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Original article

The effects of climate and bee race on *Varroa jacobsoni* Oud infestations in Brazil

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Summary — *Varroa jacobsoni* infestation rates on adult Africanized and Italian/Africanized hybrid honey bees were measured in 3 different climatic regions of Brazil : Ribeirão Preto, Rio do Sul and São Joaquim (mean temperatures 21, 18 and 13 °C, respectively), over a 2-yr period. The mean infestation rates were 3.5, 5.11 and 11.37 mites per 100 bees in the 3 regions respectively, demonstrating that climate type has a strong influence and that infestation rates are higher in the cooler regions. The type of bee also had an important effect, as the Italian hybrids were significantly more infested than the Africanized bees (7.53 and 5.78 mites per 100 bees, respectively).

***Varroa jacobsoni* / infestation rate / Africanized honeybee / climate**

INTRODUCTION

Originally, while the ectoparasitic mite *Varroa jacobsoni* Oud (Acari, Varroidae) was confined to the Asian honey bee, *Apis cerana,* beekeeping was not seriously affected due to the low degree of infestation generally found on its original host (Koeniger *et al,* 1981; De Jong *et al,* 1982). However, after the mite came into contact with *Apis mellifera,* it caused much more serious problems, was spread to many other parts of the world, and resulted in the death of hundreds of thousands of colonies of the latter species (De Jong *et al,* 1982).

The impact of a *Varroa* infestation depends on the degree of infestation in the bee colony. A low infestation apparently causes little damage, while a high infestation eventually leads to colony death.

In *Apis mellifera* colonies the population dynamics of *Varroa jacobsoni* differs in the various regions of the world. For example, in west Germany, the mite population increases 10-fold from spring to summer (Schulz *et al,* 1983), while in other countries, such as Brazil and Uruguay, the situation is much different, as the mite has been established for more than 10 yr and the population remains at a low level (De Jong *et al,* 1984; Ruttner *et al,* 1984; Gonçalves, 1987).

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One factor that directly affects the final population of *Varroa* in the bee colonies is the percentage of female mites which reproduce when they enter worker brood cells. This percentage is considerably lower in tropical and subtropical Latin America when compared with temperate areas of Europe and the Middle East (Ritter and De Jong, 1984).

Bee race also seems to be an important factor for determining the success of the mites as significantly fewer female *Varroa* that entered worker brood cells achieved successful reproduction in Africanized bee colonies than in European (Italian or Carniolan) colonies, even when they were kept in the same apiary in Brazil (Camazine, 1986; Rosenkranz, 1986).

The cape bee, *Apis mellifera capensis*, has a very much shortened sealed-cell stage, 2.4 d less in the workers when compared with *A m carnica*. The reproductive potential of the mites is considerably lower in the former, as most mite nymphs are not able to reach the adult stage (Moritz and Hänel, 1984). However, though the sealed-cell stage of worker Africanized bees is ≈ 20 h shorter than that of European bees, the number of mite offspring produced per female mite (including only those that successfully reproduce) is nearly the same (Rosenkranz, 1986).

Pure *A m carnica* colonies kept in Ribeirão Preto, Brazil, had significantly higher infestations than "wild type" Africanized bee colonies in the same apiary, though they were also much less infested than sister Carniolan colonies kept in Germany (Engels *et al*, 1986).

Differences in the infestation rate of *V jacobsoni* could be influenced by bee race, climate, origin of the mite or some combination of these factors. In South America, where *V jacobsoni* was apparently introduced from Japan in ≈ 1970 (De Jong *et al*, 1982), we find low stable infestations in Brazil and high terminal infestations in the Buenos Aires province of Argentina (De Jong *et al*, 1984). We assume that the genetic composition of the *V jacobsoni* populations is the same, since they were from the same introduction. However, it is difficult to separate the effects of climate and bee race, as in Brazil the bees are Africanized and in that region of Argentina they are European (Kerr *et al*, 1982).

The objective of our research was to determine the relative importance of climate and honey bee race for *Varroa* infestations.

MATERIALS AND METHODS

This experiment was conducted in 3 distinct climatic regions. The 3 regions have been classified according to Köppen (1948) by Andrade (1964): Ribeirão Preto, São Paulo state, 620 m altitude, 21°11'25" south latitude, with an average mean temperature of 21 °C, a humid tropical climate, well defined seasonally by a hot rainy summer (mean temperature > 23 °C and > 250 mm of rain in the hottest month) and dry and mild winter season (mean minimum temperatures ≈ 18 °C and < 30 mm precipitation in the coldest month); Rio do Sul, Santa Catarina state, 354 m altitude, 28°17'55" south latitude, with an average mean temperature of 18 °C, a humid mesothermic climate without a distinct dry period and the mean temperature of the hottest month > 22 °C, climate typical of southern Brazil; and São Joaquim, Santa Catarina state, 1 360 m altitude, 28°17'19" south latitude, with an average mean temperature of 13 °C, a humid mesothermic climate, with no distinct dry period and the mean temperature of the hottest month not reaching 22 °C; climate typical of the higher mountain regions (1 200–1 600 m). In addition, mean monthly temperatures were obtained from government monitoring stations.

Each apiary was set up with bees of 2 racial types. Africanized bee colonies were headed by queens reared from descendants of natural swarm queens captured in the region of Ribeirão Preto. The wild honey bees in this part of Brazil have predominantly African (*Apis mellife-*

ra adansonii, now called *Apis mellifera scutellata)* characteristics (Lobo *et al,* 1989).

Italian hybrid colonies were headed by queens reared from Italian queen mothers imported from the USA and Italy, and from artificially inseminated queens maintained at the experimental apiary of the Genetics Department at the University of São Paulo in Ribeirão Preto. All of the virgin queens were open-mated with wild type Africanized drones in the Ribeirão Preto apiary. Thus there was one group consisting of Africanized bee colonies and another of Italian/Africanized hybrid bee colonies.

The apiaries were installed in March 1986. Twelve standard single-storey Langstroth hives populated with bees of each region were selected and numbered for each of the 3 experimental apiaries. Half of the colonies, selected randomly, were requeened with Africanized queens and the other half with open-mated Italian queens in April and May of 1986. During the course of the study, whenever any queen was lost, it was replaced with another of the same type, also reared and mated in Ribeirão Preto.

Preliminary infestation data were collected in March and April, 1986. Adult bee infestations were estimated using a methodology developed by Stort *et al* (1981). Samples of 200–500 adult bees from each colony were brushed from 2 or 3 brood combs into beakers partially filled with ≈ 250 ml of weak detergent solution. These were agitated and then strained to separate and count the bees and mites. By June 1986, all the bees in the colonies were progeny of the introduced queens. The colonies were then sampled once a month from June 1986 to February 1988.

The total infestation rate was analyzed with a fixed model analysis of variance with 2 classification criteria and when necessary, a Tukey's multiple comparison test was performed. The data were transformed ($y = \log (p/(1-p))$) to stabilize the variance. During the 2-yr course of the experiment, several colonies were lost. The analyses were therefore restricted to 4 colonies of each racial type for each of the experimental apiaries.

RESULTS

The initial infestation rates (before the new workers of the introduced queens began to appear), measured in number of mites per 100 bees for the São Joaquim, Rio do Sul and Ribeirão Preto apiaries were 17.10, 1.10 and 1.86, respectively, for the hives requeened with Africanized queens, and 20.10, 1.23 and 1.28 for those requeened with Italian queens.

Subsequently after the bees were all substituted, the infestation rates calculated during the course of the study for the 3 locations showed no significant interaction effects between race and climate (F = 0.62) though there was a significant race effect (F = 5.23; $P < 0.05$), as Italian hybrids were more susceptible than the Africanized bees (7.53 and 5.78 mites per 100 bees, respectively).

Climate type had a highly significant influence on the mite infestations (F = 28.6; $P < 0.001$) and apparently was more important than race. A multiple comparison analysis, comparing the locations 2 by 2, demonstrated that the bees in São Joaquim (11.37 mites per 100 bees) were significantly more infested than those in Rio do Sul (5.11 mites per 100 bees) and Ri-

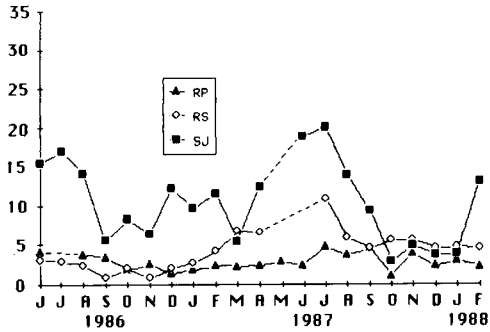

Fig 1. Monthly census of the number of *Varroa jacobsoni* per 100 adult bees in Africanized honey bee colonies in the 3 experimental apiaries. RP = Ribeirão Preto, São Paulo State; RS = Rio do Sul, Santa Catarina State; SJ = São Joaquim, Santa Catarina State. The dashed lines correspond to periods during which no data was taken.

beirão Preto (3.5 mites per 100 bees), and that the bees in Rio do Sul were more infested than those in Ribeirão Preto (figs 1, 2).

Mean monthly temperatures are given in figure 3. In general terms we could observe that the greater the annual mean temperature, the lower the mean infestation rate.

DISCUSSION AND CONCLUSION

Varroa jacobsoni was apparently introduced into Brazil about 1971 or 1972, through infested bees transported from Paraguay to São Paulo State (De Jong and Gonçalves, 1981). Now, more than 10 yr after the mites spread throughout the state, we find that the infestation rates have stabilized at ≈ 3 mites per 100 bees (Gonçalves, 1987).

Varroa probably arrived in the São Joaquim area about 1983 or 1984. An inspection of 8 apiaries, belonging to different beekeepers, made there in 1984 showed only one apiary to be infested, though the infestation rate was already high (> 10 mites per 100 bees). The mites were probably introduced through migratory beekeeping practices (De Jong, unpublished data). No previous information was available concerning infestations in Rio do Sul; however, it is only ≈ 150 km from São Joaquim. Unlike São Joaquim, which is an important beekeeping region because of the seasonally abundant wildflowers and the widespread use of bees for apple pollination, there is not much movement of bees into or out of Rio do Sul. So we presume that the infestation there was introduced a year or two later.

It is apparent that climate type has a significant impact on *Varroa* populations. The infestation rates we observed in São Joaquim, one of the few places in Brazil where snow falls on occasion, were much higher than those we have encountered in other areas. Even though the mites did not completely destroy the colonies as they do in Europe (De Jong *et al*, 1982), the infestations in some colonies in São Joaquim were high enough to retard their development and compromise their production.

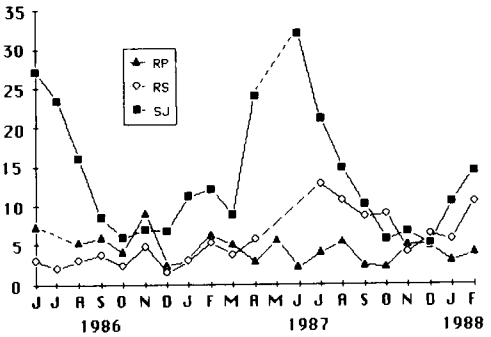

Fig 2. Monthly census of the number of *Varroa jacobsoni* per 100 adult bees in Italian/Africanized hybrid honey bee colonies in the 3 experimental apiaries. See legend to figure 1 for abbreviations. The dashed lines correspond to periods during which no data was taken.

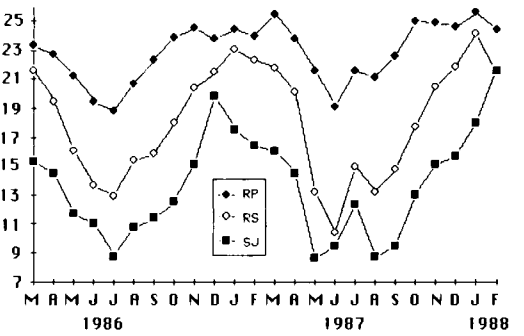

Fig 3. Mean monthly temperatures in °C of the 3 regions. See legend to figure 1 for abbreviations.

During much of the study, the infestation rates in hybrid and Africanized colonies were little different in both Rio do Sul and São Joaquim, except in the late fall and winter (April–August) in São Joaquim, when they were much higher in the European/Africanized hybrids (figs 1, 2). In Ribeirão Preto the fact that infestation levels were higher in the hybrid bees was more consistently evident.

In Ribeirão Preto, the most tropical of the 3 regions, there was little monthly variation in the infestation rates. The increased infestation rates during fall and winter were most evident in the coolest region (São Joaquim), and somewhat less so in the intermediate climate region (Rio do Sul, figs 1, 2). Some of this difference could be attributed to the reduction in brood and adult bee population during the colder months. As the number of brood cells available diminished more of the mites in the colony would be on the adult bees, and as the adult bee population declined, the mites would be distributed among fewer bees, increasing the apparent infestation, measured in mites per bee.

Interestingly, unlike *Varroa* infestations in Europe which increase rapidly over a period of 1–4 yr, by which time critical levels are reached (De Jong *et al*, 1982), the infestations within the 3 experimental apiaries did not increase overall during the 2 yr that they were monitored.

By using queens all issued from the same lines and reared and mated in the same location, we showed that the climatic effects were not merely a consequence of the variation in susceptibility of the different types of bees adapted to each climate region. However, it is not clear how climatic differences would affect the *Varroa* mites when one considers the fact that the mite reproduction is accomplished within the brood cells, which the bees maintain at a constant temperature (≈ 34 °C) during all seasons. Possibly physiological changes in the bees, mediated by climate, have some effect on Varroa reproduction and survival. De Jong (1981) found that when the bee colony produces emergency queen cells, the number of mites entering worker brood cells increases ≈ two and a half times, which demonstrates that the mites do react to changes in colony conditions.

The Africanized bees were more resistant to *Varroa* infestations than the hybrid Italian bees, a result also confirmed by Mendoza *et al* (1987) in Paraguay, though the difference was not as strong as that found between the different climatic regions we studied.

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Résumé — Influence du climat et de la race des abeilles sur les infestations par *Varroa jacobsoni* Oud au Brésil. On a pu montrer que le climat et la race des

abeilles étaient des facteurs importants du niveau d'infestation des colonies d'abeilles (*Apis mellifera* L) par *Varroa jacobsoni* Oud (Acari, Varroidae) au Brésil.

Trois ruchers comportant chacun 6 colonies d'abeilles africanisées et 6 colonies d'hybrides italiennes/africanisées, ont été installés 1) à Ribeirão Preto (État de São Paulo), région tropicale, température annuelle moyenne de 21 °C; 2) à Rio do Sul (État de Santa Catarina), climat humide modérément chaud, température annuelle moyenne de 18 °C; 3) à São Joaquim (état de Santa Catarina), climat humide modérément chaud, température annuelle moyenne de 13 °C, l'un des rares endroits du Brésil où il neige un peu en hiver. Toutes les reines ont été élevées et se sont accouplées naturellement dans le rucher de Ribeirão Preto de sorte que les mêmes lignées ont été utilisées dans les 3 endroits. Un contrôle des colonies a été fait chaque mois, de juin 1986 à février 1988 pour déterminer le taux de parasitisme des abeilles adultes. Des échantillons de 200–500 abeilles ont été prélevés sur les cadres de couvain et placés dans un récipient avec un détergent léger. Les abeilles ont été secouées et passées au crible pour les séparer des acariens et dénombrer ceux-ci. Certaines colonies ont été perdues au cours de l'expérience, les analyses ont donc porté sur 4 colonies de chaque race dans chaque rucher (soit 24 colonies au total).

Les taux moyens de parasitisme ont été de 11,37, 5,11 et 3,5 acariens pour 100 abeilles à São Joaquim, Rio do Sul et Ribeirão Preto respectivement. Ceci prouve que le climat exerce une forte influence et que les régions plus froides sont les plus parasitées. La race joue aussi un rôle : les hybrides italiennes ont été significativement plus parasitées que les abeilles africanisées (7,53 et 5,78 acariens pour 100 abeilles, respectivement), bien que cette différence ne soit pas aussi remarquable que celle due au climat.

***Varroa jacobsoni* / taux de parasitisme / climat / abeille africanisée**

Zusammenfassung — Einfluß von Klima und Bienenrasse auf den Varroabefall in Brasilien. Es konnte gezeigt werden, daß sowohl der Klimatyp wie die Bienenrasse in Brasilien wichtige Faktoren für den Befallsgrad der Bienenvölker mit Varroa sind.

Drei Bienenstände, jeder mit 6 Völkern afrikanischer Abstammung und mit 6 Hybridvölkern Italiener x Afrikanisierte Biene, wurden 1986 an folgenden Orten errichtet: 1. – Ribeirão Preto, Staat São Paulo, ein tropisches Gebiet mit einer mittleren Jahrestemperatur von 21 °C; 2. – Rio do Sul, Staat Santa Catarina, mit einem feuchten, mäßig warmes Klima, mittlere Jahrestemperatur 18 °C; 3. – São Joaquim, Staat Santa Catarina, mit mäßig warmem, feuchten Klima, mittlere Jahrestemperatur 13 °C – einer der wenigen Orte in Brasilien, an dem im Winter etwas Schnee fällt. Alle Königinnen wurden am Bienenstand von Ribeirão Preto aufgezogen und natürlich begattet, so daß an allen drei Standorten dieselben Linien benutzt wurden. Die Völker wurden in monatlichen Abständen von Juni 1986 bis Februar 1988 kontrolliert, um den Befallsgrad der erwachsenen Bienen zu bestimmen. Dazu wurden von Brutwaben Proben von 200–500 Bienen in einen Becher mit einer schwachen Waschmittellösung gekehrt. Die Bienen wurden gerührt und gesiebt, um Bienen und Milben getrennt zählen zu können. Einige Völker gingen während des Versuches verloren, deshalb beruhen die Analysen nur auf vier Völkern jeder Rasse auf jedem der drei Standorte (24 Völker insgesamt).

Die mittlere Befallsrate betrug in Sao Joaquim, Rio do Sul und Ribeirão Preto

11.37, 5.11 und 3.5 Milbe je 100 Bienen; das zeigt einen starken Einfluß des Klimatyps, wobei die Befallsraten in den kühleren Regionen höher sind. Es zeigte sich aber auch ein deutlicher Einfluß der Abstammung der Bienen: Die Italiener-Hybriden waren signifikant stärker befallen als die Afrikanisierten Bienen (7.53 gegen 5.78 Milben je 100 Bienen. Dieser Unterschied war jedoch nicht so eindrucksvoll wie der zwischen den Klimagebieten.

***Varroa jacobsoni* / Einfluß des Klimas / Tropen / Afrikanisierte Biene**

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