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The Variability of Juvenile Period, Fruits Size and Response to Diseases Attack on F_1 Interspecific Apple Hybrids and the Efficiency of Selection

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Abstract

Interspecific hybridizations represent one of the apple breeding methods by which a wide variability can be achieved, useful for creating new cultivars. The study of 2190 interspecific hybrids, obtained from 25 combinations among crab apple species (*Malus coronaria*, *M. floribunda*, *M. niedzwetzkyana*, *M. zumi*, *M. prunifolia*) and different apple cultivars, points out a large variability of the F1 seedlings for several traits, with significant importance in apple breeding programs. The first year of fructification, as mean per hybrid combination, varied from 6 (*M. zumi* x 'Jonathan') to 9.3 years; the average hybrid's age for fructification was 7.4 years. The size of fruits among families varied from 1.5 ('Starkrimson' x *M. prunifolia*) to 4.0 ('Reinette Baumann' x *M. zumi*), the mean being settled at 2.8 (therefore below mark 3, meaning 'small fruits'). The lowest infection rate both for apple scab and powdery mildew attack was noticed at hybrids from *M. coronaria* x 'Reinette Baumann'. On the whole, the hybrids with genitors of 'species x cultivars' type have had an early fruiting and a better resistance to scab and powdery mildew, compared to the ones from 'cultivars x species' combinations. The large variability of the studied traits gave the possibility to identify offsprings with desirable characteristics on nine hybrid combinations. Among these, 53 elite plants were selected, with a strength of selection of 2.42%, therefore a relative low value, correlated with the peculiarities of the interspecific population and the selection criteria for dessert apple.

Keywords: hybridization, seedlings, species, juvenile period, fruits, apple scab, powdery mildew

Introduction

Apple breeding programs are used to create both commercial and ornamental new cultivars. Currently, ornamental apple knows a wide spreading and gain interest, along with the improvement of life and with the search for beauty and a healthy environment (Zion, 1994). The ornamental apple species are frequently seen in parks, private gardens and street arrangements, due to their diversity in shapes and colour. The wreath can grow in a diversity of shapes, such as columnar, globular, weeping; the foliage is abundant and colourful, varying from intense green to reddish hues, while the flowers and fruits have the strongest decorative impact. Other uses of ornamental apple are crab trees grown in pots and containers, as bonsai, the decoration of street arrangements and edges, as individuals that focus the attention of inside arrangements (Zion, 1994; Juniper and Mabberley, 2006).

One of the first apple species known as 'flowering crab' is *M. spectabilis* (Jackson, 2003), while the most common ornamental apple is *M. floribunda*, a specie characterised by its small fruits, of 1 cm diameter (Jackson, 2003; Juniper and Mabberley, 2006). Among the apple species with large fruits, *M. niedzwetzkyana* can be mentioned as a real contributor and a good genitor for ornamental apple species. At the end of XIXth century, N. Hansen obtained hybrids from *M. niedzwetzkyana* and *M. baccata*, some of them with ornamental value, e.g. 'Rosybloom' category (Fiala, 1994). In Western Europe, USA and Asia, crab apple species and ornamental cultivars are appreciated and the researchers used them for their beauty, especially in urban areas, for their decorative effect, environmental benefits, improvement of life style, as well as for practical and economic matters.

An important function of the ornamental apple trees is the capacity to pollinate the commercial cultivars (Goldschmidt-Reischel, 1993), assuring a proper pollination process in orchards, due to the abundance of flowers, simultaneous with the fruits cultivated specie (*M. domestica* Borkh.). Thus, crab apple trees offer pollen of higher quality, both in quantity and quality, for proper germination (Kendall and Smith, 1975; Szklanowska and Dabska, 1991; Jackson, 2003; Dabska, 2005).

The numerous appropriation of *Malus* species can be seen on commercial and ornamental cultivars, sustained by traits that are transferred from the rustic species of *Malus* to the ones cultivated for fruits, such as: frost resistance (from *M. baccata* and *M. prunifolia),* apple scab resistance (*M. floribunda*, *M. atrosanguinea*), powdery mildew resistance (*M. zumi*) and others (Sestras, 2004). The use of *M. floribunda* is a relevant example for the transfer of genes of interest being frequently used in research programs dedicated to create cultivars with genetic resistance to apple scab (took to development of PRI series).

Interspecific hybridizations are also useful by arousing an extensive genetic diversity, which give possibility of selection among more species, finding useful ornamental and dessert cultivars, contributing to the expanding of the genetic base for apple selection. This aspect is worth mentioning, because due to the intense for the use of commercial cultivars, with large and tasty fruits and a good resistance to apple diseases, genetic erosion occurs, also sustained by the high risks versus stress factors and the genetic vulnerability. The current study presents the impact of the interspecific hybridisations on the variability of new genotypes, and analyzed the efficiency of selection.

Materials and methods

The biological material used in the present study was represented by interspecific apple hybrids, descendants of the following rustic, crab apple species: *Malus coronaria, M. floribunda, M. niedzwetzkyana, M. zumi,* and *M. prunifolia*.

A number of 2190 F1 hybrids were taken into analysis. These F1 hybrids are offspring of 25 hybrid combinations of *Malus* species (used both as maternal and paternal genitors), and crossed with several apple cultivars. The number of progenies varied from 17 to 248 per combination. Neither technical interventions (pruning, guidance) nor phytosanitary treatments were applied in hybrid's field.

The growth and vigour of trees of F1 hybrids, expressed as UPOV scale (Sestras *et al*., 2009), the length of the juvenile period (expressed as year when first fructification was marked), the size of fruits and the resistance to diseases in natural infection conditions were analyzed. The fruits were measured during the first three years of fructification for each hybrid according to UPOV norms (2003). The following scale was used in collecting the size of fruits: "1" = very small fruits; "3" = small fruits; "5" = medium size fruits; "7" = large fruits; and "9" = very large fruits. The data obtained by this method were processed as mean values.

The response of interspecific hybrids to apple scab and powdery mildew attack was marked, from "0" (no attack) to "5" (strong attack), in natural infection conditions. No intervention and/or treatments were applied on the investigated trees, during whole period of study (three years, for hybrids of seventh to ninth years).

The interpretation of the data collected followed the analysis of variance method (ANOVA), using synthesis tables with average values for each hybrid combination and also with the mean of experiment, as control. The variability of the studied traits was analyzed using the coefficient of variation (CV%).

Results and discussion

Hybrids' Juvenile Period and Fruit Size

The year of first fructification differ as mean value from one combination to another, getting at the analysis of data an amplitude of variation set between 6.0 and 9.3 (Tab. 1). The average age of fructification for all 25 hybrid combinations was of 7.4 years.

After processing the statistical information, four hybrid combinations have had assured differences values compared to the mean of experiment (the control value). Among these, one combination had inferior differences, while the rest of three got superior values, which actually means a tardy fructification. Therefore, the only combination with an early fructification was the one given by *M. zumi* x 'Jonathan'. Even for these F1 hybrids, an average of 6 year period was needed for the appearance of the first fruits. A long juvenile period was registered for 'Cluj II-1-2' x *M. floribunda* (9.3 years), 'Reinette Baumann' x *M. zumi* (8.1 years), 'Cluj 218/2' x *M. floribunda* (9.3 years).

Inner of the variants, the variability of the juvenile period was low for 12 hybrid combinations (CV% under 10%). Nine combinations have had a medium variability (CV% between 10 and 20%), while for the rest of four combinations the trait had a large variability (greater than 20%). It is worth mentioning that the descendants of *M. zumi* x 'Jonathan' – the combination with the shortest juvenile period, and the ones of *M. zumi* x 'Reinette Baumann', had the most extensive variability for their first fructification (27.2% and 27.8%).

The results acknowledge the data from other studies as seen in the specialty literature, according to which the rustic species, like *M. zumi*, transmit to their seedlings a shorter juvenile period, in comparison with a longer one induced by genitors belonging to a variety (Zimmerman, 1972; Schmidt, 1985). Also, the data confirms that the hybrids obtained from seeds have a slow growth, and a prolonged juvenile period which vary from 3 to 10 years, with a significant influence from the genitor's genotype (Visser, 1976; Janick *et al*., 1996).

The juvenile period of apple trees is an important trait, both in the case of cultivars and hybrids submitting the selection process. Visser (1976) showed on his studies on apple and pear trees that juvenile period is of additive nature, meaning that a complex of factors that control the growth course influences the inheritance of the length of juvenile period. As to cultivars, a short juvenile period, equivalent to an early fructification, interest from the economical point of view, directly influencing the absorption of the

Tab. 1. The length of juvenile period, the size of fruits of F1 interspecific hybrids and the coefficient of variation (CV%) upon the hybrid combinations

No	Hybrids	Year of first fructification		Size of fruits	
		Mean**	CV%	Mean**	CV%
1	*M. coronaria* × 'Jonathan'	7.3	11.1	3.0	42.2
2	*M. coronaria* × 'Reinette Baumann'	7.0	11.7	2.8	18.2
3	*M. floribunda* × 'Reinette Baumann'	7.3	7.9	2.3	49.5
4	*M. prunifolia* × 'Rosu de Cluj'	7.5	9.4	2.0	70.7
5	*M. zumi* × 'Golden Delicious'	7.6	7.2	3.0	47.1
6	*M. zumi* × 'Jonathan'	6.0 oo	27.2	2.4	40.3
7	*M. zumi* × 'Reinette Baumann'	6.6	27.8	3.2	35.5
8	'Ardelean' × *M. niedzwetzkyana*	7.1	4.7	3.0	33.3
9	'Cluj 218/2' × *M. floribunda*	9.3 xxx	13.6	2.5	40.0
10	'Cluj 218/2' × *M. niedzwetzkyana*	7.3	13.1	3.1	39.2
11	'Cluj 218/2' × *M. zumi*	7.0	6.7	3.2	46.1
12	'Cluj II-1-2' × *M. floribunda*	9.3 xx	13.6	2.3	49.5
13	'Cluj II-1-2' × *M. niedzwetzkyana*	7.3	13.1	3.1	39.2
14	'Frumos de Voinesti' × *M. floribunda*	7.8	15.8	3.2	35.5
15	'Frumos de Voinesti' × *M. niedzwetzkyana*	7.2	5.6	3.0	29.8
16	'Frumos de Voinesti' × *M. zumi*	7.3	6.9	2.5	40.0
17	'Golden Delicious' × *M. prunifolia*	7.0	13.6	2.3	42.2
18	'Reinette Baumann' × *M. floribunda*	7.6	7.1	2.4	40.2
19	'Reinette Baumann' × *M. niedzwetzkyana*	7.0	9.0	2.5	40.0
20	'Reinette Baumann' × *M. prunifolia*	6.8	21.9	2.8	24.0
21	'Reinette Baumann' × *Malus zumi*	8.1 xx	9.8	1.5 ooo	60.3
22	'Rosu de Cluj' × *M. coronaria*	7.3	13.2	3.0	54.4
23	'Rosu de Cluj' × *M. niedzwetzkyana*	7.0	9.0	3.1	36.7
24	'Rosu de Cluj' × *M. prunifolia*	6.8	21.9	3.0	42.2
25	'Starkrimson' × *M. prunifolia*	7.3	7.9	4.0 x	25.0
	Control (Mean of experience)	7.4	12.4	2.8	40.8

* The size of fruits was determined according to UPOV norms, using the following scale: 1 = very small fruits; 3 = small fruits; 5 = medium size fruits; 7 = large fruits; 9 = very large fruits. ** Symbols for differences: x, xx, xxx/o, oo, ooo; significant at P<0.05, 0.01 and 0.001 (positive, respectively negative).

orchard's founding costs (Sestras, 2004). For apple breeding programs, the juvenile period determines the number of years until hybrids gain their actual value for the specific objectives followed, while they need space and care, which implies costs for researchers. Therefore, a short juvenile period is a desirable characteristic in all cases (Janick *et al.*, 1996; Sestras, 2004; Kwon *et al.*, 2009).

The length of the juvenile period influences the precocity of fructification after grafting, a characteristic desired for all hybrids. Therefore, according to Cociu and Oprea (1989), all descendants who do not have their fructification in the first six years must be eliminated, reckoned as improper due to the implied costs.

Following this principle is still on debate for research programs, due to the fact that many hybrid combinations have seedlings with a long juvenile period and fruit only after 8-9 years. For example, among the 1.230 interspecific hybrids with different genitors, only 17.4% fructify until their sixth year, while 57.4% fructify at eight years (Sestras, 1997). Because this criterion of selection can lead to the elimination of valuable biological material it is recommended to keep all individuals, at least until the majority of hybrids fructify, despite of extra cost and effort (a long period of plants occupying the field, the need of maintenance which implies financial cost and labour, etc.).

Fruit's size is for apple an important characteristic, a significant productivity and quality trait, influenced by the genetic parameters, environmental and technical factors. The size of the F1 hybrid's fruits differ among the combinations studied, giving an amplitude of variability between 1.5 and 4 (in terms of marking with "1" very small fruits and "5" large fruits). The mean for the current discussed characteristic among the 25 combinations values 2.8 (therefore close to mark 3, which is representative for medium fruits).

After the statistical interpretation of the data collected, only the variants with extreme mean values for fruit size had significant deviation sustained with statistical arguments. Hybrids from 'Starkrimson' x *M. prunifolia* combination have had the largest fruits, while the ones having as genitors 'Reinette Baumann' x *M. zumi* had the smallest apples. Among families, the variability coefficient vary from 18.2% (*M. coronaria* x 'Reinette Baumann') to 70.7% (*M. prunifolia* x 'Rosu de Cluj'). The large interval of variation for fruit's size on the whole experiment (CV% is under 10 for only one hybrid combination, while the rest of them have had CV% bigger than 20) illustrates the existence of prominent differences among seedling, even inside the same family, regarding the size of fruits, fact sustained also by the experience mean (CV% = 40.4%).

Despite of the large variability in fruit size for all interspecific combinations, the small dimensions of the fruits related with the improper quality and the unpleasant taste, make up as an impediment of an efficient selection of F1 hybrids as regards the consumption apple.

Response to Apple Scab and Powdery Mildew Attack

Apple scab (*Venturia inaequalis*) and powdery mildew (*Podosphaera leucotricha)* are the main two apple diseases, which can determine significant damage, especially when appear in some proper environmental conditions for a strong infection. This is why the importance of creating genetically resistant cultivars is a major objective (Sestras, 2004; Sestras *et al*., 2005).

Among the studied combinations, hybrids with the lowest infection rate were the ones derived from *M. coronaria* x 'Reinette Baumann' and *M. zumi* x 'Golden Delicious' (Tab. 2).

It is worth mentioning that the hybrids with a great sensibility to apple scab had as paternal genitor *M. floribunda*, one of the recognized species for inducing genetic resistance to this disease by the transfer of *Vf* gene (Crosby *et al*., 1992; Janick, 2002). These combinations were 'Cluj 218/2' x *M. floribunda*, 'Frumos de Voinesti' x *M. floribunda*, 'Reinette Baumann' x *M. floribunda*.

The variability of hybrids to apple scab attack was high for all combinations analysed, varying from 17.2% for *M. floribunda* x 'Reinette Baumann' up to 95.6% in *M. zumi* x 'Jonathan'.

The average values obtained for powdery mildew attack upon the studied hybrids vary from 0.42 to 2.23. A strong attack was clearly showed in combinations between

Tab. 2. Average values* and the coefficient of variation (CV%) for apple scab and powdery mildew attack on interspecific combinations

No	Hybrid combination	Apple scab attack		Powdery mildew attack	
		Mean**	CV%	Mean**	CV%
1	*M. coronaria* × 'Jonathan'	1.00	47.2	1.28	55.8
2	*M. coronaria* × 'Reinette Baumann'	0.38ººº	38.5	0.42ººº	82.0
3	*M. floribunda* × 'Reinette Baumann'	1.11	17.2	1.45	26.7
4	*M. prunifolia* × 'Rosu de Cluj'	2.12	34.2	0.87ºº	45.6
5	*M. zumi* × 'Golden Delicious'	0.58ºº	69.0	1.00º	40.7
6	*M. zumi* × 'Jonathan'	1.39	95.6	1.06º	70.9
7	*M. zumi* × 'Reinette Baumann'	1.87	52.0	1.47	57.0
8	'Ardelean' × *M. niedzwetzkyana*	2.47xx	48.2	1.02º	51.2
9	'Cluj 218/2' × *M. floribunda*	3.52xxx	24.3	1.47	73.8
10	'Cluj 218/2' × *M. niedzwetzkyana*	1.13º	66.6	0.77ºº	81.8
11	'Cluj 218/2' × *M. zumi*	0.78ºº	39.1	1.38	54.1
12	'Cluj II-1-2' × *M. floribunda*	0.62ºº	51.3	1.27	61.2
13	'Cluj II-1-2' × *M. niedzwetzkyana*	2.98xxx	61.2	2.23xxx	71.2
14	'Frumos de Voinesti' × *M. floribunda*	3.23xxx	23.3	1.57	94.7
15	'Frumos de Voinesti' × *M. niedzwetzkyana*	0.53ºº	57.2	1.25	72.8
16	'Frumos de Voinesti' × *M. zumi*	0.94º	54.3	2.11xx	61.4
17	'Golden Delicious' × *M. prunifolia*	1.00º	85.2	1.81	71.0
18	'Reinette Baumann' × *M. floribunda*	2.51xx	24.4	1.01ºº	55.9
19	'Reinette Baumann' × *M. niedzwetzkyana*	1.74	64.3	1.40	50.3
20	'Reinette Baumann' × *M. prunifolia*	1.44	71.2	1.30º	49.0
21	'Reinette Baumann' × *Malus zumi*	2.12	67.8	1.51	58.1
22	'Rosu de Cluj' × *M. coronaria*	1.27º	69.1	1.46	64.8
23	'Rosu de Cluj' × *M. niedzwetzkyana*	2.10	52.3	2.02xx	28.5
24	'Rosu de Cluj' × *M. prunifolia*	2.25x	55.1	2.02xx	44.9
25	'Starkrimson' × *M. prunifolia*	2.58xx	41.2	1.31º	51.7
	Control (Mean of experience)	1.66	52.4	1.38	59.0

* The response against apple scab and powdery mildew was set by marking hybrids with 0 = no attack; 1 = very few attack symptoms; 2 = soft attack; 3 = medium attack; 4 = strong attack; 5 = very strong attack. ** Symbols for differences: x, xx, xxx/o, oo, ooo; significant at P<0.05, 0.01 and 0.001 (positive, respectively negative).

Tab. 3. Coefficient of correlation among traits when the apple species participated in hybridizations as mother genitors (♀) and father genitors (♂), respectively per ensemble of experiment (all)

Correlated traits	Year of fructification			Fruit size			Scab attack			Mildew attack		
	♀	♀	All	♀	♀	All	♀	♀	All	♀	♂	All
Vigour of hybrids	0.50	-0.27	-0.15	-0.42	-0.20	-0.23	-0.01	-0.14	-0.11	0.14	-0.26	-0.16
Year of fructification				-0.06	-0.20	-0.29	-0.21	0.22	0.23	-0.09	-0.16	-0.01
Fruit size							-0.39	0.15	0.10	-0.09	-0.04	0.06
Scab attack										0.41	0.16	0.32

Theoretical value of 'r'	♀	♂	All
r 5%	0.75	0.47	0.38
r 1%	0.88	0.59	0.49
r 0.1%	0.95	0.71	0.60

'Rosu de Cluj' x *M. niedzwetzkyana* and 'Rosu de Cluj' x *M. prunifolia*. This sensitive response could be determined by the genitor's influences; it is known that 'Rosu de Cluj' is a variety sensitive to powdery mildew, as a descendant at its turn of susceptible 'Jonathan' (Sestras, 2004). On the other hand, even if 'Rosu de Cluj' was reported to carry polygenic resistance to apple scab attacks (Quamme *et al*., 2003). This variety had valuable progenies only when combined with *M. coronaria*, regarding the apple scab resistance.

The best hybrids with the highest resistance to the scab attack as well as to the powdery mildew attack were obtained by *M. coronaria* x 'Reinette Baumann' hybrids (in terms of means). The smallest coefficient of variation when both scab attack and powdery mildew attack was obtained by *M. floribunda* x 'Reinette Baumann' hybrids. The highest variability to scab attack was obtained by *M. zumi* x 'Jonathan' hybrids while the highest variability to powdery mildew attack was obtained by 'Frumos de Voinesti' x *M. floribunda* hybrids. The large interval of variability among the hybrid combinations regarding the sensibility / resistance to the main apple diseases permits the identification of valuable genotypes resistant to apple scab and powdery mildew, making possible to effectively apply the selection.

The *Malus* species induced a shorter juvenile period when were used as a maternal genitor compared to its used as paternal genitor. The mean age of fructification of 7.0 years was transmitted to its descendants of 'cultivars x species' fruited at 7.5 years of age (Fig. 1).

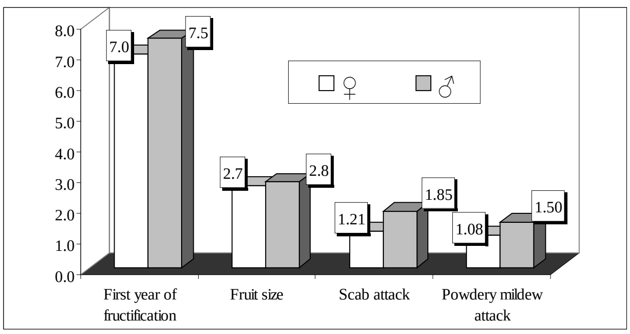

Fig. 1. The mean of values for analyzed traits per ensemble of hybrid combinations, when the *Malus* species were used as maternal (♀) and paternal (♂) genitor

In the same time, the seedlings with *Malus* species as maternal genitor have had in general a better resistance to apple scab and powdery mildew attack, toward using *Malus* species as paternal genitor. The size of fruits proved not to influence by the role played as genitors by the ornamental genotypes used in the experiment.

Even though there are no phenotypical correlations among the studied traits from the statistical approach, the correlation coefficient's values and their direction (Tab. 3) can set up and enlarge interesting theories for apple breeding programs. For hybrids which had *Malus* species as maternal genitor the response to scab and mildew attack was similar, in the sense that the resistance or the sensibility increases, and respectively decrees, in the same direction (r = +0.41). As regard the vigour and juvenile period of the hybrids, by having *Malus* species as maternal genitor, the "r" value of +0.50 suggests that a big vigour is correlated with a long juvenile period, while the seedlings with commercial cultivars as mother genitor presented a negative correlation between these traits (r = -0.27).

Intensity of Selection

Attending the selection criteria established, among the F1 hybrids elite individuals with superior characteristics have been identified. The analyzed traits were as follows: vigour, early fructification, fruit's size, resistance or tolerance to apple scab and powdery mildew attack, as well as other parameters significant for the decorative impact (e.g. architectural ideotype, fruit's quality – mainly regarding the adequate taste demands).

As mentioned before, the seedlings have prevalent inherited rustic characteristics from the wild species (crab apple, with ornamental value). This is one reason for a severe selection, due to the fact that superior values of the desired traits were present only at a few hybrids. Few seedlings proved to be significant in terms of all studied parameters, respectively a decorative ideotype and ornamental architecture of the trees, a short juvenile period, a proper quality of fruits to be served, resistance to scab and mildew.

Tab. 4 displays the results upon the elite plants chosen from among all hybrid combinations, the proportion for each family – total number of elite plants from each combination, and the proportion of elite individuals from among all seedlings from the experiment.

Out of the 25 families, 16 of them had no elites, which represent a total of 64.0% of combinations with no representatives. All other 9 combinations had proper individuals for the settled objectives of the experiment.

The most elite individuals were selected from the combination between 'Cluj II-1-2' x *M. niedzwetzkyana*, while the highest proportion of elites was given by *M. floribunda* × 'Reinette Baumann'. As such, we can say that the most efficient selection was assured by hybrid combinations between *M. floribunda* x 'Reinette Baumann', 'Reinette Baumann' x *M. niedzwetzkyana*, *M. zumi* x 'Reinette Baumann', followed by 'Frumos de Voinesti' x *M. niedzwetzkyana*, 'Cluj II-1-2' x *M. niedzwetzkyana*, *M. coronaria* x 'Jonathan', 'Cluj 218/2' x *M. floribunda*.

Among the rest of the combinations, only one elite plant was selected as representative, showing valuable parameters, belonging to 'Cluj 218/2' x *M. niedzwetzkyana* and 'Frumos de Voinesti' x *M. floribunda*.

The intensity of selection (determined by the formula I% = no. of selected elites / no. of F1 hybrids) was equal to 2.42%. This relative small value could be justified by the nature of the biological material passive to the selection process – interspecific combinations, as well as by the criteria which took into consideration several parameters characteristic for dessert apple.

The selected hybrids are slightly to become cultivars for dessert apple, due to the poor quality of the sensorial parameters of fruits, which have no commercial or tasteful value, even if the interpretation of data seams optimistic. This is the main reason for their inclusion in breeding programs for further apple improvements, by controlled hybridizations and 'modified backcross' following classic patterns and techniques (Crosby *et al*., 1992; Janick, 2002).

Besides the controlled hybridization, the selected hybrids were left to free pollinate in the field (creating the premises of inter-cross combinations among the 2190 F1 interspecific hybrids, and also offering the possibility of any new combination with the pollen from the hundreds

Tab. 4. Elite plants selected among the hybrid combinations and the intensity of selection, on the whole experiment

No	Hybrid combination (♀ x ♂)	No. of F1 hybrids	No. of selected elites	% selected elites	
				Per combination	Per total no. of F1 hybrids
1	*M. coronaria* × 'Jonathan'	154	7	4.5	13.2
2	*M. coronaria* × 'Reinette Baumann'	86	0	0.0	0.0
3	*M. floribunda* × 'Reinette Baumann'	42	9	21.4	17.0
4	*M. prunifolia* × 'Rosu de Cluj'	29	0	0.0	0.0
5	*M. zumi* × 'Golden Delicious'	67	0	0.0	0.0
6	*M. zumi* × 'Jonathan'	134	0	0.0	0.0
7	*M. zumi* × 'Reinette Baumann'	82	6	7.3	11.3
8	'Ardelean' × *M. niedzwetzkyana*	97	0	0.0	0.0
9	'Cluj 218/2' × *M. floribunda*	31	1	3.2	1.9
10	'Cluj 218/2' × *M. niedzwetzkyana*	97	1	1.0	1.9
11	'Cluj 218/2' × *M. zumi*	102	0	0.0	0.0
12	'Cluj II-1-2' × *M. floribunda*	17	0	0.0	0.0
13	'Cluj II-1-2' × *M. niedzwetzkyana*	248	12	4.8	22.6
14	'Frumos de Voinesti' × *M. floribunda*	98	1	1.0	1.9
15	'Frumos de Voinesti' × *M. niedzwetzkyana*	137	9	6.6	17.0
16	'Frumos de Voinesti' × *M. zumi*	65	0	0.0	0.0
17	'Golden Delicious' × *M. prunifolia*	131	0	0.0	0.0
18	'Reinette Baumann' × *M. floribunda*	142	0	0.0	0.0
19	'Reinette Baumann' × *M. niedzwetzkyana*	38	7	18.4	13.2
20	'Reinette Baumann' × *M. prunifolia*	76	0	0.0	0.0
21	'Reinette Baumann' × *Malus zumi*	21	0	0.0	0.0
22	'Rosu de Cluj' × *M. coronaria*	29	0	0.0	0.0
23	'Rosu de Cluj' × *M. niedzwetzkyana*	126	0	0.0	0.0
24	'Rosu de Cluj' × *M. prunifolia*	117	0	0.0	0.0
25	'Starkrimson' × *M. prunifolia*	24	0	0.0	0.0
	Total hybrids/elites	2190	53	I* =2.42%	

* I% = no. of selected elites / no. of F1 hybrids

of different genotypes planted in the near by orchards or experiments).

By doing this, the biological material was employed in creating new seedlings that can enrich the genetic found passive to selection on the further stages, and also for the application of recurrent selection, following a new strategy and the complementary technique of MAS and phenotypic selection (Oraguzie, 2003; Oraguzie *et al*., 2004; Sestras *et al*., 2009), in order to create new cultivars, for commercial or ornamental use.

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