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ECOLOGICAL CHARACTERISTICS OF *VARROA DESTRUCTOR* (PARASITIFORMES, VARROIDEA) AND ITS ENVIRONMENTAL CAPACITY AS A KEY FACTOR FOR DEVELOPMENT OF VARROOSIS PANZOOTIA

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Ecological Characteristics of *Varroa destructor* (Parasitiformes, Varroidae) and Its Environmental Capacity as a Key Factor for Development of Varroosis Panzootia. Akimov I. A., Korzh O. P. — By means of formalized schematic models of relationship with hosts the varroa mite uniqueness as a parasite is shown. The life cycle of this species requires the change of a host species at different stages of their development and physiological states. Thus the mite parasitizes not only a separate bee but a whole hive. The fact that the whole hive but not a single bee dies during varroosis development supports this idea. The impetus for this type of parasitism is the relative constancy of the environment in the hive supported by bees even in winter. Exactly this fact causes high pathogenicity of the varroa for the honey bee and its control complexity.

Key words: *Varroa destructor*, *Apis mellifera*, varroosis, carrying capacity, life cycle, development stage, environmental factors.

Экологические особенности клеща *Varroa destructor* (Parasitipormes, Varroidae) и ёмкости среды как основные предпосылки развития панзоотии варрооза. Акимов И. А., Корж А. П. — С помощью формализованных схематических моделей взаимоотношения клеща варроа с хозяевами показана его уникальность как паразита. Жизненный цикл данного вида предусматривает обязательную смену особей хозяина, находящихся на разных стадиях развития и в разном физиологическом состоянии. Благодаря этому клещ паразитирует не на отдельной особи пчёл, а на улье в целом. Подтверждает эту мысль и тот факт, что в результате развития варрооза гибнет не отдельная пчела, а улей в целом. Стимулом для такого типа паразитизма является относительное постоянство среды в улье, поддерживаемое пчёлами даже в зимний период. Именно этот факт обуславливает высокую патогенность варроа для медоносной пчёлы и сложность борьбы с ним.

Ключевые слова: *Varroa destructor, Apis mellifera*, варрооз, емкость среды, жизненный цикл, стадия развития, экологические факторы.

Introduction

The varroa mite is a representative of gamasid mites from family Varroidae parasitizing nests of honey bees of the genus *Apis*. This species was described from a bee *Apis indica* Fabricius (=*A. cerana* Fabricius, 1793) from Java as *Varroa jacobsoni* Oudemans, 1904 and it was known to a narrow circle of specialists till the second half of the last century when it became a parasite of the honey bee *A. mellifera*. Since that, its impetuous expansion began rapidly turning to panzootia. Today, not only main, but all beekeeping regions in the world are infected with varroosis (Akimov et al., 1993, Kuznetsov, Lelej, 2005). This dangerous parasitic disease yields great loss in bee-keeping, so that intensive study of this pathogen was started in the 1970s in China, Russia, Ukraine and other countries as the parasite colonized new territories. Recently, with the use of genetic molecular methods (Anderson, Trueman, 2000, and others) *V. jacobsoni* was shown to be a complex of species. Of them, the one occurring from Southeast Asia through China to the whole Eurasia, is *Varroa destructor*

Anderson and Trueman, 2000. It also lives of Korea, Russia and throughout Europe. The name *V. jacobsoni* remains with a species living in Indonesia and some other parts of the Southeast Asia.

The life cycle of varroa mite is studied in sufficient detail, and results of this study are shown in all reviews on biology of this mite (Akimov et al., 1988, 1993, and others). However, some features of its cycle are of great interest in terms of its adaptation to parasitic way of life, because they are key factors for natural resistance of mite, or its vulnerability to control means.

The aim of the work is the analysis of environmental capacity for *V. destructor* as a key factor for development of varroosis panzootia.

Environmental capacity is determined by the action of all environmental factors and therefore it measures well-being of the species. In turn, maximum number of the population when its growth rate is null, measures environmental capacity of any species or cenosis (Solbrig, Solbrig, 1982). Depending on the situation, the strength of the individual factors, first of all resources, changes, and the factors that determine the possibilities in realization of biotic potential by individuals are altered as well (Korzh, 2011). This provision is fully observed in parasitic species, because their environmental capacity entirely depends on the state of hosts populations.

Material and methods

The results of our comprehensive studies of varroa mite and its interaction with the bee (Akimov et al, 1983–1993), and also data of other authors who have studied this object, were used as a material of this work.

Results and discussion

Factors affecting the mite *V. destructor*, according to classical concepts, can be divided into three groups: abiotic, biotic and human-made (fig. 1). Naturally, such a division is conditional, since in the most cases it is impossible to separate components of a single factor, but different in origin: the temperature depends both on climate and its homeostatic maintenance by bees inside the hive, and human activity. Relationships of these components and their simultaneous effect on mite and its environment capacity are shown in bold arrows on cycle periphery. Naturally, the number of factors affecting the mite is

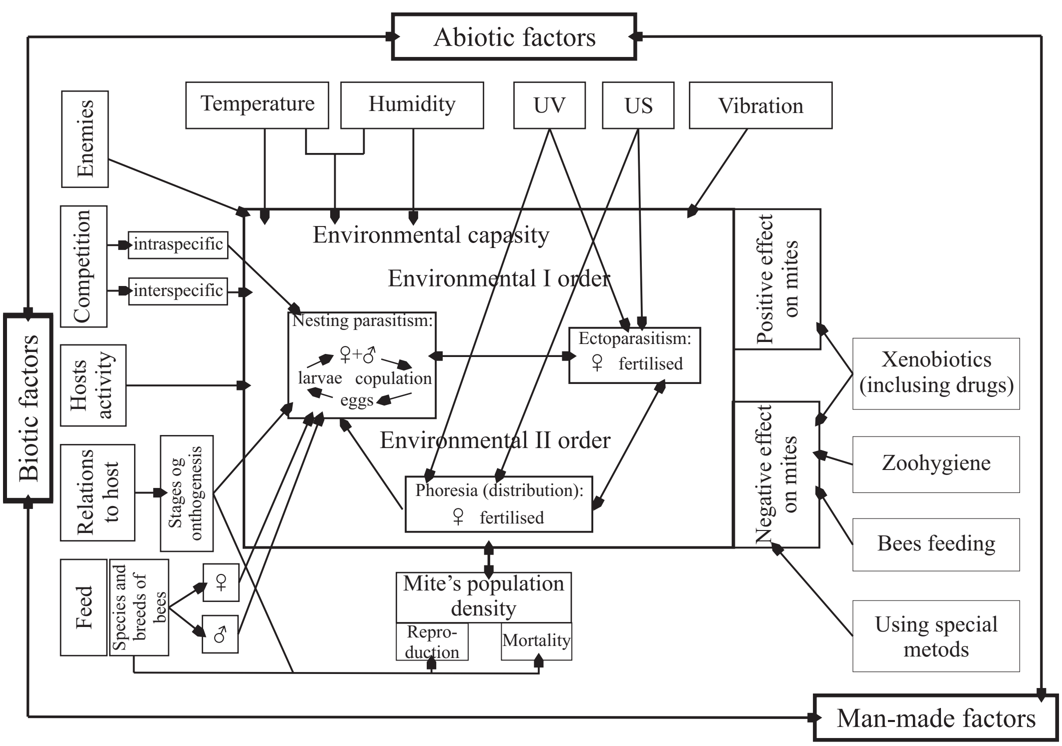

Fig. 1. Effect of some most significant factors on *V. destructor*.

Рис. 1. Влияние наиболее значимых факторов на клеща *V. destructor*.

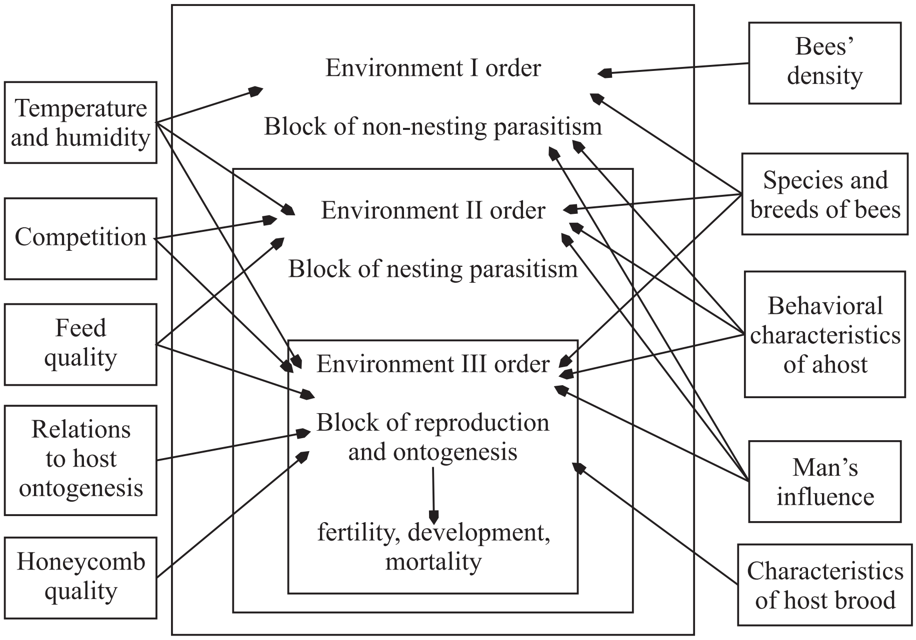

Fig. 2. General scheme of environmental capacity for mite *V. destructor*.

Рис. 2. Обобщенная схема емкости среды для клеща *V. destructor*.

much greater; however, it is not possible to show them all on the scheme. Effect of environmental factors depends on the stage of the mite life cycle where even the way of parasitism changes.

A generalized scheme of environmental capacity for *V. destructor* (fig. 2) allows us to single out the major bottlenecks in its life cycle. In particular, the reproduction unit is most sensitive even to little deviations in environmental parameters. This can be seen, for example, on the maximum number of limiting environmental factors within that block. At the same time, this block is the best isolated from external conditions by activities of working bees. Moreover, it is also isolated from internal hive conditions due to sealed honeycomb cells where bees maintain constant temperature (in brood sites) outside the combs.

One of the decisive factors for the normal life cycle of this parasite is the quality of food (host haemolymph). Female mites should obligatory feed by turns on hosts of different developmental stages and physiological states: for full maturation of reproductive organs, feeding on adult bees of specific hormonal status is mandatory; for vitellogenesis, they should feed on bee larvae of the last age having high content of juvenile hormone, etc.

Moreover, the constant environment within the beehive makes this parasite highly stenobiontic in its development. In this case, additionally to the host, the environment inside a hive should also be recognized for a mite as environment of the first order. The life cycle inside a hive includes also wintering, i. e., without breeding, and covers 5–6 months.

Block of the non-nesting parasitism is the most vulnerable to environmental factors. The mite stays out of the stable hive environment temporary, short period of time; however, the number of parasite then may be significantly reduced. Despite the fact that parasite is on bee body (under abdominal sternites), that time it is affected by many abiotic and other negative factors. In general, it confirms the idea that a single individual host can not ensure all parasite needs. Only entire bee family, considered to be a super-organism, is able to provide parasite with all necessary conditions for its feeding, reproduction, development, wintering and distribution to new bees and the new bee families.

Environmental factors affected the organism can be divided into primary, or base ones determining the possibility of existence of such organisms at all, and secondary, or quantitative determining the degree of species well-being (Korzh, 2011). For mite, qualitative factors are mostly those affecting the environment III order — block of reproduction and ontogenesis (fig. 2). Most factors effective in blocks II and III (non-nesting and nesting parasitism), should be attributed to secondary factors determining well-being of parasite population rather than the possibility of its existence as such.

Block of reproduction and ontogenesis III seemed to be crucial for the full scale varroa living and determined its successful honey bee parasitizing. The rapid colonization of new hosts through the whole modern range of honeybee keeping, i. e., beyond the tropical zone, the parasite's home, may be the result of high degree mite preadaptation that eventually led to change of its hostal specialization (*A. mellifera* instead of *A. cerana*).

Tropical origin of this species is the determining factor for prosperous existence of this mite at elevated temperatures inside the hive, and even makes such thermal conditions optimal. While parasitizing bee *A. cerana*, mite focuses mainly on drone brood located at the hive bottom. In such location, the temperature needed for drone development is slightly lower than that for bees, and is closer to the optimal parasite range 34–36 C°, while in summer the temperature in the hive of this species may be 38 C° (Akimov et al., 1993; Kuznetsov, 2005). Due to the greater ability of *A. mellifera* to keep homeostasis, such temperature is maintained almost in the entire hive making these conditions more favorable for the parasite development.

However, ontogenesis of *V. destructor* is much more preadaptive, especially due to active embryos development (Akimov et al., 1993). In particular, protonymph hatches instead of larvae making the total time of development to the adult stage only 7–10 days in females and 6–7 days in males, respectively. Such an accelerated ontogenesis makes possible parasitizing on larvae and pupae of working bees (females) even in *A. cerana*, which total duration of development is three days less than that of drones (Kuznetsov, 2005). Too short period of larval development of the queen bee (16–17 days) may explain difficulties of mite development on its larva. In *A. mellifera*, due to the large size of the cells as compared to *A. cerana*, the development of the parasite on working individuals becomes normal.

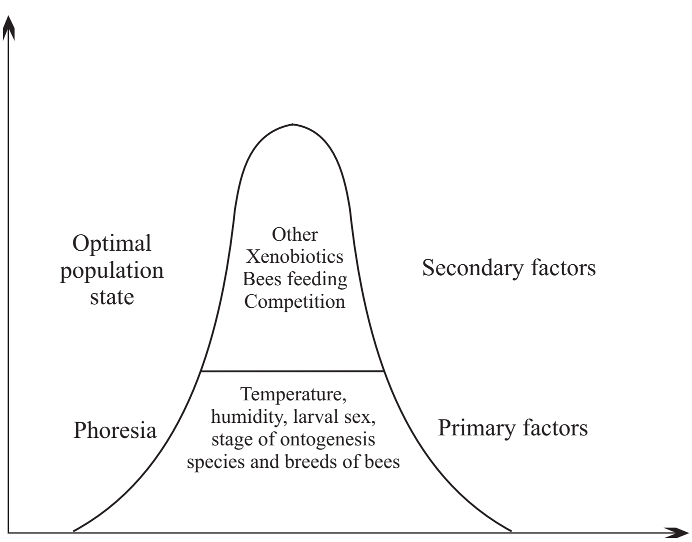

Fig. 3. Effects of individual environmental factors on mite.

Рис. 3. Значимость отдельных экологических факторов для клеща.

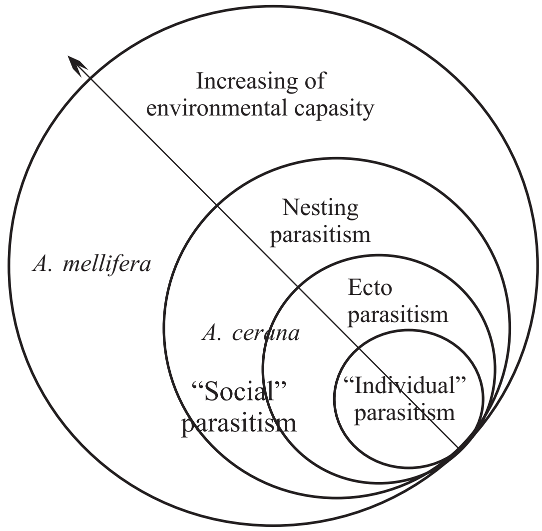

Fig. 4. Development of environmental capacity for *V. destructor*.
Рис. 4. Развитие емкости среды *V. destructor*.

Evolution in formation and development of the environmental capacity for the mite *V. destructor* can be represented as follows (fig. 4). Initial phoresia and further parasitizing on wax bee formed very limited environmental capacity for this parasite. This is especially true for the first stage of parasitism development in this species, the ectoparasitism.

Also, it is impossible to reconstruct the pattern of the formation relationship between bees and mites, their evolution without information about the relationship between mites of the same species or close species from family Varroidae with other bee species from genus *Apis*. Some of them (*A. mellifera*, *A. cerana*, *A. koschevnikovi*) build nests in cavities (hollows, microcaves, etc.), others (giant *A. dorsata*, *A. laboriosa*, and dwarf *A. florea* and *A. andreniformis*) build honeycomb in open places protecting them from bad weather by bodies of working bees (Butler, 1969; Mathew, Mathew, 1990; Michener, 1974; Roubik et al., 1985). Therefore, II order environment (space inside a hive, hollows or other cavities) is the key factor for wide spreading mites following the bee. Moreover, closed site of the family location (II order environment) was most likely place for meeting of bees from different families, mainly thieve bees which infected new bee families with varroosis. And finally, the main place for reproduction and ontogenesis for mites from family Varroidae became the most protected parts of the family (excluding bee queen) — honeycombs with bee and drone broods (III order environment).

Co-evolution of mites and wax bees contributed to a substantial conformation of their life cycles resulted in significant parasite dependence on biochemical, first of all on above-mentioned hormonal state of the host. This step significantly increased specificity of the parasite toward the host. On the base of nest parasitism, the unique, higher-level "social" parasitism is formed in mites where the subject of parasitism is not a single bee, but the whole bee family. At the same time, the short period of living of drone brood where this parasite mainly develops significantly limited spreading of this mite species in the family of bee *A. cerana*.

The subsequent combination of ectoparasitic and nest ways of living for this parasite in bee family (Akimov et al., 1993) allows mite to survive on host even in the absence of brood obligatory for successful breeding. Owing to this mite significantly extends the environmental capacity and colonizes zones without continual reproduction of its host.

It should be recognized that the most advanced stage of parasitism in *V. destructor* was its moving to a new host, the honeybee. Due to its domestication and substantial expansion of the range by man (Avetisyan, 1965), parasite's environmental capacity increases significantly, and the new host in fact is incapable to withstand the mite's pathogenic effects.

Today, the mite is the most massive parasite of bees, and therefore it can be considered to be one of the major problems of beekeeping in the world.

Further we may expect development of relations between the honey bee and its new parasite reducing mite's pathogenicity. However, we should manage this process because the bees breeding in apiculture aimed in their productivity.

Thus, the modern environmental capacity for *V. destructor* relies on its parasitism on two bee species: *A. cerana* and *A. mellifera* (fig. 4). Naturally, that spreading these hosts, including man-made (for *A. mellifera*) provides the possibility for spreading this mite. Since the honeybee substantially surpasses the wax bee both in climatic and geographical characteristics of the distribution, it is more promising host.

At the same time, the sites of distribution of the first species, the primary host, are almost all suitable for mite parasitism. In population of the honey bee with potential to inhabit its entire artificial range, marginal areas of the range with particularly severe climatic conditions are also suitable for the life of the parasite due to regulatory activities of working bees maintaining the temperature optimal for brood development.

Concerning the use of hosts by mites, honey bee is also more acceptable. In wax bee, drone brood is more suitable for the reproduction; on working bees, adult mite females can find extra feeding and phoresia may take place. In the honey bee, mite can develop in brood of working bees and drones. It is also necessary to take into account the fact that *A. cerana* leaves nest infected with *V. destructor* long before the parasite population reaches numbers life-threatening for bee family. Honeybee *A. mellifera* has no such adaptation allowing the parasite much greater environmental capacity than *A. cerana* as the number of parasites increases to values fatal for bee family.

Thus, despite the fact that the honeybee is a secondary host, and perhaps because of this, it provides much greater environmental capacity for *V. destructor* being the reason for such wide spreading of varroosis and the degree of harmfulness especially on the honey bee.

The uniqueness of the mite *V. destructor* as a parasite is also in its life cycle providing mandatory change host individuals being on different stages of development and in different physiological state. Owing to that, this mite parasitizes not a separate individual bees, but the family as a whole which should be considered as its environment. The fact that because of varroosis, a single bee died, but entire bee family, confirms this idea. Such type of parasitism is also stimulated by relatively constant environment inside the hive (II order environment) maintained by the bees, even in winter. This causes high pathogenicity of tropical mite *V. destructor* for the honeybee and difficulties in its control.

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