

## Vegetative Behaviors of the Linden (*Tilia* spp.) Seedlings

Valentin Panchev<sup>1</sup>, Valeria Ivanova<sup>1</sup>

<sup>1</sup>Agricultural University, Plovdiv, Bulgaria

### Abstract

The main goal of this study was to investigate the morphological development of the seedlings of *Tilia* spp. The experiments were carried out with seeds from three *Tilia* species. The seeds were harvested from trees in the region of Plovdiv on 30, 45, 60, 75 and 90 days after flowering. The seeds were sown in soil bed immediately after collecting. The sprouting percentage and percentage of developed and survived seedlings were recorded. In a 3-4 leaves development stage, the morphological characteristics of root, stem and leaves were determined. The seedlings have only developed from 90 days seeds. The differences between species were observed. The highest stem was measured in *Tilia tomentosa* Moench. The largest root system was developed in the seedlings of *Tilia platyphyllos* Scop. The seed propagation of linden is most effective by using 90 day old seeds.

*Key words:* root, stem, *Tilia* spp., propagation, seeds

### Introduction

Four lime species are more common in Europe: *Tilia dasystyla* Stev., *Tilia tomentosa* Moench., *Tilia cordata* Mill. and *Tilia platyphyllos* Scop and they are widely used for urban landscaping (Radoglou et al., 2009). In the area of Balkan Peninsula primarily silver linden (*Tilia tomentosa* Moench.) occurs. Radoglou et al. (2009) emphasized that the wide spread of linden is predominantly due to its high adaptability and vitality.

The seeds of linden according to Stokes (1965) fall at dormancy and they cannot germinate despite availability of appropriate environment conditions - optimal temperature, humidity and aeration. For the realization of the sprouting, the seeds can undergo physiological and morphological treatment such as scarification and stratification. Similar methods for overcoming dormancy of the seeds were recommended by Panayotov (2015). Chawla (2004) reported that the reasons for the occurrence of dormancy are specific nature of the linden seeds, such as the presence of endogenous inhibitors, specific requirements for light, the poor ripening of the seeds and embryo. The author points out that in American linden (*Tilia americana* L.), the seed dormancy is often associated with unopened pericarp, i. e. fruit coat. In this species, according to Rose (1991), seeds do not germinate when placed in the moist substrate under laboratory conditions, and the main reason for this is the difficulty of water absorption, which is a limiting factor for germination. It was also found that the seeds sown in the soil prior to the occurrence of the winter season have a relatively low germination. The seed coat of linden is no reason for dormancy, but it contributes significantly to the extension of its duration.

Extremely important for good seed germination is the location of mother trees from which they are derived. Varaksin and Kladko (2010) associated the normal development of seeds with the duration of individual phenophases. Researchers found that in urban environments, despite the strong growth of small-leaved lime (*Tilia cordata* Mill.) the maturation of the seeds is considerably postponed.

The seeds of linden tree are characterized by specific anatomical and morphological structure, which greatly prevent their germination. The strong impermeability of the seed coat to water and oxygen and a significant mechanical firmness, that also prevent the protrusion of the embryo root were observed. This water impermeability is associated with the structure of the individual layers of the seed coat as well as of the hilum and chalaza. In this sense, the seed propagation is extremely difficult (Werker, 2013).

The main goal of this study was to establish the species response to the morphological development of the seedlings of different *Tilia* spp.

## Material and Methods

The experiments were carried out with seeds of linden species small-leaved lime (*Tilia cordata* Mill.), silver linden (*Tilia tomentosa* Moench.) and large-leaved lime (*Tilia platyphyllos* Scop.). The seeds were harvested and collected from different trees of the above-mentioned species in the region of the Agricultural University of Plovdiv, through the interval of 15 days after flowering (in the beginning of June), i. e. of 30, 45, 60, 70 and 90 days.

The seeds by 150 numbers in these periods were sown in the open air bed, immediately after collecting, in three replicates. In the variants with seeds of 30, 45, 60 and 75 days the sprouting was not established, therefore the experiments continued only with seedlings, developed from 90-day seeds. The regular watering and weeding were performed. The percentage of sprouting in the stage of first true leaf and also the percentage of survivors and a developed seedling plant to the total number of sown seeds as well as to the number of sprouted seeds in March were established.

The morphological behaviors of the seedlings in phase 3-4 leaves were determined. The length, weight, volume (by the quantity of displaced water in a measuring cylinder of 100 ml) and a number of root runners; length, diameter and weight of the stem; number, weight and area of the leaves were measured on 15 plants. The air-dry matter of the root, stem and leaves was established by the method, described from Gemisheva (1980). The dispersion analyses were performed by ANOVA.

## Results and Discussion

Table 1 presents the results for the sprouting of the studied linden species. The highest percentage of sprouting was noticed in *Tilia tomentosa* Moench. - 21.17%, while the lowest was in large-leaved lime - 11.84%.

Tab. 1. Sprouting of seeds and survival of the seedlings of linden  
*Клијање сјемена и постатак преживљених садница липе*

Species / <i>Врста</i>	Sprouting / <i>Клијање (%)</i>	Survival of all sown seeds / <i>Преживљавање свих засејаних семена (%)</i>	Survival of sprouted seeds / <i>Преживљавање исклијалог семена (%)</i>
<i>Tilia cordata</i> Mill.	18.71	17.64	98.97
<i>Tilia platyphyllos</i> Scop.	11.84	9.91	83.69
<i>Tilia tomentosa</i> Moench.	21.17	21.08	99.59
GD p=1.0%	4.37	6.6	1.89
GD p=0.1%	6.33	9.56	2.74
GD p=0.01%	9.5	14.35	4.11

The survival of the seedlings, to the percentage of sprouted seeds, was relatively high. In 18.71% sprouted seeds of *Tilia cordata* Mill., the developed seedlings were 98.97%. It could be pointed out that for other species *Tilia tomentosa* Moench. this percentage was even higher and reached 99.59%, or there is almost one hundred percent of survival from sprouted seeds. The third linden species takes an intermediate position with 83.69%. However, the survival to all sown seeds was low. It changed in a range from 9.91% for *Tilia platyphyllos* Scop. to 21.08% for *Tilia tomentosa* Moench. The statistical significance of the differences between the individual variants is established.

The linden seeds germinate and sprout relatively slowly. They are characterized by the weak rate (temperature) of development. This, according to Bradley and Blazich (2005) could be due to the firmness of the pericarp, especially in small-leaved lime. Main reason for that is the impermeability of the seed coat and the current status of the embryo, which determines the considerable dormancy of these seeds. The similar opinion in this scope, as mentioned above, was also reported by Werker (2013). Furthermore, this research emphasized that this impermeability is also connected with the presence of cellulosic substances and difficulty in penetration of water and oxygen.

The morphological characteristics of the root system of the seedlings are presented in Table 2. The smallest weight was recorded in small-leaved lime - 0.3 g, and the highest in silver linden - 0.5 g.

Tab. 2. Morphological characteristics of root system

*Морфолошке карактеристике кореновог система*

Species / Врста	Weight / Тежина (g)	Length / Дужина (cm)	Volume / Запремина (cm <sup>3</sup> )	Number of root runners / Бр. корјенових огранака
<i>Tilia cordata</i> Mill.	0.30	12.21	0.23	12.17
<i>Tilia platyphyllos</i> Scop.	0.35	13.10	0.18	20.41
<i>Tilia tomentosa</i> Moench.	0.50	16.35	0.73	22.17
GD p=1.0%	0.15	3.99	0.09	4.44
GD p=0.1%	0.22	4.76	0.13	6.43
GD p=0.01%	0.33	7.14	0.19	9.65

The highest length was observed in *Tilia tomentosa* Moench. - 16.35 cm. The lowest value of the root volume was measured in *Tilia platyphyllos* Scop. - 0.18 cm<sup>3</sup> and the highest (0.73 cm<sup>3</sup>) in *Tilia tomentosa* Moench. The number of root runners of *Tilia tomentosa* Moench. is almost two times higher than in *Tilia cordata* Mill. The highest values of the observed indices for root system was present in *Tilia tomentosa* Moench. Higher statistical significance about the differences in the length and volume of the root system is established.

Some responses were observed between different linden species regarding stem weight (Table 3). The similar trend, as for root weight, was recorded also for stem weight. The highest values were measured in seedlings of silver linden - 0.40 g. The plants of small-leaved lime developed the lowest stem weight. Smaller differences were observed regarding stem length. However, silver linden stems were characterized by the greatest length - 11.27 cm. Such state was observed for the stem diameter, and its values ranged from 0.24 cm (*Tilia cordata* Mill.) to 0.30 cm (*Tilia tomentosa* Moench).

Tab. 3. Morphological parameters of stem of the seedlings

*Морфолошки параметри стабла*

Species/ Врста	Weight / Тежина (g)	Length / Дужина (cm)	Diameter / Пречник (mm)
<i>Tilia cordata</i> Mill.	0.27	10.36	0.24
<i>Tilia platyphyllos</i> Scop.	0.35	10.52	0.28
<i>Tilia tomentosa</i> Moench.	0.40	11.27	0.30
GD p=1.0%	0.07	3.38	0.06
GD p=0.1%	0.10	4.89	0.09
GD p=0.01%	0.15	7.34	0.14

Table 4 presents data obtained from the analysis of the development of true leaves in seedlings of three investigated species. Small differences were reported for the number of leaves. The highest one was in large-leaved lime - 4.5 numbers, while the lowest it was in silver lime - 3.47 numbers. Significant responses of species are present in leaves weight.

The smallest weight was determined in small-leaved lime - 0.33 g. In other two species, values for this parameter were almost identical - 0.55 for small-leaved lime and 0.53 g for silver linden, respectively. The species responses increased the sign area of the leaves.

Tab. 4. Morphology of leaves

*Морфолошке карактеристике листова*

Species / <i>Врста</i>	Number of leaves / <i>Број листова</i>	Leaf weight / <i>Тежина листова (g)</i>	Leaf area / <i>Површина листова (cm<sup>2</sup>)</i>
<i>Tilia cordata</i> Mill.	3.68	0.33	353.07
<i>Tilia platyphyllos</i> Scop.	4.50	0.55	460.90
<i>Tilia tomentosa</i> Moench.	3.47	0.53	502.30
<i>GD p=1.0%</i>	0.29	0.23	11.95
<i>GD p=0.1%</i>	0.43	0.34	17.31
<i>GD p=0.01%</i>	0.64	0.51	25.96

The difference between the lowest (*Tilia cordata* Mill.) and the highest value (*Tilia tomentosa* Moench.) is 149.23 cm<sup>2</sup>. The high statistical significance of differences between the variants is calculated for the area of leaves.

Air-dried matter (Table 5) of the root system was characterized by large differences between investigated lime species. In large-leaved lime, it reached 24.09%, which is the lowest measured value, while the highest was in silver linden - 37.42%. The stems of silver linden contain most air-dry matter. This index of leaves was in range from 27.49% in silver linden to 31.38% in small-leaved lime.

Tab. 5. Air-dry matter (%)

*Ваздушно сува материја*

Species / <i>Врста</i>	Root / <i>Корјен</i>	Stem / <i>Стабло</i>	Leaves / <i>Листови</i>
<i>Tilia cordata</i> Mill.	30.29	30.16	31.38
<i>Tilia platyphyllos</i> Scop.	24.09	30.72	29.72
<i>Tilia tomentosa</i> Moench.	37.42	32.44	27.49

## Conclusion

The seed of linden sprout is relatively weak and the survival of seedlings is equally low. The root system and stem of silver linden (*Tilia tomentosa* Moench.) seedlings are characterized by the highest development.

The highest number and weight of leaves was present in the seedlings of large-leaved lime (*Tilia platyphyllos* Scop.), while leaf area was the highest in silver linden (*Tilia tomentosa* Moench.).

The species responses were observed about the air- dry weight. In the roots and in the stems it was the highest for species silver linden (*Tilia tomentosa* Moench.), but in leaves, this was established in small-leaved lime (*Tilia cordata* Mil.).

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# Вегетативне карактеристике садница липе (*Tilia* spp.)

Валентин Панчев<sup>1</sup>, Валерија Иванова<sup>1</sup>

<sup>1</sup>Пољопривредни универзитет у Пловдиву, Бугарска

## Сажетак

Главни циљ овог истраживања био је да се утврди морфолошки развој садница липе (*Tilia* sp.) Експерименти су обављени са семеном три врсте липе. Сјемена су прикупљена са биљака у региону Пловдива 30, 45, 60, 75 и 90 дана након цвјетања. Сјемена су посијана одмах након прикупљања. Током експеримента су праћени проценат клијања, те проценат развијених и преживљених садница. У фази развоја 3-4 листа, анализиране су морфолошке карактеристике корјена, стабла и листова. Саднице су се развиле само из сјемена старог 90 дана. Установљена је разлика између врста. Највише стабло је измјерено код садница врсте *Tilia tomentosa* Moench. Саднице врсте *Tilia platyphyllos* Scop. Имале су најразвијенији корјенов систем. Пропагацију код врста из рода *Tilia* најприкладније је обавити са сјеменом старим 90 дана.

*Кључне ријечи:* корјен, стабло, *Tilia* spp., пропагација, сјемена

Valentin Panchev  
E-mail address: [valentine\\_panchev@abv.bg](mailto:valentine_panchev@abv.bg)

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