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REPRODUCTIVE PHENOLOGY AND FRUIT GROWTH DYNAMICS OF *YUCCA* L. CULTIVARS INTRODUCED IN THE CRIMEA

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Introduction

Yucca L. cultivars are highly ornamental arboreal and shrubby plants, that make parks on South Coast of the Crimea (SCC) particularly exotic. Importance of this research is undoubted, as mass introduction of yucca cultivars will be able to increase plantation ornamentality of SCC. Research subject possesses scientific novelty and practical value. Scientific novelty is that for the first time as a result of different methods of yucca controlled pollination, there are fruits with viable seeds and now plants which take quite important stage in SCC landscaping. Practical value of our results is enrichment of all plantations on SCC by exotic arboreal and shrubby plants – for benefit of yucca ornamental and aesthetic value.

Objects and methods of the research

Objects of our researches were specimens of 10 cultivars and 3 forms of yucca garden cultivars, that were introduced on SCC, many parks of the Crimea and Sevastopol in different period. All these cultivars and forms have strong morphological distinctions. Inspectation of the Crimean ornamental plantations, that took place in 1986-1988 didn`t result any other new yucca cultivars. Therefore, NBG collection includes all yucca cultivars growing on SCC, moreover there are unique cultivars presented with 1 specimen not only in the Crimea, but all over countries of former USSR [2].

During vegetative periods – 1984, 1995, 2001, 2006 and 2014 we conducted a complex of researches, aimed at seed propagation of different yucca cultivars and garden forms and their industrial cultivation. To achieve this purpose, since spring 1984 controlled pollination of flowers of all yucca cultivars growing in the Crimea was carried out. But in spring 1984 *Y. carnerosana* was capable to yield fruits with viable seeds exclusively due to our new method of controlled pollination of hard-pollinated yucca cultivars [1]. Figure and table of fruit growth dynamics present all necessary data about reproductive phenology and fruit growth dynamics, that is possible and certain key point for terms of controlled pollination of yucca cultivars and garden forms growing in the Crimea. Since spring 1984 till spring 2014 annual measurements of fruit growth were conducted for *Y.aloifolia, Y.aloifolia 'Marginata'* and *Y.aloifolia 'Tenuifolia'* as this very cultivar and its garden forms set fruits with viable seeds annually being pollinated naturally. Controlled pollination of other yucca cultivars wasn`t successful because of climatic conditions. But their complete growth pattern during certain periods were determined quite exactly.

Peculiarities of *Y. Carnerosana,* as an arboreal plant is its complicated pollination, what is labour-intensive and dangerous, as controlled pollination according to our discovered method was to realize at altitude of 5 m or more for some hours. And only due to applied new

method of controlled pollination in 1984-1986 fruits with viable seeds were successfully obtained.

Results and discussion

Growth and development of yucca fruits weren`t practically investigated. In case of juicy fruits there is enlargement of overy tissue stimulated by pollination, and development of germ and endosperm. Growth of the most fruits is presented by simple S-curve. At the beginning size increasing occurs by exponential law but later it slows down [3].

Instrument measurement with hand caliper was applied for fruit growth dynamics of yucca cultivars. It was carried out daily in the morning after controlled pollination procedures in NBG and other parks of the Crimea and Sevastopol. The way of fruit growth defines either cell distension or cytocinesis.

Phenological observation of reproduction sphere which is determined for cultivar characteristic and its value rating for ornamental gardening on SCC, was defined due to actual data, presented at figure and in table below.

Other yucca cultivars that set fruits with viable seeds as a result of common method of controlled pollination didn`t change its sex identity during our phenological investigations. In spite of that representatives of yucca genus are monoecious hermaphrodite, special deflections in their sexual identity were not fixed for 30 years of observations. Those specimens, which were found as male and female for convenience, didn`t change their sex identity during their development. These facts concern *Y. Carnerosana* as well. Moreover yucca cultivars presented in the list, but growing in other climatic zones of the Crimea followed the same manner of development [4, 5]. Polytomous key for *Yucca* L. cultivar identification by fruits, introduced in the Crimea, was published by our group before [6]. That`s why description of all elements of yucca cultivar fruit was omitted in this article.

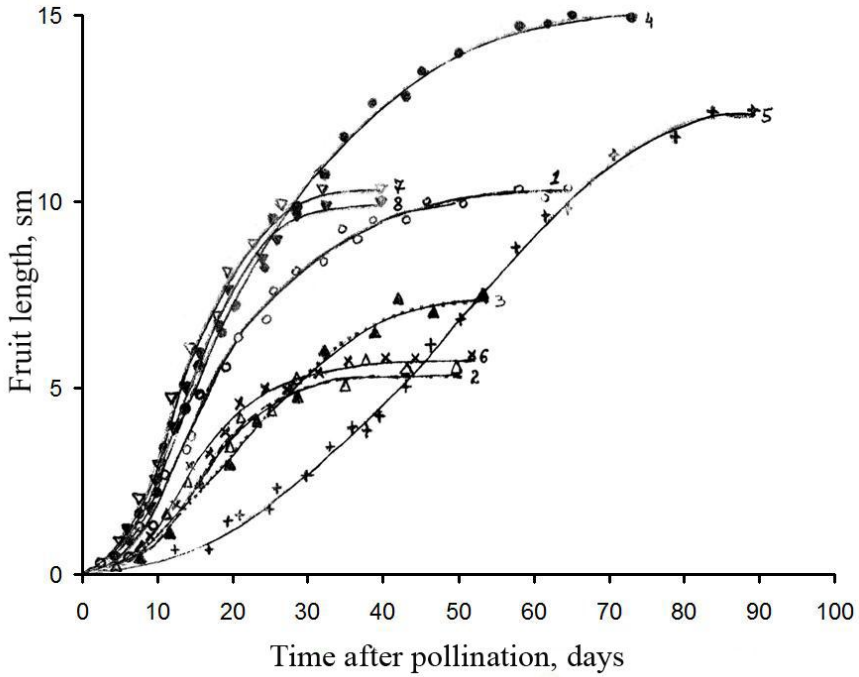

Fig. Fruit growth dynamics of yucca cultivars (Yucca L.) *

1. *Y. treculeana* - ◯ 2. *Y. recurvifolia* - △ 3. *Y. aloifolia* - ▲ 4. *Y. pallida* – ●

5. *Y. carnerosana* - ✚ 6. *Y. filamentosa* - ✖ 7. *Y. elata* - ▽ 8. *Y. glauca* – ▼

* - Each symbol corresponds to arithmetical mean of 10 fruits.

Table

Findings of reproductive phenology of *Yucca* cultivars in Nikita Botanical Gardens on South Coast of the Crimea and in Sevastopol dated by 1984-2015

Yucca cultivars	Germination of a flower stalk	Branching of flower stalks	Blossoming, Beginning end	Fruit inception, beginning end	Fruit ripening, beginning end	Visible vegetation, beginning end
1	2	3	4	5	6	7
Yucca aloifolia* L.	16.08	19.08	23.08 02.09	24.08 05.09	14.11 05.12	21.04 10.12
Y. aloifolia 'Marginata' *	15.08	20.08	23.08 01.09	25.08 03.09	15.11 03.12	20.04 10.12
Y. aloifolia 'Tenuifolia' *	16.08	20.08	22.08 02.09	25.08 04.09	15.11 04.12	21.04 10.12
Y. carnerosana* Carr.**	29.04	14.05	16.05 02.06	18.05 04.06	31.08 28.09	15.04 15.11
Y. elata* Engelm.*	20.05	26.05	02.06 29.06	02.06 30.06	04.09 21.09	15.05 30.09
Y. filamentosa* L.*	14.05	16.05	18.05 14.06	20.05 16.06	14.09 16.10	22.04 18.11
Y.flaccida* Haw.*	15.05	17.05	19.05 14.06	21.05 15.06	15.09 15.10	21.04 16.11
Y. glauca* Nutt.*	24.05	03.06	04.06 22.06	06.06 24.06	12.09 28.09	13.05 30.09
Y. gloriosa* L.*	13.05 29.08 18.10 20.12	17.05 03.09 25.10 27.12	21.05 01.06 05.09 21.09 30.10 20.11 29.12 Flower stalks having got frozen	22.05 03.06 20.05 05.06 – –	15.09 10.10 – – –	21.04 20.11 – – –
Y.pallida* McKelvey*	18.05	25.05	02.06 12.06	04.06 14.06	28.09 30.10	05.05 18.11
Y.recurvifolia* Salisb.*	12.05 28.08 20.10 18.12	18.05 02.09 26.10 28.12	20.05 02.06 04.09 22.09 29.10 21.11 30.12 20.02 Flower stalks having got frozen	21.05 04.06 – – –	14.09 12.10 – – –	20.04 19.11 – – –
Y.treculeana* Carr.*	08.05	16.05	19.05 08.06	20.05 11.06	21.09 18.10	16.04 04.11
Y.treculeana 'Canaliculata'*	05.05	14.05	16.05 02.06	16.05 11.06	21.09 10.10	05.05 12.11

*Fruit setting with viable seeds naturally. But the mechanism of this process is still unknown. Almost annually we observed all these parameters of these taxons allowing for time factor.

** Fruit setting with viable seeds due to common method of controlled pollination. We carried it out in 1985, 1995, 2001, 2006 and 2014.

*** Fruit setting with viable seeds due to invented method of controlled pollination, which was applied with this cultivar of *Yucca* in 1984-1986.

As a result of data analysis it was found out that ***Y. Carnerosana*** starts blossoming first (since April the 29th). Period from the germination of terminal inflorescence till its branching and blossoming takes 15-18 days. Blossoming continues 16 days. After controlled pollination by invented method in 3-5 days flowers set fruits, that in 90 days stop growing and ripen completely. A number of seeds in a fruit ranges from 90 till 160.

Y. treculeana and ***Y. treculeana 'Canaliculata'*** form flower stalks the second (since May the 5th). Period from flower stalk germination till its branching and blossoming takes 9-12 days. Blossoming lasts 17-21 days. Fruit setting occurs in 1-3 days being artificially pollinated by common method. Fruit ripening starts in 62 days after their setting. A number of seeds in a fruit ranges since 49 till 150.

Y. recurvifolia relieves flower-bearing stems growing since May the 12th as a rule, laterals appear in 7 days and 2-3 days later it starts blossoming. Blossoming period lasts 12 days. After common controlled pollination fruits set in 1 day. Fruit ripening occurs in 50 days after their setting. A number of seeds per one fruit gets 150-300. Usually blossoming time of this yucca cultivar can be divided into 4 terms, every 2-3 months, but as a result of controlled pollination the next 3 terms, besides the first one, weren`t marked with fruit setting. In this way during the fourth term of blossoming (in winter) flower-bearing stems got frozen.

Y. gloriosa and ***Y. filamentosa*** are almost similar according to phenological terms. Since germination (May the 13th) with its further branching till the first flowers get blossoming it takes 5 days. Blossoming period ranges from 10 to 23 days. Fruits with viable seeds are set in case of common controlled pollination only. 50-52 days pass since fruit setting till fruit ripening. A number of seeds per one fruit, that ranges from 100 till 250, isn`t distinctive feature for these cultivars. But as opposed to ***Y. filamentosa,*** blossoming of ***Y. gloriosa*** passes 3-4 terms, and fruits – as a result of the common controlled pollination are possible during the first term only (like for *Y. Recurvifolia)*. Moreover winter flowering of this yucca cultivar occurs under sub-zero conditions, that`s why flower-bearing stems get frozen.

Y. pallida is characterized by flower-bearing stems setting since May the 18th , their branching occurs in 5-7 days, while blossoming starts in 7 days and lasts 10 days. As a result of the common controlled pollination fruit setting happens in 2-3 days. Period of fruit ripening takes 72 days. A number of seeds per fruit gets 100-250.

For ***Y. elata*** flower-stem setting is typical since May the 20 and in 5-6 days they branch out and in one week blossoming takes place and lasts 31 days. After common controlled pollination set fruits ripen in 38 days. A number of seeds per a fruit ranges from 150 till 350.

Y. glauca set flower-bearing stems in the end of May. Branching occurs in 9 days, blossoming starts in 1-2 days and lasts 18 days. Common controlled pollination was also applied for this yucca cultivar and in 1-2 days fruits were set with further ripening in 42 days. A number of seeds per one fruit reaches 100-350.

Y. flaccida is characterized by the same reproductive phenology as *Y. filamentosa*. A number of seeds per one fruit ranges from 100 till 250.

Y. aloifolia, ***Y. aloifolia 'Marginata'*** and ***Y. aloifolia 'Tenuifolia'*** has the first and the only blossoming period in the middle of August and lasts 10-12 days on the whole. Period from flower-bearing stems setting till the first flowers takes 8-9 days. Fruit setting of this

cultivar and its ornamental forms occurs even without controlled pollination, however this phenomena is still unknown. Fruits ripen in 53 days. A number of seeds per one fruit is from 80 till 200.

Fruit growth dynamics of all yucca cultivars and garden forms takes S-shaped curve by exponential law with its further slowdown.

The largest fruits with more seeds set at the bottom of branch (elementary inflorescence) that is near flower-bearing stem (main inflorescence) on its bottom. As far as reaching the end of branch and the end of flower-bearing stem fruit size becomes smaller and a number of seeds decreases. Fruits can be quite often deformed and according to our long-term observations in this case, having carried out controlled pollination, 70-90% of pollen are inviable or there is a lack of it. More pollen or its better quality, used during controlled pollination, stimulating fruit size and a number of seeds there. While preparing fruits of various yucca cultivars and forms it was found out their length and form directly depend upon topography of seeds set in a fruitcase. Seed size determines fruit diameter and in case of full fruitcase it`s the same in spite of any fruit length allowing for certain yucca cultivar. If a fruitcase is partly filled (one-sided) by seeds their diameter can have a smaller size. Seed length, thickness, width, form and weight depend upon their position in a fruitcase. Typical triangular and flat seeds are located in the centre of a fruitcase and make 60-90% of a total number in a fruit. In the end of a fruit there are seeds that have pyramid or other more unusual shapes, that were formed in tight conditions of narrowing fruitcase. Seed weight isn`t determined by its length, thickness, width and form.

Conclusions

1. On South Coast of the Crimea (Nikita Botanical Gardens) *Y. Carnerosana* opens *Yucca* blossoming season and after it the following cultivars continue it: *Y. treculeana, Y. treculeana 'Canaliculata', Y. recurvifolia, Y. gloriosa, Y. filamentosa, Y. flaccida, Y. pallida, Y. elata,* and *Y. Glauca.* It`s worth to point out that all cultivars blossoming lasts during two months without a break having crossed flowering terms. *Y. aloifolia, Y. aloifolia 'Marginata'* and *Y. aloifolia 'Tenuifolia'* are ready to blossom only 1,5 months after blossom fading of others – from the middle of August – the most popular holiday season. Flowers are mainly white (neutral), but some garden forms *Y. gloriosa* – sulphureous and pink-yellow, that harmonize with various ornamental trees and bushes blossoming in the same period. Repeated blossoming terms of *Y. gloriosa* and *Y. Recurvifolia* sometimes coincide with blossoming terms of *Y. aloifolia, Y. aloifolia 'Marginata'* and *Y. aloifolia 'Tenuifolia'* that supplies color spectrum of evergreen and deciduous plants being in blossom during this period by neutral component. In other regions of South Coast of the Crimea and in Sevastopol having less number of yucca cultivars (*Y. treculeana, Y. recurvifolia, Y. gloriosa, Y. filamentosa, Y. flaccida, Y. elata, Y. glauca)* phenological terms of blossoming fruiting coincide with terms, registered in Nikita Botanical Gardens. Reproductive phenology parameters of different specimens within one cultivar can differ from selected patterns by terms ± 6-11 days.

2. Fruit growth dynamics of yucca cultivars develops according to exponential law and presents S-curve. *Y. Carnerosana,* in comparison with other yucca cultivars, fruit growth rate increases gradually and gets maximum when 2/3 of the ripening period has passed. *Y. pallida, Y. treculeana,* and *Y. Aloifolia* form pulpy fruitcases (including *Y. carnerosana*), have more prolonged ripening term for fruits with viable seeds (53-90 days). Yucca cultivars that form dry fruitcases have not so long period of fruit ripening with viable seeds *(Y. recurvifolia, Y. filamentosa,Y. elata, Y. glauca)* – 38-52 days. According to average fruit length that ranges from 5 till 15 sm depending upon cultivar, as far as their size decreases there is a line of yucca cultivars: *Y. pallida* – 15 sm, *Y. carnerosana* – 13 sm, *Y. elata* – 10

sm, *Y. treculeana* – 10 sm, *Y. glauca* – 9 sm, *Y. aloifolia* – 7 sm, *Y. filamentosa* – 6 sm, *Y. recurvifolia* – 5 sm.

3. Controlled pollination of all yucca cultivars is better to carry out during the first half of blossoming what allows to get larger fruits with more seeds. For controlled pollination of pistil of one flower it`s recommended to use pollen of all six stamens of this flower in case of autogenous or six stamens of other flower if geitonogenous, xenogenous and hybridgenous. That favors a high level of ovule fecundation and later larger fruits with more viable seeds. Controlled pollination of one main and the rest of its elementary inflorescences mustn`t be more than 10% of flowers as a plant having a lack of pollinated flowers rejects flower-bearing stem as it is. If 100% pollination, a plant rejects ¼ of set fruits or all fruits get small size and contain less than usually viable seeds. There is a sense to carry out controlled pollination of 70-80% flowers of 1 main and all of its elementary inflorescences.

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Average long-term data are presented for the first time for 30-years study of reproductive phenology and fruit growth dynamics of 10 cultivars and 3 garden forms of *Yucca*, that were bred either by natural fruit-set with viable seeds or by habitual method of controlled-pollination. *Yucca carnerosana* is of special importance in this way, as it`s capable to set fruits only by discovered method of controlled-pollination (A.S. № 1470245 USSR, 1988). Controlled-pollination, phenologic observations and study of fruit growth dynamics of *Yucca* cultivars were carried out since 1984 till 2014, that period was broken into 5 terms (1984, 1995, 2001, 2006 and 2014). Plants of Nikita Botanical Gardens, Crimean and Sevastopol parks were used as study cases. The article reports about peculiarities of fruit setting, allowing for their morphological characteristics and cultivar belonging.

Key words: *reproductive phenology, fruit growth dynamics, Yucca cultivars, methods of controlled-pollination, the Crimea.*