EFFICACY OF PERMETHRIN* AS A HONEYBEE FORAGING DETERRENT

E.H. ERICKSON
B.R. TICKES
C.L. MCKENZIE
A.H. ATMOWIDJOJO
U.S.A.

Abstract

Permethrin applied at low rates has been reported to deter foraging by honey bees. The present study was undertaken to determine the level of deterrence of honeybee foraging in alfalfa imposed by different application rates of permethrin. Bee counts were made during the time of peak foraging which had been predetermined. Permethrin applied at the rate of 112 g a.i./ha reduced foraging by 26% on day one with no significant reduction thereafter. The 168 g rate reduced post-treatment foraging by 68, 54 and 26% on days 1, 2 and 3 respectively. At the 224 g rate foraging was reduced by 67, 59 and 23%, while at the 280 g rate foraging was reduced by 84, 76 and 81% for days 1-3 respectively. There were significant differences in the mean levels of foraging deterrence between all four rates of application ($P < 0.05$). Only the 280 g rate provided an adequate level of protection for honeybee colonies for the critical three day post-treatment period in alfalfa.

Introduction

Agrochemicals damage or destroy ten to twenty percent of all honeybee colonies in the United States each year (ERICKSON & ERICKSON, 1983; ERICKSON et al., 1990). As great as these losses are to beekeepers, crop producers who rely on honeybees for pollination suffer equal and sometimes even greater financial loss. The need for a solution to the honeybee mortality issue is particularly acute in areas with high density multiple cropping practices. In Southwestern Arizona, for example, the application of insecticides to blooming bermuda grass grown for seed frequently leads to the poisoning of numerous honeybee colonies positioned nearby for melon pollination. These losses occur because the bees coincidently gather pollen from the bermuda grass. Hence, that which is done to optimize productivity in one field is detrimental to the production of a crop in an adjacent field. The beekeeper is caught in the middle. Permethrin applied at low rates has been reported to deter foraging by honeybees (ERICKSON et al., 1983; RIETH & LEVIN, 1988; JOHANSEN & MAYER, 1990; ATKINS & KELLUM, 1980, 1981). Based on preliminary studies with permethrin conducted in bermuda grass seed production fields (ATKINS & SMITH, unpub.) and, in response to a request from bermuda grass seed producers, the Arizona Department of Agriculture (ADA), in 1993, issued a Special Local Need (SLN) Registration allowing application of 112 to 224 g ai/ha) of permethrin (Pounce 3.2 EC) to Bermuda grass as a honeybee foraging deterrent.

** Mention of a trade name does not constitute endorsement by the USDA-ARS for its use over that of any other proprietary product.*

In support of this SLN, the ADA asked that meaningful field studies be conducted to ascertain the level and duration of honeybee foraging deterrence effected by permethrin under Arizona conditions. Research (ERICKSON et al., 1997; ERICKSON, unpub.) has shown that honeybees forage in Bermuda grass sporadically. Because of the unpredictability of foraging activity, we concluded that the requested studies could not be conducted in Bermuda grass as originally planned. Alternatively, we elected to conduct the needed studies in seed alfalfa where our objective was to determine the level of deterrence of honeybee foraging imposed by different application rates of permethrin under conditions of maximum honeybee foraging pressure.

Methods and Materials

In the summer of 1996 and 1997, honeybee foraging deterrence studies were conducted at the University of Arizona, Mesa Experimental Farm, Yuma, AZ, on mature alfalfa fields allowed to reach full bloom in an effort to ensure maximum bee attractiveness. Three alfalfa fields ranging in size from 2 to 8 ha served as 3 replicates in a splitplot research design used in all four studies conducted over the two year period. An apiary of 40 honeybee colonies was centrally located between the three fields with the most distant field approximately 366 m from the apiary.

Each field was equally divided into blocks separated by irrigation ditches. Three blocks from each field were selected at random and split east to west with the south side of each block treated with permethrin at rates of 112, 168, 224 and 280 g a.i./ac and the north side left untreated. Unused blocks provided additional bee forage and typically bordered the field. Permethrin was always applied at dusk when foraging activity of honeybees was minimal, using a Melroe Spra-Coupe^{R} with a 18.3 m boom.

Preliminary data to determine peak honeybee foraging activity at the study site was taken hourly between 0630 and 1830 h from June 3 to June 6, 1996 (Figure 1). At the beginning of each study period for each rate of application, foraging honeybees were counted for three consecutive days prior to spraying. Subsequent counts were taken at 24 h intervals during peak honeybee foraging activity for 3 days post-treatment.

Monitoring Honeybee Foraging. The methodology for determining levels of honeybee foraging activity was modified from that of E.L. ATKINS (unpub.). Each observer was equipped with a lightweight stick with dangling strings spaced 1 m apart, a stopwatch and counter. After setting the stop watch at 2.5 minutes and holding the stick to one side, each observer walked approximately 46 m counting all bees seen on flowers, including those landing and departing, between the strings during the 2.5 minute period. Three successive counts were taken in each subplot with a minimum of 6 m separating each data path. The dates and times of data acquisition for each of the treatment periods were as shown below.

Table 1

Study dates and times

Treatment	Morning	Midday	Afternoon
112 g permethrin (8/19 – 8/24/96)			17.30 – 19.00 h
168 g permethrin (7/28 – 8/2/97)	09.00 – 11.00	12.30 – 14.30 h	16.00 – 19.30 h
224 g permethrin (6/10 – 6/15/96)			15.00 – 17.30 h
280 g permethrin (6/23 – 6/28/97)	08.30 – 11.00 h		14.30 – 17.00 h

The daily time interval targeted for data acquisition was 14.00 – 18.00 h (Figure 1), however, the precise times varied slightly between treatments due to the constraints of field conditions, weather, and available personnel. At the 168 – 280 g rates, data were taken at times other than peak foraging to determine whether there were significant time of day effects on the efficacy of permethrin.

Statistical Analyses. The mean number of bees detected in treatment and control plots during the period of peak foraging was determined for each treatment/day/time and over all days/times. Differences in foraging activity between treatments across days and times were determined by ANOVA (SAS Institute Inc., 1995).

Results and Discussion

The preliminary data (Figure 1) demonstrated a distinct peak in foraging by worker honeybees between 14.30 and 16.00 h with elevated levels of foraging extending beyond 18.30 h. A second, measurably smaller peak in foraging activity was evident between 09.30 and 10.30 h followed by a slight decline at 11.30 h. These data coincide well with data acquired in the Yuma, AZ area, between May 27, and July 3, 1980, where in 11 day foraging means for pollen collecting honeybees were 7.2, 8.4, 12.8 and 6.3 bees at 10.00, 12.30, 17.00 and 18.30 h respectively (G.M. LOPER & B.E. VAISSIERE, unpub.). These data were based on bee counts in 18.3 m rows 1 m wide/minute (E.L. ATKINS, unpub.).

Analysis of variance for peak foraging periods revealed significant differences ($P < 0.0001$) for rate, day, and field as well as the rate X day, rate X field and day X field interactions. Analysis of variance for foraging activity between mornings and afternoon periods demonstrated significant differences for rate ($P < 0.0001$), day ($P < 0.0001$), time ($P < 0.0006$) and day x field ($P < 0.0001$). Mean pre-treatment counts were not significantly different between treated and untreated sub-plots for all study periods ($P > 0.33$).

Post-treatment foraging levels in the treated sub-plots, expressed as a percentage of foraging activity in those left untreated, for the four application rates of permethrin are presented in Figure 2. A Duncan's Multiple Range comparison demonstrated significant differences in mean levels of foraging deterrence between all four rates of application ($P < 0.05$). At the 112 g rate, foraging was reduced by only 26% on day one

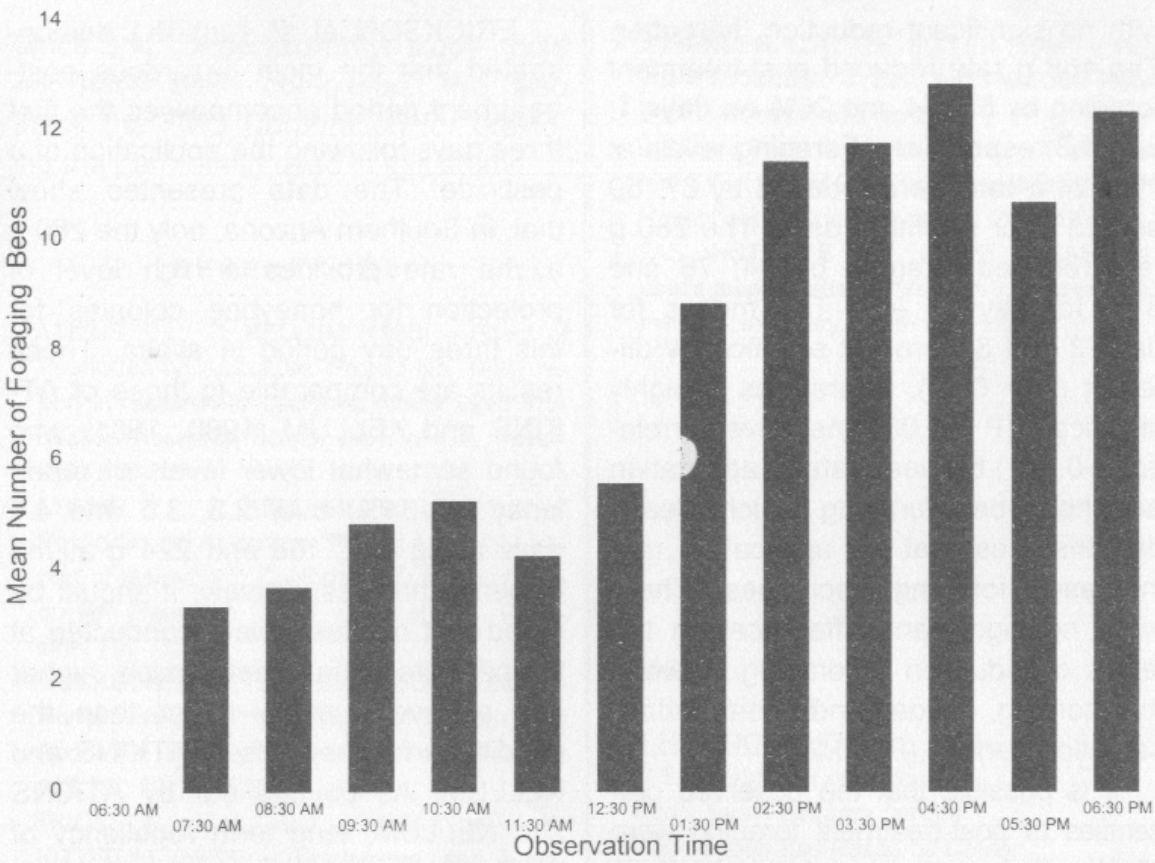

Fig. 1 – Preliminary foraging bee counts

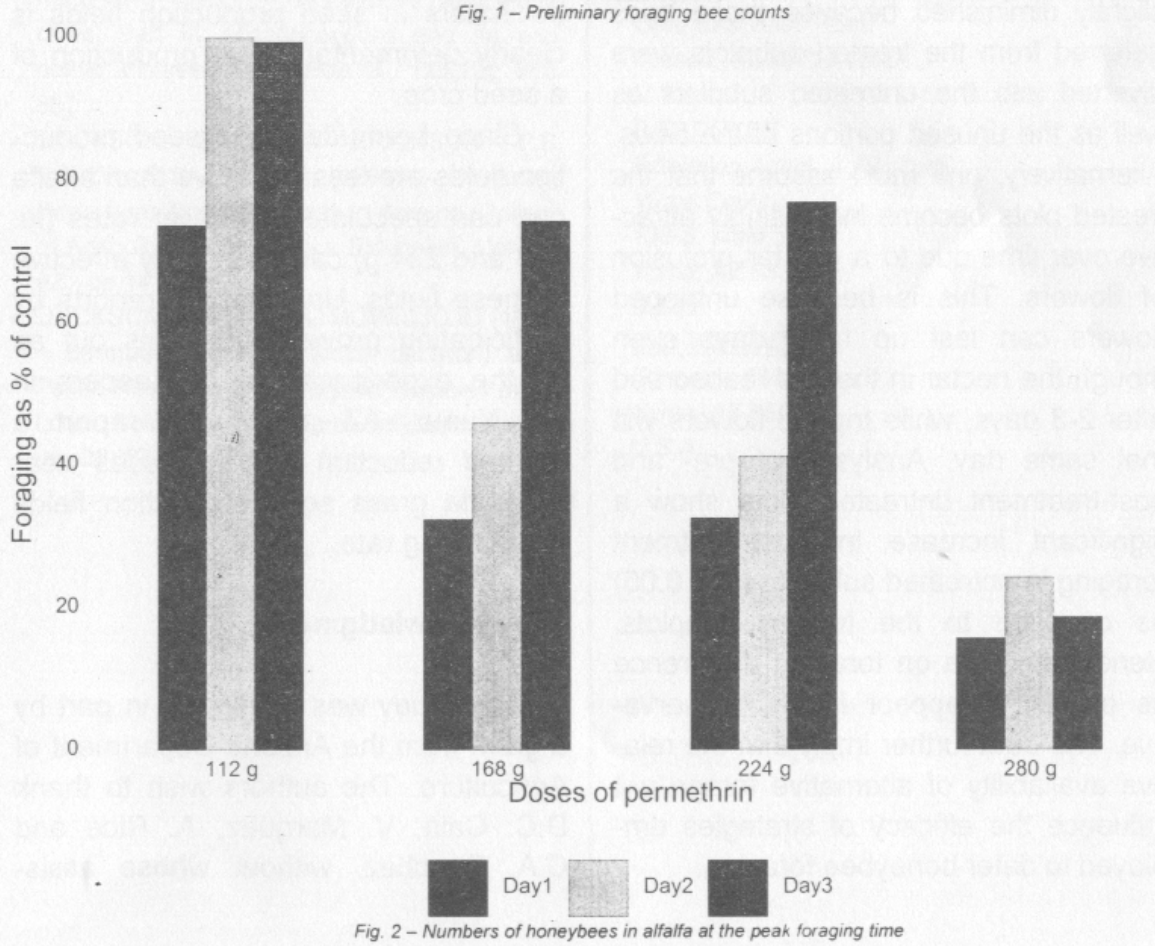

Fig. 2 – Numbers of honeybees in alfalfa at the peak foraging time

with no significant reduction thereafter. The 168 g rate reduced post-treatment foraging by 68, 54 and 26% on days 1, 2 and 3 respectively. Foraging levels at the 224 g rate were reduced by 67, 59 and 23% for the three days. The 280 g rate reduced foraging by 84, 76 and 81% for days 1 – 3: The means for days 2 and 3 were not significantly different ($P > 0.19$). There was a highly significant ($P < 0.001$) negative correlation (-0.551) between rate of application and honeybee foraging which clearly demonstrates that as application rate increases foraging decreases. There were no significant differences in the levels of reduction in foraging between the morning, midday and afternoon observation periods ($P > 0.2$).

It is possible that the observed percentiles of post-treatment foraging were slightly diminished because those bees deterred from the treated subplots were diverted into the untreated subplots as well as the unused portions of the fields. Alternatively, one must assume that the treated plots become increasingly attractive over time due to a greater profusion of flowers. This is because untripped flowers can last up to 7 days even though the nectar in them is reabsorbed after 2-3 days, while tripped flowers wilt that same day. Analyses of pre- and post-treatment untreated plots show a significant increase in post-treatment foraging in untreated subplots ($P < 0.05$) as opposed to the treated subplots. Hence, the data on foraging deterrence as presented appear highly conservative. The data further imply that the relative availability of alternative forage will influence the efficacy of strategies employed to deter honeybee foraging.

ERICKSON et al. (unpub.) demonstrated that the most hazardous post-treatment period encompasses the first three days following the application of a pesticide. The data presented show that, in Southern Arizona, only the 280 g a.i./ha rate provides a high level of protection for honeybee colonies for this three day period in alfalfa. These results are comparable to those of ATKINS and KELLUM (1980, 1981) who found somewhat lower levels of repellency (15-34%) over 2.5, 3.5 and 4.5 days using 112, 168 and 224 g a.i./ha of permethrin respectively. It should be noted that our tests were conducted at temperatures that were much higher and relative humidity lower than the conditions for the tests of ATKINS and KELLUM. As pointed out by ATKINS and KELLUM, long term repellency of pollinators in seed production fields is clearly detrimental to the production of a seed crop.

Since bermuda grass seed production fields are less attractive than alfalfa one can speculate that lower rates (ie. 168 and 224 g) can be equally effective in these fields. Unconfirmed reports by participating growers bear this out as do the experiences of beekeepers in the Yuma, AZ area, who report a marked reduction in bee losses near bermuda grass seed production fields at the 168 g rate.

Acknowledgments

This study was supported in part by a grant from the Arizona Department of Agriculture. The authors wish to thank D.C. Cain, V. Marquez, A. Rice and C.A. Sanchez, without whose assis-

tance and cooperation this study could not have been completed. We also thank the FMC Corporation for providing the permethrin used in this study.

REFERENCES

- ATKINS, E.L.; D. KELLUM (1980) – Effect of Pesticides on Apiculture. Project No. 1499, report of research to California Alfalfa Seed Production Research Board, Univ. of CA., Riverside, 658-701
- ATKINS, E.L.; D. KELLUM (1981) – Effect of Pesticides on Apiculture. Project No. 1499, report of research to California Alfalfa Seed Production Research Board, Univ. of CA., Riverside, 702-732
- ERICKSON, E.H.; B.J. ERICKSON (1983) – Honeybees and Pesticides. Part I: Plain Talk About the Past and Present. *Amer. Bee. J.*, **123**(10): 724, 726-730
- ERICKSON, E.H.; B.J. ERICKSON; P.K. FLOTTUM (1983) – Honeybees and Pesticides. Part III: Misconceptions and an economic analysis. *Amer. Bee. J.*, **123**(12): 860-867
- ERICKSON, E.H.; B.J. ERICKSON; P.B. BAKER; K.S. TAYLOR (1990) – Protecting Honeybees from Pesticides in Arizona. College of Agriculture, Cooperative Extension, Univ. of AZ., pp 14, #8923
- ERICKSON, E.H.; A.H. ATMOWIDJOJO (1997) – Bermuda Grass (*Cynodon dactylon*) as a Pollen Resource for Honeybee Colonies in the Lower Colorado River Agroecosystem. *Apidology* **28**: 67-62
- JOHANSEN, C.A.; D.F. MAYER (1990) – Pollinator Protection: a Bee and Pesticide Handbook. Wicwas Press, pp 212
- RIETH, J.P.; M.D. LEVIN (1988) – The Repellent Effect of two Pyrethroid Insecticides on the Honeybee. *Physiol. Entom.* **13**: 213-218
- SAS INSTITUTE INC. (1995) – SAS/STAT user's guide: statistics, Version 6, third ed. SAS Institute, Inc. Cary, North Carolina.

Authors' address:
E.H. ERICKSON
A.H. ATMOWIDJOJO
U.S. Department of Agriculture
Agricultural Research Service
Carl Hayden Bee Research Center
2000 East Allen Road
Tucson, AZ 85719-1596
U.S.A.
B.R. TICKES
Extension Agent, Agriculture
Yuma County
198 S. Main Street
Yuma, AZ 85364
U.S.A.
C.L. MCKENZIE
Formerly, FMC Corp.
Yuma, AZ 85364
U.S.A.