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Yield Regularity, Fruit Weight and Consumer Qualities of Triploid Apple Cultivars Developed at the All Russian Research Institute of Fruit Crop Breeding (VNIISPK)

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Abstract

For the first time in Russia, 10 triploid apple cultivars having a complex of valuable commercial traits including high productivity, more regular annual yields and highly marketable fruit, have been obtained from crossings between parents of different ploidy. Many fruitgrowers regard triploid cultivars as being of little use for commercial production. We suggest that this belief is erroneous. At the All Russian Research Institute of Fruit Crop Breeding (VNIISPK) new triploid apple cultivars have been evaluated for yield regularity, comparative fruit keeping quality, fruit size and marketability. All of the triploid cultivars were notable for their more regular yields compared to diploid cultivars. Triploid and diploid apple cultivars with different dates of fruit maturity were obtained in the program. Fruit of 'Aleksandr Boiko' and 'Vavilovskoye' showed greater storage life among the triploid cultivars as well as 'Sinap Orlovskiy' among the diploids. Most triploid cultivars had a larger fruit size in comparison with the diploids. Triploid cultivars obtained from different initial levels of ploidy did not have better fruit appearance and flavor than diploid cultivars. The introduction of triploid cultivars developed at VNIISPK into commercial use is creating great interest.

Apple breeding using polyploidy has been demonstrated through the earlier research of Swedish investigators (Nilsson-Ehle, 1994; Einset, 1947). It has been determined that triploid apple seedlings are more valuable than diploids in breeding programs (Einset, 1947; Pratt, 1963) and using polyploidy level in apple breeding was well established by the 1950s-1960s (Einset, 1947; Dermen, 1951). Some investigators have pointed out that triploid apple cultivars had better regularity of annual yields (Howlett, 1932; Bergendal and Nybon, 1966) and higher autogamy than diploids (Haskell, 1955). It was recognized early that the hybridization of diploids with tetraploids opened up new opportunities in apple breeding (Einset, 1947). Subsequently, however, that breeding direction was not further developed to any significant extent. Nonetheless, some triploid cultivars have been produced commercially, such as 'Mutsu' and 'Jonagold'.

At VNIISPK (the All Russian Research Institute of Fruit Crop Breeding) apple breeding using polyploidy has been carried out since 1970 (Sedov et al., 2008). A total of 17 triploid apple cultivars have been developed, with 10 of them being included in the State Register of Breeding Achievements Admitted to Use (zoned). These cultivars have been obtained from different-ploidy crossings: 'Avgusta' ('Orlik'×'Papirovka' tetraploid), 'Aleksandr Boiko' ('Prima'×'Wealthy' tetraploid), 'Bezhin Lug' ('Severny Sinap'×'Wealthy'

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tetraploid), 'Vavilovskoye' [18-53-22 ('Skr yzhapel'×OR18T13)×'Wealthy' tetraploid], 'Daryona' ('Melba'×'Papirovka' tetraploid), 'Maslovskoye' ('Redfree'×'Papirovka' tetraploid), 'Orlovsky Partizan' ['Orlik'×13-6-106 ('Suvorovetz' seedling)], 'Osipovskoye' ('Mantet'×'Papirovka' tetraploid), 'Patriot' [16-37-63 ('Antonovka Krasnobochka'×SR0523) × 13-6-106 ('Suvorovetz' seedling)] and 'Yablochny Spas' ('Redfree'×'Papirovka' tetraploid). In addition, four triploid cultivars have been obtained from crossings between diploid cultivars as a result of the emergence of unreduced gametes in one of parents. There is evidence that triploidy in apple is the lowest level of polyploidy which gives the highest effect (Bavtuto and Buchenkov, 2000; Buchenkov et al., 2005). Triploid apple cultivars bear larger fruit (Sedysheva and Sedov, 2008). Further, higher resistance to scab is noted in triploid apples (Lozitsky, 1970; Sedov et al., 2008). There is also evidence that triploid apple cultivars have more regular annual yields (Dutova, 1985; Tuz, 1974).

The aim of the study reported here was to determine the regularity of annual yields, fruit weight and consumer qualities in triploid apple cultivars developed at VNIISPK.

Materials and Methods

The experimental orchards of the Institute are situated in the Orel district which is in the centre of the Middle-Russian Upland (latitude between 52° and 54° North and longitude between 35° and 38° East). The climate of the region is moderately continental. Annual precipitation is 500-600 mm. The vegetative period lasts for 175-185 days. The average annual temperature is 4.6°C above zero. The absolute minimum air temperature is 39°C below zero and absolute maximum is 38°C above zero. The sum of positive temperatures above 10°C is 2250°C. The experimental orchards are sited on grey and dark-grey forest soils. Some plots are sited on leached chernozem (lower in humus and aluminium). Soils and sub-soils of the Institute orchards are favorable for apple cultivation.

Young trees of new triploid and diploid varieties were assessed in years 7 to 12. The cultivars were grown on scaffold branches on trees grafted onto hardy semi-dwarf stock 3-4-98 (*Malus baccata*×M9 rootstock). Crab (*Malus silvestris* (L.) Mill.) was used as a pollinizer. Tree spacing was 5×2 m. The soil within the plots was fallow. Minimal pruning was made only to remove any diseased limbs.

Fruit weight was assessed by weighing. The appearance and taste of fruit were assessed by ratings during the seven years of study according to Sedov (1995) and Sedov and Ogoltzova (1999).

Cultivars designated as "Summer" apple cultivars were those where picking maturity was set as being in late July to late August (as determined by starch iodine rating) and where fruit could be stored between 1 and 2°C until middle October. "Winter" cultivars were those where picking maturity was set as being in mid to late September and fruit could be stored until early January to late April in low temperature conditions (1-2°C).

Fruit appearance was assessed based on the following ratings: 5 – fairly large fruit of proper shape with fine skin color; 4 – fairly large and attractive fruit; 3 – insufficiently attractive fruit in color and shape; 2 – plain, small and unattractive fruit; 1 – plain, very small fruit with improper shape and poor color.

The following ranges of fruit size were recorded: fruit under medium size: 71-100 g; medium size: 111-150 g; above medium size: 151-200 g; large size: 201-250 g and very large: 251-350 g.

Fruit flavor was also assessed at multiple tastings by 7-8 tasters using the following ratings: 5 – excellent dessert flavor; 4 – good table flavor; 3 – satisfactory flavor; 2 – poor taste, fruit are not suitable for fresh eating; 1 – very poor flavor, fruit are absolutely uneatable.

Yield was assessed as kg per tree.

In order to characterize the triploid culti-

vars for yield regularity, a 'J' periodicity index was calculated over a number of years as the relationship of difference of yields during consecutive years to their sum (as a percentage):

$$J = ((\Sigma (\alpha_1 - \alpha_2) + (\alpha_3 - \alpha_4) + \ldots) / (\Sigma \alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 + \ldots)) \times 100,$$

where: α_1, α_2, α_3… are the yields in consecutive years. By this periodicity index, the cultivars may be divided into three groups: the 1st group – annually yielding cultivars (where the periodicity index is not less than 40%); the 2nd group – irregular yielding cultivars (41-75%); and the 3rd group – cultivars that are distinctly periodical in their yield patterns (more than 75%; otherwise referred to as biennial bearing).

Results

Yield periodicity was calculated for six triploid and six diploid apple cultivars (Table 1). The six triploid cultivars and five of the diploid cultivars were from the VNIISPK breeding program and one diploid was a control (the wild type – known as 'Antonovka Obyknovennaya'). Nearly all of the triploid cultivars had a lower index of yield than the diploid cultivars that confirms their more regular production across a number of years. In the triploid cultivars, the index of yield periodicity varied from 15.7% ('Aleksandr Boiko') to 36.5% ('Patriot'). As a mean, across the six triploid cultivars the index of yield periodicity was 25.1%. In the diploid cultivars, the lowest index was noted in 'Sinap Orlovsky' (16.3%), while the highest was with 'Antonovka Obyknovennaya' (59.8%). The average index for all six diploid cultivars was 35.8%, i.e. about 1.5 times higher than for the triploid cultivars. In mature trees, the index of yield periodicity was significantly higher than that in young trees.

In order to compare fruit keeping quality, weight, appearance and flavour in the triploid and best diploid cultivars from the VNIISPK breeding program, 10 cultivars were selected among which five were summer maturing and five were winter maturing in each group (Table 2).

In the cold storage conditions used (2ºC) the longest fruit keeping was characteristically with the triploid cultivars 'Aleksandr

Table 1. Yield regularity of selected triploid and diploid cultivars within the VNIISK breeding program.

Cultivar ploidy	Yield regularity, J (%)
Triploid cultivars	
Aleksandr Boiko (Prima×Wealthy tetraploid)	15.7
Blagodat [23-20-74 (814 – open pollination)×Giant Spy]	20.8
Orlovsky Partizan [Orlik×13-6-106 (Suvorovetz seedling)]	22.6
Rozhdestvenskoye (Wealthy×BM 41497)	22.9
Ministr Kisiliov (Chistotel×Wealthy tetraploid)	32.1
Patriot [16-37-63 (Antonovka Krasnobochka×SR 0523)×13-6-106 (Suvorovetz seedling)]	36.5
Triploid cultivars, mean	25.1
Diploid cultivars	
Sinap Orlovsky (Severny Sinap×Pamyat Michurina)	16.3
Bolotovskoye (Skryzhapel×1924)	30.6
Orlovim (Antonovka Obyknovennaya×SR 0523)	34.1
Imrus (Antonovka Obyknovennaya×OR18T13)	34.7
Veniaminovskoye (814 – open pollination)	39.5
Antonovka Obyknovennaya (control cultivar from folk breeding = landrace)	59.8
Diploid cultivars, mean	35.8

Table 2. Comparative characteristics of fruit keeping quality, weight, appearance and flavor of selected triploid and diploid apple cultivars from the VNIISPK breeding program.

	Date of maturity[z]	Fruit keeping	Fruit weight (g)	Fruit appearance, rating	Fruit flavor rating
Triploid cultivars from 2x×4x crossings					
Avgusta (Orlik×Papirovka tetraploid)	s	late September	160	4.4	4.4
Aleksandr Boiko (Prima×Wealthy tetraploid)	w	until March	190	4.4	4.3
Bezhin Lug (Severny Sinap×Wealthy tetraploid)	w	until February	150	4.4	4.3
Vavilovskoye [18-53-22 (Skryzhapel×OR18T13)× Wealthy tetraploid]	w	unitl March	170	4.6	4.3
Dariona (Melba×Papirovka tetraploid)	s	late September	170	4.5	4.3
Maslovskoye (Redfree×Papirovka tetraploid)	s	until October	230	4.4	4.3
Orlovsky Partizan (Orlik×13-6-106)	w	late January	190	4.5	4.3
Osipovskoye (Mantet×Papirovka tetraploid)	s	middle September	130	4.4	4.5
Patriot [16-37-63 (Antonovka Krasnobochka× SR 0523)×13-6-106 (Suvorovetz seedling)]	w	until February	230	4.5	4.4
Yablochny Spas (Redfree×Papirovka tetraploid)	s	late September	210	4.4	4.3
Triploid cultivars, means			183	4.45	4.34
Best diploid cultivars from 2x×2x crossings					
Afrodita (814 – open pollination)	w	late December	200	4.4	4.3
Bolotovskoye (Skryzhapel×1924)	w	until February	150	4.3	4.4
Veniaminovskoye (814 – open pollination)	w	late February	130	4.4	4.4
Veteran (King – open pollination)	w	middle March	130	4.4	4.4
Orlinka (Stark Earliest Precos×Pervy Salut)	s	late September	140	4.3	4.3
Orlovim (Antonovka Obyknovennaya×SR 0523)	s	middle September	130	4.4	4.5
Radost Nadezhdy (Wealthy – open pollination)	s	until October	140	4.3	4.3
Ranneye Aloye (Melba×Papirovka)	s	middle September	130	4.5	4.4
Sinap orlovsky (Severny Sinap×Pamyat Michurina)	w	late April	150	4.3	4.4
Zhelannoye (McIntosh – open pollination)	s	middle October	120	4.6	4.4
Diploid cultivars, means			142	4.39	4.38

[z] s = summer maturing; w = winter maturing.

Boiko' and 'Vavilovskoye' (until March) and with the diploid 'Sinap Orlovsky' (until late April) (Table 2.). The triploid cultivars had a significantly higher fruit weight than the diploid cultivars (183 g and 142 g, respectively) (LSD_{05} = 30 g).

On average, fruit appearance was assessed as 4.45 for the triploid varieties and 4.39 for the diploids. The difference was not significant ($p<0.05$). The triploid cultivars 'Vavilovskoye', 'Dariona' and 'Patriot' especially excelled in fruit attractiveness.

We did not determine a significant difference in flavor among the triploid and diploid cultivars ($F_f<F_t$). The 'Avgusta' and 'Osipovskoye' summer maturing triploid cultivars and the winter maturing 'Patriot' were characterized as having high flavor qualities. Among the diploid cultivars, the winter maturing 'Veniaminovskoye' and 'Sinap Orlovsky' and the summer maturing 'Orlovim' and 'Ranneye Aloye' were characterized as having high fruit flavor.

Conclusions

Triploid cultivars from the VNIISPK breeding program have been shown to have more regular annual yields compared to the wide spread that occurred in the diploid cultivar 'Antonovka Obyknovennaya'. The triploid cultivars significantly exceeded diploid cultivars in fruit size and were equal in fruit attractiveness and taste.

The wide use of VNIISPK triploid apple cultivars, having a complex of high quality commercial and biological traits, is of great interest for assessment in commercial and home fruit-growing.

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