CEST 2023

18th International Conference on Environmental Science and Technology

Athens, Greece, 30 August to 2 September 2023

Preliminary results of climate effect on phenology of honeydew producing insects of fir trees and the production of fir honey in Evritania - Greece

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Abstract. In a 3-year program (2019-2021) the production of fir honey in the prefecture of Evritania, the most mountainous prefecture of Greece, was studied. The production of fir honey is influenced by the condition of the tree, the phenology of the honeydew producing insect, the beekeeper's management of bee colonies, while the main regulator is the weather conditions. The weather conditions of each year affect not only honey production, but also the well-being of bee colonies and the survival of honeydew producing insects. Our effort is to correlate the biological cycle of the insect, its honeydew secretion, and the development of beehives with climatic factors, in order to isolate the most critical of them in honey production. A specific identification of these impacts is required, so that appropriate solutions can be proposed to safeguard beekeeping activity in Evritania in relation to the environmental changes.

Keywords: honeydew producing insects on *Abies* spp., P*hysokermes* spp., fir honey, climate crisis.

1. Introduction

Beekeeping is a traditional activity in the region of Evritania, being an important part of the agricultural - livestock economy. It is estimated that 70% of the total annual honey production in Greece is honeydew honey. This means that it derives from the honeydew secretions of insects living on specially forest species. Of this production, 80% corresponds to the so-called pine-honey, which originates from the honeydew secretions of *Marchalina hellenica*, Hemiptera, Marchalinidae, and lives on pine species (*Pinus* spp.) (Gounari 2006). The remaining 20% comes from the honeydew secretions of insects living on species of the genus *Abies* spp. (fir) and species of the genus *Quercus* spp. (oak) present in Greece (Gounari 2012).

The honeydew producing insects that parasitize on fir trees in the prefecture of Evritania, and in different regions of Greece, belong to two large families, the coccidae, with two species: *Physokermes* spp and *Eulecanium sericeum*, and the aphididae, with three species: *Mindarus abietinus*, *Cinara abieticola* and *Cinara confinis* (Gounari et al. 2002).

Honeydew honey is the final "product" of an environmental system, parts of which are the tree, the honeydew producing insect, the bee colony and the beekeeper, while the main regulator of this system is climatic conditions.

In the past few years, due to climate crisis (IPCC 2007, Bank of Greece 2011), it has been observed that weather conditions are increasingly affecting fir trees' health (Papadopoulos et al. 2007, Tsopelas and Karanikola 2012) and the phenology of honeydew producing insects (Gounari 2006, Gounari et al. 2004). This influences the production of fir honey combined with other factors on which fir honey production depends.

The overall goal of this study is to provide an initial investigation of the relationship between honeydew producing insects (population density, phenology), honeybee colonies (beekeeping managements, health) and fir honey production in relation to the local climatic conditions.

2. Materials and Method

The study area is in the Evritania Prefecture (38°40'-39°17'Lat. and 21°22'-21°57'Long.). Local vegetation is mostly composed of *Abies borisii regis* and *Abies cephalonica* fir forests. The area is a transitional zone between the *Abies cephalonica* found further south and the *Abies borisii regis* found further north (Athanasiadis, 1986).

Bioecology of honeydew producing insects.
Samples of fir branches with obvious infestations of *Physokermes* spp. (Fig.1) were collected from the study area during the period 2019-2021. The fir cuttings were transported to the laboratory and observed under an

Olympus dissecting microscope with an Olympus Digital camera.

From each sample the following data were collected: (i) total number of live insects, (ii) biological stage of each insect and (iii) honeydew production. Each life stage was recorded as a percentage of the total number of insects found on 100 nobles of fir branches sampling.

Honeybee colonies

Five apiaries with 5-7 bee colonies each were settled in five areas with beekeeping interest of Evritania. The beehives were mounted on beekeeping scales with weight, internal temperature sensors. The condition of the bee colonies and the manipulations were recorded on inspection cards.

Table 1. Location of the apiaries.

Site	Geographical coordinates	Altitude	Population density *Physokermes* spp.	
Klausi	N 38°.51,370′ E 21°.45,439′	780	0,3	homogeneous fir forest
Kleidi	N 39°.49,470′ E 21°.44,026′	881	0,1	Fir forest with *Quercus coccifera* and deciduous trees, *Accer* spp. (maple tree), *Carpinus*
Prousos	N 38°.44,558′ E 21°.40,105′	673	0,3	*Juniperus* spp. subfloor
Krikelo	N 38°.45,429′ E 21°.51.133′	929	0,3	homogeneous fir forest
Agrafa	N 39°.05,871′ E 21°.56,883′	1.015	0,32	homogeneous fir forest

Table 2. Inspection card of bee colonies.

		April 2019			May 2019			August 2019		
		☿☿	Honey / Pollen	Brood	☿☿	Honey / Pollen	Brood	☿☿	Honey / Pollen	Brood
Klausi	1	7	2	5	9	1	4,5	7	1	2,5
	2	8	3	6	8	1,5	4,5	7	1,5	2,5
	3	6	3	4	7	1,5	4,5	6	1	2
	4	7	2	4	7	1	3,5	6	0,5	2
Kleidi	1	6	1	3,5	8	1,5	5	3,5	0,5	1,5
	2	5	1	3	9	2	5,5	6,5	0	0
	3	5,5	1,5	3	9	3 (pollen)	4	8	0,5	3
	4	6	1,5	3,5	8	2	4	7	0	0
Prousos	1	9	3	6,5	11	5 (pollen)	7,5	6	3	0
	2	7	2	4	10	8 (pollen)	8	6	1,5	0
	3	7	2	3,5	15	6 (pollen)	10	12	2,5	2,5
	4	9	2	4	10	5	7,5	8	1,5	0
Krikelo	1	5	1,5	2,5	9	1,5	6	10	2	5
	2	6	1,5	2,5	7	1	4,5	8	2,5	5
	3	5	1	1,5	9	2	6,5	7	2	4,5
	4	5	1	2	5	1,5	3	4	1	2,5
Agrafa	1	9	1,5	7	12	5	7	12	6	5
	2	9	1,5	6	12	5	6,5	12	5	5,5
	3	7	1,5	4	10	3	5	10	4	4,5
	4	7	1	4	9	2	4,5	9	2	3

Climatic conditions

The climatic data used were daily or monthly mean, high and low temperature and precipitation, derived from two meteorological stations of Voutiro (38°54′00′′ N, 21°48′00′′ E, altitude 700 m, NOA) and Agios Nikolaos (38°53′20′′ N, 21°52′07′′ E, altitude 1120 m, ELGO Dimitra).

Figure 1. Adult *Physokermes* spp.

3. Results – Discussion

In previous decades, the female adult of *Physokermes* spp appeared on the branches of the fir tree, usually after the 15th of May. At this stage it feeds and produces large droplets of honeydew. Beekeepers used to move their beehives on the mountains after 20th of May. The ovulation of the female, and the end of honeydew production, usually begun at the end of June. So the honeybees had at least one month period to exploit the honeydew and turn it into fir honey (Gounari et al, 2004). In recent years, however, the female adult appears 1 month earlier, during the 2nd half of April (Fig. 2). At that time, however, the weather conditions have not yet stabilized, and the beehives have not grown enough to cope with the extreme weather conditions of the mountains. As a result, beehives are in danger of being lost and fir honey production is minimized.

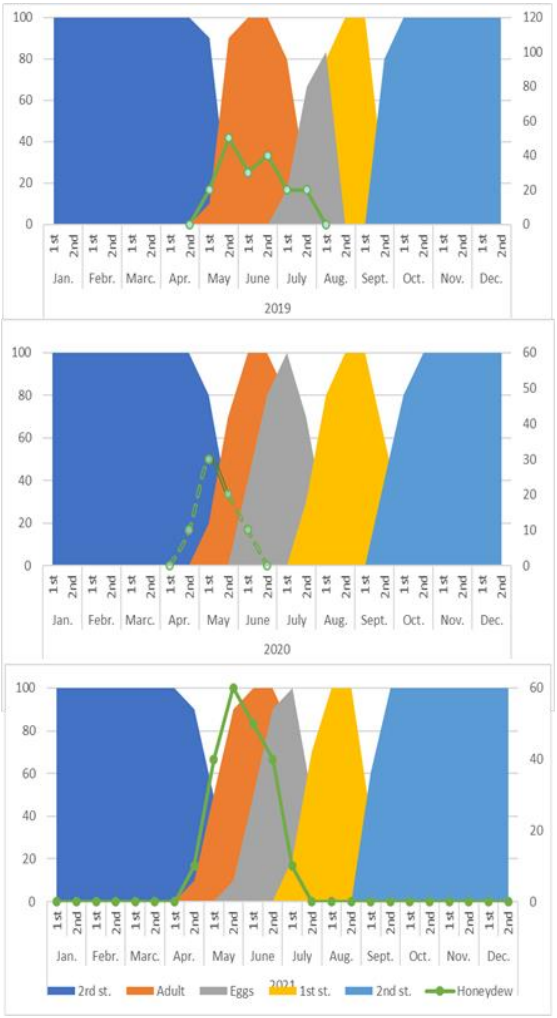

Figure2. Diagram of *Physokermes* spp biological cycle during the years 2019, 2020 and 2021.

To correlate this situation with weather conditions, we observe that as for mean, mean maximum and mean minimum temperatures there are differences in February, March and April temperatures, with the values significantly higher in 2018-2020 than in 1982-1984 (Fig. 3). A particularly important point is also the increase in temperature in February in recent years, which affects the biological cycle of *Physokermes* spp shortening its 2nd nymphal stage and accelerating the appearance of the adult, a fact that has also been observed for *Marchalina hellenica* (Coccidae), which produce honeydew on pine trees (Gounari et al., 2021).

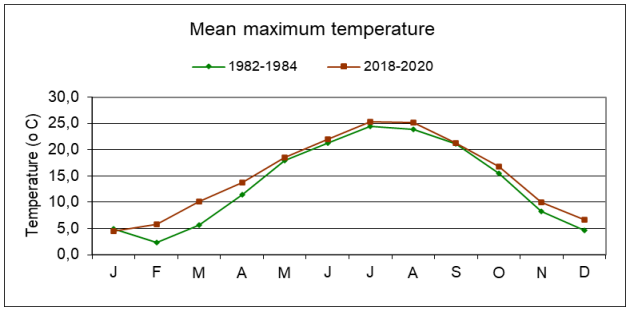

Fig. 3. Average mean maximum temperature from the periods 1982-1984 and 2018-2020**.**

A particularly important element is also the range between day and night temperature (temperature amplitude) during March and April, which particularly affects the growth of bee colonies. (Fig. 4).

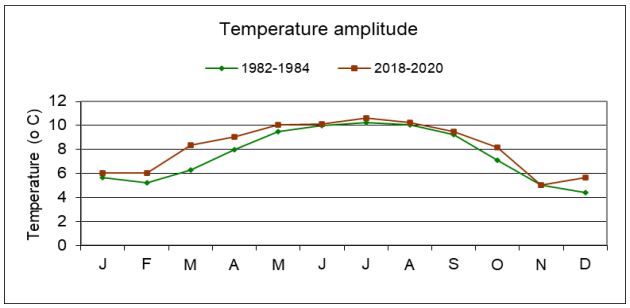

Fig. 4. Temperature amplitude of the periods 1982-1984 and 2018-2020 recorded by the meteorological station of Agios Nikolaos – Karpenisi, Evritania.

As for the precipitation large differences were observed during the three years of observations and especially during the critical months for honeydew production in April and May. The year 2021 was the worst in terms of honey production and it seems that the absence of rain during the months of April and May, played a very important role (Fig. 5).

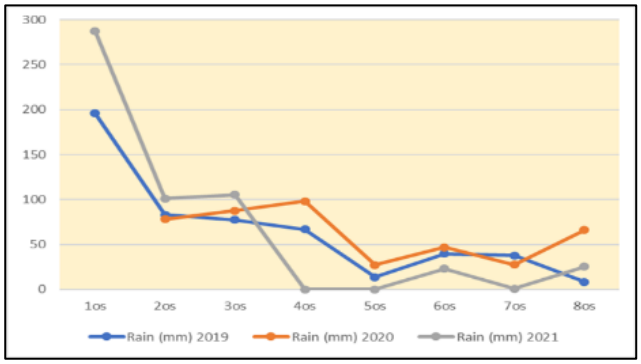

Fig**. 5**. Precipitation (January- Augoust) of the years 2019-2021.

It appears that the increase in February temperature affects the biological cycle of the fir honeydew producing insects, which leads, as shown by the phenological observations on fir branches for the period 2019-2021, to the earlier evolution of the insect's biological cycle (Fig. 2). More specifically, ovulation starts in the end of April and not in June as it used to. But weather conditions in April do not help *Physokermes* spp to feed properly and reproduce successfully, which leads to a gradual decrease in its population density. On the other hand, this April honeydew it can't fully exploited by the bees, since they are not yet strong enough, while low temperatures are still prevailing in Evritania.

In addition, the increase of thermometric amplitude in February to April, delays the growth of bee colonies, endangering their survival and making the beekeeper's manipulations particularly critical.

It is therefore apparent that weather conditions affect the biological cycle of the insect, the production of honeydew, but also the ability of beehives to collect this honeydew and produce honey. And it is obvious that not only one parameter influence in honey harvest, but many and especially their correlation.

4. Conclusions

As shown in recent years, the climate crisis has a great impact on forest ecosystems and therefore on the activities of forested populations. It is clear that completely new conditions are emerging which require further research and the search for sustainable solutions for fir forests, honeydew producing insects, honeybees and beekeepers.

Our effort is to correlate weather conditions with the biological cycle of the honeydew producing insects, as well as to find ways to manage beehives, so that they can collect and store a significant amount of honey.

A specific identification of these impacts is required, so that appropriate solutions can be proposed to safeguard beekeeping activity in Evritania in relation to the environmental changes.

Acknowledgment

The results presented in this presentation are part of the research project "*Actions for the development of beekeeping in the Prefecture of Evritania and the identification of the honey produced*", funded by the Region of Sterea Ellada with contractor the Lab. of Apiculture of Inst. Mediterranean & Forest Ecosystems, HAO DEMETER

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