M 2390

REPRINTED FROM:

Applied Myrmecology

A World Perspective

EDITED BY
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Westview Press
BOULDER, SAN FRANCISCO, & OXFORD

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Oviposition and Growth of the Fire Ant *Solenopsis invicta*

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INTRODUCTION

As monogyne ant colonies become larger, the queen's reproductive output must also increase (Wilson 1971). Oviposition and colony growth studies on the imported fire ant *Solenopsis invicta* have been reported by several investigators (Markin et al. 1973, Markin and Dillier 1971, Markin et al. 1972, Wood 1979, Green 1962, Wilson and Eads 1949 and more recently Porter and Tschinkel 1985,1986; Tschinkel 1988a). Tschinkel (1988b) reported on the social control of oviposition and indicated that queen weight, total follicles, follicles per ovariole, time spent feeding and the number of 4th instar larvae are positively correlated to *S. invicta* egg-laying rates. The purpose of this study was to examine how temperature affects *S. invicta*'s queen oviposition rates and colony growth. This paper will present an overview of this work.

OVIPOSITION RATE

Queens from 25 colonies were sacrificed each month (for eight months) to measure the effect of temperature, queen age, weight, and weight loss on the oviposition rate. The 200 queens were maintained in environmental chambers at one of five experimental temperatures in colonies held for growth studies. Before each colony was terminated for census, the oviposition rate and weight of the queen before and after oviposition were recorded. Oviposition tests isolated the queens on a damp cloth in a small weigh boat for a four-hr egg-laying period. We examined the cloth afterwards for eggs (Fletcher et al. 1980).

Temperature affected the number of eggs laid by *S. invicta* monogyne queens. Queens maintained at 27°C, 30°C, and 32°C oviposited more eggs than those at 24°C and 35°C. During eight months of tests, the mean number of eggs deposited varied less at 27°C than at 30°C; those at 30°C varied less than at 32°C. Thus, it can be concluded that temperature affects oviposition rate. Queen age had no direct effect on oviposition, although older queens are usually heavier than young queens, and heavier queens generally lay more eggs than lighter queens (Fig. 1). However, older lighter queens almost always laid fewer eggs than younger heavier ones. Tschinkel (1988b) also found a

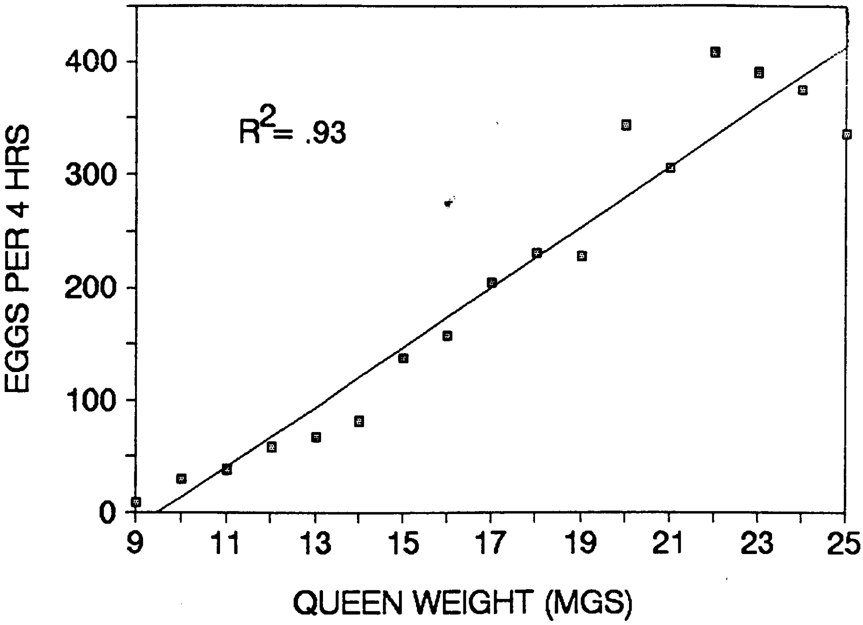

FIGURE 1. Correlation between body weight of the queen and the number of eggs laid.

positive correlation between queen weight and the egg-laying rate. In addition, queens that laid the most eggs lost the most weight during oviposition. Eggs accounted for half the weight loss during oviposition. The remaining weight loss could have been natural water or fluids and wastes expelled with the eggs.

In other studies, 100 colonies and their queens were maintained at 27°C. Food was available for only six hours twice a week. Another set of 100 colonies was fed continuously. The former group weighed less and laid fewer eggs, even though they were identical ages.

EGG WEIGHTS

Temperatures (27°, 30°, and 32°C) did not affect egg weight. However, the queen's age was an important factor in egg weights since older queens laid smaller eggs than younger queens. Tschinkel (1988a) also reported that younger queens laid larger eggs. We recorded the weights of 58,765 eggs weighed in clumps (ca. 189 eggs) from monogyne *S. invicta* queens; the mean wt. per egg was 0.0051mg (SD= ±.0025).

One hundred 80-day-old queens maintained at 30°C laid the most eggs in 24 hours, (mean ±SD) 2,748 ± 292 (Table 1). However, at 214 days and 243 days queens maintained at 27°C produced the largest number of eggs per 24 hour periods, (mean ±SD) 2,358 ± 494.1 and 2,082 ± 289.9, respectively. As

TABLE 1. Effects of age and temperature on 24-hr oviposition rates (based on 4-hr oviposition tests) and weight of queens of S. invicta. Five replicates per temperature per census day.

QUEEN AGE (CENSUS DAY)		MEAN AND SD OF EGGS LAID AND WEIGHT AT DEGREES C 24	27	30	32	35
90	EGGS	6±9.6	174±169.3	240±166.6	372±315.6	54±25.8
	WEIGHT	13±1.5	12±2.0	11±1.1	12±1.1	9±0.9
120	EGGS	168±68.9	804±206.2	600±381.7	808±447.3	
	WEIGHT	11±0.4	17±0.9	14±2.0	17±2.6	
151	EGGS	552±242.6	1980±204.2	2304±99.8	750±609.4	
	WEIGHT	15±1.4	19±0.7	20±0.8	17±1.5	
180	EGGS	594±170.5	1992±242.7	2748±292.3	2232±883.0	
	WEIGHT	15±1.5	20±1.0	22±0.9	18±2.6	
214	EGGS	558±348.9	2358±494.1	2082±474.1	1122±363.9	
	WEIGHT	16±3.2	23±2.0	20±2.3	21±1.9	
243	EGGS	834±226.4	2082±289.9	1734±413.7	1830±409.1	
	WEIGHT	18±0.6	23±1.6	21±1.8	19±2.2	

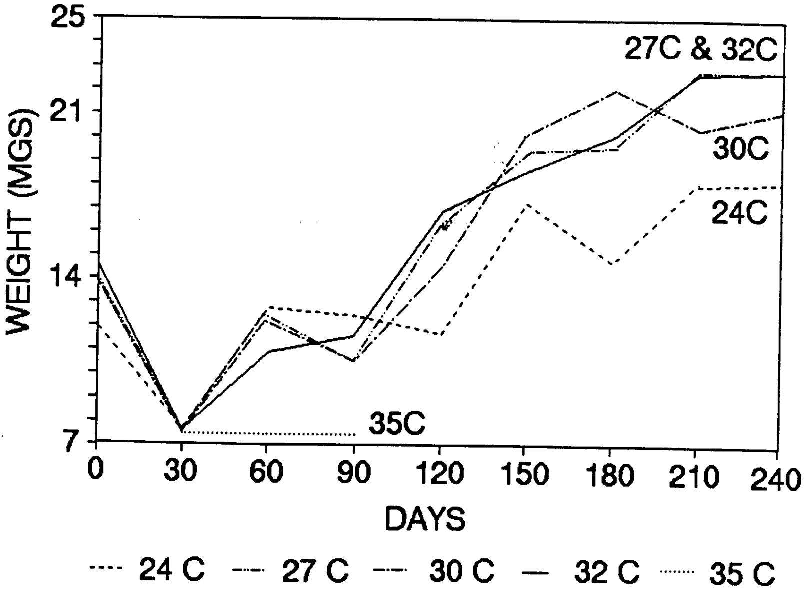

FIGURE 2. Changes in the body weights of queens maintained at constant temperatures over 243 days. Note decline in body weights during initial 30 days of colony founding regardless of temperature.

expected, queens held at the coldest temperature 24°C laid the fewest eggs over the entire study period. However, queen mortality was lower at this temperature than at any of the higher temperatures.

COLONY GROWTH STUDIES

Tschinkel (1988a) reported that colonies grew logistically, reaching half their size (110,000 workers) between 2 ½ and 3 ½ years and maximum size after 4-6 years. Porter (1988) reported *S. invicta* colony growth was highly temperature dependent and that post-founding colonies grew successfully between 24°C and 36°C with maximal rates at about 32° C.

Colony growth studies conducted at five constant temperatures (°C±SD); 24±0.4, 27±0.7, 30±0.6, 32±0.8, 35±0.6 for 8 months showed that the weights (mg) of the newly-mated queens dropped to half (ca. 7 mgs) their initial body weight during the first 30 days and then increased when minum workers appeared; the queen's weight returned to near the initial weight at 120 days (Fig. 2). By the 151st day, queens had increased their initial body weight by 50% at all temperatures except 24°C and 35°C. The greatest increases in colony growth rate (ca. 8 to 28-fold) occurred within the first 90 days at all temperatures except 24°C; at this temperature colonies grew in size between 90 and 120 days (Fig. 3). As expected, these colonies - maintained at the coldest temperature - 24°C grew the slowest.

After eight months, colonies maintained at 27°C had larger populations than those held at other temperatures (242,211 ± 42,099 total and 149,034 ±

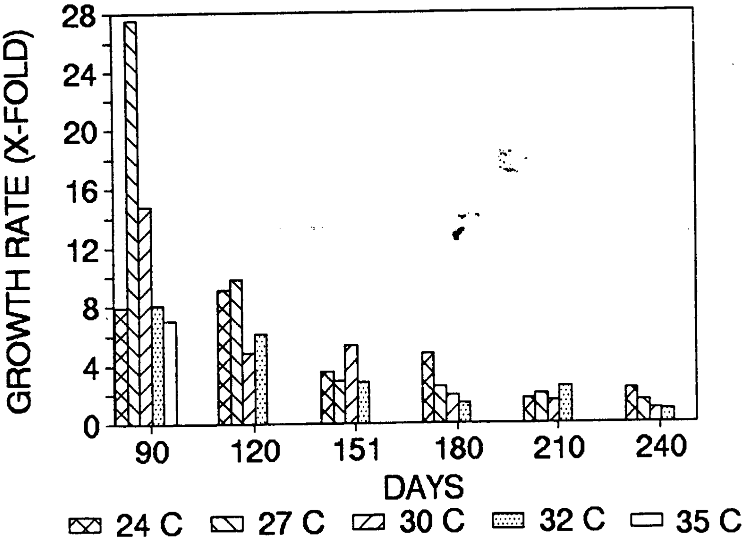

FIGURE 3. Growth rate (X-fold) in total colony size per 30 day intervals at constant temperatures during 8 months.

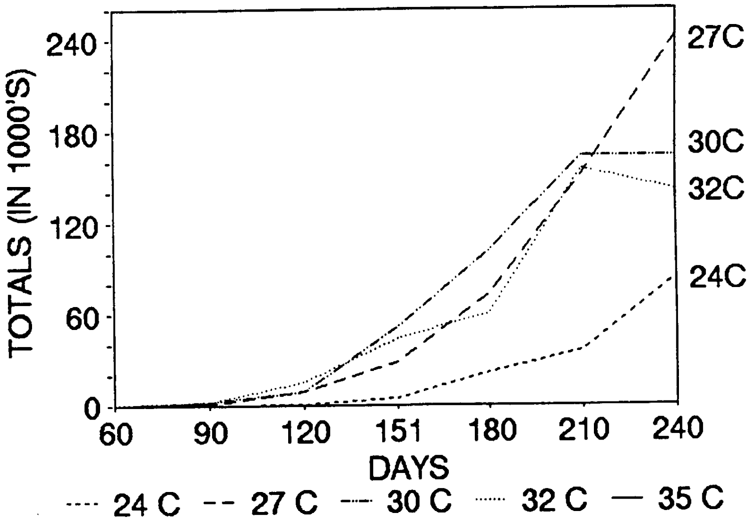

FIGURE 4. Effect of temperature on colony size in the fire ant *Solenopsis invicta*. Colonies maintained at 27°C produced larger numbers in all stages after 8 months.

31,535 workers; Fig. 4). Colonies maintained at 35°C produced workers at a faster rate than other colonies. Minum workers were present within three weeks in most colonies. However, many more workers died at 35°C, the queens constantly lost weight - never recovering their newly mated queen weight - and 91% of the colonies held at this temperature (the remaining 9 colonies were terminated for sampling) died by 90 days. Overall, queens held at 24°C and 27°C also had lower mortality rates than queens held at 30°C, 32°C, and 35°C, with the highest queen mortality at 35°C. Finally, after 8 months, the 27°C colonies contained the following mean numbers: workers 149,034 (61.5%), pupae 42,362 (17.5%), 4th instar larvae 17,613 (7.3%), and 1st-3rd instar larvae 33,203 (13.7%) with total colony size averaging 242,211 (SD = ±42099). These numbers are far greater than has previously been reported for 90 day colonies. For example, Markin et al. 1973 reported that the mean number of workers in seven-month-old field-collected colonies was 6,576 (1,850 - 19,400) while colonies 2 years old had ca. 25,000 workers. By three years, the fully mature colonies had produced 50,000 workers. At seven months, colonies in our growth studies averaged 106,934 workers (SD = ± 15,100) - more than twice the size of three year old fully mature colonies (Markin et al. 1973). One reason for the large differences is that the colonies in our studies were maintained under laboratory conditions at optimum temperatures and provided with unlimited food, factors which greatly aid colony growth. Whereas under natural conditions, seasonal effects and competition for finite food resources limit colony growth and therefore size. Tschinkel (1988a) checked the number of workers in three-six month old field colonies, (mean ± SD; 4,710 ± 3,950) and found their numbers equal to his five (mean ± SD; 1,926 ± 560) and six month-old colonies (mean ± SD; 8,076 ± 2,120). Again, these figures are small compared to those obtained in our studies. The reason is unknown but may be related to the differences in rearing procedures, temperature and /or diets used to maintain the laboratory colonies.

LOW TEMPERATURE GROWTH STUDY

Three month studies using newly-mated queens were also conducted, with the goal of collecting data on the effect of low temperatures (17, 20 and 24°C) on colony growth.

Previous studies indicated that fire ant queens could not develop and maintain colonies at temperatures below ca. 24°C. Our studies showed that queens produced colonies at 20°C. Forty percent of these colonies developed workers in 60 days, the rest within 90 days; only 20% of queens held at 17°C produced workers by the 90th day. However, all workers produced at 17°C died within a few days; therefore, no colonies were established.

CONCLUSION

In our studies, temperature, weight of the queen, and the weight loss by the queen during oviposition were factors positively associated with *S. invicta* queen's oviposition rate. This last factor may not be as important as the others since total loss may be a constant of egg number. Generally, queens laid more eggs at higher temperatures, heavier queens usually laid more eggs than lighter ones, and queens that lost the most weight laid the most eggs.

Age was unimportant except as it was related to weight. During oviposition, fifty percent of the queen's weight loss was due to the oviposited weight of the eggs.

Colony growth was temperature dependent with the maximum rate occurring at 27°C. The temperature window of growth producing complete colonies was 20 - 35°C, the lower limit being lower than has been reported in the past. At 32°C and 35°C, most growth curves dropped quickly and at 35°C colonies died within 90 days. Contributing to this was high worker and queen mortality. We believe as Porter (1988) indicated that the stress of high temperatures may have contributed to a decline in other functions such as egg-laying, brood care, and food flow through the colony. Queens lost less initial body weight at lower temperatures, but by the time minum workers appeared in a colony, the queen's weight was reduced to half her initial weight. The greatest increase in colony growth (28-fold) occurred at 27°C within the first 90 days. The slowest growth and lowest queen mortality occurred at 24°C while the fastest growth but highest queen and colony mortality occurred at 35°C. Queens produced workers at 20°C and 17°C but all workers died within 1-2 days at 17°C. After eight months, the percentages (mean ± SD) for each stage in colonies maintained at all temperatures was 63.5% ± 3.0 workers, 18.0% ± 2.0 pupae, 6.4% ± 0.8 4th instar larvae, and 12.1% ± 1.9 1st - 3rd instar larvae.

The information obtained from these and previous studies have been used to develop a comprehensive computer model of the life cycle of *S. invicta*. The model simulates the major environmental variables such as temperature, precipitation, daylength, and colony food on the population dynamics of this ant in various habitats. The life cycle of the fire ant is incremented in the model into weekly age classes and simulations are run with weekly time steps. Our future investigations will improve and validate the model in the field. These studies will be directed towards survivorship, especially the influence of temperature on brood, effects of fluctuating temperatures on colony development and growth since colonies in nature are exposed to varying temperatures, the effects of humidity and photoperiod on colony development and growth, The effect of temperature and season on the production of alates, and the effect of temperature and precipitation on mating flights. Clearly, much work remains to be done on colony development, growth and population dynamics of the fire ant especially in the field.

ACKNOWLEDGMENTS

I am grateful to Gregory Knue, Bradford Lingo, and Lynne Bundy for their excellent technical assistance which made these long, tedious studies possible. Appreciation is also given to Sanford D. Porter, Dan Haile, and Dan Kline for advice and reviewing the manuscript.

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