Antecological features and honey-bearing value of medicinal plants in the conditions of the North-West of the Russian Federation

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Abstract. The article describes the morphological features of flowers of 9 species of medicinal plants. The nature of the adaptation of their flowers to pollination by insects, the composition of insects that pollinate these plants and collect nectar and pollen have been studied. The terms of flowering of plants in years with different conditions, the duration of flowering have been determined. Pollen productivity and sugar productivity of plants have been established and the efficiency of pollination is shown, expressed by the coefficient of seed productivity.

Keywords: flowering, pollination, sugar productivity, pollen productivity, flower, inflorescence, medicinal plants

Introduction

The economically valuable properties of plants are very diverse. A rational attitude towards plants allows them to be applied simultaneously in two or more directions. The cultivation of many agricultural crops is associated with their pollination by bees; therefore, plants during flowering are used as honey plants [1]. Medicinal plants, in which the medicinal raw materials are fruits, seeds, roots, rhizomes, tubers, can also serve as a food source for pollinating insects. The efficiency of pollination of entomophilous plants depends on the intensity of visits to pollinators and leads to an increase in the yield of seeds and fruits. Bees, in turn, create bee products: honey, bee bread, pollen, royal jelly, wax, etc. Thus, the condition of pollinators and their food availability, plant productivity and the production of beekeeping products are closely interrelated.

Purpose of the study – to study the antecology and melliferous value of some types of medicinal plants in the conditions of the North-West region of Russia.

Materials, methods and objects of research

The observations of the flowering of medicinal plants were carried out in the collection nursery of medicinal and essential oil plants of the St. Petersburg State Agrarian University (St. Petersburg-Pushkin, Northwestern region of the RF).

The objects of the study were the following types of medicinal plants: *Rhodiola rosea, Bergenia crassifolia, Symphytum officinale, S.asperum, Lithospermum erythrorhizon, Cichorium intybus, Echinacea purpurea, Inula helenium, Sylibum marianum*.

The soil of the plot is soddy-podzolic, highly cultivated. The content of humus is 3.5-3.9%. The dynamics of species flowering, determination of entomofauna, extraction of nectar and determination of sugars, calculation of pollen and seed productivity were carried out according to generally accepted methods [2, 3, 4, 5, 6].

Summer 2017 was cold and rainy, average temperatures were significantly lower than the average long-term values (table 1).

Table 1. Temperature regime of the growing season 2017-2019.

Month	Year	Decade of the month, ºC			Average for the month, ºC	The long-term average,ºC	Deviation from the long-term average, +/-
		1	2	3			
April	2017	6.3	0.8	4.9	4.0	5.9	– 1.9
	2018	5.8	8.2	7.2	7.1	5.9	+1.2
	2019	6.3	6.0	7.7	6.7	5.9	+0.8
May	2017	6.4	10.4	13.0	10.0	11.8	–1.8
	2018	11.7	16.1	14.7	14.2	11.8	+2.4
	2019	9.4	13.7	11.5	11.5	11.8	–0.3
June	2017	12.0	15.6	14.6	14.1	15.8	–1.7
	2018	14.1	17.9	16.3	16.1	15.8	+0.3
	2019	19.6	17.5	18.3	18.5	15.8	+2.7
July	2017	15.4	17.3	17.7	16.8	19.1	–2.3
	2018	15.8	22.0	20.2	19.3	19.1	+0.2
	2019	15.6	15.4	16.2	15.7	19.1	– 3.4
August	2017	18.6	19.7	15.6	17.9	17.2	+0.7
	2018	21.8	19.0	19.2	20.0	17.2	+2.8
	2019	14.4	17.1	16.5	16.0	17.2	–1.2
Septembe r	2017	13.4	14.5	11.1	13.0	12.4	+0.6
	2018	17.7	15.7	14.8	16.1	12.4	+3.7
	2019	12.7	11.5	12.5	12.2	12.4	–0.2

Precipitation in April, August and September exceeded the long-term average values, and in the remaining months were close to the multiyear average. Summer 2018 turned out to be favorable and warm, average monthly temperatures were above normal. Such weather conditions adversely affected the state of plants, they lagged behind in growth and development from the indicators of previous years.

The growing season of 2018 was very warm, the average monthly air temperatures were higher than the average long-term values. The amount of precipitation exceeded the norm only in April and September, the sum of active temperatures amounted to 2643.0ºC, effective temperatures - 2397.1ºC. Temperatures were unevenly distributed in 2019: in April and May, the

average monthly temperature was close to the norm, in June it exceeded it by 2.7°C, and in July - below the norm by 3.4°C. Sufficient moisture fell in April and September, the rest of the months were dry. the sum of active temperatures was 2191.1 ºC, and effective temperatures were 1682.9ºC.

Analysis of weather conditions during the research showed that in terms of temperature and the amount of precipitation, 2018 was the most favorable for the growth and development of plants. 2019 was less favorable, 2017 was cool and rainy.

Research results

It is known that the relationship of plants with pollinating insects is established using the primary attractants - nectar and pollen. Secondary attractants are the color and shape of flowers, smell, nectar indicators - specks, stripes, dots. Flowers of entomophilous plants have special morphological and physiological adaptations that eliminate or limit autogamy and contribute to xenogamy [1]. Such mechanisms include herkogamy - the spatial separation of the stigma of the pistil and anthers, and dichogamy - the maturation of the anthers and stigma of the pistil at different times [2].

The flowers of most of the species studied by us have a bright color: crimson, pink, yellow, blue, etc. The inconspicuous whitish corollas of *Lithospermum erythrorhizon* during the period of mass flowering stand out effectively against the background of green leaves and are noticeable to insects. *Symphytum asperum* changes its corolla color from red to blue during flowering. Observations have shown that pollinators are more attracted to blue flowers to collect nectar and pollen.

Small and medium-sized flowers of medicinal plants are usually collected in elementary and complex inflorescences of various types. Such inflorescences make them well visible to pollinating insects. So, bright inflorescences of the basket - in *Cichorium intybus*, *Echinacea purpurea*, *Inula helenium*, *Sylibum marianum*; double curls in thyrsus - in *Symphytum officinale*, *S. asperum* attract the attention of insects. An important feature of an entomophilous flower is the shape of the corolla: tubular-bell-shaped flowers are preferred by bees and bumblebees, and open ones - by hover flies. Tubular, ligulate, and pseudo-lingual corollas are found in species from the *Asteraceae* family, tubular-bell-shaped corollas are found in *Boraginaceae* and *Saxifragaceae*. The flowers of the studied species have nectar and pollen indicators in the form of specks and stripes [1]. The corollas of some medicinal plants are densely covered with short papillae, which help pollinators to stay on the flower (*Symphytum officinale, S. asperum, etc.*). Herkogamy was noted by us in most of the studied plant species [1]; they are also characterized by dichogamy in the form of protandria (earlier maturation of anthers).

A comparative analysis of the beginning of flowering of medicinal plant species by years showed that in the 1st and 2nd decades of May, *Rhodiola rosea* bloomed, bloomed for 2-3 weeks (tab. 2). *Rhodiola rosea* is a perennial succulent dioecious herb with a large horizontal rhizome. Unisexual yellow flowers are collected in corymbose inflorescences. Medicinal raw materials are rhizomes and roots [7]. The study of the flowers of *Rhodiola rosea* showed that the flowers are morphologically bisexual and functionally staminate. Androeum consists of 9-14 stamens, from 4 to 9-10 carpels are formed in the gynoecium, the ovules are underdeveloped, so there are no fruits and seeds. The double perianth is 4-5-membered. Sugar and pollen productivity is low.

Bergenia crassifolia – usually begins to bloom in the 1st half of May. It is a perennial herb with a thick rhizome. Medicinal raw materials are rhizomes and leaves [7]. The flowering stem is leafless and glabrous, the inflorescence is paniculate-corymbose. The flowers are regular, 5-6-membered, 10-16 mm long. Androecium consists of 10-12 stamens, and the gynoecium consists of 2-3 accrete carpels [1]. The color of the flowers is bright pink, so they are clearly visible to insects. Bumblebees and bees actively visit flowers. Sugar productivity and pollen productivity of this species are low. However, early flowering plants are very important to pollinators because are the very first food sources.

Early summer flowering plants include *Symphytum officinale* and *S. asperum*. *Symphytum officinale* is a perennial plant with a winged stem. Medicinal raw materials are roots, less often leaves. Used in folk medicine and homeopathy. It is included in the pharmacopoeias of some countries. *Symphytum officinale* blooms in late May - early June, mass flowering occurs in 7-15 days. The bright flowers of *Symphytum officinale* are collected in double curls that form the main and lateral thyrsus, and those form the combined inflorescences - synflorescences.

The color of the corollas is bright lilac, the flowers are 15–20 mm long, the nectaries are thickened at the base of the ovary. Each flower blooms for 2-3 days. During the growing season, in *Symphytum officinale*, reproductive shoots of two generations form, bloom and bear fruit. Depending on weather conditions, the break in flowering shoots of the first and second generation is 3-10 days. Honey productivity from 1 hectare of solid planting *Symphytum officinale* ranges from 150 to 630 kg [1].

Table 2. Features of flowering and melliferous properties of some types of medicinal plants in 2017-2019.

Species	The beginning of flowering	Flowering duration, days	Pollen productivity of 100 flowers, mg	Sugar productivity of 100 flowers, mg	Seed productivity rate,%
Rhodiola rosea L. Crassulaceae *	15.05.2017	25	9.9	23.1	-
	08.05.2018	12	11.5	25.7	-
	10.05.2019	16	10.4	24.8	-
Bergenia crassifolia (L.)	15.05.2017	12	10.7	15.2	25.7
	10.05.2018	10	13.7	18.5	29.3

Frinsch Saxifragaceae	10.05.2019	11	13.5	16.7	29.5
Symphytum officinale L. *Boraginaceae*	01.06.2017 18.07.2017 27.05.2018 15.07.2018 30.05.2019 16.07.2019	33 25 27 20 31 22	195.1 183.7 198.8 196.5 195.7 193.9	150.0 147.8 165.1 164.8 151.6 153.5	51.7 45.3 55.8 60.1 48.4 47.9
S.asperum Lepech. *Boraginaceae*	01.06.2017 27.05.2018 30.05.2019	34 30 32	168.3 176.2 174.3	160.3 172.1 165.8	29.1 37.2 32.7
Lithospermum erythrorhizon Sieb.et Zucc. *Boraginaceae*	10.07.2017 23.06.2018 28.06.2019	44 25 35	85.8 94.1 85.4	10.5 12.6 11.2	66.2 68.6 70.3
Cichorium intybus L. *Asteraceae*	15.07.2017 20.06.2018 05.07.2019	41 45 42	29.6 32.3 32.5	9.9 12.6 8.9	74.8 75.3 74.5
Echinacea purpurea (L.) Moench *Asteraceae*	20.07.2017 10.07.2018 15.07.2019	60 65 63	19.8 26.7 25.1	52.4 61.1 54.6	71.4 78.3 79.2
Inula helenium L. *Asteraceae*	20.07.2017 10.07.2018 18.07.2019	37 55 45	15.8 20.5 19.4	8.5 28.3 19.6	81.2 82.7 83.2
Sylibum marianum (L.) Gaertn. *Asteraceae*	21.07.2017 15.07.2018 15.07.2019	15 15 14	11.4 19.7 13.6	25.9 48.1 32.6	70.5 75.2 72.4

*- plants with staminate flowers were studied

Symphytum asperum is a perennial herb, roots are used as medicinal raw materials [7]. Pink-blue tubular-bell-shaped flowers are collected in double curls. The structure of the complex inflorescence is the same as in the previous species. *S. asperum* is also an excellent nectar and pollen plant. Its honey productivity varies from 150 to 1000 kg/ha [1]. The flowering of these plant species provides food for bees and bumblebees in June-July. The duration of flowering of plants of this group in different years with different weather conditions ranged from 3 to 5 weeks.

Lithospermum erythrorhizon is a perennial plant found in the Far East, China and Japan. The roots contain a natural dye, shikonin, which is used in the cosmetic industry. *Lithospermum erythrorhizon* is cultivated in Korea and Japan as a medicinal plant and is used in traditional medicine [7]. In Northwest Russia, *Lithospermum erythrorhizon* blooms in the third decade of June. Five-membered whitish flowers 5-6 mm long have bilobate scales in the throat. Scales and a protective ring at the bottom of the corolla, which covers the nectaries, restrict access to the

nectar. The pistil column is not protruding from the corolla and is located at the same level with the anthers. Flowers are pollinated by honey bees, bumblebees and ants.

A group of medicinal plants from the *Asteraceae* family is an important source of nectar and pollen for pollinators in the second half of summer: *Cichorium* intybus, *Echinacea purpurea, Inula helenium, Sylibum marianum.* The beginning of their flowering is usually observed in July, and ends in autumn. The inflorescences of the basket of various shapes, colors and sizes consist of many flowers. The nectars are located in a receptacle around the ovary. The considered *Asteraceae* species are actively visited by bees, bumblebees and other pollinators, which ensures a high coefficient of seed productivity.

Cichorium intybus is a perennial herb, herb is a medicinal raw material. *Cichorium* roots are used in traditional medicine and food industry [7]. Even 20 years ago, this plant was quite rare in the Northwest, now it is found very often in yards and along roads. In our experience, *Cichorium* started blooming in June-July and bloomed for a long time. The bees actively collected nectar and pollen.

Echinacea purpurea is a perennial herb native to North America. Herbs, rhizomes and plant roots are used as medicinal raw materials [7]. Baskets of *Echinacea purpurea* form 150-200 tubular flowers. The marginal flowers are false-lingual, morphologically female, with underdeveloped ovules, therefore sterile, their purple color attracts bees and bumblebees.

Inula helenium is a perennial herb that has been growing in the medicinal plant nursery for 12 years. Baskets are large, fertile tubular flowers are yellow, marginal - pseudo-ligate bright yellow, do not form fruits.

Sylibum marianum is an annual herb, mature fruits are used as medicinal raw materials. Globular baskets contain tubular crimson flowers with hard, spiny leaves of the envelope. The plant is actively visited by bees and bumblebees, contributing to pollination and fruit formation.

Observations of the pollinators of medicinal plants showed that the flowers were visited by: honeybees - *Apis mellifera* L., gray Caucasian bees - *Apis mellifera caucasicus* L. and bumblebees - *Bombus hortorum* L., *B.*lucorum L., *B. lapidarius* L. and *B. derhamellus* Kirby., belonging to the order *Hymenoptera*. Small open flowers are visited by hoverflies from the order *Diptera*, family *Syrphidae*. From the order of the butterfly *Lepidoptera*, visitors were: the butterfly Admiral *Vanessa atalanta* L. and the day peacock's eye *Inachis io* L.

Conclusion. In conclusion, it should be noted that the studied species of medicinal plants have morphological adaptations of flowers to pollination by insects that carry out xenogamy. The flowering of medicinal plants lasts from May to September and provides pollinators with nectar and pollen. The beginning of flowering of plants depended on the temperature conditions of the growing season. The low temperature regime of 2017 led to late

blooming of all plant species. The favorable growing season of 2018 contributed to earlier flowering of plants. *Echinacea purpurea, Cichorium intybus, Inula helenium* had the longest flowering time. The highest sugar productivity and pollen productivity were observed in the *Symphytum* species. High seed productivity is characteristic of species from the *Asteraceae* family.

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