Comparative study on the growth and development of annual and biannual plants of species from genus *Catalpa* at the conditions of Sofia field

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Citation
Sokolov, R. (2019). Comparative study on the growth and development of annual and biannual plants of species from genus *Catalpa* at the conditions of Sofia field. *Rastenievadni nauki, 56*(6), 63-68

Abstract

The possibility for propagation, ecological requirements and growth peculiarities of the species from genus *Catalpa* (fam. Bignoniaceae) in Bulgaria are insufficiently studied. Catalpa is a tree with attractive ornamental value, compact form and relatively fixed size. It originates from South America and China. *Catalpa* spp. differ significantly from each other by their requirements to environmental conditions (temperature, humidity and others), growth characteristics and susceptibility to diseases and pests. In our country catalpa species and varieties with delayed growth in the time are only few. The objective of this study was to optimize the production of propagating material of catalpa species and their varieties under the conditions of Sofia field. For three years (2014 to 2016), seeds were harvested from the studied species, they were sown, and the young plants were grown for at least 2 years in order to establish their growth abilities and their performance in the ecological conditions in Sofia region. The results of our study showed that direct outdoor sowing reduces the labour costs associated with the production of young plants, but at the expense of the number of plants obtained from the seeds. Laboratory seed germination varied slightly over the years, with an average for the study duration as follows: *C. bignonioides* – 88.67%; *C. x erubescens* – 85.66%; *C. ovata* – 87% and *C. speciosa* – 91,33%, and at least in one of the years, the seeds of each species had laboratory germination equal to or greater than 90%. The germination of seeds sown in boxes in a greenhouse was on average: *C. bignonioides* – 79.66%; *C. x erubescens* – 77.66%; *C. ovata* – 74,33% and *C. speciosa* – 85,33%; and under field conditions: *C. bignonioides* – 28%; *C. x erubescens* – 20.33%; *C. ovata* – 17.33% and *C. speciosa* – 31.66%. At the direct sowing in the first year the plants of *C. speciosa* reached the biggest height of 101.87 cm and a diameter of 21.3 mm. In the second year, the biggest height was measured for *C. ovata* – on average 208.33 cm, and the largest diameter for *C. speciosa* – 32.6 mm.

Keywords: *Catalpa*; propagation; planting material; optimization

INTRODUCTION

Catalpa genus (Bignoniaceae) includes about 30 tree species, predominantly distributed in the tropics. The area of the genus expands in moderate latitudes with only 5 to 6 species distributed in North America and East Asia (Kolesnikov, 1960; Brickell, & Cathey 2004; Vakarelov, & Anisimova, 2010). In our country three species are grown as ornamental trees and two more hybrid forms and one botanical species can be found in some plant collections (Vakarelov & Anisimova, 2010; Sokolov et al., 2016). The most widely grown species in our country is *Catalpa bignonioides* Walter from North America, with its compact form 'Nana' becoming increasingly important. In addition to *C. bignonioides* 'Nana' in Bulgaria can be seen its yellowish form 'Aurea'. The other American species *Catalpa speciosa* (Warder ex Barney). Warder ex Engelm is also relatively common in culture (especially in Sofia). Another species of the genus – *Catalpa ovata* G.Don coming from China is also grown in many Bulgarian cities, but the number of specimens of this species is inferior to that of the above mentioned two species. *Catalpa x erubescens* Carrière (C.ovata x C.bignonioides) is also cultivated in our country, and in some nurseries its ornamental form 'Purpurea' with bright violet young leaves is offered. In addition, single trees of *Catalpa bungei* C.A.Mey are cultivated in Bulgaria, unfortunately at the time of the experiment, it was not possible to provide enough quantities of seeds of these species for inclusion in the study. In recent years, propagation material has been offered from various forms of *x Chitalpa tashkentensis* – intergeneric hybrid obtained from the crossing of *Chilopsis linearis* and *Catalpa spp. x Chitalpa*. It is a sterile hybrid reproduced predominantly by rooting cuttings, which is why it is also not included in this study.

Catalpa species are low to medium-high, rapidly growing in young age, trees differing in their habitus (Kolesnikov, 1960; Brickell & Cathey, 2004; Vakarelov, & Anisimova, 2010). The typical *C. bignonioides* forms a highly distorted irregular crown, while the other species cultivated in Bulgaria have significantly more correct crowns. *C. ovata* forms straight trunks, which allows in its homeland to be considered as a valuable forest species (Guofei, et al., 2010). All types of Catalpa stand out from most cultivated ornamental trees in our country with their large leaves giving them exotic appearance and the large clusters of white or yellowish blossoms appearing between late May and early July, depending on climatic conditions and the botanical species. Another very specific element of the Catalpa are the long hanging fruits, which vary considerably from species to species (they are the most massive in *C. speciosa* and the shorter and thinner in *C. ovata*). Fruits usually hang on the trees throughout the winter, giving them a distinctly weeping appearance. Fruit bearing of catalpa species is every year and relatively high, except for some ornamental forms that either do not form any fruit or form such at scarcity. Perhaps the reason for the Catalpa to fruit regularly is their late flowering, which eliminates the risk of damage caused by late frosts.

Propagation of Catalpa species can be done through seeds or vegetative (Kolesnikov, 1960; Bodzhakov et al., 1961; Toogood, 1999). Seed propagation is primarily applied to obtain a large number of plants for the needs of forestry and landscaping, and also for the propagation of rootstocks for vegetative reproduction of *C. bignonioides* 'Nana'. All Catalpa species are able to root relatively easy. According to some authors, seed propagation may yield non authentic plants when the seeds are harvested from places where more than one species grow because of the easy occurrence of hybridization. Rooting cuttings is a preferred method of propagating ornamental forms and varieties that are capable of forming the desired form themselves. The grafting is successful, but due to the higher cost of the plants, it is mainly used for the propagation of *C. bignonioides* 'Nana' (Toogood, 1999). It is grafted high, usually at 1.8 or 2.4 m on predominantly upright growing rootstocks of *C. bignonioides*, but there is no reliable information that other species are unsuitable for this purpose. High grafting could allow wider use in landscaping of the *x Chitalpa* ornamental forms, which have unique ornamental qualities but are relatively small in size and with low growth at young age limiting the possibilities for their use. No reports of incompatibility were found in grafting one species over another in the Catalpa genus. Several reports have been published in the scientific literature on successful grafting of *Catalpa bungee*, widely cultivated in China as a rapidly growing forest tree, on other members of the family (Guo, 1988; Wang et al., 2008).

This study aimed to identify the specificity of seed propagation of three species of the genus Catalpa and one interspecies hybrid, which are grown relatively frequently in Bulgaria; and to compare the growth rates and development of the young plants during the first two vegetations. In this way, it is determined seedlings from which of the tested species can be grown in Sofia region and which species show the best growth, allowing a possible profitable production of high quality rootstocks for *C. bignonioides* 'Nana' and the *x Chitalpa* forms.

MATERIAL AND METHODS

The seeds used for the propagation of each of the studied *Catalpa* species were collected in 2014 (first year), 2015 and 2016 respectively, from the same well-developed, healthy plants typical of the species. The seeds of *C. bignonioides* were collected from a tree located in the Sofia quarter of Studentski Grad; *C. ovata* seeds are collected from a well-developed tree located in the Plovdiv quarter of Trakia. The seeds of *C. speciosa* are collected from an old tree located in Park Palace Krichim. Seeds of *C. x erubescens* are harvested from a plant grown in the Botanical Garden of the Bulgarian Academy of Sciences - Sofia. This plant is reproduced from seeds obtained through international exchange. This means that the tree is from F_2 or F_3, but it may be from the next hybrid generation. This in turn means that the plants derived from its seeds are from F_3 or the next hybrid generation.

The physical characteristics of the seed were measured with a ruler for 300 seeds of each species for each of the years in which seeds were harvested (2014-2016). The weight of 100 seeds was measured three times for each species in each of the years.

To determine the growth characteristics of *Catalpa* species, 12 m^2 of seed of each species were planted in 5 row strips with 18-20 plants per linear meter (2015 and 2016 respectively). During the first vegetation, the plants grew in the beds and the next spring 90 annual saplings of each species were planted in 100 x 50 cm scheme.

Laboratory germination was established by placing 3 replicates with 100 seeds each in petri dishes between two layers of filter paper. The petri dishes were kept in a thermostat at 25 ± 10 °C 10 days, after which the percentage of germinated seeds was recorded. The germination under controlled conditions was determined by sowing 3 replicates of 100 seeds in grow containers. A substrate containing 80% peat and 20% perlite was used. The seeds were sown at a depth of about 1 cm. The germinated plants were counted 20 and 40 days after sowing. Grow containers were placed in a glass-greenhouse with filtered light. To determine the field germination 3 repetitions of 1000 seeds were sown in 3 rows. The depth of the sowing was 1 cm. The sowing took place between May 1 and May 3 in the experimental field of the Institute of Ornamental and Medicinal Plants. The soil in the field is slightly alluvial. The irrigation of the sown seeds was carried out by drip irrigation.

Measurement of the stem height was performed at the end of the vegetation after the falling of the leaves. The length of the stem from the top to the soil level was measured. Measurement of the diameter of the stem was done simultaneously with the measurement of the height – at the base of the stem above the zone of the root cervix, where no further enlargement was observed. The length of the stem's frostbite was measured in the spring after bursting of the buds. Measurement was performed from the top of the stem to the highest bud of the main stem.

In the 3 years of the study many observations on the plants were conducted to establish the uniformity of plant emergence, occurrences of diseases and pests, as well as to establish the reaction of plants to climatic conditions in the region of Sofia field.

The obtained data were processed statistically via MS Excel and SPSS, as were calculated the average values, standard deviations and a Duncan's multiple-range test ($p<0.05$) was conducted.

RESULTS AND DISCUSSION

The seeds of the different *Catalpa* species are comparatively uniform in shape (Fig. 1). They are flat with two tufts of hairs at both ends, their morphology being an adaptation for spreading by the wind. The average sizes and weights of the seeds of the studied species that we have identified are listed in Table 1. The differences between the seeds of the four species are clearly visible. The difference in weight between the species with the largest seeds – *C. speciosa*, and the one with the smallest – *C. ovata*, is 5.8 times. To a large extent we can explain some of the results obtained with that fact, especially the higher field germination of *C. speciosa* that has larger seedlings with a more penetrating primary root, which makes the seeds more independent of moisture in the immediate surface layer of the soil.

Seeds of the *Catalpa* species studied showed high laboratory germination, which varied during the three years in which their seed qualities were examined (Table 1). In the case of the seeds harvested in 2015, in all species there is a significantly lower germination. The observed germination under controlled greenhouse conditions is lower than laboratory, but the difference between them is statistically significant only for *C. ovata*. Field germination is much lower than the laboratory and the one established under controlled conditions. Perhaps this great difference is primarily due to the conditions created by us and to the lack of natural shading recommended by some authors (Bodzhakov, et al., 1961). Significant easing of the transplantation or mulching and shading work we

Table 1. Average seed weight and size of the *Catalpa* species studied

Species	Average weight per 100 seeds (g)	Average seed length (mm)	Average seed width (mm)
C. bignonioides	1,6806 ± 0, 2876	24,28 ± 3,94	4 ± 0,77
C. x erubescens	0,7643 ± 0,1022	15,71 ± 2,08	3,8 ± 0,68
C. ovata	0,4631 ± 0,0591	7,76 ± 0,99	2,38 ± 0,62
C. speciosa	2,7184 ± 0,4135	32,43 ± 2,44	6,57 ± 0,75

Table 2. Germination of seeds of the test species *Catalpa* under laboratory, controlled (greenhouse) and field conditions

Species - year of harvesting	Germination (%)		
	Laboratory	Controlled conditions	Field conditions
C. bignonioides - 2014	94,67 ± 5,68	82 ± 4	28,33 ± 1,04
C. bignonioides - 2015	83,33 ± 8,14	76,33 ± 2,52	23,67 ± 2,52
C. bignonioides - 2016	88 ± 3,51	80,66 ± 3,78	32 ± 6,56
C. bignonioides - average	88,67 ± 6,06	79,66 ± 3,97	28 ± 5,43
C. x erubescens - 2014	90 ± 2,64	82,66 ± 3,21	20 ± 2
C. x erubescens - 2015	82,67 ± 2,08	72,33 ± 3,05	22,66 ± 0,57
C. x erubescens - 2016	84,33 ± 2,51	78 ± 2	18,33 ± 1,53
C. x erubescens - average	85,67 ± 3,94	77,67 ± 5,1	20,33 ± 2,3
C.ovata - 2014	91,33 ± 1,53	79,33 ± 3,21	19,66 ± 2,08
C.ovata - 2015	84 ± 1	71 ± 1	14 ± 2,64
C.ovata - 2016	85,66 ± 2,08	72,67 ± 2,31	18,33 ± 0,58
C.ovata - average	87 ± 3,61	74,33 ± 4,41	17,33 ± 3,08
C.speciosa - 2014	98,67 ± 2,31	88,33 ± 2,08	34 ± 2
C.speciosa - 2015	86,33 ± 2,52	80,66 ± 1,52	28,67 ± 1,53
C.speciosa - 2016	89 ± 1,73	87 ± 1,73	32,33 ± 1,53
C.speciosa - average	91,33 ± 5,94	85,33 ± 3,87	31,67 ± 2,78

Table 3. Basic biometric features of 1 and 2 year old plants of the *Catalpa* species studied

Species	Hight		Diameter		Frost/ cold damage of the stem	
	First year	Second year	First year	Second year	First year	Second year
C. bignonioides	$84,1 \pm 7,32^{a}$	$169 \pm 14,5^{a}$	$10,4 \pm 1,4^{a}$	$20,3 \pm 2,1^{a}$	$5 \pm 2,6^{a}$	$13 \pm 6,5^{a}$
C. x erubescens	$79,1 \pm 6,7^{a}$	$166,2 \pm 11,7^{a}$	$12,2 \pm 1,9^{ab}$	*$25, 3 \pm 3,2^{b}$*	$6,3 \pm 2,9^{a}$	$12,2 \pm 8,7^{a}$
C.ovata	$92,3 \pm 9,3^{ab}$	$208,3 \pm 10,7^{b}$	$14,4 \pm 2,2^{b}$	*$26,1 \pm 2,7^{bc}$*	$48,6 \pm 13,7^{b}$	$37,3 \pm 16,3^{b}$
C.speciosa	$101,9 \pm 9,2^{b}$	$178,3 \pm 17,6^{a}$	$21,3 \pm 2,5^{c}$	*$32,6 \pm 3,6^{c}$*	$8,7 \pm 3,6^{a}$	$6,6 \pm 3,4^{a}$

use in our approach compensates for the reduced number of plants obtained per unit of seed in cases where the seed collection is not associated with significant costs.

In the first year the plants of *C. bignonioides*, *C.x erubescens* and *C. ovata* showed similar growth at height, with the highest average of the three species being recorded for *C. ovatas* – 92.3 cm and the lowest for *C. x erubescens* – 79.1 cm. The highest height in the first year was recorded for plants of C. *speciosa*, which reached an average height of 101.9 cm (Table 3). In the second year, the largest growth was recorded for *C. ovata* – 208.3 cm. It is important to point out that in this species the plants had lost more than half of the growth in the first year as a result of frost. While the other three species showed relatively close results, with a slightly higher average height reported for *C. speciosa*, although the difference was not statistically significant (Table 2). Regarding the diameter of the stem, there is some degree of uniformity, whereas only *C. speciosa* has a significantly higher thickness. In the case of the two-year plants, the lowest diameter is for *C. bignonioides* – 20.3 mm, and the largest diameter have those of *C. speciosa* – 32.6 mm, and *C. ovata* – 26.1 mm (Table 3). Our observations show that specimens from each of the studied species have been satisfactorily uniform. No specimens were found that were significantly different in terms of morphology and growth abilities, so we can conclude that spontaneous hybridization between species occurs with negligible frequency. Probably the reason for the observed results is that in our country the flowering in the different species overlaps insignificantly, which hinders the mutual crossing. In plants obtained from seeds of *C. x erubescens*, an unexpected homogeneity for a hybrid was also observed. This may be due to the fact that plants are of further hybrid generation, which is somewhat confirmed by the lack of a clear heterozygous effect.

The damage from early autumn frosts and winter frosts cannot be clearly distinguished, so we have presented them together in a table. 2 as frost damage. It is clear from the table that the damages of *C. bignonioides*, *C. x erubescens* and *C. speciosa* are similar in volume, whereas for *C. ovata* in both the first and the second year are significantly larger. During all three years of the study plants from *C. ovata* species showed active growth until much later in the autumn compared to the other 3 studied species. In two of the 3 years, autumn frosts caused serious damage to the top of the plants, thus significantly contributed to the formation of reported damage from the cold. From the data obtained, we can conclude that with the growth of *C. ovata* plants each year the damage from the cold decreases, probably due to a complex of factors, but as basic we can point two. First, the gentle new growth rising above the air layer most affected by the frost, and second, the growth becomes more moderate and distributed in more points, allowing a relatively larger portion of the shoots to mature enough to withstand the autumn frosts and the winter. Based on the results we can recommend in the field of Sofia to limit nitrogen fertilization after mid-July, and in the second half of August to stop irrigation so as to limit the late growth. It is also possible to move the saplings in protected areas in the autumn to reduce the effect of the colds.

The sensitivity to the late spring frosts of the 4 species studied does not differ significantly. Under the conditions of the IOMP Test Field, plants were affected by late spring frosts (from late April to early May) in 2016 and 2017. Damage to young leaves and tops of growth was observed. This leads to the development of newly deposited buds on the shoots whose peaks have been damaged. Branching caused by late frosts during the first two years (until the stem is formed) requires removal of excess shoots to form a straight and unbroken stem. This is a mandatory operation associated with additional manual labour costs.

In the autumn of 2016 and 2017 an attack of powdery mildew was observed in *C. bignonioides*, *S. x erubescens* and *C. speciosa*. No phytopatological analysis has been performed and it is not clear which of the two possible pathogens is the cause of the disease. The most susceptible to the disease was *C. bignonioides* which leaves were entirely covered by powdery gall. Plants of *C. speciosa* were attacked on average strongly, and *C. x erubescens* suffered partial attack on individual leaves (small powdery mildews). No visible symptoms of infection were observed in *C. ovata*, so we can conclude that the strain is either completely resistant to the pathogen or is highly resistant. The powdery mildew appeared after the drop of the average daytime temperatures in September and October and the increase in humidity.

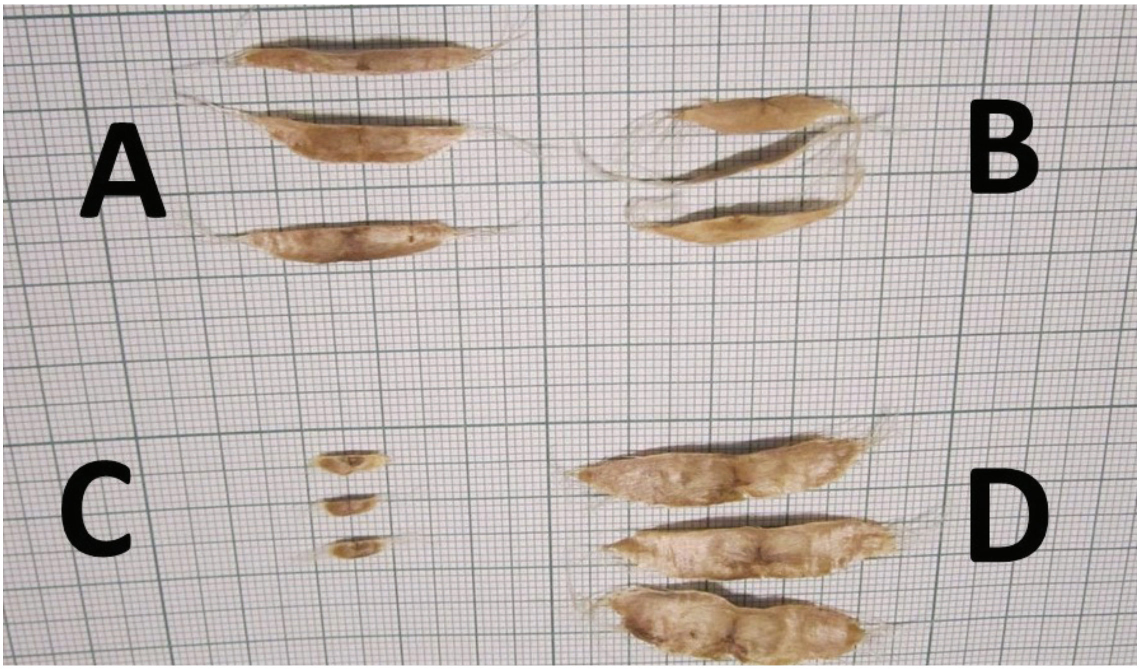

Figure 1. Seeds of the studied *Catalpa* species
A. *C. bignonioides*, **B.** *C. x erubescens*, **C.** *C.ovata*, **D.** *C.speciosa*

CONCLUSIONS

Catalpa ovata shows the fastest growth and forms the highest plants at the end of the second vegetation. At the same time, it should be emphasized that this species showed the strongest sensitivity to low temperature damage, making it the least suitable for cultivation in the Sofia Field.

The highest average diameter was recorded in both the first and the second year in the *Catalpa speciosa* plants. This species also showed satisfactory growth at hight with the one-year-old plants having the highest average height, and in the two-year period it is close to the growth of *Catalpa ovata*.

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