Comparative Resistance of Four Honey Bee (Hymenoptera: Apidae) Stocks to Infestation by *Acarapis woodi* (Acari: Tarsonemidae)

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ABSTRACT The prevalence, mean intensity, and abundance of *Acarapis woodi* (Rennie) in 4 selected stocks of honey bees (*Apis mellifera* L.) were monitored under field conditions. The test stocks used were ARS-Y-C-1 (*A. mellifera carnica* imported from Yugoslavia), Hastings (*A. mellifera carnica* imported from northern Saskatchewan), F_1 hybrid between ARS-Y-C-1 and Hastings, and Louisiana stock available at the Baton Rouge laboratory apiaries. Two trials were conducted. The 1st trial used 20 colonies per stock and continued for 2 yr. The 2nd trial used 10 colonies per stock and was monitored for 1 yr. Results of both trials showed that ARS-Y-C-1 and F_1 hybrids consistently maintained approximately a 10% level of *A. woodi* infestation, which is below the level that causes economic damage to host colonies. These stocks also had significantly lower mean intensities of mites than the Hastings and Louisiana bees. *A. woodi* was least abundant in the F_1 hybrid. Similar numbers of mites per bee were found in ARS-Y-C-1, Hastings and Louisiana stocks. These observations suggest that both ARS-Y-C-1 and F_1 hybrids are resistant to *A. woodi*.

KEY WORDS *Apis mellifera, Acarapis woodi*, honey bee, tracheal mite, resistance

AMONG THE 3 *Acarapis* species known to be specific to *Apis mellifera* L., the honey bee tracheal mite *Acarapis woodi* (Rennie), is the most studied species because of its damage to bee colonies by shortening the longevity of infested adult bees (Bailey 1958, Maki et al. 1988, Royce and Rossignol 1990). However, no decreased longevity was observed by Gary and Page (1989). High winter losses are also associated with high levels of infestation (Eischen 1987, Eischen et al. 1989, Furgala et al. 1989, Otis and Scott-Dupree 1992).

Resistance (ability of honey bees to maintain infestation lower than the economic threshold level) to tracheal mite infestation by different stocks of honey bees has been well documented (Adam 1968, Gary and Page 1987, Gary et al. 1990, Page and Gary 1990, Milne et al. 1991, Szabo et al. 1991, Williams et al. 1994, Danka et al. 1995, de Guzman et al. 1996, Lin et al. 1996) and seems to be a promising alternative control measure.

The current study was conducted to monitor trends of natural populations of *A. woodi* in 4 stocks of honey bees infested with *V. jacobsoni* and to further assess their resistance to *A. woodi*.

Materials and Methods

With the wide distribution of the 4 parasitic mites of honey bees in the United States, exclusive maintenance of 1 mite species for experimental purposes is impossible. Therefore, in our colonies maintained for *V. jacobsoni* research (de Guzman et al. 1996), the seasonal trends of *A. woodi* infestations were also monitored. Four selected stocks of *A. mellifera* were used: ARS-Y-C-1 (*A. mellifera carnica* imported from Yugoslavia), Hastings (*A. mellifera carnica* imported from northern Saskatchewan, Canada), F_1 hybrids between ARS-Y-C-1 and Hastings, and Louisiana bees from the Baton Rouge bee laboratory apiary. Queens from each stock were instrumentally inseminated with 8 μl of semen of the appropriate type and established in two-super Langstroth hives. Two trials were conducted. On 8 June 1990 before the study commenced, all colonies for the 1st trial were treated with fluvalinate (Mavrick Aquaflow; Sandoz, Des Plaines, IL) and 50 g menthol per colony to control *V. jacobsoni* and *A. woodi*, respectively. Fluvalinate treatment was conducted as described by Kulinčević et al. (1991). Methol pellets were placed in nylon mesh bags and placed on the bottom boards. Colonies for the 2nd trial were likewise treated with fluvalinate on 10 July 1991 before the experiment commenced to lessen *V. jacobsoni* populations but no menthol treatment was applied. Thereafter, no treatment to control mites was applied. The 1st trial was conducted from July 1990 to June 1992, using 20 colonies per stock, and the 2nd trial from September 1991 to August 1992, using 10 colonies per stock. Both trials were conducted in northern Florida.

Test colonies were not inoculated with *A. woodi*. Instead, initial infestations of *A. woodi* in all colonies were determined by examining 30 bees per colony before the colonies were treated with chemicals. The presence of different developmental stages of mites was determined under a dissecting microscope at 30–60× magnification. Examination of bees for *A. woodi* was done using thoracic dissection (Lorenzen and Gary 1986). The honey bee tracheal mite prevalence

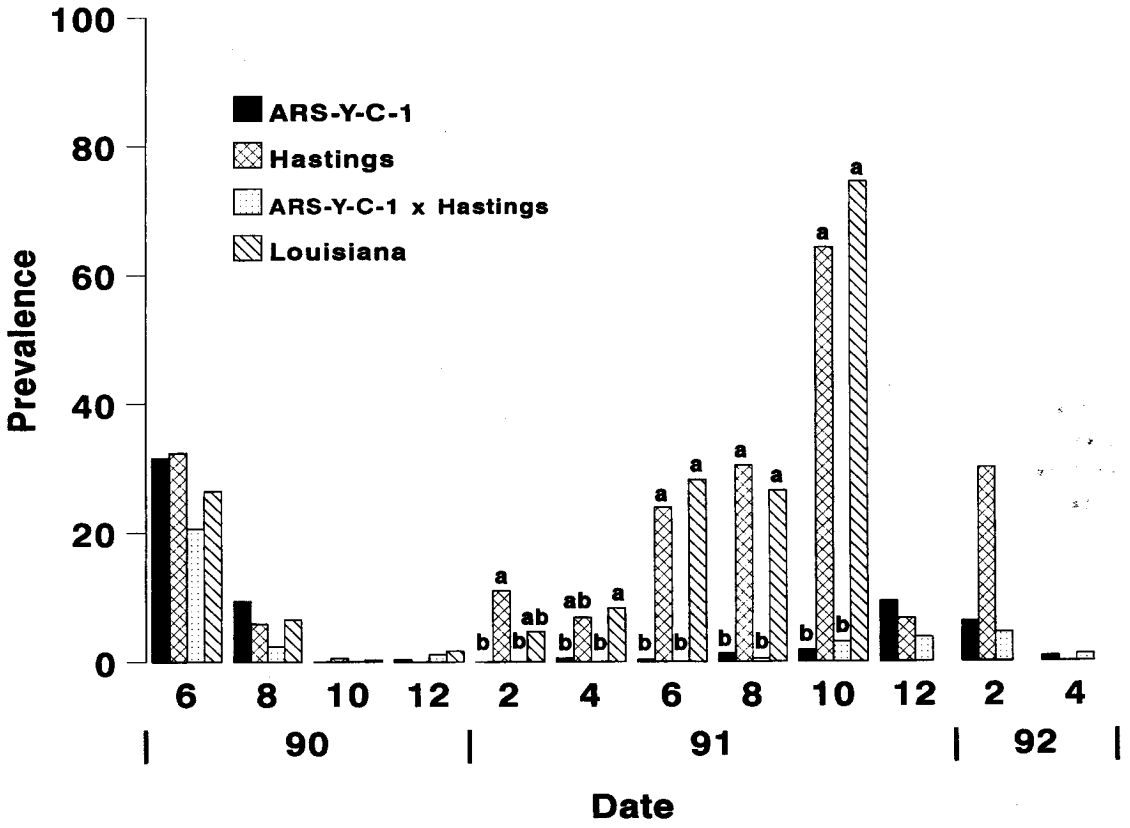

Fig. 1. Prevalence of *A. woodi* for trial 1 (June 1990 to April 1992). Unlabeled groups of stocks within months do not differ significantly. Bars with different letters indicate means are significantly different when confidence limits do not overlap.

(proportion of adult workers infested), mean intensity (number of mites per infested bee), and mite abundance (number of mites per bee) were recorded. Bees were sampled every 2 mo.

Data on *A. woodi* prevalence, mean intensity, and abundance through time were subjected to analysis of variance (ANOVA) for repeated measures using the mixed procedure (SAS Institute 1992). For trial 1, two separate analyses on the prevalence data were conducted; the 1st for data from August 1990 to October 1991 when all 4 stocks were represented, and the 2nd for data from December 1991 to April 1992 when only 3 stocks remained alive. Colonies were excluded from the experiment when supersedure or queenless conditions were observed.

The data on these colonies were excluded from the analyses becaue of the small sample size. Before analysis, data for the prevalence were transformed using the arcsine transformation to make variances homogeneous. Square-root transformation was used on data concerning the mean mite intensity and abundance. Means were considered significantly different when their 95% CL did not overlap. Initial infestations of colonies were analyzed using a randomized block design (general linear procedure, SAS Institute 1990). LIFETEST log rank chi-squared was used to test the relationships between colony longevity and the prevalence of *A. woodi* during the last month before death of colonies (SAS Institute 1990).

Results

***Acarapis woodi* Prevalence.** In trial 1, highly significant interactions between stock and sampling month and stock differences were observed when the 4 stocks were present (Fig. 1; Table 1). No differences on both variables were also detected toward the end of the experiment when only 3 stocks were present (Fig. 1; Table 1). When the experiment was initiated, *A. woodi* prevalences in all the groups of colonies receiving queens of the test stocks were similar ($F = 0.76$; df = 3, 49; $P = 0.52$) ranging from 20.6 ± 6.1 to 32.4 ± 6.9% (mean ± SE). At this time, the colonies had adult bees of commercial stocks and queens of the test stocks. There was a decline in *A. woodi* prevalence in August 1990, probably as a result of the menthol and fluvalinate treatments administered in June before the experiment was initiated. Thereafter, tracheal mite prevalences in the ARS-Y-C-1 and hybrid colonies continued to decrease and were maintained at low levels throughout the experimental period. Likewise, ARS-Y-C-1 and the F_1 hybrids never reestablished the initial tracheal mite prevalence found in the colonies before the production of the workers bees of these test

Table 1. Results of ANOVA of *A. woodi* infestations among 4 stocks of honey bees

Parameter	Source of variation	*F*	df	*P*
A. woodi prevalence	Month	16.85 (8.71)	7 (2)	<0.001 (0.017)
	Stock	11.82 (0.12)	3 (2)	<0.001 (0.892)
	Month × Stock	4.70 (2.35)	21 (4)	<0.001 (0.167)
A. woodi intensity	Month	8.34	5	<0.001
	Stock	3.20	3	0.025
	Month × Stock	2.69	15	0.001
A. woodi abundance	Month	10.13	6	<0.001
	Stock	3.88	3	0.010
	Month × Stock	2.70	18	<0.001

Numbers inside parentheses are values for trial 2.

stocks. In February 1991, prevalence in the Louisiana and Hastings stock started to increase, reaching a maximum in October, just before the death of the last Louisiana colonies. For the Hastings stock, there was a drop in mite prevalence during December, a recovery to a high level in February, and an abrupt decline in April until the last colony died in June.

In trial 2, the interaction between the stock and sampling month was also highly significant (Fig. 2; Table 1). At the start of the experiment, the prevalence of *A. woodi* was significantly higher in the Louisiana bees as compared with <10% in the other 3 stocks. Tracheal mite prevalence remained significantly higher in the Louisiana stock with its peak recorded in October. Prevalence then started to decline with a distinct drop in April until the end of the experiment. *A. woodi* prevalence in the Hastings stock increased gradually with the highest prevalence observed in February. As in trial 1, ARS-Y-C-1 and the F_1 hybrids maintained <15% prevalences throughout the

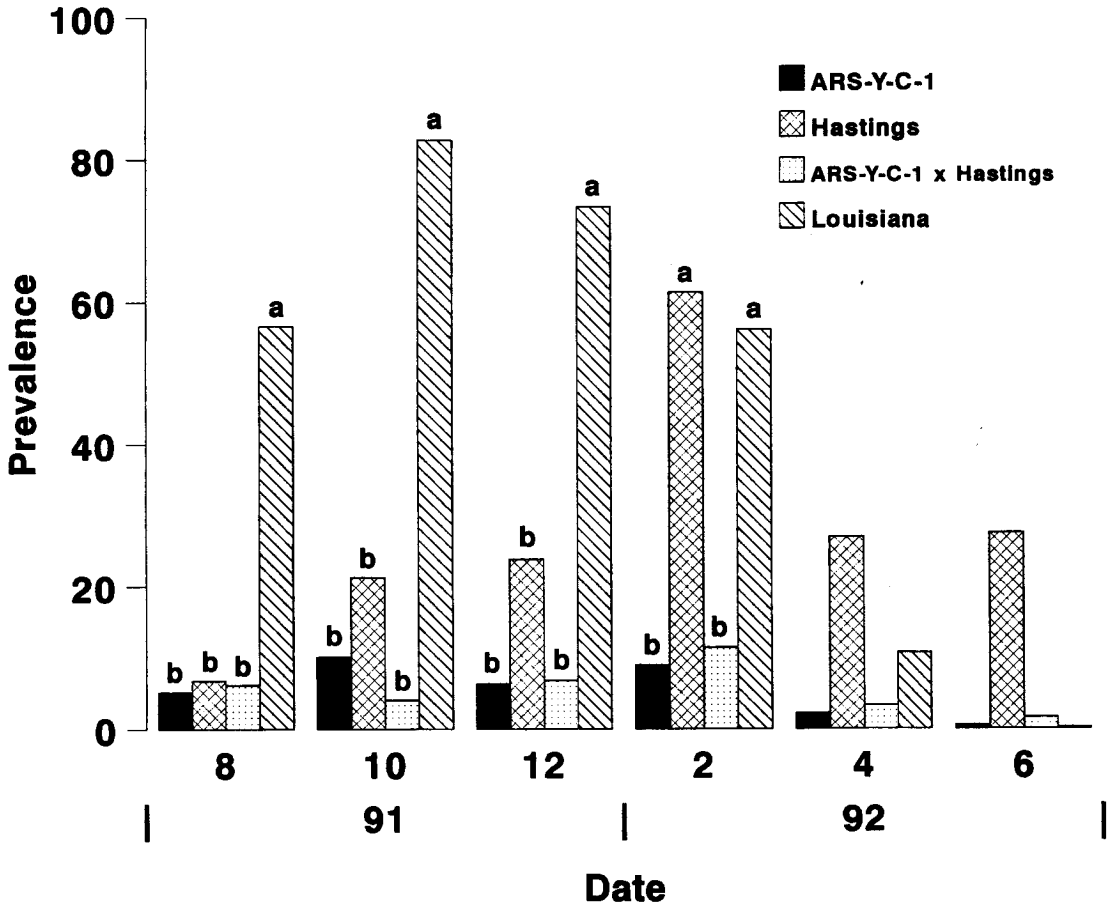

Fig. 2. Prevalence of *A. woodi* for trial 2 (August 1991 to June 1992). Unlabeled groups of stocks within months do not differ significantly. Bars with different letters indicate means are significantly different when confidence limits do not overlap.

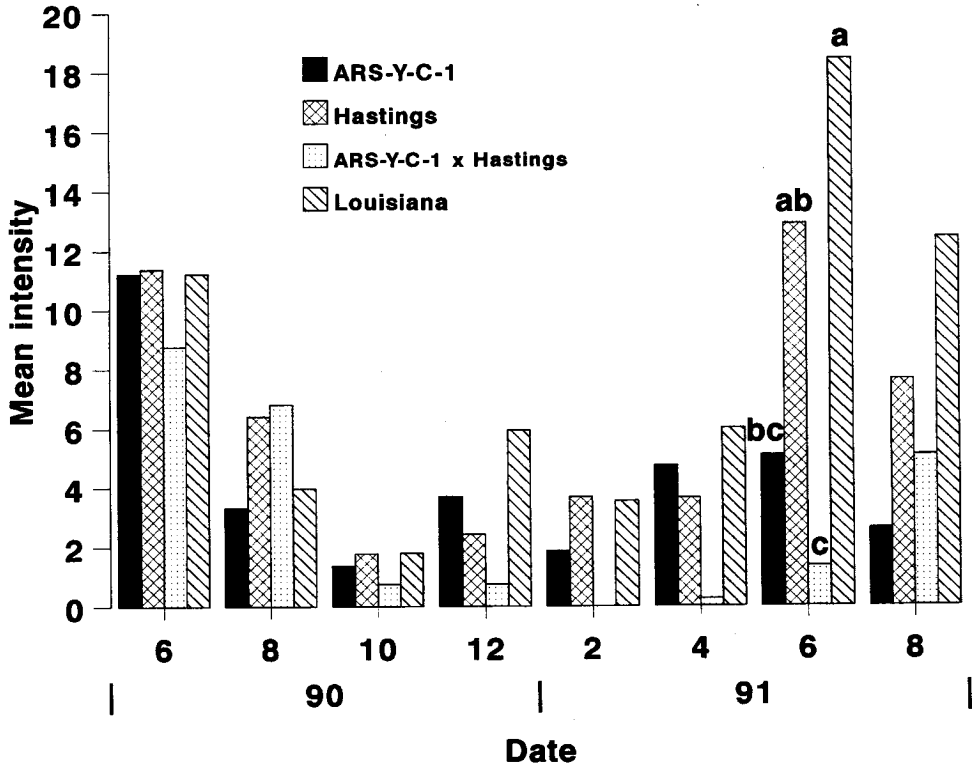

Fig. 3. Mean intensity of *A. woodi* for trial 1 (June 1990 to August 1991). Unlabeled groups of stocks within months do not differ significantly. Bars with different letters indicate means are significantly different when confidence limits do not overlap.

experimental period. Only 1 colony of the F_1 hybrid and Louisiana stocks survived through the end of the experiment in August 1992 thus, these data were not included in the analysis because of the small sample size.

***Acarapis woodi* Mean Intensity.** The mean intensity (number of *A. woodi* per infested bee) was monitored from June 1990 to August 1991 for trial 1 only. Results revealed a significant interaction between the stocks and sampling month (Fig. 3; Table 1). The mean mite intensity in all colony groups receiving test queens was not significantly different ($F = 0.41$; df = 3, 47; $P = 0.74$) before the experiment began which ranged from 8.8 ± 1.8 to 11.4 ± 2.1 mites per infested bee. The number of mites in all stocks gradually decreased, probably because of the menthol and fluvalinate applications, with a minimum recorded in October. In December, mean intensity steadily increased with a distinct peak observed in June for both Hastings and Louisiana stocks. Infested bees from these stocks had ≈13–18 mites. Number of mites decreased again in August. Infested bees from the F_1 hybrid and ARS-Y-C-1 stocks had fewer numbers of *A. woodi*.

***Acarapis woodi* Abundance.** The number of *A. woodi* per bee was monitored from August 1990 to August 1991 for trial 1 only. Results showed a significant ($P < 0.01$) interaction between the stocks and sampling month (Fig. 4). The abundance of *A. woodi* in all stocks remained low from August to April with a distinct peak recorded in June for both Louisiana and Hastings stocks. The average number of mites per bee from these stocks was 3–4 mites. *A. woodi* abundance in the hybrid colonies averaged 2 mites per worker bee. The abundance of *A. woodi* remained low in the ARS-Y-C-1 with an average of 1 mite per bee.

Number of Colony Survivors. The number of colonies that were alive during each sampling period is presented in Table 1. Results showed that longevity of the queens or colonies did not differ significantly (log-rank $\chi^2 = 2.10$, df = 3, $P < 0.55$) among the stocks (de Guzman et al. 1996). Likewise, colony longevity was not associated with *A. woodi* infestations (log-rank $\chi^2 = 0.73$, df = 3, $P < 0.39$).

Discussion

Based on this field evaluation (2 yr for trial 1 and 1 yr for trial 2) conducted in Florida, ARS-Y-C-1 and the F_1 hybrids consistently displayed resistance to *A. woodi* parasitism, as reported by Rinderer et al. (1993). Infestations in these stocks were maintained at ≈10% level with low mean intensity of mites throughout the experimental periods. This observation corroborates recent results of field tests conducted by Danka et al. (1995) in Mississippi, Texas, Iowa, and Minnesota, by Williams et al. (1994) in Kentucky, and in a bioassay

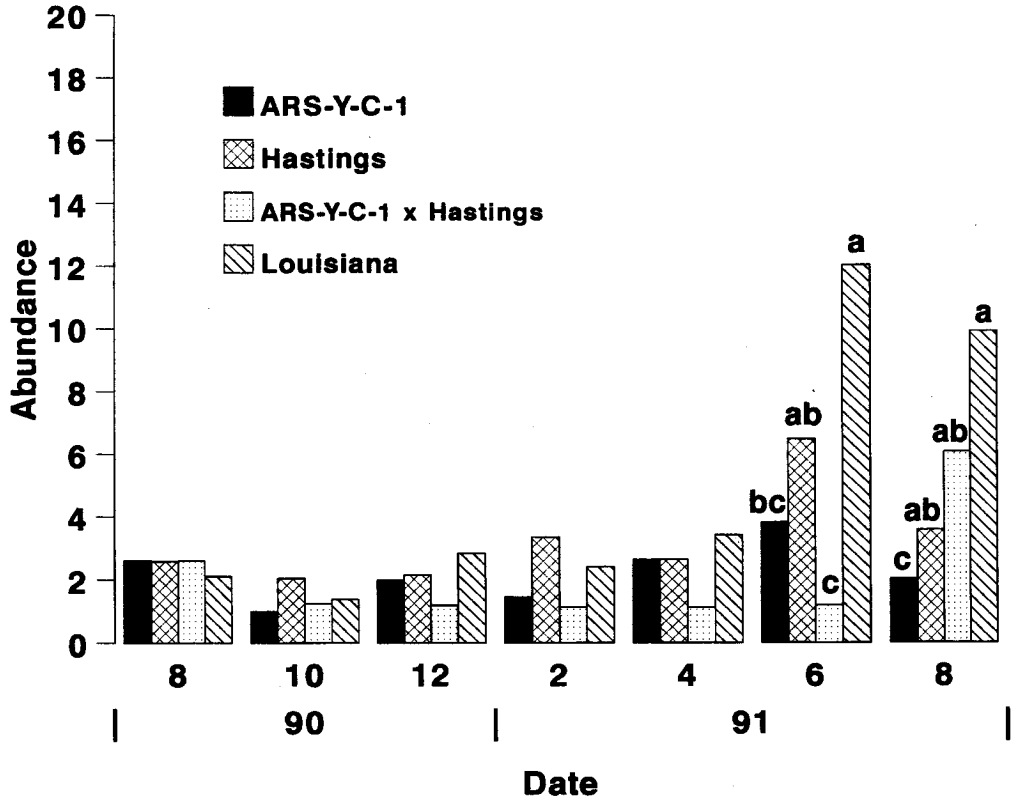

Fig. 4. Mean abundance of *A. woodi* for trial 1 (August 1990 to August 1991). Unlabeled groups of stocks within months do not differ significantly. Bars with different letters indicate means are significantly different when confidence limits do not overlap.

conducted in Louisiana (de Guzman et al. 1996). Although the Hastings stock did not show any level of resistance beyond that of the ARS-Y-C-1, the resistance observed in the F_1 hybrids indicates that the genes conferring resistance to ARS-Y-C-1 and their hybrids may be dominant in this cross. Levels of *A. woodi* infestation above 25% cause economic damage in bee colonies (Eischen et al. 1989, Otis and Scott-Dupree 1992). Because our results showed symbol 187 10% infestations in the ARS-Y-C-1 and F_1 hybrid colonies, this study suggests that colonies of these stocks may require fewer treatments or no treatment for tracheal mite control.

Table 2. Number of colonies alive at each sampling period

Date	ARS-Y-C-1 (Y)	Hastings (H)	F_1 Hybrid (Y × H)	Louisiana
		Trial 1		
June 1990	15	12	16	12
Aug. 1990	14	12	16	11
Oct. 1990	14	12	16	11
Dec. 1990	11	9	11	9
Feb. 1991	11	9	11	9
April 1991	10	9	10	8
June 1991	10	5	5	6
Aug. 1991	7	3	4	2
Oct. 1991	3	2	3	1
Dec. 1991	2	1	3	0
Feb. 1992	2	1	3	0
April 1992	2	1	1	0
June 1992	2	0	1	0
		Trial 2		
Aug. 1991	9	9	10	7
Oct. 1991	9	9	10	7
Dec. 1991	9	9	10	6
Feb. 1992	9	9	9	5
April 1992	7	9	8	4
June 1992	4	7	5	3

The longevity of the colonies was not associated with *A. woodi* infestations. However, the longevity of these colonies were influenced by the infestations of *V. jacobsoni* as reported by de Guzman et al. (1996). De Guzman et al. showed that Louisiana stock, which had low tolerance to *V. jacobsoni*, had high prevalence of *A. woodi*. This stock died earlier with low levels of *V. jacobsoni* as compared with ARS-Y-C-1 and F_1 hybrid, which lived longer despite high *V. jacobsoni* infestations in the colonies. It is possible that the reported high *V. jacobsoni* tolerance index by ARS-Y-C-1 and F_1 hybrid was influenced by low prevalence of *A. woodi*. Its is known that *A. woodi* reduces the longevity of infested bees (Bailey 1958, Maki et al. 1988, Royce and Rossignol 1990). In our study, the interaction of these 2 parasitic mites in the colonies

was not tested. The effects of concurrent infestations of *A. woodi* and *V. jacobsoni* on the longevity or performance of honey bee colonies and also their interaction with environmental factors have yet to be investigated.

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