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Cross ability between Commercial Cultivars and Intraspecific Hybrids (Andigena X Tuberosum) and Advanced Clones of Potato, *Solanum tuberosum*

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ABSTRACT: In interspecific and intraspecific crosses, and pre-zygotic barriers like pollen-pistil incompatibility may exist. And when a parent is selected as male or female, this incompatibility may disappear. In this experiment, seven high-yielding commercial cultivars of potato, two advanced potato clones of direct intraspecific hybrids (*Solanum tuberosum* ssP andigena x *S. tuberosum*) and three advanced clones of *S. tuberosum* hybrids were crossed reciprocally, in the Ardabil Natural Resources and Agricultural Research Station during the summer of 2013 and the best cultivars and clones were determined when they were selected as the female or male parent. Generally, when the commercial cultivars were used as the male parent, the number of berries, the total number of seeds, the number of the seeds per berry, cross efficiency and the germination percentage of true seeds generated were 5, 73, 15, 0.73 and 27%, respectively; and when the parent was female, the above were measured as 74, 3841, 59, 3.6 and 83%, respectively.

Key words: Potato, cross ability, tuberosum, andigena, true potato seed.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is an autotetraploid or minimum species with autotetraploid behavior. This species has two tetraploid subspecies: *S. tuberosum* (andigena) which is grown in South America and *S. tuberosum* (tuberosum) which is commercial potato and is grown in almost all countries. These two subtypes are well distinct from one another morphologically and physiologically. One of the prospects for potato breeding is the large number of wild relative species in *Solanum* genus; in this respect, potato is among the first important crop species (Hawkes, 1994). A breeder will be successful in breeding program, if he has the choice of suitable materials and enough variety. This diversity can be created both naturally and artificially. In general, one of the steps in a successful breeding program is identifying desirable genotypes (Jozani *et al*., 2003). *S. andigena* is important in the transfer of important traits such as resistance to potato cyst nematode and the viruses: PVY, PVS, PVA and PVX (Hawkes, 1994; Dick *et al*., 2010). In the process of true potato seed setting, flowers must be capable of producing seeds, meaning that in addition to the high percentage of berry, the flowers produce a greater number of seeds per berry and the size of seeds setting is very large. If a high percentage of true seeds are produced with high weight, germination will be better after planting (Gonzalez *et al*., 2010). In the potato breeding program through cross between tetraploid cultivars, about one hundred thousand genotypes must be grown and evaluated to achieve a new cultivar (Pim *et al*., 2011).

Pre-zygotic incompatibility is very effective in interspecific crosses. In interspecific and intraspecific crosses, pre-zygotic barriers, that is, pollen-pistil or stigma incompatibility may exist; and in the case where a parent is selected as male or female, this incompatibility may be eliminated (Sanetomo *et al*., 2011).

In the International Potato Center, it is more than 30 years that the research was conducted in the field of true potato seed suitable hybrids, and 30 hybrids with superior parents and proper cross ability were introduced. Among these parents, are commercial cultivars: Atzimba and Serrana. In the hybrids presented, the efficiency of the parents' crosses is high; and the number of true seeds per berry and seed germination percentage are higher. In addition, the uniformity rate of produced tubers and their yields are higher (Almekinters, 2009).

In a study, 54 common cultivars of *S. tuberosum* and 13 genotypes of wild species were grown on the farm in five regions of Peru, and the true seed setting in free pollination was measured in terms of the number of berry setting, number of seeds per berry and number of true seed setting per plant. Then, bred parents were determined using molecular marker AFLP. Simultaneously, cross between genotypes was also conducted in greenhouse and the above traits were written and cross ability between genotypes was specified. The true seeds produced were harvested and grown after drying and dormancy breaking, and their germination percentage was also recorded. The number of seeds produced by the parents of the wild species was smaller and there was lower germination percentage (Scurrah *et al*., 2008).

In another experiment, to determine the crossability between the male and female fertile cultivar, Saikai 35 of *S. tuberosum* and 25 clones of *S. demissum* were crossed reciprocally and the crosses' success rate was determined by measuring the number of berry setting, the number of seeds per berry and true seed size. The results showed that when clones of *S. demissum* were selected in crosses as male parents, the numbers of berries and seeds were more and seed size was larger (about 0.94 mg), and on the contrary, when they were crossed as the female parents, the numbers of berries and seeds, and seed size were smaller (about 0.39 mg) (Sanetomo *et al*., 2011).

In an experiment, 21 hybrids of S. commersonii were crossed with Blondi cultivar of *S. tuberosum*, and a high success rate was obtained with higher percentage of berry setting and number of seeds per berry. When the Blondi was used as male parent, high success rate of crosses was obtained with higher percentage of berry setting and number of seeds per berry. In general, in the crosses conducted, the average percentage of berry setting and number of seeds per berry were 38.2 and 31.8, respectively. (Caruso *et al*., 2008)

Domesticated andigena clones have rich and various sources of useful genes and good results have been achieved in crosses with tuberosum clones. Short day andigena genotypes produce more and smaller size tubers as compared to tuberosum. But in cross with tuberosum genotypes, due to heterosis, the traits: tuber size, performance and also lateness are increased as compared to the parents (Kumar & Kang, 2006).

The potential of production of existing cultivars of potato is 130 tons per hectare. However, 50 to 60% of this potential is actually obtained. Several factors such as diseases and other stresses such as drought, have impact on performance reduction.

Today, with new breeding technologies such as beneficial genes transfer, the yield of tubers is increasing (Graveland, 2015). All varieties cultivated in Iran except Savalan and Khavaran, are imported cultivars and have been modified in cultivation conditions of exporting countries. Economically, benefits from the introduction of new cultivar of potato can be considered in different aspects such as increased profits from high yield, storing properties, resistance to diseases, less pesticide use and less oil absorption in processing or similar cases. Despite several benefits and cost-effectiveness of TPS hybrid seed production, these seeds are less important in Iran, and there are little information on reproductive characteristics of the cultivars and advanced clones. The results of this study can be used by breeders and producers of potato seeds.

This experiment was conducted to examine the crossability between commercial cultivars and advanced clones of the species of tuberosum and andigena and to evaluate their results, with emphasis on more true seed production with better quality.

MATERIALS AND METHODS

The plant material used in this experiment consists of two groups of potatoes which were crossed with each other reciprocally. High-yielding potato cultivars including Agria, Savalan, Picasso, Caesar, Daifla, Satina and Luca were crossed with two advanced and high-yielding clones, UT452 and UT453 which were obtained from the cross of *S. tuberosum* ssP andigena X S tuberosum; and three advanced and high-yielding clones of *S. tuberosum* designated AS72, AS12 and AS20, in the field of Ardabil Agricultural Research Station (located in 47° and 59' North, 39° and 22' East, 1390 m above sea level). Flower buds were castrated one day before opening by pushing petals aside and removing anthers, and then placed in bags. The next day, they were pollinated and labeled with the pollens obtained by shaking male parent into microtubes, and then placed inside a plastic net. After about six weeks, the ripe and fallen berries were collected. The berries were washed in water, the true seeds were extracted, counted and weighed after drying. In this experiment, the number of berry setting, the total number of seeds, number of seeds per berry, cross efficiency = number of seeds / berry / number of pollination and seed germination percentage, were recorded. To measure the germination percentage of seeds, 50 seeds of each cross were treated in gibberellic acid with concentration of 1000 ppm for 24 h. After being washed, they were cultured in Petri dish on filter paper, and germination was recorded.

RESULTS

The results of the cross between direct hybrids of tuberosum and andigena potatoes species with seven cultivars of commercial potatoes are shown in Tables 1 and 2. Genotypes studied were considered once as a male parent and once as a female parent. The traits studied were different in the two modes. The difference is in the amount of pollen-pistil interaction, and reproductive and genetic characteristics traits resulting from the parents.

AS72

Male: It was not formed in the cross with the commercial cultivars of berry and seed (Table 2).

Female: In the cross with Savalan and Caesar cultivars, each one had one berry and 11 and 15 seeds per berry with cross efficiency of 0.55 and 0.75, and seed germination of 28 and 29%, respectively (Table 1).

AS12

Male: In the cross with the Satina cultivar, 2 berries and 61 seeds per berry were formed, and cross efficiency and seed germination percentage were measured as 3 and 93%, respectively (Table 2).

Female: In the cross with the Caesar cultivar, 1 berry and 19 seeds per berry were formed, and cross efficiency and seed germination percentage were measured as 0.96 and 31%, respectively (Table 1).

Table 1: The result of commercial cultivars crosses as male with andigena and tuberosum hybrids.

Crosses female × male	Number of crosses	Number of berries	Total number of seeds	Number of seed per berry	Cross efficiency	Seed germination percentage
AS72×Savalan	20	1	11	11	0.55	28
AS12× Savalan	20	0	0	0	0	0
AS20× Savalan	20	0	0	0	0	0
UT452× Savalan	20	0	0	0	0	0
UT453× Savalan	20	0	0	0	0	0
AS72×Picasso	20	0	0	0	0	0
AS12× Picasso	20	0	0	0	0	0
AS20× Picasso	20	0	0	0	0	0
UT452× Picasso	20	0	0	0	0	0
UT453× Picasso	20	0	0	0	0	0
AS72×Caesar	20	1	15	15	0.75	29
AS12× Caesae	20	1	19	19	0.96	31
AS20× Caesar	20	1	15	15	0.75	24
UT452×Caesar	20	0	0	0	0	0
UT453× Caesar	20	0	0	0	0	0
AS72×Luca	20	0	0	0	0	0
AS12× Luca	20	0	0	0	0	0
AS20× Luca	20	0	0	0	0	0
UT452× Luca	20	0	0	0	0	0
UT453× Luca	20	0	0	0	0	0
AS72×Satina	20	0	0	0	0	0
AS12× Satina	20	0	0	0	0	0
AS20× Satina	20	1	13	13	0.65	22
UT452× Satina	20	0	0	0	0	0
UT453× Satina	20	0	0	0	0	0
AS72×Daifla	20	0	0	0	0	0
AS12× Daifla	20	0	0	0	0	0
AS20× Daifla	20	0	0	0	0	0
UT452× Daifla	20	0	0	0	0	0
UT453× Daifla	20	0	0	0	0	0
AS72×Agria	20	0	0	0	0	0
AS12× Agria	20	0	0	0	0	0
AS20× Agria	20	0	0	0	0	0
UT452× Agria	20	0	0	0	0	0
UT453× Agria	20	0	0	0	0	0
Total	**700**	**5**	**73**	**15**	**0.73**	**27**

Table 2: The result of commercial cultivars crosses as female with andigena and tuberosum hybrids.

Crosses Male × female	Number of crosses	Number of berries	Total number of seeds	Number of seed per berry	Cross efficiency	Seed germination percentage
Daifla×AS72	20	0	0	0	0	0
Luca×AS72	20	0	0	0	0	0
Satina×AS72	20	0	0	0	0	0
Picasso×AS72	20	0	0	0	0	0
Caesar×AS72	20	0	0	0	0	0
Agria×AS72	20	0	0	0	0	0
Savalan×AS72	20	0	0	0	0	0
Daifla×AS12	20	0	0	0	0	0
Luca×AS12	20	0	0	0	0	0
Satina×AS12	20	2	122	61	3	93
Picasso×AS12	20	0	0	0	0	0
Caesar×AS12	20	0	0	0	0	0
Agria×AS12	20	0	0	0	0	0
Savalan×AS12	20	0	0	0	0	0
Daifla×AS20	20	4	156	39	1.95	91
Luca×AS20	20	21	665	23	1.6	98
Satina×AS20	20	0	0	0	0	0
Picasso×AS20	20	0	0	0	0	0
Caesar×AS20	20	0	0	0	0	0
Agria×AS20	20	0	0	0	0	0
Savalan×AS20	20	0	0	0	0	0
Daifla×UT452	20	9	819	90	4.5	97
Luca×UT452	20	8	408	51	2.5	96
Satina×UT452	20	4	303	69	3.8	85
Picasso×UT452	20	2	210	105	5.2	96
Caesar×AS12	20	0	0	0	0	0
Agria×UT452	20	2	120	60	3	30
Savalan×UT452	20	10	131	13	0.7	59
Daifla×UT453	20	0	0	0	0	0
Luca×UT453	20	2	22	11	0,55	61
Satina×UT453	20	5	470	84	4.7	96
Picasso×UT453	20	0	0	0	0	0
Caesar×AS13	20	1	85	85	4.2	89
Agria×UT453	20	0	0	0	0	0
Savalan×UT453	20	4	330	83	4.1	88
Total	**700**	**74**	**3841**	**59**	**3.06**	**83**

AS20

Male: In the cross with the Daifla and Luca cultivars, 4 and 21 berries and 39 and 23 seeds per berry were formed, respectively. Cross efficiency was 1.9 and 6.1, and seed germination percentage was measured as 91 and 98% (Table 2).

Female: In the cross with the Caesar cultivar, 1 berry and 15 seeds per berry were formed, and cross efficiency and seed germination percentage were measured as 0.75 and 24%, respectively (Table 2).

UT452

Male: Except the Caesar, seeds and berries were formed in the cross with the rest of the cultivars. The lowest and highest number of berries in Daifla and Agria were 9 and 2; the number of seeds per berry in Savalan and Picasso were 13 and 15; cross efficiency in Savalan and Picasso were 0.7 and 5.2; and the percentage of seed germination in Agria and Difela were 30 and 97%, respectively (Table 2).

Female: Seed and berry were not formed in the cross with commercial cultivars (Table 1).

UT453

Male: Seed and berry were not formed in the cross with Daifla, Picasso and Caesar, but there were seeds and berries in the cross with other four cultivars. The lowest and highest number of berries in cross with Caesar and Satina were 1 and 5; the number of seeds per berry in Luca and Caesar were 11 and 85; cross efficiency in Luca and Satina were 0.55 and 4.7; and the percentage of seed germination in Luca and Satina were 61 and 96%, respectively (Table 2).

Female: Seed and berry were not formed in cross with commercial cultivars (Table 1).

Cultivars

Savalan:

Male: In the cross with AS97, 1 berry with 11 seeds per berry, and cross efficiency of 0.55 and seed germination of 28% were obtained, respectively (Table 1).

Female: In the cross with UT452 and UT453, 10 and 4 berries, 13 and 83 seeds per berry, cross efficiency of 0.7 and 3.06, and seed germination of 59 and 88% were obtained, respectively (Table 2).

Picasso:

Male: In the cross with advanced clones of potatoes, no seed and berry were formed (Table 1).

Female: In the cross with UT452, 2 berries with 105 seeds per berry, cross efficiency of 5.2 and seed germination of 96% were obtained (Table 2).

Caesar:

Male: In the cross with AS12, AS72 and AS20, 1 berry was formed in each of them; 19, 15 and 15 seeds were observed in each berry; cross efficiency was 0.95, 0.75 and 0.75; and seed germination was 31, 29, and 24, respectively (Table 1).

Female: In the cross with UT453, 1 berry with 85 seeds per berry, cross efficiency of 3.06 and seed germination of 83% were obtained (Table 2).

Luca:

Male: In the cross with advanced clones of potatoes, no seed and berry were formed (Table 1).

Female: 21, 8 and 2 berries were formed in the cross with AS20, UT452 and UT453. 23, 51 and 11 seeds were observed in each berry; cross efficiency was 1.6, 2.5 and 0.55; and seed germination percentage was 98, 96 and 61%, respectively (Table 2).

Satina:

Male: In the cross with advanced clones of potatoes, no seed and berry were formed (Table 1).

Female: 2, 4 and 6 berries were formed in the cross with AS12, UT452 and UT453. 61, 69 and 84 seeds were observed in each berry; cross efficiency was 3, 3.8 and 4.7; and seed germination percentage was 93, 85 and 96%, respectively (Table 2).

Daifla:

Male: In the cross with advanced clones of potatoes, no seed and berry were formed (Table 1).

Female: In the hybrids of AS20 and UT452, 4 and 9 berries, 39 and 90 seeds per berry, cross efficiency of 1.95 and 4.5 and seed germination of 91 and 97% were obtained, respectively (Table 2).

Agria:

Male: In the cross with advanced clones of potatoes, no seed and berry were formed (Table 1).

Female: In the cross with the hybrid of UT452, 2 berries and 60 seeds per berry were formed. Cross efficiency and seed germination percentage were calculated as 3 and 30%, respectively (Table 2).

DISCUSSION

The occurrence of one-sided incompatibility relationship between self-fertile and cross-fertile cultivars pollination in potatoes, especially in diploid species, is a known issue (Jansky, 2006). In different experiments, the crossability between the parents was specified by measuring the number and percentage of berry and seed setting, cross efficiency, weight and true potato seed germination. In these experiments, commercial cultivars of potatoes, S. tuberosum, were crossed with other species. When the commercial cultivars were selected as female parent, seed and berry setting, seed germination percentage and cross efficiency increased as compared to when they were selected as male parent (Sanetomo *et al*., 2011; Jackson and Hanneman, 1999; Scurrah *et al*., 2008).

The results of the present experiment are consistent with that of the mentioned experiments, because when potato cultivars were selected as the male parent, berry setting, total number of seeds, number of seeds per berry, cross efficiency and true potato seed germination percentage were 5, 73, 15, 0.73 and 27%, respectively; and when the commercial cultivars of potato were selected as the female parent, the traits above were 74, 3841, 59, 3.6 and 83%, respectively. In general, when commercial cultivars and clones were used as male and female parents, respectively, cultivars Caesar, clone AS20 and Savalan were better than other cultivars in the studied traits, in other words, they were the best male.

The best combination is the cross of Caesar × AS12 where 1 berry with 19 seeds and cross efficiency of 0.96 were obtained; but the seed germination percentage obtained was poor (31%) (Table 1).

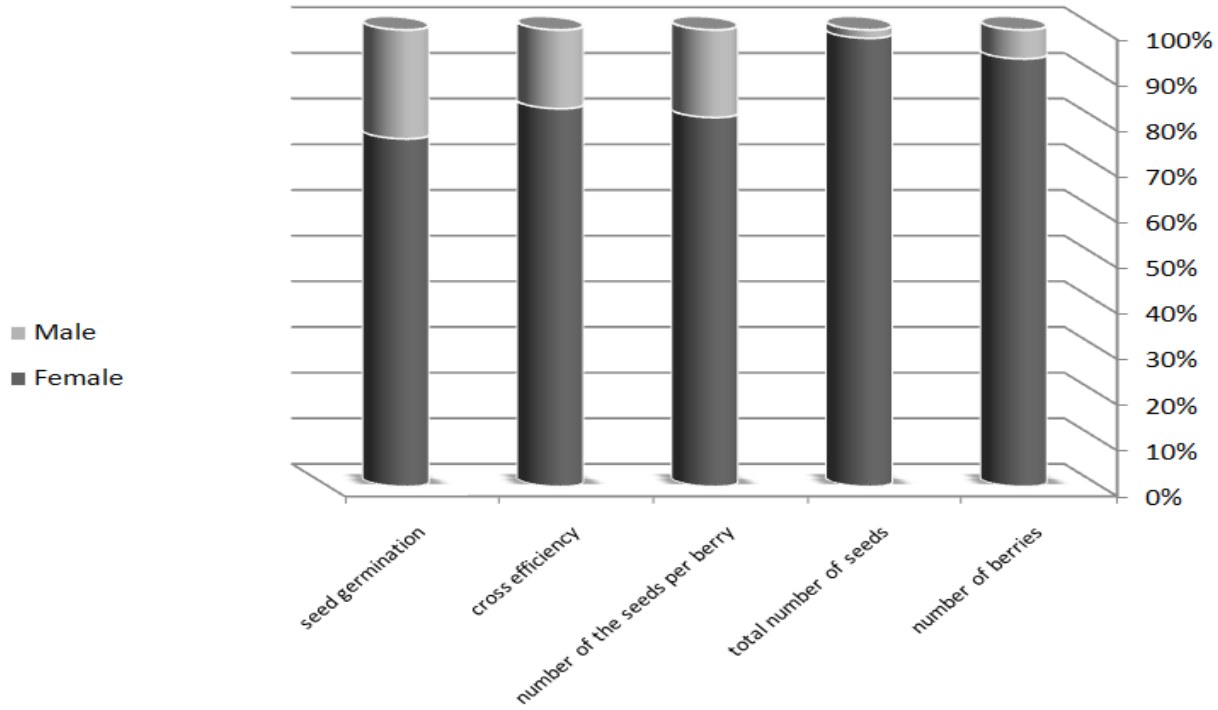

Fig. 1. Comparison of the traits studied in both male and female commercial cultivars in the crosses.

When commercial cultivars and clones were considered as female and male parents, Luca, Daifla, Satina and Savalan cultivars were better than other cultivars in the studies traits, it means that they were the best materials. The best combination is the cross of Daifla × UT452 where 9 berries with 819 seeds, cross efficiency of 4.5 and seed germination percentage of 97% were obtained (Table 2). When Agria and Satina cultivars crosses were used as male parent, no berry and seed were formed. This is due to male infertility of Agria because of lack of live pollen, and incompatibility of Satina despite the presence of live pollen. Male infertility of Agria was also mentioned in the experiment of Panahandeh *et al*. (2009).

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