

PESTICIDE RESISTANCE AND METABOLIC RATE IN
GERMAN COCKROACHES (DICTYOPTERA: BLATTELLIDAE)

MARK E. HOSTETLER, JOHN F. ANDERSON, AND CARMINE A. LANCIANI
Department of Zoology, University of Florida,
223 Bartram Hall, Gainesville, FL 32611, USA

Although physiological resistance mechanisms to most pesticides have developed in insects, costs may be associated with these mechanisms. For example, a reproductive cost is shown by resistant tobacco budworms, *Heliothis virescens*, which produce significantly fewer fertile eggs (Plapp et al. 1990), and a behavioral cost is shown by resistant *Anopheles* mosquitoes, which spend less time searching for hosts (Rowland 1987). An energetic cost may also be associated with resistance. For example, a common mechanism of pesticide detoxification is enzymatic breakdown of ingested or ab-

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sorbed toxins (Soderland & Bloomquist 1990), a process that may increase energy use as detoxification enzymes are synthesized. To determine whether an energetic cost to pesticide resistance exists, we measured metabolic rates (O_2 consumption) of resistant and susceptible German cockroaches, *Blattella germanica* (L.).

German cockroaches used in experiments were obtained from 2 different strains maintained at the USDA-ARS Medical and Veterinary Entomology Research Laboratory in Gainesville, Florida, U.S.A. The Village Green strain is physiologically resistant to a variety of organophosphates and pyrethroids. Ancestors of this strain were captured from a residential apartment complex (Village Green Apartments) in Florida in 1987. The Orlando Normal strain is susceptible to a variety of organophosphates and pyrethroids. Ancestors of this strain were captured from a building in Orlando, Florida, U.S.A., in the 1940s. Cockroaches were reared in 50 x 50 x 28 cm oblong metal tubs (temperature of 25-27°C) on Purina rat chow (Purina Mills Inc. P.O. Box 66812, St. Louis MO 63166-6812).

Metabolic-rate experiments were conducted in Gainesville during October and November 1991 on male and female adults (gravid females without oothecae protruding) that had spent 0 to 2 weeks in the adult stage. Metabolic rates were measured with "closed system" metabolic chambers (Vleck, 1987) following the procedures described by Anderson et al. (1989) and Giesel et al. (1989). On the day of each experiment, 5 male and 5 female cockroaches from each strain were placed individually in 60 cm³ syringes. After the syringes were held for approximately 5 hours in a lighted incubator at 26°C, each syringe was removed, and the change in O_2 concentration was recorded and used to determine metabolic rate. Each cockroach was weighed to the nearest 0.01 mg immediately after removal from the incubator. Separate trials were conducted on 4 different days, yielding data on 20 males and 20 females in both the Orlando Normal and Village Green strains.

Because sex and weight may affect metabolic rate, analysis of covariance (ANCOVA) was used to determine the influence of strain on cockroach metabolic rates independent of the influence of sex and weight.

Mean metabolic rates and weights of both strains are listed in Table 1. From the analysis of covariance, only gender ($P = 0.0002$) and weight ($P = 0.0046$), but not strain ($P = 0.38$), had significant effects on metabolic rates. Thus, after the effects of weight and strain were removed by the ANCOVA, females had a higher metabolic rate than did males. However, after the effects of weight and sex were removed by the ANCOVA, resistant individuals did not have a higher metabolic rate than did susceptible individuals.

Resistant and susceptible strains had similar metabolic rates, and thus resistance may not have an energetic cost. Several explanations exist for the similar metabolic rates of the two strains. (1) The Village Green cockroaches may have physiological resistance mechanisms that do not require increased enzymatic activity, e.g., altered acetylcholinesterases and sodium channels (Soderland & Bloomquist 1990). (2) The Village Green cockroaches may have detoxification mechanisms that increase metabolic rates but require the presence of the pesticide to induce accelerated production of the detoxifying enzyme(s). In several studies, enzyme production-

TABLE 1. MEAN METABOLIC RATES ($\mu\text{L } O_2/\text{HR} \pm \text{STANDARD ERROR}$) AND MEAN WEIGHTS ($\text{MG} \pm \text{STANDARD ERROR}$) OF *BLATTELLA GERMANICA*.

Strain	Sex	N	Metabolic Rate	Weight
Orlando	M	20	34.9 \pm 1.2	43.3 \pm 0.9
Orlando	F	20	64.3 \pm 4.1	84.3 \pm 4.4
VG	M	20	31.6 \pm 1.1	48.3 \pm 0.8
VG	F	20	73.4 \pm 4.7	94.8 \pm 4.1

was found to increase only after exposure to the pesticide (Terriere 1983). (3) Village Green cockroaches may have higher metabolic rates from pesticidal pressures, but the Orlando Normal individuals may have higher than "normal" metabolic rates because they have been laboratory-reared for a much longer period of time.

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SUMMARY

Metabolic rates, based on oxygen consumption, were determined for two strains of German cockroaches, one resistant and one non-resistant. Both strains had similar metabolic rates suggesting that resistance may not have an energetic cost.

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