Effects of Meteorological Factors on Defensive Behaviour of Honey Bees

by

E. E. Southwick* and R. F. A. Moritz**

ABSTRACT. — The defensive behaviour of honey bee colonies (Apis mellifera L.) was quantitated in the field throughout a three month season by the use of a standardized test in which numbers of stings in a leather target were counted after single colonies were opened and exposed to alarm pheromone. The main results show how the defensive behaviour of honey bees is highly dependent on weather factors. Eliminating genetic variance, the following meteorological variables account for 92.4% of the variation in defensive behaviour: air temperature, solar radiation intensity, wind velocity, relative humidity, and barometric pressure.

INTRODUCTION

Much attention has been focused on the defensive behaviour of honey bees during the past decade, and especially recently because of the northern advancement of the highly defensive Africanized honey bee (Maschwitz 1963, Michener 1972, 1975, Taylor 1977, Taylor and Spivak 1984, Vila 1985, Winston 1977).

Defensive behaviour in honey bees is affected by genetic composition of the colony as well as environmental conditions. The evidence of genetic control of defensive behaviour was first demonstrated by Rothenbuhler (1960). More recent field and laboratory tests by Collins and her coworkers (Collins 1979, Collins and Rinderer 1985, Collins and Rothenbuhler 1978, Collins et al. 1984) have further documented this. We have recently shown in a metabolic test that the alarm reaction is also genetically determined by maternal effects (Moritz, Southwick and Breh 1985, Moritz, Southwick and Harbo 1986a, b).

Temperament may well be caused primarily by internal factors, but it is affected or modified by external factors such as smoke, pheromones or other volatile chemicals, presence or absence of other bees (i.e., group response, Southwick and Moritz 1985), changes in the electrical charge in the air, and weather conditions (Brandenburg, Goncalves and Kerr 1982, Drum and Rothenbuhler 1984, Free 1961, Rothenbuhler 1974, Schua, 1952). Most studies have involved only single weather variables without quantitative analyses of more than one at a time. Interactions of various climatic factors however are likely to determine the degree of defensive behaviour exhibited by bees in the field.

In this paper we examine the question of the combined effect of environmental factors on this character in a multiple analysis.

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MATERIALS AND METHODS

Thirty six equal size colonies (each consisting of three shallow Langstroth supers containing about fifty thousand bees) were studied at the Bee Laboratory on the campus of the State University in Brockport, New York, USA. Two field sites separated by 3 km were used, each containing 18 colonies used in this test. Each site had colonies varying from docile to very defensive, based on genetic crosses of sister queens instrumentally inseminated with identical aliquots from a mixed semen pool (Moritz 1983). The two sites were replicates with equal representation of each genetic type at each site.

The meteorological conditions extend at these two sites were similar and typical of the summer season for this area. According to data gathered by the College Weather Center (Department of the Earth Sciences, State University of New York - Brockport) the 10-year mean monthly temperature varies between 19.4 and 21.6°C; mean daily solar radiation is 416 to 520 langleys; mean monthly precipitation is 6.45-7.45 cm; relative humidity averages 80%; barometric pressure averages 995.0 mm Hg; and the wind is from the southwest at a mean velocity of 12.8 kph.

We studied defensiveness using a standardized field test (Moritz et al. 1986b), a modification of the test used by Schua (1952). It consisted of removing the top cover of the selected colony, holding a piece of filter paper soaked with 1 ml of the alarm pheromone component isopentyl acetate, IPA, on the top bars, and exposing a 5 x 5 cm black leather target (waved back and forth at a frequency of 2/sec, in a 15 cm arc, 5 cm above the frame tops). The bees responded quickly (within 2 sec) and attacked the swinging leather. After 15 sec, the IPA paper and leather target were removed and top replaced. In each test, the number of stings in the leather was recorded. The average number of stings per site was then used for data analyses in order to eliminate the genetic intercolonial variation. The test was repeated at different times of the day, at 5-7 day intervals, under a variety of weather conditions from June through September. The interval between tests was thought to be necessary to keep the bees to return to a completely calm state and to replace those individuals lost in the sting episode.

Meteorological variables were recorded during the time of the field tests. Relative humidity and air temperature were determined in the field by a sling psychrometer. Wind velocity was recorded on a strip chart recorder from an anemometer; barometric pressure (absolute and direction of charge) was taken from a recording barometer; and incident solar radiation was measured with an Epply pyrheliometer. In addition, nectar flow was determined from the daily record of a scale hive.

RESULTS

Table 1 shows the correlation matrix between the measured climatic components and defensive behaviour. The correlation between the dependent variable, number of stings in the target, and air temperature is significantly larger than zero (r = 0.539; p < .05). There are also strong intercorrelations between various meteorological factors. Temperature is significantly correlated to wind speed, solar radiation, and barometric pressure. Wind speed shows significant correlations to solar radiation and relative humidity, which have a significant intercorrelation themselves. Since the different "independent" weather variables are highly intercorrelated, a causal analysis of the alarm behaviour was not attempted.

A multiple regression analysis, however, reveals a high predictability (Table 2). Of the total variation in defensive behaviour, 92.4% can be explained due to regression on the meteorological data (Fig. 1). There was no significant difference between sites. Defensive behaviour shows a positive regression on all climatic factors but wind speed. Thus, a high number of stings in the target would be expected under high barometric pressure on hot, sunny and humid days, with calm wind conditions. The relative predictive power of the various meteorological variables on defensive behaviour shows that the strongest predictor, using single factors only, is temperature (r^2 = 0.29). Better predictions are obtained by successively adding wind speed, solar radiation, relative humidity, and pressure into the analysis. This order represents the best predictive pair, triplet, quadruplet and quintuplet of

<table>
<thead>
<tr>
<th>Variable</th>
<th>Dimension</th>
<th>Regression Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>constant</td>
<td>-</td>
<td>-959.192</td>
<td>0.138</td>
</tr>
<tr>
<td>temperature</td>
<td>°C</td>
<td>1.181</td>
<td>0.077</td>
</tr>
<tr>
<td>wind speed</td>
<td>m/sec</td>
<td>-0.535</td>
<td>0.528</td>
</tr>
<tr>
<td>solar radiation</td>
<td>W m^-2 x 10^4</td>
<td>1.858</td>
<td>0.079</td>
</tr>
<tr>
<td>relative humidity</td>
<td>%</td>
<td>0.696</td>
<td>0.079</td>
</tr>
<tr>
<td>barometric pressure</td>
<td>Pascal x10^5</td>
<td>1.416</td>
<td>0.175</td>
</tr>
</tbody>
</table>
Fig. 1. Regression of predicted number of stings in a leather target on a set of meteorological variables and actual stings counted. The meteorological factors included: air temperature, wind velocity, solar radiation, relative humidity and barometric pressure.

variables. Each factor improves the predictability significantly (Table 3). Although nectar flow was tracked, it showed nearly no influence on defensive behaviour and does not significantly improve the predictability in the present analysis.

Table 3. Best combinations of various predicting meteorological variables and F values for test of $R_k^2 < R_{k+1}^2$ (k = number of variables involved in the analysis, and * is $p < 0.5$)

<table>
<thead>
<tr>
<th>Variable</th>
<th>% variance explained (R$^2$)</th>
<th>F-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>air temperature</td>
<td>29.01</td>
<td></td>
</tr>
<tr>
<td>+ wind speed</td>
<td>51.39</td>
<td>7.80*</td>
</tr>
<tr>
<td>+ solar radiation</td>
<td>63.19</td>
<td>5.01*</td>
</tr>
<tr>
<td>+ relative humidity</td>
<td>73.41</td>
<td>5.75*</td>
</tr>
<tr>
<td>+ barometric pressure</td>
<td>92.41</td>
<td>35.06*</td>
</tr>
<tr>
<td>+ nectar flow</td>
<td>92.56</td>
<td>0.02 n.s.</td>
</tr>
</tbody>
</table>

DISCUSSION

Defensive behaviour in honey bees is genetically and environmentally controlled. The intensity of the defense response is modified in predictable ways by measurable environmental factors. Using our results and given sets of environmental parameters, we can predict defensive behaviour (in terms of number of stings in a test leather) as shown in Table 2. Our results support assertions of higher overall activity of the bees under high temperature and high humidity conditions (Collins 1981). In addition, the bright sky provided high contrast conditions in which the target was more readily perceived and attractive to the defensive bees. Such attractiveness to high contrast has been reported by Koeniger (1979). High wind speeds are likely to reduce pheromone concentrations by convective dilution and therefore affect the initial stimulus in our test. Under cool, overcast conditions when it is windy and damp, the bees will show low intensity of defensive behaviour. There may be exceptions to the rule as our data are based on averages with some variation in a temperate climate. In the tropics or subtropics weather effects on defensive behaviour may be different. Also we have no data on defensive behaviour before a storm with rapidly falling barometer. Schua (1952) observed that honey bee colonies are more defensive under such conditions than when the pressure is steady. Changing the alarm stimulus by mishandling or rough handling of the bees could also result in more intensive defensive behaviour, while prudent use of smoke reduces the tendency to sting.

When good weather gives ideal foraging conditions, many bees are likely to be absent from the nest and the colony is in reality weaker, yet the defensive behaviour is most intense. This observation agrees with the data of Collins and Rinderer (1985) which show an apparent correlation of defensive behaviour and amount of empty comb in the nest. They reported an increase in defense with increase in the ratio of comb surface area per bee. When most of the foragers are at home in poorer weather and this ratio is low, we found the stinging response to be less. However, we quantified only the final act of defensive behaviour. Other aspects such as strikes against the veil or body (Rinderer 1982) or increased agitation (Collins and Rothenbuhl 1978), which may be sufficient to ward off attackers (or beekeepers) without the increased completed stinging behaviour, were not quantified in this test.

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REFERENCES


