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Apricot Breeding at the Faculty of Horticulture in Lednice

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Academic Editor: Peter Langridge

Received: 14 March 2016; Accepted: 18 April 2016; Published: 21 April 2016

Abstract: The aim of the apricot-breeding program in the Horticultural Faculty in Lednice, that has been developed since 1981, is to obtain new adaptable cultivars, which combine most of the valuable biological traits. Standard breeding techniques, such as crossing by emasculation and hand pollination, self-pollination and open pollination, were employed. A total of 1.154 crossings were produced from more than 110 different parents. So far more than 20,000 seedlings have been obtained, of which about 13,000 have already been evaluated. The most interesting selections were grafted and planted in trial orchards (we now have more than 650 elite genotypes). Ten of these have already been registered, and further promising new hybrids have been submitted for registration and law right protection (Betinka, Candela, Sophia and Adriana). The basic prerequisite for the initiation of the breeding program was a large collection of genetic resources, established and gradually supplemented since the 1970s. At the present time, we preserve and manage more than 300 accessions of apricot trees. In the frame of the descriptive work of the genetic resources and in order to use in breeding, a collection of apricots has been evaluated. We selected the genotypes and characters relating to an increased level of adaptation to the environment.

Keywords: apricot; *Prunus armeniaca* L.; breeding; productivity; resistance; cultivars; PPV

1. Introduction

Apricot production in Central Europe has many risks, mainly during the post-dormancy period. To improve the yield, stability and profitability of apricot production, it is first necessary to develop new varieties. Additional problems are diseases like viruses and phytoplasma. Many breeding programs are focused on selecting for Sharka (PPV) resistance [1–3].

Among all pests and pathogens affecting the stone fruit production, the most detrimental both in orchards and nurseries is the Sharka disease [4]. This disease, which is due to the Plum pox virus (PPV), was detected in Bulgaria century ago [5] but since then has spread throughout Europe and has now spread worldwide. It affects the fruit quality and production and its cost, including fruit marketing, eradication of infected trees, and Sharka management has been estimated at 10,000 million euros over the last 30 years [4].

Syrgiannidis [6] and Syrgiannidis and Mainou [7] state in their works that the cultivars Stark Early Orange and Stella did not show any symptoms on their leaves after regrafting in the first two years.

Currently, the research of Plum Pox Virus including the creation of new resistant cultivars continues in the fruit research institute in Skydra (Greek Macedonia), headed by Karayiannis [8]. They selected from field trials and artificial tests resistant cultivars for their breeding programs. Most of them come from North America: Early Orange, Stella, NJA 2, Sunglo, Veecot, Harlayne, Goldrich and Henderson, Lito and Pandora. The two cultivars Harcot and Bebecou were classified as tolerant ones. In Italy, Faggioli [9] and Crescenzi [10], based on artificial inoculation-chip budding on woody

indicator GF-305, have found the following tolerant or resistant cultivars: Antonio Errani, Cafona, Fracasso, Noumo, Paviot, Pelese di Giovanillo, Portici, Stark Early Orange, Stella and Veecot. In France, with the participation of INRA, CENTREX and CEP INNOVATION the main goals of the breeding program are: the elaboration of cultivars suitable for a durable production (including resistance to pests and disease), production regularity (including self-fertility and quality of the flowers), and fruit quality (including taste, attractiveness, and suitability for the transport). The main results issued from this program are presented: eight registered cultivars, four new selections under registration, and the first PPV resistant cultivar 'Aramis'®,'Shamade' [11]. In the last 14 years, an apricot breeding program has been developed at CEBAS-CSIC (Murcia, Spain) with the aim to release new early ripening, Sharka resistant cultivars. After a prolonged selection process, three new cultivars named 'Mirlo Blanco', 'Mirlo Naranja' and 'Mirlo Rojo' have recently been released. They fulfil high fruit quality, early ripening and Sharka resistance [12]. A breeding study for identification of new apricot cultivars resistant to Sharka disease caused by Plum pox virus (PPV) was initiated at Inonu University in 2004. Cultivars exhibiting some resistance to PPV, 'Stark Early Orange', 'Harcot', 'Stella' and 'Goldrich' were crossed to local apricot selections. The fruit weight among selected hybrids varied between 35.7–57.5 g while soluble solid content ranged between 16.0%–23.7% [13].

One of the possible ways to improve the market quality of apricot cultivars is the breeding and the subsequent selection of elite seedlings chosen in order to cross donors presenting a high level of adaptation with donors having high quality fruits. Another way to provide the selection of apricot genotypes suitable to given cultivation conditions is to introduce cultivars coming from across the world. This is the reason why several varieties, for example Veecot and Bergeron, were registered in the former Czechoslovakia. At the present time, other tolerant or resistant varieties such as Goldrich, Harcot, and Harlayne are being registered.

Zhebentyayeva [14] on the base of AFLP data analysis supported different donor's sources of resistance in 'Harlayne', 'Goldrich', 'SEO' and 'LE-3276', her team speculates that resistance of 'Harlayne' and 'Goldrich' was brought with Central Asian ancestors. Resistance genes in 'Stark Early Orange' and 'LE 3276' likely came from Chinese progenitors.

The use of genetic resistance sources offers the only definitive solution for the control of Sharka. Some of these natural sources of resistance to PPV in apricot were first identified in North America [15] and since then have been widely exploited in breeding programs [16,17]. There are different propositions about the genetic control of resistance to PPV in apricot, involving one, two or three genes [8,18].

It is a very difficult breeding task to combine the valuable pomological traits together with environmental adaptability and yield reliability. Such goal is the mail aim of breeding program in Lednice described in this this paper.

2. Material and Methods

The observation and preservation of several collections of apricot genotypes were done in the 1970s in the framework of the research program of the Department of Pomology in Lednice. In this zone, the average level of annual precipitation is 516 mm and the annual average temperature is 9.4 °C. It is a warm area; however, frost often occurs during the periods of dormancy and post dormancy and also during the periods of blooming and of fruit formation. The gathered material of genetic resources of apricots comes from different areas and countries in the world as well as from our country. The collection consists of more than 313 accessions and clones and of more than 650 elite hybrids. Plantations were realized gradually, plants were cultivated as dwarf trees with free vase crown respecting a placing of 6 × 2 m. Orchards were regularly fertilized and protected against pests and diseases. Five individuals of each cultivar were planted. The evaluation of quantities and qualitative characters was done according to our own methodology of selection of elite seedlings [19] and according to classification for the species *Armeniaca* [20].

In 1960 an apricot research program was started at the Horticulture Faculty in Lednice with the aim of improving the production of apricots in the Czech Republic by prof. Vachun and prof. Vavra. The breeding aims in the first phase of the breeding program were to extend the ripening time and to increase the frost hardiness of the flower buds. The main breeding aims in the second phase were: fruit size and attractiveness.

The third and last phase of our breeding program is currently focused on appearance, firm flesh and PPV resistance. We are also studying the genetics of resistance in many other crossings, using Sharka-resistant donors like Henderson, Orangered, Goldrich, Veecot, Harcot, Harlayne, Sunglo and Riland. Later we included our own hybrids for the PPV resistance: Betinka, Adriana and Candela, including hybrids LE-3246, LE-2904 and others.

Since 1981, the donors of resistance towards the Sharka virus—the cultivars Stark Early Orange (SEO), and Henderson—were used in crossings with the following donors of fruit quality: Vestar and Velkopavlovická (local clone of Hungarian Best). Standard breeding techniques, such as crossing by emasculation and hand pollination, self–pollination and open pollination were employed. A total of 1154 crossings were produced from more than 110 different parents. So far more than 20,000 hybrid seedlings have been obtained.

To verify the resistance of apricot genotypes to PPV, the following methods have been used: top working of tested hybrids directly into the infected trees in plantation with flat expansion of PPV (strain Rec.), and the methods of woody indicator of GF-305 peach seedling. In some populations of crossings, we used direct inoculation into one-year seedlings onto their own roots to accelerate the breeding process. The method used was chip budding using two buds of PPV-D or PPV-M strains. For genotypes, where, after a one-year evaluation of visual symptoms, no symptoms were found, the one-year shoots were inoculated with the GF- 305 indicator. The early pre-selection of resistant hybrids grown on their own roots (without grafting) was practiced since 1998 using a modification of the method described by Audergon [21]. The PPV incidence was scored individually on each replicate as follows: 0 – without symptoms; 1 – very light diffuse spots, symptoms observed in one or two leaves; 2 – diffuse spots bordering leaf veins, symptoms observed in more than two leaves; 3 – diffuse spots and leaves deformations, symptoms observed in most leaves.

The virological phenotypic assessment of populations for resistance to PPV was conducted partly at the Crop Research Institute Prague - Ruzyně, partly at Horticultural Faculty in Lednice, due to the training organized by Dr. J. Polák and his team.

Control cultivar was Velkopavlovická as one of the numerous clones of Hungarian Best.

3. Results and Discussion

From 1960s to 70s, an apricot research program was started at the Horticulture Faculty in Lednice with the aim of improving the production of apricots in the Czech Republic, by prof. Vachůn and prof. Vávra.

The breeding aims in the first phase of the breeding program were to extend the ripening time and to increase the frost hardiness of the flower buds. We subsequently registered the first generation of new cultivars: Lejuna, Leskora, Lebela, Ledana, Leala and Lerosa. Except for the cultivar Leskora, these are mostly only propagated for hobby growers.

Many hybrids used in this period came from the breeding program co-ordinated by Leon Frederic Hough at Rutgers University in New Jersey, USA. The collaboration with him was a great help and provided a good starting point for increasing our apricot germplasm.

The main breeding aims in the second phase were: fruit size and resistance to the Sharka virus. Since 2004 we have registered the following cultivars Minaret, Svatava, Palava, Marlen, Lenova and Lemeda. The cultivar Marlen is a clone of Hungarian Best.

The third phase of our breeding program is currently focused on appearance, firm flesh and PPV resistance. The cultivar Betinka (LE-3276) has a high level of resistance to the PPV D-strain, and medium resistance towards the M-strain [22]. The cultivar Candela (LE-2927) has semi-columnar type

of growth and excellent fruit quality. Other hybrids with different levels of resistance, market value and fruit characteristics are described in Table 1.

Table 1. Average values of selected features of new varieties of apricots for the period 2007–2015.

Ultivars	Productivity (1–9)	Fruit Size (g)	Flesh Firmness (1–9)	Taste (1–9)	Precocious Decline (Body 1–9)	Total Evaluation (1–9)
TOMCOT	8	47	7	7,5	7	7
GOLDRICH	9	56	8	7	8	8
HARLAYNE	8	43	7	7,5	7	7
Betinka (LE-3276)	7	57	8,5	8	7	8
Adriana (LE-3241)	8	55	8	8	8	9
Candela (LE-2927)	8	54	7	8	7	9
Sophie (LE-2926)	7	63	8	7	6	7

The study of several collections of genotypes during several years of observations helped choose the most important characters connected with adaptability to environment. The analysis of these characters enables breeders to choose parents—donors of characters and conservation of genetic characters to set up a core collection. Genetic improvement of apricots in the frame of the species is possible in all characters relating to adaptability increase. However, it usually takes a longer period of time.

4. Selection of Donors of Characters Related to an Increase of Adaptability and Breeding Value

Frost hardiness of flower buds

Harlayne, Harval, Leala, Lejuna, Leronda, Leskora, Neptun, NJA 1 A, Vivagold, Volschebnyi, Vynoslivyi, Yulskyi, Frostina, "Pozdně kvetoucí", Harrow star.

Late termination of dormancy

Henderson, Chuan Zhi Hong, Lebela, Oranzevo-krasnyi, Stark Early Orange, Vegama, Veharda, Zard, Vynoslivyi, Candela.

Frost tolerance of juvenile fruits

Leala, Lefrosta, Lejuna, Lemira, Leskora, Marculesti, Neptun, Re Umberto, Frostina, Late-blooming -Pozdně kvetoucí, Candela, Goldrich, Farclo, Hargrand.

Late Blooming

Early Gold, Machova, Marculesti, *P. brigantiaca* x Olymp, Re Umberto, Sulmona, Stella, Vynoslivyi, Farclo, Late –blooming- Pozdně kvetoucí.

High level of self-fertility

Alfred, Bergeron, Minaret, Vestar, Kostinskyi.

Field tolerance to ESFY

Vestar and Poyer.

Tolerance or resistance to Plum Pox Virus (PPV)

SEO, Harlayne, Henderson, Orangered, Betinka, Adriana, Candela, Sophia, LE-3187, Veecot.

Climatic Adaptation

Bergeron, Goldrich, Marculesti, Kecskemete Rose, Leala, Lejuna, Leskora, Re Umberto, Rose Early, Candela, Tomcot, Chuan Zhi Hong, Vynoslivyi.

Excelent taste and apricot aroma

Velkopavlovická, Sucre de Bohutice, Sabinovská, Hungarian Best, Klosterneuburg, Krasnoscokiy, Bronzoviy, Vynosliviy, Bobcot, Harrow Joy, Bergarouge, Hargrand, Skopljanska krupnoplodna, Poyer, Paviot, Sucre de Holub, Nancy apricot, Luizet, Polonais, Betinka.

5. Conclusions

The currently assessed and newly created hybrid platform offers an opportunity to select additional new genotypes with appropriately combined characteristics regarding the resistance to abiotic and biotic pathogenic agents, but also in terms of the requirements regarding fruit ideotype and growing commercial requirements.

A different value of variability was observed at all evaluated traits. This enables breeders and gene resources managers to choose donors of given characters. The variability of each single character gives breeders of apricots the possibility to integrate and to combine the given characters in the breeding process so that obtained hybrids reach a higher level of adaptability and of fruit market-value.

For practice growing we offer four promising PPV resistant varieties with a high market value of the fruits. These varieties are now in the process of registration and law protection.

Acknowledgments: In the Czech Republic, the preservation and use of the genetic resources of cultivated plants are financed by the Ministry of Agriculture (MZe) with National program of utilization and maintenance of plant genetic resources. The authors thank for technical and expert assistance and cooperation following colleagues - Ing. Sasková Hana, Ing. Jarmila Oboňová, Ing. Tomáš Nečas, Ing. Ivo Ondrášek and Josef Jandásek.

Author Contributions: Boris Krška and Zdeněk Vachůn conceived and designed the experiments. Experiments were done by Zdeněk Vachůn till 2004 after this time Boris Krška continue on. Hana Sasková, Jarka Oboňová, Ivo Ondrášek, Tomáš Nečas and Boris Krška performed the observation of hybrids and elite seedlings. Boris Krška, Hana Sasková, Tomaš Nečas and Ivo Ondrášek took participation on emasculation and pollination. Tomaš Nečas performed field resistence to ESFY, Boris Krška and Tomaš Nečas carry out other observations of germplasm collection. Boris Krška and Zdeněk Vachůn analyzed the data. Josef Jandásek contributed with on orchards management. Jan Přenosil is the author of the pictures. Boris Krška wrote the paper.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. A Brief Description of the Four Apricot PPV Resistant Varieties

Appendix A.1. Betinka-LE-3276

Origin:
Crossed by Vestar x SEO (both parents have a Chinese origin),
Horticulture Faculty, Lednice, crossing 1984, selection since 1992.
Short description:
Vigour: strong, upright
Productivity: medium to high
Maturity: middle season, + 2 days after Hungarian Best
Fruit quality: eating quality good, firm flesh, medium – to large size, nice look
Recommendation:
Ideal for totally infected PPV area, totally infected PPV area, for middle season and fresh market, self-incompatible.

Appendix A.2. Adriana-LE-3241

Origin:
Crossed by cultivars Vestar x SEO (both parents have a Chinese origin), Horticulture Faculty, Lednice, crossing 1984, selection since 1991.
Short description:
Vigour: medium – strong, globes – spreading crown
Productivity: medium, high
Maturity: middle season, - 3 days before Hungarian Best,
Fruit quality: good taste, medium soft, medium – big size
Recommendation:
Resistant to PPV, ideal for fresh market, self-incompatible.

Appendix A.3. Candela-LE-2927

Origin:
Crossed by Hungarian Best x SEO (parent SEO has a Chinese origin), Horticulture Faculty, Lednice, crossing 1984, selection since 1991.
Short description:
Vigour: medium – weak, compact, upright
Productivity: early, high
Maturity: same time with Hungarian Best
Fruit quality: excellent taste, medium – soft, medium size, good look
Recommendation:
Resistant to PPV, ideal for the fresh market and processing, self-incompatible.

Appendix A.4. Sophia-LE-2926

Origin:
Crossed by Hungarian Best x SEO (parent SEO has a Chinese origin), Horticulture Faculty, Lednice, crossing 1984, selection since 1991.
Short description:
Vigour: medium – weak, compact, upright
Productivity: early, high
Maturity: 5 to 7 days after Hungarian Best
Fruit quality: good taste, firm flesh, medium size, good look
Recommendation:
Resistant to PPV, ideal for the fresh market and processing, self-incompatible.

Appendix B. Pictures of New Bred Apricot Resistant to PPV

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