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Genetic-cytoplasmic Male Sterility in Progeny of 4x-2x Crosses in Cultivated Potatoes

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Summary. Forty-three percent of the progeny from 4x × 2x crosses [Group Tuberosum cultivar × diploid hybrid (Groups Phureja or Stenotomum × Group Tuberosum haploid)] were male sterile. In contrast only four percent of the progeny from the reciprocal crosses were male sterile. Male sterility among the former progeny is presumed to result from the interaction of Tuberosum cytoplasm with dominant genes from the cultivated diploids, Groups Phureja and Stenotomum, an interaction known to occur in crosses of Tuberosum haploid × cultivated diploid species (2n = 2x = 24). The frequency of fertile progeny from the 4x × 2x crosses (57%) was significantly higher than that from the 2x × 2x crosses (Tuberosum haploid × cultivated diploid), (28%). The frequency of male fertility among progeny from different cultivars in 4x × 2x crosses varied from 31-82 percent. The difference between cultivars strongly suggests that some cultivars may have dominant male fertility restorer genes.

Key words: Male sterility – Tuberosum haploids – (haploids) *Solanum* – Potato – 4x-2x crosses

Introduction

Genetic-cytoplasmic male sterility in the tuber-bearing Solanums was studied by Koopmans (1959) after she noted anther, stigma and ovary abnormalities in an F_2 population derived from an F_1 cross of *Solanum rybinii* × *S. chacoense*. She demonstrated that the abnormalities observed were due to genetic-cytoplasmic interactions. Later, detailed studies of genetic-cytoplasmic interactions affecting male sterility were undertaken by Grun et al. (1962) and Grun and Aubertin (1966). They described and determined these interactions for indehiscence, sporad formation, shrivelled microspore, anther-style fusion and deformed flowers. These results were used later in an attempt to identify evolutionary relationships between the cultivated potato and its proposed progenitor species as well as between Groups of the cultivated potato, *Solanum tuberosum* (Grun et al. 1977).

Similar genetic-cytoplasmic interactions resulting in male sterility have been noted by others working with inter-specific crosses among the tuber-bearing Solanums. Lamm (1941, 1953) reported on interactions involving genetic factors in *S. curtilobum* and *S. acaule* with Tuberosum cytoplasm. *S. verrucosum* cytoplasm interacted with genes of Phureja and *S. chacoense* (Buck 1960). Dionne (1961) noted an interaction between *S. demissum* cytoplasm and genes from Tuberosum that resulted in male sterility.

Male sterility due to genetic-cytoplasmic interactions has also been observed in hybrids between haploids (2n = 2x = 24) of *S. tuberosum* Group Tuberosum and diploid (2n = 2x = 24) cultivated Groups and wild species. The occurrence of male sterility in these hybrids was related to the species or Group used, the haploid involved, and the direction of the cross (Liberal 1966). The cross, Phureja × Tuberosum haploids, resulted in male fertile progeny (Ross et al. 1964). The F_2 progeny from these F_1's were also male fertile (Perez-Ugalde et al. 1964). In contrast, the cross, Tuberosum haploid × cultivated diploid species, resulted in a high level of male sterility among progeny (Carroll 1975; Ross et al. 1964). Sterility in these crosses was attributed to the interaction of dominant genes from cultivated diploids with Tuberosum cytoplasm. However, some wild species apparently do not possess dominant genes which interact with Tuberosum cytoplasm to give male sterility. Also, one Tuberosum haploid, US-W 3, gave male fertile progeny when used as a female in crosses with Phureja (Liberal 1966). About 18 percent of the backcross plants in Tuberosum haploid × (Phureja × Tuberosum haploid) crosses were male fertile. To account for the male sterility observed in these plants, it was suggested

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that two or more loci from Phureja interact with Tuberosum cytoplasm (de la Puente 1966).

This report is mainly concerned with male sterility among 4x progeny from 4x-2x crosses in relation to their use in breeding where the 4x parents are Tuberosum cultivars and 2x parents are hybrids between either Groups Phureja or Stenotomum and Tuberosum haploids.

Materials and Methods

The 4x-2x hybrid families used were produced by crossing six Tuberosum cultivars ($2n = 4x = 48$) with 107 hybrids ($2n = 2x = 24$) of Phureja or Stenotomum with Tuberosum haploids. From the 4x X 2x cross, 1786 plants were evaluated, and in the reciprocal cross, 2x X 4x, 1544 plants were studied. In addition, 748 plants from 71 Tuberosum haploid X Phureja or Stenotomum families were evaluated to compare the frequency of male sterility at the two ploidy levels. The inter-cultivar families (4x X 4x), consisting of 1231 plants, were hybrids between the cultivars used in the 4x-2x crosses. Flowers were classified as male fertile or male sterile based upon the ability of the anthers to shed pollen when either mechanically vibrated or tapped with a pencil. The data were collected on four dates at weekly intervals and were kept on a family rather than an individual plant basis. The data presented represent the greatest number of male fertile or sterile clones recorded in any one week during the four week period. Pollen shedding is recognized as an over estimate of male fertility, but it is presumed valid for comparative purposes.

Results

Summaries of male fertility for five classes of progeny are presented in Table 1. Reciprocal cross differences in male fertility occurred in the progeny of the 4x-2x crosses. Fifty-seven percent of the progeny of the 4x x 2x cross were fertile; in contrast, 96% of the progeny of the 2x x 4x cross were fertile. The frequency of male fertile progeny from the 4x x 2x cross was markedly greater than the frequency in the progeny from the 2x x 2x cross of Tuberosum haploids x cultivated diploids (28%). There was no difference in fertility of the progeny from the 4x x 4x cross and its reciprocal, with 71% and 72% male fertile plants, respectively.

A comparison of the frequency of male fertility in the progeny of the 4x x 2x cross and its reciprocal is presented for specific cultivars in Table 2. The progeny from different cultivars differed in the frequency of expression of genetic-cytoplasmic male sterility. For example, approximately 81% of the progeny from the 'Platte' x 2x cross were male fertile, while 'Kennebec' x 2x gave only 31% male fertile plants. Significant reciprocal differences for male sterility do exist between 4x x 2x and 2x x 4x families.

Table 1. Frequency of male fertility and male sterility in the progeny of five classes of crosses

		Male fertiles		Male steriles	
Class	Cross	No.	%	No.	%
1	2x X 2x (Tuberosum haploid cultivated diploid)	210	28	538	72
2	4x X 2x[a] (cultivar X hybrid)	1026	57	760	43
3	2x[a] X 4x (hybrid X cultivar)	1478	96	66	4
4	4x X 4x (cultivar X cultivar)	415	71	167	29
5	4x X 4x (reciprocal of 4)	467	72	182	28

% is based on the number of plants that flowered

[a] 2x hybrid (Phureja or Stenotomum X Tuberosum haploid)

Discussion

The 4x x 2x cross was expected to produce a higher frequency of male sterile progeny than the 2x x 4x cross because male sterility is known to result from the interaction of dominant genes from the cultivated diploids, Phureja or Stenotomum, with the cytoplasm of Tuberosum haploids (Ross et al. 1964) resulting in male sterile progeny in the haploid x Phureja or Stenotomum cross. However, genetic-cytoplasmic male sterility has not been detected in the reciprocal cross at the diploid level.

Approximately 28% of the progeny of the inter-cultivar crosses were male sterile (Table 1), providing an estimate of the background level of male sterility in Tuberosum of a genic origin. Genetic-cytoplasmic male sterility can be ruled out in the 4x-4x crosses, because the progeny of reciprocal crosses did not differ in frequency of male sterility. Furthermore, there is no reason to suspect cytoplasmic differences among the cultivars employed. The frequency of this non-cytoplasmic male sterility was very low (4%) in the progeny of the 2x x 4x crosses. The explanation for the significant difference in the frequency of genic male sterility between progeny of 4x x 4x and 2x x 4x crosses (28% vs. 4%, respectively) may reside in the increased genetic diversity of the latter.

It is evident that reciprocal cross differences for male fertility exist among progeny of 4x-2x crosses. The 4x x 2x results parallel the findings for the Tuberosum haploid x cultivated diploid hybrid families, where only 28% were male fertile; however, the frequency of male fertility was significantly greater among 4x x 2x progeny (57%). Male sterility in the progeny of both the 4x x 2x cross and the Tuberosum haploid x cultivated diploid cross is assumed

Table 2. Frequency of male fertility and male sterility among progeny, by cultivar, from 4x X 2x and 2x X 4x crosses

	4x X 2x					2x X 4x			
	Male fertiles		Male steriles			Male fertiles		Male steriles	
Cross	No.	%	No.	%	Cross	No.	%	No.	%
'Katahdin' X 2x[a]	62	49.6	63	50.4	2x X 'Katahdin'	203	88.6	26	11.4
'Kennebec' X 2x	32	31.1	71	68.9	2x X 'Kennebec'	74	86.0	12	14.0
'Merrimack' X 2x	187	61.9	115	38.1	2x X 'Merrimack'	419	98.6	6	1.4
'Platte' X 2x	75	81.5	17	18.5	2x X 'Platte'	113	100.0	0	0.0
'Wis. 231' X 2x	151	71.6	60	28.4	2x X 'Wis. 231'	272	94.4	16	5.6
'Wis. 639' X 2x	236	66.5	119	33.5	2x X 'Wis. 639'	264	100.0	0	0.0

% is based on the number of plants that flowered

[a] 2x hybrid (Phureja or Stenotomum X Tuberosum haploid)

to be due to the interaction between Tuberosum cytoplasm and dominant genes from cultivated diploids.

There are several possible reasons for differences in the frequency of expression of genetic-cytoplasmic male sterility between ploidy levels: 1) Genes of different species may vary in their interaction with the cytoplasm depending, for example, on gene dosage; 2) restorer genes may be present in the cultivars, since progeny of different cultivars differ in the frequency of male sterile progeny, and 3) cultivars may differ in their cytoplasms. These differences could be significant in a breeding program at either the diploid or tetraploid level if male sterility was a limiting factor. However, the male sterility observed among the progeny of the 4x x 2x cross should be of little consequence to the future usefulness of these vigorous, high yielding clones in potato improvement since a workable level of male fertility does exist among the progeny.

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