Variation in Response to *Nosema apis*, Longevity, and Hoarding Behavior in a Free-Mating Population of the Honey Bee[1,2]

THOMAS E. RINDERER AND H. ALLEN SYLVESTER

Bee Breeding and Stock Center Laboratory, Agric. Res. Serv., USDA, Baton Rouge, LA 70808

ABSTRACT

A free-mating population of the honey bee, *Apis mellifera* L., was evaluated for response to *Nosema apis*, longevity, and hoarding behavior. The population varied for all 3 characteristics. Response to *Nosema* and hoarding behavior fit normal distributions. Longevity responses were significantly skewed to the right. Response to *Nosema* and longevity was significantly correlated with $r_s = 0.51$.

A long-range program for the genetic improvement of stocks of honey bees, *Apis mellifera* L., has been proposed (Rinderer 1977). Reasonable implementation of this program requires knowledge of the variation of the characteristics to be improved and of the correlations between the characteristics in the population on which selection will be practiced.

Three economically important characteristics of honey bees were investigated: response to *Nosema apis*, longevity, and hoarding behavior (Kulinčević and Rothenbuhler 1973). We report here the results of an assessment of the variability and correlations of these characteristics in a population of free-mating bees.

MATERIALS AND METHODS

Source of Bees.—Thirty-eight colonies containing queens mated in free-flight and themselves the product of a free-flight mating, were selected at random from colonies managed at our laboratory. Brood combs containing emerging adult worker bees were removed from each of the colonies and placed in emergence cages in a 35°C incubator. The newly emerged worker bees, ages 0–24 h, were collected from the combs and evaluated for response to *Nosema*, for longevity, and for hoarding behavior (34 of the 38 colonies). Evaluations were made from June–Aug. 1976.

Response to Nosema.—Newly emerged worker bees from each source colony were individually fed 1.0×10^6 *Nosema* spores in 5 µl of 50% sucrose solution by the method of Rinderer (1976) without using CO_2. After feeding, 50 bees were placed in each laboratory cage (Kulinčević et al. 1973) fitted with 3 feeders, 1 containing 50% (v/v) sucrose solution, the 2nd containing water, and the 3rd containing a pollen substitute (Rinderer and Elliott 1977a,b). Four cages of bees were used to test each queen source. All cages were held in incubators maintained at 32°C and 50% RH. Dead bees were removed daily and the numbers were recorded, until 25 bees in each cage had died. Data in the form of number of days required for 25 bees in each cage to die were analyzed.

Longevity.—Newly emerged worker bees from each source colony were treated and observed in ways identical to the methods used to measure bees for response to *Nosema*, except they were initially fed a 5-µl droplet of 50% sucrose solution without *Nosema* spores.

Hoarding Behavior.—Bees from 34 source colonies were tested in 6 replicate cages (without pollen substitute) per source colony as described by Rinderer and Elliott (1977a). The amounts of sugar syrup the 50 bees in each cage removed from the feeders during the 1st 3 complete days were recorded daily and converted to ml per bee per day.

Analyses.—Analysis of variance was used to detemine if significant differences occurred between colonies for each characteristic (response to *Nosema*, longevity, and hoarding behavior) and to test the hypothesis that the responses of bees differed through the course of the 3 mo required to make the laboratory evaluations. Mean colony measures for each characteristic were compared to normal distributions by the goodness of fit test and, when appropriate, the coefficient of skewness was calculated. Source colonies were ranked on the basis of performance for each characteristic. These rankings were used to calculate Spearman rank correlations among the colony performances for the 3 characteristics. All analyses followed methods outlined by Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Bees fed *Nosema* spores become infected as judged by the gross symptoms of distended abdomens, disjointed wings, and reduced life span. With *Nosema*-infected bees (Fig. 1), mean times to 50% mortality in samples from the source colonies fit a normal distribution ($\chi^2 = 1.17$, 4 df) with a mean and SE of 22.9±0.69 days. Differences among source colonies were highly significant ($P < 0.01$, $F = 4.46$; 37 and 114 df). No significant time-related difference was found when data were classified by month observed ($F = 1.49$; 2 and 35 df).

Non-infected samples (Fig. 1) of bees from the 38 source colonies had a mean time to 50% mortality of 32.5±1.26 days that did not fit a normal distribution ($\chi^2 = 15.79$, 7 df, $P < 0.05$). The skewness to the right (coefficient of skewness = 0.97) was highly significant ($P < 0.01$). Differences among source

[1] Hymenoptera: Apidae.

[2] In cooperation with the Louisiana Agricultural Experiment Station. Received for publication Nov. 15, 1977.

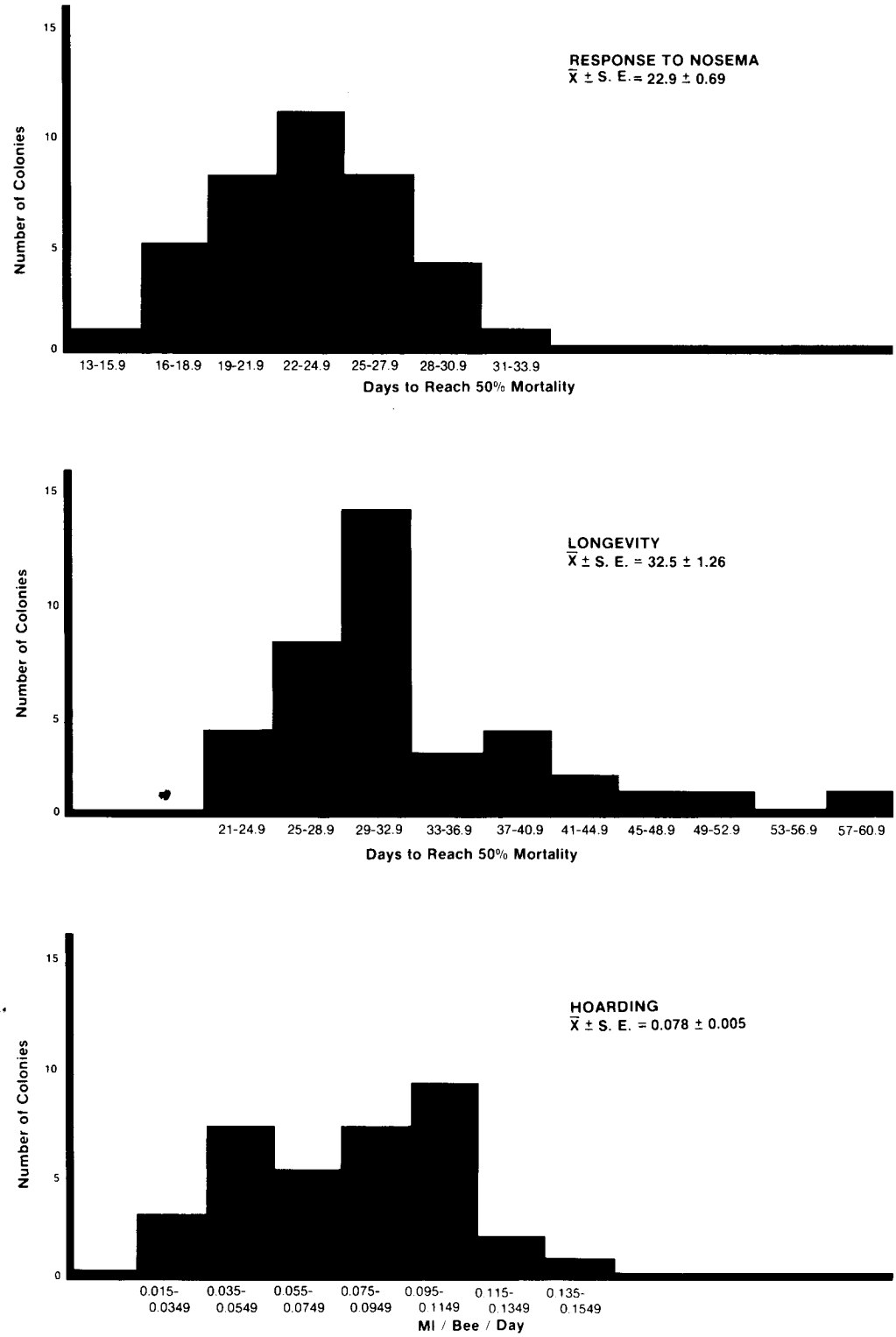

FIG. 1.—Frequency distributions of mean measurements of hoarding behavior, response to *Nosema*, and longevity of bees from colonies in a free-mating population.

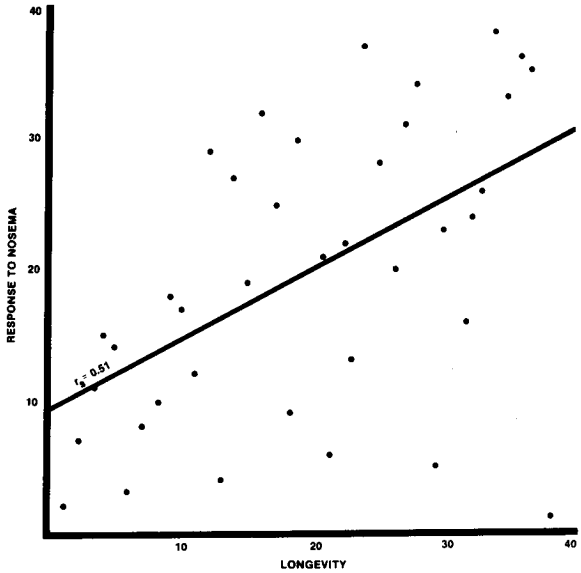

FIG. 2.—Rank correlation of source colonies based on mean colony scores for longevity and response to *Nosema*.

colonies were highly significant ($F = 5.73$; 37 and 114 df), but no significant time-related difference was found ($F = 0.89$; 2 and 35 df).

Hoarding measurements fit a normal distribution ($\chi^2 = 6.82$, 4 df) with $\overline{X}$ of 0.078±0.005 ml/bee per day. Thus, the goodness of fit test did not confirm the apparent bimodality seen in Fig. 1. Differences among source colonies were highly significant ($F = 3.21$; 33 and 170 df), but no differences ($F = 0.73$; 2 and 31 df) were associated with the time when the tests were begun.

The rank correlation ($r_s = 0.51$) between longevity and response to *Nosema* was highly significant ($P < 0.01$) (Fig. 2). Measurements from one colony (Fig. 2, point 38, 1) were exceptional to the observed correlation. Bees from this colony had the greatest longevity ($\overline{X} = 58.8 \pm 3.9$ days) but when infected with *Nosema* lived the shortest time ($\overline{X} = 13.5 \pm 5.5$ days, Fig. 2). Without this colony, the r_s would have equaled 0.64. Another colony showed a similar, although less exceptional divergence from the correlation. Hoarding behavior was not significantly correlated with either longevity or response to *Nosema* infection ($r_s = 0.10$ and 0.09, respectively).

DISCUSSION

The observed variations in response indicate good potential for the genetic improvement of hoarding behavior, resistance to *Nosema,* and longevity in bee stocks by selection procedures. Since all tests were conducted in the laboratory under similar conditions, a substantial portion of the observed variation is probably genic in origin. In all cases, the distributions observed suggest that the characteristics are influenced by polygenic systems.

Correlations indicate that there is little common genetic influence on hoarding and either longevity or response to *Nosema*. The reasonably high correlation between longevity and response to *Nosema* is interpreted to indicate a genetic relationship (perhaps 26% since $r_s^2 = 0.26$) between the 2 characters such that improvement in 1 character has a strong likelihood of improving the other. However, the performances of 2 colonies were counter to the general correlation. If such colonies were inadvertently brought into a breeding program on the basis of single characteristic testing, the 2nd characteristic might be developed in undesirable ways in the breeding stock.

ACKNOWLEDGMENT

We thank James Baxter, Cade Carter, Jr., Kathleen Dell Elliott, William Puissegur, and Barbara Theriot, employees of our laboratory, for their able assistance in this project.

REFERENCES CITED

Kulinčević, J. M., and W. C. Rothenbuhler. 1973. Laboratory and field measurements of hoarding behaviour in the honeybee. J. Apic. Res. 12: 179–82.

Kulinčević, J. M., W. C. Rothenbuhler, and G. R. Stairs. 1973. The effect of presence of a queen upon outbreak of a hairless-black syndrome in the honey bee. J. Invertebr. Pathol. 21: 241–7.

Rinderer, T. E. 1976. Honey bees: Individual feeding of large numbers of adult workers. J. Econ. Entomol. 69: 489–91.

1977. A new approach to honey bee breeding at the Baton Rouge USDA laboratory. Am. Bee J. 117: 146–7.

Rinderer, T. E., and K. D. Elliott. 1977a. Influence of nosematosis on the hoarding behavior of the honeybee. J. Invertebr. Pathol. 30: 110–1.

1977b. Worker honey bee response to infection with *Nosema apis*: Influence of diet. J. Econ. Entomol. 70: 431–3.

Snedecor, G. W., and W. G. Cochran. 1967. Statistical Methods, 6th Ed., Iowa State University Press, Ames, 593 pp.