CATERPILLAR (LEPIDOPTERA: NOCTUIDAE) FEEDING ON PASTURE GRASSES IN CENTRAL FLORIDA

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ABSTRACT

Stargrasses (*Cynodon nlemfuensis* Vanderyst var. *nlemfuensis*) and bermudagrasses (*C. dactylon* (L.) Persoon) are important warm-season forage grasses, with several cultivars developed for conditions found in central and southern Florida. Major insect pests of these grasses include grass loopers (*Mocis* spp.) and fall armyworm (*Spodoptera frugiperda* (J. E. Smith)), which annually may impose economic losses for beef cattle and hay producers. Population studies conducted during a 3-year period showed that both species had similar profiles with respect to larval population seasonality but not abundance. Plot studies with 4 stargrass and 4 bermudagrass lines showed that higher grass looper populations were found in stargrasses than bermudagrasses. Laboratory studies found grass loopers and fall armyworm larvae generally developed faster with larger weights on lines of stargrass than lines of bermudagrass. The two fall armyworm host strains also can differ substantially in their larval weight, developmental time, and survivability when grown on different lines of grasses. These results indicate that the selection of pasture grasses made by growers can significantly and differentially affect the population densities of these grass defoliators.

Key Words: *Mocis latipes*, *Mocis disseverans*, *Mocis marcida*, *Spodoptera frugiperda*, larval densities

RESUMEN

Los pastos, *Cynodon nlemfuensis* Vanderyst var. *nlemfuensis*) y *C. dactylon* (L.) Persoon, son pastos importantes para las estaciones calidas, con varias variedades desarrolladas para las condiciones encontradas en el centro y sur de la Florida. Las plagas insectiles mayores de estos pastos incluyen: gusanos medidores de pastos (*Mocis* spp.) y el cogollero, *Spodoptera frugiperda* (J. E. Smith), las cuales puedan imponer perdidas económicas para los ganaderos y productores de pastos de corte. Estudios de población realizados durante un periodo de tres años mostraron que ambas especies tuvieron perfiles similares con respecto al periodo de estación en que se encontraban las poblaciones de larvas pero no de su abundancia. Estudios de parcelas con 4 líneas de *C. nlemfuensis* y 4 líneas de *C. dactylon* mostraron que se encuentran poblaciones mas altas del gusano medidor de pasto en *C. nlemfuensis* que en *C. dactylon.* Estudios del laboratorio mostraron que las larvas del medidor y cogollero generalmente se desarrollaron mas rápidamente con peso mayores en las líneas de *C. nlemfuensis* que en las líneas de *C. dactylon*. Las dos variedades de hospederos para el cogollero pueden variar substancialmente en el peso de la larva, el tiempo de desarrollo, y su capacidad para sobrevivir cuando están criados sobre diferentes líneas de pastos. Estos resultados indican que la selección de pastos para pasturas hecha por los agricultores puede afectar significativamente y diferentialmente la densidad de estos defoliadores de pastos.

Several *Cynodon* species are used in the southeastern United States as the base forage by beef and dairy producers. These grasses yield more than bahiagrasses (*Paspalum notatum* Flugge) during short daylength periods (cool season), and depending on temperature and soil fertility, can produce considerable forage during Jan and Feb (Mislevy & Martin 1997). Improved bermudagrass (*C. dactylon* (L.) Persoon) and stargrass (*C. nlemfuensis* var. *nlemfuensis*) (Mislevy 2002) cultivars have been developed and production practices optimized for beef cattle growers in central Florida for many years, and new germplasm lines are continuously screened under grazing conditions (Mislevy et al. 1991; Mislevy et al. 1996).

Mocis spp. larvae or grass loopers are pests of *Cynodon* forage grasses in the southeastern United States (Watson 1933; Ogunwolu & Habeck 1975; Koehler et al. 1977). Meagher & Mislevy (2005) found three *Mocis* species (*disseverans* (Walker), *latipes* (Guenée) (striped grass looper), and *marcida* (Guenée)) in central Florida when developing attractants for adults. *Mocis* spp. also are important pests of both pasture and cultivated grasses in Central America, South America, and the Caribbean (Gibbs 1990; Portillo et al. 1991; Cave 1992). Determination of life history, biology, and geographic information for *Mocis* spp. has been hampered by misuse of scientific names in the literature and misidentification in the field (Dean 1985; Gregory et al. 1988).

Another lepidopteran pest of pasture grasses is the fall armyworm, *Spodoptera frugiperda* (J. E. Smith). Differential susceptibility to fall armyworm of grasses grown for hay production and grazing has been shown in various trials conducted with bermudagrass lines developed in Georgia, Louisiana, and Oklahoma (Leuck et al. 1968; Lynch et al. 1983; Lynch et al. 1986; Jamjanya et al. 1990). None of the grasses tested in the earlier studies is used in central and southern Florida, but the parents of 'Tifton 85' (an F_1 hybrid pentaploid between the bermudagrass PI 290884 (in the literature as 'Tifton 292') from South Africa and the stargrass (*C. nlemfuensis* Vanderyst) 'Tifton 68', a highly digestible but cold-susceptible hybrid released in 1983 (Burton et al. 1993)) have been compared for resistance. 'Tifton 68' was shown to be susceptible, with high larval weights and high larval survival in feeding trials (Lynch et al. 1983). The other parent, 'Tifton 292', was shown to be highly resistant to larval feeding (Leuck et al. 1968; Lynch et al. 1983) and larvae exhibited nonpreference resistance in comparative tests (Chang et al. 1985).

Research in Louisiana, Georgia, and Florida has shown that there are two host strains (corn strain and rice strain) of fall armyworm (Pashley 1986; Lu et al. 1992; Lu et al. 1994; Levy et al. 2002; Meagher & Gallo-Meagher 2003). In Florida, corn plants are invaded by both host strains, while forage and turf grasses are infested predominately by rice strain larvae (Meagher & Gallo-Meagher 2003; Nagoshi et al. 2006a; Nagoshi et al. 2006b). Pashley et al. (1987) compared feeding of 'Tifton 292' by larvae from a rice strain and a corn strain culture and found that the grass was resistant to corn strain individuals but susceptible to rice strain larvae. Further testing classified 'Tifton 292' as intermediately resistant when fed to rice strain larvae (Jamjanya & Quisenberry 1988), but other factors such as artificial diet (Quisenberry & Whitford 1988) and whether the plants were grown in the field or in the greenhouse affected larval response (Jamjanya et al. 1990; Pitman et al. 2002). Research conducted to improve 'Tifton 292' by producing a bermudagrass with both high quality and fall armyworm resistance, led to the creation of 'Tifton 85' (Burton 2001). Although there have been many published reports on agronomic and grazing attributes of 'Tifton 85', there are no reports comparing fall armyworm feeding on this grass with other forage grasses.

Field sampling and larval feeding studies with *Mocis* spp. or fall armyworm have not been conducted on the grasses grown and developed in Florida. We conducted studies to determine the population densities of *Mocis* spp. and fall armyworm supported by different grass lines in the subtropical environment of central Florida. The results of these field surveys were compared to laboratory studies examining the capacity of the different grasses to support larval development of these species. The grass lines were selected based on their popularity with growers or on field observations that certain lines were highly susceptible to feeding by caterpillars.

Materials and Methods

Field Site and Population Density

Field experiments were conducted at the University of Florida, Range Cattle Research and Education Center (RCREC), Ona (27°26'N, 81°55'W; 26 m elevation). This subtropical center contains over 1150 hectares of natural and improved grasses divided into large pastures and small plots for multi-discipline research in beef cattle and forage grass production.

Sampling of *Mocis* spp. and fall armyworm larval populations was done with sweep nets and was conducted in various bermudagrass and stargrass pastures at the RCREC during 2001, 2002, and 2003.

Grass Lines

This study was designed to compare populations of *Mocis* spp. and fall armyworm larvae on various *Cynodon* spp. *Mocis* spp. larvae can be found in large numbers but separation of larvae by species is difficult. Ogunwolu & Habeck (1979) separated *latipes/disseverans* from *marcida/texana* using the shape and length of the anal setae, but no characters were found to separate individual pairs of species. Therefore, *Mocis* larvae were not identified to species.

The grass lines used in this study are important to growers who raise beef cattle in central Florida. They include cultivars and ecotypes developed at the RCREC, cultivars developed in other locations but are popular with beef cattle growers, or lines that are being considered for use in central Florida. Grass lines (cultivars, ecotypes, and ecotypes released as cultivars (Karaca et al. 2002; Taliaferro et al. 2004)) included the bermudagrasses 'Jiggs', a common bermudagrass selection found growing along the Texas Gulf Coast (Redmon 2002), 'World Feeder', a mutant of 'Alicia' bermudagrass released by Agriculture Enterprises, Inc. in Bethany, OK (Gordon 1989), 'Tifton 85', and a locally-derived ecotype known as Bermudagrass 2000, a daylength-insensitive bermudagrass found growing at the RCREC during the cool season of 1999-2000 (PM, unpublished data). The stargrasses were 'Florona', found growing in a 'Pensacola' bahiagrass pasture in Ona in 1973 (Mislevy et al. 1989; Mislevy et al. 1993), 'Okeechobee', a local stargrass ecotype that was originally found growing with 'Callie' bermudagrass in Okeechobee Co., FL (PM, unpublished data), and two locally-derived ecotypes known as Stargrass 2000, a highly digestible coarse grass found growing in *Hemarthria altissima* (Poiret) Stapf & C. E. Hubbard, at Ona in 1999 and Ona Pasture #2 (believed to be a natural hybrid developed from a seed from 'Ona' stargrass hay fed to cattle in the middle of a bahiagrass pasture).

Grasses were planted beginning the week of 23 Jul 2001. The experiment was designed as a randomized complete block with 3 blocks and 4 replications of the 8 grass entries arranged in plots (81 m^2). Tilled ground separated plots (1 m) and blocks (10 m) from each other. Lepidopteran larvae can be located either at the ground surface or spatially within the grass canopy (Dean 1985). Therefore, larvae were sampled by either searching a 0.2787 m^2 area of grass (ground samples) or by using a sweep net (38.1 cm diameter) (sweep net samples, 30 sweeps per plot). Ground samples and sweep samples were taken in the experimental plots on 16 Oct, 30 Oct, and 1 Nov, 2001. Analysis of variance of square root (x + 0.5)-transformed data (PROC MIXED, Contrasts, Littell et al. 1996) was used to examine variation among grass plots.

Larval Feeding

This study was designed to compare larval feeding on the different grass lines grown in the field study (except Bermudagrass 2000). Striped grass looper larvae (*M. latipes*) were colonized from individuals collected, reared, and identified from the RCREC in 2002. Larvae were reared on greenhouse- and field-grown grasses in the laboratory. Neonates were placed in plastic tubs, 35 (l) × 24 (w) × 13 (h) cm, containing bermudagrass ('NuMex Sahara', Pennington Seeds, Madison, GA). The tubs were lined with paper towels (Sparkle™, Georgia-Pacific, Atlanta, GA) and the grass was placed on top of a plastic grate (holes at 1.5 cm). After 1 week a metal screen (holes at 0.7 cm) was placed on top of the grate. New grass ('Florona' stargrass, original material from the RCREC) was placed under the screen while the "old" grass was placed on top of the screen. In this way, larvae feeding on the "old" grass could migrate down to the "new" grass. The "old" grass was removed the next day and the larval rearing procedure repeated. This technique slowed the development of mold in the rearing tubs. Pupae were harvested from the grass and paper toweling, sexed, and 8 to 12 pairs of adults were placed in screen cages that were 24 × 24 × 24 cm. Paper towels were attached to 3 sides of the cage for oviposition and adults were supplied distilled water and a 2% sugar-honey solution for nourishment. Larvae and adults were reared in incubators or large rearing units at ≈23°C, 70% RH, and 14:10 photoperiod.

Fall armyworm larvae were from the same cultures described previously (Meagher et al. 2004). Larvae shown to carry the mitochondrial marker of corn strain (Tifton) were from a culture provided by Dr. James Carpenter, USDA-ARS, Tifton, GA. This culture was maintained on a pinto bean artificial diet according to the procedures of Guy et al. (1985). Larvae shown to carry the mitochondrial marker of rice strain (Ona) were from a culture of individuals collected from the RCREC in Jul 2002 (Nagoshi & Meagher 2003), and were maintained on bermudagrass and stargrass grown in Gainesville.

Grass line plants (except Bermudagrass 2000) were grown in 3.8-L pots in a greenhouse at ambient temperature, and were fertilized weekly with Miracle-Gro® 15-30-15 plant food. No pesticides were applied to the plants. New leaf growth was placed on filter paper discs (Whatman®, 90 mm) moistened with ≈1 mL deionized water in a 9-cm diameter polystyrene petri dish (Thomas Scientific, catalog #3488-B32). One neonate larva was placed on plant foliage, and the petri dishes were placed in an incubator at 23.9 ± 2°C with a 14:10 photoperiod. The filter paper in each petri dish was moistened daily with ≈ 1 mL of deionized water for the first 10 d. Larvae were supplied with fresh plant material until time of pupation. Larval weights were measured at 10 d. Development time (in d) from neonate to pupa was calculated and pupal weight was recorded at pupation.

For both *M. latipes* and fall armyworm, 15 larvae were arranged in 3 replications on different dates, and mortality on each host plant was recorded. Analysis of variance of log10-transformed data (PROC MIXED, Contrasts, Littell et al. 1996) was used to examine variation among grass lines.

Results

Population Density

Larval populations were variable both within and across years. In 2001, populations were low until early Sep, when *Mocis* spp. peaked at 90 and fall armyworm peaked at 30 larvae per 30 sweeps on 11 Sep. Larval populations of both species declined to 19.6 and 2.2, respectively, in early Nov (Fig. 1a). In 2002, the increase in larval populations of both species occurred about one month earlier, with the highest number of *Mocis* spp. larvae collected in mid-Aug and comparatively low numbers found through early Nov (Fig. 1b). Populations of fall armyworm were low with fewer than 5 larvae per 30 sweeps collected in mid-Aug.

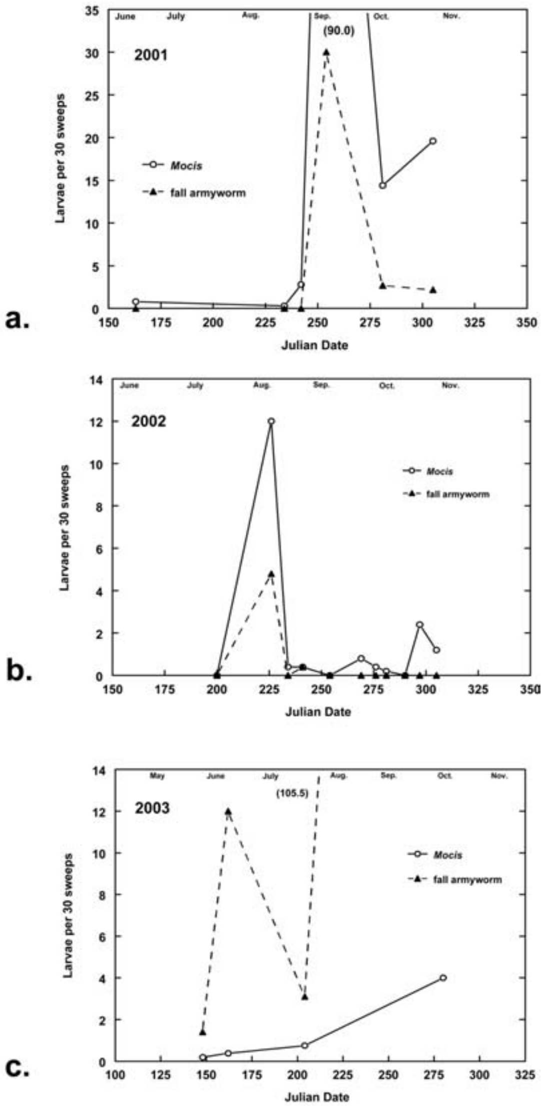

Fig. 1. Populations of *Mocis* spp. and fall armyworm larvae sampled with sweep nets from bermudagrass and stargrass pastures in 2001, 2002, and 2003, Ona, FL.

Substantially different population dynamics was observed in 2003. *Mocis* spp. populations were low throughout the sampling period, not reaching more than 4 larvae per 30 sweeps (Fig. 1c). Fall armyworm larval numbers were high in mid-Jun (12 per 30 sweeps) and very high in early Oct, with over 100 fall armyworm larvae per 30 sweeps collected.

Grass Lines

The effects of different grass germplasm on larval populations were examined by sweep net and ground sampling. Significant differences were found among grasses in number of *Mocis* spp. larvae collected by sweep net and ground samples (Fig. 2). Stargrass plots ('Florona', 'Okeechobee', Ona Pasture #2, and Stargrass 2000) contained more larvae than bermudagrass plots (Bermudagrass 2000, 'Jiggs', 'Tifton 85', and 'World Feeder') (sweep net samples (mean number of larvae per 30 sweeps ± SE), stargrass 25.5 ± 2.3 vs. bermudagrass 13.7 ± 1.7; $F = 14.3$, $df = 1, 14$, $P = 0.0020$; ground samples (mean number of larvae per m^2 ± SE), stargrass 75.6 ± 4.6 vs. bermudagrass 55.6 ± 3.8, $F = 11.3$, $df = 1, 14$, $P = 0.0046$).

Compared to *Mocis* spp., about a 10-fold lower number of fall armyworm larvae was collected and stargrass and bermudagrass plots showed similar numbers of larvae. For sweep net samples, stargrass plots contained 2.1 ± 0.55 larvae per 30 sweeps compared to bermudagrass plots which contained 2.4 ± 0.63 ($F = 0.07$, $df = 1, 14$, $P = 0.8001$). Ground sample stargrass plots had 4.3 ± 0.7 larvae per m^2 vs. bermudagrass plots which had 3.4 ± 0.6 ($F = 0.87$, $df = 1, 14$, $P = 0.3665$). Selected larvae were returned to the laboratory and all were shown to carry the mitochondrial marker for rice strain (Meagher & Gallo-Meagher 2003).

Larval Feeding

There was no difference in striped grass looper larval weights among grass lines ($F = 0.7$, $df = 6, 12$, $P = 0.6326$), however there was a trend for larvae fed stargrasses (31.9 mg ± 4.5) to be heavier than those fed bermudagrasses (21.3 ± 3.7; $F = 3.1$, $df = 1, 12$, $P = 0.1069$). Development time to pupation differed among grass lines, and larvae fed 'Florona' stargrass developed 4 days faster than those fed 'World Feeder' bermudagrass (Table 1). Overall, larvae fed stargrasses developed 2.4 days faster than those fed bermudagrasses. Pupal weights were not different among lines ($F = 1.9$, $df = 6, 12$, $P = 0.1687$), however larvae fed stargrasses (234.8 mg ± 7.6) produced larger pupae than those fed bermudagrasses (206.2 ± 7.0; $F = 6.8$, $df = 1, 12$, $P = 0.0228$). There was no difference in neonate survival among lines ($F = 1.3$, $df = 6, 12$, $P = 0.3373$) or between grass species ($F = 2.1$, $df = 1, 12$, $P = 0.1777$), as survival averaged 0.793 ± 0.03.

Feeding by fall armyworm larvae provided differences between insect cultures (host strains), between grass species, and among grass lines. Rice strain (Ona culture) larvae were heavier and developed faster than corn strain (Tifton culture) larvae (Table 2). Pupal weights and survival were similar between host strains. However, there was a significant insect culture × grass line interaction with larval weight ($F = 4.1$, $df = 6, 26$, $P = 0.0049$), therefore host strains were compared among each grass line, and grass lines were compared within both host strains. The insect culture × grass line interactions for the other variables were not sig-

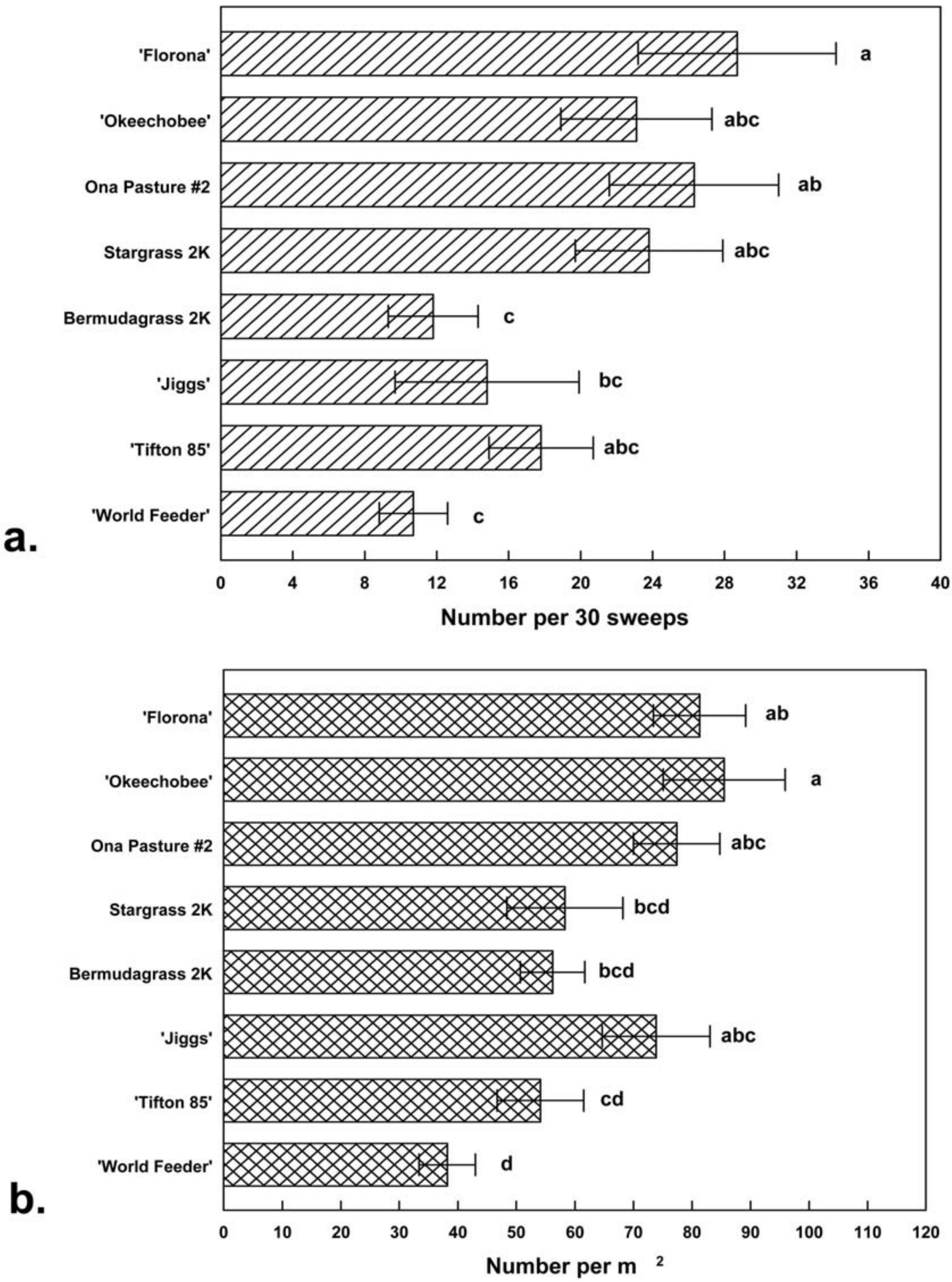

Fig. 2. Number of *Mocis* spp. larvae collected in sweep net (a) and ground samples (b) from different *Cynodon* spp. grasses, Ona, FL, 2001. Means (± SE) with the same letter are not significantly different ($P > 0.05$). The top 4 lines are stargrasses (*C. nlemfuensis* var. *nlemfuensis*); the bottom 4 lines are bermudagrasses (*C. dactylon*).

TABLE 1. DEVELOPMENT TIME TO PUPATION (D) OF STRIPED GRASS LOOPER FED 7 DIFFERENT *CYNODON* SPP. GRASSES. MEANS (± SE) WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT (CONTRASTS, $P > 0.05$). THE TOP 4 LINES ARE STARGRASSES; THE BOTTOM 3 LINES ARE BERMUDAGRASSES.

Grass line	Development time
'Florona'	21.6 ± 0.3 a
'Okeechobee'	22.6 ± 1.2 ab
Ona Pasture #2	23.8 ± 0.7 abc
Stargrass 2000	22.4 ± 0.1 ab
'Jiggs'	25.0 ± 1.6 bc
'Tifton 85'	24.4 ± 1.0 bc
'World Feeder'	25.6 ± 0.5 c
	$F = 2.9$; $df = 6, 12$; $P = 0.0561$
Stargrasses	22.6 ± 0.38 A
Bermudagrasses	25.0 ± 0.57 B
	$F = 13.0$; $df = 1, 12$; $P = 0.0036$

nificant (development time, $F = 2.5$, $df = 6, 26$, $P = 0.0521$; pupal weight, $F = 0.7$, $df = 6, 26$, $P = 0.6276$; survival, $F = 1.4$, $df = 6, 26$, $P = 0.2363$).

Differences in larval feeding parameters were found between stargrasses and bermudagrasses when host strains were analyzed separately. Both rice strain and corn strain larvae showed significantly enhanced growth and development when fed stargrass leaves (Table 3). Larval survival for rice strain larvae was not different between grass species, but there was a trend for corn strain larvae to have higher survival on stargrasses.

Rice strain larvae fed Stargrass 2000 and 'Florona' were heavier and developed more quickly than the other lines (Table 4). Pupal weights averaged 138.9 mg ± 3.8 and did not differ among lines ($F = 1.8$, $df = 6, 12$, $P = 0.1859$). Larval survival also did not differ among lines, averaging 0.607 ± 0.04 ($F = 2.4$, $df = 6, 12$, $P = 0.0896$). Corn strain larvae were heavier, developed faster, and had larger pupal weights when fed Stargrass 2000 leaves (Table 5). Survival was not different among lines ($F = 2.4$, $df = 6, 12$, $P = 0.0896$), averaging 0.505 ± 0.04. However, there was a trend for corn strain larvae placed on 'Tifton 85' (0.333 ± 0.067) and 'World Feeder' (0.361 ± 0.02) to have very low survival.

DISCUSSION

Surveys of bermudagrass and stargrass pastures showed similar population profiles for *Mocis* spp. and fall armyworm with respect to larval population dynamics. The peaks of larval abundance occurred at different times in each of the 3 years and were typically associated with sharp increases and sudden declines in numbers. In each case the timing of the changes in *Mocis* populations coincided with that of fall armyworm larvae, suggesting that these species were possibly responding to the same environmental factors with respect to oviposition and development on their plant hosts. However, the level of infestation between species was more variable. In the first 2 years, approximately 2-3 fold higher *Mocis* larval numbers were observed than fall armyworm. This changed dramatically in 2003 when high fall armyworm larval density coincided with low *Mocis* infestation. Little is known about what factors influence the severity of infestations in these species and why conditions suitable for high fall armyworm density in 2003 were apparently less for *Mocis*.

Several lines of bermudagrasses and stargrasses were tested for their ability to support *M. latipes* and fall armyworm populations. This was the first examination of *M. latipes* feeding of *Cynodon* spp. germplasm developed or isolated in Florida, and both bermudagrasses and stargrasses are important forage grasses for the beef cattle industry in the central and southern parts of the state. Bermudagrasses as a group were generally associated with lower densities of *Mocis* larvae than stargrasses when tested in field settings. This observation compared well with the results of laboratory feeding studies showing that *M. latipes* larvae were smaller and developed slower on bermudagrasses. *M. latipes* larvae took approximately 2.4 d longer to develop to pupation, which prolongs the period of larval exposure to natural enemies and disease.

Fall armyworm showed a similar preference for a subset of stargrasses over bermudagrasses. Larvae reared on Stargrass 2000 or 'Florona' were heavier and developed 2-4 d quicker than those reared on bermudagrasses. However, this difference was not reflected in changes in population densities in the field. It may be that localized variations between plant hosts in their ability to

TABLE 2. FEEDING PARAMETERS OF FALL ARMYWORM RICE AND CORN STRAIN LARVAE WHEN FED DIFFERENT STARGRASS AND BERMUDAGRASS LINES.

Variable	Rice strain	Corn strain	*F*-value	*df*	*P*-value
Larval weight (mg)	28.5 ± 2.9	23.9 ± 3.7	12.20	1, 26	0.0018
Development (days)	20.6 ± 0.4	23.2 ± 0.6	47.20	1, 26	<0.0001
Pupal weight (mg)	138.9 ± 3.8	140.8 ± 3.2	0.23	1, 26	0.6335
Survival (prop.)	0.607 ± 0.04	0.505 ± 0.04	3.60	1, 26	0.0706

TABLE 3. FEEDING PARAMETERS BETWEEN STARGRASS AND BERMUDAGRASS LINES WHEN FED TO FALL ARMYWORM RICE AND CORN STRAIN LARVAE.

Variable	Stargrass	Bermudagrass	*F*-value	*df*	*P*-value
Rice strain					
Larval weight (mg)	33.4 ± 4.5	22.0 ± 1.9	25.70	1, 12	0.0003
Development (d)	19.9 ± 0.5	21.7 ± 0.4	20.80	1, 12	0.0006
Pupal weight (mg)	143.8 ± 4.7	132.5 ± 5.8	4.30	1, 12	0.0594
Survival (prop.)	0.600 ± 0.064	0.615 ± 0.044	0.05	1, 12	0.8194
Corn strain					
Larval weight (mg)	32.9 ± 5.0	11.9 ± 1.9	69.10	1, 12	<0.0001
Development (d)	21.3 ± 0.5	25.9 ± 0.5	64.30	1, 12	<0.0001
Pupal weight (mg)	149.5 ± 2.4	129.2 ± 4.3	17.00	1, 12	0.0014
Survival (prop.)	0.568 ± 0.053	0.42 ± 0.069	4.60	1, 12	0.0541

support fall armyworm are substantially masked by the mobility of this species, requiring larger plot size and/or sample size to detect statistical differences between grass species.

Fall armyworm strain-specific differences were observed for larvae reared on the various grass lines. In most cases, rice strain larvae were heavier, had better survival, and developed faster than corn strain larvae. Previous studies showed that rice strain also produced larger larvae, faster development times, and higher survival even when grown on plant hosts favored by the corn strain (Meagher et al. 2004). This suggests that the observed differences reflected general characteristics of the strains rather than specific responses to the plant hosts tested.

TABLE 4. LARVAL WEIGHT (MG) AND DEVELOPMENT TIME TO PUPATION (D) OF FALL ARMYWORM RICE STRAIN FED SEVEN DIFFERENT *CYNODON* SPP. GRASSES. THE TOP 4 LINES ARE STARGRASSES AND THE BOTTOM 3 LINES ARE BERMUDAGRASSES. MEANS (± SE) WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT ($P > 0.05$).

Grass line	Larval weight	Development time
'Florona'	38.5 ± 4.6 b	18.9 ± 0.5 a
'Okeechobee'	22.7 ± 2.9 cd	21.5 ± 0.5 b
Ona Pasture #2	18.7 ± 4.3 d	21.1 ± 0.6 b
Stargrass 2000	53.4 ± 4.6 a	18.0 ± 0.4 a
'Jiggs'	20.8 ± 1.7 d	22.0 ± 1.0 b
'Tifton 85'	27.7 ± 3.6 c	20.7 ± 0.5 b
'World Feeder'	17.4 ± 0.7 d	22.3 ± 0.2 b
	$F = 22.7$, $df = 6, 12$, $P < 0.0001$	$F = 9.8$, $df = 6, 12$, $P = 0.0005$

TABLE 5. LARVAL WEIGHT (MG), DEVELOPMENT TIME TO PUPATION (D), AND PUPAL WEIGHT (MG) OF FALL ARMYWORM CORN STRAIN FED 7 DIFFERENT *CYNODON* SPP. GRASSES. THE TOP 4 LINES ARE STARGRASSES AND THE BOTTOM 3 LINES ARE BERMUDAGRASSES. MEANS (± SE) WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT ($P > 0.05$).

Grass line	Larval weight	Development time	Pupal Weight
'Florona'	24.7 ± 8.1 b	21.3 ± 0.2 ab	146.5 ± 5.3 a
'Okeechobee'	28.8 ± 8.5 b	22.8 ± 1.2 b	151.7 ± 3.8 a
Ona Pasture #2	29.7 ± 8.5 b	21.3 ± 0.4 ab	148.8 ± 4.4 a
Stargrass 2000	48.2 ± 13.5 a	19.7 ± 0.9 a	151.1 ± 7.3 a
'Jiggs'	13.6 ± 5.5 c	26.1 ± 1.1 c	137.5 ± 2.3 ab
'Tifton 85'	12.0 ± 2.6 c	25.7 ± 0.8 c	124.6 ± 4.9 b
'World Feeder'	10.0 ± 2.1 c	25.8 ± 0.7 c	125.4 ± 11.7 b
	$F = 13.6$, $df = 6, 12$, $P < 0.0001$	$F = 12.5$, $df = 6, 12$, $P = 0.0002$	$F = 3.4$, $df = 6, 12$, $P = 0.0346$

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REFERENCES CITED

BURTON, G. W. 2001. Tifton 85 bermudagrass—early history of its creation, selection, and evaluation. Crop. Sci. 41: 5-6.

BURTON, G. W., R. N. GATES, AND G. M. HILL. 1993. Registration of 'Tifton 85' bermudagrass. Crop. Sci. 33: 644-645.

CAVE, R. D. 1992. Inventory of parasitic organisms of the striped grass looper, *Mocis latipes* (Lepidoptera: Noctuidae), in Honduras. Florida Entomol. 75: 592-598.

CHANG, N. T., B. R. WISEMAN, R. E. LYNCH, AND D. H. HABECK. 1985. Fall armyworm (Lepidoptera: Noctuidae) orientation and preferences for selected grasses. Florida Entomol. 68: 296-303.

DEAN, T. W. 1985. Behavioral Biology of the Striped Grass Looper, *Mocis latipes* (Guenée), in North-Central Florida, Ph.D. Dissertation. University of Florida, Gainesville, FL 123 p.

GIBBS, I. H. 1990. The guinea grass moth- an occasional pest of pasture grasses in Barbados. Proc. Barbados Soc. Tech. Agric. 67-69.

GORDON, L. R. 1989. World Feeder bermuda grass. U.S. Plant Patent 7081. Date issued: 19 Dec. 1989.

GREGORY, JR., B. M., C. S. BARFIELD, AND J. B. CHAPIN. 1988. Morphological differences between adult *Anticarsia gemmatalis* and *Mocis latipes* (Lepidoptera: Noctuidae). Florida Entomol. 71: 352-359.

GUY, R. N., N. C. LEPPLA, J. R. RYE, C. W. GREEN, S. L. BARETTE, AND K. A. HOLLIEN. 1985. *Trichoplusia ni*, pp. 487-494 *In* P. Sing and R. F. Moore [eds.], Handbook of Insect Rearing, vol. 2. Elsevier, Amsterdam.

JAMJANYA, T., AND S. S. QUISENBERRY. 1988. Fall armyworm (Lepidoptera: Noctuidae) consumption and utilization of nine bermudagrasses. J. Econ. Entomol. 81: 697-704.

JAMJANYA, T., S. S. QUISENBERRY, S. S. CROUGHAN, AND R. N. STORY. 1990. Comparison of bermudagrass lines grown in different cultural conditions and the effect on screening for fall armyworm (Lepidoptera: Noctuidae) resistance. J. Econ. Entomol. 83: 585-590.

KARACA, M., S. SAHA, A. ZIPF, J. N. JENKINS, AND D. J. LANG. 2002. Genetic diversity among forage bermudagrasses (*Cynodon* spp.): evidence from chloroplast and nuclear DNA fingerprinting. Crop Sci. 42: 2118-2127.

KOEHLER, P. G., R. G. GOUGER, AND D. E. SHORT. 1977. Control of striped grass loopers and armyworms in pasture: 1976. Florida Entomol. 60: 103-104.

LEUCK, D. B., C. M. TALIAFERRO, G. W. BURTON, R. L. BURTON, AND M. C. BOWMAN. 1968. Resistance in bermudagrass to the fall armyworm. J. Econ. Entomol. 61: 1321-1322.

LEVY, H. C., A. GARCIA-MARUNIAK, AND J. E. MARUNIAK. 2002. Strain identification of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) insects and cell line: PCR-RFLP of cytochrome oxidase subunit I gene. Florida Entomol. 85: 186-190.

LITTELL, R. C., G. A. MILLIKEN, W. W. STROUP, AND R. D. WOLFINGER. 1996. SAS system for mixed models. SAS Institute, Inc., Cary, NC.

LU, Y., M. J. ADANG, D. J. ISENHOUR, AND G. D. KOCHERT. 1992. Restriction fragment length polymorphism analysis of genetic variation in North American populations of the fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Mol. Ecol. 1: 199-208.

LU, Y. J., G. D. KOCHERT, D. J. ISENHOUR, AND M. J. ADANG. 1994. Molecular characterization of a strain-specific repeated DNA sequence in the fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Insect Mol. Biol. 3: 123-130.

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.

LYNCH, R. E., W. G. MONSON, B. R. WISEMAN, G. W. BURTON, AND T. P. GAINES. 1986. Relationship of forage quality to developmental parameters of the fall armyworm (Lepidoptera: Noctuidae). Environ. Entomol. 15: 889-893.

MEAGHER, R. L., AND M. GALLO-MEAGHER. 2003. Identifying host strains of fall armyworm (Lepidoptera: Noctuidae) in Florida using mitochondrial markers. Florida Entomol. 86: 450-455.

MEAGHER, R. L., AND P. MISLEVY. 2005. Trapping for *Mocis* spp. adults using different attractants. Florida Entomol. 88: 424-430.

MEAGHER, R. L., R. N. NAGOSHI, C. STUHL, AND E. R. MITCHELL. 2004. Larval development of fall armyworm (Lepidoptera: Noctuidae) on different cover crop plants. Florida Entomol. 87: 454-46.

MISLEVY, P. 2002. Stargrass. Florida Coop. Ext. Serv. SS-AGR-62. 4 p.

MISLEVY, P., AND F. G. MARTIN. 1997. Comparison of Tifton 85 and other *Cynodon* grasses for production and nutritive value under grazing. Soil Crop Sci. Soc. Florida Proc. 57: 77-82.

MISLEVY, P., G. W. BURTON, AND P. BUSEY. 1991. Bahiagrass response to grazing frequency. Soil Crop Sci. Soc. Florida Proc. 50: 58-64.

MISLEVY, P., F. G. MARTIN, G. W. BURTON, AND L. F. SANTOS. 1996. Influence of grazing frequency on production and quality of *Paspalum*, *Brachiaria* and *Setaria* grasses. Soil Crop Sci. Soc. Florida Proc. 55: 97-103.

MISLEVY, P., W. F. BROWN, L. S. DUNAVIN, D. W. HALL, R. S. KALMBACHER, A. J. OVERMAN, O. C. RUELKE, R. M. SONODA, R. L. STANLEY, JR., AND M. J. WILLIAMS. 1989. 'Florona' stargrass. Florida Agric. Exp. Stn. Circ. S-362. 13 p.

MISLEVY, P., W. F. BROWN, L. S. DUNAVIN, D. W. HALL, R. S. KALMBACHER, A. J. OVERMAN, O. C. RUELKE, R. M. SONODA, R. L. STANLEY, JR., AND M. J. WILLIAMS. 1993. Registration of 'Florona' stargrass. Crop Sci. 33: 359-360.

NAGOSHI, R. N., AND R. L. MEAGHER. 2003. *FR* tandem-repeat sequence in fall armyworm (Lepidoptera:

Noctuidae) host strains. Ann. Entomol. Soc. Am. 96: 329-335.
NAGOSHI, R. N., R. L. MEAGHER, G. NUESSLY, AND D. HALL. 2006a. Effects of fall armyworm (Lepidoptera: Noctuidae) interstrain mating in wild populations. Environ. Entomol. 35: 561-568.
NAGOSHI, R. N., R. L. MEAGHER, J. J. ADAMCZYK, JR., S. K. BRAMAN, R. L. BRANDENBURG, AND G. NUESSLY. 2006b. New restriction fragment length polymorphisms in the cytochrome oxidase I gene facilitate host strain identification of fall armyworm (Lepidoptera: Noctuidae) populations in the southeastern United States. J. Econ. Entomol. 99: 671-677.
OGUNWOLU, E. O., AND D. H. HABECK. 1975. Comparative life-histories of three *Mocis* spp. in Florida (Lepidoptera: Noctuidae). Florida Entomol. 58: 97-103.
OGUNWOLU, E. O., AND D. H. HABECK. 1979. Descriptions and keys to larvae and pupae of the grass loopers, *Mocis* spp., in Florida (Lepidoptera: Noctuidae). Florida Entomol. 62: 402-407.
PASHLEY, D. P. 1986. Host-associated genetic differentiation in fall armyworm (Lepidoptera: Noctuidae): a sibling species complex? Ann. Entomol. Soc. Am. 79: 898-904
PASHLEY, D. P., S. S. QUISENBERRY, AND T. JAMJANYA. 1987. Impact of fall armyworm (Lepidoptera: Noctuidae) host strains on the evaluation of bermuda grass resistance. J. Econ. Entomol. 80: 1127-1130.
PITMAN, W. D., S. S. CROUGHAN, AND M. J. STOUT. 2002. Field performance of bermudagrass germplasm expressing somaclonal variation selection for divergent responses to fall armyworm. Euphytica 125: 103-111.
PORTILLO, H. E., H. N. PITRE, D. H. MECKENSTOCK, AND K. L. ANDREWS. 1991. Langosta: a lepidopterous pest complex on sorghum and maize in Honduras. Florida Entomol. 74: 287-296.
QUISENBERRY, S. S., AND F. WHITFORD. 1988. Evaluation of bermudagrass resistance to fall armyworm (Lepidoptera: Noctuidae): influence of host strain and dietary conditioning. J. Econ. Entomol. 81: 1463-1468.
REDMON, L. A. 2002. Forages for Texas. Texas Coop. Ext. SCS-2002-14. 16 p.
TALIAFERRO, C. M., F. M. ROUQUETTE, JR., AND P. MISLEVY. 2004. Bermudagrasses and Stargrasses, pp. 417-475 *In* L. E. Moser, B. L. Burson and L. E. Sollenberger [eds.], Warm-season (C_4) Grasses. Agronomy Mon. #45, ASA, CSSA, SSSA, Madison, WI.
WATSON, J. R. 1933. An outbreak of *Mocis repanda* Fabr. Florida Entomol. 17:15.