

Screening Sugarbeet for Resistance to *Heterodera schachtii* Schm.

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Received for publication April 14, 1969

The cyst nematode, *Heterodera schachtii* Schm., has long been one of the most destructive pests of sugarbeets in many of the major sugarbeet growing areas of the world. Control has been largely by crop rotation. Resistance to other *Heterodera* species has been found and successfully incorporated into other crop plants, such as oats (4)², potato (5), and soybeans (1,2). Resistance in these crops has been largely qualitative and selection has been based on nematode cyst counts.

An apparent qualitative resistance has been found in the *Patellares* section of *Beta* (3,7). However, interspecific breeding has been extremely difficult and the incorporation of this resistance into the cultivated sugarbeet has not yet been achieved. Screening for a qualitative resistance in the cultivated sugarbeet has been carried on in the past without success. However, screening for different levels of quantitative resistance has achieved moderate success (6).

The purpose of this study was to determine if programs could be made within the *Beta vulgaris* species by selecting for different levels of quantitative resistance based on white female counts.

Methods and Materials

A great deal of plant-to-plant environmental variation for number of nematode cysts has been observed (8); therefore, the following technique was developed to reduce this variation. Instead of planting in nematode-infested soil, test plants were inoculated with surface-sterilized sugarbeet nematode larvae. The larvae were hatched and surface sterilized by a method developed by Whitney and Doney (9).

Figure 1 shows the type of containers used. These were 55 and 185 ml clear plastic vials with a hole in the bottom for drainage. The vials were filled with a dark, well aerated, sandy soil. In order to prevent growth of algae, masonite covers were placed on flats and the vials were placed in holes drilled through the tops as shown in Figure 2. Seedlings grown from surface sterilized seed were transplanted into these containers.

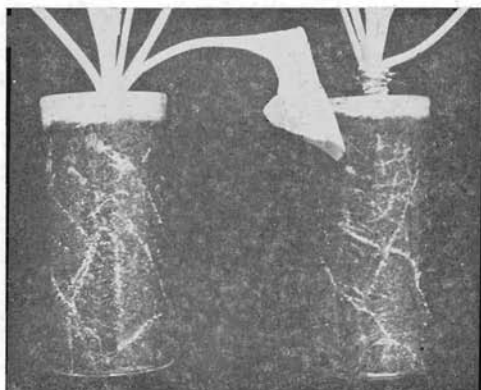


Figure 1.—Clear plastic vials used for nematode counting. White dots along roots are white females.

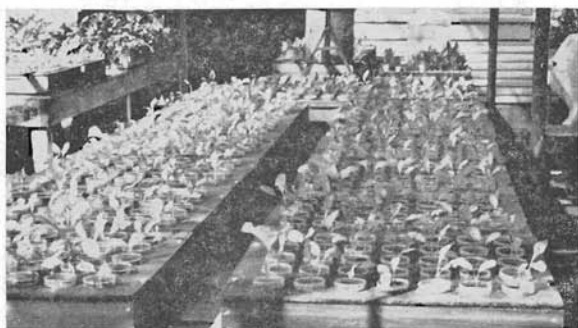


Figure 2.—Flats in which vials were placed.

ml vials, and 3,000 larvae onto the 185 ml vials, when good root growth was observed at the soil-vial interface. White females were counted about 4 weeks after inoculation.

Three separate studies were conducted in which the number of white females at the soil-vial interface was correlated with the total number of cysts. In all three tests a correlation of greater than .90 was obtained. Thereafter, the counting consisted of white females at the soil-vial interface only.

Table 1.—Mean numbers of white females at the soil-vial interface.

Variety or selection	Parent or source	Tests					
		615	607	608b1	608b2	608a1	608a2
590-1	S2	50.4 ^a	123.9 ^a	27.1 ^a	138.1 ^{ab}	30.1 ^a	85.7 ^{bc}
S2	Spreckels Sugar Co.	-----	150.5 ^a	31.8 ^a	118.8 ^{ab}	9.2 ^b	87.8 ^{bc}
228-1	US 41	30.3 ^c	169.8 ^a	31.1 ^a	141.3 ^{ab}	15.3 ^{ab}	94.2 ^{abc}
US 41	USDA	42.0 ^{abc}	187.8 ^a	32.5 ^a	143.2 ^{ab}	11.0 ^b	109.0 ^{ab}
592-3	US 33	32.1 ^{bc}	149.1 ^a	28.8 ^a	141.1 ^{ab}	8.3 ^b	112.8 ^a
US 33	USDA	33.1 ^{bc}	160.6 ^a	33.0 ^a	131.1 ^{ab}	12.0 ^b	97.2 ^{abc}
594-2	US 22	29.1 ^c	116.6 ^a	29.1 ^a	173.0 ^a	15.8 ^{ab}	82.7 ^c
56-408	Amer. Crystal	37.8 ^{abc}	154.4 ^a	34.9 ^a	129.8 ^{ab}	12.6 ^b	114.9 ^a
Acc 107	Klein E mix*	45.8 ^{ab}	189.8 ^a	33.2 ^a	108.9 ^b	7.1 ^b	107.2 ^{ab}
62-9134, F ₁	R. Hecker	-----	189.4 ^a	28.9 ^a	107.3 ^b	-----	-----
C5600	B. Hammond	12.7 ^d	150.4 ^a	29.8 ^a	92.1 ^b	15.4 ^{ab}	106.4 ^{ab}
US 15	USDA	41.8 ^{abc}	-----	33.5 ^a	157.7 ^{ab}	10.2 ^b	-----

Note: Any two means followed by the same letter are not significantly different at $P = .05$.

* A mixture of nematode tolerant lines from Klein E seed obtained from G. J. Curtis, Cambridge, England.

The plant materials selected for these trials were as follows: (1) several of the best sugarbeet nematode tolerant selections; (2) parents, if available, of the above mentioned selections; (3) other open-pollinated varieties of different origin having a broad genetic base; and (4) a uniform hybrid and a homozygous line for estimation of environmental error. Altogether, a total of 27 different lines were tested. Each line was tested in at least two tests, and some lines were tested in as many as six tests. Each test consisted of approximately 800 plants.

In order to evaluate quantitative resistance and compute the expected progress, an estimate of the genotypic variance is necessary. When evaluating a heterozygous population on a per plant basis, the total phenotypic variation is a combination of the environmental variation plus the genotypic variation as illustrated below.

$$\begin{aligned} \text{Phenotypic variance (Heterozygous)} &= \text{Var}_e + \text{Var}_g \\ \text{where: } \text{Var}_e &= \text{the environmental variance} \\ \text{Var}_g &= \text{the genotype variance} \end{aligned}$$

The total phenotypic variation of a homozygous population gives an estimate of the environmental variance as illustrated below.

$$\text{Phenotypic variance (Homozygous)} = \text{Var}_e$$

An estimate of the genotypic variance can be obtained from the difference between these two variances. An F test for the homogeneity of variance is the appropriate test for a significant genotypic variance.

Results

The mean number of white females per plant for each line in each test is shown in Tables 1, 2, and 3. In most of the tests there was little difference between the varieties for number of white female nematodes. However, there were a few tests in which significant differences were found between varieties. In no test did the selections have significantly fewer white females than their parents. On the other hand, there was a large variation among tests. Because of the nature of the tests statistical inferences could not be made on the pooled means over tests; therefore, tests were not combined.

There was a large variety times test interaction; i.e., varieties differed in their relation to each other from test to test. However, two varieties were somewhat consistent from test to test. US 41 (Table 1) was relatively high in number of white females in all tests it appeared in. One of the check varieties (C5600) was consistently high in nematode counts in the series of tests shown in Table 2. However, it ranged from low to high in the other two series of tests (Tables 1 and 3). To measure the consistency

Table 2.—Mean number of white females at the soil-vial interface.

Variety or line	Source	Tests		
		708g1	708g2	708g3
F58-554H1	J. McFarlane	9.40 ^b	13.64 ^b	69.46 ^{ab}
C5600	B. Hammond	15.70 ^a	18.50 ^a	74.03 ^a
GW 359	Great Western	11.10 ^b	18.86 ^a	45.95 ^d
C877	Great Western	8.50 ^b	14.48 ^b	53.50 ^{cd}
C878	Great Western	11.30 ^b	—	—
B888	Great Western	10.70 ^b	13.65 ^b	67.19 ^{ab}
B889	Great Western	9.70 ^b	14.23 ^b	57.87 ^c
54-604-0	American Crystal	10.60 ^b	11.60 ^b	50.97 ^{cd}
60-604-0	American Crystal	10.40 ^b	13.38 ^b	52.70 ^{cd}

Note: Any two means followed by the same letter are not significantly different at $P = .05$.

Table 3.—Mean number of white females at the soil-vial interface.

Variety or line	Source	Tests	
		708d1	708d2
F58-554H1	J. McFarlane	19.31 ^c	21.67 ^{ab}
C5600	B. Tammond	35.40 ^b	27.17 ^a
Tetra-Tri-Polanowice	G. Coe (European origin)	43.30 ^a	25.22 ^a
Budapest Poly Beta 4	G. Coe (European origin)	40.30 ^{ab}	25.94 ^a
Poly Mono Poli-0	G. Coe (European origin)	19.20 ^c	—
Budapest Poly Beta 2	G. Coe (European origin)	25.00 ^c	26.80 ^a
A. J. Poli 2	G. Coe (European origin)	19.70 ^c	24.59 ^a
Buszycynski P Poly	G. Coe (European origin)	35.50 ^b	26.01 ^a
56-gH#3-M-1	American Crystal	29.50 ^b	18.80 ^b

Note: Any two means followed by the same letter are not significantly different at $P = .05$.

of varieties in relation to each other from test to test, varieties were ranked in each test and Spearman's rank correlation coefficient computed for each pair of tests. A significant ranked correlation was not found between any pair of tests.

Even though differences were observed between varieties in some tests, when the large variation among tests and the large variety times test interaction are considered, no variety consistently produced fewer females than another.

For each test, the total environmental variance and the total phenotypic variance for the heterozygous populations were computed and tested for a significant genotypic variance (Table 4). In no test was there a significant total genotypic variance. In addition to the total variances, the individual varieties in each test were tested for a genotypic variance. There were 7 varieties that exhibited a significant genotypic variance in one test. Even though each variety was tested several times, no variety exhibited a significant genotypic variance for the number of white females in more than one test.

To test the reliability of these results a selection scheme was set up in a population of 1,300 plants of several heterozygous varieties. From this population 215 plants that had less than 10

Table 4.—Estimated total phenotypic variances for white female counts.

Test	Homozygous Pop'n (Var _e)	Heterozygous Pop'n (Var _e + Var _g)
607	8,254	6,063
608a1	178	211
608a2	3,077	2,642
608b1	350	277
608b2	9,208	11,222
708g1	112	94
708g2	1,409	1,081
708g3	124	104
708d1	288	284
708d2	231	377

Var_e = environmental variance.

Var_g = genotypic variance.

white females at the soil-vial interface were selected. These were classed as resistant. Another group of 75 plants with high nematode counts was also selected from this population and classed as susceptible. These plants were tested in two more successive tests. At the conclusion of the third test the selection group classed as resistant had almost the same number of white females per plant as the selection group classed as susceptible (Table 5).

Table 5.—Selection for nematode resistance from an initial population of 1,300 plants.

Test	No.	\bar{x} nematode count of Resistant selections	No.	\bar{x} nematode count of Resistant selections
1	215	5.98	75	56.60
2	207	63.50	73	81.64
3	203	50.60	73	49.60

Discussion and Conclusions

These results indicate that there is either little or no resistance to the sugarbeet nematode in the cultivated sugarbeet; or, the environmental variation involved in this method of selection is too great to detect small differences. This indicates that very little progress can be expected by selecting for a quantitative resistance based on this technique.

Many attempts have been made to reduce this large environmental variance. The technique developed in this study was one attempt. Different methods of inoculation have been studied by the authors. One rather important factor contributing to this variation is the number of available fibrous roots. When inoculation takes place the number of available fibrous roots may vary greatly from plant to plant as a result of genetic and environmental variation. This variation may be reflected later in the white female counts.

An estimate was made in one test of the number of observed roots at the time of inoculation with the later white female counts. A significant correlation of .34 was obtained.

If the more vigorous seedlings have more available fibrous roots for nematode invasion at the time of inoculation, greater numbers of white females may be observed on the more vigorous seedlings. Thus, by selecting plants that have fewer white females, selection may then be for the least vigorous seedlings. However, if the plant to plant variation in amount of fibrous roots is largely environmental, selection for fewer white females would not change the seedling vigor.

Summary

A technique was developed for counting white females of *Heterodera schachtii* Schm. on the soil-vial interface without disturbing the roots. Twenty-seven sugarbeet varieties and selections from different sources of origin were tested for a genotypic variance and number of white females.

Differences between varieties were found in some tests, but these differences were not consistent from test to test. Selections did not have significantly fewer white females than their parents. There was a large test times variety interaction and test variance. Little genotypic variance for number of white females was observed.

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