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Correlation of Fruit Size with Morphophysiological Properties and Germination Rate of the Seeds of Service Tree (*Sorbus domestica* L.)

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### ABSTRACT

**Background and Purpose:** The current study aims to evaluate the effect of the fruit size of service tree (*Sorbus domestica* L.) on physio-morphological properties of seeds and the seed germination process.

**Materials and Methods:** The fruit samples varying in size and divided on the basis of weight into small (5-10 g), medium (11-15 g) and large (16-20 g) were collected from the area of Vukomeričke gorice (45°34′45″N 16°00′11″E), Zagreb County, Croatia.

**Results:** In all fruits, a significant, positive and very high correlation was found between the fruit length and width (r=0.92). There was a negative and significant correlation between the fruit weight and the fruit shape index (r=-0.47). The number of filled seeds in fruit was significantly higher in large fruits (2.62 seeds) than in medium and small fruits (1.81 and 1.46, respectively). Seeds from large fruits had significantly greater length of radicle (3.89 mm) than those from medium and small fruits (3.27 and 2.88, respectively) after 120 days of stratification at 3°C. The mean germination time of seeds for all fruits in total was 107 days. The seeds with the highest weight had significantly lower rate of moisture absorption. After stratification the seeds of large fruits had the highest germination percentage (83.7%).

**Conclusions:** The findings obtained will likely impact the propagation of this plant species in the future, because the results of the study favour the usage of seeds obtained from large fruits since they showed highest germination rate.

**Keywords:** Fruit morphology, radicle emergence, seed germination, stratification, *Sorbus domestica* L.

### INTRODUCTION

Service tree (*Sorbus domestica* L.) is a rare wild tree with deciduous nature, 15-20 (rarely 30) m tall with broad, roundish ovoid crown that has the diameter of up to 100 cm (Figure 1). Service tree grows slowly (except in the juvenile period), reaches the age of 200-300 years and prefers warm and mild climate. It does not require any specific soil properties, but it grows well on deep and fertile soils. It can withstand drought, but is sensitive to late spring frosts [1]. In a forest ecosystem, the ecological significance of this tree is great due to the forage (fruits) which it offers to wildlife species. Furthermore, its timber is valuable due to its excellent aesthetic and technical characteristics [2].

It is hard to determine the exact boundaries of natural expansion of service tree because it has been planted and expanded sub-spontaneously since ancient times. It is distributed either patchy or densely in southern and central Europe, northern Africa, Crimea and Asia Minor. However, the Balkan Peninsula, the Apennine Peninsula and southern France are considered as the main area of its cultivation. Nevertheless, *S. domestica* is very rare and threatened in
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trees is not more than 800 m [9]. Allogamy is possible if the distance between the
yields. Service tree produces more seeds when it is cross-

stratification for 4 months at a temperature ranging from 3
to 5°C. However, Winkler [16] found that the seeds of service
tree and wild service tree need stratification conditions, that
they germinate well in darkness and should be mixed with
appropriate substrates, as well as kept in refrigerator at a
temperature from 0°C to 4°C. Temperatures lower than 0°C
are not favorable because they freeze down the water that
further stops seeds to swell. Moreover, the seeds should be
stratified at the beginning of December. Kausch-Blecken
von Schmeling [8] found that it is very important to rinse
the mesocarp of fruits properly to avoid the occurrence of
mold during the storage of seeds. Likewise, Meier-Dinkel
[9] suggested that two and a half months before sowing,
the seeds should be placed on moist sand in a covered jar
and kept in the refrigerator at 4°C where some seeds can
germinate at the end of stratification. After stratification, the
seeds should be kept on a warm place (20°C) where after
a few days they start to germinate. However, Pipinis et al.
[17] suggested a 3-month period of stratification at 3-5°C
since this is essential for breaking dormancy in the seeds
of S. domestica. Service trees have double dormant seeds
due to undeveloped seed embryo and an impermeable seed
coeat [6].

Surprisingly, very little work has been done so far
regarding the morphological studies of service tree fruit and
the impact of the fruit size on the physiological properties
of seeds. Henceforth, the current study was conducted to
determine the morphological characteristics of service tree
fruits of different weight and their correlations with physical
properties of seeds. In addition, the aim was also to test the
laboratory seed germination of fruits of various weight after
120 days of stratification.

MATERIALS AND METHODS

The fruits of service tree were collected in the area of
Vukomeričke gorice (45°34′45″N 16°00′11″E), Zagreb
County, Croatia, in autumn when fruit ripens. A total of 150
fruits were collected from 10 trees for the analysis and were
grouped on the basis of weight as small (5-10 g), medium
(11-15 g) and large (16-20 g). The length (mm) and width
(mm) of fruits were measured using digital caliper, while fruit
weight was measured with laboratory balance (accuracy
0.01 g). The seeds were manually extracted from fruits with
the help of a little knife and then the number of filled seeds
in every fruit was recorded. After the seeds were air-dried,
the weight of each seed (309 seeds from 150 fruits) was
measured. The seeds were then stratified. The seeds were
moistened and placed on an absorbing filter paper before
they were used for stratification. Every seed was coded for
recognition of its origin and placed on moistened filter paper
covered with another layer of moistened filter paper to avoid
draining. Stratification was carried out at a temperature
of 3°C and lasted in total for 120 days in accordance with
rules of ISTA for overcoming seed dormancy from species
of the genus Sorbus. The moistening of the filter paper was
continued as per need during stratification time. After 120
days, at the end of stratification period, the weight of each
seed was measured to calculate the percentage of moisture
absorption. The daily monitoring of seeds was performed in

many European countries [3]. Croatia is one of the countries
where the environmental conditions favor the cultivation
of service tree. This species is extensively found in the
Mediterranean area, as well as in the continental part of
Croatia [4].

Service tree fruit is edible, apple- or pear-shaped, with
a diameter of about 1.5 to 3 cm, yellow-reddish or yellowish
with brown spots. In the wild, service tree propagates itself
by seed, especially within its natural range [5]. It flowers in
March while its fruit ripens from August to September [6].
According to Drvodelić et al. [7], the good yield of service
tree in Croatia happens in intervals of every four years.
Whereas, according to Kausch-Blecken von Schmeling [8],
 service tree yields highly every two to three years. The
reason behind such differences can be justified with a fact
that when service tree yields highly it spends a lot of energy
for the growth of fruits and seeds and therefore it is not
strange that there are big intervals between the years of high
yields. Service tree produces more seeds when it is cross-
pollinated. Allogamy is possible if the distance between the
trees is not more than 800 m [9].

Fresh seeds from the species of genus Sorbus L. do not
germinate easily and need low temperatures under moist
conditions (stratification) [10]. Numerous studies mentioned
that fresh Sorbus spp. seeds do not germinate immediately
after maturation because they need longer period with cold
stratification [11-14]. Moreover, as per rules of International
Seed Testing Association (ISTA) [15], before the testing of
seed germination it is necessary to keep the seeds in cold

FIGURE 1. Service tree (S. domestica L.) in Croatian agro-
climatic conditions.
order to record the time of seed shell bursting and radicle emergence (Figure 2) up to the length of 2 mm during entire stratification period. The increase in length after radicle cracking was measured on a daily basis using digital caliper. The radicle length after 120 days of stratification is described in detail in the current study.

The statistical analysis was performed with statistical package SAS 9.2 using ANOVA and correlation analysis. The means were compared using LSD test at p≤0.05.

RESULTS AND DISCUSSION

The descriptive statistical data of some morphological characteristics of service tree fruits with different weight is shown in Table 1. Statistically significant differences were determined in length (mm) and width (mm) of the fruits between groups defined by weight (p≤0.0001). Small fruits showed statistically significant difference (p≤0.0001) having the highest fruit shape index (0.98) in comparison with medium (0.94) and large (0.91) fruits. Therefore, it can be concluded that small fruits had a more round shape. A number of filled seeds in *S. domestica* L. fruits were statistically significant (p≤0.0001) and higher in large fruits (2.62 seeds) in comparison with medium (1.81 seeds) and small (1.46 seeds) fruits (Figure 3).

![Figure 2. Germination of service tree (S. domestica L.) seeds.](https://www.seefor.eu)  

![Figure 3. Different sizes of fruits of service tree (S. domestica L.) showing the variations in the number of obtained seeds.](https://www.seefor.eu)
Regarding all fruits in total, a positive and very high correlation was found between fruit length and width ($r=0.92$), fruit length and weight ($r=0.93$) and fruit width and weight ($r=0.98$). Statistically significant ($p \leq 0.0001$) correlations were found between the number of filled seeds per fruit and fruit length ($r=0.42$), fruit width ($r=0.50$), fruit shape index ($r=-0.36$) and fruit weight ($r=0.50$). There was a negative and statistically significant correlation between fruit weight and fruit shape index ($r=-0.47$) (Table 2).

Within small fruits, a positive and very high correlation was obtained between fruit length and width ($r=0.80$), fruit length and weight ($r=0.87$) and fruit width and weight ($r=0.96$). Statistically significant ($p \leq 0.05$) negative correlation was found between the fruit shape index and the number of filled seeds in fruits ($r=-0.29$) (Table 3).

Within medium fruits, a positive and high correlation was obtained between fruit width and weight ($r=0.75$) with statistically significant difference at $p \leq 0.001$. Statistically significant ($p \leq 0.01$) correlation was also found between fruit length and weight ($r=0.48$) and between fruit width and the number of filled seeds per fruit ($p \leq 0.05$, $r=0.41$) (Table 3).

In the case of large fruits, a positive and very high correlation was obtained between fruit width and weight ($r=0.94$). Statistically significant ($p \leq 0.001$) difference was found between fruit length and width ($r=0.53$) and between fruit length and weight ($r=0.68$). Less positive, but statistically significant ($p \leq 0.05$) correlation was obtained between the number of filled seeds in fruit and fruit width ($r=0.30$) and fruit weight ($r=0.23$) (Table 3).

### Table 1. Descriptive statistics of some morphological traits of service tree (*S. domestica* L.) fruits of different sizes.

| Fruit size       | Fruit length (mm) | Fruit width (mm) | Fruit shape index (FL/FW) | Fruit weight (g) | The number of filled seeds per fruit |
|-------------------|-------------------|-------------------|---------------------------|------------------|-------------------------------------|
| Small (5-10 g)    | 23.19±1.90 a      | 23.81±1.86 a      | 0.98±0.05 a               | 7.67±1.61 a      | 1.46±0.65 a                         |
| Medium (11-15 g)  | 27.45±1.38 b      | 29.31±0.81 b      | 0.94±0.05 b               | 13.52±0.88 b     | 1.81±0.90 a                         |
| Large (16-20 g)   | 29.93±1.65 c      | 32.67±1.71 c      | 0.91±0.05 b               | 18.83±2.81 c     | 2.62±1.18 b                         |

Means followed by different letters in columns indicate that there is statistically significant difference based (LSD test at $p \leq 0.05$)

### Table 2. Correlation coefficients for the morphological traits of service tree (*S. domestica* L.) fruits (all sizes combined together).

| Variables                     | Fruit length (mm) | Fruit width (mm) | Fruit shape index (FL/FW) | Fruit weight (g) |
|-------------------------------|-------------------|-------------------|---------------------------|------------------|
| Fruit width (mm)              | 0.92****          | 0.98****          | -0.47****                 | 0.93****         |
| Fruit weight (g)              | 0.93****          | 0.96****          | NS                        | 0.48**           |
| The number of filled seeds per fruit | 0.42****          | 0.50****          | -0.36****                 | 0.50****         |

**** - correlation significant at $p \leq 0.000$

### Table 3. Correlation coefficients for some morphological traits evaluated on service tree (*Sorbus domestica* L.) fruits of different sizes.

| Variables                     | Fruit length (mm) | Fruit width (mm) | Fruit weight (g) | Fruit shape index (FL/FW) |
|-------------------------------|-------------------|-------------------|------------------|---------------------------|
| Small fruit                   |                   |                   |                  |                           |
| Fruit width (mm)              | 0.80***           | NS                | NS               | NS                        |
| Fruit weight (g)              | 0.87***           | 0.96***           | NS               | NS                        |
| The number of filled seeds per fruit | NS                | NS                | NS               | -0.29*                    |
| Medium fruit                  |                   |                   |                  |                           |
| Fruit weights (g)             | 0.48**            | 0.75***           | NS               | NS                        |
| The number of filled seeds per fruit | NS                | 0.41*             | NS               | NS                        |
| Large fruit                   |                   |                   |                  |                           |
| Fruit width (mm)              | 0.53***           | NS                | NS               | NS                        |
| Fruit weight (g)              | 0.68***           | 0.94***           | NS               | NS                        |
| The number of filled seeds per fruit | NS                | 0.30*             | 0.23*            | NS                        |

NS, *, **, *** - correlation nonsignificant or significant at $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$, respectively
There are several reports available worldwide mentioning the fruit morphological characteristics of service tree but with little variations. Ballian et al. [18] stated that the service tree fruit length was between 17.5 and 35.1 mm, and its width between 15.5 and 24.9 mm. Whereas, according to Miko and Gažo [19], the average fruit width was between 25.0 and 27.6 mm which varied between 16.39 and 32.9 mm, and the average length between 26.0 and 33.2 mm which varied between 20 and 37 mm. Furthermore, the fruit weight was between 7.4 and 21.0 g which varied between 4.3 and 22.3 g. Similarly, Majošovský [20] when mentioning the botanic description of service tree reported that fruit width was between 21.4 and 27.7 mm, fruit length between 15.0 and 30.0 mm, and fruit weight between 20 to 30 g. However, according to Brindza et al. [21], average fruit length was between 19.84 and 36.29 mm and width between 18.9 and 32.58 mm, while the average weight was from 4.91 to 18.64 g. The reasons behind such variations might be, as Kárpáti [22] found in his studies, due to the fact that service tree fruits with diameter bigger than 1.5 cm are the result of selection. It is interesting to mention a research conducted by Végvári [23] in Hungary who reported that service tree fruits that have different color (yellow, red, brown) also differ in shape. Whereas, according to the findings of Drvodelić et al. [24], who conducted extensive studies on service tree in different parts of Croatia, the average length of fruit was between 22.05 mm (Ogulin) and 25.66 mm (Novi Vinodolski), average width between 24.55 mm (Ogulin) and 27.30 mm (Novi Vinodolski), and average weight of fruit from 8.75 g (Ogulin) to 11.23 g (Novi Vinodolski). In addition, the fruit weight in 2003 was between 3.42 and 17.24 g or on average 7.92 g, in 2004 between 4.65 and 12.20 g or on average 8.37 g, in 2005 between 7.14 and 11.36 g or on average 9.29 g, in 2006 between 6.69 and 10.49 g or on average 8.72 g, and in 2007 between 8.35 and 12.98 g or on average 10.01 g. He further stated that in comparison with the sites from which the samples were taken in Republic of Croatia during five years of research (2003-2007), the average fruit weight of service tree increased from western to eastern parts of the country.

As per findings of Ballian et al. [18], the differences between trees are mostly contributed by fruit length of service tree and the genotypes that have large fruits and thus should be used for propagation. According to Drvodelić [7], the service tree fruit’s width and length features are more similar between geographically closer sites, such as Nova Kapela and Ogulin, or Rab and Novi Vinodolski in Croatia. He found that the average index of length/width of fruits for all five years he studied was 0.92 for Novi Vinodolski site, 0.97 for Ogulin site, 0.99 for Rab site and 1.03 for Nova Kapela site. He also found that the highest range of length/width index was between trees are mostly contributed by fruit length of service tree and the genotypes that have large fruits and thus should be used for propagation. According to Drvodelić [7], the service tree fruit’s width and length features are more similar between geographically closer sites, such as Nova Kapela and Ogulin, or Rab and Novi Vinodolski in Croatia. He found that the average index of length/width of fruits for all five years he studied was 0.92 for Novi Vinodolski site, 0.97 for Ogulin site, 0.99 for Rab site and 1.03 for Nova Kapela site. He also found that the highest range of length/width index was 0.99 for Rab site and 1.03 for Nova Kapela site. He further stated that in comparison with the sites from which the samples were taken in Republic of Croatia during five years of research (2003-2007), the average fruit weight of service tree increased from western to eastern parts of the country.

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between radicle length after 120 days of stratification and seed weight in air-dried condition was positive and small ($r=0.26$) (Table 5).

In the case of seeds from small fruits a positive and statistically significant ($p \leq 0.05$) correlation was obtained between radicle length after 120 days of stratification and the percentage of moisture absorption ($r=0.46$). Negative and significant correlation ($r=-0.48$) was obtained between radicle length after 120 days of stratification and the time needed for the beginning of seed germination, as well as between the percentage of moisture absorption and seed weight in air-dried condition ($r=-0.32$). Negative and weak ($r=-0.39$) but statistically significant ($p \leq 0.01$) correlation was obtained also between the percentage of moisture absorption and the time needed for the beginning of seed germination (Table 6).

For seeds from medium and large fruits a negative and significant ($r=-0.49$) correlation was obtained between the length of radicle after 120 days of stratification and the time needed for seed germination, as well as between the percentage of moisture absorption after 120 days of stratification and the time needed for the beginning of seed germination ($r=-0.33$). The difference between the above-mentioned parameters was significant at $p \leq 0.01$. Although negative and small, but statistically significant ($p \leq 0.001$), the correlation was obtained between the percentage of moisture absorption after 120 days of stratification and seed weight in air-dried condition ($r=-0.32$) (Table 6).

For seeds from large fruits, negative and high correlation was obtained between radicle length after 120 days of stratification and the time needed for seed germination.

**TABLE 4.** Descriptive statistics of some morphological and physiological traits of seeds from service tree (*S. domestica* L.) fruits of different sizes.

| Fruit size | Length of radicle after 120 days (mm) | Absorbed moisture after 120 days (%) | Air-dried seed weight (g) | Time to begin germination (days) |
|------------|--------------------------------------|-------------------------------------|---------------------------|---------------------------------|
| Small (5-10 g) | 2.88±0.81 a | 43.01±7.99 a | 0.0283±0.0078 a | 107.66±13.31 a |
| Medium (11-15 g) | 3.27±0.85 a | 46.03±28.07 a | 0.0365±0.0092 b | 108.72±9.79 a |
| Large (16-20 g) | 3.89±1.48 b | 42.64±6.84 a | 0.0398±0.0090 c | 104.85±10.73 a |

*Means followed by different letters in columns indicate that there is statistically significant difference (LSD test at $p \leq 0.05$)*

**TABLE 5.** Correlation coefficients for the morphological and physiological traits of seeds from service tree (*S. domestica* L.) fruits (all sizes combined together).

| Variables | Length of radicle after 120 days (mm) | Absorbed moisture after 120 days (%) |
|-----------|--------------------------------------|-------------------------------------|
| Time for germination (days) | -0.66*** | -0.40*** |
| Air-dried seed weight (g) | 0.26*** | -0.22*** |

*** - correlation significant at $p \leq 0.001$, respectively

**TABLE 6.** Correlation coefficients for some morphological and physiological traits of seeds from service tree (*S. domestica* L.) fruits of different sizes.

| Variables | Length of radicle after 120 days (mm) | Absorbed moisture after 120 days (%) |
|-----------|--------------------------------------|-------------------------------------|
| Small fruit | Absorbed moisture after 120 days (%) | 0.46* | - |
| Time for germination (days) | -0.48* | -0.39** |
| Air-dried seed weight (g) | NS | -0.32* |
| Medium fruit | Time for germination (days) | -0.49** | -0.33** |
| Air-dried seed weight | NS | -0.32*** |
| Large fruit | Absorbed moisture after 120 days (%) | 0.29** | - |
| Time for germination (days) | -0.79*** | -0.45*** |
| Air-dried seed weight (g) | NS | -0.26** |

NS, *, **, *** - correlation nonsignificant or significant at $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$, respectively
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(r = -0.79). Correlation between the percentage of moisture absorption and the time needed for seed germination was negative and significant (r = -0.45). The difference between the above-mentioned parameters was significant at ps0.001. There is positive and small, but statistically significant (ps0.01) correlation between radicle length after 120 days of stratification and the percentage of moisture absorption after 120 days of stratification (r = 0.29), and negative and small correlation between the percentage of moisture absorption after 120 days of stratification and seed weight in air-dried condition (r = -0.26) (Table 6).

After 120 days of stratification the seeds from the group of large fruits (16-20 g) had the highest percentage of germination (83.7%). With the help of Chi-squared test statistically significant difference (ps0.001) was found between the examined groups in germination of seeds from fruits with different weight, wherein seed germination in the group of large fruits was significantly higher than seed germination in groups of medium (59.4%) and small (56.2%) fruits. It can be concluded that seed germination of service tree in controlled conditions increased from the group of small to the group of large fruits (Figure 4).

According to Lenartowicz [27], the seeds from the species of the genus Sorbus L. have problems with germination, which could indicate relatively high dormancy of embryo. It is one of the mechanisms by which embryos created by self-pollination and by inbreeding could be eliminated. According to Paganová [28], service tree seeds’ low temperature and high humidity stratification needs to be longer than 8 weeks to germinate (depending on year). Piagnani and Bassi [29] reported that for overcoming seed dormancy from the species of the genus Sorbus L. cold and moist stratification is needed in the period of 3 to 9 months. On the other hand, Drvodelić [7] found that only 105 days of stratification (15 days less than as suggested by ISTA [15]) was needed for overcoming double seed dormancy from four species of the genus Sorbus L. in Croatia. It can completely coincide with the results from the current study where mean germination time regarding all fruits in total was 107 days. Powell and Matthews [30] reported the methodology according to which the appearance of radicle was defined as RE (radicle emergence) and mean germination time (MGT). As per findings of Drvodelić [7], the average service tree seed germination rate at the end of stratification period in 2003 was 9.3%, in 2004 15.4%, in 2005 31.2%, in 2006 53.7% and in 2007 only 3.8%. Average service tree seed germination at the end of stratification period (120 days) for all five years of research (2003-2007) was 22.5%. He also reported that it is important to mention that in the years with the highest yield (2003 and 2007) the highest seed germination rate was not achieved at the end of stratification time. That means that the quality of yield does not have effect on the time needed for overcoming seed dormancy in this species.

In our study we obtained much higher seed germination rate after 120 days of stratification, wherein seed from large fruits had germination percentage of even 83.7%.

CONCLUSIONS

The findings obtained in this study will likely impact the propagation of service tree in the future. The obtained results suggest using the seeds obtained from large fruits because they had higher number of filled seeds per fruit and showed highest germination rate, as well as earlier germination in comparison to the seeds from medium and small fruits. After 120 days of stratification, the seeds from large fruits (16-20 g) had the highest percentage of germination (83.7%). Although no statistically significant difference was found in mean germination time (MGT) between the examined groups defined by weight, the seeds from larger fruits have germinated four days earlier than seeds from medium fruits and three days earlier than seeds from small fruits. This means that only large fruits should be used for propagation of service tree.

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