Original Research

Comparative foraging distances of Africanized, European and hybrid honey bees (*Apis mellifera* L.) during pollination of cantaloupe (*Cucumis melo* L.)

Robert G. Danka, José D. Villa
USDA-ARS Honey-Bee Breeding, Genetics & Physiology Laboratory
Baton Rouge • Louisiana • 70820

and Norman E. Gary
Department of Entomology • University of California • Davis • California • 95616

INTRODUCTION

The spread of Africanized honey bees (AHB) into south Texas in 1990 indicates that these bees and Africanized-European hybrid honey bees (HHB) eventually may be incorporated into U.S. crop pollination systems. We anticipate that AHB will disrupt contemporary pollination systems because of adverse behavior and associated quarantines. For example, they respond poorly to pollination management (Danka *et al.* 1987). Deficiencies in pollination-related foraging activities of the bees are less likely according to the results of comparative foraging studies with European honey bees (EHB) (see Danka and Rinderer 1986 and Rinderer and Collins 1991). However, other behavioral traits of AHB affecting crop pollination warrant study.

One undocumented characteristic of AHB is their relative foraging distance from hives. Knowledge of foraging distance is of practical importance for determining colony placement within and near orchards and fields to optimize pollination. Locations of colonies can significantly affect ongoing crop management practices. Hives should be near crops to optimize fruit and seed set. The defensive behavior of AHB colonies, however, may require a space buffer between hives and intensive agricultural activities.

Cantaloupe, one form of muskmelon (*Cucumis melo* L.), requires honey bee pollination. Cantaloupes are grown extensively in areas of Texas, Arizona, California and Florida where AHB currently exist or will become established. Cantaloupes also are grown commercially in Africanized areas of Mexico and Central America where pollination is provided by managed colonies.

Gary *et al.* (1975) studied the foraging distance of honeybees used to pollinate honeydew melons, another type of muskmelon, in California. Foraging ranges of colonies located next to the target field were relatively short owing to the pattern of hive distribution. Greater flight ranges were observed for pollen collectors than for nectar collectors.

The objective of this research was to compare foraging distances of AHB, EHB and HHB in a commercial crop pollination setting.

MATERIALS AND METHODS

Observations were made during January 29-31 and February 4-6, 1992 at Hacienda "La Zopilota" (10°30'N, 85° 25'W), Guanacaste Province, Costa Rica. The study area was characterized by irrigated melons and sugar cane, cattle pasturage and remnants of tropical dry forest.

The cantaloupe field used in the study was planted January 1, 1992. The main cultivar was "Mission Hybrid"[1]; <10% of the stand was "Hy-Mark"[2]. The 13-ha field was approximately 900 x 125 m, and was divided into five 900 x 25 m plots. Plots were separated by 3- to 4-m tall windbreaks of king grass (*Pennisetum* sp.) planted perpendicular to prevailing easterly winds (Fig. 1). Row spacing was 1.8 m (14 rows per plot); plant spacing was 0.2 m within rows. Typically there were 80-100 flowers in 1-m lengths of row during the test period.

Ten EHB, 10 HHB and 20 AHB colonies were moved into the field on the evening of January 26, 1992. Apiaries of 5 colonies of a single bee type were placed near long-axis ends of the field beside windbreaks (Fig. 1). Queens in EHB colonies had been imported from commercial U.S. sources. Queens in HHB colonies were grafted from one of the EHB stocks[3] and allowed to mate locally with predominantly AHB drones; HHB queens were not produced from the EHB and AHB colonies used in the study. We selected the 20 AHB colonies from apiaries based on characteristic behavior during inspection (Spivak *et al.* 1988), and then further selected 10 of the 20 as being most Africanized based on short worker forewing lengths

ABSTRACT

Foraging distances were compared for Africanized, European and hybrid honey bee colonies used for commercial pollination of cantaloupe in Costa Rica. Randomly chosen foragers (n=2,398) were identified by tagging with ferrous discs at sampling stations located 0≤50, 250, 550 and 800 m from study colonies. Tags (n=727) were recovered by magnetic traps at hive entrances. Africanized colonies consistently foraged closer to their nests (*e.g.* 71% of Africanized honey bees *versus* an average of 47% of European and hybrid bees were tagged at ≤50 m). Differences in foraging distances between bee types were greater for pollen foragers than for nectar foragers. European and hybrid bees had similar foraging distances. Pollen collectors foraged at greater distances than nectar collectors. The relatively shorter foraging distances of Africanized honey bees may require that, for effective pollination, colonies be distributed more uniformly and closer to target crops with less distance between apiaries.

Received for publication: 27 January 1993
Accepted for publication: 19 March 1993

KEY WORDS

Africanized honey bees, foraging, pollination, cantaloupe, *Apis mellifera*, *Cucumis melo*.

CONTACT ADDRESS

Robert Danka: USDA-ARS Honey-Bee Breeding, Genetics & Physiology Laboratory, 1157 Ben Hur Rd., Baton Rouge, Louisiana, 70820-5502. Phone: 504-766-6064, facsimile: 504-389-0383.

BIOGRAPHICAL SKETCHES

Dr. Robert Danka is a research entomologist with primary research responsibilities in pollination and Africanized bee behavior. Dr. José Villa is an entomologist and has studied the behavior and management of Africanized bees. Dr. Norman Gary is professor of entomology and has studied many aspects of honey bee behavior, especially foraging and mating.

FOOTNOTES

[1]Asgrow Seed Co., 7000 Portage Rd., Kalamazoo, MI 49001.

[2]Petoseed Co., Inc., 1905 Livio Ave., Saticoy, CA 93004.

[3]Kona Queen Co., P.O. Box 768, Captain Cook, HI 96704.

(colony means of 8.76-8.88 mm) (Rinderer *et al.* 1987). These 10 AHB colonies and the 10 EHB and 10 HHB colonies were placed in or adjacent to plot #2 where sampling of foragers occurred (Fig. 1).

Foraging patterns of these 30 colonies near the sampling plot were determined using magnetic traps and a mark-recapture system (Gary 1971). Five remaining traps were placed on Africanized colonies in plot #4. Four sampling zones were established in plot #2 at distances of ≤50 m, 250 m, 550 m and 800 m from colonies on each end of the field (Fig. 1). Between 0630 and 1100 h each day, 75-120 bees were captured in each sampling zone, narcotized by exposure (<10 s) to CO_2 generated from dry ice, and identified by gluing a ferrous disc to the abdominal dorsum. Discs were color-coded to identify sampling zones and nectar *versus* pollen foragers (bees without visible pollen pellets were classified as nectar foragers). Tagged bees were released immediately. Tags were retrieved with minimal colony disturbance at dusk each day from magnetic traps attached to hive entrances. In total, 2,398 bees were tagged during the six sampling days.

There were numerous colonies of honey bees without magnetic traps in the area. For example, an additional 20 colonies were moved into the field on January 31 at the request of the grower (Fig. 1); we prevented flight from these colonies during tagging by screening entrances. The number of managed colonies in adjacent fields and in neighboring fields within 5 km varied during the test. In addition, an unknown number of feral colonies, all likely AHB, probably existed within 5 km.

HHB and AHB test colonies were characterized further by morphometric analyses of adult workers. Worker samples were stored in ethanol, and 10 bees per colony were dissected and mounted on microscope slides. Morphological measurements taken from projected images of wings, hind legs and sternites were submitted to multivariate discriminant analysis (Daly and Balling 1978; Daly *et al.* 1982), modified to include expanded reference populations of European and Africanized bee standards (T. E. Rinderer *et al.* in press). The analysis indicates probability of Africanized group membership.

Data on forager distribution were analyzed by chi-square comparisons of numbers of foragers of the three bee types at various sampling distances. Data from the 550-m and the 800-m sampling stations were pooled, as were data from the first and second 3-day tagging sessions. Pooling was done to avoid violating minimum expected value assumptions of the chi-square test.

RESULTS

In total, 727 tags were recovered from the 35 colonies equipped with traps. As expected, the frequency of tag recovery for each bee type decreased as tagging distance from hives increased (Fig. 2). However, AHB foraged at comparatively shorter distances than EHB and HHB

Table 1

Results of chi-square analysis of proportions of European, Africanized and hybrid honey bees foraging at different distances from 10 colonies of each bee type in a cantaloupe field near Palmira, Costa Rica, during January 29-31 and February 4-6, 1992.

Forager class	Bee type comparison	Chi-Square	df	*P*>Chi-Square
Total (*n*=651)	All	42.0	4	<0.001
	EHB *vs.* AHB	33.5	2	<0.001
	HHB *vs.* AHB	22.7	2	<0.001
	EHB *vs.* HHB	4.3	2	0.12
Pollen (*n*=402)	All	33.5	4	<0.001
	EHB *vs.* AHB	29.6	2	<0.001
	HHB *vs.* AHB	17.0	2	<0.001
	EHB *vs.* HHB	3.7	2	0.16
Nectar (*n*=249)	All	9.8	4	0.04
	EHB *vs.* AHB	6.5	2	0.04
	HHB *vs.* AHB	6.0	2	0.05
	EHB *vs.* HHB	1.4	2	0.51

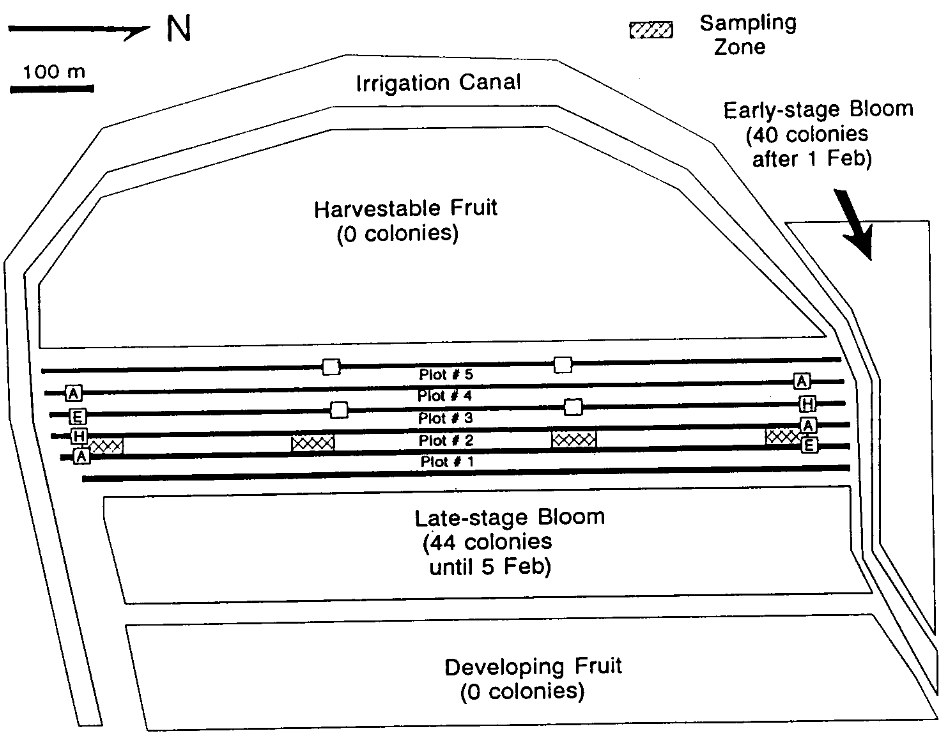

Figure 1. Schematic diagram of test cantaloupe field at Hacienda "La Zopilota", Guanacaste, Costa Rica. Squares represent apiaries of five colonies moved into place on January 26, 1992. A, E and H represent bee type within each apiary. Unlabeled squares in the center of the field represent apiaries added on January 31 but not used for measurements.

(Fig. 2; Table 1). Based on 651 tag recaptures (274 AHB, 217 HHB and 160 EHB) from the 10 colonies per bee type closest to sampling plot #2, all classes of AHB foragers (*i.e.* total foragers, pollen foragers and nectar foragers) had shorter foraging distances than did corresponding classes of EHB and HHB foragers. Differences between bee types were greater for pollen foraging (Fig. 3) than for nectar foraging (Fig. 4). Spatial distributions of EHB and HHB foragers were similar within each resource class (Table 1).

These foraging results varied only slightly when colonies comprising the AHB group were changed according to classification criteria determining "Africanization". For example, if the criterion is a probability of AHB morphology of ≥0.99, then seven colonies (four original AHB and three original HHB) qualify. If data from only these seven colonies are used for analysis, then differences in distributions for total foragers and pollen foragers remain as described previously, but differences in flight distances of nectar foragers are marginal (P=0.05). Another approach is to consider all colonies that are not fully European to be Africanized (n=25); this group would include all 10 HHB colonies (which had AHB morphology at probabilities of 0.26-1.00). In this case, distributions of EHB and AHB foragers again differed for total resources and for pollen, but not for nectar (P=0.14).

When data from all bee types were pooled, we found greater flight distances for pollen foragers than for nectar foragers (P<0.001; chi-square = 14.8; df=2; Fig. 5). Overall, 48% of pollen collectors and 34% of nectar collectors were tagged at 250 m or further from their hives. The foraging distance of AHB nectar foragers was notably short, *i.e.* 75% of these bees were tagged at ≤50 m (Fig. 4). In contrast, at least as many EHB and HHB pollen foragers were tagged at 250 m as at ≤50 m (Figs. 3 and 4).

The percentages of recaptured bees that were pollen foragers were similar for the three bee types (P=0.15; chi-square =4.0; df=2). Overall, 62.0 ± 2.6% (mean ± SE, n=3) of foragers had pollen.

Tag recovery from different locations and times varied greatly. Compared with plot #2 (where bees were tagged), total tag recoveries per colony decreased *ca.* 50% in adjacent plots. We found an additional decrease of *ca.* 13% for colonies located two plots away. Total tag recovery decreased dramatically in the second tagging period. Daily tag recovery was 49.5 ± 1.9% during the first 3-day period (days 3, 4 and 5 after bees were moved into the field), but was only 13.0 ± 1.3% during the second period (days 9, 10 and 11). This may have been caused in part by changes in the wind, which decreased between the first three days of tagging (easterly, *ca.* 24-40 km/h) and the second three days of tagging (light and variable, mostly westerly, maximum *ca.* 8-24 km/h). Comparative foraging distributions of the bee types appeared to be consistent between the two tagging periods, despite these changes.

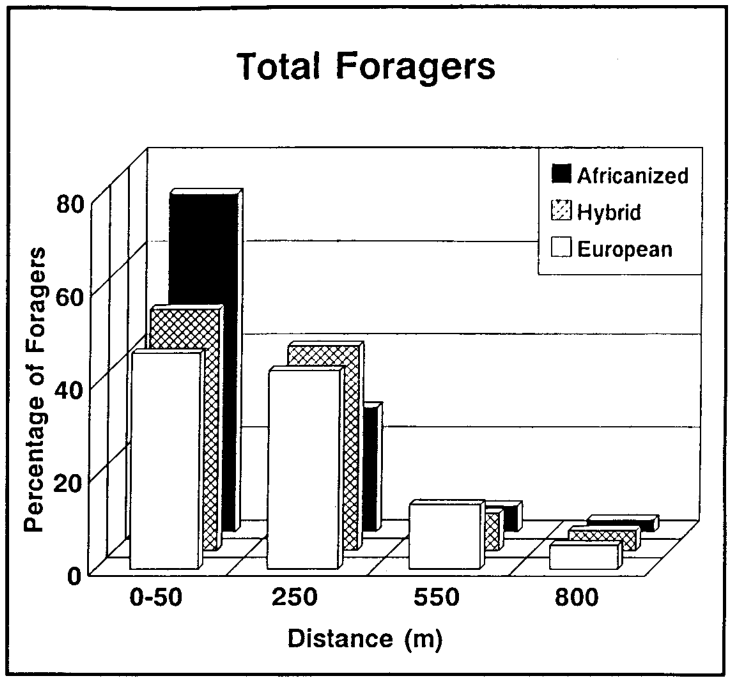

Figure 2. Proportions of total foragers of the three bee types foraging at four distances from home colonies.

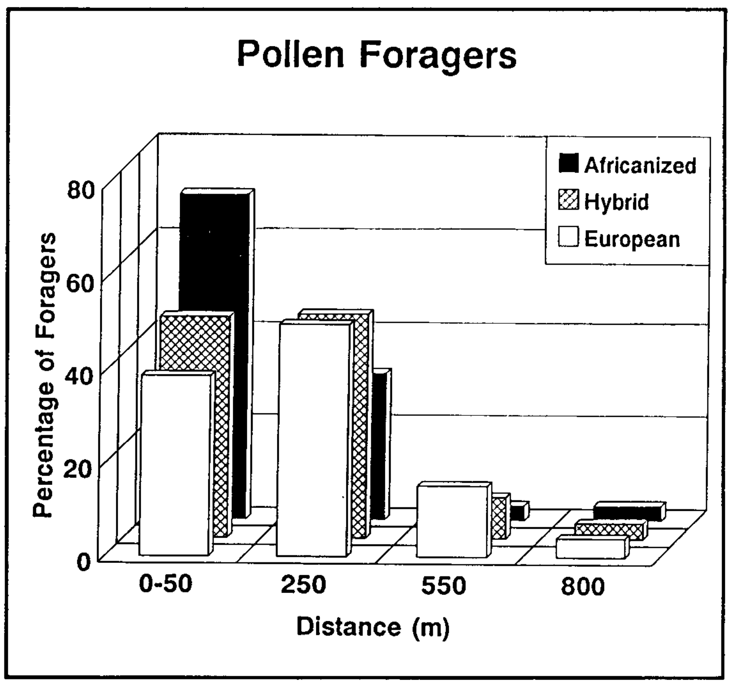

Figure 3. Proportions of pollen foragers of the three bee types foraging at four distances from home colonies.

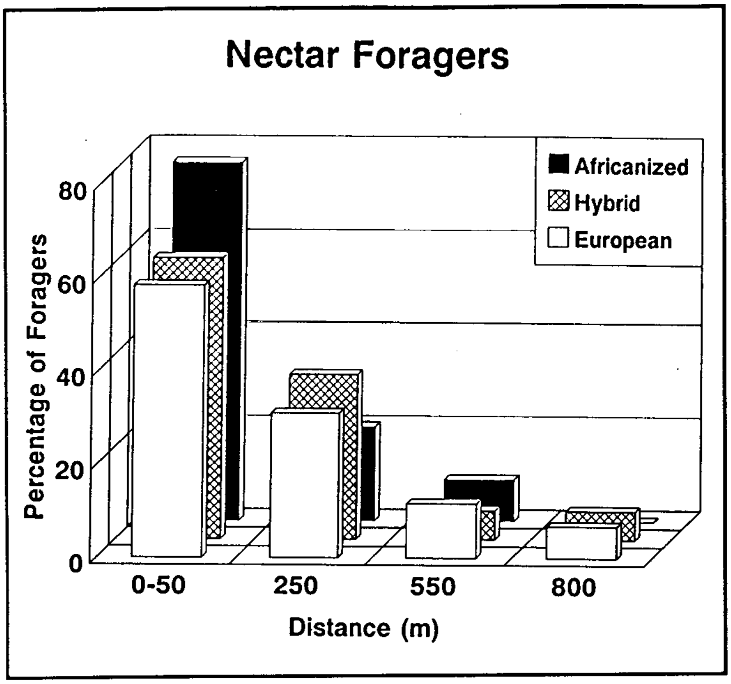

Figure 4. Proportions of nectar foragers of the three bee types foraging at four distances from home colonies.

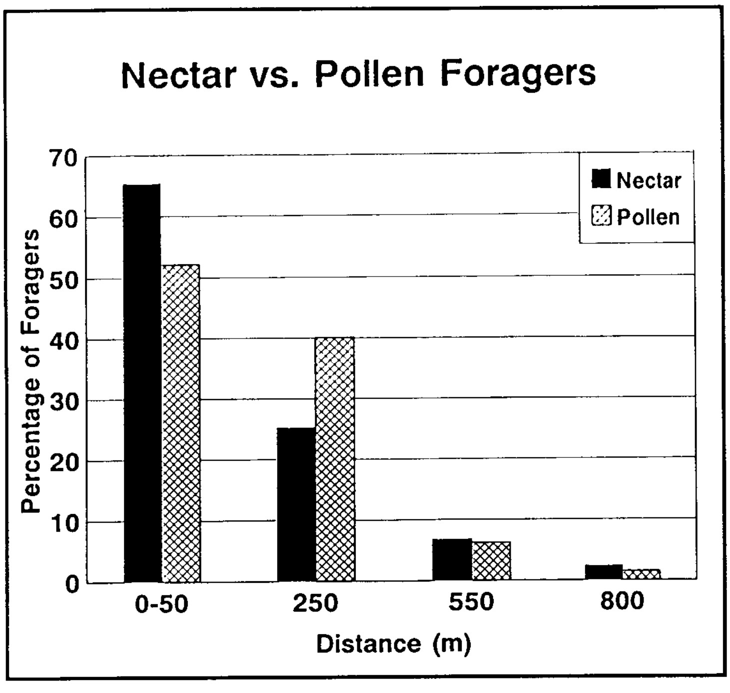

Figure 5. Proportions of all nectar and pollen collectors foraging at four distances from home colonies.

DISCUSSION

The most important contrast in this study was the relative foraging distances of the respective bee types. Absolute flight ranges vary greatly according to hive distribution and crop conditions (Free 1970; Gary and Witherell 1977; Gary *et al.* 1978a; 1978b; 1978c; 1980); thus comparative flight distance data are more useful. The relatively short foraging distance of AHB foragers, especially pollen collectors, has several implications in commercial crop pollination. An obvious disadvantage is the potential for inefficient distribution of pollinators throughout target fields and orchards. Because AHB forage relatively near their colonies, hives must be distributed closer to the crop (increasing sting hazards) and more uniformly in smaller apiaries (increasing costs). One potential advantage of a short foraging distance is that foraging activity may be intensified in restricted areas as required in special situations (Gary *et al.* 1978b), *e.g.*, isolating fields more effectively during pollination of hybrid seed to prevent or minimize genetic contamination.

Foraging behavior of HHB colonies was more similar to EHB colonies than to AHB colonies. The consistently similar foraging distance of these two bee types suggests that selection and use of stocks from among hybrids may be one approach to reducing pollination problems following Africanization.

In Costa Rica, colonies for cantaloupe pollination currently are distributed at 300-m intervals along the king grass windbreaks. This practice is cumbersome and labor intensive, but may be necessary in long plots if AHB colonies are used. The cantaloupe growers believe that colonies placed at the ends of long fields may not generate sufficient activity in the center of the field. Our comparative approach suggests that pollinator distribution in the field depends upon the bee type used. Based on just the subset of recaptured foragers, mean foraging distances in this test are estimated to be 105 m for AHB, 167 m for HHB bees and 204 m for EHB; more extensive sampling would be needed to calculate more precise foraging distributions. Given equal foraging populations, this suggests that the distance between apiaries of AHB colonies should be *ca.* half that of EHB apiaries. AHB colonies, however, tend to have relatively small foraging populations (Danka *et al.* 1986); this further reduces their value for crop pollination.

Greater foraging distances of pollen collectors relative to nectar foragers is in agreement with some previous studies with EHB-derived stocks (Gary *et al.* 1972, 1975). It conflicts with the findings of Schneider (1989), who inferred (from recruitment dances) greater flight distances for nectar foragers in African colonies. Schneider also suggested that *A. m. scutellata* colonies foraged at shorter distances than EHB bees found in North America. This notion, supported by our data, is consistent with evolutionary theory of more expansive resource requirements for temperate-adapted bees, compared with tropical-adapted bees (Gould 1982).

The pollination milieu can be dynamic; this was shown by changes in tag recovery rates through time. Foraging bee distributions, and therefore tag recapture, were probably influenced significantly by wind velocity and by changes in the numbers of honey bee colonies in the semicultivated study ecosystem. The absence of typically strong, dry season winds during the second tagging period apparently favored an influx of bees from nearby managed and feral colonies without traps, as documented by reduced tag recapture percentage. The cantaloupe field likely was a rich resource for feral colonies in the area. Numbers and locations of managed colonies in the area varied between the first and second tagging periods. In addition, foragers from test colonies may have extended their foraging area beyond the study plot.

Our results suggest that the use of AHB in commercial pollination could pose problems in addition to those of greater defensive behavior and more difficult management. Owing to relatively shorter foraging distances, AHB colonies may require less distance between apiaries and closer proximity to the crop to pollinate effectively. Additional hive manipulations near the crop would aggravate troublesome defensive reactions of AHB. These problems are likely to increase the costs of honey bee pollination services. HHB may be useful pollinators if other behavioral traits prove to be acceptable.

ACKNOWLEDGMENTS

Ricardo Acosta, Nelger Barrantes, Enrique Cascante, Olger Chavarria and MacDonald Gonzales tagged bees. MacDonald and Gonzalo Gonzales of APES Agroindustrial provided helpful beekeeping cooperation. Grupo GISA granted access to the cantaloupe field. Rita Riggio dissected and measured bees for morphological analysis. Steven Buco provided statistical advice. Frank Eischen, John Harbo, Gerald Loper and Eric Mussen reviewed the manuscript. This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement or a recommendation for its use by USDA. This research was completed in cooperation with the Louisiana Agricultural Experiment Station.

REFERENCES

Daly, H. V. and S. S. Balling. 1978. Identification of Africanized honey bees in the Western hemisphere by discriminant analysis. *J. Kans. Entomol. Soc.* 51: 857-869.

Daly, H. V., K. Hoelmer, P. Norman and T. Allen. 1982. Computer-assisted measurement and identification of honey bees (Hymenoptera: Apidae). *Ann. Entomol. Soc. Am.* 75: 591-594.

Danka, R. G. and T. E. Rinderer. 1986. Africanized honey bees and pollination. *Am. Bee J.* 126: 680-682.

Danka, R. G., T. E. Rinderer, R. L. Hellmich II and A. M. Collins. 1986. Foraging population sizes of Africanized and European honey bee (*Apis mellifera* L.) colonies. *Apidologie* 17: 193-202.

Danka, R. G., T. E. Rinderer, A. M. Collins and R. L. Hellmich II. 1987. Responses of Africanized honey bees to pollination-management stress. *J. Econ. Entomol.* 80: 621-624.

Free, J. B. 1970. *Insect pollination of crops.* Academic Press, London.

Gary, N. E. 1971. Magnetic retrieval of ferrous labels in a capture-recapture system for honey bees and other insects. *J. Econ. Entomol.* 64:961-965.

Gary, N. E., P. C. Witherell and J. M. Marston. 1972. Foraging range and distribution of honey bees used for carrot and onion pollination. *Environ. Entomol.* 1: 71-78.

Gary, N. E. and P. C. Witherell. 1977. Distribution of foraging bees of three honey bee stocks located near onion and safflower fields. *Environ. Entomol.* 6: 785-788.

Gary, N. E., P. C. Witherell and J. M. Marston. 1975. The distribution of foraging honey bees from colonies used for honeydew melon pollination. *Environ. Entomol.* 4: 277-281.

Gary, N. E., P. C. Witherell and K. Lorenzen. 1978a. A comparison of the foraging activities of common Italian and "Hy-Queen" honey bees. *Environ. Entomol.* 7: 228-232.

Gary, N. E., P. C. Witherell and K. Lorenzen. 1978b. The distribution and foraging activities of common Italian and "Hy-Queen" honey bees during alfalfa pollination. *Environ. Entomol.* 7: 233-240.

Gary, N. E., P. C. Witherell and J. M. Marston. 1978c. Distribution and foraging activities of honeybees during almond pollination. *J. Apic. Res.* 17: 188-194.

Gary, N. E., P. C. Witherell and K. Lorenzen. 1980. Distribution of foraging honey bees to multiple, small floral plots of various species. *Environ. Entomol.* 9: 43-46.

Gould, J. L. 1982. Why do honey bees have dialects? *Behav. Ecol. Sociobiol.* 10: 53-56.

Rinderer, T. E. and A. M. Collins. 1991. Foraging behavior and honey production. *In* The "African" Honey Bee, M. Spivak, D. J. C. Fletcher and M. D. Breed (eds.). Westview Press, Boulder, CO. pp. 235-257.

Rinderer, T. E., H. A. Sylvester, S. M. Buco, V. A. Lancaster, E. W. Herbert, A. M. Collins and R. L. Hellmich II. 1987. Improved simple techniques for identifying Africanized and European honey bees. *Apidologie* 18: 179-196.

Rinderer, T. E., S. M. Buco, W. L. Rubink, H. V. Daly, J. A. Stelzer, R. M. Riggio and F. C. Baptista. (In press). Morphometric identification of Africanized and European honey bees using large reference populations. *Apidologie.*

Schneider, S. S. 1989. Spatial foraging patterns of the African honey bee, *Apis mellifera scutellata*. *J. Insect Behav.* 2: 505-521.

Spivak, M., T. Ranker, O. Taylor, Jr., W. Taylor and L. Davis. 1988. Discrimination of Africanized honey bees using behavior, cell size, morphometrics, and a newly discovered isozyme polymorphism. *In* Africanized Honey Bees and Bee Mites, G. R. Needham, R. E. Page, Jr., M. Delfinado-Baker and C. E. Bowman (*eds.*). Ellis Horwood Ltd, Chichester, UK. pp. 313-324.