RETENTION OF CODED WIRE TAGS, AND THEIR EFFECT ON MATURATION AND SURVIVAL OF YELLOW MEALWORMS (COLEOPTERA: TENEBRIONIDAE)

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A variety of methods have been used to mark insects for studies of movement or population dynamics (Hagler et al. 1992). Paints, dyes, and other external marks are commonly used, but generally last for only a short period within a single life stage (White 1970; Charlwood et al. 1986; Lutwama and Mukwaya 1994). By incorporating rare earth elements (Akey 1991) or radioisotopes (Baldwin and Cowper 1969, Lafleur et al. 1985) into the diet of insect larvae, marked individuals have been identified through multiple life stages. However, this technique is generally limited to only a few molts before concentrations of the marking agent are reduced to background levels. The binary coded wire tag first reported by Jefferts et al. (1963) is characterized by high tag retention and has little effect on growth or survival of tagged individuals. This tag has been successfully used to mark crustaceans (Prentice and Rensel 1977; Uglem and Grimsen 1995; Isely and Eversole 1998) but has yet to be evaluated for use on insects. The objective of this study was to evaluate the retention across life stages of the coded wire tag in the yellow mealworm, *Tenebrio molitar* (Coleoptera: Tenebrionidae), and to determine the effects of tagging on growth and survival.

Late instar mealworms (n = 207, mean weight = 0.18 g) were obtained from a local pet store. One group (n=155) was tagged with sequentially numbered, standard length, binary-coded wire tags using a Mark IV Tag Injector (Northwest Marine Technologies, Shaw Island, Washington). Each tags measured 1 mm (length) × 0.1 mm (diameter) and was etched with an unique binary code readable under a dissecting microscope. Tags were injected through the exoskeleton parallel to the long axis of the abdomen with a fixed injection needle imbedded beneath the dorsal surface of the second abdominal segment (Fig. 1). One group (n = 52) was not tagged and served as a control. Each mealworm was placed in an individual 50 ml plastic container. Each container was filled with approximately 20 g of rolled oats, which provided nutrition and a substrate. Mealworms were held at 21 C under a 12 h light, 12 h dark photoperiod. Individual mealworms were evaluated every 7 d after tagging for mortality, tag retention, molting, and metamorphosis until they reached adulthood. The presence of tags was verified using a hand-held coded wire tag detector (Northwest Marine Technologies, Shaw Island, Washington). Differences between experimental and control groups in mean time to pupation and adulthood were evaluated using a *t*-test ($P < 0.05$). Differences between experimental and control groups in survival to pupation and adulthood were evaluated by chi-square analysis ($P < 0.05$).

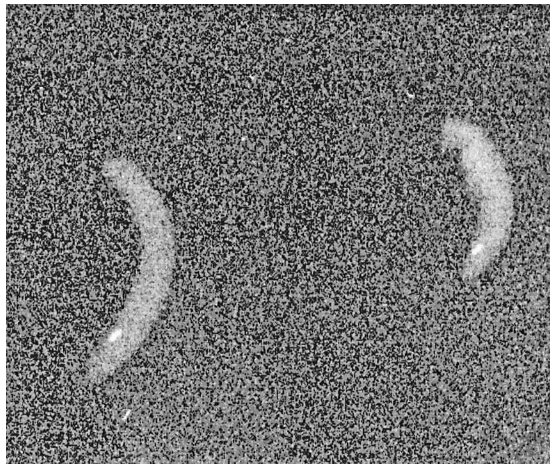

Fig. 1. X-ray of yellow mealworm, *Tenebrio molitar* (Coleoptera: Tenebrionidae), larva and pupa tagged with a 1 mm × 0.1 mm coded wire tag. coded wire tag appear as a white line.

After 70 d, 5 experimental and 1 control individual had not metamorphosed from larva to pupa. These individuals were counted as mortalities for the purpose of the analyses. We found no difference in the mean time to pupation for tagged and untagged mealworms (Table 1). There was also no difference in the mean time to adulthood between tagged or control groups. However, initial (72 h) mortality of tagged individuals was 14%, and mortality of tagged individuals was higher than mortality of control individuals to both the pupa and adult phases (Table 2). Survivorship of tagged mealworms to the pupal stage

TABLE 1. INITIAL NUMBERS AND TIME TO METAMORPHOSIS (MEAN ± S.E.) OF MEALWORMS TAGGED WITH CODED WIRE TAGS AND UNTAGGED CONTROLS.

		Time to metamorphosis (days)	
Treatment	N	Larvae to pupae	Pupae to adult
Tagged	85	12.1 ± 2.69	21.8 ± 3.56
Control	52	12.3 ± 3.58	23.9 ± 3.34

was 82%. Survivorship from pupa to adult was 79%. All mortalities occurred during molting, either within the larval stage, or between larvae and pupae, or pupae and adult. This was likely the result of not imbedding the tag completely through the exoskeleton. Included in this were 12 pupae that only partially metamorphosed. In these individuals, the head and thorax exhibited adult characteristics, while the abdomen retained the appearance of the pupae. It appeared that the presence of the tag may interfere with metamorphosis in some cases. These partially metamorphosed individuals lived approximately one week and were counted as pupae for statistical analysis. This resulted in 65% survival from larvae to adulthood, in contrast to the 98% survivorship exhibited in the control group. This mortality rate is higher than has been reported for other invertebrates tagged with coded wire tags (Uglem and Grimsen 1995; Isely and Eversole 1998) or insects tagged with fluorescent powder (Naranjo 1990), but compares favorably with insects marked with trace elements (Moss and Van Steenwyk 1984; Armes et al. 1989).

Tag retention within surviving larvae was 99% (Table 2), and the proportion of pupae retaining tags was 86%. However, as many pupae which lost tags did not survive to adulthood, the proportion of adults retaining tags was 93%. All tags were lost during metamorphosis and located in shed exoskeletons. Tag retention rates we observed compare favorably with retention rates of coded wire tags in other studies on invertebrates (Brandt and Schreck 1975; Joule 1983; Isely and Eversole 1998). Further, coded wire tags do not degrade with time, as has been noted with pigments (Naranjo 1990) and trace elements (Moss and Van Steenwyk 1984; Armes et al. 1989).

TABLE 2. PROPORTION OF INDIVIDUALS WITHIN LIFE STAGES RETAINING TAGS AND PERCENT SURVIVAL WITHIN LIFE STAGES FOR MEALWORMS TAGGED WITH CODED WIRE TAGS AND UNTAGGED CONTROLS.

Treatment	Life Stage	N	Tag Retention (%)	Survival (%)
Tagged	Larvae	155	99	86
Control	Larvae	52	—	100
Tagged	Pupae	127	86	82
Control	Pupae	51	—	98
Tagged	Adult	100	93	79
Control	Adult	51	—	100

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SUMMARY

This study demonstrates that coded wire tags can be used to mark certain insect larvae without adverse effects on maturation, and that tags are retained through the adult phase in high enough proportion for practical application. Coded wire tags also offer the benefit that marked organisms can be identified to the batch or individual level.

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