Influence of weather conditions on the honey productivity of bee colonies in the Valdai district of the Novgorod region

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Abstract. The article discusses the natural climatic factors affecting the yield of nectar from plants and the collection of nectar by honey bees (*Apis mellifera*) in the Valdai district of the Novgorod region of the Russian Federation. The objective of the study was to determine the effect of air temperature and rainfall on the honey flow in the climatic conditions of North-West Russia. The meteorological observations in the main flow period were collected and analyzed during two years. The relationship between weather conditions and bees honey productivity is established. In the course of the work, the key role of air temperature and rainfall in the intensity of honey collection was confirmed. Optimum weather conditions have been established for nectar production and its collection by bees in the study area.

1. Introduction
The Novgorod region is located in the North-West of the Russian Federation. The territory belongs to the risky farming zone. This term itself indirectly speaks of difficult climate conditions. Beekeeping is a specific branch of agriculture, but the term mentioned above and all related definitions are quite suitable for beekeeping in a given area. Living conditions for honey bees (*Apis mellifera*) in the North-West region of the Russian Federation, in particular in the Novgorod region, cannot be called favorable. If we consider the evolutionary settlement of honey bees around the globe, we can see that it was in the northeastern districts of the region that the conditional border of their mass habitat passed, speaking about the distribution areal of the honey bee as a biological species. But the difficult climatic conditions in this area did not become an obstacle to the development of beekeeping. Moreover, it was the Novgorod Republic in the Middle Ages that was the leader in the beekeeping products trade and provided European countries with honey and beeswax [1].

Currently, beekeeping in the region is quite developed. There are professional beekeepers in the region, keeping over 200 bee families or more. Also there is a large number of amateur beekeepers. Due to the latter, the number of bee colonies is increasing in the region. The fact is that, firstly, the region is geographically located between Moscow and St. Petersburg, and secondly, there are many picturesque places in the region, especially on the Valdai Upland, which is considered one of the natural attractions of the Northwest. This provides a large seasonal influx of summer residents, who, among other things, keep bees.

Despite the small territory, the region climate cannot be assessed as standard and uniform for all districts. The southern and western districts of the region are located geographically on the territory of the Priilmenskaya lowland, and the Valdai Upland is situated to the east, where the climate begins to change gradually. There is a difference in the climate between the southwestern regions on the one hand,
and the northeastern regions on the other, which, in turn, leads to a significant variability in the honey collection conditions. The climate of the eastern regions, including Valdai, is colder by an average of 2°, the average annual temperature is 2.5°. In the east, there is more rainfall (800 mm versus 600 mm in the western regions), and respectively, a greater snow cover (almost twice bigger). This provides a long and cold spring in the Valdai region. Summer is usually cool and rainy. It is in summer that most of the precipitation falls, which greatly complicates the honey flow, and sometimes even completely reduces it. Autumn is long, damp, with a minimum number of sunny days. Winter is generally mild, but at the same time with large and sharp temperature fluctuations, periodically severe frosts are replaced by frequent thaws. As can be seen from the description, climatic conditions do not favor the successful keeping of bees and high honey flows in the study area [2–4].

Most of the Valdai district (about 72%) is occupied by various types of forests. About 15% are meadows. Meadows, cuttings and woodlands are the main places for honey plants growing. In general, the species composition of the region’s melliferous plants is diverse. In spring, the most important are different types of willows, dandelion, garden shrubs. Usually, spring honey flow in the study area is very strong, primarily due to the good yield of nectar from willow trees and shrubs of various species. But it is rarely possible to make good use of spring honey flow because of adverse weather conditions and not optimal state of bee colonies. The main collection of marketable honey is provided by summer melliferous plants, blooming from mid-June to late July. Of the greatest importance are raspberries, clover, white and pink, narrow-leaved rose-bay, white melilot, meadow cornflower, common heather, field thistle, small-leaved linden. In different apiaries, the degree of these melliferous plants significance is different. For example, linden matters only where it is planted, because in the wild, in the forest, it practically does not occur. It should be noted that agricultural melliferous plants (buckwheat, sunflower, coriander, etc.), on which the industrial beekeeping is based in the agricultural regions of the country, have no practical value in the Novgorod region and in the Valdai district in particular, due to their almost complete absence [5–7].

The marketable honey amount per bee family varies greatly over the years, due to the weather conditions again. On average, the marketable honey yield in terms of one overwintered bee family in the region is 15–20 kg. By modern standards, especially comparing with more developed agrarian regions, this yield cannot be considered good. Although in the advanced apiaries of professional beekeepers, the average honey collection is 2–3 times higher. The reason for the average low honey yield is the difficult bee wintering conditions, cold springs, which do not contribute to the development of bee families, and unstable, cool and rainy weather during the summer honey flow [2, 8].

A single summer honey collection cannot be considered in a vacuum, separately from other factors, such as the results of bee colonies wintering, the spring development rate, weather conditions in early spring, breed of bees, age of queens, technology for keeping bees, etc. However, in the apiaries, where favorable conditions are created for the life and development of bee families, all the necessary technological aspects of keeping bees are observed, regular treatments against varroaosis are carried out, bee families are almost in the same condition for summer honey flow. A separate technological problem for the studied region is swarming. Weather conditions in the region not only complicate the honey flow, they are also very conducive to the reproduction of bees in their natural way – by swarming. When the family has developed to the appropriate state, and instead of warm, dry weather and good honey flow, inclement weather occurs, a large percentage of bee families fall into a swarm state. This creates additional difficulties to use effectively the honey flow period [7, 8].

The influence of climate and weather in general, and of individual factors (temperature, precipitation, wind, etc.) is studied in many works of scientists and beekeepers-practitioners from different countries. Moreover, research results are often contradictory. It can be clearly stated that the activity in nectar collection by bees, first of all, depends on the intensity of nectar production of honey plants. Bees themselves are able to work actively at positive temperatures above 12 °C, if in nature there is an abundant source of nectar. Poor nectar production or its complete absence is observed in plants in cool weather, especially in case of regular rains. The optimal conditions for nectar production are warm, calm, sunny days with temperature 20–25 °C. Two main factors can be identified on which nectar
production depends — air temperature and air humidity, which depends on the amount of precipitation. They, in the first place, determine the nectar production intensity and the content of sugars in it [9–17].

Basing on the studies in this topic, computer models for predicting honey flow and monitoring the bees activity are created. But it should be noted that these models are not universal for different honey flow types and different conditions for keeping bees [18–20].

In addition to these factors, there are a large number of minor ones, which also affect the nectar productivity of plants in combination with temperature and rainfall. For example, the strength of the wind and its direction. As a rule, the northerly wind, especially strong, significantly reduces the nectar production. Cloudiness, as a rule, also reduces nectar production, compared with sunny clear days. It is also necessary to take into account the peculiarities of local geology and local climates. For example, melliferous plants that grow on sandy soil produce better nectar when there is a lot of rainfall and worse in dry weather [19–22].

Thus, nectar production and, accordingly, subsequent honey collection by bee colonies largely depends on the weather conditions during the honey season. Frequent adverse weather conditions limit the development of beekeeping in the Valdai region. The objective of our study was to find out how much they affect the honey harvesting conditions in the summer, during the main honey flow.

2. Materials and methods

The observations were carried out in an experimental apiary in the Valdai district of the Novgorod region. The apiary had 42 families. A control scale was used; a standard strong family was placed on them, which was not in a swarm state. The observations were carried out during the two summer seasons of 2018 and 2019, during the main honey flow, which in this area lasts from June 15 to July 25. As long-term observations show, it is during these 40 days that the bees gather the bulk of marketable honey. An important factor for our research is the approximately uniform supply of nectar to the hives during this period in favorable weather.

The meteorological data (air temperature and precipitation level) were taken from the resources rp5.ru, gismeteo.ru and pogoda-service.ru. We also took into account our own observations. When analyzing the temperature data, the daily air temperature was registered. The amount of precipitation was taken in mm per day.

The studied apiary is characterized by a stable mild summer honey collection, in which the gain is usually 1–3 kg, provided that the weather is good. As a rule, there are several days, during the flowering period of raspberries and the onset of fireweed blooming, when honey collection can reach 4–6 kg per day. However, this does not happen every season. In general, during the summer season, the main honey plants are raspberry (Rubus idaeus), narrow-leaved fireweed (Chamerion angustifolium), creeping and hybrid clover (Trifolium repens, Trifolium hybridum), common chickweed (Aegopodium podagraria), meadow cornflower (Centaurea jacea) white melilot (Melilotus albus), field cirsium, also known as pink sow thistle (Cirsium arvense). Periodically, honeydew may be collected, especially in hot, dry weather.

The bees of the investigated apiary belong to the Carnica and Carpathian breeds (Apis mellifera carnica, Apis mellifera carpathica) and their crosses with local bees of the first and second generation. A special feature of these bees is the ability to effectively use mild honey collection, inherent to this area.

Thus, we compared weather conditions (air temperature and rainfall) over 40 days of honey period and the control hive gain. Indirectly, we also tried to analyze secondary weather factors, such as cloudiness, direction, and strength of winds.

3. Results

Weather conditions during the main honey season during 2018 and 2019 are shown in figures 1 and 2. Also, for clarity, the line of daily gains is also shown there. The gain of the control hive is shown as a line graph below on a separate chart (figure 3). The graphs also show the average daily air temperature.
Table 1 shows the total weather statistics for the 40-day period of the main honey collection in 2018 and 2019. As we can see, weather conditions differed over the years.
Table 1. Weather statistics during the study period.

| Period        | Average daily air temperature °C | Maximum temperature °C | Minimum temperature °C | Total precipitation, mm | Number of rainfall days | Honey yield during all period, kg | Average gain during the period, kg/days |
|---------------|----------------------------------|-------------------------|-------------------------|-------------------------|-------------------------|----------------------------------|----------------------------------------|
| 16.07.–25.07.2018 | +17.6                            | +28.0                   | +8.8                    | 86                      | 24                      | 50.4                             | 1.26                                   |
| 16.07.–25.07.2019 | +15.2                            | +26.9                   | +7                      | 132                     | 27                      | 40.8                             | 1.02                                   |

During the recorded periods, the summers of 2018 and 2019 were cool and rainy. In 2019, the temperature was on average 2.4 °C lower than in 2018. However, it can be noted that such temperature conditions are quite standard and frequent in the Valdai district in particular and in the Novgorod region as a whole. In 2019, there was a large amount of precipitation – 132 mm, which is 46 mm more than in 2018. It should be noted that some days recorded in Table 1 as “rainfall” are not shown in the graphs if the daily amount of precipitation did not exceed 1 mm. We considered such days as dry. According to the temperature background and the amount of precipitation, 2019 was colder and rainier. This was reflected in the gain and in the total honey yield (table 1, figure 3.)

![Figure 3. Control hive gain during the honey season, 2018 and 2019.](image)

We divided the days of honey flow into groups according to the daily air temperature and rainfall. A correlation was made between the temperature, precipitation and honey collection, reflected in the nectar gain in the control hive. The total data for two years were registered. The results are presented in tables 2 and 3.
Table 2. Dependence of honey flow intensity on the daily air temperature.

| Average daily temperature, ºС | Number of days in the study period | Average honey gain, kg/day |
|-------------------------------|-----------------------------------|---------------------------|
| 14 and less                   | 9                                 | 0                         |
| 15-17                         | 18                                | 0.07                      |
| 18-20                         | 16                                | 0.87                      |
| 21-23                         | 18                                | 1.34                      |
| 24-26                         | 15                                | 2.80                      |
| 27 and more                   | 4                                 | 3.07                      |

Table 3. Dependence of honey flow intensity on the precipitation.

| Total daily precipitation, mm | Number of days in the study period | Average honey gain, kg/day |
|-------------------------------|-----------------------------------|---------------------------|
| 0 (no precipitation)          | 46                                | 1.41                      |
| Less than 3 mm (light rain)   | 13                                | 1.22                      |
| 4-8 mm (moderate rain)        | 11                                | 0.57                      |
| 9-14 (heavy rain)             | 6                                 | 0.16                      |
| 15-30 (very heavy rain)       | 2                                 | 0.40                      |
| More than 30 (very strong shower) | 2                               | 0                         |

Even visually from the results shown in tables 1, 2 and 3, it is noticeable that there is a direct correlation between weather conditions, nectar production by plants and its collection by bees.

4. Discussion

When comparing the weather conditions and the honey yield of 2018 and 2019, the more favorable conditions of 2018 and, accordingly, the higher nectar gains in this year immediately attract attention. The average daily gain in warmer and less rainy 2018 was 23.5% higher, 1.26 kg versus 1.02 kg. The total weight gain of the control hive during the honey flow in 2018 was 9.6 kg more. It should be noted that the relatively high total gains (50.4 kg and 40.8 kg) do not quite correctly reflect the overall honey production of apiaries under these conditions. This is the total gain, and not the total marketable honey, since part of this honey will subsequently be spent by bees on feeding brood in August, and part is left for wintering as fodder honey.

According to the results presented in table 2, the temperature influence on the nectar production and its collection by bees is clearly traced. The maximum gains were observed at an average daily temperature of more than 24 ºC. The gain was 2.8 kg at 24–26 ºC and increased at the rise of temperature to 27 ºC up to 3 kg. When the temperature dropped to 21–23 ºC, the average daily gain was more than halved, by 51.4 %, to 1.34 kg. A further decrease in the air temperature led to an even greater decrease in the gain. At a temperature less than 18 ºC the honey flow was practically absent. We emphasize once again that we are talking about the average daily temperature, and not about the average day-and-night or maximum.

Thus, in the studied climatic conditions, there is a directly proportional relationship between daily air temperatures, nectar production by plants, and collection of nectar. The warmer the weather, the better the nectar is produced, the greater is the gain of the control hive. In the works of other researchers, there is an evidence that nectar production of plants decreases or completely stops at high temperatures, 30 or more degrees Celsius. Due to the specifics of the local climate, we were not able to verify these data.

Similarly, a direct relationship, if we look at the data in Table 3, can be traced between the amount of precipitation and honey collection. Maximum daily gains were recorded in dry weather – an average of 1.41 kg per day. As a rule, light rains with an intensity of up to 3 mm per day had practically no effect on honey collection and weight gain. Nectar supply decreased slightly, by 13.5 %, to 1.22 kg. But a moderate rain (4–8 mm/day) significantly influenced the nectar collection, lowering the average gain by
more than two times, by 59.6 %, to 0.57 kg. Heavy rains influenced even more, as a rule, practically neutralizing the flying activity of bees.

If we compare our results with the works of other researchers, we can notice some distinctive points. In the Valdai district, in the summer, as a rule, there is no lack of moisture in the soil, therefore the precipitation affects the honey collection negatively, the soil and plants do not need excess water, especially on clay soils. At the same time, rains negatively affect not so much the nectar production of plants (although this is the case), but rather the honey collecting flying activity of bees, worsening summer conditions and washing away nectar from flowers. Even after a light rain, flight activity almost ceases temporarily, until the flowers dry out and a new portion of nectar is produced. At the same time, in a more continental, warmer and drier climate, rains, on the contrary, have a positive effect on the nectar production, increasing the moisture content in the soil and increasing the air humidity.

Analyzing the weather factors for collecting honey more deeply, we can notice the relationship between them. So, the precipitation, most often, lowers the air temperature. The precipitation is observed to a greater extent in cloudy weather. Dry weather is often observed on clear and slightly cloudy days, increasing nectar production by plants due to the greater intensity of sunlight. The north wind often correlates with cool weather in the area.

5. Conclusion
In the climatic conditions of the Valdai district of the Novgorod region, there is a direct correlation between the daily air temperatures, nectar production and honey collection. The warmer the weather, the greater the gain of the control hive. The largest gains during the observation period (2018, 2019) were recorded at an average daily air temperature of more than 24 ºС. A decrease in temperature leads to a corresponding decrease in collecting nectar. At a temperature less than 18 ºС the collecting stops.

The largest nectar gains were recorded in the absence of precipitation in dry weather. Small rains with an intensity of up to 3 mm per day had little effect on honey collection. With an increase in precipitation to 4-8 mm/day, the collection of nectar by bees sharply decreased, lowering the average gain by more than two times. Heavy rains were even more significant, as a rule, practically terminating the flying activity of bees.

Basing on the data obtained, it was possible to find some distinctive characteristics of the study area. In the conditions of the Valdai district, in the summertime there is no lack of moisture in the soil. The precipitation affects the collection of honey negatively. In regions with other climatic conditions, especially hot and dry, the precipitation, on the contrary, is often necessary for the nectar production. In other regions, there is often no direct correlation between a temperature rise and honey collection. In more southern regions, high temperatures can significantly reduce the nectar productivity. This is not observed in the Valdai region. In summer, arid periods with high air temperatures are rare. Moisture is always enough for plants, and an increase in the air temperature under such conditions has a positive effect on honey collection.

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