Variation in Honey Bee[1] Morphology, Behavior, and Seed Set in White Clover[2]

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ABSTRACT

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Five behavioral and six morphological characteristics of honey bees, *Apis mellifera* L., from 24 colonies were measured, and many varied significantly. Several of these measurements were significantly correlated with seed set by white clover, *Trifolium repens* L.

Pollination by honey bees, *Apis mellifera* L., has high agricultural value (McGregor 1976). However, selective breeding has been used to enhance the effectiveness of pollination by bees in only a few cases. Lines of bees with high frequencies and others with low frequencies of alfalfa pollen-collecting bees have been produced (Nye and Mackenson 1965), as has a line of bees with longer mouthparts capable of foraging on, and hence pollinating, red clover, *Trifolium pratense* L., (Henricksen and Hammer 1957).

Several morphological and behavioral characteristics of honey bees contribute to their efficiency as pollinators. Martin (1975) listed branched hairs, pollen baskets (corbiculae), specialized mouthparts, a crop modified for nectar transport, nests with storage areas, and specific behavioral characteristics associated with pollen and nectar collection. One such behavioral characteristic is the intensity of body movement (scrabbling behavior) associated with foraging for pollen (Free 1970). Possibly these and other characteristics vary among bees. If so, such variability might serve as a basis of selective breeding to improve pollination effectiveness. In this study, we determined the variability of several bee characteristics and their correlation with the bees' pollination effectiveness on white clover.

Materials and Methods

Twenty-four colonies of bees were developed, each consisting of a queen instrumentally inseminated with the semen from a single drone and of worker bees from this mating; thus all workers in each colony were closely related (r = 0.75). However, there was no known genic relationship among colonies; all queens and drones were reared from different colonies. Throughout the experiment each colony had the appropriate queen, ca. 1 kg of adult workers, and equal amounts of brood and stored food. Each colony was placed in a screened cage (2.75 by 3.65 by 1.98 m) in a field of white clover, *Trifolium repens* L. var. Louisiana S–1.

T. repens is well suited for this study. It is self sterile and dependent upon insect pollen vectors for cross-pollination (Darwin 1876). Also, florets of a flower head bloom sequentially through time, and on a given day only a ring of florets contain pollen and nectar and can be pollinated (Erith 1924). Both pollen- and nectar-collecting insects are effective pollinators of this plant, and blossoms are only attractive to bees when ambient temperatures reach ca. 27° C (Oertel 1961). Presumably, this is so because only then are pollen and nectar available in the newly matured florets.

This experiment was replicated three times with the 24 colonies, which provided 72 sets of observations. For each replicate new plots were used. Before each of the three experimental replications, 50 immature clover flower heads of similar maturity in each cage were individually tagged and placed in glassine bags. Also, a 1–m² plot was marked in each cage for future observation. In each plot, the tagged flowers which had developed a mature ring of florets were unbagged, exposed ca. 30 min to possible bee visits, and then rebagged. During these 30 min the foraging behavior of bees was observed on flowers that had not been bagged. Each of 15 randomly chosen bees was graded for the percentage of the circumference of a flower head traversed by mouthparts, legs, or abdomen during a foraging visit. The same 15 bees were also graded on a scale of 1 to 5 for the intensity of body movement during the visit. The time spent visiting the flower head also was recorded. A second group of 15 bees were watched for 2 min each, and the number of flower heads each bee visited was recorded. Also, the number of bees that entered the 1–m² plot during 10 min was recorded.

Behavioral observations for each experimental replication were made on the day the bagged flowers had a ring of mature florets during the first hour of the morning after the clover began producing nectar. In this way, the pollen and nectar availability to bees from all colonies was equalized. The tagged flowers were allowed to mature and were harvested, and the seeds from each head were counted. Also, 10 bees were collected from each colony and six morphological features were measured: (1) length of the fringe of hairs on the posterior margin of the metathoracic tibia; (2) length of hairs on the margin of

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the metathoracic basitarsus; (3) width of the metathoracic basitarsus; (4) length of the metathoracic basitarsus; (5) length of the "tongue" from the distal end of the glossa to the proximal end of the prementum; and (6) number of hairs on the most dorsal area of the scutellum on the mesotergum per mm².

Data for each measured characteristic were submitted to analysis of variance. Also, correlation coefficients were calculated for all pairs of characteristics.

Results

Significant differences were found among colonies for most measurements of bees including the number of seeds they set per flower head (Table 1). The only differences that were not significant were those for seconds spent on flower heads and for width of basitarsi.

No very strong correlations were found between any of the bee characteristics and seed set (Table 2). However, three characteristics (flower heads visited in 2 min, the number of bees entering a 1-m² plot in 10 min, and the intensity of motion when bees were on the flower heads) were weakly, but significantly, correlated to seed set. Four other characteristics (hair length on tibiae, hair length on basitarsi, length of basitarsi, and tongue length) were also weakly correlated with seed set, but for these characteristics there were too few degrees of freedom to determine if the correlations were significant.

Other correlation coefficients between pairs of characteristics were generally small to nonexistent.

Table 1.—Means, standard errors, ranges, and results of analyses of variance for 12 measurements of honey bees from 24 colonies caged over white clover plots

Colony characteristic	Mean ± SE	Range	P^a
Seeds set/flower head (SS)	51.4 ± 8.3	31.1–85.1	0.0001
Flower heads visited in 2 min (FV)	9.2 ± 0.9	7.0–11.0	0.0001
Bee entering 1 m² in 10 min (BE)	39.8 ± 3.2	1.6–75.4	0.0001
% of flower head covered during visit (PC)	38.0 ± 5.6	27.5–51.6	0.0001
Duration of visit (sec) (DV)	12.3 ± 2.7	8.0–16.7	0.1033
Intensity of movement during visit (IM)	1.9 ± 0.1	1.4–2.7	0.0001
Hair length on tibia (mm) (HT)	0.60 ± 0.02	0.44–0.81	0.0001
Hair length on basitarsus (mm) (HB)	0.48 ± 0.02	0.29–0.68	0.0001
Width of basitarsus (mm) (WB)	1.08 ± 0.02	1.00–1.15	0.0994
Length of basitarsus (mm) (LB)	1.69 ± 0.04	0.94–2.30	0.0001
Length of tongue (mm) (LT)	5.77 ± 0.11	4.86–6.38	0.0001
Hair density (no./mm²) (HD)	84.3 ± 2.8	60.5–106.3	0.0001

[a] Significance of differences among colonies.

Table 2.—Correlation coefficients of 12 measurements of honey bees from 24 colonies caged over white clover plots[a]

	FV	BE²	PC	DV	IM	HT	HB	WB	LB	LT	HD
SS	0.303**[b] 70	0.201* 70	0.050 70	−0.001 70	0.249* 70	0.315 22	0.271 22	0.013 22	−0.261 22	−0.264 22	0.058 22
FV		0.351** 70	−0.114 70	−0.131 70	0.213 70	0.471* 22	0.391 22	0.081 22	−0.272 22	−0.149 22	0.097 22
BE²			0.034 70	0.047 70	0.193 70	0.018 22	0.182 22	−0.045 22	−0.131 22	−0.055 22	−0.040 22
PC				0.700** 1,068	0.342** 70	0.133 22	0.248 22	−0.111 22	−0.253 22	−0.050 22	−0.035 22
DV					0.250** 1,068	0.255 22	0.055 22	−0.122 22	−0.150 22	0.070 22	0.233 22
IM						0.267 22	0.261 22	−0.086 22	−0.204 22	0.041 22	−0.167 22
HT							0.612** 238	0.057 238	−0.594** 238	−0.179** 238	−0.003 238
HB								0.013 238	−0.760** 238	−0.140* 238	−0.108 22
WB									0.089 238	0.372** 238	−0.064 238
LB										0.241** 238	0.112 238
LT											−0.180** 238

[a] Measurement codes are explained in Table 1. *, $P < 0.05$; **, $P < 0.01$.
[b] Correlation coefficient, d.f.

A few, however, were strong. Hair lengths on basitarsi and on tibiae were significantly correlated ($r = 0.612$), as was length of basitarsi with hair length on tibiae ($r = -0.594$) and with hair length on basitarsi ($r = -0.760$). Of the behavioral measurements, intensity of movements on flower heads was significantly correlated with percentage of flower heads covered during visits ($r = 0.342$) and with duration of visits ($r = 0.250$). Durations of visits were also correlated with percentages of flower heads covered ($r = 0.700$). The number of flowers visited was significantly correlated with the number of bees entering the 1–m^2 plots in 10 min ($r = 0.351$).

Discussion

The observed significant variation among colonies for almost all characteristics measured indicates that these characteristics could be changed by selective breeding. Since all measurements were made under similar environmental conditions, large portions of the observed variation probably have a genetic basis. Furthermore, the measurements of the characteristics were normally distributed which suggests that the characteristics are influenced by polygenic systems.

The low correlations between the measured honey bee characteristics and seed set show that no one characteristic is a superior candidate for inclusion in a selective breeding program designed to improve pollination ability. However, single-bee–single-flower studies should be undertaken to understand more thoroughly the relationships we have identified. Such work might show how several such characteristics could be collected into a selection index (Rinderer 1977) to provide a sound basis for improving pollination ability through selective breeding.

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