New stress-resistant Krymsk rootstocks for stone fruits

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Abstract: The Krymsk Experimental Breeding Station has a long history of breeding interspecific rootstocks for stone fruit. The 6000 Prunus accessions in their collection are being used for combining useful traits of stress and disease resistances into new interspecific rootstock genotypes suitable as rootstocks for multiple stone fruit species. For testing and propagation in Europe, the United States and several other countries outside Russia, Varieties International has obtained a license and has imported several promising rootstocks suitable for almond, apricot, cherry, nectarine, peach and plum. The selection of these interspecific rootstocks was made on basis of the induced tree vigor and tolerance to various environmental stresses like drought, flooding, frost and the pH and salt content of the soil. At present seven Krymsk rootstocks have been patented and have been commercially released. Since 2017 about 20 new selections have been imported into Europe and the USA. After release from quarantine these rootstocks have been propagated and test trees have been grown. In Europe the first test trees of plum varieties ‘Jubilieum’ and ‘Opal’ and sweet cherry varieties ‘Kordia’ and ‘Regina’ were planted in 2023, using rootstock genotypes with a vigor between very dwarfing to semi-dwarfing. After the first growing season in the differences in tree vigor are already becoming visible. However, it will take several more years to evaluate how the fruit production and growth the trees will develop and to find out which of these rootstocks will be a better choice for the fruit grower than the ones currently used.

Keywords: Prunus, Cherry, Apricot, Plum, Peach, Almond, drought

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1. Introduction

The use of clonal rootstocks as alternative for seedling rootstocks has made a large contribution to improve the production and fruit quality of pip and stone fruit species. The genetic stability of clonally propagated rootstock results in more homogeneous tree vigour and fruit production in the orchard than the use of seedling rootstocks. The practise of growing fruit cultivars on rootstocks goes back centuries. Originally, mainly seedling rootstocks were used to vegetatively propagate fruit cultivars by grafting or budding to maintain the distinct genetic characteristics of the cultivars and to overcome the difficulties in propagation of many cultivars by cuttings. Specific rootstock breeding programs worldwide have selected rootstocks that tolerate adverse local soil conditions, pests and diseases. Other important reasons for using a specific rootstock is to control the vigour of tree and to increase fruit quality and orchard yields of the fruit cultivar. As many fruit species are grown in a wide range of geographical regions with different climatic conditions, soil composition and pressures of pests and diseases, there is not a single rootstock for a cultivar that that meets all the requirements of the orchard and the grower.

An important factor to successfully grow a fruit cultivar on a rootstock is the compatibility between the rootstock and the cultivar grafted or budded onto the rootstock. Incompabitily issues are more likely to occur when a rootstock of a different genus than that of the cultivar is used. In pear (genus *Pyrus*) incompatibility issues often occur when a pear cultivar is grafted onto a quince (genus Cydionia), a problem that can be overcome by using a Pyrus genotype that is compatible with both pear cultivar and quince rootstock. In stone fruit cultivar (genus Prunus) incompatiblity is much more widespread problem and finding a suitable rootstock has been the topic of many studies (Reig et al., 2018, 2019; Salazar et al., 2018; Solonkin et al., 2022; Zarrouk et al., 2006).

2. Breeding of interspecific rootstocks for stone fruit in Krymsk

The Krymsk Experiment Breeding Station in Russia has a long history of breeding rootstocks for different stone fruit species. Over a period of more than 60 years scientist Gennady Eremin has collected more than 5000 genotypes of Prunus (Eremin et al., 2017). These genotypes, widely differing in characterisc like vigour, easiness of propagation by cuttings and resistances to drought, winter frost, flooding (asphixia) and soil pathogens, have be used as parents in the breeding program. The most used Prunus selections in the breeding program and their most important traits are listed in table 1. In order to combine as many positive traits into a new rootstock, different Prunus species are crossed to create interspecific hybrids. In vitro embryo rescue technique is being used to grow plants from seeds that fail to germinate due to postgamous incompatibility. Interspecfic hybrids are selected to for their compability with several Prunus species. Many of the current selections from the Krymsk breeding stations can be used as rootstocks for peach, nectarine, apricot, almond as well as for plum. A second part of the breeding program is focussed on selecting semi-dwarf to dwarf stress-tolerant rootstocks for sweet and sour cherries.

Table 1. Species of the genus *Prunus* L. from wich genotypes were selected as sources of characteristics that are imported for breeding and selection. Source: Eremin et al. (2017).

Characteristic	**Prunus species**
Weak growth	*P. pumila, P. incana, P. tomentosa. P. spinosa, P. nana, P. kurilensis, P. incisa, P. prostrata, P. canescens*
Rooting of cuttings	*P. cerasifera, P. pumila, P. dasycarpa, P. lannesiana, P. mahaleb, P. pseudocerasus, P. serrulata*
Frost resistance	*P. pumila, P. tomentosa, P. spinosa, P. nana, P. fruticosa, P. sachalinensis, P. kurilensis, P. ulmifolia, P. davidiana*
Drought resistance	*P. nana, P. bucharica, P. spinosissima, P. mahaleb, P. fruticosa, P. spinosa, P. incana, P. armeniaca*
Flooding (asphixia) resistance	*P. cerasifera, P. tomentosa, P. dasycarpa*
Resistance to soil pathogens	*P. cerasifera, P. spinosa, P. tomentosa, P. pumila, P. davidiana, P. fruticosa*

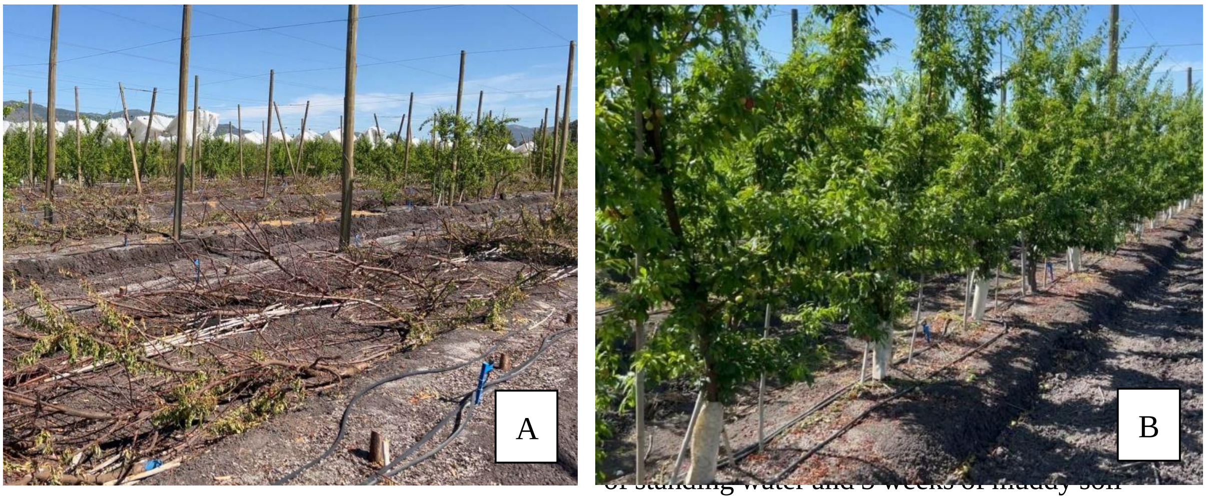
3. Released and patented Krymsk rootstock selections

Several Krymsk rootstock selections have been patented and are commercially used in cherry, plum, peach and almond orchards in Europe, Turkey, Russia, United States, Chile and Australia. Krymsk 86 (=Kuban 86) is widely used as a rootstock for almond in the USA. Krymsk 5 and Krymsk 6 are used as rootstocks for cherry, especially in areas with dry hot summers because of high tolerance to heat stress, drought as well as flooding. (Long et al., 2017, 2018; Maas et al. 2014). Krymsk 1 has become an important rootstock for high density European plum orchards in The Netherlands (Maas et al., 2011). An overview of the commercially available Krymsk rootstocks is presented in Table 2.

Table 2. Released Krymsk rootstocks and their use for different stone fruits

Krymsk rootstock	US patent	Used as rootstock for
Krymsk®1 (VVA-1)	USPP 15,955	Almond, apricot, nectarine, peach, plum
Krymsk®2 (VSV-1)	USPP 15,957	Almond, apricot, nectarine, peach, plum
Krymsk®5 (VSL-2)	USPP 15,723	Cherry
Krymsk®6 (LC-52)	USPP 16,114	Cherry
Krymsk®7 (L2)	USPP 14,353	Cherry
Krymsk®86 (Kuban 86)	USPP 16,272	Almond, apricot, nectarine, peach, plum
Krymsk®99 (AP3)	USPP 26,299	Apricot, peach, plum

In an orchard in Chile the resistance of rootstock Krymsk®86 to asphixia was clearly demonstrated this year in a part of the orchard of that was flooded for several weeks (Figure 1).



of standing water and 3 weeks of muddy soil in an orchard in Chile (A). Trees of same cherry-plum variety on rootstock Krymsk®86 planted in the same orchard in the same year all survived the flooding (B). (photos: Adam Weil, Varieties International/TreeConnect, Oregon, USA).

4. New Krymsk rootstocks under trial in Europe

Since 2017 a series of 17 new selections from the Krymsk breeding program has been imported into Europe, partly suited as rootstocks for cherry and partly for almond, apricot, nectarine, peach, and plum (Table 3). The vigour range of these rootstocks at the site of origin in Krymsk varies between semi-dwarf to dwarf. All the genotypes are interspecific hybrids originating from single or multiple crosses between two or more different Prunus species.

Table 3. New selections of Krymsk rootstocks imported for evaluation in Europe

Krymsk selection	Vigour range	Used as rootstock for
A9 x VSL-2	dwarf	cherry
C56-12 x VSL-2	dwarf	cherry
Rulan-8	dwarf	cherry
RVL-4	semi-dwarf	cherry
P. serrulata x P. sachilinensis	semi-dwarf	cherry
P. serrulata x P. fructicosa	semi-dwarf	cherry
P. serrulata 42-21-6 nr. 1	semi-dwarf	cherry
P. serrulata 42-21-6 nr. 2	semi-dwarf	cherry
Kolibry	very dwarf	almond/apricot/peach/nectarine/plum
Sava	dwarf	almond/apricot/peach/nectarine/plum
Trio 22-07	dwarf	almond/apricot/peach/nectarine/plum
Trio 25-07	dwarf	almond/apricot/peach/nectarine/plum
Trio 27-07	dwarf	almond/apricot/peach/nectarine/plum
P. pumila x Kuban 86	dwarf	almond/apricot/peach/nectarine/plum
E5 (P. pumila x Alab-1)	dwarf	almond/apricot/peach/nectarine/plum
Achete	semi-dwarf	almond/apricot/peach/nectarine/plum

5. Propagation of Krymsk rootstocks and raising of trees for evaluation trials.

After release from quarantine at Naktuinbouw in The Netherlands, the imported Krymsk selections were propagated by soft wood cuttings. Most selections can also be propagated by hard wood cuttings taken in winter, which is the most used propagation method by the Krymsk Experimental Breeding Station. As propagation by cuttings of selections 18-7-17 was not successful, in vitro propagation was used to propagate this particular rootstock selection. Rooted cuttings were grown in pots for one season to reach a size suitable for grafting. For the first trial the rootstocks for cherry were grafted with cultivars ‘Kordia’ and ‘Regina’ and those for almond/apricot/nectarine/peach/plum with the plum cultivars ‘Jubileum’ and ‘Opal’. The bench-grafted rootstocks were grown for two years in the nursery into feathered trees using the ’knipboom’ practise (Wertheim & Webster, 2003). Figure 2 shows finished two-year old ‘Kordia’ trees on rootstock Rulan-8 next to a ‘Kordia’ tree on rootstock Gisela 13.

Figure 2. Finished feathered 'knipboom' trees of cv. 'Kordia' grafted on rootstock Gisela 13 and Krymsk selection Rulan 8 after 2 seasons in the nursery. (photo: Frank Maas)

5. Results and discussion

The success of the first time grafting of cherry cultivars 'Kordia' and 'Regina' was low in some of the rootstock selections. In a few rootstocks grafting failed completely in one of the two cultivars. More research is needed to improve the grafting success and to find out if the total failure of grafting in some combinations is caused by incompatibility between the scion cultivar and the rootstock or was caused by unfavourable conditions during and inmediately after grafting. The best grafting success of about 45% was obtained for rootstock Rulan-8. Except for rootstock Kolibry, the the grafting success for the European plum varieties was much higher and was on average 85% for cv. 'Jubileum' and 77% for cv. 'Opal'.

In spring 2023 the first test trees were planted in the demonstration plots of two fruit tree nurseries and in an orchard of a commercial plum growers in The Netherlands. In the test field of nursery Botden & Van Willigen in The Netherlands plots of 5 trees each of plum cultivars 'Jubileum' and 'Opal' were planted in April 2023 (Figure 3). In May the caliper of the rootstock and scion below and above the graft union, the number of lateral branches >30 cm and the tree height were measured as the starting point of the measurements of tree delopment in the next years.

Figure 3. Test field of 'Jubileum' (A) and 'Opal' plum trees (B) on different Krymsk rootstock selections at Botden & Van Willigen nurseries in The Netherlands. Trees were planted as two-year old nursery trees on April 7, 2023. (Photos: Frank Maas, May 25, 2023)

Tree growth vigour during the first year after planting, determined as the increase in scion trunk diameter at 20 cm above the graft union and the increase in length of the trees, is presented in Figure 4. At planting in Spring 2023 the difference in tree height of 'Jubileum' trees on the different rootstock were very small and varied between 205 cm on rootstock P. pumila x Kuban 86 and 224 cm on rootstock Achete (Fig 4A). The height Opal trees was generally a bit less and varied between185 cm and 224 cm on rootstocks P. pumila x Kuban 86 and E5, respectively (Fig. 4 B). 'Jubileum' showed the smallest increases in tree height in 2023 on rootstocks Sava, E5 and P. pumila x Kuban 86, and the largest increases height on rootstocks Achete and Trio 22-07. In 'Opal' the smallest increases in tree height were observed on rootstocks E5, Kolibry and P. pumila x Kuban 86, and the largest increases on rootstocks Achete and Trio 25-07. At the time of planting both the 'Jubileum' and 'Opal' trees already showed some differences in trunk diameter. Trunk circumference, calculated form two crosswise-made measurents of the trunk diameter using digital calipers, was smallest for 'Jubileum' on rootstock VVA-1, followed by E5 and the largest on rootstock Trio 22-07 (Fig. 4C). The increase in trunk circumference in 'Jubileum' in 2023 was the

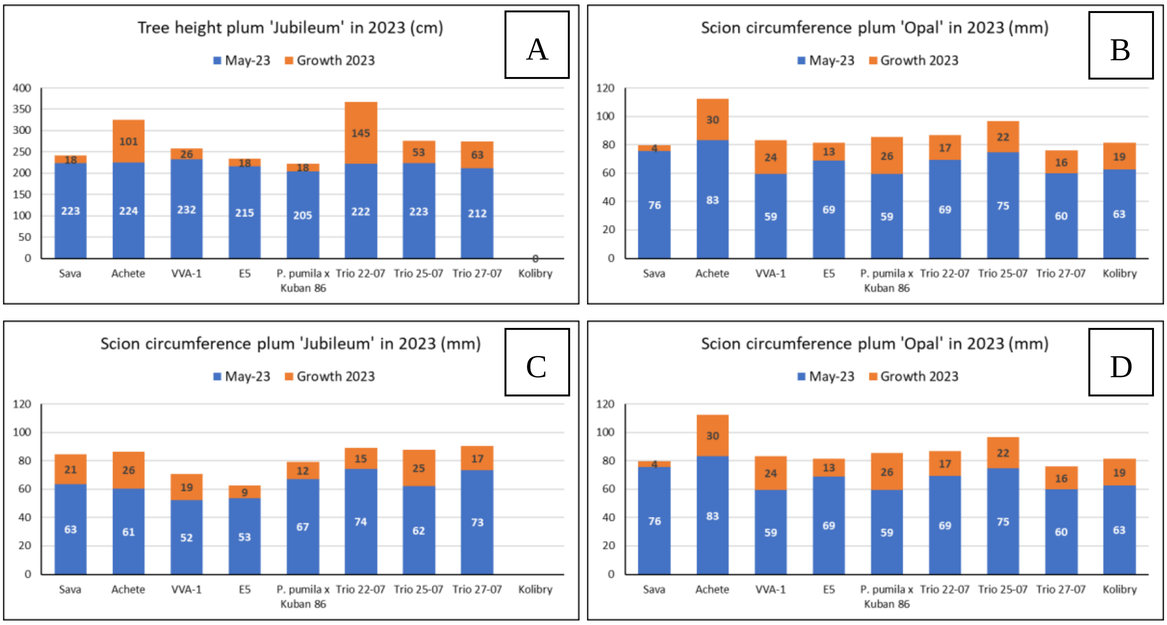


Figure 4. Tree height and scion trunk circumference of plum cultivars 'Jubileum' (A, C) and 'Opal' (B, D) determined at the start and end of the first growing season in the orchard. The data represent the means of 3 trees per scion-rootstock combination.

smallest on rootstocks E5, followed by rootstocks P. pumila x Kuban 86, Trio 22-07 and Trio 27-07. The largest increases in trunk circumference were observed for ‘Jubileum’ on rootstocks Achete and Trio 25-07 (Fig. 4C). In ‘Opal’ trees the smallest trunk circumferences were noted for trees on rootstocks VVA-1 and P. pumila x Kuban 86, followed by Trio 27-07 and Kolibry. The largest increases in trunk circumference of ‘Opal’ was observed on rootstocks Achete, followed by P. pumila x Kuban 86, VVA-1 and Trio 25-07 (Fig. 4D).

Figure 5. Test field of cherry cvs. ‘Kordia’ and ‘Regina’ on different Krymsk rootstock selections at Fleuren nurseries in The Netherlands. Trees were planted as two-year old feathered nursery trees on May 3, 2023. (Photos: Frank Maas, May 12, 2023).

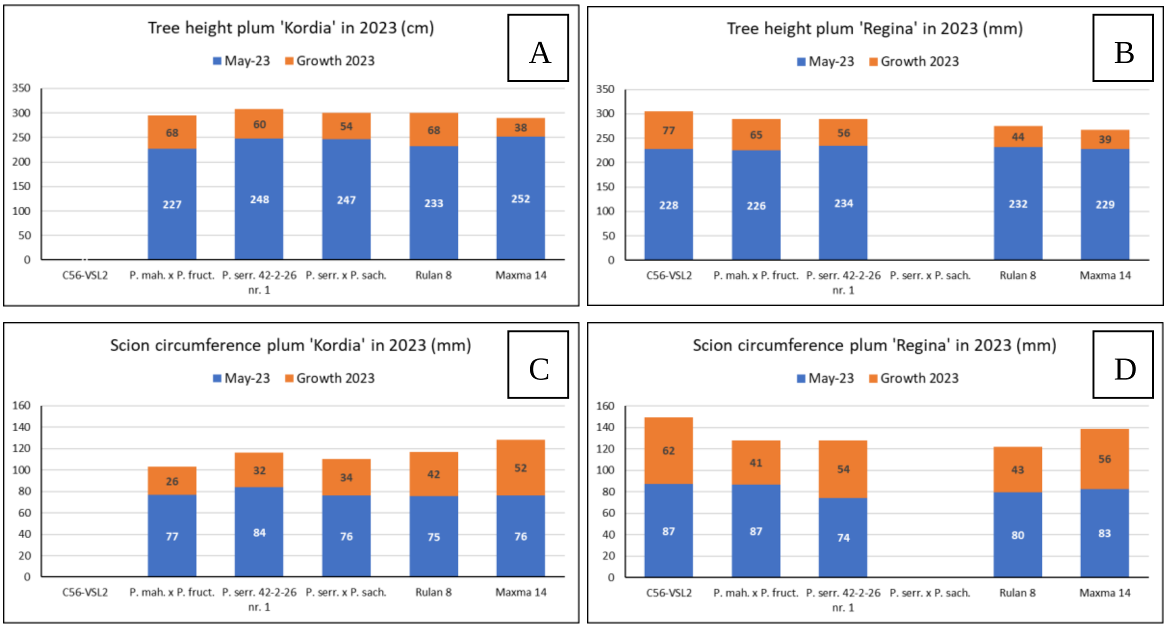


Figure 6. Tree height and scion trunk circumference of cherry cultivars ‘Kordia’ (A, C) and ‘Regina’ (B, D) determined at the start and end of the first growing season in the orchard. The data represent the means of 2 trees per scion-rootstock combination.

At the time of planting in Spring 2023 the height of the ‘Kordia’ and ‘Regina’ trees on the different Krymsk and Maxma 14 rootstocks varied between 224 and 252 cm for ‘Kordia’ and 226 and 234 cm for ‘Regina’ (Fig. 6A, 5B). During the first year in the orchard the smallest increase in tree length in both cultivars was observed on rootstock Maxma 14. ‘Regina’ showed the largest increase in tree length in 2023 on rootstock C56 – VSL2 while the length of ‘Kordia’ increased the most on rootstocks P. mahaleb x P. fructicosa and Rulan 8. Trunk circumference of the scion cultivars measured at 20 cm above the graft union varied between 70 and 84 mm and 74 and 87 mm for ‘Kordia’ and ‘Regina’, respectively (Fig. 6C, 5D).

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