FALL ARMYWORM:[1] EXPRESSIONS OF ANTIBIOSIS IN SELECTED GRASSES

N. T. Chang,[2] B. R. Wiseman,[3] R. E. Lynch,[3] and D. H. Habeck[2]
(Accepted for publication April 18, 1985)

ABSTRACT

Selected grasses, 'Coastal,' 'Tifton 10,' and 'Tifton 292' bermudagrass, *Cynodon dactylon* (L.) Pers., 'common centipedegrass,' *Eremochola ophiuroides* (Munro) Hack., zoysiagrass, *Zoysia* sp., and corn, *Zea mays* L., were evaluated in the laboratory as hosts for the fall armyworm, *Spodoptera frugiperda* (J. E. Smith), in forced-feeding tests to delineate more clearly the expressions of antibiosis. Data were recorded at 5, 7, and 9 days on weights of larvae, days to pupation, weights of pupae, pupal duration and survival on the various host grasses. Corn was the most suitable host for development of fall armyworm larvae, followed by Tifton 10 and Coastal bermudagrass. Larval development was slower on common centipedegrass than on Coastal bermudagrass. Tifton 292 bermudagrass and zoysiagrass were unsuitable hosts because of nonpreference and antibiosis. Wing pad deformities in pupae and/or serious lessions in adult wings were observed when resistant grasses (e.g., centipedegrass and Tifton 292 bermudagrass) were incorporated into pinto bean diet and fed to fall armyworm larvae.

Key Words: Plant resistance, nonpreference, *Spodoptera frugiperda,* insect diet, larval development.

J. Entomol. Sci. 20(2): 179-188 (April 1985)

INTRODUCTION

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), is a destructive pest of over 50 species of plants in the southern and central United States. Crops such as corn, sorghum, and bermudagrass are among its preferred hosts (Luginbill 1928).

Different species or varieties of plants may dramatically influence development of FAW (Pencoe and Martin 1981; Wiseman et al. 1981). Considerable biological variation of FAW occurs when larvae are reared on corn, *Zea mays* L. (Keller 1980; Wiseman et al. 1981), peanuts, *Arachis hypogaea* (L.) (Leuck and Skinner 1971; Garner and Lynch 1981; Lynch et al. 1981), cotton, *Gossypium* sp., corn, soybean, *Glycine max* (L.) Merr. (Pitre and Hogg 1983), and several grasses. For example, Leuck and Skinner (1970) reported higher larval and pupal mortality, reduced pupal weight, and a shorter life cycle for FAW larvae feeding on 'Tifton 239' than for larvae feeding on 'Coastal' bermudagrass, *Cynodon dactylon* (L.) Pers. Pencoe and Martin (1981, 1982) found that FAW reared on 15 grasses or sedges had significantly different development rates, numbers of instars, and pupal weights. Wiseman et al. (1982) also noted that FAW larvae feeding on common centipedegrass, *Eremochola ophiuroides* (Munro) Hack, were significantly lighter than larvae feeding on Coastal bermudagrass. Combs and Valerio (1980)

[1] Lepidoptera: Noctuidae.
[2] Dept. of Entomology and Nematology, Univ. of Florida, Gainesville, FL 32611.
[3] Insect Biology and Population Management Research Laboratory, USDA, ARS, Tifton, GA 31793.

reported faster development of larvae, heavier pupae, and greater longevity of female FAW when larvae were reared on common bermudagrass rather than on 'Alicia' bermudagrass. Moreover, Lynch et al. (1983) noted a faster development rate, lower leaf consumption, higher pupal weight, and a higher survival rate for FAW reared on 'Tifton 68' and 'Tifton 84' than for larvae reared on seven other bermudagrass varieties. Conversely, based on a low weight gain and high mortality of larvae, Tifton 292 was rated highly resistant to FAW by Lynch et al. (1983).

"Antibiosis" involves the adverse effects exerted by a plant on an insect's biology, as defined by Painter (1951). Insect parameters obtained from antibiosis expressions of resistance are basic methods for evaluating insect resistance in plants (Dahms 1972). We evaluated several grasses as hosts for the FAW to define more clearly their antibiotic effects on larvae of the FAW.

MATERIALS AND METHODS

Six grasses, 'Coastal,' 'Tifton 10,' and 'Tifton 292' (P.I. 290884) bermudagrass, common centipedegrass, zoysiagrass, and corn served as hosts for FAW larvae in this study. Corn, Coastal, and Tifton 10 are susceptible to FAW feeding, while Tifton 292, centipedegrass, and zoysiagrass have varying levels of resistance (Wiseman et al. 1982; Lynch et al. 1983; Chang et al. 1985a). Cultures of each grass were transplanted from pure stands in the field to pots (12 cm diam, 12.5 cm high) and maintained under ambient greenhouse conditions. Grasses in each pot were fertilized ca every two weeks with 5 g ammonium nitrate(34% nitrogen available). Corn leaves were excised from ca 30-day-old plants of open-pollinated 'Pioneer 3369A' in the field and transported to the laboratory for feeding trials. FAW larvae used in the experiments were obtained from a laboratory colony reared on pinto bean diet (Perkins 1979).

Five to ten leaf sections (ca 4 to 5 cm long) from each of the selected grass treatments were placed in each of 30 plastic cups (5 cm diam, 3.5 cm high) containing moist filter paper. The grass treatments were then infested with one neonate FAW per cup. Larvae feeding on pinto bean diet (Burton 1969) at a density of one larva per cup served as checks. The experiment was designed in a randomized complete block (RCBD) with 30 replications. The uneaten grass was removed and replaced each day during the experiment. The experiment was conducted in an incubator with 26.7 ± 2 C, 70 $\pm 5\%$ relative humidity, and a photoperiod of LD 14:10. Records were kept on larval weights at 5, 7, and 9 days after infestation, number of days to complete larval development, pupal weight (at 24 hr of age), pupal duration, and percent survival to adult emergence. Data were subjected to analysis of variance, and grouped means were compared by Duncan's multiple range test (Duncan 1955).

A second test was designed to evaluate the antibiotic effects of selected grasses when the grass was incorporated into a standard FAW pinto bean diet (Burton 1969). This experiment was also designed in RCBD with 36 replications. Corn and Tifton 10 bermudagrass were excluded from this experiment because they showed no antibiosis to FAW in Test 1.

Twenty grams (fresh weight) of selected grasses were blended for 3 min into 300 ml of pinto bean diet plus 80 ml of water. The mixture was dispensed into 36 one-oz plastic cups and allowed to solidify and cool. Also, 80 ml of water was added to a pinto bean diet check and blended for 3 min. One neonate FAW larvae was then placed in each cup. This test was conducted in the incubator as previously described. In addition to the records kept in Test 1, data were recorded on the percentage of moths having major deformities of the wings or wing pads. Statistical analysis and mean separation for this test were the same as those described earlier.

RESULTS AND DISCUSSION

FAW larvae fed on corn and Tifton 10 bermudagrass gained significantly more ($P = 0.05$) than larvae fed on pinto bean diet (Table 1). However, by seven days, weight gain was significantly ($P < 0.05$) greater for larvae fed on pinto bean diet than for those fed on plant material. At 5, 7, and 9 days after infestation, larvae fed on corn and Tifton 10 bermudagrass weighed significantly more than larvae fed on any of the other grasses. Larvae fed on Coastal bermudagrass and common centipedegrass weighed significantly more ($P < 0.05$) than larvae fed on Tifton 292. All larvae on the zoysiagrass treatments died within 2 days. At 9 days, larvae weighed 14 to 25 times more on suitable hosts (i.e., pinto bean diet, corn, and Tifton 10 bermudagrass) than they did on Tifton 292 bermudagrass. Larvae also weighed 3 to 5 times more on the best hosts than on Coastal bermudagrass or common centipedegrass.

Weights of FAW larvae at 9 days were significantly correlated ($r = -0.86$, $P < 0.05$) with larval development (Fig. 1). Moreover, FAW larvae required only the normal 6 instars to complete larval development on the more suitable hosts (corn, Tifton 10 bermudagrass, and diet). But 6 or 7 molts were required before pupation on less suitable hosts (common centipedegrass and Tifton 292). Thus, it appears that the relatively poor larval weight gain on the less suitable hosts would have a cumulative resistant effect because of the increase time for larval development.

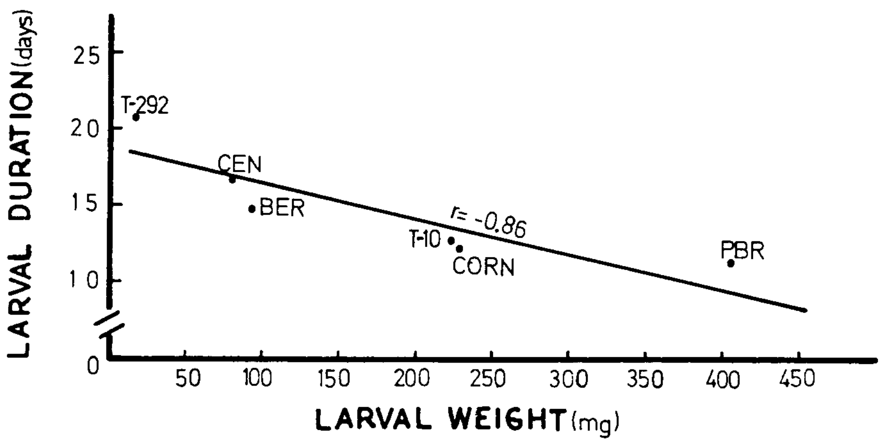

Fig. 1. Relationships among weights of FAW larvae at 9 days and developn time for larvae fed on 'Coastal' bermudagrass (BER); 'Tifton 10' bermı grass (T10); 'Tifton 292' bermudagrass (T292); centipedegrass (CI corn; and regular pinto bean diet (PBR).

Table 1. Weight and duration of fall armyworm larvae fed on selected grasses or pinto bean diet.*†

	$\bar{x}$ wt (mg) on indicated day after infestation			$\bar{x}$ duration
Host diet	5	7	9	(days)
Pinto bean diet	18.7 ± 4.9 b	141.5 ± 35.5 a	404.9 ± 98.5 a	11.5 ± 0.5 e
Corn	23.8 ± 15.5 a	90.0 ± 35.9 c	225.5 ± 58.0 b	12.2 ± 1.0 d
'Tifton 10' bermudagrass	23.8 ± 9.6 a	111.0 ± 30.7 b	224.4 ± 61.6 b	12.6 ± 1.8 d
'Coastal' bermudagrass	10.0 ± 4.0 c	31.3 ± 13.0 d	93.5 ± 36.2 c	14.8 ± 1.3 c
Common centipedegrass	8.5 ± 4.1 c	28.4 ± 13.0 d	78.4 ± 33.3 c	16.7 ± 1.5 b
'Tifton 292' bermudagrass	2.4 ± 1.1 d	6.4 ± 3.1 e	15.7 ± 8.0 d	20.8 ± 1.7 a
Zoysiagrass‡	–	–	–	–

* Data expressed as Mean ± 1SD.

† Means within columns followed by different letters are significantly different at the $P = 0.05$ level using Duncan's multiple range test.

‡ All larvae died within 48 hr.

Both male and female pupae recovered from the pinto bean diet treatment were significantly heavier than pupae produced from any other treatment (Table 2). Similarly, male and female pupae from the corn treatment were significantly heavier than pupae produced by any of the other hosts. Weights of female pupae also were significantly greater than larvae that fed on Tifton 10, Coastal, or centipedegrass than from larvae fed on Tifton 292. However, except for pupae from the Tifton 292 treatment, there were no significant differences between the weights of male and female pupae from any of the other diets.

Weights of both male and female pupae were highly correlated (r = 0.88 and 0.85, $P < 0.05$) with the weight of larvae at 9 days on a respective host (Fig. 2). Thus, FAW larvae that fed on more suitable hosts resulted in not only a faster weight gain and shorter larval duration, but also in larger pupae. Furthermore, the delayed development of larvae on the less suitable hosts, i.e., Tifton 292 and centipedegrass, was not completely compensated for and resulted in significantly smaller pupae than for the more suitable corn or pinto bean diet.

Hosts of the larvae did not influence the development rates of subsequent pupae for either males or females (Table 2). However, pupal duration was signficantly shorter ($P < 0.05$) for females than males in all treatments except Tifton 292.

Survival to adult emergence was significantly influenced by larval hosts (Table 2). As might be expected, survival of larvae through adult emergence was greatest on the pinto bean diet since this diet is routinely used to rear FAW in the laboratory. FAW survival on corn, Tifton 10, Coastal, and centipedegrass was ca 80%. Only 20% of the larvae fed on Tifton 292 survived to adult emergence. Zoysiagrass was essentially immune to FAW feeding and none of the larvae survived. This is the first report of an extremely high level of zoysiagrass resistance to FAW.

Table 3 summarized the data from the second antibiosis test of FAW larvae that were fed on selected grass foliage incorporated into the standard pinto bean diet. FAW larvae from the pinto bean diet again weighed significantly more than those fed on the grass-diet mixtures after 5 days. Larvae from the common centipedegrass-diet mixture developed more slowly than those fed on the other grass-diet mixture at 7 days. Also, a longer time was required for completion of the larval development (11.9 days) for those fed centipedegrass-diet mixtures than those fed on other grass-diet mixtures. The slower development of FAW larvae on the centipedegrass-diet mixture could have been due to inhibition of feeding or by the presence of unknown growth-resistant chemical(s) that resulted from oxidization of chemical(s) from centipedegrass at the diet surface (Chang et al. 1985b). These chemical(s) turned the surface of the diet in each cup dark brown after the mixture had been dispensed ca 2 hr.

The antibiosis exhibited by Tifton 292 and zoysiagrass resulted in lighter larvae at 9 days after infestation and lighter pupae (both female and male) than when these grasses were incorporated into the pinto bean diet. The antibiosis of zoysiagrass was demonstrated by significantly higher mortality of larvae fed on the zoysiagrass-diet mixture than for those fed on bermudagrass-diet mixture. We found that 17.6% of the FAW pupae in this test that died had serious wing deformities. Although there were no significant differences in percentage survival for FAW reared on centipede-diet and Tifton 292-diet mixture, compared with survival on other treatments, significantly more ($P < 0.05$) adults from these two grasses had major wing deformities. The serious wing lesions that developed in

Table 2. Weight, duration, and percent survival of fall armyworm pupae from larvae confined on pinto bean diet or selected grasses.*†

Host diet	$\bar{x}$ wt (mg) Female		$\bar{x}$ wt (mg) Male	$\bar{x}$ duration (days) Female		$\bar{x}$ duration (days) Male	% survival adult emergence
Pinto bean diet	255.6 ± 18.1 a		249.4 ± 15.2 a	8.0 ± 0.8 a	*	8.8 ± 0.4 a	96.7 a
Corn	171.1 ± 39.5 b		166.7 ± 20.7 b	8.0 ± 0.9 a	*	8.6 ± 0.7 a	76.7 b
'Tifton 10' bermudagrass	131.3 ± 17.4 c		133.2 ± 19.7 c	7.5 ± 0.7 a	*	8.1 ± 1.0 a	83.3 b
'Coastal' bermudagrass	148.0 ± 26.2 c		143.5 ± 22.5 c	7.9 ± 0.6 a	*	8.7 ± 0.8 a	80.0 b
Common centipedegrass	134.8 ± 18.5 c		141.1 ± 19.2 c	8.0 ± 0.7 a	*	8.9 ± 0.7 a	80.0 b
'Tifton 292' bermudagrass	111.8 ± 4.8 d	*	135.6 ± 14.9 c	8.3 ± 0.5 a		9.0 ± 0.0 a	20.0 c
Zoysiagrass	–		–	–		–	0.0 d

* Data expressed as Mean ± 1SD.

† Means within a vertical column followed by different letters, or marked with an * within each horizontal comparison, are significantly different at the $P = 0.05$ level using Duncan's multiple range test.

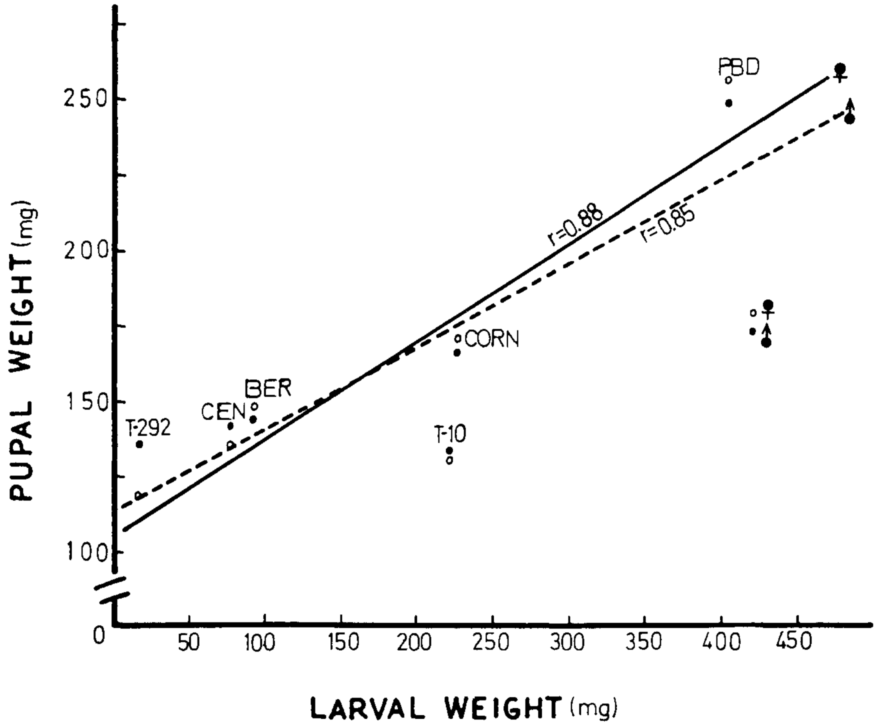

Fig. 2. Relationships among weights of FAW larvae at 9 days and weights of pupae (combined male and female) for larvae fed on 'Coastal' bermudagrass (BER); 'Tifton 10' bermudagrass (T10); 'Tifton 292' bermudagrass (T292); corn; centipedegrass (CEN); and pinto bean diet (PBD).

FAW reared on centipedegrass-diet or Tifton 292-diet mixtures, and the abnormal wing pads in pupae reared from zoysiagrass-diet mixtures should not have been caused by nutritional deficiencies since a "complete" diet was used, i.e., standard pinto bean diet in the diet mixture. We think that certain unspecified secondary plant chemical(s) in the resistant grasses adversely affected wing formation.

Insect parameters of a suitable host are characterized by high insect survival, rapid insect development, and high pupal weight. Lynch et al. (1983) noted that insect survival is paramount for host suitability since insect reproduction must occur. Large larvae are also very important since they are correlated with high fecundity (Leuck and Perkins 1972). As can be noted in Tables 1, 2, and 3, FAW larvae fed on pinto bean diet and corn leaves gained weight rapidly, required a shorter period to complete development, and obtained greater pupal weights. Thus, the pinto bean diet and corn leaves would be classified as highly suitable. Using the above criteria, Tifton 10 and Coastal bermudagrass would be classified as suitable, common centipedegrass would be moderately suitable, Tifton 292 would be unsuitable and zoysiagrass would be highly unsuitable as hosts for development of FAW larvae.

Table 3. Biological responses of fall armyworm larvae on pinto bean diet and pinto bean diet-grass mixtures.*†

Treatment	$\bar{x}$ larval wt (mg) at			$\bar{x}$ larval duration (days)	$\bar{x}$ pupal wt (mg)		$\bar{x}$ pupal duration (days)		% survival to adult emergence	% adult with wing deformity
	5 DAI‡	7 DAI	9 DAI		Female	Male	Female	Male		
Pinto bean diet (CK)	26.1 a (8.7)	135.7 a (27.7)	417.6 a (84.1)	11.6 ab (0.6)	276.4 a (24.2)	254.9 a (26.2)	7.9 a (0.6)	8.7 b (0.5)	97.2 a	2.9 a
PBD + 'Coastal' bermudagrass	21.6 b (8.2)	125.1 a (26.4)	389.1 a (76.1)	11.4 b (0.6)	264.8 a (27.5)	262.1 a (18.8)	8.1 a (0.5)	9.0 b (0.3)	94.4 a	3.1 a
PBD + Common centipedegrass	21.1 b (7.9)	101.8 b (31.9)	314.4 b (84.8)	11.9 a (0.9)	261.7 a (14.7)	261.9 a (16.7)	8.1 a (0.5)	9.0 b (0.4)	86.1 ab	10.3 b
PBD + 'Tifton 292' bermudagrass	18.8 b (8.6)	131.0 a (47.7)	331.4 b (121.6)	11.1 b (1.6)	229.7 b (52.3)	234.2 b (23.5)	8.0 a (0.7)	9.4 a (0.7)	82.4 ab	14.3 b
PBD + Zoysiagrass	22.8 b (8.6)	127.9 a (35.6)	338.5 b (110.8)	11.1 b (1.2)	237.3 b (20.9)	219.4 b (15.6)	8.1 a (0.8)	8.6 b (1.1)	77.8 b	3.6 a

* Data expressed as Mean ± 1SD. Numbers in parenthesis are the standard deviations of the means.
† Means within a vertical column followed by different letters are significantly different at $P = 0.05$ level using Duncan's multiple range test.
‡ DAI = Days after infestation.

In conclusion, the adverse effects of plant resistance on FAW parameters such as a slower larval weight gain, delayed larval development, smaller pupae, and higher mortality, are noted for FAW feeding on Tifton 292 and zoysiagrass as a high level of resistance. Tifton 292 showed a high level of antibiosis to (Lynch et al. 1983) and nonpreference against the FAW (Chang et al. 1985a). Zoysiagrass appears to have a very high level of antibiosis against the FAW. However, when FAW larvae were fed on a zoysiagrass-diet mixture, resistance was not strongly expressed. Thus, it appears that nonpreference of FAW for zoysiagrass may be due to physical characteristics of the grass. The high level of resistance resulted in the high mortality early in the development of the larvae when they were feeding on zoysiagrass leaves. Both antibiosis and nonpreference resistance have been found in common centipedegrass (Wiseman et al. 1982). However, the antibiosis found in our tests resulted in only slightly lighter larvae than those fed on susceptible grasses and ca 4 to 5 days delay in larval duration (Table 2); it is probably of secondary importance to nonpreference in the resistance of common centipedegrass. Although the pinto bean diet supplied sufficient nutrients for FAW development, lower larval weight gains, longer larval durations, lighter pupal weights, abnormal pupae, and wing deformity in adults was still observed when resistant grasses were incorporated into the artificial diet. Thus, several antibiosis expressions were manifested when FAW were fed these resistant grasses.

LITERATURE CITED

Burton, R. L. 1969. Mass rearing the corn earworm in the laboratory. USDA ARS 33-134, 8 pp.

Chang, N. T., B. R. Wiseman, R. E. Lynch, and D. H. Habeck. 1985a. Fall armyworm (Lepidoptera: Noctuidae) orientation and preference for selected grasses. Fla. Entomol. 68: 296-303.

Chang, N. T., B. R. Wiseman, R. E. Lynch, and D. H. Habeck 1985b. The influence of N fertilization on the resistance of selected grasses to fall armyworm larvae. J. Agric. Entomol. 2: 137-46.

Combs, R. L., Jr., and J. R. Valerio. 1980. Biology of the fall armyworm on four varieties of bermudagrass when held at constant temperatures. Environ. Entomol. 9: 393-6.

Dahms, R. G. 1972. Techniques in the evaluation and development of host plant resistance. J. Environ. Qual. 1: 254-9.

Duncan, D. B. 1955. Multiple range and multiple F test. Biometrics 11: 1-42.

Garner, J. W., and R. E. Lynch. 1981. Fall armyworm leaf consumption and development on Florunner peanuts. J. Econ. Entomol. 74: 191-3.

Keller, M. A. 1980. Effects of temperature and corn phenology on fall armyworm biology. M.S. Thesis, University of Florida, Gainesville, 83 pp.

Leuck, D. B., and J. L. Skinner. 1970. Resistance in bermudagrass affecting control of the fall armyworm. J. Econ. Entomol. 63: 1981-2.

Leuck, D. B., and J. L. Skinner. 1971. Resistance in peanut foliage influencing fall armyworm control. J. Econ. Entomol. 64: 148-50.

Leuck, D. B., and W. D. Perkins. 1972. A method of estimating fall armyworm progeny reduction when evaluating control achieved by host plant resistance. J. Econ. Entomol. 65: 482-3.

Luginbill, P. 1928. The fall armyworm. USDA Tech. Bull. 34. 92 pp.

Lynch, R. E., W. D. Branch, and J. W. Garner. 1981. Resistance of *Arachis* species to the fall armyworm, *Spodoptera frugiperda*. Peanut Sci. 8: 106-9.

Lynch, R. E., W. G. Monson, B. R. Wiseman, and G. W. Burton. 1983. Bermudagrass resistance to the fall armyworm (Lepidoptera: Noctuidae). Environ. Entomol. 12: 1837-40.

Painter, R. H. 1951. Insect resistance in crop plants. The MacMillan Co., N. Y. 520 pp.

Pencoe, N. I., and P. B. Martin. 1981. Development and reproduction of fall armyworm on several wild grasses. Environ. Entomol. 10: 999-1002.

Pencoe, N. I., and P. B. Martin. 1982. Fall armyworm (Lepidoptera: Noctuidae) larvae development and adult fecundity on five grass hosts. Environ. Entomol. 11: 720-3.

Perkins, W. D. 1979. Laboratory rearing the fall armyworm. Fla. Entomol. 62: 87-91.

Pitre, H. N., and D. B. Hogg. 1983. Development of the fall armyworm on cotton, soybean and corn. J. Ga. Entomol. Soc. 18: 182-7.

Wiseman, B. R., W. P. Williams, and F. M. Davis. 1981. Fall armyworm: resistance mechanisms in selected corn. J. Econ. Entomol. 74: 622-4.

Wiseman, B. R., R. C. Gueldner, and R. E. Lynch. 1982. Resistance in common centipedegrass to the fall armyworm. J. Econ. Entomol. 75: 245-7.