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【Research report】

夜盜幼蟲對數種食物利用效率之定量研究【研究報告】

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Abstract

摘要

本試驗測試夜盜蟲 (*Spodoptera frugiperda* (J. E. Smith)) 幼蟲對數種草類及人工飼料之取食後食物利用效率。最後二齡 (五、六齡) 之幼蟲攝取食物佔總幼蟲期食量百分七十五以上。人工飼料促使此夜盜蟲幼蟲之高生長率並非其取食增加，而是幼蟲對食物轉換效率較高的緣故，此高轉換效率更因代謝效率提高而非消化力增強所致。夜盜蟲飼育於百慕草上則因取食降低而使其生長緩慢，以低取食率則與牧草含水量低有關。轉換食物對夜盜取食率及食物利用之影響試驗證明幼蟲最初取食之食物種類對以後轉換寄主植物之抗性及幼蟲表現影響甚大，例如夜盜蟲由感受性食物 (如玉米) 轉換至抗性草類 (如 Centipedegrass)，可因取食量及消化食物轉換率之提高而使夜盜蟲生長率與轉換至其他感受性草類 (如 Coastal bermudagrass) 之幼蟲生長率相當。另外原先寄主植物對轉換食物後幼蟲生長、取食及代謝影響之原因亦於文中探討。

Key words:

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QUANTITATIVE UTILIZATION OF SELECTED GRASSES BY FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE) LARVAE

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Abstract

Quantitative measurements of food utilization by larvae of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith), on selected grasses and artificial diet indicated greater consumption of corn (*Zea mays* L.) than 'Tifton 10' or 'Coastal' bermudagrass (*Cynodon dactylon* (L.) Pers.). More than 75% of the total amount of food was consumed by the last two instars. Differences in larval growth rates were due to differences in larval consumption rates when they were transferred from pinto bean diet to susceptible grasses such as corn, 'Tifton 10' and 'Coastal' bermudagrass. However, the suppression of larval growth when larvae were transferred from pinto bean diet to resistant grasses such as 'common' centipedegrass (*Eremochola ophiuroides* (Munro) Hack.), 'Tifton 292' and zoysiagrass (*Zoysia* sp.) was caused by a low rate of consumption and/or greater metabolic expenditures. Larvae transferred to the resistant grasses were unable to compensate for the low efficiency of conversion of digested food by increasing relative consumption rate. The host on which fall armyworm larvae initially fed was extremely important to larval performance when they were transferred to other hosts. Larvae grew significantly faster on corn when they were initially fed on 'Tifton 10', 'Coastal' bermudagrass, or 'common' centipedegrass than when larvae were continuously fed corn.

Introduction

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), is one of the most persistent and destructive pests in the southern and central United States. Among more than 50 species of host plants, this insect prefers members of the grass family, e. g., corn, sorghum, and bermudagrass (Luginbill, 1928). Information on the quantitative and qualitative effects of FAW damage on various host plants is needed to define the resistance-susceptibility of host plants and to manage this pest.

Luginbill (1928) reported that ca. 90 cm² of corn foliage and ca. 13.8 cm² of crabgrass were needed for FAW larvae to complete larval development. Several recent reports have also presented data on leaf consumption by FAW larvae on corn (*Zea mays* L.) (Wiseman *et al.*, 1981), peanut (*Arachis hypogaea* L.) (Barfield *et al.*, 1980b, Garner and Lynch 1981), and various grasses and sedges (Pencoe and Martin 1981, 1982, Lynch *et al.*, 1983). In general, leaf consumption was measured to provide basic information for

establishing economic injury levels (e.g., Martin *et al.*, 1980) or as a parameter in evaluating host suitability and host plant resistance (e.g., Lynch *et al.*, 1981). However, none of these reports provides quantitative measurements of FAW host utilization, such as available for certain other polyphagous lepidopterans (Slansky and Scriber, 1982).

The present study was undertaken to (1) measure the consumption by FAW of selected grasses throughout larval development, (2) analyze the consumption and post-ingestive utilization of these grasses by late instar FAW larval, and (3) determine the effect of changing diets, during larval development on the post-ingestive utilization of these plants. These studies provide information on the nutritional ecology of FAW, including the mode of action of plant resistance to the FAW.

Materials and Methods

Fall armyworm larvae were obtained from the laboratory culture at the Insect Biology and Population Management Research Laboratory (IBPMRL) ARS, USDA, Tifton, Georgia (Perkins, 1979). Six grasses ranging from highly susceptible to highly resistant to FAW were selected for study: 'Coastal', 'Tifton 10', and 'Tifton 292', bermudagrass, (*Cynodone dactylon* (L.) Pers.), 'common' centipedegrass (*Eremochola ophiuroides* (Munro) Hack.), zoysiagrass (*Zoysia* sp.), and corn (*Zea mays* L.). Cultures of each grass, except corn, were obtained from pure stands from the field and planted in clay pots (12 cm diam, 12.5 cm high) under greenhouse conditions. Grasses in each pot were fertilized ca. every 2 weeks with 5 g ammonium nitrate (34% available nitrogen). Corn leaves were excised from plantings of open-pollinated Pioneer 3369A maintained at the IBPMRL experimental farm.

Leaf Consumption per Instar

Food consumption (C) of FAW larvae on leaves of corn and 'Tifton 10' bermudagrass, both highly preferred by FAW larvae, and 'Coastal' bermudagrass, moderately preferred by FAW larvae (Chang *et al.*, 1985a) was calculated from the formula: $C = (A \times B) - (C + D)$ (Axelsson and Agren, 1979). Freshly excised leaves were weighed prior to feeding (A) and placed in 36 plastic cups (5 cm diam, 3.5 cm high) per treatment. First instar larvae were then placed individually on the leaves, and the cups, containing wet filter paper in the bottom for moisture, were capped. The experiment was designed in a randomized complete block with 36 replications. An additional group of five cups containing weighed leaves (E) and wet filter paper was used in each test to check for weight changes due to leaf metabolism during each feeding period. All cups were maintained in an incubator at $26.7 \pm 2^\circ\text{C}$, $70 \pm 5\%$ RH, and a photoperiod of LD 14:10. The average percentage of dry weight (B) of each grass tested was obtained by weighing and oven-drying five sets of excised leaves at 60°C for 24 h. Larvae were checked daily, and at the initiation of each instar, 18 uniformly molting larvae were used to evaluate leaf consumption. After each molt, unconsumed leaf material was dried at 60°C for 24 h for dry weight (C) determination. The dry weight of the leaves in the five check cups was also determined at this time (F). The average metabolic loss (D) of the tested grasses was obtained from the formula: $D = (E \times B) - F$.

Analysis of variance was used to test for differences in consumption by each instar among the grasses, and treatment means were separated by Duncan's multiple range test.

Food Consumption and Utilization

The post-ingestive utilization of corn, 'Tifton 10', 'Coastal' bermudagrass, and the artificial pinto bean diet (Burton, 1969) by individual FAW larvae was determined using

standard gravimetric techniques (Waldbauer, 1968). About 50 neonate larvae were confined in 25 cm diam dishes and fed a selected grass. Freshly excised grass leaves were added each day until the larvae reached the penultimate stage. For the artificial diet, larvae were maintained in plastic rearing cups as described by Burton (1969). Ten to 15 newly molted, final (6th) instar FAW larvae were selected from each of the grasses or diet less than 3 hr after ecdysis and weighed. These larvae were transferred individually to plastic cups (5 cm diam, 3.5 cm high) containing the same food on which they had previously fed and the cups were then placed in an incubator maintained as previously described. Five additional larvae and the diet from each treatment were weighed to determine wet weight, dried at 60°C for 24 h, and re-weighed to determine the dry weight (dw) of both the insect and food introduced into the cups. After feeding for 24 h, the larvae were weighed and the remaining food and feces were removed, oven-dried, and weighed as above. The following parameters of food, utilization were then calculated on a dry, weight basis (Waldbauer, 1968, Scriber and Slansky, 1981, Chang, 1986):

GR: Growth Rate

=mg of biomass gained per day

=CR×ECI

RGR: Relative Growth Rate

=mg of biomass gained per mg of larval biomass per day

CR: Consumption Rate

=mg of food ingested per day

RCR: Relative Consumption Rate

=mg of biomass ingested per mg of larval biomass per day

AD: Approximate Digestibility

$$\bullet \quad = \frac{\text{food ingested (mg)} - \text{feces (mg)}}{\text{food ingested (mg)}} \times 100$$

ECD: Efficiency of Conversion of Digested food

$$= \frac{\text{biomass gained (mg)}}{\text{food ingested (mg)} - \text{feces (mg)}} \times 100$$

ECI: Efficiency of Conversion of Ingested food

$$= \frac{\text{biomass gained (mg)}}{\text{food ingested (mg)}} \times 100$$

=AD×ECD

Means of these rates and efficiencies for larvae fed each of the selected grass were subjected to ANOVA in a randomized complete block design with unequal replication and Tukey's studentized range test (Winer, 1971) was used to separate means.

Effect of Changing Diet on Food Consumption and Utilization of FAW larvae

Seven treatments, pinto bean diet, corn, 'Coastal' bermudagrass, 'Tifton 10', 'Tifton 292', 'common' centipedegrass, and zoysisgrass were used in a randomized complete block with 15 replications to determine the effect of changing diet on food consumption and utilization. Initially, FAW larvae were reared on each grass in 25 cm diam dishes or on pinto bean diet in 5 cm×3.5 cm cups until they reached the final instar. Nine to 15 freshly molted, 6th instar larvae were then selected from each treatment and placed individually on one of these seven grasses or diet. Food consumption and utilization were estimated by the gravimetric technique described above. The calculation of each parameter of larval growth, the statistical analysis, and the separation of means were identical with those described in the previous test.

Results and Discussion

Leaf Consumption per Instar

There were differences among the three foods in leaf consumption per instar (Table 1). In general, more corn was consumed than 'Tifton 10', and more 'Tifton 10' than 'Coastal' bermudagrass; although the difference in early instars was not significant. These within-instar differences were reflected in total leaf consumption with more corn being consumed during larval development than on the other two hosts, and more 'Tifton 10' being consumed than 'Coastal' bermudagrass (Table 1). These differences in consumption may be due to differences in efficiency of utilization or in nutrient content per unit leaf area of these grasses. Also differences in preference may be involved in the feeding behavior of FAW larvae on these hosts. Chang *et al.* (1985a) noted that corn and 'Tifton 10' were highly preferred and 'Coastal' bermudagrass was moderately preferred by FAW larvae.

On each grass leaf consumption during the first three instars was ca. 5 to 7.5% of total consumption, whereas the last two instars accounted for more than 75% of total consumption. Luginbill (1928) reported that ca. 90% of total corn leaf area was consumed by the last two FAW instars. Thus, the penultimate and final instars of FAW are the most destructive; and the management of FAW populations on field crops should be aimed at preventing these last two stages from reaching economic levels.

Table 1. Leaf consumption by instar of fall armyworm fed on corn, 'Tifton 10', and 'Coastal' bermudagrass

Host	Leaf consumption (mg dw) by instar for fall armyworm larvae ^{a, b)}						Total
	1st & 2nd	3rd	4th	5th	6th		
Corn	2.7±1.0b (0.99%)	10.9±4.8a (4.04%)	43.3±18.7a (16.03%)	67.5±15.3a (24.97%)	145.9±39.7a (53.97%)		270.3 (100%)
'Tifton 10' bermudagrass	5.0±3.4a (2.14%)	10.3±3.2a (4.43%)	40.2±14.5a (17.28%)	58.7±12.4b (25.21%)	118.5±22.7b (50.93%)		232.7 (100%)
'Coastal' bermudagrass	2.8±1.0b (1.83%)	8.6±2.7a (5.67%)	13.3±3.2b (8.70%)	45.7±7.3c (29.99%)	82.0±12.6c (53.80%)		152.4 (100%)

^{a)} Data expressed as Mean±SD. Means within each column not followed by the same letter are significantly different at the $p < 0.05$ level by Duncan's (1955) multiple range test.

^{b)} Data in parentheses indicate the percentage of total consumption consumed by each instar.

Food Consumption and Utilization

Table 2 presents data on consumption rates, efficiency of utilization, and growth rates for final instar FAW larvae feeding on corn, 'Tifton 10' bermudagrass, 'Coastal' bermudagrass, and pinto bean diet. Significantly greater growth rates, both absolute (GR) and relative (RGR), occurred on pinto bean diet than on the other three hosts. The RGR of larvae on pinto bean diet was 1.4 times greater than that on corn, 1.2 times greater than on 'Tifton 10', and 2.4 times greater than on 'Coastal' bermudagrass. These higher growth rates on the pinto bean diet are related to a higher efficiency of conversion of ingested food into biomass (ECI) rather than to a higher consumption rate. Moreover, the higher ECI was not due to a higher digestive efficiency (AD) but rather to a significantly higher efficiency of conversion digested food in to biomass (ECD), indicating that the high suitability of pinto bean diet for FAW larvae is due to their lower metabolic costs compared with larvae feeding on the grasses.

A comparison of the performance of final instars on the grasses showed significantly

Table 2. Growth rates, consumption rates, and efficiencies of 6th instar fall armyworm fed on selected grasses and pinto bean diet^{a)}

Diets	Diet water Content (%)	Growth rate		Consumption rate		Efficiency			No. of larvae (n)
		GR (mg/day)	RGR (mg/mg/day)	CR (mg/day)	RCR (mg/mg/day)	AD (%)	ECD (%)	ECI (%)	
Pinto bean	75.38b (0.18)	51.37a (1.59)	0.88a (0.02)	164.51a (4.56)	2.81b (0.06)	33.40a (2.88)	85.52a (4.27)	31.32a (0.58)	12
Corn	82.97a (0.46)	27.64b (1.33)	0.63b (0.03)	161.63a (9.57)	3.76a (0.29)	34.30a (2.96)	56.98b (7.40)	17.53b (1.08)	12
'Tifton 10' bermudagrass	72.11c (0.20)	24.48b (0.65)	0.74b (0.01)	130.91b (4.48)	3.96a (0.10)	33.63a (1.94)	59.23b (4.18)	18.87b (0.54)	15
'Coastal' bermudagrass	68.90d (0.41)	8.05c (1.08)	0.37c (0.05)	53.12c (2.83)	2.41b (0.13)	36.98a (4.70)	47.76b (7.55)	15.30b (1.78)	11
HSD ^{b)}	1.26	4.46	0.11	22.46	0.62	11.78	12.25	4.08	

^{a)} All data were calculated on a dry-weight basis and presented as mean \pm (SE).

^{b)} HSD=Honestly significant difference ($p < 0.05$) by Tukey's studentized range test for unequal sample sizes (Steel and Torrie 1960).

lower GR and RGR on 'Coastal' bermudagrass, associated with significantly lower CR and RCR values of larvae on this grass (Table 2); there were no significant differences in AD, ECD or ECI values among larvae on the three grasses. The lower consumption may be a result of the significantly lower water content in the leaves of 'Coastal' bermudagrass (Table 2), which may influence both consumption rate and larval preference for this grass. Leaf water content of corn was significantly higher than that of 'Tifton 10' bermudagrass, but there were no significant differences in rates or efficiencies for larvae feeding on these two hosts, except for the greater CR of larvae on corn. This greater CR confirms the differences previously noted in leaf consumption (Table 1) and in days to pupation for larvae feeding on corn (Chang *et al.*, 1985b).

Comparing FAW larval performance on corn, 'Tifton 10', and 'Coastal' bermudagrass with the average performance values for grasschewing Lepidopteran in Slansky and Scriber (1982) showed that FAW larvae had ca. 1.2 to 2.0 times higher RCR values, which resulted in faster RGR values for FAW larvae on the tested grasses. However, the ECI values, 15.3 to 18.9% for FAW feeding on these grasses, are slightly lower than the average (19%) reported by Slansky and Scriber (1982). Thus, the designation of the FAW as one of the most destructive pests on preferred grasses is not only the result of its high mobility and polyphagy (Barfield *et al.*, 1980a), but also because of the high consumption rate of this pest.

Effect of Changing Diet on Food Consumption and Utilization

The effects of food switch on 6th (final) instar FAW consumption rate, growth rate, and efficiency of utilization after initial feeding on pinto bean diet are presented in Table 3. Larvae fed continuously on pinto bean diet had significantly higher ($p < 0.05$) GR and RGR values than larvae transferred to the various grasses. This high growth on the pinto bean diet was again due to a significantly higher ECI and ECD rather than to higher consumption rate. Comparing among the grasses, the RGR of larvae on corn was 1.4 and 1.9 times greater than that of larvae on 'Tifton 10' and 'Coastal' bermudagrass, respectively; and 5.5 to 27.5 times greater than that of larvae on 'Common' centipede-grass, 'Tifton 292', and zoysiagrass. These differences in RGR's are associated with differences in ECI, ECD and RCR values. For example larvae fed corn had a significantly higher RCR than larvae fed any of the other hosts. Corn also had the highest water

Table 3. Growth rates, consumption rates, and efficiencies of 6th-instar fall armyworm fed on selected grasses after initial feeding on pinto bean diet^{a)}

Diets	Diet water Content (%)	Growth rate		Consumption rate		Efficiency			No. of larvae (n)
		GR (mg/day)	RGR (mg/mg/day)	CR (mg/day)	RCR (mg/mg/day)	AD (%)	ECD (%)	ECI (%)	
Pinto bean (check)	75.38b (0.18)	51.37a (1.59)	0.88a (0.02)	164.49a (4.56)	2.81b (0.06)	33.40a (2.88)	85.52a (4.27)	31.32a (0.58)	12
Corn	86.04a (1.65)	22.32b (1.36)	0.55b (0.02)	138.47ab (13.59)	3.46a (0.31)	41.27a (4.52)	49.22b (8.49)	17.20b (1.53)	12
'Tifton 10' bermudagrass	74.03c (0.20)	18.40b (2.36)	0.39c (0.08)	112.53b (8.84)	2.28bc (0.17)	37.12a (1.54)	45.40b (6.51)	16.78b (2.63)	12
'Coastal' bermudagrass	67.30d (0.36)	8.42c (1.39)	0.29c (0.01)	69.88c (4.37)	1.84cd (0.12)	27.44a (2.86)	48.13b (9.43)	12.51bc (2.27)	15
'Common' centipedegrass	77.33b (0.22)	2.66d (0.79)	0.08d (0.02)	45.80cd (3.65)	1.28de (0.08)	41.06a (2.49)	16.12c (6.58)	5.71c (1.77)	12
'Tifton 292' bermudagrass	66.20d (0.29)	0.57d (0.39)	0.02d (0.01)	30.46d (3.19)	0.69e (0.05)	28.87a (3.96)	12.89c (0.01)	4.29c (3.31)	15
Zoysiagrass	65.56d (0.31)	3.74cd (0.82)	0.10d (0.02)	42.33d (2.51)	1.10e (0.07)	27.61a (3.39)	30.49bc (8.72)	8.45bc (1.82)	15
HSD ^{b)}	2.66	5.65	0.16	27.46	0.64	14.55	28.5	9.68	

^{a)} All data were calculated on a dry-weight basis and presented as mean±(SE).

^{b)} HSD=Honestly significant difference ($p<0.05$) by Tudey's studentized range test for unequal sample sizes (Steel and Torrie 1960).

content of all hosts (Table 3). These factors combined with the high ECI on corn, resulted in the highest RGR of larvae among all the grass diets. The higher RCR and ECI of larvae on the two bermudagrasses contributed to their higher RGR's compared with the resistant, unsuitable 'Common' centipedegrass, 'Tifton 292' bermudagrass, and zoysiagrass.

'Common' centipedegrass, 'Tifton 292' bermudagrass and zoysiagrass are resistant to FAW feeding (Wiseman *et al.*, 1982, Lynch *et al.*, 1983, Chang *et al.*, 1985b). Growth of final instars was significantly slower on these resistant grasses than than for either corn or the two susceptible bermudagrasses. This growth suppression was not mediated by a reduction in AD, but instead by lower CR and RCR values and also by greater metabolic expenditures as reflected by a reduction in ECD. The low ECD for larvae on these resistant grasses, especially 'Tifton 292', indicates that some antimetabolites are present in these grasses. Thus, after transfer of sixth instars from suitable pinto bean diet to these grasses, the factor(s) that produce resistance in these grasses act to reduce feeding and to incur a metabolic cost to apparently detoxify them.

Table 4 presents larval performance of sixth-instar FAW on seven selected diets after they were initially fed con. The highest GR and RGR values occurred on pinto bean diet, resulting from high CR and RCR values and a significantly higher ECI. Comparing among the grass diets to which larvae were transferred, all the RGR, RCR, AD, ECD, and ECI were statistically comparable for larvae on corn, 'Tifton 10', 'Coastal' bermudagrass, and 'Common' centipedegrass, with the exception of a lower RCR for larvae on 'Coastal' bermudagrass. The reductions in both GR RGR on 'Tifton 292' and zoysiagrass were due to the significantly lower CR and RCR values, and the low ECI values for larvae on these two grasses compared with larvae on other tested grasses (Table 4).

Larval growth performance of final instars after transfer from 'Tifton 10' bermudagrass to the alternate diets is presented in Table 5. The RGR of larvae transferred to

Table 4. Growth rates, consumption rates, and efficiencies of 6th-instar fall armyworm fed on selected grasses and pinto bean diet after initial feeding on corn^{a)}

Diets	Diet water Content (%)	Growth rate		Consumption rate		Efficiency			No. of larvae (n)
		GR (mg/day)	RGR (mg/mg/day)	CR (mg/day)	RCR (mg/mg/day)	AD (%)	ECD (%)	ECI (%)	
Pinto bean	73.33c (0.30)	37.43a (1.34)	0.98a (0.05)	150.61ab (8.10)	3.94a (0.26)	49.13a (1.91)	53.03ab (3.35)	25.36a (0.99)	14
Corn (check)	82.97a (0.46)	27.64b (1.33)	0.63b (0.03)	161.63a (9.57)	3.76ab (0.29)	34.30abc (2.96)	56.97a (7.40)	17.55bc (1.09)	12
'Tifton 10' bermudagrass	76.19b (1.12)	25.78b (2.49)	0.67b (0.06)	120.85bc (9.56)	3.08bc (0.14)	40.60ab (1.55)	52.76ab (2.74)	21.50ab (1.54)	11
'Coastal' bermudagrass	66.72d (0.28)	14.10c (0.88)	0.51b (0.03)	69.35de (3.40)	2.53c (0.10)	41.33ab (1.62)	50.30ab (2.73)	20.29ab (0.63)	15
'Common' centipede grass	74.79bc (0.37)	15.85c (1.01)	0.52b (0.02)	95.76cd (7.19)	3.10bc (0.12)	30.86bc (1.32)	57.32a (5.91)	17.03bc (1.13)	11
'Tifton 292' bermudagrass	66.04d (0.56)	8.03d (1.77)	0.22c (0.04)	52.55ef (8.69)	1.52d (0.15)	28.81bc (6.03)	47.89ab (9.24)	14.02cd (1.27)	9
Zoysiagrass	62.54e (0.36)	3.00d (0.56)	0.14c (0.03)	27.73f (3.06)	1.38d (0.15)	25.09c (5.99)	29.26b (8.77)	10.97d (2.14)	15
HSD ^{b)}	2.48	5.85	0.17	30.63	0.82	15.67	26.74	5.99	

^{a)} All data were calculated on a dry-weight basis and presented as Mean±(SE).

^{b)} HSD=Honestly significant difference ($p<0.05$) by Tudey's studentized range test for unequal sample sizes (Steel and Torrie 1960).

Table 5. Growth rates, consumption rates, and efficiencies of 6th-instar fall armyworm fed on selected grasses and pinto bean diet after initial feeding on 'Tifton 10' bermudagrass^{a)}

Diets	Diet water Content (%)	Growth rate		Consumption rate		Efficiency			No. of larvae (n)
		GR (mg/day)	RGR (mg/mg/day)	CR (mg/day)	RCR (mg/mg/day)	AD (%)	ECD (%)	ECI (%)	
Pinto bean	69.08d (0.23)	36.28a (1.53)	1.02a (0.01)	130.56a (5.99)	3.69a (0.14)	38.99ab (2.55)	71.35a (5.19)	28.18a (1.21)	14
Corn	83.53a (0.32)	25.35b (1.38)	0.94a (0.02)	98.77b (5.88)	3.69a (0.16)	32.79b (2.24)	79.38a (5.81)	26.29a (1.48)	14
'Tifton 10' bermudagrass (CK)	72.11c (0.20)	24.48b (0.65)	0.74b (0.01)	130.91a (4.48)	3.96a (0.10)	33.62b (1.94)	59.23ab (4.18)	18.87b (0.54)	15
'Coastal' bermudagrass	69.52d (0.42)	16.41c (1.04)	0.57c (0.03)	68.40c (4.07)	2.40b (0.14)	33.17b (2.08)	74.76a (4.63)	24.08a (0.64)	15
'Common' centipede grass	76.20b (0.39)	11.77d (0.78)	0.54c (0.03)	76.85cd (3.76)	3.59a (0.18)	38.43ab (1.62)	41.03b (2.85)	15.27b (0.61)	15
'Tifton 292' bermudagrass	65.75e (0.34)	8.03d (1.19)	0.34d (0.04)	44.81e (5.01)	1.99b (0.13)	37.98ab (1.60)	48.64b (7.33)	17.59b (2.06)	12
Zoysiagrass	61.83f (0.64)	7.60d (0.81)	0.33d (0.03)	55.03de (5.70)	2.39b (0.19)	45.62a (5.14)	41.51b (8.78)	14.32b (1.52)	13
HSD ^{b)}	1.60	4.65	0.11	21.37	0.65	11.23	21.96	5.09	

^{a)} All data were calculated on a dry-weight basis and presented as Mean±(SE).

^{b)} HSD=Honestly significant difference ($p<0.05$) by Tudey's studentized range test for unequal sample sizes (Steel and Torrie 1960).

pinto bean diet or corn was significantly higher than that of larvae fed continuously on 'Tifton 10' (Check), associated with significantly higher ECI values on the former two foods; RCR values were statistically comparable among the three feeds.

The RGR for larvae transferred to either 'Coastal' bermudagrass or 'Common' centipede grass were comparable, although this was achieved in different ways. On 'Coastal', a low RCR was partially balanced by a high ECI, whereas on 'Common' centipede grass the converse was true. In addition ECD for larvae on 'Common' was low, the RGR values for larvae on these two grasses were significantly lower than that of larvae on 'Tifton 10' bermudagrass.

The RGR was the lowest among all the treatments when larvae were transferred to 'Tifton 292' or zoysiagrass (Table 5). The reduction of both RCR and ECI for larvae on these two resistant grasses produced the low RGR values. However, compared with larvae on 'Tifton 10' bermudagrass it was the significant reduction in RCR rather than ECI that was responsible for lower RGR for larvae on these resistant grasses.

In order to compare the impact of previous foods on the growth rates, consumption rates and efficiencies of FAW larvae after they being transferred to seven alternate foods, data in Table 3-5 were reorganized and combined with some results obtained from larvae fed on various diets after transferred from 'Coastal' bermudagrass and 'Common' centipede grass and presented as Fig. 1. However, data for 'Tifton 292', zoysiagrass as initial hosts are not obtained because FAW larvae died on these resistant hosts prior to reaching the final instar. The significant greater RGR of larvae initially fed on either corn or 'Tifton 10' and then switched to pinto bean diet compared with larvae continuously fed on the Pinto bean diet resulted from significantly high RCR and AD values for larvae in the former two treatments, in spite of their lower ECD and ECI values.

Larvae that initially fed on the preferred grasses 'Tifton 10' or 'Coastal' bermudagrass showed an increase in RGR after they were transferred to corn compared with larvae continuously reared on corn. This increase in RGR was primarily due to an increase in ECD and ECI, but not AD or RCR. The significantly lower RGR for larvae transferred to corn after initially feeding on pinto bean diet compared to larvae initially feeding on other grasses was due primarily to a reduction in ECD, indicating increased metabolic costs.

Larvae that initially fed on resistant 'Common' centipede grass prior to transfer to corn showed an increase in RCR that produced an extremely high RGR compared with larvae on the other foods that was switched to corn. The increased RCR when larvae were transferred from centipede grass to corn (Fig. 1, b) may have result from the removed of constraints on larvae feeding on the resistant common centipede grass, which possesses both non-preference and antibiosis type resistance that is possibly chemically mediated (Chang *et al.*, 1985a, 1985b), and/or from the increased water content in corn leaves that stimulated feeding. Chang *et al.* (1985a) reported that the RGR for most FAW larvae was greater when larvae initially fed on other grasses prior to feeding on corn than when larvae were continuously fed on corn. This same trend is also illustrated in our results for the RGR of FAW larvae fed on 'Common' centipede grass, 'Tifton 10', and 'Coastal' bermudagrass prior to transfer to corn (Fig. 1, a). Under field conditions, movement of FAW larvae from grasses such as bermudagrass to corn plants occurs when the grass becomes unsuitable or limited as a food source. Thus, the growth rate of FAW larvae that move from these grasses to corn will increase as their ECI increases. Moreover, the corn will be damaged more rapidly in those cases where consumption rate of the larvae also increases.

The RGR of larvae on 'Tifton 10' was not statistically different between larvae previously fed corn or 'Tifton 10' (Fig. 1). However, these comparably high RGR's were achieved in quite different ways. Larvae transferred from corn had a significantly higher AD than larvae reared continuously on 'Tifton 10', and these latter larvae had a significantly higher RCR (Fig. 1, b, c). On the other hand, larvae transferred from pinto bean

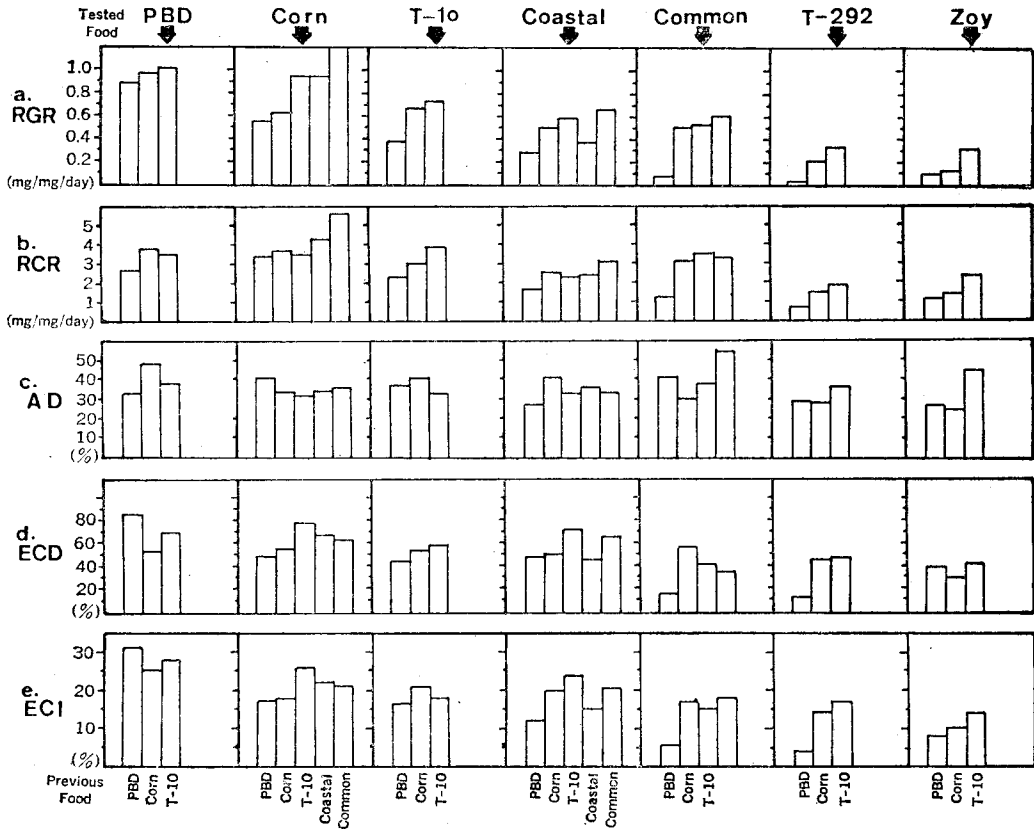


Fig. 1. Influence of previous host on the growth rate (a), consumption rate (b), and efficiencies (c, d, e) of 6th instar fall armyworm after transfer to selected grasses. PBD=Pinto Bean Diet, T-10=Tifton 10 bermudagrass, Coastal=Coastal bermudagrass, Common=Common centipede grass, T-292=Tifton 292 bermudagrass, Zoy=Zoysiagrass.

diet to 'Tifton 10' had a significantly lower RGR than larvae transferred from corn or those reared continuously on 'Tifton 10'. The reduction in RGR was associated with lower RCR, ECD, and ECI values.

The initial host for larvae transferred to 'Coastal' bermudagrass dramatically influenced larval performance. Larvae reared continuously on 'Coastal' bermudagrass and larvae transferred from pinto bean diet to 'Coastal' showed a depressed RGR. A low ECD, indicating a high metabolic cost, rather than a reduced RCR, resulted in the lower RGR for larvae continuously fed 'Coastal', even the AD of these larvae was not significantly lower than all other larvae feeding on 'Coastal' (Fig. 1, c, d). Low RCR, ECD and ECI values led to the low RGR for larvae transferred from pinto bean diet to 'Coastal'. Larvae that previously fed on centipede grass, 'Tifton 10', or corn showed an increased RGR once transferred to 'Coastal' bermudagrass compared with larvae reared continuously on 'Coastal'. As before, once the larvae were removed from the factors that impart resistance to centipede grass, the RGR and RCR increased substantially.

Larvae transferred from pinto bean diet to 'Common' centipede grass showed a significantly reduced RGR, RCR, ECD and ECI compared with larvae transferred from the three grasses. For larvae initially reared on 'Coastal' and switched to 'Common', there was a trade-off between the low ECD and the high AD (Fig. 1, c, d) to produce ECI and

RGR values statistically comparable to the larvae that were initially fed on corn or 'Tifton 10' and switched to 'Common'. Thus, the adjustment for FAW larvae transferred to the resistant centipedegrass might be physiologically different depending on initial food, but RCR and RGR values are comparable. Yu (1982, 1983) demonstrated that different host plants induced different levels of mixed function oxidase (MFO) activity in FAW larvae and that MFO activities of sixth-instar larvae were highest for larvae fed on corn (ca. two to four times higher than larvae fed artificial diet). Reduced MFO activity could explain the higher ECD (i.e., lower metabolic cost) for larvae in the corn to Centipedegrass transfer than for larvae in the other diet-centipedegrass transfer treatments (Fig. 1, d).

Final instar larvae transferred to the resistant 'Tifton 292' bermudagrass or zoysiagrass showed a significantly higher RGR when initially reared on 'Tifton 10' bermudagrass than when initially reared on corn or pinto bean diet. Higher RCR, AD and ECI values contributed to these higher RGR's (Fig. 1, b, c, e).

Conclusion

The quantity of food required by FAW is influenced by both host on which it feeds and the stage of larval development. Slansky and Scriber (1982) summarized performance values for the immatures of various arthropods in different feeding guilds. Comparing FAW larval performance on pinto bean diet reported here with their average value for Lepidoptera on artificial diets (0.07 mg/mg/day) showed a surprising 12.6 times higher RGR for sixth-instar FAW larvae. Both higher RCR and ECD values contribute to the high RGR for FAW larvae, indicating that the high suitability of pinto bean diet for FAW larvae (Perkins, 1979) is characterized by low metabolic costs of digesting the diet along with a high consumption rate.

Nutritional value of a host is of prime importance to an insect (Scriber and Slansky, 1981) but allelochemical effects on feeding behavior, toxicant effects on survival, and other factors may be of equal importance in the performance of insects (Reese 1979). High metabolic costs, (reflected by low ECD) as well as consumption rates, were observed FAW larvae were transferred from artificial diet to resistant grasses such as 'common' centipedegrass, 'Tifton 292' and zoysiagrass. The low ECD for FAW feeding on these resistant hosts may reflect the metabolic costs associated with detoxication of allelochemicals, or of energy 'waste' associated with production of metabolic water (Fraenkel and Blewett, 1944; Scriber, 1978a). Thus, the allelochemicals might existing in these grasses that impart resistance to FAW feeding also suppress larval growth by reducing conversion efficiency and/or consumption rates.

Moreover, unlike *Spodoptera eridania* (Scriber, 1979), FAW larvae were not able to compensate for high metabolic costs by increasing their consumption rates on our tested unsuitable host grasses. These results support the hypothesis of Feeny (1975) and Blau *et al.* (1978) that the variation in qualitative plant allelochemicals is of primary importance for plants being attacked by 'unadapted' herbivores.

Several reports have illustrated that when insects are switched from one diet to another, the growth rates and efficiencies of food utilization are significantly affected (Scriber, 1981, Grabstein and Scriber, 1982). In our switching diet tests, the polyphagous FAW larvae also exhibited a high degree of variation in RCR, AD, and ECD after initially feeding on susceptible or resistant grasses. For example, the growth of sixth-instar larvae on resistant centipedegrass, was improved by an increase in RCR and/or ECD when larvae were transferred from pinto bean diet to these grasses. Thus, the initial host and stage of larval development may drastically alter the influence of resistant hosts in later feeding.

Larvae initially fed on susceptible 'Tifton 10' and 'Coastal' bermudagrass or on resistant centipedegrass had a higher growth rate when transferred to corn than larvae that fed continuously on corn. The same results were also obtained when larvae were reared continuously on 'Coastal' bermudagrass compared to when they were initially fed on other grasses and then transferred to 'Coastal' bermudagrass. These results are contradictory to those reported by Schoonhoven and Meerman (1978), who suggested that 'physiological adaptation' by larvae on one host results in better performance on the initial host than on subsequent hosts, and by Grabstein and Scriber (1982), who suggested that behavioral induction on a previous food can suppress the consumption of a new food. The results of our changing diet test are presumably related to the variation in MFO activity induced by the different hosts (Yu, 1982, 1983).

The quantitative nutritional study reported here revealed the responses of FAW to different hosts, the effects of initial food on performance of insects when transferred to another host. These findings provide a better understanding of the nutritional ecology of the highly polyphagous FAW, and such information may be used to better manage this destructive pest.

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References

- Axelsson, B., and G. I. Agren 1979. A correction for food respiration balancing energy budgets. *Entomol. Exp. & Appl.* 25: 260-266.
- Barfield, C. S., J. L. Stimac, and M. A. Keller 1980a. State-of-the-art for predicting damaging infestations of fall armyworm. *Fla. Entomol.* 63: 364-375.
- Barfield, C. S., J. W. Smith, Jr., C. Carlisle, and E. R. Mitchell 1980b. Impact of peanut phenology on selected population parameters of fall armyworm. *Environ. Entomol.* 9: 381-384.
- Blau, P. A., P. P. Feeny, L. Contardo, and D. S. Robson 1978. Allylglucosinolate and herbivorous caterpillars: a contrast in toxicity and tolerance. *Science* 200: 1296-1298.
- Burton, R. L. 1969. Mass rearing the corn earworm in the laboratory. *USDA ARS* 33: 134. 8 pp.
- Chang, N. T. 1986. The meaning and evaluation of post-ingestive utilization of food by insects. *Sci. Agr.* 34: 78-86.
- 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. Fall armyworm: expressions of antibiosis in selected grasses. *J. Entomol. Sci.* 20: 179-188.
- Chang, N. T., B. R. Wiseman, R. E. Lynch, and D. H. Habeck 1986. Growth and development of fall armyworm (Lepidoptera: Noctuidae) on selected grasses. *Environ. Entomol.* 15: 182-189.
- Duncan, D. B. 1955. Multiple range and multiple F tests. *Biometrics* 11: 1-42.

- Feeny, P. P. 1975. Biochemical coevolution between plants and their insects herbivores. pp. 3-19 In L. E. Gilbert and P. H. Raven (eds.) *Coevolution in animals and plants*. Univ. Texas Press, Austin. 246 pp.
- Fraenkel, G., and M. Blewett 1944. The utilization of metabolic water in insects. *Bull. Entomol. Res.* 35: 127-140.
- Garner, J. W., and R. E., Lynch 1981. Fall armyworm leaf consumption and development on florunner peanuts. *J. Econ. Entomol.* 74: 191-193.
- Grabstein, E., and J. M. Scriber 1982. The relationship between restriction of host plant consumption and post-ingestive utilization of biomass and nitrogen in *Hyalophora cecropia*. *Entomol. Exp. & Appl.* 31: 202-210.
- 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: 106-109.
- 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: 1837-1840.
- Martin, P. B., B. R. Wiseman, and R. E. Lynch 1980. Action thresholds for fall armyworms on grain sorghum and Coastal bermudagrass. *Fla. Entomol.* 63: 375-405.
- Pencoe, N. L., and P. B. Martin 1981. Development and reproduction of fall armyworm on several wild grasses. *Environ. Entomol.* 10: 999-1002.
- Pencoe, N. L., and P. B. Martin 1982. Fall armyworm (Lepidoptera: Noctuidae) larval development and adult fecundity on five grass hosts. *Ibid.* 11: 720-723.
- Perkins, W. D. 1979. Laboratory rearing of the fall armyworm. *Fla. Entomol.* 62: 87-91.
- Reese, J. 1979. Interactions of allelochemicals with nutrients in herbivore food. pp. 303-330. In G. A. Rosenthal and D. H. Janzen (eds.) *Herbivores: their interaction with secondary plant metabolites*. Academic Press, N. Y.
- Schoonhoven, L. M., and J. Meerman 1978. Metabolic cost of changes in diet and neutralization of allelochemicals. *Entomol. Exp. & Appl.* 24: 689-693.
- Scriber, J. M. 1978. The effects of larval feeding specialization and plant growth form on the consumption and utilization of plant biomass and nitrogen: an ecological consideration. *Ibid.* 24: 494-510.
- Scriber, J. M. 1979. Post-ingestive utilization of plant biomass and nitrogen by Lepidoptera: Legume feeding by the southern armyworm. *New York Entomol. Soc.* 87: 141-153.
- Scriber, J. M. 1981. Sequential diets, metabolic costs, and growth of *Spodoptera eridanis* (Lepidoptera: Noctuidae) feeding upon dill, lima bean, and cabbage. *Oecologia* 51: 175-180.
- Scriber, J. M., and F. Slansky, Jr. 1981. The nutritional ecology of immature insects. *Annu. Rev. Entomol.* 26: 183-211.
- Slansky, F. Jr., and J. M. Scriber 1982. Selected bibliography and summary of quantitative food utilization by immature insects. *Entomol. Soc. Amer. Bull.* 28: 43-55.
- Steel, R. G. D., and J. H. Torrie 1960. *Principles and procedures of statistics*. McGraw-Hill, New York.
- Waldbauer, G. P. 1968. The consumption and utilization of food by insects. *Adv. Insect Physiol.* 5: 229-289.
- Winer, B. J. 1971. *Statistical principles in experimental design*. 2nd Ed. McGraw-Hill, New York.
- Wiseman, B. R., W. P. Williams, and F. M. Davis 1981. Fall armyworm: resistance mechanisms in selected corns. *J. Econ. Entomol.* 74: 622-624.
- Wiseman, B. R., R. C. Gueldner, and R. E. Lynch 1982. Resistance in common centipede-grass to the fall armyworm. *Ibid.* 75: 245-247.
- Yu, S. J. 1982. Induction of microsomal oxidases by host plants in the fall armyworm, *Spodoptera frugiperda* (J. E. Smith). *Pestic. Biochem. Physiol.* 17: 59-67.

Yu, S.J. 1983. Induction of detoxifying enzymes by allelochemicals and host plants in the fall armyworm. *Pestic. Biochem. Physiol.* 19: 330-336.

夜盜幼蟲對數種食物利用效率之定量研究

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本試驗測試夜盜蟲 (*Spodoptera frugiperda* (J.E. Smith)) 幼蟲對數種草類及人工飼料之取食後食物利用效率。最後二齡 (五、六齡) 之幼蟲攝取食物佔總幼蟲期食量百分之七十五以上。人工飼料促使此夜盜蟲幼蟲之高生長率並非其取食量增加，而是幼蟲對食物轉換效率較高的緣故，此高轉換效率更因代謝效率提高而非消化力增強所致。夜盜蟲飼育於百慕達草上則因取食率降低而使其生長緩慢，以低取食率則與牧草含水量低有關。轉換食物對夜盜取食率及食物利用之影響試驗證明幼蟲最初取食之食物種類對以後轉換寄主植物之抗性及幼蟲表現影響甚大，例如夜盜蟲由感受性食物 (如玉米) 轉換至抗性草類 (如 Centipedegrass)，可因取食量及消化食物轉換率之提高而使夜盜蟲生長率與轉換至其他感受性草類 (如 Coastal bermudagrass) 之幼蟲生長率相當。另外原先寄主植物對轉換食物後幼蟲生長、取食及代謝影響之原因亦於文中探討。