Supplement to Journal of Nematology 22(4S):795–799. 1990.


# Evaluation of Soybeans in Maturity Groups I–IV for Resistance to *Heterodera glycines*[1]

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*Abstract:* Forty-seven private and public soybean (*Glycine max*) cultivars in maturity groups I, II, III, and IV were evaluated in the field for resistance to *Heterodera glycines* race 3 and race 4 at two sites, Kilbourne and Urbana, Illinois. The soil at Kilbourne was an irrigated sand infested with race 3. The soil at Urbana was a nonirrigated silty clay loam infested with race 4. Yield of nematode-susceptible controls was reduced at both locations, and yield differences were observed among the other cultivars. Soybeans grown in sand yielded less than the soybean grown in silty clay loam. Although populations of *H. glycines* recovered at planting were lower at Kilbourne than at Urbana, a greater percentage of loss in yield was associated with the sand at Kilbourne. Several soybean cultivars had a high level of resistance to both populations of *H. glycines*.

*Key words: Glycine max, Heterodera glycines,* resistance, soybean, soybean cyst nematode.

The source of resistance to *Heterodera glycines* Ichinohe from PI 88788 has been incorporated into the soybean (*Glycine max* (L.) Merr.) germplasm L77-994 and cultivar Fayette (a subline of L77-994)(1). L77-994 was released in 1980 and Fayette in 1981. These two lines are probably the source of resistance to *H. glycines* transferred into most of the resistant soybeans in maturity groups I–III. At present, there are approximately 90 early-maturing public cultivars and private product lines with resistance to the nematode. Some of the private product lines are blends which are given brand names, but the contents in the seed bag may be unknown to the purchaser because Illinois seed law does not require disclosure. Since Fayette and some other public resistant cultivars are not protected by the Plant Variety Protection Act, private companies may sell them under their own label as a brand with the cultivar not stated. The objective of this study was to evaluate eight resistant public cultivars and 35 private product lines in the field against *H. glycines* races 3 and 4.

## MATERIALS AND METHODS

Experiments with soybeans in maturity groups (MG) I–II, III, and IV are established at the University of Illinois, Illinois River Valley Sand Field farm near Kilbourne on 28 May 1989 and at the USDA nematology research farm at Urbana on 2 June 1989. Public cultivars Century 84 (MG II), Williams 82 (MG III), and Union (MG IV) and the private cultivar A3127 (MG III) were used as controls susceptible to *H. glycines*. The public cultivars used for resistant controls were Bell (MG I); CN290 and Jack (MG II); Cartter, Fayette, and Linford (MG III); and Franklin and Pyramid (MG IV). The private soybeans tested were ST 1350 (MG III), ST 1397 (MG III), and ST 1460 (MG IV) from AgriPro Seeds, Ames, Iowa; Assure (MG II), Conquest (MG III), Spirit (MG III), and Jackson (MG IV) from Americana Seeds, Bowen, Illinois; A3415 (MG III), A3636 (MG III), and A4009 (MG IV) from Asgrow Seed Co., Des Moines, Iowa; BT 390c (MG III), BT 399c (MG III), and BT 440c (MG IV) from Bergman-Taylor Seeds, St. Jacob, Illinois; 8270N (MG II), 1380Nx (MG III), 9320Nx (MG III), 1466Nx (MG IV), and 9455Nx (MG IV) from Callahan Seeds, Westfield, Indiana; G-3407 (MG III) and G-3808 (MG III) from Funk, Ciba-Geigy Seed Division, Greensboro, North Carolina; HS 3411 (MG III) and HS 4011 (MG IV) from Growmark, Bloomington, Illinois; JMS 3309 (MG III), JMS 3609 (MG III), and JMS 4100 (MG IV) from JM Schultz Seed Co.,

Received for publication 20 March 1990.

[1] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products that also may be suitable.

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The authors thank M. K. Zimmerman, Research Technician, Plants, and S. K. Sipp, Farm Manager, for assistance.

Dieterich, Illinois; Cherokee VI (MG II) and Madison II (MG III) from Merschman Seeds, West Point, Iowa; 9402 (MG IV) from Pioneer Hi-bred International, Tipton, Indiana; 340 (MG III), 360 (MG III), 394 (MG III), and 440 (MG IV) from Seedex, Sheriden, Indiana; and 3012 (MG III), 3062 (MG III), and 3880 (MG III) from Stine Seed Farm, Adel, Iowa.

Cyst counts at planting were 0–21/250 $cm^3$ soil at Kilbourne and 7–31/250 $cm^3$ soil at Urbana. The soils at Kilbourne (series Plainfield [mixed, mesic Typic Udipsamments; surface layer texture = sand, organic matter = 1%, pH = 6.5]) and at Urbana (series Drummer [fine-silty, mixed, mesic Typic Haplaquolls; surface layer texture = silty clay loam, organic matter = 6%, pH = 5.5]) were maintained at fertility levels recommended by the University of Illinois. The field at Kilbourne required an application of 0-0-60 (N-P-K) fertilizer at 168 kg/ha. A soybean cultivar trial had been planted at Kilbourne in 1988, and the soil was infested with *H. glycines* race 3. The site at Urbana, planted with a susceptible soybean cultivar in 1988, was infested with *H. glycines* race 4. Fall tillage was not done at either site; both sites received minimum tillage in the spring. No herbicides were applied at Kilbourne before or at planting, whereas at Urbana metolachlor was preplant incorporated at the rate of 2.78 kg a.i./ha. Sethoxydim was applied at Kilbourne on 16 June at the rate of 0.26 kg a.i./ha, and on 16 July sethoxydim and bentazon were applied at rates of 0.32 and 1.12 kg a.i./ha, respectively, with 1.17 liters of crop oil concentrate/ha. Experiments at both sites also were cultivated for weed control. Depending on the amount of rainfall, the field at Kilbourne was scheduled to receive 20 mm of supplemental irrigation every 5 days, but the irrigation system was not operational from planting (28 May) until 13 June and from 13 July to 28 July. Rainfall and irrigation were recorded at Kilbourne.

Entries within a test (MG) were arranged in a randomized complete block design. There were two replications at Kilbourne and three at Urbana. Each experimental unit was four 7-m-long rows on 76-cm centers. Seeds were planted at the rate of 33/m. A two-row combine was used to harvest 4.7 m from the two center rows. Because of poor stands at Kilbourne, only 1.8 m of the two center rows were harvested from some plots and other plots were not harvested. Seeds were cleaned, dried, and weighed. Moisture content was adjusted to 14% and yield was determined.

At both sites, numbers of cysts were determined at planting and numbers of females were determined at 6 weeks after planting. Twenty soil cores were collected with a 2-cm-d soil probe in a zig-zag pattern from the center two rows of each experimental unit 3–7 cm from the base of plants and to a depth of 10–15 cm. Cysts and females were extracted from 250-$cm^3$ aliquants (2) with nested 850-$\mu$m-pore and 180-$\mu$m-pore sieves and counted with a dissecting microscope. Numbers of females and a developmental factor (Df = females at 6 weeks/cysts at planting) were determined for each line.

Since many plants in plots planted with resistant cultivars were not vigorous at Kilbourne, plants in border rows of several plots were sampled on 20 July and the root systems were placed in a mist extraction chamber on Baermann funnels for 3 days to extract *Pratylenchus* spp. Numbers of nematodes per gram of dry root were determined.

Because of missing values in the data from the trials at Kilbourne, yield, numbers of females, and Df were analyzed using the PROC GLM procedure of SAS (5). Data obtained at Urbana were subjected to the analysis of variance. Means for the data obtained from both sites were separated using Fisher's protected least significant difference (FLSD) ($P \leq 0.05$) except for the MG I–II test at Kilbourne where the data were insufficient to calculate an error mean square for numbers of females. Since those treatments for which the mean number of females was 0 would not contribute any variability to the data, those data were not included in the analysis. The

data also were transformed using $\log_{10}$ (x + 1) and analyzed, but separation of means did not differ from that of nontransformed data.

## Results and Discussion

Yield of susceptible controls in each of the three tests at both Kilbourne and Urbana was low, indicating that sufficient numbers of nematodes were present to cause crop loss (Table 1). At both locations, yields from the MG III test were higher than those from the MG I–II and MG IV tests. The percentage of loss in yield was greater at Kilbourne than at Urbana, as indicated by comparing the lowest and highest yielding entries in each test. In the MG I–II test at Kilbourne, the yield of Century 84 was 37% that of resistant Jack, whereas at Urbana the yield of Century 84 was 54% that of 8270N. In the MG III test at Kilbourne, the yield of 3880 was 22% that of Cartter, and at Urbana the yield of Williams 82 was 52% that of 1380Nx. A similar trend was observed in the MG IV tests. At Kilbourne the yield of Union was 32% that of A4009, and at Urbana the yield of Union was 59% that of A4009. The results of these tests confirm earlier observations that loss in yield caused by *H. glycines* is more severe when soybeans are planted in lighter textured soil (3,6) and damage thresholds are near 0 when the soil is a sand (6).

Several factors confounded the results of these experiments. The lack of early season rainfall and breakdown of the irrigation system at Kilbourne resulted in poor stands. The lack of soybean development delayed the initiation of the weed control program which resulted in moderate weed infestation throughout all three tests during the entire season. The breakdown of the irrigation system during the last 2 weeks of July was not a problem, since approximately 80 mm of rain fell during that period. Numbers of *Pratylenchus scribneri* Steiner recovered from plants sampled on 20 July ranged from 0 to 1,450/g dry root, but fewer than 100/g dry root were recovered from most samples. Some plots probably were infested with sufficient numbers of *P. scribneri* to reduce yield (4). At Urbana, the experiment was placed in the lower area of the field. There was some Phytophthora root rot, primarily in the MG III test. Symptoms indicated that the disease was not severe, but yield of some lines may have been affected. For example, in an adjacent test in an area of the field having better drainage, Fayette and Williams 82 yielded 3,095 and 2,104 kg/ha, respectively, compared with 2,445 kg/ha for Fayette and 1,747 kg/ha for Williams 82 in this cultivar trial (Table 1). Williams 82 has resistance to several races of *Phytophthora megasperma* Drechs. f. sp. *glycinea* Kuan and Erwin, but Fayette does not. The MG IV soybeans and the later maturing MG III lines were injured by an early frost at Urbana. Although Kilbourne is approximately the same latitude as Urbana, soybeans ripened earlier and there appeared to be no damage due to frost. Many growers prefer to plant MG IV soybeans on the sandy soils typical of that area of Illinois.

The public cultivars Bell (MG I), Jack (MG II), and Cartter, Fayette, and Linford (MG III) have PI 88788 as their source of resistance to *H. glycines*. During the development of these cultivars, greenhouse and field evaluations demonstrated that they have a moderate level of resistance to both races 3 and 4. Numbers of females recovered from these cultivars were approximately 15% of those recovered from susceptible controls such as Williams 82. That so few females were recovered on these cultivars and private product lines at Kilbourne does not necessarily indicate a high level of resistance to race 3, but rather that the females were below the detection level. The public cultivars CN290 and Franklin have the cultivar Peking as their source of resistance, and Pyramid has resistance from both PI 88788 and Peking. In view of the low yields of CN290 and Franklin at Urbana, the low number of females recovered from these cultivars and the low Df values were unexpected.

All of the private soybeans included in the experiments were evaluated because

TABLE 1. Yield of soybeans in maturity groups (MG) I–IV resistant to *Heterodera glycines*, and populations of *H. glycines* at two sites† in Illinois.

| Kilbourne | | | | Urbana | | | |
|---|---|---|---|---|---|---|---|
| Entry | Yield (kg/ha) | Females/ 250 cm³ soil | Df‡ | Entry | Yield (kg/ha) | Females/ 250 cm³ soil | Df‡ |
| | | | MG I–II | | | | |
| Jack | 1,353 | 0 | 0.00 | 8270N | 2,688 | 1 | 0.06 |
| Bell§ | 1,184 | < 1 | 0.03 | Cherokee VI | 2,551 | 4 | 0.30 |
| Cherokee VI | 901 | 0 | 0.00 | Bell | 2,536 | 0 | 0.00 |
| 8270N | 866 | < 1 | 0.03 | Assure | 2,417 | 1 | 0.09 |
| CN290 | 767 | 0 | 0.00 | Jack | 2,340 | 1 | 0.05 |
| Assure | 582 | 0 | 0.00 | CN290 | 1,673 | 8 | 0.66 |
| Century 84‖ | 498 | 7 | 0.78 | Century 84‖ | 1,462 | 20 | 1.40 |
| FLSD ($P \leq 0.05$) | 372 | —¶ | 0.02 | | 268 | 9 | 0.58 |
| CV % | 13.6 | — | 1.1 | | 6.72 | 86.2 | 74.0 |
| | | | MG III | | | | |
| Cartter | 2,187 | 0 | 0.00 | 1380Nx | 3,349 | < 1 | 0.02 |
| 1380Nx | 1,976 | 0 | 0.00 | 3062 | 3,239 | 2 | 0.11 |
| G-3407 | 1,841 | 0 | 0.00 | ST 1397 | 2,969 | 1 | 0.10 |
| HS 3411 | 1,782 | 0 | 0.00 | HS 3411 | 2,946 | 0 | 0.00 |
| 3062 | 1,690 | 0 | 0.00 | A3415 | 2,864 | 1 | 0.06 |
| BT 390c | 1,669 | 0 | 0.00 | Conquest | 2,846 | 2 | 0.14 |
| 9320Nx | 1,645 | 0 | 0.00 | Cartter | 2,842 | < 1 | 0.02 |
| Linford | 1,621 | 0 | 0.00 | G-3407 | 2,839 | 3 | 0.24 |
| G-3808 | 1,600 | 0 | 0.00 | BT 390c | 2,804 | < 1 | 0.03 |
| Fayette | 1,522 | 0 | 0.00 | G-3808 | 2,800 | 2 | 0.15 |
| Madison II | 1,282 | 1 | 0.14 | 9320Nx | 2,796 | 2 | 0.19 |
| Conquest | 1,242 | 0 | 0.00 | 340 | 2,793 | 0 | 0.00 |
| ST 1397 | 1,236 | 0 | 0.00 | JMS 3309 | 2,755 | 1 | 0.10 |
| BT 399c | 1,154 | 0 | 0.00 | BT 399c | 2,730 | 0 | 0.00 |
| A3415 | 1,139 | 0 | 0.00 | Linford | 2,678 | 3 | 0.21 |
| Spirit | 1,122 | 0 | 0.00 | Madison II | 2,676 | 2 | 0.25 |
| 340 | 998 | 5 | 0.36 | 360 | 2,652 | 4 | 0.24 |
| JMS 3309 | 923 | 0 | 0.00 | 3012 | 2,466 | 4 | 0.27 |
| JMS 3609 | 912 | 0 | 0.00 | Fayette | 2,445 | 1 | 0.07 |
| 360 | 878 | 2 | 0.12 | Spirit | 2,280 | 1 | 0.08 |
| ST 1350 | 761 | 6 | 0.41 | A3636 | 2,260 | 1 | 0.17 |
| A3127‖ | 744 | 2 | 0.40 | JMS 3609 | 2,243 | 2 | 0.19 |
| Williams 82‖ | 667 | 3 | 0.22 | A3127‖ | 2,112 | 14 | 1.36 |
| 394 | 658 | 4 | 0.41 | ST 1350 | 1,997 | 15 | 1.48 |
| A3636 | 561 | 2 | 0.23 | 394 | 1,840 | 18 | 1.31 |
| 3012 | 528 | 2 | 0.26 | 3880 | 1,838 | 6 | 0.44 |
| 3880 | 484 | 4 | 0.57 | Williams 82‖ | 1,747 | 20 | 1.83 |
| FLSD ($P \leq 0.05$) | 708 | NS | NS | | 498 | 6 | 0.60 |
| CV % | 25.7 | 2.7 | 95.1 | | 11.7 | 78.3 | 95.2 |
| | | | MG IV | | | | |
| A4009 | 1,637 | 0 | 0.00 | A4009 | 2,960 | 3 | 0.33 |
| Jackson | 1,469 | 0 | 0.00 | JMS 4100 | 2,858 | 1 | 0.09 |
| Franklin | 1,462 | 0 | 0.00 | Jackson | 2,685 | 0 | 0.00 |
| 9402 | 1,398 | 0 | 0.00 | HS 4011 | 2,491 | 0 | 0.00 |
| JMS 4100 | 1,385 | 0 | 0.00 | 9402 | 2,360 | 1 | 0.07 |
| HS 4011 | 1,233 | 2 | 0.22 | 440 | 2,255 | 7 | 0.55 |
| Pyramid | 1,114 | 0 | 0.00 | BT 440c | 2,238 | 1 | 0.12 |
| 9455Nx | 987 | 1 | 0.40 | 1466Nx | 2,059 | 4 | 0.23 |
| 1466Nx | 841 | 2 | 0.45 | Pyramid | 1,847 | 0 | 0.00 |
| BT 440c | 701 | 8 | 0.92 | 9455Nx | 1,837 | 2 | 0.16 |
| ST 1460 | 655 | 4 | 0.44 | ST 1460 | 1,751 | 12 | 1.28 |

TABLE 1. Continued.

| Entry | Kilbourne Yield (kg/ha) | Kilbourne Females/ 250 cm³ soil | Kilbourne Df‡ | Entry | Urbana Yield (kg/ha) | Urbana Females/ 250 cm³ soil | Urbana Df‡ |
|---|---|---|---|---|---|---|---|
| Union‖ | 524 | 0 | 0.00 | Union‖ | 1,711 | 3 | 0.35 |
| 440 | 383 | 5 | 0.56 | Franklin | 1,141 | 1 | 0.06 |
| FLSD ($P \leq 0.05$) | NS | NS | NS | | 357 | 6 | 0.48 |
| CV % | 43.2 | 130.1 | 96.9 | | 9.5 | 109.4 | 124.8 |

Data are means of two replications at Kilbourne and three replications at Urbana. When no females were recovered, those values (mean = 0) were not included in the analysis of females and Df. FLSD = Fisher's protected least significant difference. NS = no significant ($P \leq 0.05$) differences among entries.

† Kilbourne and Urbana infested with *H. glycines* race 3 and 4, respectively.

‡ Df = females at 6 weeks/cysts at planting.

§ MG I cultivar.

‖ *Heterodera glycines*-susceptible control(s) within each maturity group.

¶ Since the error mean square could not be calculated, data were not analyzed.

they either were marketed in 1989 or sold in 1990 for control of *H. glycines.* Certain private soybeans appeared to have a low level of resistance to the race 3 and race 4 populations infesting the fields used for these experiments. During their development these soybeans may have been evaluated against other populations of the nematode for which they had a higher level of resistance. Some of the private soybeans had high yields and low numbers of females at both sites. The high level of resistance provided by 1380Nx in the MG III test and A4009 and Jackson in the MG IV test indicated that they have resistance genes from both Peking and PI 88788. At least one entry, A3636, is a blend consisting of 25% A3415. Other blends may have been included in the test, but that information was not available.

Our results may not be applicable in other locations, because of the various environmental factors, races of *H. glycines,* and population levels of the nematode that might be encountered. In Illinois, many county agents of the Cooperative Extension Service conduct soybean trials in their counties. Although these trials usually do not include analysis of nematode populations, the yield results are meaningful. Those local tests, as well as the information presented here, should provide information on the expected performance of private and public soybeans used for management of *H. glycines* in the state.

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