Vestnik zoologii, **44**(1): 49–54, 2010

UDC 595.42:595.799

ETOLOGICAL ASPECTS OF HONEYBEE *APIS MELLIFERA* (HYMENOPTERA, APIDAE) ADAPTATION TO PARASITIC MITE *VARROA DESTRUCTOR* (MESOSTIGMATA, VARROIDAE) INVASION

I. A. Akimov, V. E. Kiryushyn

Shmalhausen Institute of Zoology NAS of Ukraine
B. Chmielnicky str., 15, Kyiv, 01601 Ukraine
E-mail: kyrya1@yandex.ru

Received 3 November 2009
Accepted 2 December 2009

Ethological Aspects of Honeybee *Apis mellifera* (Hymenoptera, Apidae), Adaptation to Parasitic Mite *Varroa destructor* (Mesostigmata, Varroidae) Invasion. Akimov I. A., Kiryushyn V. E. — Some ethological aspects of *A. mellifera* Linnaeus, 1758 (Hymenoptera, Apidae), adaptation to parasiting the mite *V. destructor* Anderson et Trueman (Mesostigmata, Varroidae) are shown. The basic complexes of behaviour reactions, directed on a fight against the parasitic mites of bees brood at the genus *Apis* are shown, their comparative efficiency under various conditions and evolutional perspective. Possibility of ethological adaptation of honey bee to *V. destructor* parasiting, direction of selection by this sign and influencing of human on parasitic-host system was discussed. An approach to the selection of bees with the purpose of resistanse to varroosis promoution is proposed.

Key words: *Apis mellifera, Varroa destructor,* hygienic behaviour of bees, resistance, adaptation, selection.

Этологические аспекты адаптации медоносной пчелы, *Apis mellifera* (Hymenoptera, Apidae), к паразитированию на ней клеща *Varroa destructor* (Mesostigmata, Varroidae). Акимов И. А., Кирюшин В. Е. — В статье освещаются некоторые этологические аспекты адаптации медоносной пчелы *Apis mellifera* Linnaeus, 1758 (Hymenoptera, Apidae) к паразитированию на ней клеща *Varroa destructor* Anderson et Trueman (Mesostigmata, Varroidae). Показаны основные комплексы поведенческих реакций, направленных на борьбу с клещами-паразитами расплода у пчел рода *Apis*, их сравнительная эффективность в различных условиях и эволюционная перспективность. Обсуждается возможность этологической адаптации медоносной пчелы к варроа, направленность отбора по этому признаку и влияние человека на данную паразито-хозяинную систему. Предложен подход к селекции пчел с целью повышения устойчивости к варроозу.

Ключевые слова: *Apis mellifera, Varroa destructor,* гигиеническое поведение пчел, адаптация, селекция.

Introduction

It is impossible to study honeybee adaptation paths to *Varroa destructor* Anderson et Trueman, 2000 parasitism without examination of the mite and bee population interactions as a whole. It should be done because of host-parasite relationships in mite — bee system being not fully fixed and are being formed nowadays due to recent switching of *V. destructor* to parasitizing honeybee (Akimov et al., 1993). Previously, species from the genus *Varroa* parasitized other species from the genus *Apis* including *Apis cerana F.* At the same time, it is known that Asiatic and European honey bees are quite similar biologically and they readily get into their colonies bees from the other species brood. This fact and direct observations indicate that behavioral acts and their complexes, as well as communication and information transmission systems among individuals in colonies of these species are similar in many aspects (Rath, 1993; Kuznetsov, 2005).

Being similar in general, European and Asian honey bees have different thresholds and levels of ethological reactions common to both species, and these appear to allow Asian honey bee to control parasite population. For example, Asian honey bee has greater excitability and propensity to slough-offs and, in addition, it has less diameter of comb cells and slightly shorter period of brood development (Peng et al., 1987; Kuznetsov, 2005). However, both species have inherent reactions fn body cleaning as a response to irritation, and are also able to identify cells with mity brood. All this determines the Asian honey bee adaptive reactions complexity to *Varroa* parasitism and causes certain methodical complications in studying them as compared to those reactions in European honeybee.

As possible preadaptations, one should consider different growth rate of parasite number in colonies of different European honeybee breeds and populations, which may depend on different size of honeycomb cells (Harbo, Harris, 1999; Rosenkranz, 1999) or some asynchronies in development of mite and pupae in brood (Akimov et al., 1993).

Results

Complex studies of the parasite biology and different aspects of its interactions with European honeybee allow focusing mainly on such kinds of bees resistance to the parasite as their adaptive behavioral reactions studied by us and other authors. (Akimov et al., 1993; Akimov, Kiryushyn, 2008; Ritter et al., 1990; Rosenkranz et al., 1997; Spivak, Gilliam, 1998; Correa-Marques, de Jong, 1998; Moretto, Melco, 2001; Fries et al., 2006; Fries, Bommarco, 2007).

Such reactions consist of three basic behavioral complexes. The **first** of these behavioral complexes is the most primitive, mostly observed in Asian honey bee. It consists in slough-off of all bee imaginal forms. At that combs and brood are abandoned together with parasites, most part of which remains in the brood. Such extraordinary response takes place when there is abundant number of parasites considerably disturbing bees (Kuznetsov, Proschalycin, 2004; Kuznetsov, 2005).

Slough-offs at varroatosis is described for European honeybee as well (Rosenkranz, 1999; Khmara, 2002). Primitiveness of such reaction consists in heavy losses. Bees have to completely restore the nest and accumulate new feedstuffs. Such technique of colony cleaning is successful only if long-term honey gathering in nature is possible, which enables accumulation of feedstuffs for winter and rearing enough number of bees. In fact, bee slough-offs are possible during swarming only, however, the extensiveness of bees infection with the parasite is relatively low at this period. The number of mites on adult bees increases in August and September when forage gathering appears to be impossible. The fact of autumn slough-offs is an indirect evidence of bee tropical origin, as it is in the South Asia where the stable honey gathering in October and November is observed, and where the vast majority of species from the genus Apis is described. Such kind of honey gathering is not observed in the Eastern Europe, where, as a rule, it is finished in August — beginning of September. In the temperate climate of the Eastern Europe, the autumn slough-offs may result in bees death during winter, so such form of adaptation to varroa can not be prospective, and bee population under our conditions will selectively be cleaned from colonies tending to slough-offs.

The **second** complex of behavioral reactions associated with adaptations to varroa parasitizing is the development of bee body cleaning reactions investigated by us and other authors. Such behavioral reactions in bees are divided into self-cleaning and mutual cleaning, similar to grooming in higher vertebrates, when one bee cleans another one (Akimov, Kiryushyn, 2008). Self-cleaning of adult Asian honey bees aimed at relieving from varroa mites was described by Y. S. Peng (Peng et al., 1987). It is a modification of the typical body cleaning movements and is used when the mite is present on bee's body (Rath, 1993). It is necessary to note that the body cleaning movements are rather conservative and only slightly in different species not only in Apis, but also in Apoidea on the whole. Cleaning of body vestiture is a typical reaction of any insect on body contamination, mechanical irritation or stress. Even with the increasing of insects sociality, such reactions remain almost unchanged (Michener, 1974).

On the other side, the reactions of body self-cleaning observed in European honeybees are not specific. The complex of movements starts at the presence of any irritant.

A bee gets rid from a mite only in insignificant number of cases (Kiryushyn, 2005 a). Highly conservative movements of body vestiture cleaning suppose that the Asioan honey bee have the same pattern as seen in the other bees. Probably, their threshold values of irritation are lower than in the European honeybee, so they do more acts of self-cleaning in mite presence and chances to throw the mite off or to damage it also increase.

It is known, that with the insect sociality increase, the division of labor in a nest increases as well (Levchenko, 1976). Since the European honeybee have the largest colonies with the greatest degree of labor division and information exchange between colony members as compared to other bees, we may logically assume new behavioral models at irritation, e. g. mutual body cleaning, built-in the system of age and caste labor division in a bee nest, and specific, directed against varroa, self-cleaning techniques.

The comprehensive study of honeybee body cleaning reactions found out their dependence of the environment temperature, honey gathering, and stress factors. Thus, the highest intensity of such reactions was observed at temperatures close to optimum for bee colony: 30–35°C. Consequently, honey gathering is increased by the bees cleaning their bodies, however its intensity in some individuals reduces. We confirmed the presence of developed reactions of both body self-cleaning and mutual cleaning in bees. Also, within this study, we established the role of age-dependent bee polyethism in development of such reactions (Kiryushyn, 2005 b). Under significant stress irritations, such as mechanical effect or bee "narcotization", the reactions of body cleaning in bees were considerably activated. However, such reactions of body cleaning appeared to be nonspecific and ineffective against varroa. Moreover, within an hour after the parasite introduction, bees stopped cleaning movements that may be explained by the CNS inhibition developed during a long-term irritation. This significantly reduced reactions efficiency, as the intensity of movements rose only for a short time after the mite transfer to another bee, but went down quickly.

Thus, we may speak about potentially possible European honeybee adaptation to the varroa infection by the development of body cleaning reactions such as those seen in Asian honey bee, however, at this stage, such behaviour is not able to restrain parasite reproduction due to its unspecificity, low efficiency and rapid extinguishing. At the same time, the parasite easily recognizes the main host, that makes possible its transfer among bees of the same colony. It also gives the mite an opportunity to infect bees and remain on them up to ceasing of the body cleaning reaction.

As far as the primary reactions already exist, their adaptive specialization against varroa irritation may evolve within an evolutionary insignificant period of time. According to our data, the presence of varroa on an adult bee induces, at this stage, general activation of body cleaning reactions, which, however, are not specific and, being the same as the reactions against mechanical or stress irritation, remain ineffective.

The **third** complex of behavioral reactions against varroa is the bee colony particular control of varroa population in brood. Since the varroa reproduction and development occur in brood, the most effective control method for the bee colony could be recognition and elimination of the parasites during their development in the brood. It would result in the lowest loss rates for colony as compared to other control methods. Moreover, larval stages of mite in beehive environment, out of brood cells, are unviable, therefore their elimination would not require bees considerable efforts.

Our own data and literary information show that bees have certain mechanisms for recognition of affected brood, which, however, are studied insufficiently (Rosenkranz et al., 1997; Spivak, Gilliam, 1998). Such differences may be due to the development of secondary microflora on pupae, weakened by the varroa parasitism. On the other hand, the connection between the hygienic capabilities of bee colonies and rates of growing of varroa population may be mediated (Maslennikova, 2003).

Brazilian bees and some lines of Italian bees partly throw out pupae affected by varroa, however, it is not effective mechanism to control the parasite population and when extensiveness of brood affection is over 5% such reaction goes down or stops completely (Rosenkranz et al., 1997).

Recognition and the following unsealing and rapid elimination of the affected and dead larvae and pupae from cells is one of the main methods to control brood diseases among bees. Mechanisms of such recognition are not clear enough, however its great efficiency against many diseases are doubtless (Rudenko, 2004; Spivak, Gilliam, 1998).

We found out great variability of this trate in a group of bee colonies.

During the study of growth rates of varroa population in some bee colonies we found out the dependence between extensiveness of individual infection and hygienic capabilities of bee colonies. Namely, colonies, where bees recognized cells with the infected brood in a shorter period of time, had lower growth rate of varroa population during three beekeeping seasons and had significantly lower extensiveness of adult bees infection after leaving the brood cells (Kiryushyn, 2007 a; Akimov, Kiryushyn, 2008).

However, even in the colonies with the greatest hygienic capabilities the number of mites grows so quickly that may result in death of the colony in two seasons after the last treatment with acaricide. Some parameters of winter resistance in bee colonies correlate with their hygienic capabilities. So, when analyzing winter resistance of bee colonies with the different level of hygienic capabilities, some differences were observed such as colony attenuation in wintering period and forage consumption of bees. Moreover, there is a correlation between the level of hygienic capabilities and brood amount in bee colonies after flying around, probably due to different way of colony development in the period before flying around (Kiryushyn, 2007 b).

Thus, as in the case of body cleaning reactions, bee colonies have already had mechanisms for certain control of varroa population in brood, however they are not specific to the mite and just slow down increasing of the parasite population in a colony. On the other hand, the bee colonies able to rapidly recognize infected brood and maintain acceptable sanitary condition of nests, in addition to the lower growth rate of V. destructor population inside them also have a complex of other trates useful for surviving, such as higher winter resistance, earlier colony activation in spring, greater resistance to other diseases (Kiryushyn, 2008; Rudenko et al., 2006).

As is obvious from the forementioned, bee adaptations to varroa parasitism are within adaptations to many unfavorable environmental factors and are only slightly modified depending on these factors. Therefore hygienic activity, winter resistance, and other reactions towards decreasing of parasite reproduction rates and its effect on the bee colony became vital. It is especially important to emphasize, that natural resistance of Asian honey bee known to be resistant to varroosis is initially limited by biological characteristics of European honeybees and their living conditions.

Our data gives us certain hope on gradual spontaneous increase in bee resistance to varroa invasion. Moreover, bees have principle possibility to slow down parasite reproduction by decreasing cell diameter to 4.7–4.9 mm, and reducing period of pupa development, or changing the timing of its hormonal transformations. However, it may appear to be another biologically or economically limiting factor. Anyway, at this stage we can not see anything of this kind even at hands of man (Maslennikova, 2003; Kulincevuc, 1987; Moretto, 2001).

Honeybee adaptation to varroa parasitizing seems to still be in on the first phases of emerging, however there are approximate paths and specific mechanisms of subsequent mutual bee and mite adaptation to the stable coexistence, as well as man's role in this process. It is also obvious that the control on varroa population in a bee nest develops as a difficult complex of different and disconnected trates inherited with participation of the large number of genes. Therefore, bee selection to varroa resistance is confronted with great difficulties complicated with such biological habits of bees as polyandry and uncontrolled queens coupling.

Akimov I. A., Kiryushyn V. E. Possible ways of adaptation of Apis mellifera (Hymenoptera, Apidae) to parasitizing of mite Varroa destructor // Vestnik zoologii. — 2008. — **42**, N 3. — P. 45–55. — Russian : *Акимов И. А., Кирюшин В. Е.* Возможные пути адаптации Apis mellifera (Hymenoptera, Apidae) к паразитированию клеща Varroa destructor // Вестн. зоологии.

Akimov I. A., Grobov O. F., Piletckaya I. V. et al. Bee mite Varroa jacobsoni. — Kyiv : Naukova dumka, 1993. — 254 p. — Russian : *Акимов И. А., Гробов О. Ф., Пилецкая И. В. и др.* Пчелиный клещ Varroa jacobsoni.

Chmara P. M. The case of bees fouling at the winter 2001–2002 // Pasica. — N 6. — 2002. — P. 9. — Ukrainian : *Хмара П. М.* Причини загибелі бджіл зимою 2001–2002 року // Пасіка.

Correa-Marques de Jong D. Uncapping of worker bee brood, a component of hygienic behaviour of Africanized honey bees against Varroa jacobsoni // Apidologie. — 1998. — **29**. — P. 283–289.

Fries I., Bommarco R. Possible host-parasite adaptations in honey bees infested by Varroa destructor mites // Apidologie. — 2007. — **38**. — P. 1–9.

Fries I., Imdorf A., Rosenkranz P. Survival of mite infested (V. destructor) honey bee (A. mellifera) colonies in a Nordic climate // Apidologie. — 2006. — **37**. — P. 1–7.

Harbo J. R., Harris J. W. Heritability in honey bees (Hymenoptera: Apidae) of characteristics associated with resistance to Varroa jacobsoni (Mesostigmata: Varroidae) // J. of Economic Entomology. — **92**, N 2. — 1999. — P. 261–265.

Kiryushyn V. E. The age polyethism role at bee`s grooming // Naukovyj Visnyk NAU. — Kyiv : 2005 a. — N 86. — P. 34–37. — Ukrainian : — *Кірюшин В. Є.* Роль вікового поліетизму бджіл у розвитку грумінга // Науковий вісник НАУ.

Kiryushyn V. E. Bee grooming behaviour in dependence on temperature, feeding and presence of mites Varroa destructor // Vestnik zoologii. — Suppl. N 19. — 2005 b. — P. 173–175. — Ukrainian : *Кірюшин В. Є.* Залежність грумінгових реакцій бджіл від температури, взятку, наявності кліщів Varroa destructor // Вестник зоологии.

Kiryushyn V. E. The mite Varroa destructor (Parasitiformes, Varroidae) infestation level dynamics at the bee colonies with different hygienic behaviour // Tezy dopovidej Siomoho zjizdu Ukrajinskoho entomolohichnoho tovarystva. — Nizhyn, 2007 a. — P. 253. — Ukrainian : *Кірюшин В. Є.* Зміни чисельності кліщів Varroa destructor (Parasitiformes, Varroidae) у бджолиних сім'ях з різними гігієнічними здатностями // Тези доповідей Сьомого з'їзду Українського ентомологічного товариства.

Kiryushin V. E. The wintering of honeybee colonies Apis mellifera (Hymenoptera, Apidae) and their hygienic ability // Contribution of entomology to the agroindustrial complex, forestry and medicine : Abstracts of the XIII-th congress of Russian Entom. Society (Krasnodar, Sept. 9–15, 2007). — Krasnodar, 2007 b. — P. 93–94. — Russian : *Кирюшин В. Е.* Зимостойкость пчелиных семей Apis mellifera (Hymenoptera, Apidae) и их гигиенические способности // Достижения энтомологии на службе агропромышленного комплекса, лесного хозяйства и медицины : Тез. докл. Тринадцатого съезда Русского энтомол. об-ва (Краснодар, 9–15 сент. 2007 г.).

Kulincevuc L. Breeding honey bees for resistance to Varroa jacobsoni. Analises of mite populatin dynamics // Africanized honey bees and the mites. — Ohio, 1987. — P. 434–443.

Kuznetsov V. N. Chinese Wax Bee (Apis cerana cerana F., Hymenoptera, Apidae) in the Russian Far East. — Moscow : KMK, 2005. — 111 p. — Russian : *Кузнецов В. Н.* Китайская восковая пчела (Apis cerana cerana F., Hymenoptera, Apidae) на Дальнем Востоке России.

Kuznetsov V. N., Proschalycin M. U. Chinese Wax Bee (Apis cerana cerana F., Hymenoptera, Apidae) in the south of Russian Far East. — Vladivostok, 2004. — 56 p. — Russian : *Кузнецов В. Н., Прощалыкин М. Ю.* Китайская восковая пчела (Apis cerana cerana F., Hymenoptera, Apidae) на Юге Дальнего Востока России.

Levchenco I. A. Passing to information about the coordinates of source of forage for a honey bee. — Kyiv : Naukova dumka, 1976. — 249 p. — Russian : *Левченко И. А.* Передача информации о координатах источника корма у пчелы медоносной.

Maslennicova V. I. The population of the mit*e* V. jacobsoni genesis at bee colonies of Central Russia zone- Works of beekeeping inst. (Rybnoe). — Moscow, 2003. — P. 184–204. — Russian : *Масленникова В. И.* Формирование популяции клещей V. jacobsoni в пчелиных семьях центральной зоны России // Сб. тр. Ин-та пчеловодства в г. Рыбном.

Michener C. D. The social behaviour of bees. — Cambrige : Belknap press, 1974. — 404 p.

Moretto G., Mello de L. Infestation and distribution of the mite V. jacobsoni in Africanized honey bee colonies // INCI, Caracas. — 2001. — **26**, N 9. — P. 28–32.

Peng Y. S., Fang Y., Xu S., Ge L. The resistant mechanism of Asia honeybee A. cerana Fabr. to an ectoparacite mite Varroa jacobsoni // J. invert. Pathol. — 1987. — **19**. — P. 54–60.

Rath W. Aspects of preadaptations in Varroa jacobsoni while shifting from its original host Apis cerana to Apis mellifera / L. J. Connor, T. Rinderer, H. A. Silvester, S. Wongsiri // Asian Apiculture. — Cheshire USA : Wicwas Press, 1993. — P. 417–426.

Ritter W., Michel P., Bartholdi A., Schwendemann A. Development of tolerance to Varroa jacobsoni in bee colonies in Tunisia / *W. Ritter, O. Laere van, F., Jacobs, L. Wael de* // Proc. Recent Reseach on Bee Pathology. Apimondia. — Gent, Belgiumpp. — 1990. — P. 54–59.

Rosenkranz P. Honey bee (Apis mellifera L.) tolerance to Varroa jacobsoni Oud. in Southn America // Apidologie. — 1999. — **30**. — P. 159–172.

Rosenkranz P., Fries I., Boecking O., Sturmer M. Damaged Varroa mites in the debris of honey bee (Apis mellifera L.) colonies with and without hatching brood // Apidologie. — 1997. — **28**. — P. 427–437.

Rudenko E. V. Mixed infectious brood deseasis of honey bees (epizootology, differential diagnosis, complex system of measures and preventive maindenance : Avtoref. Doct. Vet. Sc. Manuscript. — Kharkiv, 2004. — 44 p. — Ukrainian : *Руденко Є. В.* Змішані заразні хвороби розплоду медоносних бджіл (епізоотологія, диференційна діагностика, комплексна система заходів боротьби та профілактики : Автореф. дис. ... докт. вет. наук.

Rudenko E. V., Kalinina I. G., Kiprych Y. V. Activity of hygienical behaviour of bees value and increase of bee colony productivity // Nauk. Visn. NAU. — Kyiv, 2006. — N 94. — P. 266–270. — Ukrainian : *Руденко Є. В., Калініна І. Г., Кіпріч Ю. В.* Значення активності гігієнічної поведінки бджіл для підвищення продуктивності бджолиної сім'ї // Наук. вісн. Нац. аграрн. університету.

Spivak M., Gilliam M. Hygienic behaviour of honey bees and its application for control of brood diseases and varroa // Bee World. — 1998. — **79** (3). — P. 124–134.