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ORIGINAL ARTICLE

Current state of *Acarapis* Hirst mites (Acariformes, Tarsonemidae) distribution and honeybees infestation in Russia

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This paper summarized the distribution of the *Acarapis* Hirst mites in Russia. Honeybees are parasitized by three mites species of the *Acarapis* genus: *A. woodi* Rennie, 1921, *A. externus* Morgenthaler, 1931 and *A. dorsalis* Morgenthaler, 1934. The first species, the tracheal mite, parasitizes in the tracheae of the bees and causes acarapidosis. In Russia, the tracheal mite was first found in 1926. During the 20th century, it was detected in several regions of the European part of the country and the Urals. We concluded there had been practically no registered cases in the country before 1991. However, starting from 1991, many newly discovered tracheal mites have been revealed in all geographical regions of Russia: in the European part, in the North Caucasus, in the Urals, in Siberia, and the Far East. Besides the tracheal mite's geographical expansion, a steady increase in this disease is observed in Russia. Two other species of external mites of *Acarapis* genus, causative agents of exoacarapidosis, are known to be found in far fewer cases in Russia, which is probably connected with little research on this disease's topic and perception as not a serious one.

Keywords: Acarapidosis, tracheal mite, *Acarapis woodi, Acarapis externus, Acarapis dorsalis*, Russia

Introduction

Mites of *Acarapis* Hirst genus (Acariformes, Tarsonemidae) parasitize honey bees of *Apis mellifera* Linnaeus, 1758, and other *Apis* species (*A. cerana* Fabricius, 1793*, A. dorsata* Fabricius, 1793). Three species belong to this genus: *Acarapis woodi* Rennie, 1921, *Acarapis externus* Morgenthaler, 1931 and *Acarapis dorsalis* Morgenthaler, 1934. *A. woodi*, known as honey bee tracheal mite (HBTM), causes acarapidosis. It is an obligate internal parasite of the respiratory system that lives and reproduces mainly in the large prothoracic tracheae of the bee. However, it may also be found in the head, thoracic, and abdominal air sacs (Giordani, 1965). Unlike other species of this genus, HBTM parasitism causes serious pathologies in bees: mites cause blockage of the thoracic trachea, by this reducing oxygen diffusion to the flight muscles and the brain, and they can also be carriers of various pathogens such as bacteria and viruses (Sammataro et al., 2000). The pathogenic effect of infestation with *A. woodi* on the bees depends on the number of parasites in the trachea. It manifests itself in mechanical and physiological disorders caused by tracheas' blockage, damages of tracheal walls, and hemolymph exhaustion (Garrido-Bailón et al., 2012). If, in addition to HBTM, a bee colony is infected with mites of *Varroa destructor* Anderson and Trueman, 2000, then a synergistic effect occurs, leading to a rapid colony collapse (Downey & Winston, 2001).

HBTM are most dangerous to bees in winter (Khezri & Moharami, 2017). In winter, abundance and distribution of mites grew in numbers, probably due to the increased longevity of bees at this time of the year and increased clustering with cooler temperatures (Otis & Scott-Dupree, 1992). With that, infected families suffer from a reduced ability of temperature regulation. As a result, a colony with heavy tracheal mite infestation may die in late winter/early spring (McMullan & Brown 2009). A high HBTM load causes a decrease of bee brood area, a decrease of a bee population, weakening of winter food stores, an increase in honey consumption, a decrease in honey production, and, ultimately, the death of the colony (Eishen, 1987; Sammataro et al., 2000). *Acarapis woodi* was responsible for the significant loss of colonies throughout North America (Sammataro et al., 2000). Bailey (1985) assumed that the death of honeybees infected with tracheal mites was caused by the chronic bee paralysis virus (CBPV). However, the exact causes of the death of colonies infested with tracheal mites remain undetermined. This problem is aggravated by a lack of unique symptoms associated with acarapidosis (Shakib & Mehdi, 2016).

When *A. woodi* mites invade new territory, they rapidly increase their population and accelerate their distribution. For example, a rapid spread of tracheal mites was observed in the United States in 1985, where 17 states got infestation over 13 months (Woodward & Quinn, 2011). First reported in Japan in 2010, the invasion spread over the Japanese islands of Honshu, Shikoku, and Kyushu from 2010 to 2018, and more than 40% of all bee colonies got infested (Sakamato et al., 2017; Maeda & Sakamoto,

2020). Two other species of the genus are causative agents of exoacarapidosis. The biological characteristics of *A. dorsalis* and *A. externus* are similar. The place of location of *A.externus* is the cervical area while *A. dorsalis* is found on the thorax's dorsal surface in the area of scuto-scutellar suture, less often on wings roots, on wings themselves, in the first abdominal segment. (Grobov et al., 1987; Ibay, 1989).

External mites cause minor damage to bees, although it was reported that *A. externus* causes a deficiency of wing or loss its function (De Jong et al., 1982). When mites are located at the base of the wings, bees are reported to suffer from muscle atrophy; they lose their ability to fly and crawl around the hives (Grobov et al., 1987). Mites can be carriers of pathogens of infectious diseases of bees (Gaponova & Grobov, 1978). Seasonal fluctuations in population numbers of external mites of the *Acarapis* genus have not been assuredly determined. High infestation rates were reported at different times of the year (Ibay, 1989). Many research works stated that the infestation rates of acarapidosis have decreased in recent decades (Bailey, 1985; Orantes & García-Fernández, 1997; Bacandritsos & Saitanis, 2004; Moore et al. 2017). Therefore, no thorough research has been conducted in many countries to study this parasite distribution (Bober & Gajda, 2019). So, as far as it concerns Russia's territory, in recent years, no detailed data have been reported on the distribution and occurrence of acarapidosis in its regions, and there are only a few research works devoted to studying this disease.

At the same time, HBTM has been acknowledged as a dangerous quarantine pest requiring strict official control (Order of December 19, 2011 ..., 2016; Klochko et al., 2015). Besides, in recent years, the causative agent of acarapidosis has been reported to be found in many new countries (Fakhimzadeh et al., 1993; Neira, M. et al., 2007; Ahn et al., 2015; Maeda & Sakamoto, 2016; Stachurska-Hagen et al., 2018). Therefore, complete control of this parasite is required. This research work aims to review all available data on Acarapis mites' distribution in Russia.

Materials and methods

We have analyzed all available literature sources containing information on the distribution of acarapidosis in Russia. These are reports of large international and Russian organizations engaged in the field of veterinary diseases control World Organization for Animal Health, formerly the Office International des Epizooties, from now on - OIE (World Organisation..., 2021); Rosselkhoznadzor information releases (2021); reports and information releases received from veterinary stations and specialized institutes. Also, all available publications were reviewed. The print copies of rare and hard-to-find publications have been read in large state and small regional libraries. Occasionally, we have specially contacted the publication authors to clarify the information reported.

Results and discussion

Distribution of the tracheal mite (*Acarapis woodi*) in Russia

The disease caused by tracheal mites was first described in 1904 in England. By now, acarapidosis has widely spread throughout the world, except Australia, New Zealand, Sweden, and several countries in Africa, Asia, and South America (Lajtha, 2006; Garrido-Bailón, 2012; Sammataro et al., 2013; Chantawannakul et al., 2016). Reproduction of this parasite in apiaries located in low damp places (in floodplains of rivers, near lakes, and swamps) happens more intensively (Grobov et al., 1987).

In the USSR, acarapidosis was first discovered in the spring of 1926 by L.I. Perepelova in the Tula region (Grobov, 1978). In 1927 HBTM was detected in the Saratov region (Gaponova & Grobov, 1978). Later on, separate sites of this infestation were found in the Voronezh, Oryol, Kursk regions (Perepelova, 1940) and Udmurtia (Dizer, 1953). By 1970, acarapidosis had been discovered in Ryazan, Leningrad, Bryansk, Sverdlovsk, Moscow, Kostroma, Kirov, Tambov, Arkhangelsk regions (Perepelova & Samyshkina, 1969). By 1978 Grobov O.F. confirmed in his dissertation (Grobov, 1978) that HBTM was found in the last six of the abovementioned regions in 1964-1967. In all these regions mentioned in this work, *A. woodi* was reported to have low occurrence; however, in the nests where the mites were found, their abundance was high. (Gaponova & Grobov, 1978). In 1972, *A. woodi* was detected in the Republic of Bashkortostan (Smirnov, 1972).

In 1991 there were practically no registered cases of acarapidosis in Russia's territory (Grobov, 1991). A similar point of view was shared worldwide; thus, large-scale surveys of apiaries for detecting this disease ceased to be held (Bober & Gajda, 2019). Therefore, the tracheal mite had a very local distribution in Russia in 1991; it was found only in 16 regions of the European part of the country and in the Urals (Sverdlovsk region and the Republic of Bashkortostan). However, throughout the years, this forgotten and supposedly eliminated infestation has been registered in many new Russian regions (Melnik et al., 2005), mainly in the south of the country (Bakina, 2016). According to the data known to us, since 1991, acarapidosis has been detected in 27 regions of Russia (Table 1, Fig. 1). Of these, in 23 regions, the disease was found for the first time: in the republics of Ingushetia, Karelia, Tatarstan, and Chechnya, in the krai territories of Altai, Krasnodar, Krasnoyarsk, Perm, and Primorsky, in the oblasts of Belgorod, Volgograd, Vologda, Ivanovo, Kaliningrad, Nizhny Novgorod, Novgorod, Orenburg, Penza, Rostov, Samara, Sakhalin, Tver, and Tomsk. Thus, the disease was detected in all geographical regions. The acarapidosis had been known before in the European part and the Urals. For the first time in Western and Eastern Siberia, the Far East, and the Caucasus, the disease was found.

For example, in Western Siberia, the tracheal mite was regularly detected in the Altai Krai. The infestation of honey bee colonies with acarpidosis in the Altai Krai from the late 1980s to 2009 comprised 1.3 - 7.4% of the total number of surveyed bee colonies (Kashina, 2009). In 2007 acarpidosis was found in the Tomsk region. In other Western Siberia regions, HBTM has not been detected so far despite a thorough study conducted in some regions (in the Tyumen Oblast) (Domatskaya & Stolbov, 2009; Domatskaya et al., 2019a). In the Eastern Siberia territory, acarapidosis was found for the first time in two areas of the Krasnoyarsk Krai in 2009 and 2011 (OIE). Other regions and republics of this vast territory have not reported any registered cases of this disease. In the Urals, acarapidosis has been detected in most regions where beekeeping is developed. For example,

in the Orenburg region, HBTM was first found in 2018. According to the results of a survey conducted by the epizootic group in the Orenburg region, acarapidosis cases were never registered in the years of 2003-2013 (Ilyina & Aladina, 2014).

In the Caucasus, acarapidosis was first found in the Krasnodar Krai (Melnik et al., 2005). Since it was first detected, acarapidosis has remained one of the most common diseases in apiaries in the Krasnodar Krai (Moreva et al., 2008). According to the statistics provided by the State Veterinary Administration of the Krasnodar Territory and personal research done by Stepanenko et al. (2019), in 2015-2018, acarapidosis was found in 45 out of 4093 samples (1.1%) taken in apiaries of the Krasnodar Krai. In recent years acarapidosis has been registered in Chechnya and Ingushetia.

In the Russian Far East, the first data on acarapidosis were obtained indirectly, from the fact that infected bees were exported to the United States from Primorsky Krai in 1997 (De Guzman et al., 2002). Later, in this region, acarapidosis was registered repeatedly. In 2017 the tracheal mite was first detected in the Sakhalin region. The acarapidosis was registered in Kirov and Leningrad oblasts, in Bashkortostan and Udmurtia's republics before and after 1991. There are 12 regions of Russia where acarapidosis was detected only before 1991. These regions are Arkhangelsk, Bryansk, Voronezh (Belgorod IVL, 2016), Kostroma (Lozhkina, 2020), Kursk, Moscow, Oryol, Ryazan, Saratov, Sverdlovsk, Tambov (Belgorod IVL, 2016), and Tula oblasts.

In general, acarapidosis was registered in 39 regions of Russia, almost half of the country's total number from 1926. However, it is quite noticeable that beyond the Urals, cases of infestation of bees with a tracheal mite are rare while in the European part of the country, in the Caucasus, and especially in the Urals, i.e., in the regions where beekeeping is most strongly developed, the disease has been found in most areas. Also, there is no information on the presence or absence of acarapidosis cases in many regions (Decision of the Rosselkhoznadzor..., 2017). A possible reason is that acarapidosis is recognized as a quarantine disease, and quarantine measures must be imposed on apiaries after its detection. This fact makes some beekeepers keep secret the actual state of things concerning this disease in their apiaries (Melnik & Muravskaya, 2007).

Table 1. Distribution of acarapidosis in Russia since 1991

Region	Year	Cases	Source
	European Russia		
Belgorod oblast	2008	388	OIE
	2012	1	OIE
Volgograd oblast	2012	7	OIE
Vologda oblast	2019	1	OIE
Ivanovo oblast	2014	1	OIE
Kaliningrad oblast	2019	+	Bober & Gajda, 2019
Kirov oblast	2017	2	Results of the work ..., 2017
	2017	6	OIE
	2018	1	Rosselkhoznadzor Inf. release 22.06.2018
	2018	20	OIE
Leningrad oblast	2010	4	OIE
	2011	12	OIE
	2012	5	OIE
Nizhny Novgorod oblast	2013	5	Piyunkina, 2014
Novgorod oblast	2008	8	OIE
	2011	3	OIE
Penza oblast	2017	4	OIE
Republic of Karelia	2009	3	OIE
Republic of Tatarstan	2005	1	Vasilevsky & Domolazov, 2011
	2009	5	Vasilevsky & Domolazov, 2011
	2014	+	Rosselkhoznadzor Inf. release 08.10.2014
Udmurt Republic	2009	9	OIE
	2010	5	OIE
	2011	13	OIE
	2012	8	OIE
	2013	2	OIE
	2006-2013	18	Vorobyova, 2015
	2012-2014	+	Belyaeva, 2016
	2014	10	OIE
	2015	6	OIE
	2015	+	Kolbina et al., 2015
	2015	10	Rosselkhoznadzor Inf. release 06.06.2015-11.06.2015; Rosselkhoznadzor Inf. release 22.06.2015
	2016	67	OIE

	2017	34	OIE
	2018	8	OIE
	2019	100	OIE
Rostov oblast	2006	10	OIE
	2007	10	OIE
	2010	200	OIE
Samara oblast	2010	17	OIE
Tver oblast	2009	2	OIE
	2011	1	OIE
	2015	+	Rosselkhoznadzor Inf. release 29.07.2015
	2018	1	OIE
	2019	+	Rosselkhoznadzor Inf. release 31.05.2019
	2020	+	Rosselkhoznadzor Inf. release 25.09.2020
Caucasus			
Krasnodar krai	1998	+	Melnik et al., 2005
	1999	2	Melnik et al., 2005
	2005	16	OIE
	2006	16	OIE
	2007	13	OIE
	2005-2007	+	Fedorenko & Lysenko, 2012
	2015-2018	45	Stepanenko et al., 2019
Republic of Ingushetia	2020	+	Dolgieva et al., 2018
Chechen Republic	2017-2018	6	Moussheva & Gadaev, 2018
Ural			
Orenburg oblast	2018	+	Rosselkhoznadzor Inf. release 27.07.2018
Perm Krai	2012	24	OIE
	2013	6	OIE
	2014	2	OIE
	2015	5	OIE
	2016	3	OIE
	2017	2	OIE
	2017	8	Rosselkhoznadzor Inf. release 03.11.2017
	2018	1	OIE
	2019	1	OIE
Republic of Bashkortostan	2005	4	OIE
	2006	61	OIE
	2008	29	OIE
	2009	3	OIE
	2011	3	OIE
Western Siberia			
Altai krai	1984-2009	+	Kashina, 2009
Tomsk oblast	2007	2	OIE
Eastern Siberia			
Krasnoyarsk krai	2009	23	OIE
	2011	23	OIE
Russian Far East			
Primorsky krai	1997	+	De Guzman et al., 2002
	2015	15	OIE
	2017	+	Report of Administration r..., 2017.
Sakhalin oblast	2017	2	OIE

Therefore, much more cases of acarapidosis have been detected in Russia from the first detection in 1991. In this period, the tracheal mite did not occur here. Isolated cases of acarapidosis are registered in most regions. Only three regions have had high rates of infestation of bees with tracheal mites for many years: Perm Krai, Tver Oblast, and the Republic of Udmurtia. According to Rosselkhoznadzor data, these regions have an unfavorable acarapidosis situation as of 2020, so quarantine measures have been imposed (Decision of the Rosselkhoznadzor ..., 2017).

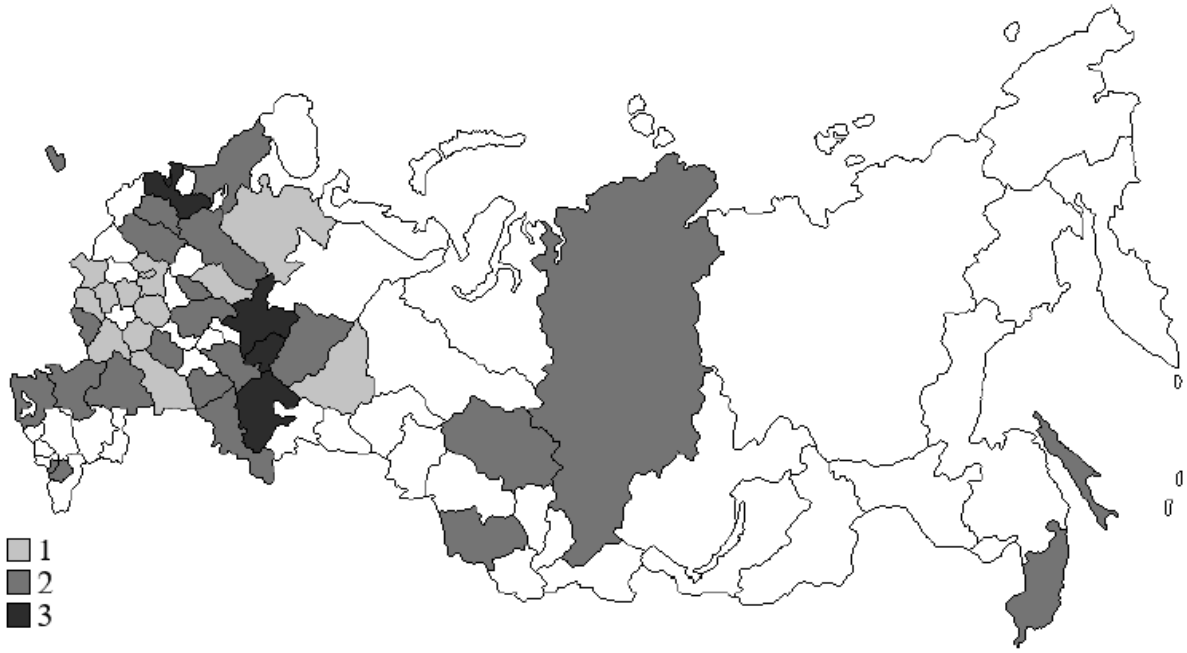

Fig 1. Distribution of acarapidosis in Russia: 1 – records before 1991; 2 – records after 1991; 3 – records before and after 1991.

In Perm Krai and Tver oblast, acarapidosis cases are registered every year, but the number of cases is insignificant, while Udmurtia acarapidosis is widespread. In this republic, the tracheal mite disease was first found in 2006, the infection rate was 0.5 ± 0.1%, and in the years of 2007 and 2008, the rate did not exceed 0.1 ± 0.1%. In 2009 the percentage of bee colonies infested with this disease increased sharply and amounted to 2.3 ± 0.1% of the surveyed bee colonies' total number. In 2010 there was a drop to 0.9 ± 0.0%. However, since then, there has been a stable increase in the infestation, and by 2013 the percentage was 2.5 ± 0.1%. By that year, acarapidosis was registered in 18 apiaries in six republic regions (Vorobyeva, 2015). In 2012 the disease was found only in northeast Udmurtia, and it had spread throughout the republic in 2014, except the southwestern part (Belyaeva, 2016). As of 2015, the infestation rate of acarapidosis in the surveyed apiaries reached 3.5 ± 0.3% (Kolbina, 2015). The total number of acarapidosis in Russia varies significantly from year to year (Fig. 2).

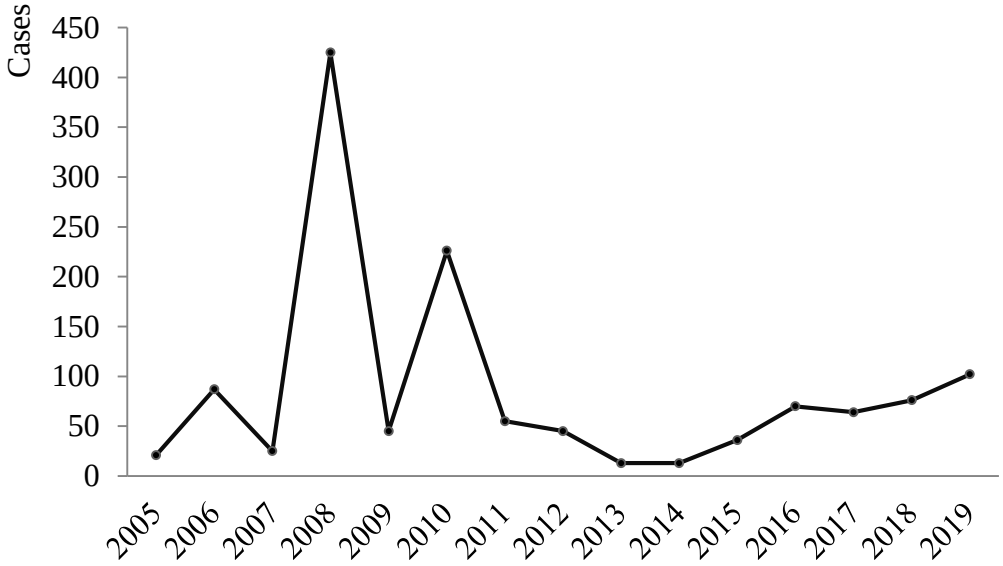

Fig. 2. The number of detected cases of acarapidosis in Russia over the past 15 years (according to Table 1).

Except for two peaks in numbers in 2008 and 2010, caused by outbreaks of the disease in the Belgorod and Rostov oblasts, where practically no cases of acarapidosis were registered in the subsequent years, the total number of cases per year does not exceed 100-150 cases. With that, it is noticeable that there has been a steady growth of registered disease cases in recent years. If different countries are compared according to the OIE data, an exciting tendency can be noticed: in recent years, in most European countries, the number of acarapidosis cases has been low. However, at the same time, there are high tracheal mite infestation rates in bees in Asia. The disease has appeared in many new countries in Asia(Maeda & Sakamoto, 2020). Recent studies have shown widespread acarapidosis in Azerbaijan and Uzbekistan (Khanbekova et al., 2013; Turaev & Safarov,

2016). The tracheal mite disease had an intensive development in Iran where 10-15 years ago, tens of thousands of acarapidosis cases were registered annually (OIE). According to Shakib & Mehdi (2016), the prevalence was not high as mites were found in 19 out of 139 surveyed apiaries; however, a very high mean parasite load was observed in some apiaries. However, in the last few years, there has been a significant decrease in the number of tracheal mite cases in Iran (OIE).

Thus, while decreasing its presence in Europe, acarapidosis spreads to new regions, mainly in Asia, and the same trend is observed with its spread in the eastern regions of Russia.

Distribution of the external mites of *Acarapis* genus in Russia

The distribution of external acarapis has a wider geographical span than that of *A. woodi's*; external mites are found in Australia, New Zealand, Sweden, and many other countries where acarapidosis has not been registered (Grobov, 1991). The worldwide distribution of *A. externus* is similar to that of *A. dorsalis*, but it is believed that *A. externus* occurs more often and in more significant numbers than *A. dorsalis* (Delfinado-Baker, 1982). However, in many regions, the second species might have larger numbers than the first-mentioned one (De Guzman et al., 2019). Many publications do not identify a species of mites, and the disease is simply mentioned as exoacarapidosis, which makes it problematic to discover the veritable distribution of these two species of mites. Because external mites are less dangerous than tracheal mites, they are paid far less attention in research, data on their numbers are scarce, and there can appear that these mites are rare. However, the study of the infestation of bee colonies in Korea using the PCR method in 2015 showed that the colonies were infested with *A. dorsalis*, the rate was 32.3% (32/99), and with *A. externus*, the rate was 9.1% (9/99)(Ahn et al., 2015).

Both species of external mites were found in Russia's territory (Poltev, 1948; Kulikov, 1966). However, *A. externus* cases were registered much more often. *A. externus* was first detected on bees in Central Siberia, a particular region was not mentioned (Grobov, 1991). Later, in 1966, isolated specimens of this species were found in several Primorsky Krai districts (Grobov, 1978, 1991). As a result of thorough research of the Tyumen region's apiaries, it was possible to obtain data on the distribution and abundance of *A. externus* in this region. This species was first detected in 2009 in apiaries of nine districts of the region (Domatskaya & Stolbov, 2009; Yamov & Domatsky, 2013; Zinatullina et al., 2017; Domatskaya et al., 2020). In 2019, exoacarapidosis was found in 11% of the region's surveyed apiaries (Zinatullina et al., 2018; Domatskaya et al., 2019b). In 2020 *Acarapis externus* was revealed in the Kostroma region. When honey bees in private apiaries in the Kostroma region were examined for exoacarapidosis, infestation rates amounted to 7.3%, mean parasite load comprised 2.2. (Lozhkina, 2020).

Acarapis dorsalis on Russia's territory was revealed in 1956 in the Kaliningrad region by a specific egg deposition character, but mites themselves were not found (Danilin, 1958). We do not have any other reliable information about detecting this particular type of external mites in Russia. Finally, during research, only the presence of external acarapis is mentioned without identifying the species. Thus, according to the Rosselkhoznadzor reports, external mites were found in 2015 in Karelia (The Federal Service ..., 2015). In 2017, the disease was detected in Sakhalin (On the detection ..., 2017).

Currently, there are few known cases of exoacarapidosis in Russia. However, these mites species are found in most geographical regions of Russia (the European part, Siberia, the Far East), and in the regions where targeted studies of these mites were conducted, their numbers were high. It can be assumed that external mites are more widespread in Russia, but this type of infestation is rarely detected due to the lack of special surveys.

Conclusion

The main reason cited for the decrease in the number of tracheal mites in Europe and Russia by 1991 was the widespread, systematic use of various acaricide treatments to combat varroatosis (Grobov, 1991). Due to the reduction observed in acarapidosis infestation, systematic monitoring of tracheal mites disease has ceased to be conducted in many countries and regions.

However, our research work results show that acarapidosis in Russia has not disappeared but, on the contrary, has spread to all geographical regions, and the number of registered cases has noticeably increased compared to 1991. Thirty years ago, it was believed that this disease had practically no occurrence in Russian territory, but at the present moment, we observe the expansion of the geographical distribution of this type of parasite and an increase in its abundance numbers in many regions.

Thus, we assumed that nowadays, acarapidosis is widespread in all territories of Russia. The number of registered cases is increasing every year; therefore, complete systematic control of the tracheal mite species is necessary to prevent further distribution.

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