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UDC 631:525:631.52:634.3

INTRODUCTION AND BREEDING OF WILD RELATIVES AND RELATED SPECIES OF CITRUS

The broad prospects for the development of domestic citrus growing—that is, the cultivation of citrus in open ground—are connected in our country with increasing the frost resistance of citrus plants. This should therefore be the principal focus of Soviet citrus breeders.

Under our conditions, the only way to develop frost-resistant forms of fruit-bearing citrus plants is to obtain them by breeding methods and techniques.

Breeding of citrus plants by means of interspecific and intergeneric hybridization was first undertaken on a large scale by Weber and Swingle (Swingle W. T., 1948). As frost-resistant partners they used trifoliolate orange (*Poncirus trifoliata* Raf.), also known as (*C. trifoliata* L.), partly Ichang citrus (*C. ichangensis* Sw.), Australian desert lime/eremocitrus (*Eremocitrus glauca* Sw.), and kumquat (*Fortunella* Sw.). Under our subtropical conditions, similar investigations were carried out by the cytologists N. V. Ryndin, N. M. Murray, V. I. Esinovskaya, N. I. Maisuradze, M. V. Kolelishvili, N. Ya. Lomaya, and others.

Many hybrids were obtained, but all differed somewhat from the cultivated species, and none achieved wide industrial distribution.

Many of these hybrids were used for repeated crosses with cultivated partners—lemon, orange, and others—but the crosses carried out on the scale attempted did not produce positive results: fruit quality improved, but frost resistance declined.

Breeders were no less successful in crossing lemon with Chinese Ichang citrus for the same purpose. This is the most frost-resistant of all the species and retains its leaves through the winter.

Although the hybrids obtained were close to true lemons in fruit size and shape, the experiment mentioned had not yet produced positive results because of the low quality of the fruit.

The collection of citrus plants at the Sukhum Experimental Station currently contains a variety of this same species whose fruits are free of the deficiency just mentioned and whose juice resembles lemon

juice. It is already being used by us in directed hybridization.

However, all the circumstances surrounding the breeding of frost-resistant citrus plants are such that it is difficult to expect rapid success in this work.

Consequently, at present only one species is represented on our citrus plantations as sufficiently frost-resistant—the Unshiu mandarin. Thanks to its abundant fruiting, cultivation of this mandarin in the open ground is economically feasible.

The Sukhum Experimental Station of the Order of the Red Banner of Labor, VIR, is carrying out the introduction of new citrus crops and their use in breeding work.

Such searches are especially important at the present time because we cannot be satisfied with a monoculture of Unshiu mandarin. One result of these searches was the introduction from Japan's Shikoku Island, by a VIR expedition, of the then-unknown species Yuko, belonging to the group of wild species of the genus *Citrus*. Although this species was discovered under a frost-free climate, in our conditions it proved more frost-resistant than Unshiu mandarin. In Japan itself, until relatively recently, orange cultivation was completely absent, so on the southern Japanese islands Yuko was cultivated as an orange.

Yuko fruits are pear-shaped, with an average weight of 110 g, a readily detachable, egg-yellow peel, and a sweet-and-sour taste with a pleasant aroma. In the absence of foreign pollinators they are seedless. At the juvenile stage, plants of this species have one or two growth flushes, while at fruit-bearing age they always have only one growth flush. Finally, they possess a deep winter dormancy that is not broken by any weather conditions.

On trifoliolate-orange rootstock, plants enter fruiting in their third year. They fruit annually; a heavy crop (1,300–1,500 fruits per tree) alternates with a moderate crop. In years with cool summers, the fruit ripens simultaneously with Unshiu mandarin; in years with normal summers, it ripens two, and sometimes three, weeks earlier.

An approximate fruit count (average fruit weight 100 g) showed that, with 1,000 plants per hectare (5×2 m), the yield was 50 metric tons.

Thanks to the successes of Soviet introduction work, we have acquired a new valuable citrus crop for which the climate of humid subtropics is favorable, where the absolute minimum in citrus-growing areas never falls below the critical level for this plant.

In our investigations, begun in 1968 with the aim of obtaining new frost-resistant cultigens and cultivars (F_1), ancient cultigens were used for the first time: *Citrus Yoko*, *Yunos Yuzu* (No. 30044,

monoembryonic), Yunos Se-chen, and Yunos Kinosu, which are superior in frost resistance to almost all known cultigens of citrus plants.

As cultivated components, all the principal cultivated species of world citrus growing represented in the collection were used, as well as their valuable interspecific hybrids obtained at the station over half a century. A total of 335 crosses were made, using Yuko and almost all the partners as parents. Among the latter were monoembryonic and polyembryonic species and forms. About 9,000 hybrids were obtained, from which, as a result of three rounds of selection, 1,973 breeding numbers were selected.

Own-rooted seedlings of the F_1 hybrids were planted in the open ground in the coldest section of the Sukhum Experimental Station, and later they were propagated by grafting onto rootstocks.

It was established that many of the hybrids obtained, in almost all crossing schemes, possess frost resistance fully sufficient for our conditions (Kokaya Ts. D., 1973). Among the fruit-bearing hybrids, the following are of particular practical interest, provided they have sufficient frost resistance and positive pomological qualities:

Yuko $\times$ Ponkan mandarin; Yuko $\times$ Eritroza mandarin; Yuko $\times$ Pervenets orange; Yuko $\times$ Hamlin orange; Yuko $\times$ Sippibai lemon; Yuzu $\times$ Sippibai lemon; Sippibai lemon $\times$ *C. ichangensis* (No. 30411); Yuko $\times$ Duncan grapefruit; Duncan grapefruit $\times$ Yuko; Yuko $\times$ G. 2974 (Azahikan $\times$ Pernambuco); Yuko $\times$ G. 1642 (Unshiu $\times$ Zuchera pommelos); Yuko $\times$ G. 6607 (Pear-shaped Shaddock $\times$ Shiva-mikan); and many others.

The F_1 hybrids that have entered fruiting are used in further breeding for repeated crosses and for obtaining new forms with economically valuable qualities. The presence of viable pollen in their flowers demonstrates the broad possibilities for using the hybrids obtained in the future.

The possibility of continuing this very important work by introducing, in parallel into the hybridization process, another sufficiently frost-resistant genus—*Fortunella* Sw. (kumquat)—is very promising. Its critical temperature is -13°C ; the fruits are small, oval, 30–50 g in weight, bright orange, somewhat sour-sweet, with an edible peel. The fruits are used fresh and for making high-quality preserves.

All F_1 hybrids of kumquat with cultivated forms obtained by Soviet and American scientists inherited frost resistance, deep winter dormancy, and a single growth flush.

The trait for the number of locules in the ovary proved to be almost dominant.

According to studies by I. S. Kapakadze (1977), it was demonstrated that species of the genus

Fortunella possess suppressive properties with respect to the genes for the bitter essential oil of the genus Poncirus. In one case, essential-oil glands do not form in the juice vesicles of hybrids between Fortunella and citrange; in another, although the glands develop, they accumulate non-bitter essential oil. Examples include the triple hybrids citrangequat (*C. sinensis* × *P. trifoliata*) × *Fortunella*, limequat (*C. lim[e]* × *Fortunella*) × *P. trifoliata*, and many others.

Considering the morphogenetic consequences of hybrid combinations between representatives of these two genera, with the physiological and phenological characteristics of kumquats dominant, we decided to continue the work of our predecessors, aiming to obtain new hybrid forms valuable also in pomological respects.

Thus, Nagami kumquat, Meiwa kumquat, Omi kumquat, hybrids of Nagami kumquat with Kaden orange, kumquat with lemon, and kumquat with citron were included in the hybridization program. The hybrids have not yet entered the fruit-bearing stage, and the results of the experiment will be presented in future publications.

CONCLUSIONS

1. In the breeding of frost-resistant citrus, the most promising method is distant hybridization.
2. Of decisive importance in obtaining frost-resistant fruit-bearing forms of citrus at the level of the first hybrid generation is the use in crosses of frost-resistant wild relatives with fruits free of bitterness and unpleasant aroma. They cross readily with all fruit-bearing species of citrus plants and with their interspecific hybrids.
3. Among the wild species, the most promising is Yuko citrus. It is of great practical interest as a component for interspecific crosses with all the well-known, sufficiently frost-resistant cultivated forms—lemons, oranges, grapefruits, and pommelos—with the aim of obtaining new frost-resistant forms of citrus plants for various pomological uses.

Being a sufficiently frost-resistant species (critical minimum -13°C) with quite edible fruits, Yuko, when crossed with non-frost-resistant cultivars, ensures the production of F_1 hybrids that are both frost-resistant and valuable in pomological terms.