Analysis of honey productivity of robinia (*Robinia pseudoacacia* L.) plantations in forest vegetation conditions of the steppe Don region

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Abstract. Robinia (*Robinia pseudoacacia* L.) is known for high honey productivity: in Ukraine, in Romania it is 600-800 kg, in Nonblack soil area it is up to 360 kg from 1 ha of a continuous forest stand. According to observations of the scientists, a bee family can collect up to 8 kg of honey under favorable weather conditions from a Robinia tree, and under adverse weather there were from 4 to 6 kg of Robinia honey in strong families at the apiary. The task of our study was to determine honey productivity of Robinia depending on locality, exposure and the slope steepness. Optimum forest vegetation conditions for maximum nectar emission by Robinia flowers were defined. A number of methods defining taxation indices, sugar content in nectar, blooming intensity and honey productivity was used to solve the assigned tasks. Carried out comparative analysis of honey productivity indices showed that local topography influences the blooming terms of plants and nectar emission. So, the most productive locality for beekeeping is locality with gulches. It provides the best honey yield under favourable meteorology and forest vegetation conditions.

1. Introduction
A great number of melliferous plants grow on the forested lands of the steppe Don region. Among them the main melliferous species providing the first productive honey yield is *Robinia pseudoacacia* L. The age composition of forest communities has changed significantly in recent years. The area of Robinia plantations has greatly increased in recent decades (from 13.0 thousand ha in 1980 to 18.2 thousand ha in 2009) [1]. It is established that on lands of forest fund *Robinia pseudoacacia* L. is one
of the most perspective species for beekeeping not only by the occupied area (20144 hectares), but also by the largest bioresource potential (8165 t) among melliferous plants [2]. The main melliferous species of forest belts is Robinia pseudoacacia L. with planting area of 83.0 % (116866 ha) in relation to the total area of shelterbelts [3].

Studying of ecological and biological characteristics, blossoming phenology, honey productivity of Robinia (locust), defining of areas of Robinia plantations in South Federal District and their dynamics was carried out by the scientists of API-laboratory of Kuban state university L Ya Moreva, M P Otrishko, A A Efimenko [4]. Robinia is a fast growing, light and warmth requiring, rather drought resistant tree species that belong to the xerophyte group. Its extensive root system allows survive droughts successfully. Robinia doesn’t tolerate overwatering − moist, waterlogged soils.

Natural climate, especially meteorology and agrotechnology, influence life sustaining activity of plants significantly, including nectar formation and emission [5].

The role of meteorological factors cannot be considered in isolation because they are interrelated and always act together. For example, the increase of solar radiation intensity enables the increase of temperature and decrease of air moisture [6].

Biometrical indices of Robinia plantations in most cases depend on the type of forest vegetation conditions and proper choice of codominant tree and shrub species [7].

Many authors [8] point out that relief is one of the main factors of forming of forest vegetation. Meteorological and soil conditions of different relief elements favour the formation of various flora, quick change of various groups and types of vegetation in space. As mentioned before, nectar emission is effected by growth conditions.

In gulches and gullies where trees are protected from dry winds and temperature regimen is more even, dynamics of nectar emission is quite different of that on plains [9].

Robinia is a good melliferous plant, especially on gully lands. The flowering period, because of its different beginning on slopes of various exposure, is lasting that is very important for beekeeping [10].

Robinia as a melliferous culture is studied in Hungary and Romania most of all. The most important of growth development of black locust according to B Keresteshy in Hungary [11] is the improvement of quality of Robinia forests by means of distribution of selection varieties of black locust that respond the demands of users.

The aim of research is to carry out the comparative analysis of honey productivity of Robinia plantations on different elements of the relief in forest vegetation conditions of the steppe Don region.

2. Methods and Materials

To define honey productivity of woodlands, the amount of melliferous trees and shrubs on sample plots was accounted. Melliferous and nonmelliferous trees were registered in a tally sheet. To determine dynamics of honey productivity of pure Robinia plantations in various forest vegetation conditions, sample plots were laid out and taxation indices were defined (table 1). Taxation indices of a plantation were defined on sample plots in various forest types. Location and relief (steepness and exposure of slope and banks) for each plot under research were taken from «The Scheme of forest vegetation conditions (FVC) and forest types of Rostov region». Forest type and FVC, the age were specified according to taxation descriptions.

| № of sample area | Forest type | Type of FVC | Bonitet (quality) class | Stand-density | Age, years | $H_{av}$, m | $D_{av}$, cm |
|------------------|-------------|-------------|------------------------|---------------|------------|-------------|-------------|
| 49               | DOS         | $D_{0}$     | III                    | 0.5           | 21         | 4.3         | 4.5         |
| 72               | DOZ         | $D_{1}$     | III                    | 0.6           | 21         | 9.4         | 8.0         |
| 73               | DOS         | $D_{1}$     | I                      | 0.7           | 21         | 13.2        | 14.0        |
| 105              | DOZL        | $D_{1}$     | IV                     | 0.5           | 21         | 7.1         | 6.3         |

| Salsk forestry |

Table 1. Characteristics of sample areas of pure Robinia plantations.
For study the peculiarities of honey productivity of Robinia plantations, sample plots were laid out in each age group. The age was determined by taxation descriptions. As a result of data processing, the average taxation indices (diameter, height, density, composition) were obtained and type (sample) trees were marked.

The blossoming period was defined by the amount of open flowers. The start of blossoming is the time when a quarter of all flowers is open, mass blossoming is the time when a half of all flowers is open, and the end is when less than 25% is open.

To study the peculiarities of honey productivity of Robinia plantations, sample plots were laid out in each age group. The age was determined by taxation descriptions. As a result of data processing, the average taxation indices (diameter, height, density, composition) were obtained and type (sample) trees were marked.

The average flower-bearing capacity was defined on 10 suited typical branches of sample trees at the end of flowerage taking into consideration all flowers of different stage of development and a number of branches on Robinia crown. The final results to account all the flowers were determined on one hectare of a plantation.

Observations of duration of blossoming were made by the marked pieces of paper fixed at each separate flower on 10 Robinia trees.

Materials of field researches were processed by means of mathematical and statistical methods, were tabulated and represented graphically using a package of the Microsoft Office application programs.
Sugar productivity \( (X_c) \) of a particular species was accounted as production of the corresponding quantity (\( m_c \)) of sugar (\( m_s \)) in nectar of one flower per day on amount of flowers on one plant (\( b \)), then on quantity of plants (\( n \)) on 1 hectare under a continuous covering and on average life expectancy of one flower in days (\( a \)) related to \( 10^6 \) (transfer coefficient of mg into kg) according to P. Nesterov’s formula [15]:

\[
X_c = \frac{m_s \cdot b \cdot a \cdot n}{10^6}, \tag{2}
\]

Honey productivity \( (M) \) of melliferous plants (lands) on 1 ha of area was defined of calculation that 100 parts of honey contain 80 parts of sugar and 20 parts of water, i.e. sugar productivity \( (X_c) \) of a particular melliferous plant on area of 1 ha was multiplied on 1.25 and accounted the amount of potential honey productivity per unit of area (kg/ha) according to the formula [15]:

\[
M = 1.25 \times X_c \tag{3}
\]

3. Results and Discussion

To observe the growth and dynamics of honey productivity on various slope exposures of a gully network, sample plots in pure Robinia plantations were laid out (table 2, figure 1).

### Table 2. Honey productivity of pure Robinia plantations in Rostov region.

| № of sample plot | Age, years | Blossoming terms | Slope exposure/ Steepness, ° | Average sugar content in one flower, mg | Average flower number per one tree, thousand pce | Number of trees per 1 ha, pce | Honey productivity, kg/ha |
|------------------|------------|------------------|-------------------------------|----------------------------------------|---------------------------------------------|-------------------------------|--------------------------|
|                  |            |                  | Southwestern part of the region |                                        |                                            |                               |                          |
| 49               | 26         | 4.05             | plain                         | 1.06±0.09                              | 53.04±2.35                                  | 713                           | 306.3  |
| 72               | 26         | 4.05             | plain                         | 1.20±1.21                              | 51.75±4.38                                  | 750                           | 232.9  |
| 73               | 21         | 4.05             | plain                         | 1.18±0.02                              | 49.05±6.12                                  | 821                           | 237.6  |
| 105              | 21         | 4.05             | Southeast/3                  | 1.09±0.05                              | 47.46±21.6                                  | 634                           | 164.0  |
| 80               | 50         | 3.05             | Northwest/1                   | 2.21±0.19                              | 90.53±7.45                                  | 323                           | 323.1  |
| 39               | 50         | 8.05             | plain                         | 2.48±0.06                              | 80.06±6.21                                  | 350                           | 347.5  |
| 81               | 8          | 4.05             | plain                         | 0.85±0.12                              | 20.67±8.12                                  | 1450                          | 127.4  |
|                  |            |                  | Eastern part of the region     |                                        |                                            |                               |                          |
| 48               | 13         | 9.05             | Northwest/9                  | 1.15±0.04                              | 26.73±3.87                                  | 1523                          | 234.1  |
| 64               | 27         | 7.05             | plain                         | 1.13±0.13                              | 58.86±8.23                                  | 707                           | 235.1  |
|                  |            |                  | Central part of the region     |                                        |                                            |                               |                          |
| 74               | 50         | 6.05             | plain                         | 1.86±0.55                              | 90.56±9.00                                  | 350                           | 294.8  |
|                  |            |                  | Northern part of the region    |                                        |                                            |                               |                          |
| 79               | 8          | 15.05            | plain                         | 0.97±0.26                              | 21.73±4.53                                  | 1450                          | 152.8  |
| 25               | 13         | 15.05            | plain                         | 1.09±0.45                              | 25.03±9.23                                  | 1348                          | 183.9  |
| 56               | 27         | 15.05            | plain                         | 1.68±0.06                              | 50.16±11.6                                  | 709                           | 298.7  |
| 78               | 47         | 13.05            | Southwest/8                  | 3.0±0.24                               | 85.02±4.52                                  | 454                           | 584.8  |
| 88               | 39         | 14.05            | South/8                      | 2.56±0.13                              | 68.28±8.12                                  | 386                           | 337.0  |
| 108              | 39         | 16.05            | South/8                      | 2.56±0.34                              | 67.82±10.1                                  | 402                           | 349.0  |
| 55               | 13         | 14.05            | Southeast/6                  | 0.68±0.05                              | 25.05±3.87                                  | 1470                          | 125.2  |
|                  |            |                  | Southwestern part of the region |                                        |                                            |                               |                          |
| 101              | 38         | 5.05             | Southwest/7                  | 2.18±0.46                              | 75.63±6.21                                  | 425                           | 350.4  |
| 89               | 38         | 6.05             | plain                         | 2.13±0.17                              | 60.64±4.76                                  | 352                           | 227.3  |
| 71               | 38         | 9.05             | Northeast/13                  | 2.24±0.35                              | 65.03±3.88                                  | 409                           | 297.9  |
| 87               | 12         | 5.05             | Southwest/8                  | 0.97±0.21                              | 40.24±11.6                                  | 1207                          | 235.6  |
| 63               | 21         | 5.05             | South/5                      | 2.56±0.43                              | 46.09±0.98                                  | 652                           | 384.7  |
As it was noted earlier, relationships of ravine forests are regulated by environmental conditions, mainly by moisture and soil fertility.

Analysis of table 1 shows that the best taxation indices have plantations that grow in conditions of dry grass-broomsubor in comparison with dry sedge oak forest (at the age of 8 years). The same analogy is seen between conditions of fresh bishop’s weed-sedge oak forest and dry sedge oak forest (at the age of 38 years).

Robinia has the best growth and durability on fresh, well-drained, rather fertile soils. It never forms productive and sustainable plantations on extremely poor, dry and shallow soils, especially of coarse mechanical structure [16].

These table data show that Robinia grows very quickly on all sites. Average taxation values of a forest stand change considerably depending on the age. Robinia plantations of dry oak groves and sudubrava are characterized by a high honey productivity (table 2). Blossoming duration of one Robinia flower when calculating honey productivity was accepted as 4 days on average.

Definition of sugar content in nectar of one flower in various forest vegetation conditions, plenty of blossoming and honey productivity of pure uneven-aged Robinia plantations showed that the most productive are the plantations at the age of 50 years (345.5 kg/ha) and 13 years (234.1 kg/ha) growing in conditions of fresh sedge-grass oak forest, those of 26 years (303.6 kg/ha) in dry sedge oak forest comparing respectively with conditions of dry sedge oak forest (323.1 kg/ha), dry grass sudubrava (183.9 kg/ha) and fresh sedge-grass oak forest (232.9 kg/ha).

Thus, observing nectar emission and defining honey productivity one can state that studied indices of a melliferous plant depend on forest vegetation conditions.

Observing nectar emission on different exposures of gulch’s slopes, intensity of nectar emission depending on light as well as plenty of blossoming and honey productivity depending on growth conditions was studied.

To observe the dynamics of sugar emission by Robinia flowers two sample plots were laid out on the plain in dry conditions (D), and in a gulch in fresh forest vegetation conditions (D) in pure Robinia plantations at the age of 38 years of Shakhty forestry.

According to our observations carried out on a plain and in a gulch, a flower emits on average an equal amount of sugar in nectar independently of a tree disposition per day (table 3). Nevertheless, maximum of nectar emission depends on it. According to observations carried out by Blazhievskaya A P [9] in plantations on a plain, it is at 10 o’clock in the morning, and in a gulch, it is from 12 to 2 o’clock in the afternoon. According to our observations, maximum is at 12 (2.83 ±0.34 mg) and at 2 o’clock in the afternoon (2.97 ±0.56 mg).
Table 3. Dynamics of Robinia sugar emission depending on tree disposition.

| Tree disposition | Indices, mg of sugar in nectar of one flower | Time of sample selection, h | Average |
|------------------|---------------------------------------------|-----------------------------|---------|
|                  |                                             | 8   | 10  | 12  | 14  | 16  | 18  |
| On a plain       | Observations by Blazhievskaya AP, 1983       |     |     |     |     |     |     |
|                  |                                             | 2.62| 3.50| 2/61| 2.16| 2.98| 2.21| 2.68|
| In a gulch       |                                             | 2.57| 2.58| 2.94| 2.76| 2.93| 2.59| 2.78|
| On a plain       | Our observations (Shakhty forestry, 2012)   |     |     |     |     |     |     |
|                  |                                             | 2.18±0.02| 2.60±0.04| 2.83±0.34| 1.84±0.06| 1.63±0.06| 2.15±0.02| 2.33±0.04|
| In a gulch,      |                                             | 1.60±0.05| 2.23±0.02| 2.56±0.04| 2.97±0.56| 2.25±0.21| 1.89±0.34| 2.25±0.13|

Sunlight is one of the most critical factors in plant’s life. Not only photosynthesis occurs in the result of absorption of sunlight, but plant’s temperature is maintained, transpiration takes place, water together with mineral salts rises from roots and soil. So, sunlight, its composition and degree of insolation, influences nectar emission greatly.

According to observations done by V Fominykh [17], emission activity of melliferous plants which honey-cups are deep in corolla is 2-5 times higher on sunny days in comparison with gloomy ones. As for plants which honey-cups are open and not protected the result is quite the opposite.

Nectar is the product of photosynthesis that takes place in green parts of plants. The more intense is photosynthesis, the more intense is nectar emission. Therefore, little amount of nectar in open flowers is the result of nectar transpiration from flowers, but not negative influence of insolation on honey-cups.

Our observations showed that under equal conditions (air temperature was 20°C and humidity was 65% at 10 o’clock, 26°C and 45% at 2 p.m. respectively) sugar emission in nectar is higher in gulches because of scattered light dominance than on plains under great direct lighting. Data given in table 4 demonstrate everything said earlier.

Table 4. Dynamics of sugar content in nectar of one Robinia flower depending on light intensity.

| Plant disposition | Bright light | Scattered light |
|-------------------|-------------|----------------|
|                   | Time, h     |                |
|                   | 10 a.m.     | 2 p.m.         |
|                   | 10 a.m.     | 2 p.m.         |
| Indices of sugar in nectar of one flower, mg | 2.60±0.18 | 1.84±0.04 | - | - | 1.82±0.04 | 2.36±0.03 | 2.14±0.12 | 2.24±0.02 | - | - | 2.23±0.06 | 2.97±0.14 | 2.18±0.11 | 2.56±0.02 | - | - | 1.96±0.09 | 2.12±0.06 |

As it is seen from the table, Robinia has an average daily amount of sugar in flowers on a plain less than in gulches under bright sun light.

Thus, data of table 4 confirm completely the opinion that direct sunlight is dangerous for a plant because protoplasm and chlorophyll are destroyed under its high intensity; scattered light is assimilated more completely than bright light. According to this author’s opinion, scattered light is more beneficial in composition than direct light because it contains 50-60% of yellow-red rays that are important for plants, while direct rays do not contain more than 37% of them. Studying this problem AP-Shennikov [18] points out that «ecological importance of light differs depending on the degree of direct radiation in it». Therefore, scattered light is less intensive, but it is used better than direct one,
coefficient of its application is higher. So, Robinia that grows in a gulch, emits more nectar because of scattered sunlight and normal air temperature and moisture.

Peculiarities of relief prolong the terms of flowerage of melliferous plants, that in its turn, favours durability and volume of honey yield. Robinia starts to blossom on southern slopes earlier than on northern ones.

It is noted that slope exposure influences the plenty of blossoming. According to our observations, trees differ greatly in appearance in plantations of same gulch.

Observations of uneven-aged pure Robinia plantations on slopes of various exposure of the same gulch showed that trees located on southwestern slopes in conditions of fresh oak forest have the most sugar content in nectar of one flower and the number of flowers on one tree.

Honey productivity of pure Robinia plantations was on average 350.4 kg/ha at the age of 38 years, 235.6 kg/ha at the age of 12 years on sample plots on the southwestern slope, 235.6 kg/ha at the age of 12 years, 297.9 kg/ha at the age of 38 years on the northeastern slope, 234.1 kg/ha at the age of 13 years on the northwestern slope that is exemplified by figure 2. Flowerage intensity at the age of 50 years on the northeastern slope (80 thousand flowers on one tree) is less than on the southwestern slope (90 thousand flowers). Honey productivity is inversely proportional to flowerage intensity and is 347.5 kg/ha and 323.1 kg/ha respectively that justifies dependence on forest vegetation conditions (table 2).

Thus, in our region the most favourable conditions for nectar emission and maximum honey productivity are on southwestern slopes where optimum regimen of moistening and soil fertility are noted as well as scattered lighting under optimum air temperature and humidity.

Therefore, the more various is the relief with much amount of gulches and gullies, the more productive it is for honey yield.

**Figure 2.** Dynamics of Robinia plantations honey productivity depending on the gulch slope exposure.

### 4. Conclusions

1. Robinia plantations at the age of 50 years (345.5 kg/ha) and of 13 years (234.1 kg/ha) growing in conditions of fresh bishop’s weed-sedge oak forest are the most productive.

   Robinia has the best taxation indices as well as maximum sugar emission in nectar, plenty blossoming and high honey productivity in mentioned forest vegetation conditions.

2. Sugar in nectar is more emitted (2.18 mg) in gulches because of dominance of scattered light than on the plain under intense direct lighting (1.84 mg).
Intense nectar emission by Robinia growing in a gulch is explained by scattered sunlight and normal air temperature and moisture.

3. Southwestern slopes are the most favourable for nectar emission and maximum honey productivity is 350.4 kg/ha.

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