Effect of functional female and male fertilities on crossability in diploid potato breeding

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Summary

Functional female fertility (FFF) and functional male fertility (FMF) were studied in diploid potato clones, including *S. tuberosum* haploids, *F*₁ hybrids between haploids and other *Solanum* species, and in progenies from subsequent hybridisations. The results of 402 crosses between 91 diploid potato clones revealed that 60% of all genotypes had low levels of FFF as well as low levels of FMF regardless of their origin and degree of hybridity. Failed crosses (without any fruits at all) and those with a low level of success (with less than 3 seeds per pollinated flower) constituted 69% of all studied crosses. Most of these had resulted from parents with low levels of FFF and FMF, and these two characteristics were expressed independently. Functional female fertility affected crossability behaviour no less than FMF, therefore both FFF and FMF should be controlled in diploid potato clones involved in breeding. Reliable FFF and FMF estimates can be based only on crossing results. The coefficient of multiple correlation between seeds per pollinated flower in crosses and FFF and FMF estimates of the parental clones was 0.80 (P<0.01). Hence the compilation and analysis of the results of diploid potato crosses allow a reliable assessment of FFF and FMF and consequently the prediction of crossability with a degree of sufficient accuracy.

Introduction

Potato breeding at the diploid level depends mainly on the success of the actual crosses. Low female fertility, male sterility, cytoplasmic male sterility, self- and cross-incompatibility systems limit gene exchange and recombination. The reasons for these limitations are well studied, and suggestions on how to overcome them have been proposed (Ross, 1986; Hermsen, 1994; Watanabe et al., 1995). However, some diploid potato clones, which produce sufficient amounts of stainable pollen grains, fail to produce seeds when used as male parents. The ability to produce seeds has been denominated as functional male fertility, which has been shown to be due to a balance of fertility factors (Carroll & Low, 1976). It was assumed to be a polygenic trait (Sari-Gorla et al., 1992).

Another element affects crossability between diploid potato; it is related to the female effect and is analogous to functional male fertility (FMF). This element is not usually taken into account when analysing crossability between diploid potatoes, although the effects of female parents in crosses at the diploid level have been described by Perez-Ugalde et al. (1964), Landeo & Hanneman (1979) and Trognitz...
We will describe this phenomenon as functional female fertility (FFF). If general fertility is defined as the ability to produce offspring, functional fertility (female or male) could be defined as the ability of viable germ cells to fertilise or to be fertilised.

Dihaploids of tetraploid *S. tuberosum* usually have low male fertility. The fraction of highly fertile tetraploid potato cultivars from which dihaploids were derived, generally constituted 20–30% of the population used (Chalyuk, 1982; Chernikova & Soloviyova, 1985). The frequency of polygenes providing high functional male fertility is therefore low in tetraploid *S. tuberosum*. This could be the result of absence of FMF control during the breeding process and use of clones with low FMF as female parents. The coefficient of inbreeding in dihaploids is greater than in initial tetraploid cultivars (Haynes, 1993), hence FMF being a polygenic trait could also be decreased due to inbreeding (haploid) depression (De Jong & Rowe, 1971; De, Maine, 1984). Hybrids between *S. tuberosum* dihaploids and fertile diploid potato species have an increased level of FMF (Gorea, 1970; Carroll, 1975; Zadina, 1980; Budin, 1986). This could have resulted from decreasing levels of inbreeding depression. However, among such hybrids, clones with low FMF were also detected (Carroll, 1975).

Diploid potato breeding is a long-term process including several cycles of crossing and selection (Chase, 1963; Hermsen, 1984; Ross, 1986; Yermishin, 1998). Its success depends mainly on the crossability behaviour of the diploid potato clones used in the breeding process. Such clones are not usually represented by primary dihaploids or their F₁ hybrids but by progenies from subsequent crosses with various dihaploids. The functional male fertility of such progenies is unknown, and it could range from low to high according to the general segregation of polygenic traits. As sterile genotypes are generally excluded from the breeding process, functional fertility (female and male) and incompatibility systems are the main reasons limiting crossability between diploid potatoes. However, it is difficult to predict the effect of functional male fertility on the success of crosses in long-term breeding programmes.

The aim of this research was: (i) to estimate FFF and FMF of diploid potato clones of different origin and with different degrees of hybridity, and (ii) to evaluate the effects of FFF and FMF on crossability behaviour during the breeding process.

**Materials and methods**

Crosses between diploid potato clones were carried out at the Institute of Genetics and Cytology in Minsk between 1991–1996 to develop alternative methods of potato breeding, utilising the effects of heterosis (Yermishin, 1998). The results of these crosses were used in the present study. The diploid potato clones used were divided into three groups:

1. The *tbr* group represented by dihaploids of *S. tuberosum* obtained from selfing primary dihaploids derived from the tetraploid cultivars Pokra, Polesskij rosowyj and Adretta.
2. The *tbr-sp* group represented by hybrids between primary dihaploids of *tuberosum*...