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INFLUENCE OF MICROCLIMATIC CONDITIONS ON NECTAR EXUDATION IN *GLECHOMA HIRSUTA* W. K.

MARINA MAČUKANOVIĆ-JOCIĆ[1] and L. DJURDJEVIĆ[2]

[1]*Faculty of Veterinary Medicine, Department of Botany*, 11000 Belgrade, Serbia and Montenegro;
[2]*Siniša Stanković Institute for Biological Research*, 11060 Belgrade, Serbia and Montenegro

Abstract - The nectar production of *Glechoma hirsuta* W. K. grown under different microclimatic habitat conditions was evaluated by determining the total daily nectar quantity per flower, diurnal dynamics of nectar secretion, the nectar secretion rate, and sugar concentration. Comparative analyses of nectar production in *Glechoma hirsuta* grown in a forest and on a test plot confirmed that this process varied as a function of microclimatic parameters (atmospheric humidity and air temperature), but did not reveal a close relationship between these parameters and sugar concentration in nectar. More intensive nectar secretion, with a decreasing tendency during the day, and higher total daily nectar volume per plant (1.603 ml/flower) were measured in the forest habitat. Diurnal variation in nectar production with two secretion peaks was found at both localities, and the secretion patterns were rather similar. Regarding the nectar secretion rate, *G. hirsuta* is a slow producer, secreting less than 0.07 ml/h.

Key words: *Glechoma*, secretion, nectar production, sugar concentration

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INTRODUCTION

Angiosperm flowers produce nectar in order to attract pollinating animals (insects, birds, small mammals) collecting this aqueous solution of sugars for its nutritional properties. Nectar production is a complex physiological process variable due to species-specific characteristics and depends to a great extent upon the environmental conditions. Due to the role of nectar in pollination, it is secreted during the anthesis phenophase and relies, among other factors, upon the stage of flower development (Š k e n d e r o v and I v a n o v, 1986). The difference in timing and duration of the anthesis phenophase and period of sequential flower formation characterizes melliferous species.

As in most Lamiaceae species (F a h n, 1990), floral nectaries of *Glechoma hirsuta* are placed around the ovarian base. The position of the floral nectaries of this species provides protection from fast evaporation and rinsing of nectar away by rain. At the same time, it represents an adaptation of the flowers to entomophilia.

Study site

The investigation area was Košutnjak, a forest in the surroundings of Belgrade that belongs to the forest-steppe region and has a moderately continental climate. Košutnjak is situated on the south-east side of Belgrade at the edge of the Pannonian depression (44° 46' S ; 20° 27' E).

Košutnjak has a mixture of different floristic elements (about 400 meadow, forest, steppe, ruderal, and segetal plant species). This is a result of irrational human activity as well as specific history and climate. Felling of trees and thinning of the forest have caused changes in microclimatic conditions and appearance of new species. Košutnjak forest vegetation today contains secondary associations ("Tilietum" and Chrysopogonetum Grylli) and fragments of the degraded previous fundamental phytocoenoses: Querceto-Carpinetum serbicum (Rudski), Quercetum confertae-cerris serbicum (Rudski), and Quercus pubescens-Fraxinus Ornus (G a j i ć, 1952).

The examined species is an element of the Querceto-

Carpinetum plant community. The study site is the most typical fragment of this phytocoenosis - which also includes *Ruscus aculeatus*, separated in the subassociation aculeatetosum (Jov.) - and is situated on the left side of the Hajdučka Česma spring.

The aim of the present work was to estimate the significance of *Glechoma hirsuta* as a melliferous plant and to explore the influence of environmental conditions, especially climatic factors, on nectar production of this species grown in dissimilar habitats.

MATERIAL AND METHODS

Study species

Glechoma hirsuta is a creeping, rooting, very hairy, often purplish-tinged perennial with opposite, stalked, nearly orbicular to kidney-shaped leaves numbering up to 50(25) x 60(25). Ascending shoots usually bear pairs of flowers in the axils of life-like bracts. Flowers are 20-30 cm long, and pale blue with white spots on the lower lip. The flowering period is April-June. The given species is distributed throughout East-Central and Southeast Europe. It grows in woodlands and scrubs.

Nectar production

The investigation was conducted in summer of 2003 at two localities: under conditions of the natural habitat in a mixed-species forest in the Belgrade area and on a test plot. In order to analyze the influence of microclimatic parameters, natural populations of this species in the bud stage were removed to the test plot, without destroying the root system.

Intensity of nectar secretion was determined directly by the capillary method of K u l i e v (1951). The nectar was withdrawn from flowers with glass microcapillaries having a diameter of 0.5 or 0.6 mm without destroying the nectaries. Length of the nectar column was measured with millimeter paper immediately in the field. The results were converted to ml (mm^3) and presented as the mean value of repeated measurements using the formula:

$$V \text{ (mean value)} = \frac{\Sigma (r^2\pi \times H)}{\text{flower number}} \pm SE \text{ (ml per flower)}$$

r - radius of the capillary glass tube (mm)

H - nectar height in the tube (mm)

Nectar production of this melliferous species was measured in the peak blooming period (June). Inflorescences were covered with a fine mesh or perforated plastic bags (20 x 20 cm) for 24 hours prior to nectar removal and between daily measurements (six times) to prevent visitors or wind and rain influence. Individual flowers were marked at random from different plant whorls. Only fully open flowers without signs of senescence were included. Five flowers from each plant were used for nectar collecting.

Diurnal dynamics of nectar production was determined by measuring the amount of nectar secreted at two-hour intervals from 08:00 to 18:00 h. At the time of nectar removal, microclimatic parameters were measured: atmospheric humidity and air temperature.

Total daily nectar amount per flower was obtained from periodical nectar collecting (at two-hour intervals) and presented as the sum of the single measurements.

Sugar concentration in nectar was estimated with the aid of a field refractometer.

Microclimatic measurements

At the time of nectar collecting, microclimatic measurements [(air temperature (^{0}C) and relative atmospheric humidity (%)] were carried out at both localities 10 and 100 cm above the ground (average values are shown) at two-hour intervals from 08:00 to 18:00 h.

RESULTS

Figure 1 presents the diurnal dynamics of nectar secretion in *Glechoma hirsuta* grown at two localities on the nectar collecting day in June, while Fig. 2 shows parameters of the microclimate (atmospheric humidity, air temperature).

The early summer of 2003 was characteristically warm and sunny without wind and rain. The natural habitat (forest locality) was in deep shade, since the sun was hidden by treetops during the whole day. Owing to the absence of direct sunlight, plants were exposed to lower temperatures and higher humidity compared to conditions at the second locality. At both localities, gradual temperature increase and decrease of atmospheric humid-

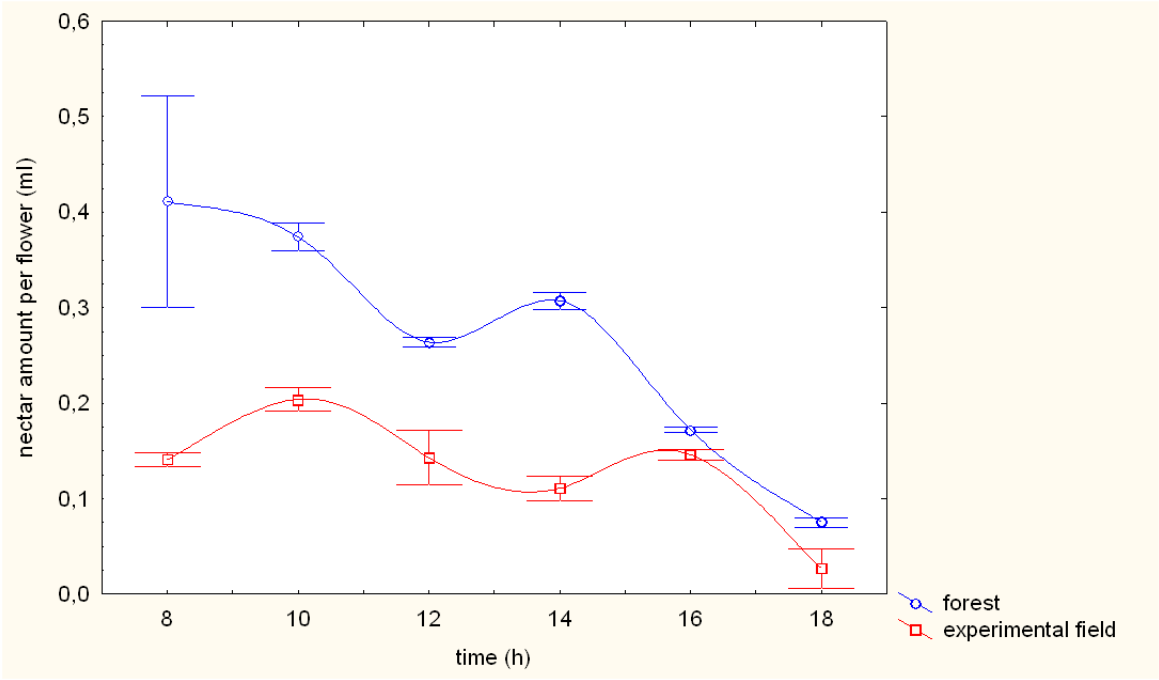


Fig. 1. Diurnal dynamics of nectar production in *Glechoma hirsuta* W. K. (June 2003) grown in natural and experimental conditions. Results are presented as mean values (±SD); n=5;(*p<0.05; **p<0.01; ***p<0.001; ns not significant).

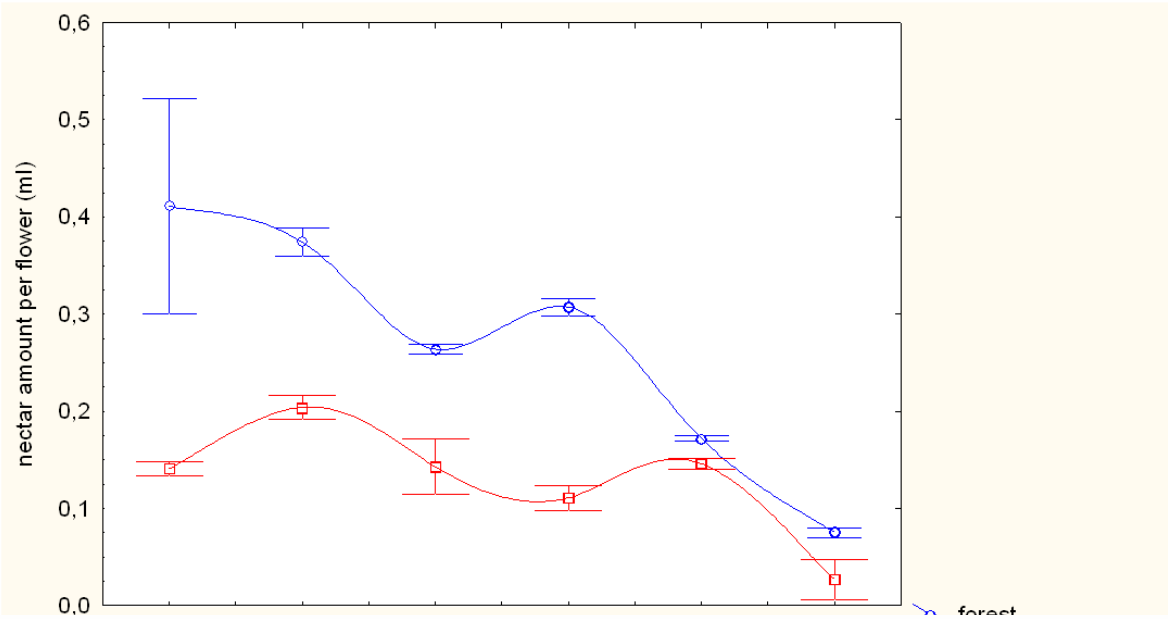


Fig. 2. Microclimatic parameters (air temperature and air humidity) in natural and experimental habitats during the nectar collecting day in June 2003.

ity from morning to afternoon were noted, but these trends were more intensive in the sunny habitat, which had higher temperature and evaporation, together with lower atmospheric humidity.

Periodical nectar collecting revealed that production tended to decrease during the day. There were two peaks at each locality: at 8:00 and 14:00 h in the forest and at 10:00 and 16:00 h on the test plot. Nectar production of *Glechoma* was higher in the natural habitat in terms of both the estimated daily maximum (0.411 ml) and the total daily volume (1.603 ml). The nectar secretion rate was nearly twice as high in the natural habitat (average of 0.07 ml/h) as on the test plot (0.03 ml/h).

Figures 3 and 4 show the correlation between temperature and nectar production of *Glechoma* in the forest and on the test plot.

A negative correlation exists between this microclimatic parameter and nectar secretion in *Glechoma*. Thus, nectar production decreases with increase of air temperature. Nectar secretion is positively correlated with air humidity in both habitats (Figs. 5 and 6), meaning that nectar production declines with decrease of atmospheric humidity during the day.

The sugar concentration determined at 8:00 h was 42% in nectar from *Glechoma* in the forest and 40% in nectar of *Glechoma* on the test plot.

DISCUSSION

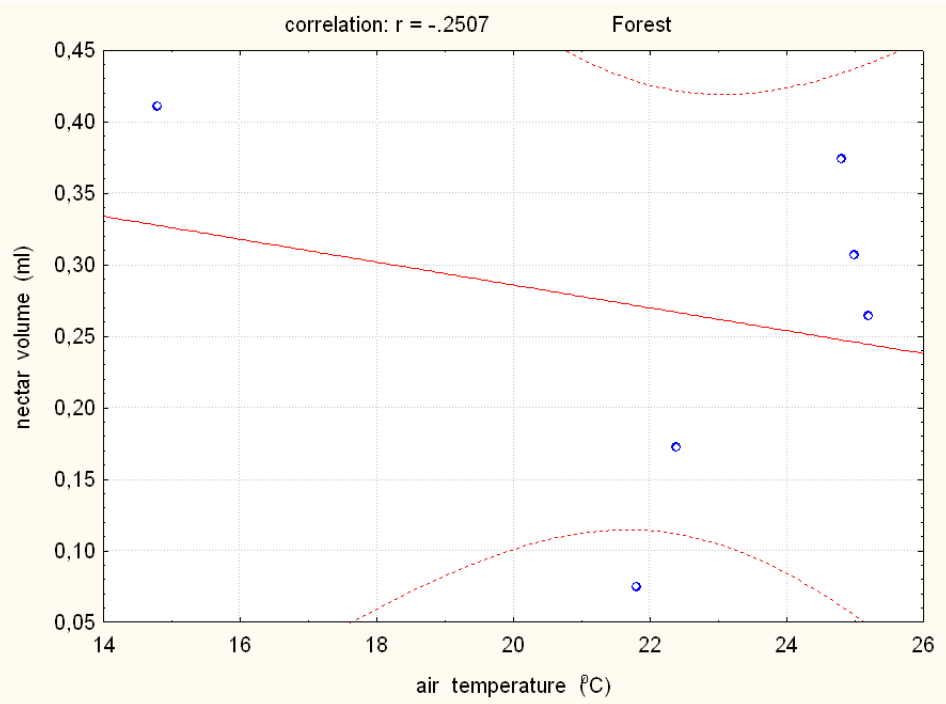
As mentioned before, nectar production is a complex physiological process constantly governed by numerous endogenous and exogenous factors. The majority of studies of nectar production were concerned with its pollinator dependence (Scobel and Scott, 2001) and microclimatic influences on this process (Jakobsen and Kristjansen, 1994; Lake and Hughes, 1999). Influence of other physiological processes in plants on nectar secretion has also been evaluated (Zauralov, 1966; Žukov, 1968), as have changes in nectar secretion during flower onthogenesis (Southwick and Southwick, 1983; Real and Rathcke, 1991). Corbet (1978) characterized changes in nectar production and composition during the day in the families Boraginaceae and Brassicaceae. Diurnal and seasonal dynamics of nectar secretion were studied by Mačukanović and Blaženčić (1988) and Mačukanović *et al*. (2004) in the family Lamiaceae and by Farkas and Orosz-Kovács (2003) in the family Rosaceae.

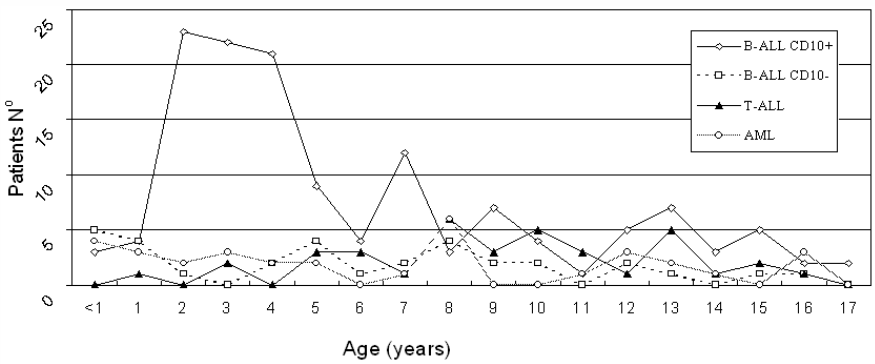
Nectar secretion in *Glechoma hirsuta* during the day showed a similar patern at both localities, the amount of nectar secreted per flower tending to decrease towards evening. Comparative analyses of diurnal dynamics of nectar secretion in *Glechoma hirsuta* grown at two environmentally different localities revealed a close relationship between nectar production and microclimatic conditions. Although the microclimatic conditions in the habitats were different in early summer, nectar secretion patterns were similar. Fluctuations in nectar secretion around midday were not significant. However, the two peaks were reached two hours later on the test plot. Thus, plants followed similar patterns of nectar production at both localities, but the volumes of nectar per day and the nectar secretion rate were higher in the natural habitat. The expected higher production in the forest was recorded due to more favorable natural conditions. The lower nectar production recorded in plants on the test plot can be attributed to extreme increase of air temperature. According to Škenderov and Ivanov (1986), optimal temperature for nectar production varies between 10 and 30°C , while Lazarov *et al*. (1971) found that optimal temperature levels were 16-25°C, with peaks between 25 and 27°C. Higher temperatures lead to sudden cessation or diminuation of nectar production. According to Vogel (1983), periodicity of nectar secretion is, above all, temperature-dependent.

The more pronounced decrease of nectar secretion during the day in the forest was probably mostly due to higher atmospheric humidity (64-82%). Atmospheric humidity on the test plot ranged between 40 and 73%, which is below the optimal levels of between 60 and 80% for most plant species (Lazarov *et al.* 1971).

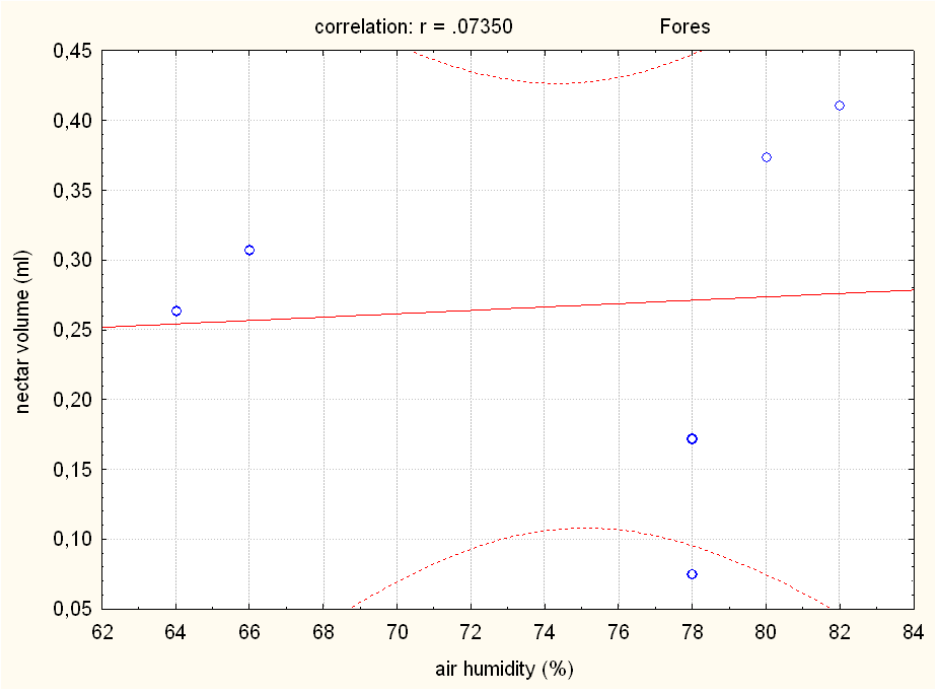
In comparison to other forest species of Lamiaceae (Mačukanović *et al*. 2004), the opposite pattern of nectar secretion with a tendency to increase during the day was found in *Lamium maculatum* and *Ajuga reptans*, while a regular secretion pattern with one secretion maximum in the middle of day was observed in *Lamiastrum galeobdolon*.

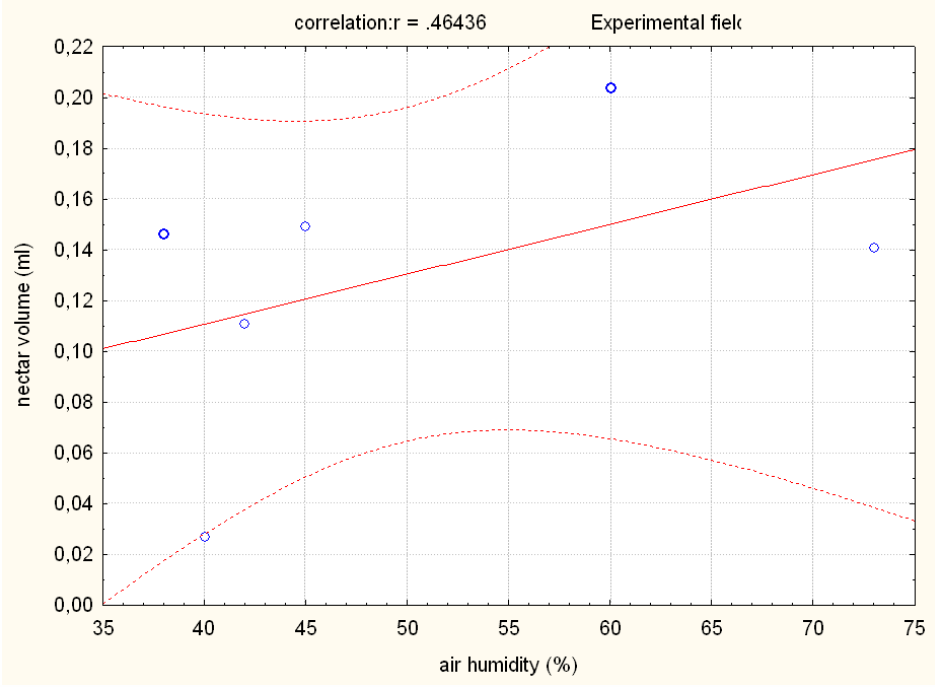
The nectar sugar concentration in *G. hirsuta* was around 40% at both localities. The values recorded here are only suggestive, since sugar concentration was estim-





Figs. 3 and 4. Correlation between air temperature and diurnal dynamics of nectar production in *Glechoma hirsuta* grown in two different habitats.





Figs. 5 and 6. Correlation between air humidity and diurnal dynamics of nectar production in *Glechoma hirsuta* grown in two different habitats.

ated just once during the day. Sugar concentration in nectar is quite variable, owing in large measure to environmental conditions such a temperature, atmospheric humidity, soil moisture, wind, elevation, etc. (C o r b e t, 1978; B a k e r, 1978). It has been established that concentration also varies as a function of the time of day, the flower lifespan, and the anthesis period. Earlier studies indicated that it also depends upon pollinator type (S c h e m s k e, 1980; S a z i m a and S a z i m a, 1980). Honeybees have a preference for nectar containing around 50% sugar (L a z a r o v *et al.* 1971). They unwillingly collect very diluted or too viscous nectar because it entails reduced productivity.

Glechoma hirsuta is characterized by a short flowering period (IV-VI) and is not very abundant out of its natural habitat, as it is virtually unable to tolerate more extreme environmental conditions. This insect-pollinated species represents a late-spring and early-summer constant source of food (nectar and pollen) for honeybees and bumblebees. It has high nectar production and low pollen production with poor dispersal, but the plants are so widespread inside and at the edge of a forest that it can be considered a good nectariferous plant for this habitat.

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УТИЦАЈ МИКРОКЛИМАТСКИХ УСЛОВА НА СЕКРЕЦИЈУ НЕКТАРА КОД *GLECHOMA HIRSUTA* W. K.

МАРИНА МАЧУКАНОВИЋ-ЈОЦИЋ[1] и Л. ЂУРЂЕВИЋ[2]

[1]*Факултет ветеринарске медицине, Одсек за ботанику, 11000 Београд*, Србија и Црна Гора;
[2]*Институт за биолошка истраживања "Синиша Станковић", 11060 Београд*, Србија и Црна Гора

У овом раду анализирана је нектарска продукција код *Glechoma hirsuta*, у различитим микроклиматским условима станишта. Истраживање је обухватило одређивање укупне дневне количине нектара по цвету, дневне динамике секреције нектара, стопе нектарске секреције и концентрације шећера у нектару.

Компаративном анализом нектарске продукције код *Glechoma hirsuta*, која је расла у шуми и у експерименталним условима огледне парцеле, потврђена је зависност овог физиолошког процеса од микроклиматских параметара (влажност и температура ваздуха). Нектарска продукција је негативно корелисана са температуром, а позитивно са влажношћу ваздука. Није установљена значајна разлика у количини шећера у нектару у цветовима са два локалитета. Укупна дневна количина нектара по цвету је виша на шумском станишту (1,603 ml/цвет). Дневна варирања у продукцији нектара са два секрециона максимума током дана су установљена на оба локалитета. Интензивније лучење нектара уз тенденцију наглог опадања током дана забележено је у природном станишту, на коме је стопа нектарске секреције релативно ниска (0,0 7 ml/h).