Soybean Maturity Group and Incidence of Velvetbean Caterpillars (Lepidoptera: Noctuidae) and Mexican Bean Beetles (Coleoptera: Coccinellidae)

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ABSTRACT Five soybean varieties from maturity groups IV–VIII were routinely monitored in the 1993 and 1994 growing seasons to examine the effect of plant maturity on the seasonal abundance of velvetbean caterpillars, *Anticarsia gemmatalis* Hübner, and Mexican bean beetles, *Epilachna varivestis* Mulsant. Differences were detected in the population density of pest populations, percentage of defoliation, and yield. The early maturing varieties (groups IV and V) had lower mean infestations, although the peak *A. gemmatalis* populations occurred in all varieties at the same time in Georgia. During the population peak in mid-September, the group IV–V varieties were already maturing and no longer attractive to the damaging population densities of 30–60 *A. gemmatalis* per 25 sweeps that were present on the group VI–VIII varieties. Similar trends were noted for *E. varivestis* populations. Population peaks occurred in all varieties in mid-September, with highest densities in the group VIII variety and much lower populations in all the earlier-maturing varieties. Plots treated with diflubenzuron at 0.28 kg (AI)/ha in mid-August had lower insect populations and percentage defoliation and higher yields than corresponding untreated plots for all varieties except the group IV variety, in which no differences were detected because of low insect populations. Significant linear regressions were obtained between peak *A. gemmatalis* population densities and percentage defoliation for all 5 maturity group soybeans. Significant linear regressions also were obtained between population peaks and yield reductions for the group V-VIII varieties. The economic injury levels (EIL) for *A. gemmatalis* were lower for the group IV and V entries (25–30 per 25 sweeps) than for the group VI-VIII entries (35-40 per 25 sweeps). Thus, it appears that a standard EIL for *A. gemmatalis* cannot be established across all maturity group soybeans in the southern region. The soybean maturity group affected the density of both the *A. gemmatalis* and *E. varivestis* population peaks, but the timing of these peaks was similar across all varieties. The group IV and V varieties can be planted to escape high populations of these pests and resultant plant injury, and these varieties had yields comparable to the later maturing entries.

KEY WORDS *Anticarsia gemmatalis, Epilachna varivestis*, soybean, cultural control

INTEREST IN PLANTING soybean varieties over a wide range of dates to maturity has increased in the southern United States (Woodruff 1995a). This practice spreads out the risk of having all the soybean acreage at the same developmental stage during hot/dry periods of the summer and it also extends harvest maturity date into late fall, so that the soybean harvest will not entirely coincide with cotton and peanut harvesting. The maturity grouping for each variety is determined by the amount of daylength needed to stimulate flowering and pod set; the earlier maturing varieties require longer daylengths. Soybeans are placed into maturity groups ranging from 00 (earliest maturing) to X (latest maturing; Teare and Hodges 1995). In Georgia, and throughout the southern region, soybean varieties are now being planted from a wide range of maturity groups, from maturity group IV to group VIII (Woodruff 1995b). How this production practice will affect the seasonal incidence of arthropod pests and the damage they cause is unclear.

The velvetbean caterpillar, *Anticarsia gemmatalis* Hübner, causes significant defoliation and yield loss of soybean, *Glycine max* (L.) Merrill, throughout the southern United States (Funderburk 1994). This pest is an annual economic threat in Georgia, and costs Georgia producers >$25 million in chemical control costs and crop losses in some years (Suber and Todd 1980). *A. gemmatalis* population outbreaks and resultant soybean injury typically occur late in the growing season (August and September) in the Gulf Coast region of the United States (Funderburk 1994). *A. gemmatalis*

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larvae are voracious feeders and high populations can rapidly defoliate soybeans, leaving nothing but the mainstems (Beach and Todd 1988).

The Mexican bean beetle, *Epilachna varivestis* Mulsant, also can be a serious defoliator of soybean. Both adults and larvae cause plant injury by scraping, crushing and ingesting leaf fluids and tissue, leaving a lacy appearance on the damaged leaves (Nolting and Edwards 1988). *E. varivestis* outbreaks vary considerably from season to season but most economic injury occurs during moist growing seasons in the mid-Atlantic region of the United States, although isolated damage to soybean can occur in the southern region (Edwards et al. 1994). Populations may occasionally cause economic damage early in the season, but the greatest potential for economic loss occurs from the time of flowering through pod fill (Edwards et al. 1994). Three soybean plant introductions possess resistance to *E. varivestis* (Van Duyn et al. 1971, 1972) and 2 insect resistant soybean varieties with germplasm from these introductions have subsequently been released, 'Crockett' (Bowers 1990) and 'Lamar' (Hartwig et al. 1990). However, grower acceptance of these varieties has been limited (Rowan et al. 1993).

Little information is available on how the wide range of maturity groups of soybean will affect the seasonal abundance and resultant plant injury caused by *A. gemmatalis* and *E. varivestis*. It has been reported that soybean maturity can affect the expression of resistance in plant introductions to certain lepidopterous insects in small plot and greenhouse trials (Rowan et al. 1993). A greater understanding of this variety-pest relationship and the effects, if any, of a wide range in phenological plant responses (date of bloom and date of pods filling with seeds) to immigrating *A. gemmatalis* and *E. varivestis* in large field plots is needed. This would allow better predictions of when and where economically damaging populations could occur and would improve the decision guidelines for management of these pests. Thus, this study was initiated to determine the effect of maturity group IV–VIII soybeans on the seasonal abundance of *A. gemmatalis* and *E. varivestis*, to determine if peak populations are associated with certain phenological plant responses, and to compare the defoliation and yield for these varieties when the pest populations were controlled with insecticides or left untreated.

Materials and Methods

'Northrup King S4884' (group IV), 'Essex' (group V), 'Davis' (group VI), 'Northrup King S6847' (group VII), and 'Cook' (group VIII) soybeans were planted in field plots at the Coastal Plain Experiment Station in Tifton, GA, on 10 June 1993 and 14 June 1994. Plots were 12 rows wide (0.9-m row spacing) by 22 m long and planted in a randomized block design with 4 replications, with 1.8-m alleys between replications. The fields were conventionally moldboard plowed and a preplant tank mix of pendimethalin (2.4 liters/ha, American Cyanamid, Wayne, NJ) and vernolate (2.7 liters/ha, Drexel, Memphis, TN) was incorporated with a tillivator into the soil for grass and broadleaf weed control. Each plot was split and 6 rows were treated with diflubenzuron 25 W (Uniroyal, Middlebury, CT) at 0.28 kg/ha on 21 August 1993 and 18 August 1994. The diflubenzuron was applied with a CO_2-powered backpack sprayer with 4 TX-12 nozzles on a 1.8-m boom (2 nozzles per row) at 276 KPa (40 psi) that delivered 161.5 liters/ha.

All plots were sampled every 6–10 d from mid-June to mid-October using a standard 38-cm-diameter sweep net, taking one 25-sweep sample down a single row in each plot (Kogan and Pitre 1980). The numbers of *A. gemmatalis* larvae and *E. varivestis* adults and larvae were recorded on each sampling date and the means were plotted on a seasonal distribution curve. The dates of flowering and when pods began to fill with seeds was recorded for each entry. All plots were rated for percentage of defoliation at late R6 plant development (full seeds in the pods, Fehr and Caviness 1977). Ten random plants from each plot were returned to the laboratory, the trifoliolates removed and scaned through an area meter (Li-Cor model Li-3000, Lincoln, NE). All feeding holes were then covered with masking tape and the trifoliolates rescaned through the area meter to determine the amount of foliage removed. In mid-August, after all entries had begun setting pods and had terminated foliage growth, plant heights were determined by randomly measuring 10 plants (from the 1st cotyledon to last raceme) on rows 2 and 3 of each plot ($n = 80$ plants for each variety). Total leaf area for each variety also was determined at this time by running all leaves from the plant height samples through an area meter. All plots were harvested with a small plot combine for yield evaluations: the NKS-4884 and Essex in late September, the Davis in mid-October, and the NKS-6847 and Cook in early November. Data were analyzed with an analysis of variance (ANOVA)($P = 0.05$), and significant differences among variety means were separated using the least significant difference (LSD). Data from the treated and untreated plots for each variety were compared within varieties using a paired t-test (SAS Institute 1985). A general linear model (PROC GLM, SAS Institute 1985) was used to analyze the linear relationship between the peak *A. gemmatalis* population and the percentage defoliation and yield reductions.

Results and Discussion

Plant heights were significantly different among the 5 varieties both years, but the pattern among varieties varied between years (Table 1). Essex was significantly shorter than NKS-6847 in 1993 and shorter than Davis and Cook in 1994. Total leaf

Table 1. Plant height and total leaf area per plant of soybean varieties from five different maturity groups, Coastal Plain Experiment Station, Tifton, GA, 1993–1994

Soybean variety	Maturity group	16 Aug. 1993		15 Aug. 1994	
		Plant ht, cm	Leaf area (cm^2) per plant	Plant ht, cm	Leaf area (cm^2) per plant
NKS-4884	IV	55.6ab	1,603.4c	70.5bc	1,850.6b
Essex	V	41.8b	1,556.0c	68.6c	1,985.4b
Davis	VI	52.2ab	2,010.6a	75.7ab	2,351.3a
NKS-6847	VII	58.6a	1,830.4ab	71.1bc	2,183.5a
Cook	VIII	53.0ab	1,650.2bc	81.3a	2,312.5a
LSD (P = 0.05)		14.5	210.3	6.2	193.3

Column means followed by the same letter are not significantly different, LSD, $P \geq 0.05$.

area per plant also was significantly different among varieties each year. Davis and NKS-6847 had more foliage than NKS-4884 and Essex in 1993, whereas the Davis, NKS-6847, and Cook varieties had greater leaf area than the NKS-4884 and Essex varieties in 1994. Rainfall patterns undoubtedly influenced the plant growth responses. The 1993 season could be characterized as hot and dry in May and June, wet in July, then dry again in August. Monthly rainfall totals at the test site were 2.7, 5.6, 24.3, 4.7, and 9.9 cm from May to September, respectively. The 1994 season was both cooler and wetter than 1993. Monthly total rainfall amounts in 1994 were 3.4, 21.8, 19.5, 13.1, and 9.9 cm from May to September. A total of 44 d had measurable precipitation in 1994 compared with 31 d in 1993.

Anticarsia gemmatalis population densities in the untreated plots were very low in all soybean varieties in 1993 until early August, then they steadily rose until 24 August, followed by a decline on 31 August (Fig. 1A). A rapid population increase occurred in mid-September, with peak populations in the group VI–VIII varieties at 29–38 *A. gemmatalis* per 25 sweeps, then populations quickly declined. Population peaks occurred in all 4 of the remaining varieties on this date (group IV was already maturing in September), irrespective of plant phenological stage. Population densities in the group IV and V varieties were never high in 1993, peaking in the group IV variety on 24 August at 8.4 *A. gemmatalis* per 25 sweeps and in the group V variety on 14 September at 20.5 *A. gemmatalis* per 25 sweeps (Fig. 1A). The *A. gemmatalis* population densities in the untreated plots peaked earlier in the season in 1994 (31 August) and at population levels about twice as high as in 1993 (Fig. 1B). The population peaks occurred on all varieties on the same date (31 August). The group IV variety was beginning to yellow (R7 growth stage) on this date while the group VIII variety had just begun to fill pods with seeds (R5 growth stage). The group VI-VIII varieties again had much higher populations than the group IV and V varieties.

Epilachna varivestis population densities were low throughout the entire season in the untreated plots in 1993 (Fig. 2A). The highest populations were on the group VII variety in mid-August, but estimates were only 1.5 *E. varivestis* adults and larvae per 25 sweeps. *E. varivestis* populations were much higher in 1994 (Fig. 2B), although populations were low until mid-to-late August. On 8 and 16 September, population densities quickly rose to a peak of 20 beetles per 25 sweeps on the group VIII Cook. Then, the population rapidly declined, and little defoliation occurred. Populations on the other varieties remained low, peaking during this same period at from 3 to 6 beetles per 25 sweeps. Thus, as with *A. gemmatalis,* the timing of the *E. varivestis* population peaks was not influenced by maturity grouping; however, maturity grouping did influence the density of the population peak.

The diflubenzuron treated plots experienced significantly less defoliation than the untreated plots for all varieties, except the group IV NKS-4884, in both 1993 and 1994 (Table 2). This may have been the result of 2 factors: (1) population densities were relatively low in the NKS-4884 plots both years, and (2) this variety had pods containing nearly full-sized seeds and was nearing maturity when the insecticide treatment was applied. Davis had significantly more defoliation in its untreated plots than the defoliation in the untreated NKS-4884, Essex, and Cook in 1993. The defoliation in the NKS-6847 and Essex also was significantly higher than the defoliation in Cook and NKS-4884, whereas Cook had more defoliation than NKS-4884 in 1993. Similar trends in defoliation were observed in 1994, with Davis having the highest and NKS-4884 the lowest. Only Davis had significantly higher yields in the treated plots versus the untreated plots both years. The yields in all other treated plots were numerically higher than in the untreated plots of their corresponding variety, except the 1993 Essex variety, although none of these increases were statistically significant.

Significant linear regressions were obtained between peak *A. gemmatalis* populations and percentage of defoliation for each variety and for the overall regression analysis (Table 3). If using the linear equation to obtain 30% defoliation for each variety, the population peaks for the IV and V va-

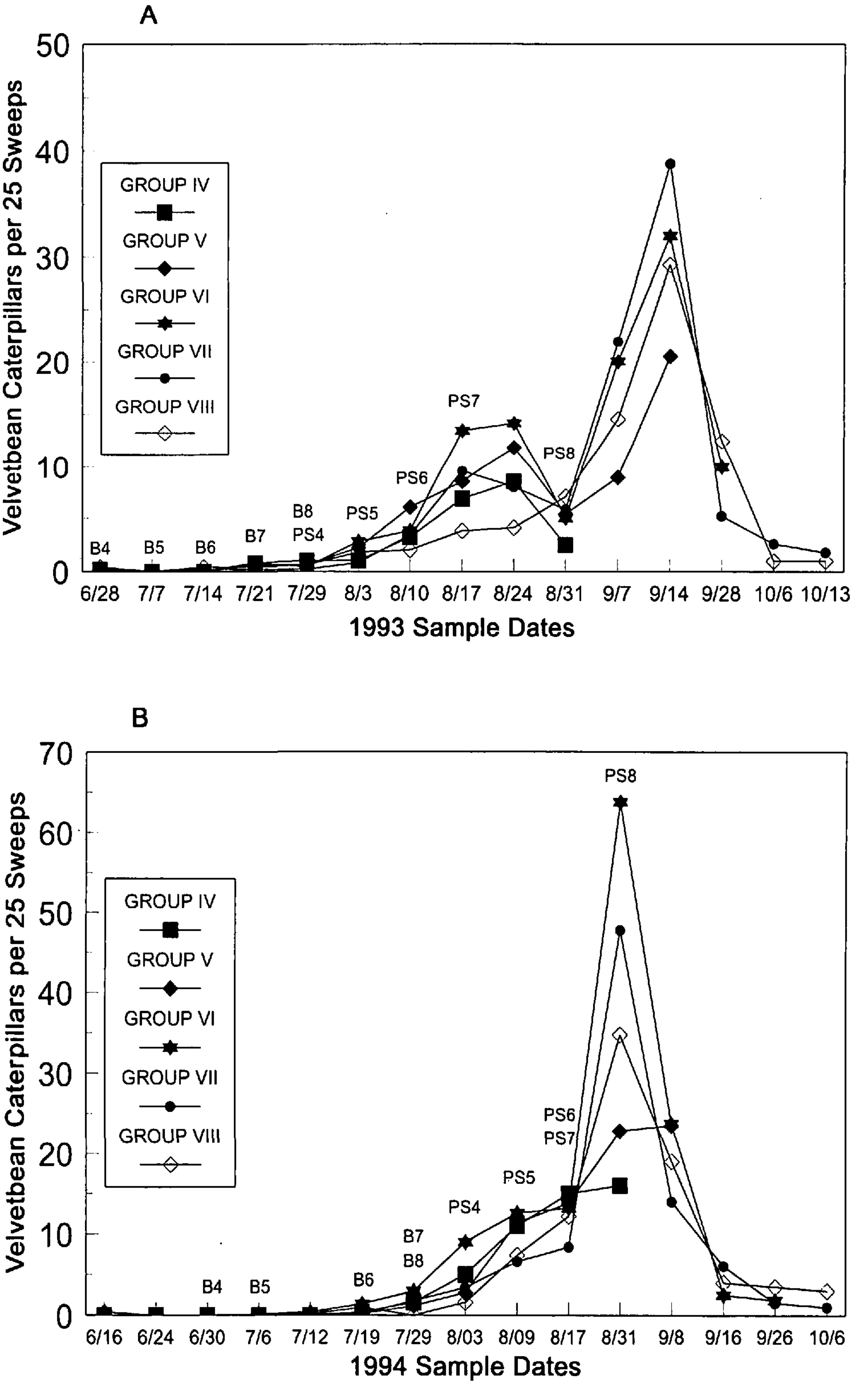

Fig. 1. Seasonal abundance of velvetbean caterpillars on 5 different maturity group soybeans in 1993(a) and 1994(b) in Tifton, GA. The B and number (for each maturity group IV–VIII) identifies the date that each maturity group soybean was in full bloom, and the PS and number identifies the date that each maturity group soybean had pods beginning to fill with seeds.

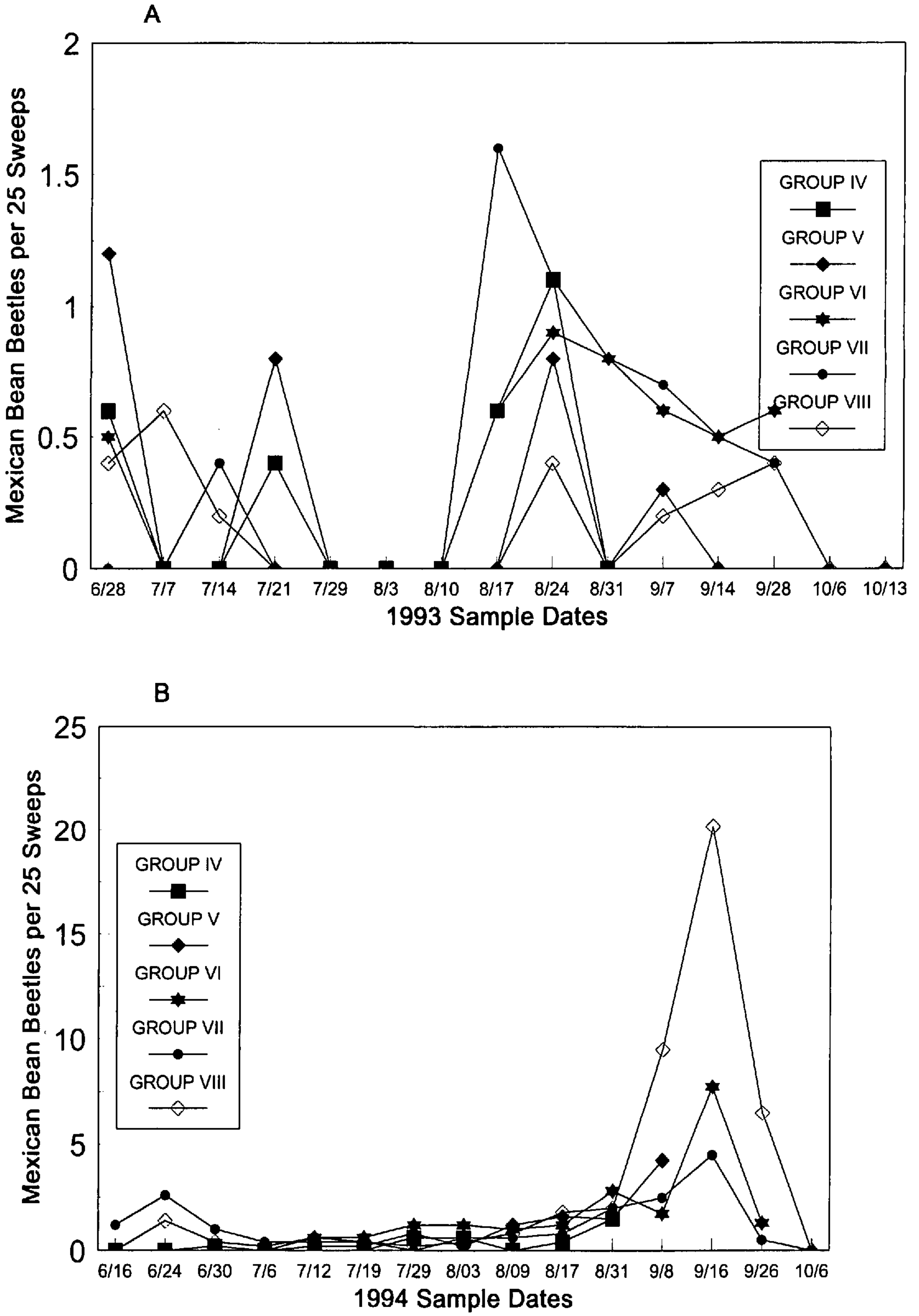

Fig. 2. Seasonal abundance of Mexican bean beetles on 5 different maturity group soybeans in 1993(a) and 1994(b) in Tifton, GA.

Table 2. Velvetbean caterpillar population (pop.) peaks (larvae per 25 sweeps), percentage defoliation, and yields of 5 soybean varieties in maturity groups IV–VIII either treated with diflubenzuron (Trt) or left untreated (Untrt), Coastal Plain Experiment Station, Tifton, GA, 1993–1994

Soybean variety		Maturity group	1993			1994		
			Pop. peak	% defoliation	Yield, kg/ha	Pop. peak	% defoliation	Yield, kg/ha
NKS-4884	Trt	IV	6.8	4.8	2,021	15.0	10.5	2,459
	Untrt		8.4	10.3	1,987	16.0	16.3	2,391
Essex	Trt	V	8.4	6.0	2,364	13.8	7.5	2,358
	Untrt		20.5[a]	28.5[a]	2,607	22.8	22.5[a]	2,243
Davis	Trt	VI	13.4	11.0	2,405[a]	13.2	10.8	2,304[a]
	Untrt		32.0[a]	35.0[a]	2,068	66.0[a]	43.8[a]	1,637
NKS-6847	Trt	VII	9.4	5.0	2,358	8.4	5.8	2,647
	Untrt		38.8[a]	30.3[a]	2,075	48.5[a]	36.3[a]	2,452
Cook	Trt	VIII	5.2	10.3	2,499	12.2	8.8	2,324
	Untrt		29.3[a]	20.5[a]	2,385	37.8[a]	31.3[a]	2,210

[a] The mean comparison between the treated and untreated plots for a particular variety is significantly different, paired *t* test (P = 0.05). Plots were treated on 21 August 1993 and 18 August 1994.

rieties are 29.2 and 24.9 *A. gemmatalis* per 25 sweeps, respectively. The population peaks to achieve 30% defoliation for the VI–VIII varieties are 37.8, 39.3, and 35.9, respectively. The 30% level of leaf loss is currently what most Cooperative Extension Service IPM programs consider as economic injury levels or EILs (Hudson 1993). Higley (1992) discusses the need for established EILs for pest species of soybean. It is apparent that a standard EIL for *A. gemmatalis* cannot be established across all maturity group soybeans. The EIL of *A. gemmatalis* needs to be lower for the earlier maturing varieties. This is because of the fact that these varieties have less total leaf area (Table 1). Therefore, a higher percentage of foliage is removed by *A. gemmatalis* in these varieties than when comparable populations are feeding on the later-maturing varieties that have more total plant foliage.

Significant linear regressions also were obtained between peak *A. gemmatalis* populations and yield reductions for the group V–VIII varieties (Table 4). No linear relationship was noted for NKS 4884, because this variety had lower *A. gemmatalis* populations both years and no yield responses to an application of diflubenzuron. Using the linear model, the group VI–VIII varieties would have a 135 kg/ha yield loss if peak populations were from 37 to 43 *A. gemmatalis* per 25 sweeps. For the group V variety, Essex, a 135 kg/ha yield reduction would occur with a peak population of 22 *A. gemmatalis* per 25 sweeps. This further justifies the need for a lower EIL for *A. gemmatalis* in early-maturing soybean varieties. The population densities causing these yield losses in Essex soybean are lower than the 50 *A. gemmatalis* per 25 sweeps EIL currently being used in the Georgia integrated pest management program (Hudson 1993). Thus, these EILs need to be different for *A. germmatalis* infestations in different soybean maturity groups.

In conclusion, it appears that soybean maturity group affects the density, but not the phenology, of velvetbean caterpillar and Mexican bean beetle populations in Georgia. The early-maturing varieties (maturity groups IV and V) had lower overall infestation levels. The population peaks for these pests occur in late August to mid-September in all varieties and the maturity group IV and V varieties are already maturing at this time. However, the EIL for *A. gemmatalis* is lower in the earlier-maturing varieties and control measures will be nec-

Table 3. Linear relationship ($y = bx + a$) between the peak velvetbean caterpillar population, larvae per 25 sweeps, on soybean and percentage of defoliation, Tift County, GA, 1993–1994

Soybean variety	Maturity group	P level	b (slope)	a (y-intercept)	r^2
NKS-4884	IV	0.01	0.86	3.41	0.755
Essex	V	0.01	0.71	3.62	0.808
Davis	VI	0.01	1.37	−3.34	0.864
NKS-5647	VII	0.01	1.29	0.59	0.945
Cook	VIII	0.01	1.36	−4.93	0.928
Total	All	0.01	1.32	−2.34	0.899

P, probability level of the ANOVA; degrees of freedom for the regression analysis were 14 for each variety and 78 for the total. Population peaks occurred on 14 September 1993 and 31 August 1994. Percentage of defoliation determined at R6 growth stage for each variety.

Table 4. Linear relationship ($y = bx + a$) between the peak velvetbean caterpillar population, larvae per 25 sweeps, and soybean yield reduction (kg/ha) in Tift County, GA, 1993–1994

Soybean variety	Maturity group	P level	b (slope)	a (y-intercept)	r^2
NKS-4884	IV	>0.05	—	—	—
Essex	V	0.01	0.013	19.8	0.451
Davis	VI	0.05	0.039	35.8	0.288
NKS-6847	VII	0.03	0.069	33.8	0.335
Cook	VIII	0.05	0.038	31.8	0.302
Total	All	0.01	0.048	31.8	0.332

P, probability level of the ANOVA; degrees of freedom for the regression analysis were 6 for each variety and 38 for the total. Population peaks occurred on 14 September 1993 and 31 August 1994.

essary if the EIL is attained. The maturity group IV and V varieties examined in this study yielded about as good as the later maturing varieties, and thus it appears that planting more of these earlier-maturing varieties would be economically feasible for the southern region. However, selection of specific maturity group IV and V varieties should be based on data from controlled agronomic trials from each southern state. The maturity group VI–VIII varieties have much higher population peaks, and resultant higher rates of defoliation and yield loss, than the group IV and V varieties. This has significant implications for decision-making for *A. gemmatalis* management. These late-maturing varieties need to be extensively monitored for defoliating pests during August and September, a relatively narrow window of time, and control measures applied when *A. gemmatalis* populations reach 35–40 per 25 sweeps, to prevent economic losses.

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