. Two semi-automatic elutriators for extracting nematodes and certain fungi from soil. *Journal of Nematology* 8:206-212.
4. Elliott, A. P., P. M. Phipps, D. A. Komm, D. Babineau, K. Yoder, J. Reilly, and C. Harris. 1983.

The predictive nematode assay program at Virginia Tech. Extension Publication 450-071. Virginia Polytechnic Institute and State University Cooperative Extension Service, Blacksburg, Va.

5. Fox, J. A., and L. Spassoff. 1976. Resistance and tolerance of tobacco to *Heterodera solanacearum*. *Journal of Nematology* 8:284-285.

6. Golden, A. M., J. M. Epps, R. D. Riggs, L. A. Duclos, J. A. Fox, and R. L. Bernard. 1970. Terminology and identity of infraspecific forms of the soybean cyst nematode (*Heterodera glycines*). *Plant Disease Reporter* 54:544-546.

7. Grant, C. E., J. J. Reilly, and A. P. Elliott. 1981. Reproduction of *Globodera solanacearum* and its effects on growth and development of three flue-cured tobacco cultivars under greenhouse conditions. *Journal of Nematology* 14:443 (Abstr.).

8. Ichinohe, M. 1959. Studies on the soybean cyst nematode *Heterodera glycines* and its injury to soybean plants in Japan. *Plant Disease Reporter Supplement* 260:239-248.

9. Jenkins, W. R. 1964. A rapid centrifugal-floitation technique for separating nematodes from soil. *Plant Disease Reporter* 48:692.

10. Komm, D. A., J. A. Reilly, and A. P. Elliott. 1983. Epidemiology of a tobacco cyst nematode (*Globodera solanacearum*) in Virginia. *Plant Disease* 67:1249-1251.

11. Komm, D. A., T. R. Terrill, and A. P. Elliott. 1982. Evaluation of selected flue-cured tobacco varieties with and without a nematocide for control of a tobacco cyst nematode. *American Phytopathological Society. Fungicide Nematicide Reports* 37:33.

12. McCann, J., V. H. Dropkin, and V. C. Luedders. 1980. The reproduction of differentially selected populations of *Heterodera glycines* on different R-lines of soybean (*Glycine max*). *Journal of Nematology* 12:230-231 (Abstr.).

13. Miller, L. I. 1967. Comparison of the pathogenicity of and development of the VA 2 isolate of *Heterodera glycines* on Pickett and Lee soybean. *Phytopathology* 57:647 (Abstr.).

14. Miller, L. I., and B. J. Gray. 1968. Horsenettle cyst nematode *Heterodera virginiae* n.sp., a parasite of solanaceous plants. *Nematologica* 14:535-543.

15. Miller, L. I., J. A. Fox, and L. Spassoff. 1972. Genetic relationships of resistance to *Heterodera solanacearum* in dark-fired and Burley tobacco. *Phytopathology* 62:778 (Abstr.).

16. Price, M., C. E. Caviness, and R. D. Riggs. 1978. Hybridization of races of *Heterodera glycines*. *Journal of Nematology* 10:114-118.

17. Riggs, R. D. 1982. Cyst nematodes in the southern USA. Pp. 77-95 in R. D. Riggs, ed. *Nematology in the southern region of the United States*. Southern Regional Cooperative Series Bulletin 276. Fayetteville, Ark.

18. Riggs, R. D., M. L. Hablen, and L. Rakes. 1977. Development of *Heterodera glycines* pathotypes as affected by soybean cultivars. *Journal of Nematology* 9:312-318.

19. Ross, J. P. 1964. Physiological strains of *Heterodera glycines*. *Plant Disease Reporter* 46:766-769.

20. Spassoff, L., J. A. Fox, and L. I. Miller. 1971. Multigenic inheritance of resistance to Osborne's cyst nematode. *Journal of Nematology* 3:329-330 (Abstr.).

21. Stone, A. R., H. M. Platt, and L. F. Khalil.

1983. Concepts in nematode systematics. New York: Academic Press.

22. Triantaphyllou, A. C. 1975. Genetic structure of races of *Heterodera glycines* and inheritance of ability

to reproduce on resistant soybeans. *Journal of Nematology* 7:356–364.

23. Vanderplank, J. E. 1982. Host–pathogen interactions in plant disease. New York: Academic Press.