Studies on Backcross Generations and Advanced Generations of Interspecific Hybrids between B. vulgaris and B. webbiana

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In the quest to develop sugar beets with resistance to the sugar beet nematode, *Heterodera schachtii*, several investigators (1, 2, 3, 4, 5, 6, 7)[2] have attempted to make crosses between sugar beets and one or more of the nematode resistant species of the section *Patellares* of the genus *Beta*. Most attempts have resulted in failure of the F_1 seedlings to survive. The reason for this failure of the F_1 seedlings to survive is that they are generally incapable of developing a satisfactory root through which they can draw nutrients and moisture from the soil.

Stewart (7) reported survival of some offspring from a cross between sugar beets and *Beta procumbens*, but this material was lost in later generations due to a combination of inviability of the seedlings and both male and female sterility in the resulting plants. Coe (1), in trying to improve the viability of F_1 seedlings of a cross between sugar beets and *Beta procumbens*, developed a grafting method using small seedlings of both cion and root stock to provide in effect an artificial root on which the F_1 seedlings might survive. Survival rate of the F_1 seedlings was about seven percent. Johnson (3) reported a method of grafting small seedlings of the F_1 plants of the cross between sugar beets and *Beta webbiana* to a well established root stock of sugar beets. This method resulted in 70% survival.

Other approaches to combining the genotypes of one of these wild-type species of the genus, *Beta*, with sugar beets have been reported. Gaskill (2) made a bridge hybrid which consited of initially crossing Swiss chard with *Beta webbiana* and later crossing the F_1 plants, which would survive on their own roots, to sugar beets. Oldemeyer, et al. (5) reported a similar type of cross between *B. maritima* and *B. procumbens* and then crossing the resulting F_1 plants, which also survived on their own roots, to sugar beets. Savitsky (6) has crossed tetraploid *B. patellaris* × tetraploid sugar beets. Crosses of this type produce some F_1 seedlings which grow readily on their own roots.

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[2] Numbers in parentheses refer to literature cited.

Methods and Materials

This paper deals with several generations of crosses between *Beta vulgaris* and *Beta webbiana*. These include the F_1, four backcrosses (B_1, B_2, B_3, and B_4) and the advanced generations of B_2. The main purpose in these crosses was an attempt to transfer the nematode resistance in *B. webbiana* to sugar beets. Seed was produced on male sterile sugar beet plants by supplying pollen from *B. webbiana*. Grafting, as described by Johnson (3), was used to prevent death of the F_1 plants. The surviving F_1 plants were pollinated with pollen from sugar beets. Of the F_1 plants that survived, none produced any pollen. Female sterility was extremely high but a few viable B_1 seedlings were produced. These B_1 seedlings also required grafting for survival. The B_1 plants more closely resembled sugar beets than did the F_1, but they still possessed many of the characteristics of the F_1 plants. All were pollen sterile and female sterility was again very high. The B_1 plants that survived the grafting technique were again pollinated with sugar beet pollen and seed was produced from which five B_2 plants grew. These five plants looked very much like sugar beets. They grew on their own roots, flowered and set seed. One of these plants produced viable pollen, but the other four were male steriles. Table 1 gives the description of these five B_2 plants.

The occurrence of these five plants which grew on their own roots made possible a nematode evaluation which had not been possible through the generations of grafting. The five plants were put in greenhouse flats in cylinders of soil which contained a high population of sugar beet nematode in a manner described

Table 1.—Description of five B_2 plants from a cross between *B. vulgaris* and *B. webbiana*.

Plant number	Description
N51	Indistinguishable from sugar beet in appearance. Small root, produced no pollen, flowered normally and set viable seed. No satisfactory nematode evaluation.
N52	Indistinguishable from sugar beet. Small root produced viable pollen and fertile ovules. Roots contained only one female nematode larvae up to third stage when planted in nematode infested soil.
N53	Indistinguishable from sugar beet, small root, no pollen, fertile ovules. Root contained 2nd and 3rd stage larvae and one dead 4th stage.
N55	Indistinguishable from sugar beet. Large root, no pollen, fertile ovules, susceptible to sugar beet nematode.
N56	Indistinguishable from sugar beet. Large root, no pollen, fertile ovules, suspectible to sugar beet nematode.

by Wheatley and McFarlane (8). As can be seen from Table 1, no satisfactory nematode evaluation was made on plant N51. Plants N52 and N53 appeared to show some resistance to the sugar beet nematode and plants N55 and N56 appeared to be completely susceptible.

Because one of the plants did produce pollen, it was possible to interpollinate the plants of this B_2 generation using plant No. N52 as the pollinator. It was also possible to self-pollinate plant No. N52 and to backcross one more generation to sugar beets, in this manner producing a B_3 generation.

Of the progenies produced from plants in this generation, ten had sufficient seed that some progeny testing could be made under greenhouse conditions for nematode resistance. Only crosses involving plants N51, N52 and N53, as one or both parents of the cross, were used. These plants were grown in nematode infested soil as described previously. Table 2 shows the results of nine of the progenies from these B_2 plants, plus a commercial check when grown in the greenhouse in soil infested with nematodes.

Under the conditions of this test, it can be seen from Table 2 that most of the progenies performed about the same as the open pollinated check variety, S-2, which is susceptible to the sugar beet nematode. There are some exceptions, however. The self-pollinated progeny of plant N52 appears to be excellent

Table 2.—Classification of sugar beet roots of ten progenies from a cross of *B. vulgaris* × *B. webbiana* when grown in greenhouse soil infested with sugar beet nematode, *H. schachtii*.

	Nematode class[1]				
Types of cross:	1	2	3	4	5
N51 × N52		3	7	1	1
N51 × A5601				2	1
N51 × SL340 (4N) Triploid		3	32	11	
N51 × A5218 (2N)			33	12	
N52 (selfed)	3	1	2		
A5218 (4N) × N52 Triploid		4	4		
A5218 (2N) × N52	1		8	12	1
N52 × A5218 (2N	2		9	10	2
N53 × N52				7	2
S-2 (Check)			7	4	1

[1] Classification from 1 to 5 indicate range from 1 (freedom from visible mature female nematodes on the beet roots) to 5 (large numbers of visible mature females on the roots.)

in that it produced no plants in classes 4 or 5 and half of the plants rated as No. 1. Other progenies also contained some very satisfactory plants.

From the ten progenies shown in Table 2, 14 individual plants were selected as being relatively free (class 1 or 2) from sugar beet nematode. As a further check on the visual evaluation of this material, root cuttings were sent to Dr. Morgan Golden of the USDA Station at Salinas, California, for a more accurate determination by staining. The results of his staining counts on these 14 selected plants are shown in Table 3.

Table 3.—Results of examination of stained roots of progeny several generations removed from a cross of *B. vulgaris* × *B. webbiana*.

Plant number	Development of the sugar beet nematode
1	6 larvae (2nd and 3rd stage)[1]; 1 male molting into last stage.
2	6 larvae (3rd stage); 2 males in advanced 3rd stage.
3	4 larvae (3rd stage).
4	2 larvae (3rd stage).
5	6 larvae (3rd stage); 1 molting male.
6	3 larvae (3rd stage).
7	67 larvae in all stages to maturity; females, some developing males and 1 mature male.
8	No nemas found.
9	No nemas found.
10	9 larvae (2nd stage) and 1 molting male.
11	No nemas found.
12	6 larvae in various stage to maturity; 2 mature males.
13	No nemas found.
14	26 larvae (2nd to 4th stage).

[1] Stages from 1 to 5 represent different stages of development in the nematode within the root from very tiny, immature larvae to adults, respectively.

Of the fourteen plants, four (No. 8, 9, 11 and 13) had no larvae in the roots. One plant (No. 7) was apparently misclassified on the basis of visual observation because it contained many larvae in all stages of development. The other plants (12 and 14) also appeared to have some advanced larvae in their roots. The remaining seven beets appeared to have only immature larvae in their roots and were considered to be the group of most value. Roots with advanced stages of larvae development could not be considered resistant and roots with no larvae in the roots are probably escapes because even the roots of the resistant parent, *B. webbiana*, are entered by the larvae of this nematode; however, in this case the larvae are incapable of completing their life cycle.

The seven plants containing only immature larvae were allowed to interpollinate or were crossed back again to sugar beets as desired. This provided a B_4 generation and another advanced generation of B_2 plants. From progenies thus produced 55 were selected in 1958 to plant in progeny rows in a field plot uniformly infested with sugar beet nematode.

Each plot consisted of a single row 20 feet long. They were planted in July and represented the first field testing of this material in soil heavily infested with sugar beet nematode. These beets were indistinguishable in appearance from sugar beets and had excellent vigor. The roots were dug and examined in November of 1958. From the standpoint of nematode resistance, the performance of these roots was disappointing. None of the progenies was without mature female sugar beet nematode on the roots which was similar to the open pollinated standard check with which they were compared. Not a single beet in the entire plot was free from the female nematode cysts.

As a final evaluation of this material, a test was planned to determine the yielding ability of this interspecific hybrid material. For this test, three strains resulting from the interspecific hybrids were compared with an open pollinated check, A5218. Descriptions of the strains follows:

A5920, a composite of all progenies of the B_4 and advanced generations of *B. vulgaris* × *B. webbiana*.

A5921, a composite of 2N lines whose ancestry included crosses involving plant N52 in Table 2.

A5922, a composite of 2N lines whose ancestry included plants N51 and N53 in Table 2.

A5218, a locally adapted, widely used, open pollinated, check variety.

This test was planted April 29 and harvested August 19. The test consisted of eight replications of each strain. Each plot consisted of two rows, 30 feet long, which were harvested for yield. Two samples of ten beets each from each plot were used for sugar determination. The soil in which this test was planted was known to be heavily infested with sugar beet nematode, so heavy that crop failure would result in normal sugar beet strains planted in such soil.

The yield of the check variety, A5218, in this test was only 6.25 tons per acre. One of the interspecific progenies produced a yield significantly different from it. The low yield of the lines in the test was observed to be almost entirely due to sugar beet nematode. Large numbers of nematodes were found on all roots in the plot at harvest time. There were no significant differences among the sugar content of any of these lines.

In the B_2 and B_3 generations, some plants in these lines appeared to show some nematode resistance. Yet in the B_4 and the advanced generations of B_2, no nematode resistance could be observed in either greenhouse or field tests in any of this material. The reason for this at present cannot be readily explained. Future studies will concentrate on further propagation of B_2 and B_3 plants in an attempt to determine more about the nature and inheritance of resistance to the sugar beet nematode. The greenhouse evaluation method used in the B_2 and B_3 generations should also be studied for reliability.

One accomplishment of this test was the demonstration that crosses of this nature can be made in the genus, *Beta*, and plants can be recovered by backcrossing which are indistinguishable from the recurrent parent, in this case sugar beet. The problem here was that the goal of nematode resistance was not achieved.

Summary

1. Interspecific hybrids between *B. vulgaris* and *B. webbiana* were made, propagated and studied through several generations in an attempt to combine the desirable characteristics of *B. vulgaris* with resistance to the sugar beet nematode, *Heterodera schachtii*. From the data presented it can be seen this goal was not achieved.

2. Plants which appeared to show some resistance to the nematode in the B_2 and B_3 generations failed to produce progenies resistant to it.

3. After four backcrosses to sugar beets, the plants produced were indistinguishable from sugar beets in all characteristics evaluated or observed.

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