Survival and Development of the True Armyworm *Pseudaletia unipuncta* (Haworth) (Lepidoptera: Noctuidae), on Endophyte-infected and Endophyte-free Tall Fescue[1]

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ABSTRACT True armyworms, *Pseudaletia unipuncta* (Haworth), were fed tall fescue leaves either infected or uninfected with the symbiotic fungus, *Acremonium coenophialum* Morgan-Jones and Gams. Young larvae fed endophyte-infected leaves weighed less than cohorts fed endophyte-free leaves, but developmental and survival rates were unaffected by endophyte infection. Older instar larvae fed endophyte-infected leaves weighed the same as those larvae fed endophyte-free leaves. Pupal weights also were unaffected by endophyte infection. These results were similar to recent studies conducted with other armyworm species and suggest that endophyte infection in tall fescue does not enhance resistance to a number of lepidopteran larvae.

KEY WORDS *Pseudaletia unipuncta* (Haworth), tall fescue, endophyte, *Acremonium,* host-plant resistance.

Tall fescue is one of the most important and widely grown pasture grasses in the southeastern United States. Some reasons for its popularity are its ability to grow under a wide range of soil and climatic conditions, its drought, pest and trampling tolerance, and its ability to produce good quality forage favorable for animal growth. Tall fescue's deep, thick root system also helps in soil conservation along most roadsides, and it is also a popular turfgrass in the southeast region (Buckner 1985, Ball et al. 1991).

Most tall fescue pastures are infected with a symbiotic, endophytic fungus, *Acremonium coenophialum* Morgan-Jones and Gams, that produces, or induces its host to produce, a number of biologically-active alkaloids. These endophyte-associated alkaloids are responsible for reduced weight gains, lower conception rates, lower milk production, and heat intolerance in cattle, agalactia in sheep, and high foal mortality in horses. Collectively, these symptoms are known as fescue toxicosis. Fescue toxicosis results in economic losses estimated at about $600 million each year, thus the interest in renovating endophyte-infected tall fescue pastures with endophyte-free tall fescue (Fribourg et al. 1991). However, research over the last decade has shown that *Acremonium*-infected grasses also are more resistant to a number of insect pests.

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The fall armyworm, *Spodoptera frugiperda* (J. E. Smith), a common grass-feeding insect, is deterred from feeding, grows more slowly, and gains less weight when isolated on endophyte-infected tall fescue (Clay et al. 1985, Hardy et al. 1986). Hardy et al. (1986) and Riedell et al. (1991) suggest that lolines, pyrrolizidine-type alkaloids only found in *Acremonium*-infected tall fescue are responsible for fall armyworm antibiosis and deterrence. Clay and Cheplick (1989) demonstrate that some ergoclavine and ergopeptide alkaloids associated with fungi related to *Acremonium* have antifeedant and antibiotic activities against the fall armyworm.

Another common graminivorous insect, the true armyworm, *Pseudaletia unipuncta* (Haworth), is considered one of the most important pests of cereal and forage crops during widespread but infrequent outbreaks throughout the eastern United States (Guppy 1961). An infestation of newly-hatched armyworms on greenhouse-grown tall fescue plants enabled us to observe if endophyte infection in tall fescue alters survival and development of this grass pest.

Materials and Methods

Armyworms. During the summer of 1988, we observed an armyworm infestation on tall fescue plants grown in the greenhouse. Similar numbers of neonates were wandering on both endophyte-free (EF) and endophyte-infected (EI) plants. We collected these neonates into a 27 × 21 × 9 cm plastic box and randomly transferred, with a fine, wet camel's hair brush, groups of 5 larvae to 100 × 20 mm polystyrene petri dishes containing leaf blades from either EF or EI 'Kentucky 31' tall fescue plants. The leaf blades rested on a moistened paper tissue (Kimberly-Clark, Roswell, GA) placed in the bottom of each dish. We randomly placed dishes into 2 boxes with moistened paper towels and covered boxes with lids to keep relative humidity near saturation. These boxes were held in an incubator at 25°C with 16L:8D photoperiod. We collected enough neonates to use 11 dishes for each endophyte treatment.

We removed frass and exchanged old leaves with fresh green leaf blades from EI and EF plants every other day until the armyworms needed to be fed daily. At this point we placed armyworms into new petri dishes with fresh, moist tissue at each feeding. We recorded survival of larvae, larval weights, pupal weights, and the number of days to pupation and adult eclosion for each individual. The effect of endophyte infection on these parameters was compared with a two-sample t test using Statistix P. C. DOS version 3.1 (NH Analytical Software, Saint Paul, MN).

Plant Material. P. B. Burrus, Jr. (Retired, U.S. Department of Agriculture, University of Kentucky) supplied us with EF and EI 'Kentucky 31' tall fescue seeds which were harvested from tall fescue nurseries in 1986 at Lexington, KY and Princeton, KY, respectively. Both seed lots can be traced back to plants originally collected from the same tall fescue population on the Suiter farm in Menifee County, KY, the original source for 'Kentucky 31' (Fergus and Buckner, 1972, Burrus pers. comm.). Enzyme-linked immunosorbent-assay (Johnson et al. 1982) detected *A. coenophialum* in 80% of the plants grown from the endophyte-infected seed lot. No endophyte was detected in EF plants. Occasional microscopic examination confirmed these results.

Individual plants were grown in a 2:1 (v:v) mixture of Maury silt loam and Redi-Earth potting soil in subirrigated 10-cm diam. clay pots. Each plant was fertilized with 60 mg Peters 20: 20: 20 (N: P: K) (Grace Horticultural Products, Cambridge, MA) every other week. Greenhouse temperatures ranged between 23° and 34°C during the time of the experiment and leaves fed to the armyworms came from plants older than 12 weeks after germination. Light was supplemented with 40-watt Gro-lux wide spectrum fluorescent lamps (GTE Sylvania, Danvers, MA) with 16L:8D photoperiod.

Results

Armyworm survival was not significantly altered by endophyte infection. Similar numbers of armyworms survived to pupation and adult eclosion fed either EI or EF tall fescue (Table 1, Fig. 1). Endophyte infection did not significantly ($P > 0.05$) alter armyworm development rates (Fig. 1). Armyworms fed both EI and EF leaves took, on average, 24 d to pupate and 34 d to emerge as adults. Very young larvae fed EI leaves weighed significantly less than larvae fed EF leaves after 8 d (Table 2), but later larval and pupal weights were similar and suggest that small larvae were sensitive to endophyte infection.

Table 1. Armyworm survival (larvae, pupae and adults) per dish at day indicated.

Day	Mean no. ± SE		t
	Endophyte-free*	Endophyte-infected*	
6	4.6 ± 0.3	4.7 ± 0.2	-0.27
15	4.1 ± 0.3	3.9 ± 0.3	0.43
21	3.4 ± 0.3	3.5 ± 0.2	-0.24
28	3.2 ± 0.4	2.9 ± 0.4	0.49
35	3.1 ± 0.4	2.5 ± 0.4	0.91

* 11 dishes per endophyte treatment, begin with 5 neonates/dish.

Discussion

Pseudaletia unipuncta larvae survived and grew at similar rates when fed either EI or EF tall fescue although early instars weighed less in dishes containing EI tall fescue. Clay et al. (1985) and Hardy et al. (1986) demonstrated that fall armyworm larval weights were significantly reduced when isolated on EI tall fescue eight days after hatching without affecting subsequent survival. We also found that young 8-d-old true armyworm larvae had reduced weight gains on EI tall fescue without significantly altering the survival rates of the caterpillars. These observations can be explained by the

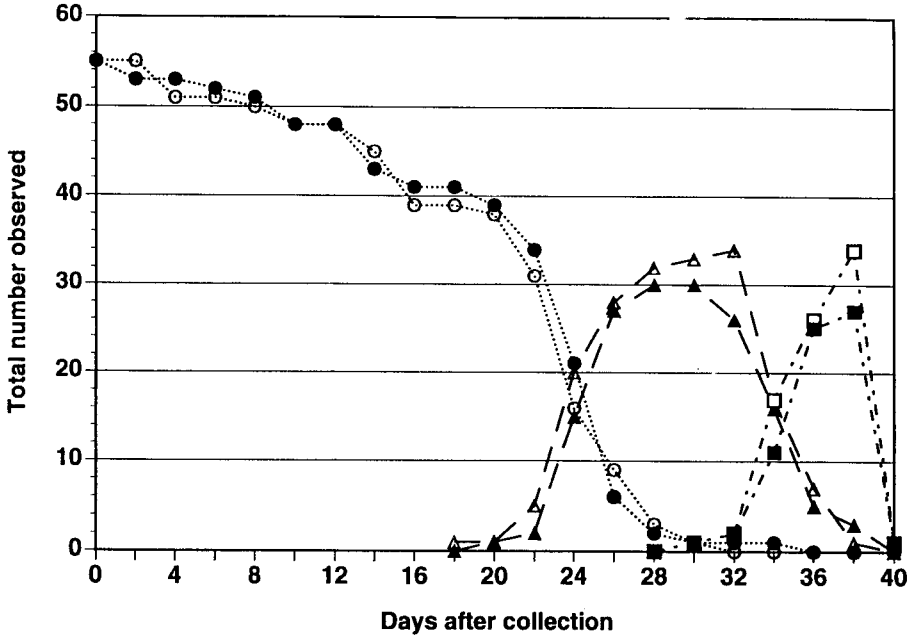

Fig. 1. Total number of larvae (circles), pupae (triangles), and adults (squares) observed each day after introduction into dishes and fed endophyte-free (open symbols) and endophyte-infected (filled symbols) 'Kentucky 31' tall fescue.

deterrent quality of endophyte-associated alkaloids (Hardy et al. 1986, Clay and Cheplick 1989, Riedell et al. 1991, Patterson et al. 1991). Habituation of the older larvae to endophyte-associated alkaloids could explain the non-significant effect of EI tall fescue on their survival and development. Initial contact with nicotine or caffeine spread over the surface of corn leaf disks reduced the feeding time of true armyworms, but deterrency decreased in later encounters (Usher et al. 1988). Naive early-instar true armyworm larvae may consume EI tall fescue at slower rates and grow more slowly (Mukerji and Guppy 1970) due to the presence of deterrent alkaloids, but as they become habituated to the alkaloids, consumption rates increase and larvae develop and survive at similar rates as those larvae fed EF tall fescue. We did not test the deterrent qualities of EI tall fescue to the true armyworm.

More recently, Breen (1993) reported that both the fall armyworm and southern armyworm, *Spodoptera eridania* (Cramer), are unaffected by EI tall fescue. No differences in consumption or developmental rates of the fall armyworm were observed between EI or EF tall fescue diets. In addition, both Johnson et al. (1985) and Dubis et al. (1992) reported that the southern armyworm is unaffected by the presence of endophyte-associated alkaloids.

Table 2. Larval and pupal armyworm weights at day after introduction into dishes containing endophyte-free or endophyte-infected 'Kentucky 31' tall fescue.

Day	Mean (±SE) weight (mg) Endophyte-free	N	Endophyte-infected	N	*t*
Larvae:					
8	24.8 ± 1.6	50	14.9 ± 1.0*	51	5.17
17	269.7 ± 12.9	39	265.9 ± 15.2	41	0.19
19	391.7 ± 17.4	37	365.2 ± 19.6	40	1.00
21	489.6 ± 20.0	33	482.3 ± 17.9	35	0.27
26	276.2 ± 13.5	33	283.6 ± 13.9	30	-0.38
Pupae:					
31	269.2 ± 5.4	33	273.2 ± 7.0	30	-0.46

* Significant difference in larval weights between EF and EI treatments at $P < 0.05$, two sample t test.

Oviposition by true armyworms is probably unaffected by endophyte infection because they prefer to oviposit in dry, dead leaf material or in grass stubble (Guppy 1961). The fall armyworm is more discriminating in its oviposition habits (Whitford et al. 1988), so endophyte infection may alter adult host plant selection.

Thus, from our laboratory study and more recent research with both the fall and southern armyworm, it appears that endophyte-infection will not confer resistance to many lepidopteran larvae and suggests that outbreaks of armyworms can potentially damage tall fescue pastures. No study has been conducted to determine if herbivory by any armyworm species actually affects yield or forage quality of a tall fescue stand, although Potter et al. (1992) suggest that both EI and EF tall fescue tolerate feeding damage by grub herbivory. Although resistance to armyworms is not enhanced by endophyte infection, the symbiont may aide in better regrowth and competitive ability after damage by herbivores. Such studies, especially in the pasture agroecosystem, are needed.

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