

Flight Activity of USDA–ARS Russian Honey Bees (Hymenoptera: Apidae) During Pollination of Lowbush Blueberries in Maine

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ABSTRACT Flight activity was compared in colonies of Russian honey bees, *Apis mellifera* L. (Hymenoptera: Apidae), and Italian bees during commercial pollination of lowbush blueberries (principally *Vaccinium angustifolium* Aiton) in Washington Co., ME, in late May and early June in 2003 and 2004. Colonies of the two stocks were managed equally in Louisiana during autumn through early spring preceding observations in late spring each year. Resulting average populations of adult bees and of brood were similar in colonies of the two bee stocks during pollination. Flight during pollination was monitored hourly on 6 d each year by counting bees exiting each colony per minute; counts were made manually with flight cones on 17 colonies per stock in 2003 and electronically with ApiSCAN-Plus counters on 20 colonies per stock in 2004. Analysis of variance showed that temperature, colony size (population of adult bees or brood), and the interaction of these effects were the strongest regulators of flight activity in both years. Russian and Italian bees had similar flight activity at any given colony size, temperature, or time of day. Flight increased linearly with rising temperatures and larger colony sizes. Larger colonies, however, were more responsive than smaller colonies across the range of temperatures measured. In 2003, flight responses to varying temperatures were less in the afternoon and evening (1500–1959 hours) than they were earlier in the day. Russian colonies had flight activity that was suitable for late spring pollination of lowbush blueberries.

KEY WORDS *Apis mellifera*, *Vaccinium angustifolium*, pollination, foraging behavior

The Agricultural Research Service of the U.S. Department of Agriculture (USDA) developed Russian honey bees, *Apis mellifera* L. (Hymenoptera: Apidae), primarily to provide U.S. beekeepers with a stock having genetic resistance to the parasitic mites *Varroa destructor* Anderson & Trueman and *Acarapis woodi* (Rennie), and having good honey production (Rinderer et al. 2005). Another aspect of the stock development program is evaluating the abilities of Russian bees for crop pollination. Two studies have examined the comparative flight activity of Russian bees in commercial pollination settings. During late winter pollination of almonds in California, Russian bees had flight activity similar to Italian honey bees when bee populations and other significant environmental variables (temperature and time of day) were the same for the two bee types. However, Russian colonies on average were smaller than Italian colonies during this early season pollination, and Russian colonies had less total flight (Danka et al. 2006). During midsummer pollination

of upland cotton (*Gossypium* spp.) in Louisiana, Russian and Italian colonies with equalized brood populations had equal flight activity overall during an 11-d test, although Italian colonies had more flight on 1 of 3 d of measurement (Danka 2005).

Here, we report on flight activity of Russian colonies during pollination of lowbush blueberries (principally *Vaccinium angustifolium* Aiton). Lowbush blueberry production occurs on cleared “barrens” in Maine and in five eastern Canadian provinces. Lowbush accounts for about half of all blueberry production in North America (Yarborough 1998). The flowers require insect pollination, and honey bees commonly are used for commercial production. In 2000, ≈60,000 colonies were used in Maine (Yarborough 2002). Bloom in Maine usually occurs between mid-May and early June. Weather during bloom sometimes is cool, windy, and rainy and thus marginally adequate for bee flight and pollination. Our objectives were to determine whether the flight activity of Russian and Italian colonies differed during pollination of lowbush blueberries, and how environmental effects influence the flight activity of honey bees in this pollination setting.

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Materials and Methods

The research took place in cooperation with Merimack Valley Apiaries (MVA), a beekeeping company that specializes in honey bee pollination of apples (*Malus* spp.), highbush blueberries, lowbush blueberries, and cranberries in the northeastern United States. Colonies are managed and propagated by MVA in central Louisiana during winter and spring. Observations during lowbush blueberry pollination were made in 2 yr.

2003. Russian colonies were established at Lebeau, LA, in late summer 2002 by using commercial queens (Country Honey, Little Valley, NY). Italian colonies had queens of Minnesota Hygienic stock (Glenn Apiaries, Fallbrook, CA) that were propagated and open mated in Louisiana. All colonies were housed in 1½ story Langstroth hives. In October and November, bees were fed dry pollen substitute (BeePro, Mann Lake, Ltd., Hackensack, MN) from open bins in the apiary, fed high fructose corn syrup, and medicated with oxytetracycline (Terra Patties, Mann Lake, Ltd.) and coumaphos (Check Mite, Bayer Corp., Shawnee Mission, KS). They were fed again with fructose syrup beginning in February. Twice during spring 2003, MVA personnel equalized bee populations and brood populations within each stock by exchanging brood combs between colonies and removing surplus bees and brood.

Seventeen colonies of each bee type that had approximately equal bee populations were trucked directly to Maine and arrived on 25 May. The bees were placed for pollination on lowbush blueberry barrens in Washington County. These colonies were part of 2500 colonies placed on 500 acres of the crop. Colonies were fed fructose syrup while on site.

Flight activity was measured on 6 d between 31 May and 7 June. Two observers used flight cones (Gary 1967) to count the number of bees exiting each colony for 30 or 45 s once every hour (in some cases, every 30 min) through the day. Observers alternated which bee type they counted during consecutive hours. Colonies were measured in random order during each count. Data were standardized to bee exits per minute for analysis.

Population sizes were measured on 1 June by estimating the coverage of adult bees and sealed brood on each comb to the nearest tenth of a standard deep comb. During the measurements, there was no bee flight because the temperature was $\approx 15.6^{\circ}\text{C}$ (60°F), and light rain was falling.

"Black globe" temperatures at the apiary were measured at 1-min intervals by using HOBO dataloggers (H08-00804, Onset Corp., Bourne, MA). Black globe measurements integrate the effects of air temperature, solar radiation, and wind speed on a model of an organism and have been used to study temperature effects on honey bee flight (Corbet et al. 1993). We shaped 10-mm-diameter black globes from black laboratory stoppers and embedded the end of a thermocouple (HOBO TMC6-HB) in a hole drilled to the center of the globe. Unshaded black globes were po-

sitioned 1 m off the ground. Temperature readings were matched with flight counts from specific minutes.

2004. Russian colonies were established in late summer 2003 by using queens propagated by us (white/yellow/dark blue breeder line; Rinderer et al. 2005) and mated in isolation to Russian drones. Italian colonies (Minnesota Hygienic, as described above) were selected from MVA colonies that had been requeened in spring 2003. Colonies were managed from autumn 2003 to spring 2004 as described for the 2003 test. Twenty colonies of each stock were trucked from Louisiana and arrived at the same pollination site in Maine on 27 May. Bee and brood populations were measured on 28–29 May when the air temperature was $\approx 12.8^{\circ}\text{C}$ (55°F).

Flight activity was measured in 2004 with ApiSCAN-Plus electronic counters (Lowland Electronics, Leffinghe, Belgium). These units are mounted at the hive entrance (Fig. 1) and register interference of infrared light beams as a measure of activity of outgoing and incoming bees; the principal and design were described by Struye et al. (1994). ApiSCAN-Plus counters are ApisSCAN counters (Lowland Electronics 2005) that are modified to log data. Counters were placed on hive entrances for 3 d in Louisiana immediately before the bees being moved so that foragers could acclimate to them. Flight in Maine for all 40 colonies was recorded continually at 5-min intervals on 6 d between 30 May and 6 June. The data within each hour from 0700 through 1959 hours were converted to an average hourly count of bee flights per minute. Electronic counts often are artificially high because of bees clustering at the hive entrance. We adjusted for this effect by simultaneously measuring flight activity using flight cones (as in 2003) and ApiSCAN-Plus counters. Counts were taken on 3 d from 10 colonies. These data (unpublished data) were collected separately from the blueberry experiment but under similar conditions of temperature, colony populations, and bee types. Flight cone counts were significantly influenced by ApiSCAN-Plus counts (according to analysis of variance [ANOVA]), and counts were adjusted using the results of regression analysis: $\text{count} = \text{ApiSCAN-Plus count} \times 0.67$. The 95% confidence interval (CI) of this parameter estimate was 0.65–0.68.

Temperatures were recorded at 5-min intervals using methods as in 2003. We calculated mean hourly temperatures that coincided with hourly flight counts.

Statistical Analyses. Preliminary analysis found a significant effect of year and significant interactions of year with environmental factors (bee population and temperature). Data from each year therefore were analyzed separately based on a completely randomized design within each year. There was a split-plot treatment structure having colonies within bee type as the main unit and repeated measures of colonies through time as the subunit. ANOVA and regression analysis were used in three steps to evaluate the influence of bee stock and environmental factors on flight activity. First, a full model submitted to ANOVA



Fig. 1. ApiSCAN-Plus flight counters in use on experimental colonies.

(PROC MIXED, SAS Institute 2000) evaluated the main effects of bee stock, adult bee population, brood population, temperature, and time of day, plus squares of effects, all two-way interactions and a cubic effect of temperature. Time of day segregated observations into counts taken in the morning (before 1100 hours), during midday (1100–1459 hours), and in the afternoon (1500 hours and later). Second, a reduced model retained terms found to be significant at $P < 0.01$. Because of the large number of observations used, type I sums of squares were used to further evaluate the contributions of the retained effects. Terms that affected individual colonies (bee stock and colony size) were first in the model followed by terms that affected all colonies simultaneously (temperature and time). Effects whose type I sums of squares contributed only to the smallest 10% of total variation for that effect (i.e., main effect and interactions) were removed. Third, the final retained terms were used as regressor variables to show the number of bees leaving a colony under defined environmental conditions. When a regression line was fitted for a significant environmental effect of interest, other factors were held constant by using mean values for them in regression equations. Differences between the bee

stocks in colony size (bee and brood populations) were evaluated with t -tests.

Results

Russian and Italian colonies had similar populations of adult bees and of sealed brood in both years (Table 1). The effect of bee stock on flight activity was not significant in either year. Furthermore, the effect of bee stock did not interact with any of the other terms in the model, indicating that Russian and Italian bees responded similarly to variation in temperature, colony size, and time of day. Mean hourly flight observed from Russian and Italian colonies in 2003 is shown in Fig. 2. Temperature was the strongest regulator of flight activity during both seasons. Rising temperatures resulted in increased flight across the range of diurnal temperatures ($\approx 6.5\text{--}27.5^\circ\text{C}$ [$43.5\text{--}81.5^\circ\text{F}$]) recorded during lowbush blueberry pollination. Flight activity also increased linearly with larger colony size. There was an interaction between the effects of temperature and colony size in both years (Table 2).

In 2003, in addition to the main effects of temperature and colony size (best represented by brood area), the predictive model contained interactions of

Table 1. Colony sizes (mean \pm SE) of the two bee stocks and results of t -tests comparing colony sizes between stocks

Yr	Bee stock	Adult bee pop	Brood pop
2003	Russian	8.69 \pm 0.53	3,276 \pm 305
	Italian	9.30 \pm 0.43	3,755 \pm 308
	$t = 0.88, df = 32, P = 0.385$	$t = -1.09, df = 32, P = 0.284$	
2004	Russian	10.34 \pm 0.48	5,756 \pm 263
	Italian	10.28 \pm 0.34	6,340 \pm 292
	$t = -0.11, df = 38, P = 0.912$	$t = 1.50, df = 38, P = 0.141$	

Adult bee populations are the number of standard deep combs covered with bees. Brood population is the area (square centimeters) of sealed brood (for reference, one deep comb has $\approx 1,770\text{ cm}^2$ [275 in.^2] of surface area). There were 17 colonies of each type used in 2003 and 20 of each type used in 2004.

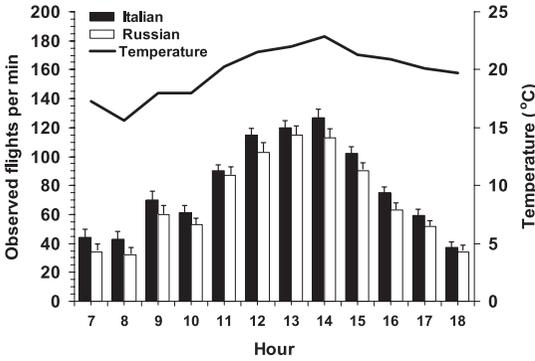


Fig. 2. Hourly flight activity of Russian and Italian colonies observed in 2003. Data are mean and one SE based on an average $n = 106$ (range 51-136) counts per hour.

brood area \times temperature, brood area \times time of day, and temperature \times time of day. For example, consider colonies categorized into two size classes by segregating them at the overall mean size of 1.99 full combs (3,525 cm²) of brood. Higher temperatures resulted in more flight from large colonies (mean 4,765 cm²) than from small colonies (mean 2,657 cm²) (Fig. 3). Temperature effects on colonies of different sizes were more pronounced in the morning and midday than in the afternoon. At the overall mean recorded temperature of 20.4°C (68.7°F), an additional entire comb of brood (1,770 cm² [275 in.²]) yielded 42 more flights per minute in the morning and midday, but only 27 more in the afternoon (Fig. 3). In addition, flight at the lower range of temperatures recorded in the afternoon (≈ 18 –22°C [64.4–71.5°F]) was much lower than at the same temperatures earlier in the day (Fig. 4).

Table 2. Test results from reduced models submitted to ANOVA

Effect	SS ($\times 1,000$)	F	df	P	Parameter estimate
2003					
Brood	1,512	43.94	1, 2,160	<0.0001	-66.06
Temp	2,740	13.52	1, 2,160	0.0002	1.20
Time of day	501	17.92	2, 12	0.0002	-19.73 ^a
Brood \times temp	309	139.82	1, 2,160	<0.0001	5.32
Brood \times time of day	86	20.49	2, 2,160	<0.0001	0.00 ^b
Temp \times time of day	91	24.46	2, 2,160	<0.0001	0.00 ^c
2004					
Bees	493	7.01	1, 3,607	0.008	-9.79
Temp	9,908	36.86	1, 3,607	<0.001	4.61
Bees \times temp	97	87.32	1, 3,607	<0.001	0.74

Shown are type 1 SS, *F*-tests from type 3 tests from GLM, and parameter estimates for regression equations that describe the influences of temp, brood population, adult bee population, and time of day on honey bee flight activity. Bee stock was not a significant effect in either year of study, so a term for stock was not included in the reduced models.

^a Estimate for the morning; other estimates are midday, -29.09 and p.m., -167.99.

^b Estimate for the morning; other estimates are midday, 0.32 and p.m., -15.63.

^c Estimate for the morning; other estimates are midday, 0.40 and p.m., 6.87.

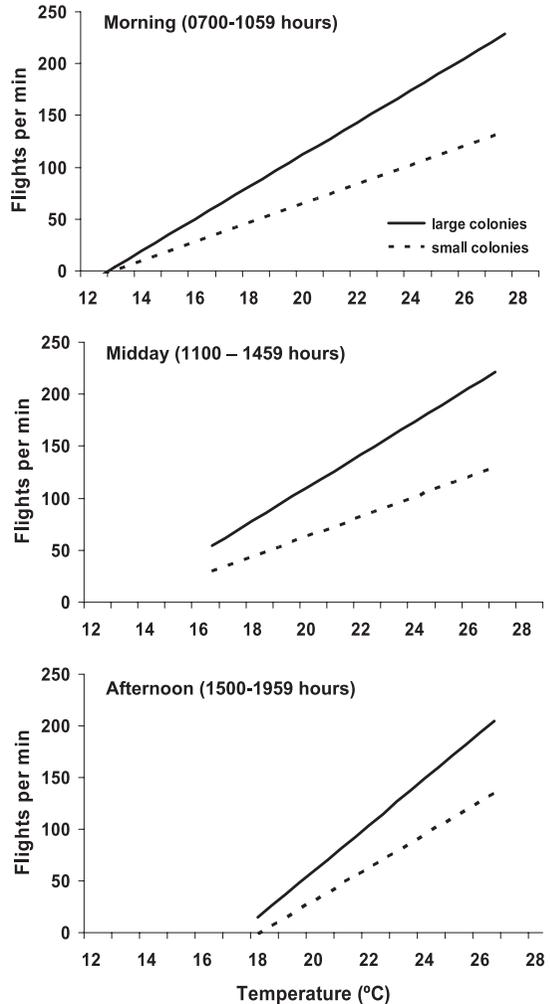


Fig. 3. Flight activity in 2003 from large and small colonies of honey bees in relation to temperature and time of day. These are flight responses fitted from regression parameter estimates and using the average broodnest size of large (2.69 combs of brood; 4,765 cm² [739 in.²]) and small (1.50 combs of brood; 2,657 cm² [412 in.²]) colonies. Temperature effects on different size colonies were more pronounced in the morning and midday than in the afternoon.

Many of these counts were made as temperatures were decreasing. Diminished flight late in the day despite temperatures being suitable for foraging has been reported previously (Burrill and Dietz 1981).

In 2004, flight activity was predicted well by just temperature and colony size (best represented by adult bee population) plus the interaction of these effects. Flight activity was greater at higher temperatures and in colonies with larger bee populations. Categorizing colonies into two sizes classes based on the mean size (10.3 combs of bees) showed that an additional full comb of bees yielded 6.7 more flights per minute from large colonies (mean 11.9 combs of bees) versus 5.6 more flights per minute from small colonies (mean 8.9 combs of bees) (Fig. 5).

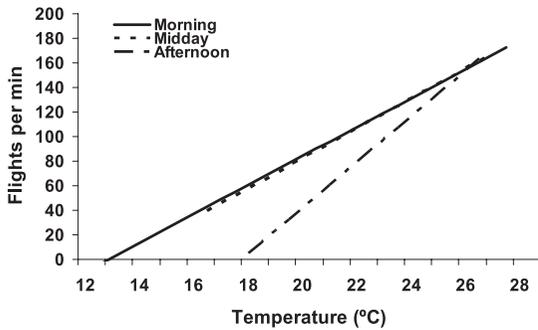


Fig. 4. Honey bee flight activity in 2003 as influenced by time of day and temperature. Morning and midday responses of bees are similar. In the afternoon, flight activity when temperatures were in the lower portion of the range (i.e., at the end of the day) was less than flight in the morning and midday at the same temperatures. These results are for colonies of average broodnest size (1.99 combs of brood; 3,525 cm² [546 in.²]).

Discussion

Russian honey bee colonies had flight activity that equaled that of commonly used Italian bees during late spring pollination of lowbush blueberries. Responses of flight activity were similar for the two stocks under changing conditions of the environmental stimuli that significantly regulated flight (i.e., temperature, colony size, and time of day).

Populations of adult bees and of brood were similar in Russian and Italian colonies. Thus, bee populations in the two stocks remained of comparable size for at least 2 mo after bee populations had been equalized in March and April. The later spring population growth typical of "cold temperate" European honey bee subspecies (Ruttner 1988), presumably the major progenitors of Russian bees, matched the growth of Italian bees during this period. This finding differs from that found in late winter during pollination of almonds, when Russian colonies on average had smaller adult bee and brood populations and thus had

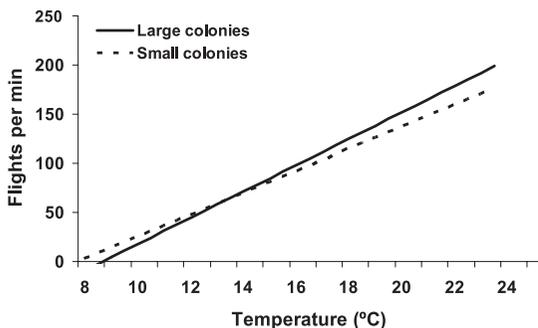


Fig. 5. Flight activity in 2004 from large and small colonies of honey bees in relation to temperature. These are flight responses fitted from regression parameter estimates and using the average adult bee populations of large (11.9 combs of bees) and small (8.9 combs of bees) colonies.

relatively less flight than Italian colonies (Danka et al. 2006).

Temperature was the major determinant of honey bee flight during pollination on the lowbush blueberry barrens. The data show that Russian and Italian colonies had the same level of activity at all temperatures, including those marginal for flight. Our casual observations in the field similarly revealed no flight differences when conditions were very cool, rainy, or windy. The predicted threshold temperatures for flight of average size colonies were 12.5–13°C (54.5–55.4°F) in 2003 and 8.5–9°C (47.3–48.2°F) in 2004. These values are within the range previously reported for black globe threshold temperatures (Corbet et al. 1993, Danka et al. 2006). The difference between seasons could have come because colonies were larger (Table 1) and temperatures were cooler in 2004. The ranges of average daily temperatures were 11.8–27.4°C (average 20.4°C [68.7°F]) in 2003 and 6.5–23.3°C (average 13.9°C [57.0°F]) in 2004. Flight thresholds may be lower when temperatures are consistently cooler.

Preliminary investigation into aspects of foraging behavior other than overall flight activity yielded an interesting additional finding. In 2003, we measured the proportion of *Vaccinium* pollen that was collected by the test colonies. Pollen was trapped on 2 d from six colonies of each bee type, and the plant sources of pellets in 10-g samples were identified. Surprisingly, the largest percentage of pollen, 36.6 ± 9.0 (mean \pm SE), came from *Pinus* (pine). *Prunus* (chokecherry; $32.0 \pm 8.7\%$) and blueberry ($30.1 \pm 9.1\%$) were the sources of almost all other pollen. The proportions of blueberry (but not *Pinus* or *Prunus*) pollen differed for the bee types ($t = 2.75$, $df = 5.73$, $P = 0.034$); Italian colonies collected a larger proportion ($49.8 \pm 13.8\%$) than Russian colonies ($10.4 \pm 4.2\%$). Pines are planted in windbreaks on barrens at the Washington Co. site. Pine pollen is nutritionally very poor for bees (Maurizio 1950). Beekeepers should be aware of a possible nutritional deficiency in their bees and may consider feeding protein supplements to maintain populations that are adequate for pollination services.

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References Cited

- Burrill, R. M., and A. Dietz. 1981. The response of honey bees to variations in solar radiation and temperature. *Apidologie* 12: 319–328.
- Corbet, S. A., M. Fussell, R. Ake, A. Fraser, C. Gunson, A. Savage, and K. Smith. 1993. Temperature and the pollinating activity of social bees. *Ecol. Entomol.* 18: 17–30.

- Danka, R. G. 2005.** High levels of cotton pollen collection observed for honey bees (Hymenoptera: Apidae) in south-central Louisiana. *J. Entomol. Sci.* 40: 316-326.
- Danka, R. G., H. A. Sylvester, and D. Boykin. 2006.** Environmental influences on flight activity of USDA-ARS Russian and Italian stocks of honey bees (Hymenoptera: Apidae) during almond pollination. *J. Econ. Entomol.* 99: 1565-1570.
- Gary, N. E. 1967.** A method for evaluating honey bee flight activity at the hive entrance. *J. Econ. Entomol.* 60: 102-104.
- Lowland Electronics. 2006.** Lowland Electronics. (<http://users.pandora.be/lowland/>).
- Maurizio, A. 1950.** The influence of pollen feeding and brood rearing on the length of life and physiological condition of the honey bees. Preliminary report. *Bee World* 31: 9-12.
- Rinderer, T. E., L. de Guzman, and R. Danka. 2005.** A new phase begins for the U.S. Dep. Agric.-ARS Russian honey bee breeding program. *Am. Bee J.* 145: 579-582.
- Ruttner, F. 1988.** Biogeography and taxonomy of honey bees. Springer, Berlin, Germany.
- SAS Institute. 2000.** The SAS system, version 8.01. SAS Institute, Cary, NC.
- Struye, M. H., H. J. Mortier, G. Arnold, C. Miniggio, and R. Borneck. 1994.** Microprocessor-controlled monitoring of honeybee flight activity at the hive entrance. *Apidologie* 25: 384-395.
- Yarborough, D. E. 1998.** Wild blueberry culture in Maine. Fact Sheet 220, Univ. Maine Coop Ext. (<http://wildblueberries.maine.edu/FactSheets/220.htm>).
- Yarborough, D. E. 2002.** Honey bees and blueberry pollination. Wild Blueberry Bulletin Fact Sheet 629, Univ. Maine Coop Ext. (<http://www.wildblueberries.maine.edu/FactSheets/629.htm>).

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