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Preliminary observations of autumn feeding of USDA-ARS Russian honey bees to enhance flight performance during almond pollination

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Summary

We attempted to increase bee populations of Russian and Italian honey bee colonies by feeding two pounds of patties of bee-collected pollen in October and November, and comparing fed colonies to unfed colonies of both types (*n*=16 per treatment group) in late winter. Flight activity of colonies in the four treatment groups was monitored electronically with ApiSCAN Plus® counters on 17-25 February 2006 while the colonies were used for almond pollination. At the beginning of almond bloom, the mean area of sealed brood was 56% greater in the fed colonies (both bee types) than in the unfed colonies. Adult bee populations were 17% larger in the fed group but this increase was not significant. Bee populations and brood populations both were similar for Russian and Italian bees (i.e., when feeding groups were combined). Changes in bee and brood populations did not differ statistically between Russian and Italian colonies. Flight activity during almond pollination was affected neither by feeding treatment nor by bee stock, presumably because these factors did not influence populations of adult bees. Flight activity was significantly affected by temperature, adult bee population and period of the day. The results showed that supplemental feeding maintained adult bee populations in Russian colonies through winter; more extensive or earlier feeding may increase bee populations.

Keywords: pollen supplement, foraging

Introduction

USDA-ARS developed Russian honey bees (*Apis mellifera*) primarily to provide U.S. beekeepers with a stock that resists parasitic mites and that has good honey production (Rinderer *et al.* 2005). These bees are now being used to help fill the recent increased demand for colonies to pollinate almonds in California in late winter. We previously found that Russian and Italian colonies that had equal adult bee populations during almond bloom had similar flight activity (Danka *et al.* 2006). However, Russian colonies often had less flight activity because they were less populous on average than Italian colonies. Those observations raised the issue of whether stimulative feeding of Russian colonies before almond pollination can enhance bee populations and flight activity during almond bloom. The situation is of practical importance for beekeepers who need to meet rental contracts. It also is of interest from the standpoint of behavioral ecology, as it is unknown whether these northern-adapted bees can be made to expand their populations in the autumn or winter. Supplemental protein supplied in the autumn or winter previously has been shown to boost non-Russian bee populations during the time of almond bloom (Peng *et al.* 1984, DeGrandi-Hoffman *et al.* 2008).

We began to address this question with exploratory feeding trials with colonies overwintering in Louisiana in two years prior to the results presented here. Mid-winter (January) feeding of two formulations of a commercial pollen substitute yielded no appreciable population expansion in either Russian or Italian bees in February or March 2004; Italian colonies were larger than Russian colonies whether fed or not. We then chose to evaluate natural bee-collected pollen as a supplement. A test of feeding one pound of pollen in November 2004 indicated that fed Russian colonies had greater populations of bees and brood than unfed Russian colonies in February and March 2005. The trial described here is a larger investigation of the effect of feeding pollen in autumn on population expansion and resultant flight activity of Russian bees during almond pollination. There is no standard regime among beekeepers for feeding supplemental protein in autumn. We chose to feed two pounds of supplement because this amount sometimes is given by commercial beekeepers, and also was the amount used in a recent autumn feeding test of a new protein supplement (Feedbee®; Saffari *et al.* 2004) which resulted in larger bee populations in the following April (A. Saffari, pers. comm.).

Materials and Methods

Colonies were established in spring and summer 2005 in cooperation with a commercial beekeeper in central Louisiana. Russian queens from four commercially available lines (Rinderer et al. 2005) were mated to Russian drones at isolated research mating stations maintained by our laboratory. Italian queens were reared from commercial stock [Bordelon Apiaries (Moreauville, LA) and Ohio Queen Breeders (Worthington, OH)] and open-mated to drones of the same sources. All colonies were kept on six-way pallets, with colonies of one stock per pallet and with colonies of both stocks kept in two apiaries.

The population of adult bees and the area of sealed brood of each colony were measured to the nearest 10% coverage of a deep Langstroth comb in late October 2005. The 32 Russian and 32 Italian colonies selected for use, and the fed and unfed groups within these stocks, initially had equal populations of adult bees and equal amounts of sealed brood (Fig. 1). Half of the colonies of each stock were given supplemental pollen in the form of patties made of bee-collected, autumn pollen mixed with 15% sucrose syrup (66% solids) by volume. The 'fed' colonies each were given combined feeding treatment groups. Bee populations in February did not differ significantly from those in November (P=0.237 for all colonies; P=0.883 for fed colonies; P=0.128 for unfed colonies), but some trends we apparent. First, bee populations of fed colonies (combined bee stocks) were about 7% larger in February than in November, while unfed colonies were about 6% smaller. Second, fed Italian colonies were 12% larger in February than in November while fed Russian colonies showed no change in bee population. Third, unfed Russian colonies showed a loss of about 16% while unfed Italian colonies gained about 4%.

Flight activity during almond pollination was affected neither by feeding treatment nor by bee stock, presumably because these factors did not influence populations of adult bees. Flight activity was significantly affected by temperature, adult bee population and period of the day (Table 2). Flight was greater at higher temperatures, and temperature and colony size interacted such that flight responses to temperature were more pronounced in large colonies. For example, Fig. 2 shows responses of colonies grouped as "large" (average of 6.55 combs of bees) and "small" colonies (average of 2.84 combs of bees) by segregating all colonies at the overall average size of 4.76 combs of bees. A 1.8° F (1° C) rise yielded 6.6 more flights per minute in large colonies and 2.5 more flights per minute in small colonies when all other factors were equal. Temperature effects, regardless of colony size, were more pronounced in the morning than in the midday and afternoon (Fig. 3). An additional comb of bees yielded 8.0 more flights per minute in the morning, but only ca. 3.6 more in the midday and afternoon. Flight was inhibited by factors other than temperature later in the day (e.g., depletion of nectar and pollen), as activity at all but the lowest temperatures recorded in the afternoon was much lower than at the same temperatures earlier in the day.

Table 2. Test results from analysis of variance of a reduced model of honey bee flight activity. Shown are Type 1 SS, F-tests from Type 3 tests from GLM, and parameter estimates for regression equations that describe the influences of temperature, adult bee population and time of day on flight.

Effect	SS (× 1000)	F	df	$P > F$	Parameter estimate
bees	1,398	24.19	1,4402	<0.001	-5.36
temp	10,005	7.58	1,4402	0.006	-1.37
time	1,262	45.17	2,24	<0.001	am=-28.81[1]
bees*temp	792	1165.84	1,4402	<0.001	0.91
temp*time	742	390.71	2,4402	<0.001	am=4.29[2]
col(type)	719	NA	NA	NA	NA
time(day)	639	NA	NA	NA	NA
day(col, type)	250	NA	NA	NA	NA
residual	2,996	NA	NA	NA	NA

[1] midday = 61.19, pm = 4.26
[2] midday = -0.17, pm = -0.00

Discussion

Feeding two pounds of bee-collected pollen in autumn affected brood populations more than it affected adult bee populations in late winter. This suggests that bees stored the food, ceased brood rearing as usual in late autumn, and then used the stored nutrients when brood rearing resumed in mid winter. Feeding appeared to stimulate brood rearing in the Russian colonies in particular. Fed Russian colonies had twice as much brood as unfed Russian colonies, whereas the feeding yielded a 27% increase in brood of Italian colonies (Fig. 1). This is interesting because it might be expected that bees from northern areas, where the brood rearing cycle around winter is expected to be highly programmed, would be less likely to respond to winter feeding. The value of feeding Russian colonies was further supported by the observation that fed Russian colonies tended to maintain their adult bee populations through the winter, while unfed colonies tended to lose bees (Fig. 1). The current high rental fees being paid for colonies in almond pollination thus may make more intensive feeding regimes cost effective.

Flight activity of Russian colonies was consistent with what we observed previously in comparisons of Russian and Italian bees during pollination of almonds (Danka *et al.* 2006) and lowbush blueberries (Danka and Beaman 2007). The environmental effects of temperature, colony population and period of the day affected flight, but bee stock did not. Furthermore, Russian and Italian bees

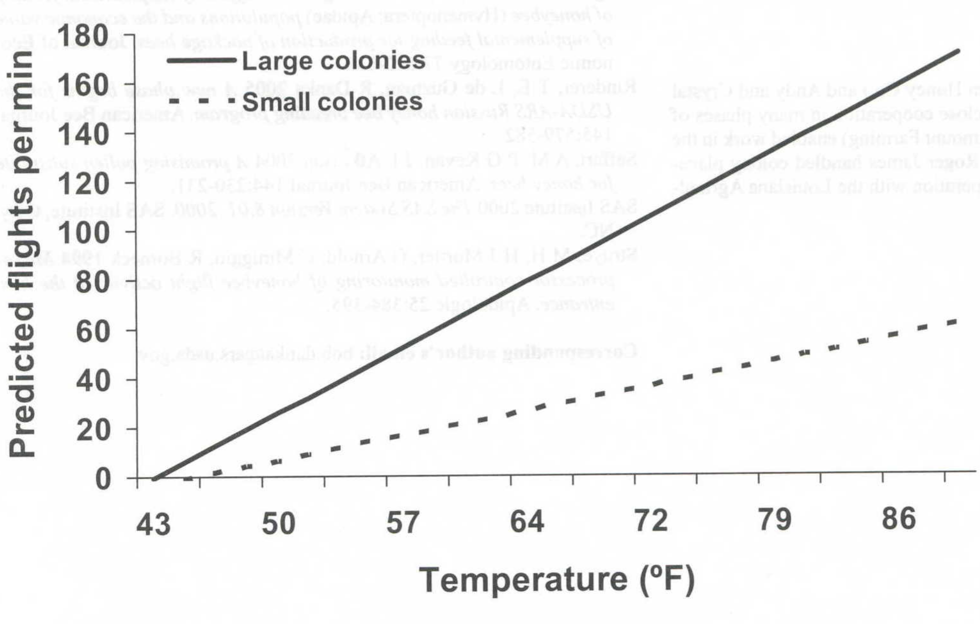

Figure 2. Flight activity of large and small colonies of honey bees in relation to temperature. These are flight responses modeled using regression parameter estimates and the average adult bee populations of "large" (mean of 6.55 combs fully covered with bees) and "small" (mean of 2.84 combs of bees) colonies.

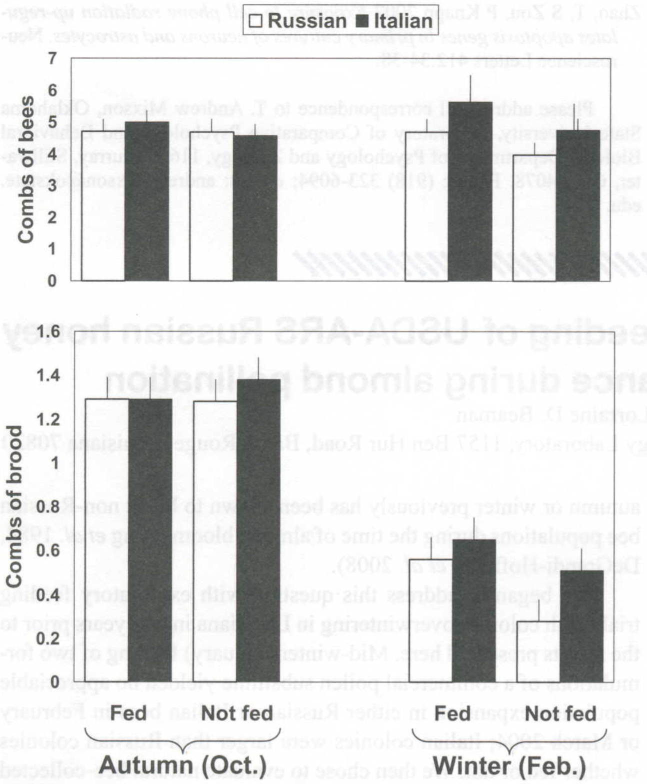

Figure 1. *Mean populations of adult bees and brood in colonies of Russian and Italian bees either fed two pounds of supplemental pollen in autumn or not fed supplement. Error bars represent one SE. The only difference between fed colonies and unfed colonies occurred in brood populations in winter. For reference, one deep comb has about 273 sq in (1760 sq cm) of surface area.*

1-lb (454-g) pollen patties on 27 October and 9 November. This feeding schedule coincides with the last normal cycle of brood rearing in the region. All colonies were given 2 gal (7.6 liters) of high fructose corn syrup during the feeding period. The bees were held over winter in the two Louisiana apiaries until they were moved for almond pollination.

The colonies were trucked directly to an almond orchard near Lost Hills, CA, and distributed along a quarter mile (ca. 400 m) of one central orchard road on 30 January 2006. The orchard had ca. 500 acres each of 'Nonpareil' and 'Monterey'. Bee and brood populations were measured on 16 February at the start of bloom. Six colonies were not included further because their queens had superseded.

Flight activity was measured during nine days of the major bloom period (17-25 February) using ApiSCAN-Plus® electronic counters (Lowland Electronics; Leffinge, Belgium). These counters are mounted at the hive entrance and register interference of infrared light beams to quantify the activity of outgoing and incoming bees. The principal and design were described by Struye *et al.* (1994). The data obtained from 0700 through 2000 h were converted to an average hourly count of bee flights per minute. ApiSCAN counts were adjusted by multiplying by 0.67 to account for the average effect of bees clustering at the hive entrance (Danka and Beaman 2007). Temperatures were recorded at 5-min intervals as black globe temperatures (Corbet *et al.* 1993) 39 inches (1 m) above ground using HOBO dataloggers (#H08-00804) and thermocouples (# TMC6-HB) (Onset Corp.; Bourne, MA). Temperatures were converted to hourly averages for analysis.

Populations of adult bees and sealed brood were evaluated with analysis of variance (Proc Mixed; SAS 2000) for effects of stock and feeding treatment; season was included in the analysis of adult bee populations. Bee populations were transformed to $\log_{10}$ counts to make variances homogeneous. Comparisons of means following a significant ($\alpha = 0.05$) F-test were made by Fisher's protected least significant difference (LSD) test. Flight activity was analyzed as a completely randomized design involving a split-plot treatment arrangement (colonies within type as the main unit; repeated measures of colonies through time as the subunit). Regression analysis followed analysis of variance to evaluate how flight activity was influenced by bee stock, feeding treatment, adult bee population, brood population, temperature and period of the day. Period of day was a classification variable that segregated observations into morning (before 1100 h), midday (1100 – 1359 h) and afternoon (1400 h and later) counts. The full model analysis evaluated the main effects, squares of main effects and all 2-way interactions. Effects found to be highly significant at $P < 0.01$ were retained in the reduced model. The model was further reduced by eliminating terms found to contribute to less than 10% of variation for each main effect according to Type I sums of squares. Retained terms were used as regressor variables to model the number of bees leaving a colony under defined conditions of the significant effects.

Results

At the beginning of almond pollination (three and a half months after feeding), the mean area of sealed brood was 56% greater in the 28 fed colonies (0.61 ± 0.09 (SE) combs of brood) than in the 30 unfed colonies (0.39 ± 0.06 combs of brood) (Fig. 1); this was a significant increase (Table 1). (Note that here 1.0 comb means a comb that is fully covered with bees, not a comb that is as little as 2/3 covered, as is commonly used for strength inspections during pollination rentals.) The brood increases of fed colonies within the two bee stocks did not differ statistically despite varying by nearly four-fold (100% for Russians, 27% for Italians). When feeding treatment groups were pooled within each stock for analysis, brood populations were statistically similar for Russian and Italian bees.

Populations of adult bees were 19% larger in the fed group but this increase was not significant (Table 1, Fig. 1). Feeding increased adult bee populations similarly in Russian and Italian colonies, and bee populations were similar for Russian and Italian colonies of

Table 1. Results of analysis of variance of the effects of bee stock and feeding treatment on populations of adult bees and brood. There were 32 colonies each of Russian and Italian colonies, and half of each type were given 2 lbs (0.91kg)of supplemental pollen beginning in late October 2005. Bee and brood populations were measured at feeding and at the beginning of almond pollination in mid February 2006.

Parameter	Effect	F	df	$P > F$
sealed brood	stock	2.26	1,54	0.139
	feeding	4.05	1,54	0.049
	stock × feeding	0.42	1,54	0.521
adult bees	stock	0.10	1,55	0.754
	feeding	2.10	1,55	0.153
	season	1.43	1,55	0.237
	stock × feeding	0.36	1,55	0.553
	stock × season	0.04	1,55	0.839
	feeding × season	1.31	1,55	0.184

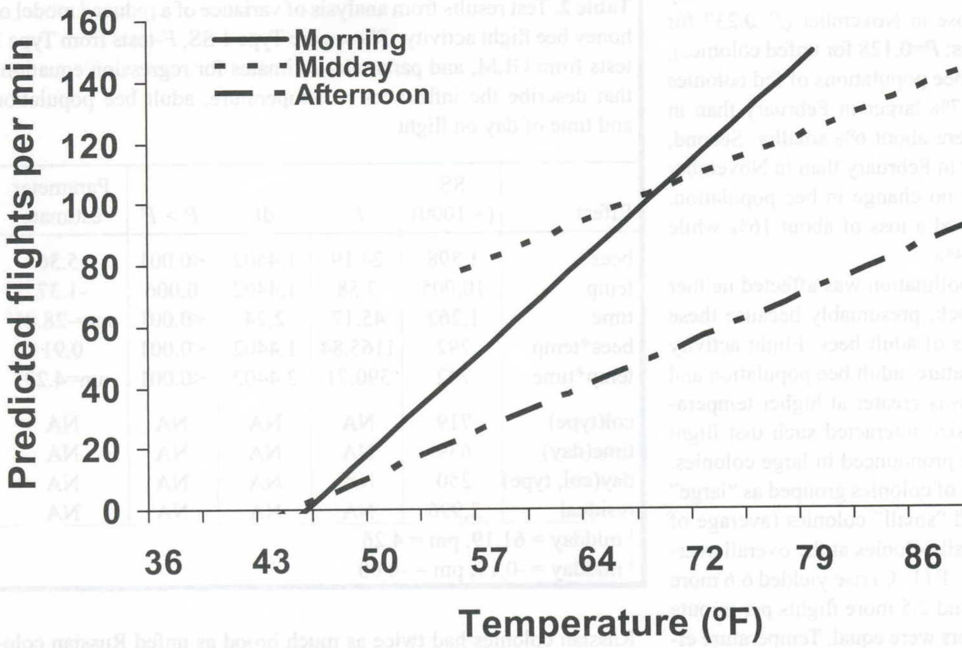

Figure 3. *Honey bee flight activity as influenced by temperature and time of day. Colonies responded more strongly to varying (rising) temperatures in the morning than they did later in the day. The results shown are predicted responses of colonies that have an overall average population of adult bees (4.76 combs of bees).*

responded similarly to varying environmental effects. Our cumulative observations indicate that Russian colonies of adequate size are useful pollinators of almonds.

Conclusions and Recommendations

Russian colonies that were fed two pounds of supplemental pollen in the autumn had larger brood populations than unfed colonies in late winter. Although this feeding program did not increase the populations of adult bees, the results indicate the potential to do so. We recommend feeding a minimum of two pounds of supplemental protein to maintain bee populations in Russian colonies. Population increases perhaps could be obtained if feeding is begun earlier than late autumn and if more than two pounds of supplement is given.

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