colonies have become Africanized. Monitoring will continue as levels of Africanization are expected to increase with time. We thank B. Underwood, Texas A&M University, and all members of the USDA, ARS laboratory who assisted with the survey.

3. **Danka, R.G.,[c] J.D. Villa,[c] & N.E. Gary[d] – COMPARATIVE FORAGING DISTANCES OF AFRICANIZED, EUROPEAN AND HYBRID HONEY BEES DURING CANTALOUPE POLLINATION** – An undocumented characteristic of the foraging behavior of Africanized honey bees is their foraging distance on a target crop. Knowing the distance at which colonies forage is important for determining hive locations in agricultural settings that maximize pollination efficiency yet minimize interactions of bees with humans.

Foraging ranges were compared for Africanized, European and hybrid colonies used for commercial pollination of cantaloupe during January and February 1992 in Guanacaste Province, Costa Rica. Colonies were located near the ends of 900-m-long plots in a 13-ha field of the cultivar 'Mission, hybrid'. Randomly chosen foragers ($n = 2398$) were tagged with ferrous discs during six mornings at sampling stations located 0-50, 250, 550 and 800 m from study colonies. Tags ($n = 651$) were recovered with magnetic traps at entrances of 10 colonies per bee type. Other tagged bees presumably returned to managed and feral colonies without traps.

Africanized bees consistently foraged closer to their nests (e.g., 71% of all Africanized bees versus an average of 47% of all European and hybrid bees were tagged at ≤50 m; see figure). Differences in foraging distance between Africanized bees and the two other bee types occurred for total foragers ($P \leq 0.001$ by chi-square analysis), pollen foragers ($P \leq 0.001$) and nectar foragers ($P \leq 0.049$). European and hybrid bees had similar foraging ranges within each resource class ($P = 0.12$, 0.16 and 0.51 for total, pollen and nectar foragers, respectively). The percentage of foragers collecting pollen was similar for the three bee types (overall 62 ± 4% [$\bar{x} \pm$ sd]). Pollen collectors overall foraged over longer distances than nectar collectors did.

The results suggest that in pollination settings the relatively shorter foraging distances of Africanized bees may aggravate the well documented problems of greater defensive behavior and difficult management. Shorter foraging distances may require that colonies be distributed closer to target crops (thus threatening field workers), more uniformly, and with less distance between apiaries.

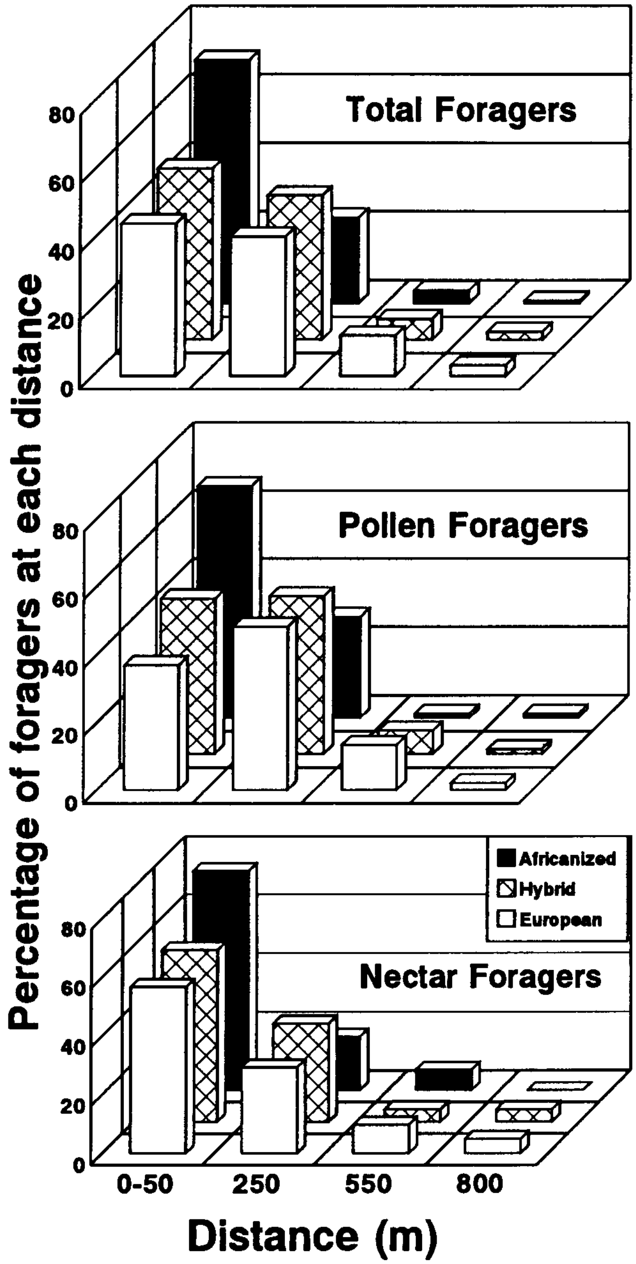

Figure – For each of three bee types, the percentages of bees that foraged at four distances from colonies in a cantaloupe field.

4. **de Guzman, L.I.,[b] T.E. Rinderer,[c] B.P. Oldroyd,[c] S. Wongsiri,[e] & H. A. Sylvester – SURVIVAL OF *VARROA JACOBSONI* ON ASIAN HONEY BEES** – The survival of Varroa jacobsoni on four Asian honey bees (*Apis andreniformis*, *A. cerana*, *A. dorsata*, and *A. florea*) was investigated. Five worker bees from each bee species were placed separately in plastic cages (*ca.* 7.5 cm long and 2.5 cm in diameter) and inoculated with 3-5 mites per cage using a soft brush to place mites directly on the bees. The cages were individually wrapped with cotton cloth and plugged with cotton balls. All treatments were maintained at room temperature (26 ± 0.1°C). After 24 h, live and dead mites were counted and examined under a microscope for injuries. Additionally, we conducted a field survey to determine the natural occurrence of *Varroa* mites on these Asian bee species.

The proportion of *Varroa* mites that survived on the four *Apis* species for 24 h did not differ significantly ($\chi^2 = 5.778$; df = 3; $P = 0.123$)(Table). Mites were found on different parts of bees' bodies. Some mites were noted on the abdomen, thorax, legs, wings, and between head and thorax. However, most mites were observed between the thorax and abdomen (for *A. andreniformis* and *A. florea*). This area is probably used for mites' protection during the bees' flight. Concealed mites between the sternites were noted on *A. cerana* only. No injured mites were observed.

In our mite survey, *Varroa* was found in 11 *A. cerana* colonies (n = 26) from the Philippines and from two *A. andreniformis* colonies (n = 22) from Thailand. One *A. andreniformis* sample had a high infestation (32 mites on *ca.* 50 bees), while the other sample had only one mite. That *Varroa* had probably

Table – Survival of *V. jacobsoni* on four Asian species of honey bees.

Bee species	Live mites	Dead mites	Total*	% Survival
A. andreniformis	11	11	22	50
A. cerana	12	6	18	67
A. dorsata	5	13	18	28
A. florea	10	8	18	56

*total for two trials with 2-3 cages per bee species inoculated with 3-5 mites colonies have become Africanized. Monitoring will continue as levels of Africanization are expected to increase with time. We thank B. Underwood, Texas A&M University, and all members of the USDA, ARS laboratory who assisted with the survey.

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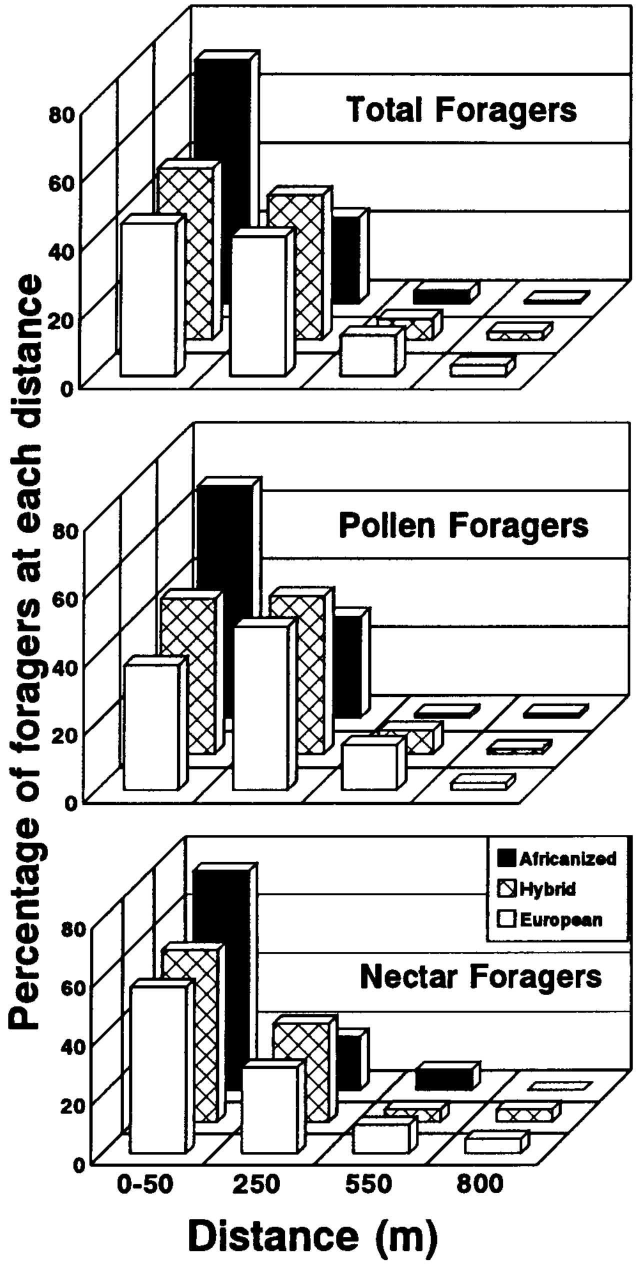

Figure – For each of three bee types, the percentages of bees that foraged at four distances from colonies in a cantaloupe field.

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4. de Guzman, L.I.,[h] T.E. Rinderer,[c] B.P. Oldroyd,[c] S. Wongsiri,[e] & H. A. Sylvester – **SURVIVAL OF *VARROA JACOBSONI* ON ASIAN HONEY BEES** – The survival of Varroa jacobsoni on four Asian honey bees (*Apis andreniformis, A. cerana, A. dorsata,* and *A. florea*) was investigated. Five worker bees from each bee species were placed separately in plastic cages (*ca.* 7.5 cm long and 2.5 cm in diameter) and inoculated with 3-5 mites per cage using a soft brush to place mites directly on the bees. The cages were individually wrapped with cotton cloth and plugged with cotton balls. All treatments were maintained at room temperature (26 ± 0.1°C). After 24 h, live and dead mites were counted and examined under a microscope for injuries. Additionally, we conducted a field survey to determine the natural occurrence of *Varroa* mites on these Asian bee species.

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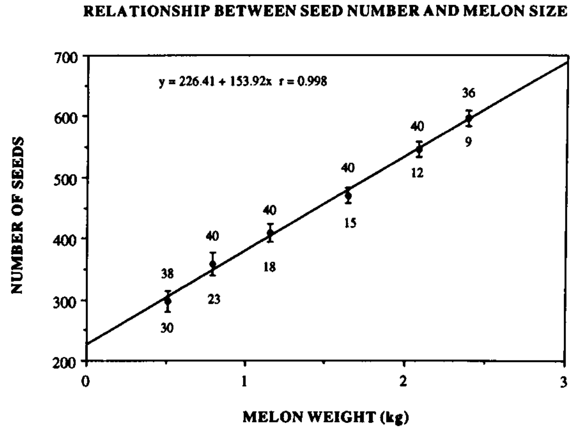
*total for two trials with 2-3 cages per bee species inoculated with 3-5 mites developed and reproduced in these colonies was indicated by the presence of two young adult mites. This is the first record of *Varroa* in *A. andreniformis*. No *Varroa* mites were found on *A. dorsata* (n = 9) or *A. florea* (n = 16).

This observation suggests that dwarf honey bees (*A. andreniformis* and *A. florea*) can be potential hosts of *V. jacobsoni* which was confirmed by our survey results showing infestations in two *A. andreniformis* samples.

5. Eischen, F. A.[b] & B. A. Underwood[b] – FRUIT QUALITY, SEED SET, AND POLLINATION OF CANTALOUPES – Fruit quality was monitored in eight fields of cantaloupes (var. Cruiser) in the Rio Grande City, TX area. Fields were direct seeded on 80-inch (2 meter) beds that had previously received drip irrigation lines and black plastic mulch. Fields ranged from 18-102 acres. At, or near peak harvest, five melons from each of six size classes (30, 23, 18, 15, 12, & 9) were randomly selected. Significant correlations were found between melon weight and seed number (see figure), total seed weight, and mean seed weight. Soluble solids (strongly correlated with sugar content) were significantly correlated with melon weight, seed number, total seed weight, and mean seed weight. Mean seed weight was the most consistent indicator of melon quality; in all cases it was significantly correlated with melon weight and soluble solids. The sugar content of melons from a single field (Los Puertos, E-2-4) was examined. Sucrose was found to be significantly correlated with the number of seeds, total seed weight and mean seed weight. No significant correlations were found with either glucose or fructose. These data support our 1991 study with Primo cantaloupes, another commonly planted variety in the Lower Rio Grande Valley.



Data points represent means for six size classes (indicated by numerals below points.) Numbers above SE bars indicate sample size. Correlation was calculated from the means only.

6. Eischen, F. A.[b] & B. A. Underwood[b] – THE EFFECT OF DELAYED POLLINATION ON CANTALOUPE PRODUCTION – At what stage in a cantaloupe plant's growth should it be pollinated for optimum fruit set? If the plant grows larger before setting melons, will yield change? To answer these questions, three varieties of cantaloupe commonly planted in the Lower Rio Grande Valley, viz., Cruiser, Explorer, and Primo, were either left uncovered, covered for six days at the onset of female flowering, or covered for 12 days with Reemay floating row covers. In all three varieties, the number of melons/plant was significantly increased by delaying pollination 12 days. However, the percentage of culled fruit increased significantly in the Cruiser and Primo varieties. Though there were more Explorer fruit, they were significantly smaller. Delaying pollination by six days in Primo melons resulted in a significant increase in fruit/plant and fruit size. Fruit quality was equivalent to that of fruit produced by uncovered plants. Cruiser and Explorer varieties followed the trend observed in the plants delayed 12 days, i.e., more fruit/plant, but fruit were smaller. We speculate that delaying pollination is associated with increased female flowering, resulting in increased fruit set. The ability to produce quality fruit, however, is uneven and may be variety-related.

7. Ellis, M. D.[f] & F. P. Baxendale[a] – COMPARISON OF FORMIC ACID SAMPLING WITH OTHER METHODS USED TO DETECT VARROA MITES – Formic acid was compared with 5 other commonly used sampling methods: ether roll, drone scratch, tobacco smoke, Apistan and examination of debris falling from untreated colonies. All colonies used were known to be infested (range of 1 to 9 mites on preliminary ether roll test). Ether roll sampling was done using a sample size of approximately 400 bees. For drone scratches, 75 drone pupae were removed with a capping scratcher and examined. Tobacco smoke, Apistan, formic acid, and debris sampling were done by placing DeWill Sticky Boards on the bottom board and covering with a wire screen. Sticky boards were removed and read after 24 hours. Tobacco smoke sampling was done by burning tobacco leaves in a smoker and applying 5 puffs of smoke at 3 minute intervals for 3 times. Apistan sampling was done by placing 2 strips in colonies as per label instructions. Formic acid sampling was done by applying 40 ml of 65% formic acid to an absorbent pad placed on the top bars of two story colonies. Debris sampling was done by reading sticky boards with no treatment.

Another test was conducted to monitor the mite drop over a 5 day period following formic acid treatment. Mites were counted on sticky boards after 1, 8, 24, 48, and 120 hours. After 120 hours, 2 Apistan strips and new sticky boards were

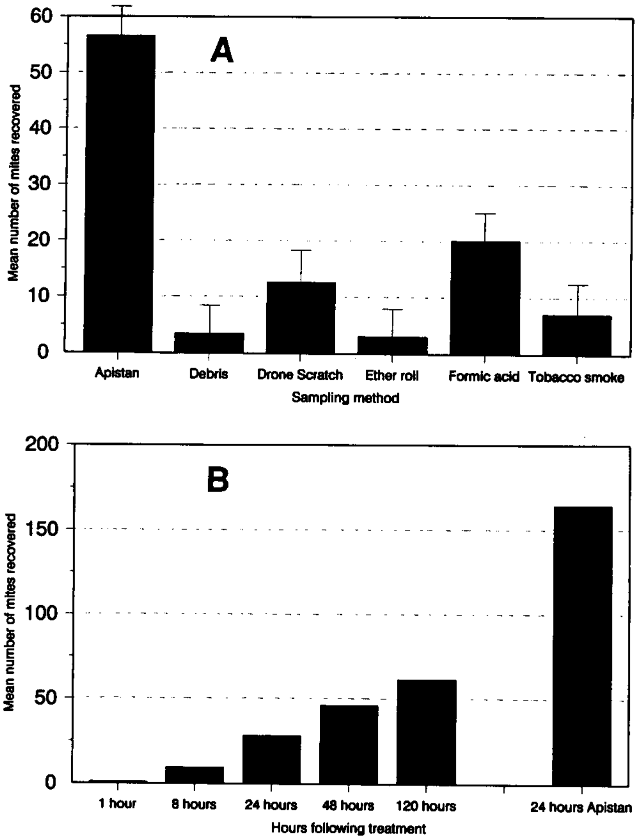


Figure – (A). Sampling sensitivity of 6 methods used to detect varroa mites (n = 44). Apistan® was significantly better than all other methods. Formic acid sampling was better than ether roll and debris sampling. Differences in the other methods were not significant (LSD, Alpha = .05). (B). Cumulative mite drop over time following treatment with 40 ml of 65% formic acid (n = 10). The response to formic acid was not rapid enough to recommend it as a quick method of checking colonies for varroa mites.

placed in all colonies. These sticky boards were removed and read after 24 hours to give an indication of the number of mites remaining on adult bees.

Apistan sampling was significantly better than all other methods (see figure for results). Formic acid sampling may be a useful tool to check colonies for varroa mites; however, it does not cause a rapid mite drop. When used, observers must wait at least 24 hours before reading sticky boards for the test to be more sensitive than other commonly used methods.

It appears that a longer post application sampling period would increase the ability of formic acid sampling to detect mites relative to other sampling methods. However, because of excessive costs and accumulation of debris on the sticky boards, tests that require more than 24 hours were not considered.

8. Harbo, J. R.[c] — EFFECT OF HIVE COLOR ON POPULATIONS OF HONEY BEES AND TRACHEAL MITES — Color on the outside of a hive affects the temperature on the inside. Of the finishes tested (aluminum paint, a reflective coating, and various colors of paint) white paint provided the coolest interior temperature.

Single-story Langstroth hives made of unpainted wood that had been dipped in hot paraffin were compared in a sunny location with identical hives that had been painted white. Twenty-four uniform colonies of 5048 ± 125 (mean ± SD) bees were established by subdividing a population of bees that had been collected into one large cage. When bees were added to the hives on 8 May, the 5 preweighed combs contained honey and pollen, but no brood.

During summer, bees produced more brood and honey in the white hives than in the dark hives (see table). Midday, temperatures in dark hives were 5 - 6°C (≈10°F) warmer than in white hives; temperatures were equal at night and on rainy days. Many times in June and July, the interior of dark hives exceeded 40°C (104°F), with maximum temperatures of 44.8° and 37.9°C recorded in the brood areas of dark and white hives, respectively.

On 5 August, when 30 bees from each hive were checked for tracheal mites, mites were found in 10 of the white, but in only 1 of the dark hives ($P < 0.01$). 8.6% of the bees in the white hives and 0.5% of the bees in the dark hives were infested, whereas 38% (45/120) of the bees had been infested on 8 May. Heat in hives may directly or indirectly reduce the survival, migration, or reproduction of tracheal mites.

Table — Comparing 12 colonies of honey bees in unpainted (dark) hives with 12 colonies in white hives. Data are mean ± SD.

Hive color	Number of capped cells 28 May	27 July	Adult population 5 August	Wt. loss[1] of combs 8 May–5 Aug.
white	4778±816	2753±613	6495±1207	32±580g
dark	4807±682	1601±492	5410±1295	902±347g
Prob.[2]	0.93	0.0001	0.016	0.0001

[1] This weight included pollen, honey, and brood.

[2] Probabilities that the means for dark and white colonies represent the same population. Statistical anlyses were part of a 2 × 2 factorial analysis of variance where an additional variable (queen genotype) and an interaction were part of the analysis.

9. Harbo, J. R.[c] & R. T. Daniel[c] — OVARY DEVELOPMENT OF WORKER BEES CAGED ALONE OR IN PAIRS IN AN INCUBATOR — Newly emerged, adult worker bees were placed into wooden cages (8 × 8 × 9 cm) and kept in an incubator (34°C, 50% RH). One gram each of pollen and honey was put into cells near the top of a comb (8 × 5 cm) that was inside the cage. Water was fed from an inverted vial at the top of the cage. A preliminary study showed that bees were more likely to lay eggs when pollen was available in the comb than when it was fed in vial caps at the bottom of the cage.

The first study compared ovary development of bees caged alone with that of bees caged in pairs. Twelve source colonies were used. Three newly emerged worker bees were taken from each source colony; one of the three workers was caged alone and the other two were together. Ovary development of each bee was evaluated 14 days later by measuring the diameter of the largest ovariole. The mean ovary development of two bees in a cage was compared with ovary development of the bee caged alone. Combs were examined daily for eggs.

Ovary development was significantly greater in worker bees that were caged in pairs than in workers caged alone. Ovary development was 0.21 ± 0.09 mm ($\bar{x} \pm$ SD) for paired bees and 0.09 ± 0.08 mm for bees alone in a cage (paired t test: $t = 3.8$, $df = 11$, $P = 0.003$). Ovary development ranged from undeveloped (0.03 mm) to a maximum of 0.33 mm for those containing eggs. Eggs were laid in 6 of the 12 cages that contained 2 workers but in none of the 12 cages with workers caged alone. Only once (in a different but similar study) did we observe egg laying from a worker that was caged alone.

A second experiment tested whether a bee caged with a supersister has ovary development that differs from a bee that is caged with an unrelated worker bee. The design consisted of 3 stocks in all 6 possible combinations of 2 bees. Ovary development did not depend on whether or not the two bees in a cage were related. Results suggested that some stocks may enhance or inhibit ovary development in other stocks (see table).

Table — Ovary development of bees that were caged with one other bee of the same age. Bees in the cage were either of the same stock (a supersister with a probably relatedness of 0.75) or from one of the other two stocks (unrelated) in both combinations. Data from each worker were the diameter of the largest ovariole measured after 14 days; below are mean (number of workers)

Stock[1]	With supersister	With unrelated worker
A	0.19 mm (8)	0.25 mm (9)
B	0.14 mm (10)	0.12 mm (10)
C	0.09 mm (10)	0.05 mm (8)

[1] The workers chosen for this experiment were daughters of queens mated to a single drone. They were not chosen at random. Stocks A and B were from colonies that had produced eggs in an earlier experiment. When caged with a supersister, stocks A and C were different at the 0.05 level; stock B was not different from the other two.

10. Harris, J. W.[1] & J. P. Woodring[1] — EFFECT OF QUEENLESSNESS ON LEVELS OF BIOGENIC AMINES IN THE BRAINS OF WORKER HONEY BEES — Levels of octopamine, dopamine and serotonin in the brains of worker honey bees have been shown to change with season, stress and source colony (Harris and Woodring, *J. Insect Physiol.* 38: 29-35), and age-related behaviors of workers might be mediated by changes in biogenic amine levels (Taylor *et al.*, *J. Comp. Physiol.* A 170: 715-721). Biogenic amines are also important in controlling learning and memory in honey bees (Bicker and Menzel, *Nature* 337: 33-39).

We investigated the effects of queenlessness on levels of octopamine, dopamine and serotonin in the brains of worker bees. We postulated that such a drastic change in social organization of the colony might result in changes within the honey bee central nervous system. In the first experiment (I) we formed two 5-framed nucs with equal worker populations placed in all colonies. These sticky boards were removed and read after 24 hours to give an indication of the number of mites remaining on adult bees.

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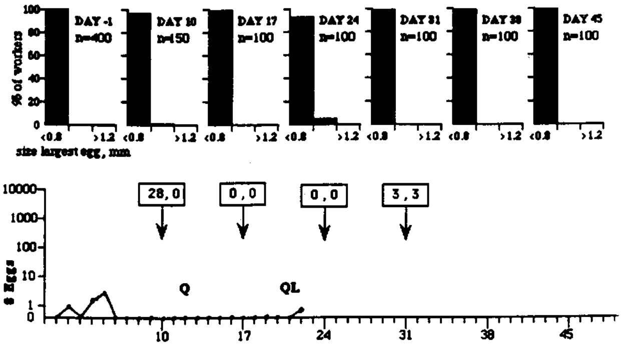
A computer simulation program has also been developed which gives sample realizations for this stochastic (Markov) model. The program is written using the MATHEMATICA software, and is available from J.M. Kiffe.

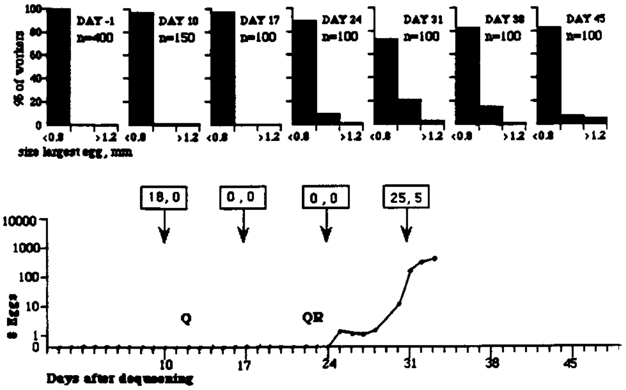
17. Miller, D. G.[s] & Ratnieks, F. L. W.[s] — ONSET OF WORKER REPRODUCTION IN QUEENLESS HONEY BEE COLONIES — Worker egg-laying eventually occurs in honey bee colonies which have lost their queen and have failed to rear a replacement. The data reported here are part of a study investigating ovarian development, egg-laying and egg-removal behavior in colonies following queen loss.

Four colonies were dequeened and split into two queenless portions, each housed in a small hive consisting of one frame of drone comb and 4 frames with worker sized comb. One of the two queenless colonies was allowed to requeen (ultimately queenright); the other was dequeened again one week after the virgin queen emerged (ultimately queenless). Weekly samples of workers were collected and dissected: the largest egg in the ovaries was measured and compared against a standard egg size of 1.6mm and classified into <.8mm, 8-1.2mm, and >1.2mm development categories. Drone frames were inspected daily for worker-laid eggs. Weekly egg-removal trials were run: 40 queen-laid male eggs and 40 worker-laid eggs from unrelated hives were introduced to the study hives and the rate of their removal noted after 24 hr (2 hr and 24 hr, 1992).

The figure presents results for one pair of ultimately queenright and queenless colonies. Egg-laying remains minimal for the ultimately queenright portions, but increases sharply after Day 28 in the ultimately queenless colony. "Q" refers to the virgin queen's emergence, "QL" to the onset of her laying, "QR" to her removal in the ultimately queenless colony. In the boxes are egg removal trial results: the number to the left is the percentage of queen-laid male eggs remaining after 24 hrs; to the right, that of the worker-laid eggs. The histograms represent the proportion of worker ovarian development (undeveloped, partially, fully developed).



ULTIMATELY QUEENRIGHT, COLONY G



ULTIMATELY QUEENLESS, COLONY G

The onset of worker reproduction in these assays is well-coordinated. In the egg-removal trials, worker-laid eggs were discriminated against vs queen-laid eggs, but both were removed completely in the second and third trials, suggesting a period of greater than normal removal. Both ovarian development and egg laying preceded increased acceptance of introduced eggs; this supports the idea of worker-worker conflict over onset of reproduction.

18. Nasr, M.E.,[m] G.W. Otis,[m] C.D. Scott-Dupree[m] and O. Welsh[m] — POTENTIAL USES OF CANADIAN HONEY BEES IN BREEDING FOR RESISTANCE TO TRACHEAL MITES — Following the realization that tracheal mites are serious economic pests of bees in North America (Otis and Scott-Dupree, *J. Econ. Ent.* 85: 40-46; Furgala *et al.*, *Am. Bee J.* 129: 195-197; Eischen, *Apidologie* 18: 293-304), numerous researchers and queen producers have initiated efforts to breed for resistance to tracheal mites. We have a major project underway which utilizes Canadian bees in two ways.

1. *Canadian bees as a standard stock against which to base comparisons.*

As tracheal mites have become widespread in the U.S., they have caused extensive mortality of colonies. The surviving colonies are presumably more resistant to the mites. In short, tracheal mites are exerting intense selection pressure for mite resistance over much of North America. The net result will be a shift in the genetics of North American bees, toward increasingly greater mite resistance. This makes it difficult if not impossible to evaluate progress in selecting for resistance.

To overcome this problem, we established a Canadian standard stock (CSS) to serve as a basis for comparison in our evaluation of mite resistance. The CSS originated with 32 colonies established in an isolated site (Tobermory, Ontario). Colonies were requeened with queens obtained from six Ontario queen producers, or daughters of those queens open-mated in Guelph. We planned to make this a closed breeding population, but that goal has not yet been realized because of repeated hive depredation by bears and heavy winter mortality (20-25%). Replacement queens have come from the same beekeepers, or have been daughter queens open mated in Tobermory. We plan to "close" the population in 1993, and can be contacted by other researchers who require the stock for evaluations of resistance.

We have utilized this stock in our comparisons of British stock imported by Roger Morse (Morse, *Am. Bee J.* 130: 106-107, 116-120) and Buckfast bees (imported from England and Weaver's commercial stock) (see Lin *et al.*, Abstract # 13, this issue).

2. *Canadian bees as breeding material.*

One of the results of our evaluations of the British bees is the observation that Canadian bees exhibit extreme variation (*e.g.*, the best and the worst colonies we evaluated). Such high variation suggests that selection to improve resistance is likely to be successful. Consequently, we have initiated a selection program utilizing the CSS and British bees. Based on both bioassay and field test results, we selected colonies with high and low resistance, raised daughters, and instrumentally inseminated them with single drones. Colonies with these queens were overwintered, but all the colonies with low resistance died.

We are continuing to develop the high line. We will test the third generation this fall. We are realizing progress in our breeding and will complete evaluations in 1993.

19. Oldroyd, B. P.,[c] W. S. Sheppard,[t] & J. A. Stelzer[c] — POPULATION GENETICS OF THE HONEY BEES OF KANGAROO ISLAND — On Kangaroo Island, South Australia, a population of Italian bees, *Apis mellifera ligustica*, was introduced in 1884. These bees did not come directly from Italy, but spent some time on the mainland, either in Sydney or Brisbane, before being taken to the island. Since then the bee's genetic integrity has been preserved by the *Ligurian Bee Act* and a 20 km stretch of ocean.

Whether or not these bees are indeed pure Italian bees (*A. m. ligustica*) or some kind of hybrid dating from last century or from more recent illegal imports is of great interest. If the bees are a direct lineage from Italy, then they represent an important reference population for studies of racial variation in honey bees and may have considerable commercial value in crosses with other strains.

To study the racial origin of these bees, specimens were collected from each of 25 Kangaroo Island colonies. Based on ten bees per colony, allelomorph relative frequencies for the Kangaroo Island population were: MDH enzyme system Mdh^{65} = 0.13, Mdh^{80} = 0.11 and Mdh^{100} = 0.76; esterase system (five bees per colony) Est^{100} = 0.95, and Est^{130} = 0.05. Such frequencies are dissimilar to other *A. m. ligustica* populations (Badino *et al.*, *Experientia* 41:752-754 or to black bees (*A. m. mellifera*) (Sheppard & Berlocher *J. Apic. Res.* 23:64-69) or Sicilian bees (*A. m. sicula*) (Badino *et al.*, *op cit.*).

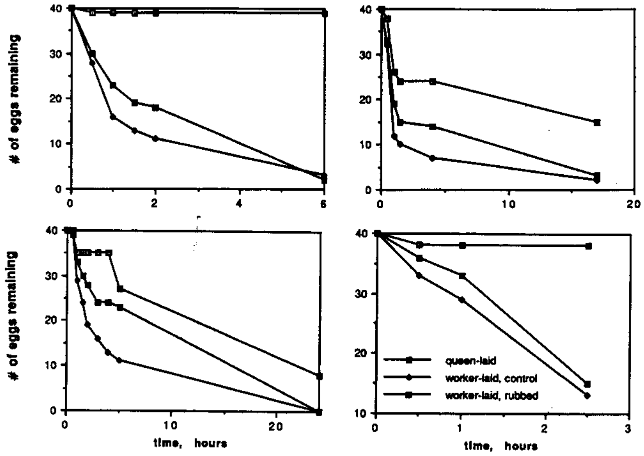
Discriminant function analysis revealed that the morphology of Kangaroo Island bees was more similar to *A. m. ligustica* reference specimens than to *A. m. mellifera* reference specimens. Total DNA was extracted and probed as described by Sheppard et al. (*Nature* 349: 782-784). Digestion of this DNA with the EcoR I restriction enzyme produced a set of fragments usually associated with *A. m. mellifera* (Sheppard *et al.*, *op cit.*) for all colonies. Detailed restriction mapping of one colony with 15 enzymes confirmed a mitochondrial genome of *A. m. mellifera* origin (Smith & Brown *Ann. Ent. Soc. Am.* 83:81-88).

We conclude that available reference material is inadequate to conclusively determine the racial origin of the Kangaroo Island population, but that recent hybridization has not occurred.

20. Ratnieks, F. L. W.[*] — EVIDENCE FOR AN EGG-MARKING PHEROMONE IN THE HONEY BEE — Honey bee workers possess ovaries and can produce ca. 20 eggs per day in queenless colonies with laying workers. However, in queenright colonies worker reproduction is rare. Only about one worker in ten thousand has fully developed ovaries (Ratnieks, submitted), and only about one adult drone in a thousand is a worker's son (Visscher, *Behav. Ecol. Sociobiol.* 25:247-254, 1989). The low production of males by workers is surprising. Kin selection theory suggests that a worker could increase her inclusive fitness by producing males, because she is more related to sons (0.5) than to brothers (queen's sons, 0.25). Low worker male-production is thought to be due to "worker policing", the mutual prevention of reproduction by workers. Worker bees remove worker-laid eggs from cells but leave queen-laid eggs (Ratnieks & Visscher, *Nature* 342:796-797, 1989). This discrimination necessitates a source of information by which police workers determine egg maternity.

One possible source of information is a queen-produced egg-marking pheromone. Such a pheromone would be favored by natural selection in the honey bee. In particular, it could evolve as both the producer (queen) and receiver (police workers) would benefit. The queen would benefit because the pheromone would help workers rear her sons (relatedness 0.5) over her grandsons (relatedness 0.25). Police workers would benefit because it would help them rear brothers (relatedness 0.25) over nephews (mean relatedness ca. 0.15).

The figure shows experimental evidence for an egg-marking pheromone in the honey bee. The graphs show the removal rates of male eggs from drone cells located in a queenright honey bee colony on four trial days. Worker-laid eggs, obtained from queenless colonies with laying workers, were removed more rapidly than queen-laid male eggs. However, worker-laid eggs treated by gently rubbing them against a queen-laid egg were removed more slowly than untreated control eggs. Additional research (Ratnieks, submitted) suggests that the pheromone is produced in the queen Dufour gland. Worker-laid eggs treated with ethanol extract of queen Dufour gland are removed significantly more slowly than untreated worker-laid eggs.



21. Rowell, G. A.,[°] M. E. Makela[°] & L. T. Wilson[°] — BEEMIG: A POPULATION GROWTH AND MIGRATION MODEL OF AFRICANIZED HONEY BEES ACROSS TEXAS[dd] — Recent computer models addressing the biology of honey bees have dealt with colony population dynamics (DeGrandi-Hoffman *et al.*, *Ecological Modelling* 45: 133-150) and the genetic interface between Africanized and European honey bees (Makela *et al.*, *Ecological Modelling*, in press). BEEMIG is an object-oriented program which models the migration dynamics of Africanized honey bee populations in a georeferenced environment.

BEEMIG was designed with two hierarchically related classes of objects: "populations" and "colonies". Populations are managed as linked-lists of colonies. During a run, the program creates a stationary population, a mobile population and a list of dead colonies. Colonies are passed from the stationary population to the mobile population following swarming and absconding events and from the mobile population to the stationary population once they have located adequate resources in new localities. If colonies starve while absconding, they are passed from the mobile population to the dead list.

Two trial runs addressed possible effects of competitive interactions among colonies during the migration process. In both runs, the starting population consisted of 30 colonies lo-

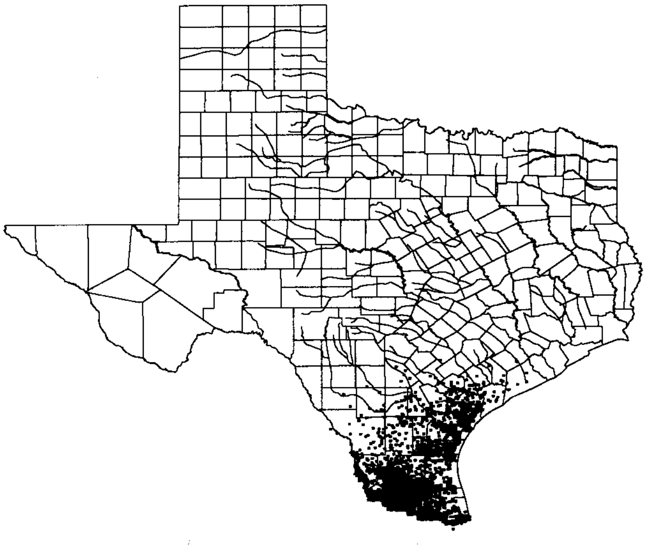


Figure — Distribution of final simulated population of Africanized honey bees after 2 years. Nectar availability assumed to be density-dependent.

Station, Weslaco, Texas. High-density treatments (1-5) were planted according to recommendations for machine harvest (80" beds, 4 rows per bed, 55,000 plants/A), while the standard treatment (6) was planted according to present practices for multiple hand-harvest (40" beds, single rows, 19,000 plants/A). Because pickling cucumbers grow quickly, a difference of 2 days in the timing of a harvest may make as much as a 100% difference in harvest weight. For this reason, the number of well-formed cucumbers probably provides a more reliable measure for comparison of yields. On either basis, weight (1 bu = 50 lbs) or number of cucumbers, the standard planting out-produced the high-density plantings by a wide margin (at least 30-40%, see Table). Yields from the first harvest of high-density treatments were probably not high enough to justify a machine harvest, but it is possible that a twice-over harvest (the first by hand and the second by machine) might be economically advantageous. Of the high-density treatments, the second (covered until bloom) produced significantly more ($p<0.05$, t-test, N=5 replicates for each treatment) well-formed cucumbers at the first harvest than any of the others (see Table). Delaying pollination did not result in higher yields for any of the treatments with this particular cultivar.

Table — Comparison of yields and values of cucumbers harvested from high-density (1-5) and standard (6) plantings

Treatment[a]	Harvest Date	Yield[b] (cucumbers/A)	Yield[c] (Bu/A)	Value ($/A)
1	14 Oct	61500	215	945
	19 Oct	50800	158	714
		112300	373	1659
2	18 Oct	69300	251	1066
	23 Oct	48700	137	629
		118000	388	1695
3	21 Oct	60300	272	1129
	28 Oct	39000	199	808
		99300	471	1937
4	21-22 Oct	—	244	1011
	28 Oct	—	118	479
			362	1490
5	25 Oct	44000	224	908
	1 Nov	6200	22	91
		50200	246	999
6	10 Oct - 1 Nov (six dates)	167500	623	2758

[a] 1) no covers; 2) covered until bloom; 3) covered until bloom + 5 days; 4) 0.95 A field covered until bloom + 7 days; 5) covered until bloom + 11 days; 6) standard, no covers

[b] Well-formed cucumbers (includes oversize, but not culls)

[c] Useable (excludes both oversize and culls)

30. Villa, J. D.[c] — BEHAVIOR OF EUROPEAN-DERIVED HONEY BEE SWARMS IN SOUTHERN LOUISIANA — Studies were conducted from 1989 to 1992 to characterize the reproductive behavior of honey bee colonies around Baton Rouge, Louisiana. Swarms were obtained either through telephone reports or through captures in 40-liter wood pulp bait hives during the spring and early summer of each year. These natural swarms, and artificial swarms to supplement them, were relocated for observations on the dances of scouts. Swarms that departed the observation area and then were recaptured in bait hives were moved to new sites, where their survival without any feeding or management was observed.

Swarms were reported and captured from late February to the middle of July, with the highest number of swarms in mid to late April. Swarm weights varied more than ten-fold (table) and did not vary significantly with time of year. Artificial and natural relocated swarms did not differ in scouting times (the number of daylight hours from shaking at a location to their departure). Scouting times did not differ between swarms that occupied available bait hives within 200 m and swarms that moved further to unknown locations. Swarms for which consensus dances were obtained immediately prior to departure showed a broad range of movement directions and distances, with longer distances than reported for swarms in Europe (Lindauer, *Naturwissenschaften* 22:509) and New York (Seeley & Morse, *Psyche* 83:199) (table). One distinctly marked queen was recovered from a colony in a wall cavity 2.2 km from the release point; although no consensus dances had been observed for that swarm, earlier dances had indicated that direction and distance. Swarms established in bait hives had a constant mortality during the first year with 40 to 50% surviving 12 months. The mortality of swarms surviving the first year appeared to decrease in the following year.

This information on swarm phenology, weight, scouting times, movement distances and survival characterizes a well-established and successful but variable introduced population. These data provide a reference point with which to compare future characteristics of the local honey bees when *Varroa jacobsoni* and Africanized bees move into the area.

Table — Characteristics of swarms observed around Baton Rouge, Louisiana from 1989 to 1992.

	Mean	S.D.	Range	n
Swarm Weight (kg)	1.48	0.85	0.29–3.66	63
Scouting Time (Light h)	20	15	4–60	31
Distance Moved (km)	3.3	2.9	0.2–10	15
Survival Time* (mo)	–	–	1–29	31

*Mean is not given since 15 of the swarms started in either 1990, 1991 or 1992 were alive in September 1992.

31. Webster, T. C.[z] — MONITORING HONEY BEE QUEEN REARING ACTIVITIES — Activities of worker honey bees provisioning royal jelly for larvae in plastic queen cups were monitored by measuring changes in resistance of a weak electric current passed through the cup (cf. Webster, *Ann. Entomol. Soc. Am.* 82:121-125). The bees and cups were contained in cages contained in an incubator and monitored for four day periods.

Recorded signals indicate both the addition and removal of royal jelly by the bees in the time that the larvae in the cups matured. Bees in some cages were fed Nosema spores in sucrose syrup, and bees in other cages were feed pure sucrose syrup. In these trials, Nosema spores did not clearly alter the activities of the bees. For seven cells, monitored for a total period of 453 cell-hours, 133 additions and 93 removals of royal jelly were recorded.

Some signals seem to result from "grooming" activities, as the bees wet and clean the inner surface of the cups. Other signals which occur after the cell has been capped are apparently the result of movement of the prepupa or its consumption of jelly within the cell.

32. Wenner, A.M.[aa] — ESTIMATING EFFECTIVE FORAGING RANGES OF HONEY BEE COLONIES — Bees forage an average distance from their colony under any given set of circumstances, based on the logarithm of that distance (Wenner, et al. 1991, *Amer. Zool.* 31:768-782). In a series of studies during the late 1920s (1933, *J. Agric. Res.* 47:257-285), John Eckert gathered excellent data in that regard — although bees ranged as far as 14km from their colonies when forced to, the effective foraging range was much less — often less than 1km (see figure). There likely exists an effective limit to energy gain — individuals that travel too far expend more energy accumulating a load than others in the colony who