A Sugarbeet × Beta Procumbens Hybrid and Its Backcross Derivatives

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The species in the *Beta patellares* section of the genus *Beta* remain in the only known source of immunity or high resistance to sugar beet nematode, *Heterodera schactii*. Efforts to find an economical level of resistance to nematode within sugar beet varieties and other races of *Beta vulgaris* have not been successful. Only partial success has been achieved through recurrent mass selection within sugarbeet varieties by which a number of genes each with a minor effect have been concentrated (7)[2].

A number of research stations are apparently continuing a study of the Patellares species in attempt to transfer immunity to sugar beet (1,2,4,5). Most notable of these is the work of Helen Savitsky at Salinas, California (9) in which the major effort is on a polyploid level because it is easier to maintain tetraploid and triploid plants having Patellares germ plasm than diploid ones.

Plants having nematode resistance will be sought in the progeny of the hybrid plants. Resistance might be expected to be transferred as the result of crossing over or the development of trisomics. Irradiation or some other manipulation of trisomics could be used to make a permanent transfer of resistance germ plasm to the sugarbeet genome.

The purpose of this paper is to record the breeding behavior and describe the progeny of a *Beta vulgaris* × *B. procumbens* hybrid referred to as the Turkish wild hybrid because the *B. vulgaris* parent was an annual type commonly found in Turkey. The breeding behavior of sugarbeet hybrids involving this Turkish wild accession did not indicate that cytogenetic differences existed between it and sugarbeet. However, the Turkish wild naturally had cytoplasmic male sterility. The hybrid was first reported by Oldemeyer (6) and was analyzed cytogenetically by Helen Savitsky (8). A description of plants in three generations, F_1, backcross one and backcross two follows:

F_1 hybrid:

This F_1 hybrid was diploid ($2n = 18$), had indeterminant growth and was more or less continually reproductive; morphologically, it was typical of that reported for other Patellares

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[2] Numbers in parentheses refer to literature cited.

hybrids except that it lived on its own roots; it was completely pollen sterile. The F_1 hybrid plant was different from others reported in that it set a relatively large number of fruit when the flowering plant was exposed to sugarbeet pollen (estimated at 10% of the flowers). Examination of the seeds within the fruit indicated seed aborted at all stages of development, but a fraction of them were fully formed and viable. Savitsky's cytogentic investigation indicated, and the breeding behavior confirmed, that this fertility was apparently caused by a process allowing eggs with a non-reduced number of chromosomes to be formed resulting in viable triploid embryos.

Backcross-one plants:

About 150 viable backcross-one plants were produced from a total population of about 300. About one-third of the backcross-one plants died because they produced no secondary roots, behaving as has been reported typically for F_1 hybrids. A smaller group was unthrifty and lived for varying lengths of time, and very few of them grew to produce seed.

The thrifty plants were remarkably uniform morphologically; all were annual, being a little more vegetative than the F_1 hybrid; the new growth was less chlorotic than the F_1 hybrid. No nematode cysts were found on several backcross-one plants after they were grown in nematode infested soil. All the plants were completely male sterile and relatively female sterile although the population was quite variable as to number of fruit set when the plants were exposed to sugarbeet pollen. All plants produced a few seeds; several produced seed enough for a 20 to 80-plant backcross-two population.

Chromosome numbers of 10 of the thrifty plants, counted by Helen Savitsky, indicated they were triploid ($3n = 27$).

Backcross-two plants:

About 700 backcross-two plants were produced of which a few were inviable. The viable plants were of three distinct types. The predominant class was composed of annual or biennial plants which looked like sugarbeets and were fully female fertile. Pollen viability varied from apparently normal to sterile. Neither annualism nor male-sterility could be used as indicating an exchange of germ plasm, because the parental female *B. vulgaris* plant was annual and cytoplasmic male-sterile. Helen Savitsky's counts of the chromosomes of 50 of this class of plants revealed them to be normal diploids ($2n = 18$).

The next most frequent class was one with plants which were sugarbeet-like but were morphologically different from the predominant class. Several types of plants were represented in this class. These plants were generally less vigorous and less fertile than the predominant class. Some had gigas characteristics, i.e. thick, stubby leaves, thick stems and thick expanded flower bracts. The growth of others was quite fine and leafy. The nine extraordinary plants were found to be trisomic ($2n = 19$) by Helen Savitsky.

The other class, composed of only four plants, was morphologically similar to the F_1 hybrid and backcross-one plants except they had gigas characteristics and were completely female sterile as well as male sterile. Chromosome counts indicated these plants were tetraploid and aneuploid. Two had 36, one had 37, and one had 38 chromosomes.

Cytogenetic conclusions:

The relatively high female fertility of the F_1 hybrid apparently was conditioned by a genetic complex which allowed nonreduced eggs to be formed. This was also manifested in the formation of triploid eggs for the production of tetraploid backcross-two progeny. It can be presumed the triploid backcross-one plants had two genomes of *Beta vulgaris* and one genome of *B. procumbens* while the tetraploid backcross-two plants had three genomes of *B. vulgaris* and one of *B. procumbens*. Where the extra chromosomes came from in the 37 and 38 chromosome plants of the backcross-two generation, is open to conjecture. Apparently, the only female gametes of the backcross-one plants which were viable, and which produced viable zygotes, embryos and plants were ones with a full complement of *B. vulgaris* chromosomes.

With the isolation and identification of eight or nine of the nine possible trisomics by Butterfass (3), it might be possible, by comparison to known trisomics, to determine if the extra chromosomes in these new trisomics are of *B. vulgaris* or Patellares origin.

Transfer of germ plasm for *B. procumbens* conditioning nematode resistance might occur as the result of crossing over. Helen Savitsky (9) has indicated three or four chromosomes of *B vulgaris* $\times$ *B. procumbens* or *B. webbiana* hybrids are associated during meiosis. Whether true pairing, with consequential crossing over and resultant germ plasm transfer occurs has never been proved.

It is presumed that nematode resistance is genetically dominant based on our observations of the resistance of plants known to contain Patellares germ plasm and from the similar observations of others (10,11).

Nematode resistance reaction of derivatives:

All pollen fertile backcross-two plants were allowed to interpollinate while the male-sterile ones were pollinated by sugarbeets.

Seed was harvested separately from individual plants. Some 8000 plants in about 400 of these maternal families were transplanted into nematode infested soil in flats in the greenhouse. A maximum of 25 plants were used per family. After 3 months, the soil was gently washed away from the roots of seedlings and the nematode-free plants selected. The intertwining of roots made selection very uncertain so that it was necessary to transplant 2300 plants individually into aluminum foil pots[3] which were filled with soil uniformly infested with nematodes. After about 6 weeks, the aluminum foil was rolled back and the roots examined. Wide degrees of resistance or tolerance were observed. At this time, several plants appeared to be immune of which about 100 plants from this screening were transplanted to 6-inch clay pots filled with nematode infested soil for further screening. After the plants had grown in clay pots for a time, 25 were selected as having no cysts and were therefore presumed to be immune. No one maternal family was represented by more than two plants in this group. Eventually, however, every plant of this group had at least some cysts.

Remnant seed of backcross-two maternal families was planted in a field known to be uniformly heavily infested with nematodes. Considerable inter-family variation as to vigor was observed. All plants of some families died or were very weak while some families were comprised of nearly normal plants, Figure 1.

Figure 1.—Five maternal lines derived from a Turkish wild × *B. procumbens* hybrid grown in soil which had a high population of sugarbeet nematodes (*Heterodera schachtii*). Two lines appear to be tolerant while the alternate rows beginning on the left are highly susceptible. Initial stands were about equal.

[3] McFarlane, J. S. 1953. Mimeographed report to the Beet Sugar Development Foundation.

The roots of all the vigorous plants contained many cysts, indicating the vigor was not due to nematode resistance. No cysts were found on the roots of some of the weak plants, but the necrosis of the fine roots indicated nematode damage. There was no way to ascertain whether this variation was caused by germ plasm from *B. procumbens* or whether it existed in the *B. vulgaris* germ plasm.

With the development of a relatively large population of backcross-one plants, the nematode reaction of backcross-two plants was tested directly rather than growing seed from them. No immunity was found among 550 backcross-two plants.

Following the eventual infection of all plants in the greenhouse and the inconclusive observations in the field, the sugarbeet breeders of Great Western discontinued this project and placed remnant seed of all generations except the F_1 in storage.

It was concluded that the full-time services of a skilled cytologist and nematologist would be required before basic or practical results can be realized from a program such as this. It is hoped that eventually this research can be pursued to a successful end.

Monogerm seed from Procumbens hybrids:

The *Patellares* species cannot be considered a source of a new monogerm seed character. Although the seed clusters on hybrid derivatives, in some cases, were not as tightly fused, it is obvious that several fruits occur at one point and that in the case of Patellares species, their being "monogerm" is dependent upon abscission layers between fruits (10). Such abscission layers could be a definite disadvantage in commercial seed production because the seed would drop after ripening. Premature falling of seed was observed on some plants in this material and in other sugarbeet lines. Although the individual fruit of the multigerm clusters of backcross-one plants were loosely bound, the clusters in backcross-two plants were like those occurring on sugarbeet plants.

Summary

Viable backcross-one progeny of a *Beta vulgaris* × *B. procumbens* plant were uniformly sterile, although a few seeds were set and chromosome numbers of those examined were triploid (2n = 27). Chromosome counts of backcross-two plants revealed diploid (2n = 18), trisomic (2n = 19) or tetraploid (2n = 36, 37, 38) plants. No nematode immunity was observed to be transferred to backcross-two from *Beta procumbens* as determined by extensive screening of hybrid derivatives.

Literature Cited

(1) BANDLOW, GERHARD. 1961. Die Beta wildarten der Sektion Patellares und Kreuzungsversuche mit Zuckerruben. Der Zuckter 31 (8): 362-372.

(2) BORNSCHEUER, E. and E. SCHLOSSER. 1961. Uber Kreuzungen von Beta vulgaris mit Arten der Sektion Patellares der Gattung Beta. Zucker 14: 140-142.

(3) BUTTERFASS, THEODOR. 1964. Die Chloroplastenzahlen in verschiedenartigen Zellen trisomer Zuckerruben (*Beta vulgaris* L.) Zeitschrift für Botanik 52 (1): 46-77.

(4) CURTIS, G. J. 1968. Observations of fruit shape and other characters in the species of the section *Patellares*, genus *Beta*. Euphytica 17: 485-491.

(5) FILUTOWICZ, VON A. and A. KUZDOWICZ. 1959. Artbastarde zwischen Zuckerruben und Beta Patellaris Moq. Zuchter 29: 179-183.

(6) OLDEMEYER, R. K. 1956. Interspecific hybrids in the genus *Beta*. J. Am. Soc. Sugar Beet Technol. 9 (1): 15-20.

(7) PRICE, CHARLES. 1965 Breeding sugar beets for resistance to the cyst nematode *Heterodera schachtii*. J. Am. Soc. Sugar Beet Technol. 13 (5): 397-405.

(8) SAVITSKY, HELEN. 1960. Meiosis in an F_1 hybrid between a Turkish wild beet *Beta vulgaris*, ssp. *maritima* and *Beta procumbens*. J. Am. Soc. Sugar Beet Technol. XI (1): 49-67.

(9) SAVITSKY, HELEN. 1960. Viable diploid, triploid and tetraploid hybrids between *Beta vulgaris* and species of the section *Patellares*. J. Am. Soc. Sugar Beet Technol. XI(3): 215-235.

(10) SAVITSKY, HELEN and CHARLES PRICE. 1965. Resistance to the sugar beet nematode *Heterodera schachtii* in F. tetraploid hybrids between *Beta vulgaris* and *Beta patellaris*. J. Am. Soc. Sugar Beet Technol. 13 (4): 370-373.

(11) SHEPHERD, A. M. 1959. Testing populations of beet eelworm *Heterodera schachtii* Schm. for resistance breaking biotypes using wild beet (*Beta patellaris* moq.) as indicator. Nature 183: 1141-1142.