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I. V. MICHURIN'S WORK ON EXPANSION OF THE PLANT HORTICULTURE ASSORTMENT AND IMPROVEMENT OF FOOD QUALITY

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October 2015 marks the 160th anniversary of the birth of Ivan V. Michurin. As a scientist and plant breeder, he made a significant improvement of many fruit and berry plants, and flowers. He developed methods of plant breeding, especially regarding long-distance hybridisation of fruit plants, and promoted gardening to the north and east of Russia. He introduced some new berry species, such as Actinidia and black chokeberry, and was the first in Russia to use dwarf and semi dwarf stocks of apples. Michurin initiated the mass movement of gardeners and horticulture experimenters in USSR who changed and significantly extended the assortment and areas of fruit and berries cultivation in the country. He not only brought together a representative collection of species and varieties of fruit, berry and flower plants from around the world, but also used them in breeding by hybridization, including interspecific. He created some new artificial interspecific hybrids such as Cerapadus (cherry and bird cherry tree hybrid), and others. Michurin created 132 cultivars. Eleven of them are not only cultivated, but are also included in "The State Register of Protected Plant Breeding of the Russian Federation".

Key words: *I. V. Michurin, plant breeding, horticulture, long distance hybridisation, epigenetics.*

INTRODUCTION

The quality of life and health of a modern person is directly related to sufficiency of varied, high quality and balanced biogenic components of food. Fruit growers play an important role in providing products foe human nutrition — Jean-Baptiste Van Mons, Luther Burbank, Ivan V. Michurin and many other gardeners, made massive efforts to ensure that a wide variety of horticultural products became available to the public at large. From them, only Luther Burbank is known to the public (Stansfield, 1995).

So, who is Michurin, the Great Russian horticulture breeder? Not so long ago, he was known almost to everybody in countries of the former USSR and Eastern Europe, and his work was studied at schools. It was with his support, that "Michurin gardens" became widespread — small land allotments within cities. These pieces of land were cultivated by citizens and made it possible to solve substantially a few problems of provisioning. Therefore, after his death on 7 June 1935, all the leading newspapers of the country published funeral obituaries. Currently, his name is almost forgotten by society and the scientific community. Only the species of chokeberry named

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in his honour — *Aronia mitschurinii* A. K. Skvortsov & Maitul. (= syn. ×*Sorbaronia mitschurinii* (A. K. Skvortsov & Maitul.) Sennikov) from time to time remind botanists of his former greatness. For a long time I. V. Michurin was a symbol of the whole epoch, and quite a political figure, as Lysenko's ideologized agrobiology was called "Michurin's". I. V. Michurin's biography is one of the best examples in the history of agricultural science, in regard of how not to mix fact and fiction[1]. It happened that "... around Michurin's name there were accumulated a lot of superfluous and slanderous statements. All this obscures the true merits his name is immortalized by" (Kompaneets, 1976, p. 90). In fact, the "Michurin's advanced biology" has no relation to I. V. Michurin and his practical work (see Roll-Hansen, 2005 and others)[2]. I. V. Michurin did not deny the reality of Mendel's laws and Morgan's location of genes in the chromosomes. Thousands of hybrids were in his hands, mainly fruit, berry and flower plants, and as their features are formed during several years, he was able to observe that Mendel's laws are not absolute. As an example, he cites the difficulty of expressing anthocyanin pigmentation in the hybrid of apple of 'Nedzvetski' and cv. 'Antonovka'. That is why he wrote, "All this quite clearly points to the insufficient development of not only Mendel's laws, but also of the doctrine of cell chromosomes in a certain number in each form of plants..." (Michurin, 1948a, p. 120). One can only admire the thoughtful insight of this man — by now we know that only about 10% of the genetic material is transmitted and expressed according to Mendel's laws, and for the rest these processes are complex (Matsuda and Takahashi, 2005). Therefore, only in the last decades, with the development of molecular techniques, it became possible to study the mechanisms of non-Mendelian principles of hereditary characters implementation (Shi and Lai, 2015).

BIOGRAPHY

Ivan Vladimirovich Michurin (born October 27 [October 15 by old style] 1855 in Versina Village of Tambov province, Russian Imperia, died on 7 June 1935 in the town of Michurinsk of Tambov region, Russia, former Soviet Union) was a hereditary fruitgrower ("originator" as he preferred calling himself). After completing military service, which was compulsory for nobles of that time, he was tought by his great-grandfather Ivan Naumovich Michurin and grandfather Ivan Ivanovich, who were successfully engaged in gardening and became authors of several cultivars of pears. In the neighborhood his father was considered an "enlightened man". He placed orders from "Works of the Imperial Free Economic Society" in St. Petersburg for seeds of crops, fruit and vegetable crops, which he used in the garden for conducting a variety of experiments with fruit trees and ornamental plants. I. V. Michurin inherited this family passion and from early childhood spent days in the garden cultivating fruit trees, vegetables and ornamental plants. By eight years of age, he already mastered all kinds of grafts, and preparation of stocks and scions. His regular education was more than modest. After graduation from the Pronsky District Primary School in 1869, he was preparing to enter the Imperial Alexander Lyceum (former the Imperial Lyceum in Tsarskoye Selo). However, suddenly his father fell ill. To repay the debt he had to sell their "estate"; consequently, the financial opportunity to study in St. Petersburg was lost. In 1872, at the age of 17, I. V. Michurin entered the Ryazan gymnasium, but a few months later, he was expelled "for disrespect to superiors."

His work experience began from 1873. He worked as a commercial clerk at Kozlov's goods station of Ryazan and Tambov railway, while studying horology at the same time. A year later, he made his first steps in horticulture on a small rented plot in the Russian town Kozlov (now Michurinsk) of Tambov region, where he accumulated a significant collection (over 600 cultivars) of fruit and berry plants. His work aided his collecting: in 1877–1889, he was a clock and signalling devices fitter on the Kozlov– Ryazan–Dankov–Lebedyan railway site. Regular business trips gave him the opportunity to assess the state of the horticulture in Voronezh, Orel, and Kursk regions of central Russia, Donbass, the northern parts of Kiev and Kharkov and the southern districts of Tambov and Penza regions. As a result, he made the following conclusion: "After thirteen years (from 1875) of comprehensive theoretical and practical study of plant life and mainly horticulture and its needs in central Russia (...) I came to the conclusion that the level of gardening is too low. Assortments were extremely poor and, in addition, had various half-cultural and sometimes even wild forest trees. (...) An urgent need to replenish their number with new better varieties has become apparent. (...) In 1888, these considerations drove me to establish a nursery garden for the only purpose of developing new better and more productive varieties of fruit plants" (Michurin, 1948a, pp. 11–12). He developed a talent in business and caught correctly the trend of time. The industrial development of Russia began, and growth of the urban population required ensuring agricultural products in increasing volumes. At the same time, it is desirable to produce it as close to the places of consumption as possible, and thus industrial horticulture in central Russia was becoming economically promising. Representatives of the new Michurin's assortment, mainly apple trees, pear trees, cherries, and plums, amounting to 50 000 trees, were sold in the period between 1888 and 1916 to various farms located in 60 regions of the country, and in the pre-revolutionary years selling seedlings provided him with a comfortable existence. In the early phases of his breeding practice, Michurin attempted to expand the assortment by acclimatisation of existing cultivars and use of grafting of less winter-hard cultivars on more winter-hardy ones, according to Grell's method. However, later, based on over a decade of experience, he concluded that the use of material made for regions with less severe climate than in central Russia, did not lead to success. Therefore, he started a wide use of long distance hybridisation. This method was well known since the times of the Dutch plant breeder J.-B. Van Mons (Anonymous, 1942). While it had not given practical results for a long time, I. V. Michurin with this method managed to obtain economically important forms of cultivated plants.

[1] Although already deceased at the time of T. D. Lysenko's agrobiology, I. V. Michurin had no direct relation to it, none of the historians of agricultural science in Russia or abroad professionally studied his work and investigations.

[2] The most ardent critics of Lysenko, being themselves 'Darwinists', put the term "creative Darwinism" out of use. However, the blame of Michurin for the creation of "Michurin's biology" is no more than Ch. Darwin for producing "creative Darwinism".

N. I. Vavilov (1936) believed that I. V. Michurin was the first in our country to utilise practical use of distant hybridization as a radical method to combine the best properties of distant species and genera, and to begin his remarkable work on improvement of fruit trees by interbreeding wild species with cultural ones and improving hybrids by repeated crossings.

LONG-DISTANCE HYBRIDISATION

It is necessary to note his extraordinary insight; by objecting to accepted opinion about sterility of distant hybrids, he underlined that "... through interspecific and intergeneric crossings ... new forms of plants (...) could occur in nature" (Michurin, 1948a, p. 231). Therefore, proposing such an approach in breeding, he adopted what nature used in order to create a variety of species of natural flora. Experimental evidence of this assumption appeared later in the writings of L. Stebbins and colleagues (Stebbins, 1950 among others).

Michurin understood long-distance hybridisation as crossings of both taxonomically distant forms and representatives of one species from geographically remote areas. Researchers who worked and are working on obtaining distance hybrids face prezygotic, zygotic and postzygotic sterility. Currently, we have knowledge about the mechanisms of these phenomena, and can overcome problems. Nevertheless, I. V. Michurin worked using the trial-and-error method and his unlimited capacity for work and outstanding observation. Thus, to overcome prezygotic sterility, he proposed the following methods: 1) vegetative rapprochement; 2) pollination with a mixture of pollen and pre-application to the recipient stigma of homogenate from tissues of the father's parent stigma followed by pollination; 3) electrostimulation of pistil. The method of vegetative rapprochement involves preliminary grafting of one species of plant to the other; thereby interference of scion and stock is occurring in the exchange of metabolic products and regulatory substances, which apparently leads to a weakening of blocking the growth of alien pollen. This approach allowed him to obtain hybrids between species that did not interbreed in the usual way. It is remarkable that Michurin noticed different expression of prezygotic sterility, depending on the age of the forms to be interbred, and used young shoots from the south side of the crown as much as possible. He was able to identify the influence of this factor due to exceptional observation and extensive experience with fruit crops. The method of preliminary vegetative rapprochement was used by Michurin to successfully produce hybrids between rowan and pear. To this end, the annual rowan seedling sapling (scion) was grafted in the crown of pear plant (stock). After 5–6 years of nutrition by substances produced by stock, changes occurred in the scion exchange that allowed to obtain sexual hybrids of diverse species. I. V. Michurin applied different variants of a pollen mixture. He mixed a small amount of the maternal plant pollen with the paternal pollen. In this case, its own pollen irritated pistil stigma, which became able to accept alien pollen. At pollination of apple blossoms by pear pollen, the latter was added a bit of apple pollen. Part of the ovules were fertilised by its own pollen (apple), while others by an alien one (pear).

Lack of successful pollination was overcome also by pollinating of maternal plant blossoms by a mixture of pollen of different types without adding the pollen of its own species. Essential oils and other secretions excreted by alien pollen, irritated the maternal plant stigma and contributed to its perception of father pollen. He paid special attention to the study of the influence of electric and electromagnetic effects on growth, development and fertilisation of fruit plants. As a result of these studies, it was found that the use of static electricity and other biophysical factors on pollen and female generative sphere increased the effectiveness of distance crossings.

The next critical step in obtaining distant hybrids (interspecific and intergeneric) is zygotic and postzygotic incompatibility which are caused by a variety of phenomena, of which genomic imprinting is the strongest (Sokolov, 2006). In the days of Michurin, this phenomenon was not yet known, although many researchers noted the death of embryos in the early stages of development, not only in distance crossings, but in hybridisation of heteroploid forms of one and the same species. This effect is due to the interaction of maternal and paternal genome in endosperms, when genes of mother or father must correspond exactly to the ratio of two maternal to one paternal. Otherwise, the endosperm does not develop and hybrid embryos die in the first days of embryogenesis. Due to the fact that the imprint signals of maternal and paternal genes of distant hybrids are not coordinated, very often there is abnormal development of the seeds and their high inclination to abortion. Michurin paid attention to the fact that the distant hybrid seeds often have an irregular shape, and they have an abnormal development of the endosperms. Due to experience, he knew that with a large number of crossings, it is possible to get viable seeds. This has been associated with polymorphism in the expression of imprinted genes. In this regard, he recommended carrying out the selection of seedlings on the "level of culture", starting with the cotyledonous state. Larger sizes of cotyledons, their considerable thickness, and short and thick caulicle are signs of the culture level and viability of hybrid seedlings. Moreover, he insisted that the seeds should not be over dried, but that it is necessary to attempt immediately to germinate seed to avoid abortive embryos. Michurin noted that hybrid seedlings often have phenotypes not common of their parent forms. One of the explanations for this phenomenon is "genomic shock" proposed by McClintock (1984), but possibly other epigenetic phenomena (paramutation, histone modifications, etc.) which are then inherited (Springer 2013; Holbrook 2015; Poland 2015).

One of the most interesting intergeneric hybrids of Michurin's breeding is *Cerapadus* (F_1 hybrid of cherry *Padus vulgaris* L. with the Amur chokecherry *Padus maackii* Rupr.) (Fig. 1). Later, after the introduction of the Amur chokecherry in the Pamir Botanical Garden, *Cerapadus* appeared in nature as a result of spontaneous interspecific hybridisation. Based on *Cerapadus* and *Padocerus* reverse hybrids between bird cherry and cherry, which were produced by I. V. Michurin, the All-Russian Research Institute of Genetics and Breeding of Fruit Plants (Michurinsk) bred high-quality commercial cultivars of cherries, Feya and Kharitonovskaya, with resistance to dangerous diseases of stone fruits like cherry leaf spot. The All-Russian Breeding and Technological Institute of Horticulture and Nursery (Moscow) is successfully working on it as cv. 'Rusinka' was produced. In addition, *Cerapadus* fruits were gathered in racemes, and I. V. Michurin believed

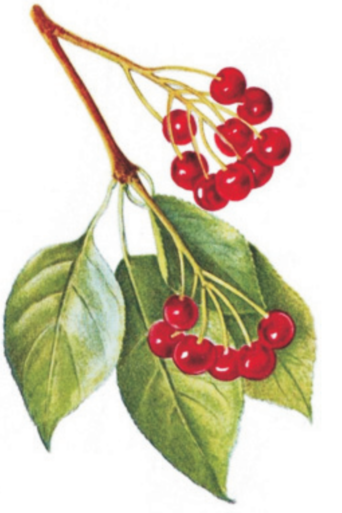

Fig. 1. Cerapadus (according to Michurin, 1949).

that on the basis of such plants it was possible to breed yielding varieties of cherry with fruits that could be gathered in racemes as in bird cherry, and not be located in pairs like in cherry. *Cerapadus* obtained by I. V. Michurin has 3 to 6 fruits in racemes, weighing 1–1.5 g each.

I. V. Michurin first started breeding work on rowan in Russia in 1905. He wrote, "For thousands of years rowan as a fruit tree has not been used in the work of hybridisers, and therefore, in the assortment of our gardens rowan as a valuable fruit tree is not listed" (Michurin, 1948c, p. 137). As initial forms (parents) for crossings he first used rowan (*Sorbus aucuparia* L.) and black chokeberry (*Aronia melanocarpa* (Michx.) Elliot) received from Germany. On their basis, sweet-fruited rowan cv. 'Likernaya' was obtained using interspecific hybridisation of Alpine rowan (*S. alpina* (Wild.) Scheid.) with the *S. aucuparia* L. (Yakovlev, 1949). Michurin obtained cv. 'Burka'. In order to improve the palatability of rowan and to increase fruit mass, he involved hawthorn, medlar, pear, and apple in hybridisation to produce cvs. 'Grenade' *(S. aucuparia* L. × *Crataegus sanquinea* Pall.) and dessert 'Michurinskaya' ('Likernaya' × *Mespilus germanica* L.).

STEPPED HYBRIDISATION.

It was often not possible to directly obtain a hybrid progeny. I. V. Michurin introduced the stepped hybridisation method into everyday practice of fruit crops breeding, which was previously proposed by the well-known Russian gardener P. I. Schwarz who focused on breeding of flower crops (Goncharov and Savel'ev, 2015).

The new approaches developed by I. V. Michurin for choosing parental pairs for hybridisation and subsequent selection of seedlings had great influence on breeding of fruit and other crops in the former Soviet Union. His proposed method of hybridisation of ecologically and geographically distant forms found widespread use in breeding.

MICHURIN'S METHODS OF BREEDING

As organisms can vary within the normal response under effect of the environment, external factors can be used to change phenotype features. Michurin (1952) used this process in cultivation of fruit and berry crop hybrids by changing specific conditions at various stages of ontogenesis. He proposed a number of different approaches, the most important of which was the "mentor" method, by which the graft with needed properties made into the crown of a hybrid seedling. In the reverse variant, the resulting hybrid is grafted on an appropriate stock. In both cases, due to the metabolic interaction between stock and scion, regulatory changes in gene expression occur, which Michurin experimentally observed. It is possible that a certain role in this phenomenon is played by small interfering RNAs (siRNA & miRNA). Using the mentor method, Michurin bred two cultivars of apple, 'Bellefleur-Kitaika' and 'Kandil'-Kitaika'. 'Kandil'-Kitaika' was the result of hybridisation of 'Kitaika' and Crimean apple cv. 'Kandil'-synap'. Michurin grafted a hybrid in the crown of the winter hard mother 'Kitaika' in order to develop and consolidate frost resistance. The second cv. 'Bellefleur-Kitaika' was bred to prevent deflection of the hybrid towards the winter-hardy and early-maturing Chinese apple, and therefore, the hybrid fruits could not be stored for a long time. To increase the fruit storage potential of hybrid plants, Michurin grafted several saplings of late-ripening cultivars to the crown of hybrid seedlings of 'Bellefleur-Kitaika'. As a result, the 'Bellefleur-Kitaika' fruits were late-ripening and could be stored for a long time. The effect of this method can be regulated by the following methods: 1) duration of the mentor action; 2) ratio of the age of the mentor and hybrid; 3) quantitative ratio of foliage of the mentor and hybrid. An older mentor results in richer crown foliage. Longer action results in higher intensity of action. During the breeding, Michurin performed repeated and sufficiently rigorous selection that allowed him to receive high-quality hybrids.

While interbreeding southern varieties with local ones, Michurin noticed that features of local landraces dominated in the F_1 hybrids. This observation led him to the conclusion that it was necessary to select parents originating from different ecological and geographical regions. For example, he bred pear cv. 'Bere winter' by hybridisation of southern European 'Bere royal' pear with Ussuriysk pear. The offspring of such an interbreeding had the genetic basis of initial parental forms in unusual natural conditions In the so called "method of hybrids education", Michurin changed the conditions of cultivation to obtain economically valuable features borrowed from both parents. In this case the cv. 'Bere winter' inherited the large-fruited feature, high palatability and possibility of long winter storage from the southern parent, and cold resistance from the second parent (Ussuriysk pear). We note here that the hypothesis of epigenetic landscapes, i.e. variants of forming features in the interaction of genotype and environment, would be formulated by Waddington (1957) later, but came into scientific use not long ago (see review Holbrook, 2015). To influence the display of the required features, I. V. Michurin used different methods of tillage, fertilisation and the mentor method, calling this approach "dominance management". Sixty years later, Michurin's observations were finally experimentally proved by A. Durrant in works with flax (Durrant, 1962; 1971; 1974). It was shown that differences in the conditions of mineral nutrition are responsible not only for modification of variability of plants, but can cause epigenetic changes passed from generation to generation by both an egg cell and pollen (Durrant, 1974).

While not always consistent, Michurin outlined the basic principles of obtaining, growing and evaluating hybrid breeding material, which were repeated many times with some variations in many of his articles over the years. We present them here from archival materials published in 1948 and titled "Production of works to improve assortments of fruit trees": "As a result of 52-year-old work in a special nursery for new commercial cultivars (established in the 1970s of the last century in the town Kozlov of Tambov region), I come to the following conclusions:

1. It is necessary to create regional advanced institutions for breeding new varieties of fruit plants.

2. The best results are obtained by the hybridisation of local hardy or wild northern species with southern ones, followed by the cultivation of obtained hybrid seeds of plants and their strict selection. At the same time, more distant producers, according to their kinship and place of homeland, give hybrids that are more adaptive to the environmental conditions.

3. It is necessary to raise seedlings in relatively Spartan (close to natural) conditions without excessive receptions of culture and in a relatively meagre sandy-loam soil.

4. Producers must be on their own roots, not grafted, as stocks and wildings deflect significantly the structure of the seed (and, therefore, the future plant) towards wild species.

5. In any case, the hybrid seeds should not be over dried, otherwise they lose their best qualities. Sowing should be carried out immediately after ripening of seeds. It is necessary to grow seedlings in locations sheltered from wind.

6. New hybrid varieties only gradually improve in structure and quality during the whole period from germination of a seed to the first 3–4 years of fruiting, they have continuous struggle of genes. External conditions control which genes are manifested.

7. After 3–4 years of fruiting, characteristics and quality of a new cultivar become fixed and are not amenable to change and can reproduce by conventional methods (inoculation, copulation).

8. Grafting of young hybrid saplings in the crown of an adult tree hastens fruiting only in rare cases, but always worsens the quality.

9. It is possible to interbreed not only species, but also genera, and for this the method of "preliminary vegetative rapprochement" is used (cross-pollination of young hybrid seedlings of 1–2 years of age, for example, apple to pear, pear to rowan, etc.). While grafted specimens are flowering, their sexual interbreeding is conducted.

10. Plants unusual for the area are introduced into culture by method of mass sowing of seeds at the northern border of their habitat, with selection of hardy specimens.

Using the techniques described, I managed to breed more than 100 new cultivars of apple trees, winter pears, plums, cherries, sweet cherries, raspberries, blackberries, currants, strawberries, wild strawberries, *Actinidia*, apricots, grapes, walnuts, almonds, roses, etc. Currently, thousands of hybrid seedlings are under testing. Moreover, work on introduction into culture of peach, sweet almond, sweet chestnut, persimmon, magnolia vine, *Actinidia* large-fruited and other brand-new for our region fruit plants are being conducted" (Michurin, 1948b, pp. 197–198).

HERITAGE

Epistolary heritage. N. I. Vavilov gave the most accurate assessment of I. V. Michurin's epistolary heritage, "(...) of course, in the writings of Ivan Vladimirovich, for all his great merits, there are many unscientific elements, as well as in Burbank. It is necessary to discuss these issues only in a quiet atmosphere with sufficient training of the audience and the judges, which, as you know, is not always possible" (Vavilov, 1987, p. 159). Apparently, it is necessary to consider I. V. Michurin's publications not as scientific work establishing the laws of nature, but as recommendations for horticulture and methods of fruit crops breeding. Michurin considered himself not as a scientist but as an "originator". In 1922, during an All-Russian meeting at the People's Commissariat of the Russian Soviet Federative Socialist Republic, N. I. Vavilov proposed a scientific inventory of the gene pool of Michurin's Advanced Pomological Nursery for a special edition of "Flora of Michurin nursery". Apparently, it was a deeply thought-out proposal, as Vavilov understood the need for classification of the gene pool of Michurin's plants while its author was alive, as he did not bother to keep field diaries and journals.

Being a modest person in all aspects, I. V. Michurin never insisted on the completion of his results and understood the applied character of regularities he discovered. In this regard, he wrote, "My followers should outpace me, contradict me, even destroy my work, at the same time keep it. The progress develops from such a consistently destroyed work" (Michurin, 1948d, p. 402).

Cultivars. Michurin bred more than 132 commercial cultivars of apples, pears, plums, grapes, apricots, blackberries, currants, tobacco, and some ornamental (flower) plants (Table 1). He attached great importance to the introduction in culture of new horticultural crops and non-traditional ones for cultivation not only for Russia, such as Actinidia, Siberian ginseng, hawthorn, sweet chestnut and others. Michurin bred vitamin-rich cultivars of *Actinidia*, namely 'Ananasnaya Michurina', 'Krupnaya Michurina', 'Clara Zetkin' (Fig. 2), and others. He acquired positive results in breeding of apricot, grapes, as well as other exotic crops for the central part of European Russia. To improve winter hardiness and sustainability of new cultivars to diseases, Michurin included in hybridisation wild species and produced hybrids of such hybridisation: pearleaf apple, Chinese apple, Ussuriysk pear, cherry steppe, bird cherry, and others. On the basis of distant hybridisation, he and his followers created new varieties of apple tree, pear tree, cherries, and other crops. He obtained unique intergeneric hybrids between apple and pear trees, rowan and pear trees, bird cherry and cherry, blackthorn and peach, and almond and peach. Not all of them went into production, but they were and are the donors of useful traits.

Michurin cultivars of fruit and berry crops have not lost their importance so far, and many decades later, some of them are still zoned in many regions of Russia and CIS countries. These include cultivars of apple 'Bessemyanka Michurinskaya', 'Bellefleur-Kitaika', 'Doch Korichnogo', 'Pepin shafranoviy'; pear tree — Michurin 'Bere winter'; plum — 'Renklod kolkhozniy'; steppe cherry — 'Polevka'; and currant— 'Michurin's Memory'.

Using the Michurin hybrid fund obtained by hybridization of ordinary rowan with pear, his long-standing employee A. S. Tikhonova created cv. 'Krasavitsa' and 'Rubynovaya'. The large-fruited Scarlet large variety was obtained from hybridisation of rowan and pear hybrid with Moravian rowan. Currently, Michurin rowan commercial cultivars 'Alaya krupnaya', 'Rubynovaya' and 'Titan' are included in the "The State Register of Protected Selection Achievements Admitted to Economic Use" (Anonymous, 2013) (Table 2).

Table 1

MICHURIN CULTIVARS (according to Yakovlev, 1949)

Name	Species	Number of cultivars	Notes
Pear	*Prunus commumis* L.	11	
	P. ussuriensis Kov. et Kost.	4	
Apple	*Malus domestica* Borkh.	27	
	M. prunifolia (Willd.) Borkh.	13	
	M. domestica × *M. prunifolia*	6	Interspecific hybrids
	M. prunifolia × *M. domestica*	1	Interspecific hybrids
	M. niedzwetzkyana Dieck.	2	
Apricot	*Armeniaca mandshurica* (Maxim.) Skvortsov	7	
	A. sibirica (L.) Lam.	1	
Cherries	*Prunus avium* (L.) L.	4	
	P. cerasus L.	9	
	P. fruticosa PALL. (syn. *P. chamaecerasus* (Jacq.) Loisel.)	4	
	P. cerasus × *P. avium*	2	Interspecific hybrids
	P. fruticosa × *P. pensylvanica* L.f.	11	Interspecific hybrids
	(*P. fruticosa* × *P. pensylvanica*) × *P. maackii* Rupr.	1	Intergeneric hybrid
	P. tomentosa Thunb.	1	
	P. virginiana L.	2	
Plums	*Prunus domestica* L.	3	
	P. hortulana Bail.	1	
	P. insititia L	4	
Sloe	*P. spinosa* L.	3	
Chinese plums	*P. salicina* Lindl. (syn. *P. triflora* Roxb.)	3	
Almond	*Amygdalus mongolica* Maxim.	1	
Rowan	*Sorbus aucuparia* L.	4	
Quince	*Cydonia oblonga* Mill.	1	
Grapes	*Vitis* ssp.	4	
Actinidia	*Actinidia kolomikta* (Maxim. et Rupr.) Maxim.	2	
In total:		132	

Fig. 2. Michurin cultivar 'Clara Zetkin' of *Actinidia* (according to Michurin, 1949).

Table 2

MICHURIN'S COMMERCIAL CULTIVARS INCLUDED IN THE "THE STATE REGISTER OF PROTECTED SELECTION ACHIEVEMENTS ADMITTED TO ECONOMIC USE" [1](Anonymous, 2013)

Crops, species	Cultivar name	Year including in "The state register"*	Pedigree
Apple	Bessemyanka Michurinskaya	1947	Skrizhapel' ×Komsinskaya
Apple	Bellefleur-Kitaika	1947	Belfler zheltii × Kitaika
Apple	Doch Korichnogo	1965	Korichnoe polosatoe × Kitaika
Apple	Pepin shafranoviy	1947	[Renet Orleanskii × (Pepin Lytovskyi × Kitaika)]
Pear	Bere zymnyaya Michurina	1947	Ussuriyskaya × Bere Royal
Plums	Renklod kolkhoznii	1947	Renklod zelenii × *ternosliva*
Cherry (степная)	Poleovka	1947	seedling of cv. Ideal
Rowan	Alaya Krupnaya	1999	[(*Sorbus aucuparia* L. × pear mixture pollen) × *S. aucuparia* var. *moravica*]
Rowan	Rubynovaya	1999	*S. aucuparia* L. × pear mixture pollen
Rowan	Titan	1999	(Burka × apple and pear mixture pollen)
Currant	Pamyat' Michurina	1959	*Ribes sibiricum* L. × *Ribes europaeum* L.

[1] See Anonymous, 2013. * State test system of fruit crops in the USSR was started only in 1947.

Using materials of Michurin as donors of agronomic traits, Russian breeders produced more than 150 new commercial cultivars of fruit and berry crops in the time to present. Valuable parental forms in breeding were Michurin cvs. of apple 'Bellefleur-Kitaika', 'Bessemyanka Michurinskaya', 'Kandil-Kitaika', and 'Pepin shafranoviy', which were used to create more than 35 commercial cultivars included in “The State Register of Protected Breeding Achievements, admitted to use. Vol. 1. Plant cultivars” (Sedov, 2006). Michurin cultivars were also effectively used in breeding of pears, cherries, sweet cherries, plums, currants, gooseberries, grapes and many other fruit and berry crops.

Michurin’s activity was aimed at improving methods of breeding, development of new cultivars of fruit plants, as well as the full development of the Russian gardening and its scientific foundations. In this regard, he set two tasks: 1) to promote the border of growing of fruit plants far north and east; 2) to expand the assortment of fruit and berry crops in central Russia with new winter-hardy and high- yielding varieties with valuable gastronomic qualities.

Industrial gardening. I. V. Michurin always noted the need for a close connection of scientific research with practice. For the development of Russian industrial horticulture, he emphasised that it is important to make an inventory of the varietal and cultivar composition of the existing gardens, to replace unproductive local landraces with new cultivars, and to develop industrial planting, as well as to organise an extensive network of fruit nurseries for increased production.

For mechanised care and harvesting, sparse and low gardens are the most suitable. Michurin saw the solution to this problem in the creation of sparse-crowned cultivars and the use of dwarf stocks, “Formely, everybody was trying to produce the mighty, tall fruit plants. However, experience has shown that there is a need for fast-ripening dwarfs that are suitable for mechanized maintenance and cleaning” (Michurin, 1948c, p. 219). Since 1891, he was the first in the country[3] who enthusiastically tackled the problem of creating dwarf fruit trees. He managed to create weak-grown cultivars of cherries, plums, quince, rowan, and he vegetatively propagating dwarf stock for apple 'Paradizka Michurinskaya'. As weak-grown pear stock, I. V. Michurin recommended using the 'Ayvu Severnuyu' (quince) produced by him, and plum — different types of thorns with restrained growth.

Development of horticulture is related to the name of I. V. Michurin in the Urals, Siberia, and the Far East. He maintained close ties with enthusiasts, growers and breeders of these harsh regions through correspondence and exchange of gene pools. He represented the idea of commercial horticulture in harsh climatic conditions of the Urals and Siberia, but only in the case of producing local cultivars of fruits. On his initiative, in the 1930s, in the Urals, Siberia and the Far East, scientific institutions (experimental fields, strongholds, fruit breeding station on gardening were organised. His successor, M. A. Lisavenko, established fruit-growing in Altai (Kalinina, 2007), his colleagues N. F. Kashchenko (1963) in West Siberia, Vs. M. and V. M. Krutovsky in Eastern Siberia, and A. M. Lukashev in the Far East.

The activity of I. V. Michurin is related with the establishment of two scientific and one educational institution of national importance in Kozlov (now Michurinsk). In the autumn of 1929 the I. V. Michurin Breeding and Crop Cultivation College was established. In 1930, the Central Fruit and Berry Station was established, which in 1931 was reorganized into the Central Research Institute of the North Fruit and Berry Farm (now I. V. Michurin All-Russian Research Institute of Horticulture). The town of Michurinsk is named in his honour, as was the Bulgarian town of Tsarevo between 1950 and 1991.

For the preparation of scientists and agronomists of higher qualification, the Institute of Breeding Fruit and Berry Crops (the I. V. Michurin Horticultural Institute) was opened; currently, it is part of the Michurinsk State Agrarian University.

Michurin’s material in collections. Presently, it is very difficult to answer the question about the safety of cultivars and hybrid materials produced by Michurin in the collections of Russia and the former Soviet Union gene banks and horticultural institutions. The largest collection is in Michurinsk in the I. V. Michurin All-Russian Research Institute of Genetics and Breeding for Fruit Plants (Savel’ev, 2005). Before the Second World War, the Pavlovsk Experiment Station of the Vavilov Institute of Plant Industry included a Michurin garden. However, like all VIR collections of Pushkin and Pavlovsk, German occupation Special Forces — Special Sonder teams of the Centre studying the eastern provinces of the Imperial Ministry of Food and Agriculture (head R. Darre, later H. Vaske), they were taken to Germany. Unfortunately, nobody tried to find or return the stolen collection to the USSR (Elina *et al.*, 2005). The “Michurin Garden” was not restored in the VIR. A Michurin garden was planted in 1948 in the Komarov Botanical Institute (St. Petersburg).

We would like to conclude the overview of works and major achievements of I. V. Michurin by A. A. Lubishchev’s words from his unpublished book, “No doubt, the heritage of Michurin is large and interesting and worth exploring. But now this heritage is in a very chaotic state” (cited by Goncharov and Savel’ev, 2015, p. 342), and it is still waiting for its researchers.

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[3] In England, the first work on standardization of dwarf stocks (Dusen, laradizka and quince) were launched in 1875 (Kas’yanenko, 1963).

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I. MIČURINA DARBS AUGĻU UN OGU SORTIMENTA PAPLAŠINĀŠANĀ UN PĀRTIKAS KVALITĀTES UZLABOŠANĀ

Aprakstīts izcilā krievu selekcionāra Ivana Mičurina (1855–1935) devums augļu un ogu šķirņu selekcijā. I. Mičurins izmantoja dažādas selekcijas metodes, ieskaitot attālo hibridizāciju, kā rezultātā pat izveidoja vairākas jaunas augļaugu sugas. Vairākas viņa radītās šķirnes joprojām ir oficiāli reģistrētas un tiek kultivētas līdz mūsdienām. Ilgus gadus I. Mičurina vārds pēc viņa nāves Padomju Savienībā tika nepamatoti izmantots, lai pretstatītu tā saucamo Mičurina bioloģiju zinātniskai, uz G. Mendeļa atklājumiem balstītai zinātnei par iedzimtību.