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MELLIFEROUS POTENTIAL OF SILVER LINDEN TREES (*Tilia tomentosa* Moench.) GROWING IN THE FORESTS FROM SOUTH ROMANIA

Nicoleta ION[1], Răzvan COMAN[2], Viorel ION[3]

[1]Research and Development Institute for Beekeeping Bucharest, 42 Ficusului Blvd., District 1, 013975, Bucharest, Romania
[2]Beekeeping Complex Vaceslav Harnaj Bucharest, 42 Ficusului Blvd., District 1, 013975, Bucharest, Romania
[3]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, 011464, Bucharest, Romania

Corresponding author email: nicoleta.ion@icdapicultura.ro

Abstract

Apart the linden trees are important as source of wood and have medicinal and ornamental uses, they are also important from the melliferous point of view, being a good source of food for melliferous insects as well as an important honey source for beekeepers. Among the different linden species, the silver linden is appreciated to have a good melliferous potential. Taking into account these aspects, the aim of this study was to investigate the melliferous potential of the silver linden trees (Tilia tomentosa Moench.) growing in the forests from South Romania. In this respect, a study was carried out in the years 2009, 2010 and 2011 in two forests located in South Romania. The following parameters were analyzed: 1) the average sugar yield of the silver linden flowers, which is given by the quantity of nectar secreted by the flowers and the nectar concentration in sugar; 2) the number of flowers per silver linden tree and per hectare; 3) the lifespan of the silver linden flowers. Our study performed in the two forests from South Romania showed the good melliferous potential of the silver linden trees, which was in average of 318 kg.ha^{-1} of honey, respectively 0.76 kg of honey per linden tree. However, it must be taken into account the influence on this good melliferous potential of the silver linden trees determined by the climatic conditions of the year and the number of flowers the linden trees can produce in the respectively year, as well as the number of linden trees from the forest.

Key words*: nectar secretion, nectar concentration in sugar, flowers, honey, silver linden.*

INTRODUCTION

Tilia genus (linden, lime) from *Tiliaceae* family includes about thirty species widespread in cool temperate regions from Europe, Asia and America, out of which only four occur naturally in Europe, i.e. small-leaved linden (*Tilia cordata* Mill.), large-leaved linden (*Tilia platyphyllos* Scop.), silver linden (*Tilia tomentosa* Moench.), and Caucasian linden (*Tilia dasystyla* Stev.) (Radoglou et al., 2009).

In Romania, linden is presented through three species, respectively *T. cordata*, *T. platyphyllos* and *T. tomentosa* (Ivanov et al., 2014), which form large natural stands, usually mixed with other hardwoods. Also, these species are frequently planted in parks in the cities and along roadsides because of their ornamental value. Their valuable features include the regular shape of their crown, the early development of leaf buds, and abundant flowering (Weryszko-Chmielewska and Sadowska, 2010). However, in Romania, the most important species from the point of view of beekeeping is *T. tomentosa*, which grows in both plains and hills (Sănduleac and Lăzărescu, 1960; Ion et al., 2008).

Linden trees are generally considered to be among the best nectariferous species (Waś et al., 2011). They are considered to be a good source of food for melliferous insects as well as an important honey source for beekeepers. The specific floral fragrance invites insects to feed with the abundant nectar that the yellowish-green blossoms produce.

The melliferous value is given by the long blooming period (about 12 days, even 16 days according to species) as well as to the good nectar secretion. Moreover, the different linden species have diverse blooming dates which extend their melliferous importance for honey production. Thus, in Poland the blooming

duration of the *T. cordata* and *T. platyphyllos* species was of 16 days, while the blooming duration of the *T. tomentosa* species was of 12 days, the total duration of all species being about six weeks (Weryszko-Chmielewska and Sadowska, 2010). Also in Poland, Dąbrowska et al. (2016) reported that the blooming period of all the analysed linden taxa lasted 7 weeks, on average, from June 7 to July 24.

The melliferous value of the linden trees is given also by their flowering period at a time when alternative floral resources are scarce. Therefore, not incidentally, the linden blossom is considered to be the "Queen of Nectar".

Linden honey is among the most known and popular honeys, together with acacia, rapeseed, and multifloral honey. A honey is called "linden honey" when it contains at least 30% of *Tilia* pollen (Bonod et al., 2003). Linden honey is defined by an intense specific flavour.

In Romania, it is estimated that over the years the value of the honey obtained from linden trees has been greater than the value of their timber cut during the same period.

Research indicates that honey has functional properties in human health promotion which depend largely on the floral source of the honey (Savatovića et al., 2011). Linden honey as well as acacia and multifloral honey have a high content in polyphenolic compounds and contain an important amount of C vitamin, which is necessary for human body (Purcărea and Chiş, 2011). In a study performed by Savatović et al. (2011) on antioxidant activity of three different Serbian floral honeys (acacia, linden and "Homoljski med"), it resulted that linden honey had the highest content of total phenolic and flavonoid compounds. This means that linden honey has a beneficial effect on human health.

Linden trees are valued not only for their high honey production, but also due to the medicinal proprieties of their flowers. Linden flowers (*Tiliae flos*) have been used in phytotherapy, as they have antispasmodic, sudorific, expectorant, diuretic and sedative effects (Rădulescu and Oprea, 2008). In Romania, the linden flowers are usually collected by foresters as a byproduct of the forests.

Apart the numerous usage of linden as universal and renewable raw material (wood, bark, fibre), as well as usage as medicinal, melliferous and ornamental species, the linden tree is presented as a Romanian cultural and literary symbol in various situations (Ţenche-Constantinescu et al., 2015).

The aim of this study was to investigate the melliferous potential of the silver linden trees (*Tilia tomentosa* Moench.) growing in the forests from South Romania.

MATERIALS AND METHODS

The study was carried out in years 2009, 2010 and 2011 in two forests located in South Romania, respectively one closed to Malu Spart village - Giurgiu county (44°26' North latitude and 25°40' East longitude) and one closed to Ciocăneşti village - Dâmboviţa county (44°36' North latitude and 25°52' East longitude).

In order to calculate the melliferous potential of the linden trees (also called "honey potential"), the following parameters were analysed: 1) the average sugar yield of the silver linden flowers; 2) the number of flowers per silver linden tree and per hectare; 3) the lifespan of the silver linden flowers.

Based on a sugar content of 80% for honey (CODEX STAN 12-19811), the melliferous potential was calculated as follow:

Melliferous potential (MP) = sugar/flower x no of flowers x blooming duration x 0.8^{-1} x 10^{-6}

where:

- MP is expressed in kg/ha;
- sugar/flower is expressed in mg of sugar/flower and it is calculated by the following formula:

sugar/flower = (n x c)/100

where: n = nectar secreted by a flower during 24 hours (mg/flower);
c =nectar concentration in sugar (%);

- no of flowers is calculated at hectare based on number of trees per hectare and number of flowers per tree;
- blooming duration represents the number of days that a single flower is blooming.

The average sugar yield of a single flower was calculated based on two parameters, respectively the nectar secretion (the quantity of nectar produced by a flower, which is expressed in mg) and the nectar concentration in sugar (expressed in percent). Observations

regarding these two parameters were performed in 2009 and 2010 in both studied forests.

Before nectar determinations, it was intended to localize the nectary glands. In this respect, fresh open flowers were collected, and examined in laboratory under a binocular loupe coupled with a digital camera.

The nectar secretion (mg per flower) was determined in randomly chosen, unvisited flowers by insects (isolated flowers) at different stages of development. In this respect, there were selected five silver linden trees per forest and per year, and five tertiary branches full with inflorescences were isolated in tulle isolators (in total, 25 branches per forest and per year). The selected trees and branches were among those selected by foresters for collecting the linden flowers for medicinal purposes. The isolation operation is necessary to exclude the potential visits of the insects in order to gather nectar. After 24 hours from the isolation, the respectively branches were cut from trees and the nectar was immediately sampled from 10 flowers per each isolated branch using microcapillary method (see Ion et al., 2012). The nectar determinations were performed in the first half of the day. Immediately after extractions from flowers, for each nectar sampling, there was determined the nectar concentration in sugar using a hand refractometer.

The average number of inflorescences per tree was established in both forests in 2011 during the peak of flowering of silver linden trees. This activity was coupled with the activity of foresters to collect the linden inflorescences for medicinal purpose, and which involves cutting of some tertiary branches from marked trees. For our purpose, we have selected five silver linden trees from those marked by the foresters in each forest. In choosing the trees, there was payed attention their crowns not to be under the shallow of the crowns of other trees. The objective was the analysed trees to have flowers uniformly spread in their crown.

For each analysed tree, there were counted the number of secondary branches that grow off of scaffold branches, as well as the number of tertiary branches that grow off of secondary branches.

The counting of the inflorescences was performed on five tertiary branches per each selected tree (in total, five selected tree and five tertiary branches per tree, respectively 25 tertiary branches per forest), but only on the branches resulted from the cutting operations for collecting the inflorescences for medicinal purpose (Figures 1 and 2). The assessments of the total number of inflorescences per each analysed linden tree was done starting from the average number of inflorescences on tertiary branches and the average number of tertiary branches on a secondary branch, and the average number of the secondary branches on scaffold branches.

Figure 1. The counting of silver linden inflorescences in the forest

Figure 2. The silver linden inflorescences after counting

The average number of flowers per inflorescence was determined by randomly analysing a number of 10 inflorescences per

each tertiary branch used for counting the number of inflorescences. So, the determination of the average number of flowers per inflorescence was coupled with the determination of the number of inflorescences. For each of the analysed inflorescences, the flowers were counted and registered. The average number of flowers per inflorescence multiplied by the average number of inflorescences per tree gives the average number of flowers per linden tree.

The number of flowers per hectare was calculated by multiplying the average number of flowers per linden tree by the average number of linden trees per hectare. The number of linden trees per hectare was estimated starting from the number of trees counted in each forest on an area of one thousand square metre (0.1 ha).

The lifespan of the linden flowers (expressed in days) was determined in 2009, 2010 and 2011. In this respect, there was determined how long a single flower in blooming lasts. The blooming duration of a flower was considered to be the number of days from the bud opening to the first signs of senescence on tagged flowers. The beginning of blooming was defined as the moment when the perianth was sufficiently open to permit the entry of an insect and the end of blooming when the perianth began to wilt.

In view to establish the lifespan of the silver linden flowers, the flower buds were randomly marked with tags at opening, respectively 10 flower buds per tree and 10 trees per forest in the two forests and the three years of study. The marked flowers were monitored until flower senescence. In this respect, twice a day, respectively in the morning and in the evening, the flowers were checked to see their flowering progress.

RESULTS AND DISCUSSIONS

1. The nectar secretion and the nectar concentration in sugar

The nectar glands are found on the upper surface of the sepals of the linden flowers; nectar drops accumulate in the depression of the sepals, being visible by naked eye (Figure 3).

The nectar secretion was in average of 1.8 mg/flower/24 hours and the nectar concentration in sugar was in average of 51.9% (Table 1). The nectar secretion varied from 0.2 to 4.2 mg/flower/24 hours and the nectar concentration in sugar varied from 42 to 57.5%, according to the forest location and climatic conditions of the year. These findings on nectar secretion and nectar concentration in sugar are according to those reported during the time in Romania either for *Tilia tomentosa* (Table 2) or for *Tilia* spp. (Table 3).

It has to be said that the nectar secreted by the linden flowers are directly exposed to the air, which means the nectar (in fact, the water from nectar) readily evaporates. This characteristic makes the nectar available to the insects to be strongly dependent on weather conditions during flowering, respectively on air humidity and temperature.

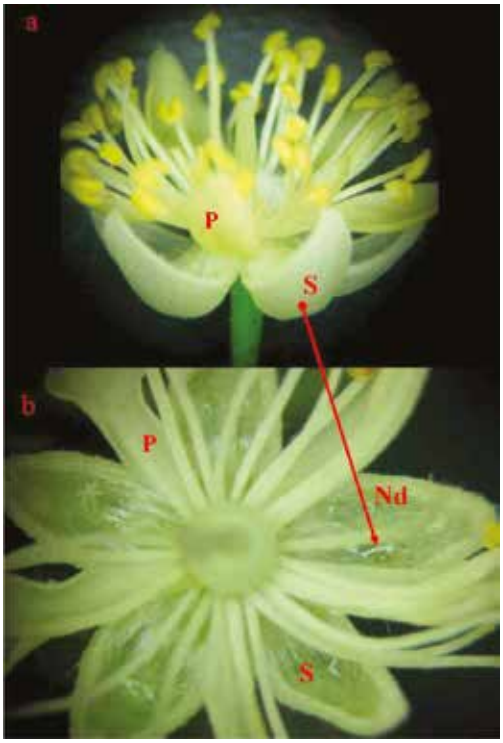

Figure 3. The flower at *Tilia* spp. with boat-shaped sepals (S), petals (P) and nectar drops in the upper side of the sepals (Nd): (a) flower seen from lateral; (b) flower seen from above

Table 1. Nectar secretion and nectar concentration in sugar of the silver linden flowers

Forest location	Year	Nectar secretion (mg nectar/flower in 24 hours)			Nectar concentration in sugar (%)		
		Min.	Average	Max.	Min.	Average	Max.
Malu Spart	2009	0.2	0.4	0.7	52.0	54.0	55.5
	2010	0.9	2.0	3.4	51.0	53.5	55.0
Ciocăneşti	2009	0.8	2.7	4.2	42.0	49.0	56.5
	2010	0.9	2.0	4.0	43.5	51.0	57.5
Average values		-	1.8	-	-	51.9	-

Table 2. Nectar secretion and nectar concentration in sugar of the silver linden flowers (*Tilia tomentosa*) - values reported in Romania

Forest location	Year	Nectar secretion (mg nectar/ flower/ 24 hours)	Nectar concentration in sugar (%)	Authors who reported the data
Giurgiu (South of Romania	1957	0.48	-	Sănduleac, 1965
	1958	0.40	48.5	
	1959	0.62	58.2	
Tulcea (South-East of Romania)	1958	0.65	61.0	
	1959	0.25	52.0	
	1960	1.20	-	Baculinschi, 1961
Average values		0.60	54.9	-

Table 3. Nectar secretion of the linden flowers (*Tilia* spp.) - values reported in Romania by Sănduleac (1965)

Forest location	Period	Nectar secretion (mg nectar/ flower/ 24 hours)
Moldova (East of Romania)	1958-1959	2.6 - 3.5
Banat (West of Romania)	1959-1960	2.4 - 3.3
Tulcea (South-East of Romania)	1958-1960	2.1 - 3.4
Giurgiu (South of Romania)	1957-1959	2.2 - 3.4

We have noted that the nectar concentration in sugar recorded the next day after a rainy day was very low, which means that a good water status of the linden trees dilutes the nectar concentration in sugar. However, a good water status of the linden trees was associated with a good nectar secretion, the nectar being indeed less concentrated in sugar.

It has to be underlined that day to day variation in nectar secretion was somewhat greater than daily variation in nectar concentration in sugar.

The daily yields of sugar of the silver linden flowers were between 0.2 and 1.3 mg per flower, with an average of 0.9 mg sugar per flower (Table 4).

Table 4. The daily yields of sugar of the silver linden flowers

Forest location	Year	Average sugar yield per flower (mg sugar/flower/24 hours)
Malu Spart	2009	0.2
	2010	1.1
Ciocăneşti	2009	1.3
	2010	1.0
Average value		0.9

2. The flower lifespan

Our results indicated that one flower lasted in bloom in average for five days, with limits of variations from 4 to 8 days. Weather conditions had significant direct effects on blooming duration of a single flower. Our observations indicated that the flowers blooming under low moisture conditions last up to 6 days. The highest longevity up to 8 days was seen for flowers blooming under wet conditions.

3. The number of flowers per linden tree

The analysed linden trees were large trees, with a basic structure formed by scaffold branches that start directly from the trunk and many lateral branches that are formed on the scaffold branches. It has to be noted that on each scaffold branches there are some secondary branches that grow off of them, and on each secondary branch there are some tertiary branches.

The number of inflorescences on each tertiary branch was in average of 71, with limits of variations between 42 to 106 inflorescences.

In average, on each inflorescence there were found a number of 9 flowers.

Based on the total number of tertiary branches estimated on linden tree, the average number of inflorescences per linden tree was found to be of 15,082, respectively 135,738 the average number of flowers per linden tree. Based on these data, and knowing the number of trees from studied forests, we calculated the number of flowers per unit of surfaces for each studied forest (Table 5).

We have noted that the most productive branches in term of inflorescences were the ones located in the upper part of the crown, especially those grown at an angle of 60 to 75 degrees from the vertical trunk. These branches

have the tendency to grow less vigorously and to produce more flowers than those growing in an upright position.

Table 5. Average number of silver linden flowers per ha

Forest location	Number of linden trees/ha	Average number of flowers per linden tree	Average number of flowers per ha
Malu Spart	400	135,738	54,295,200
Ciocănești	425		57,688,650

The linden trees that flowered abundantly and almost annually were those exposed completely to the light, respectively those linden trees that were not affected during the day by the shadow of the crowns of other trees. The linden trees under the complete shadow all over the day flowered very little or not at all. The linden trees under low shadow flowered more than the trees under intense shallow.

The parts of the same crown that was exposed to the light flowered more, producing more inflorescences than the ones under the shadow. The number of flowers in the crown was according to the intensity of shadow the crown was exposed to. Thus, there were crowns with parts under intense shadow that did not flowered at all.

4. The melliferous potential

The melliferous potential calculated for the two studied forests with silver linden trees are, in average, of 318 kg.ha^{-1} of honey, with limits of variations from 68 to 469 kg.ha^{-1} (Table 6).

The melliferous potential of an individual silver linden tree is in average of 0.76 kg of honey, with limits of variations from 0.17 to 1.1 kg of honey (Table 7).

Table 6. Melliferous potential of the silver linden trees from the studied forests - kg honey/ha

Forest location	Year	Average sugar yield per flower (mg sugar/flower/24 hours)	Average number of flowers per ha	Blooming duration of a single flower (days)	Melliferous potential of the linden trees (kg honey/ha)
Malu Spart	2009	0.2	54,295,200	5	68
	2010	1.1			373
Ciocănești	2009	1.3	57,688,650		469
	2010	1.0			360

Table 7. Melliferous potential of the silver linden trees from the studied forests - kg honey/linden tree

Forest location	Year	Average sugar yield per flower (mg sugar/flower/24 hours)	Average number of flowers per linden tree	Blooming duration of a single flower (days)	Melliferous potential of the linden trees (kg honey/linden tree)
Malu Spart	2009	0.2	135,738	5	0.17
	2010	1.1			0.93
Ciocănești	2009	1.3			1.10
	2010	1.0			0.85
Average					0.76

In our study we focused on the melliferous potential of the silver linden trees, but it has to be said that in the same forests usually several linden species grow naturally in a mix. So, speaking of the melliferous potential of the linden trees from a forest, it is quite difficult to estimate their melliferous potential since it has to be established the number of linden trees in the forest, but also the percentage of the linden species which has different melliferous potentials. Also, it has to be taken into consideration the several factors that influence the melliferous potential. Thus, besides that the melliferous potential is depending of the sugar yield produced by the flowers, respectively the nectar secretion and the nectar concentration in sugar which are influenced at their turn by climatic factors, there is of great importance

also the floral abundance. For individual trees, the number of inflorescences, respectively the number of flowers (floral abundance) is influenced by the tree-specific factors that affect the ability of each tree to access the growing factors, such as tree age and position in the canopy. In fact, it has to be paid attention that all these factors influence the melliferous potential of the linden trees and determine variations in time and space of its values.

CONCLUSIONS

Our study performed in two forests from South Romania showed the good melliferous potential of the silver linden trees, which was in average of 318 kg.ha^{-1} of honey, respectively 0.76 kg of honey per linden tree. However, it must be taken into account the influence on this good melliferous potential of the silver linden trees determined by several factors among which are counting the climatic conditions of the year and the number of flowers the linden trees can produce in the respectively year, as well as the number of linden trees from the forest.

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