Influence of Irrigation and Maturity Group on the Seasonal Abundance of Soybean Arthropods[1]

R. M. McPherson,[2] R. C. Layton,[3] W. J. McLaurin[4] and W. A. Mills, III[5]

The University of Georgia, Department of Entomology, College of Environmental and Agricultural Sciences, Coastal Plain Experiment Station, Tifton, GA 31793-0748 USA

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Abstract The effects of irrigation and soybean maturity group (Group V 'Forrest' variety vs Group VII 'Braxton' variety) on the seasonal abundance of arthropod pest and beneficial population densities were examined in large-plot field tests at the Attapulgus Research Center in Attapulgus, GA, in 1987 through 1990. In general, soybean plant growth was more abundant, yields were higher, and canopy closure indices were lower in irrigated than in non-irrigated plots for both varieties. Irrigation and the resultant increased soybean vegetation supported a greater overall seasonal abundance of all five of the insect pests monitored: stink bugs, primarily *Nezara viridula* (L.), velvetbean caterpillars, *Anticarsia gemmatalis* Hübner, soybean loopers, *Pseudoplusia includens* (Walker), threecornered alfalfa hoppers, *Spissistilus festinus* (Say), and green cloverworms, *Plathypena scabra* (F.). No overall varietal effects were noted for *N. viridula*; however, each year, population densities were higher in the early-maturing 'Forrest' up to julian day 250 then densities were higher in the later-maturing 'Braxton' for the remainder of the grown season. Mean estimates of the seasonal abundance of *A. gemmatalis* and *P. scabra* populations were similar between the two varieties; however, *P. includens* and *S. festinus* were more abundant on Forrest than on Braxton. Total arthropod predators, including *Nabis* spp., *Geocoris* spp., and spiders, also were more abundant on irrigated soybeans, while overall varietal means were similar. Yearly analyses revealed significant irrigation and variety effects for most of the species sampled.

Key Words Soybean maturity group, irrigation, *Nezara viridula*, *Anticarsia gemmatalis*, *Plathypena scabra*, *Pseudoplusia includens*, *Spissistilus festinus*

Numerous arthropod pests are annual economic threats to soybean, *Glycine max* (L.) Merrill, produced in the United States, especially in the South (Kogan and Turnipseed 1987). Economic losses due to arthropod-induced soybean yield and quality reductions plus costs of insecticide controls exceed $25 million in Georgia in some years (Douce and McPherson 1991). The stink bug complex, primarily *Nezara viridula* (L.), the soybean looper, *Pseudoplusia includens* (Walker), the velvetbean caterpillar, *Anticarsia gemmatalis* Hübner, the threecornered alfalfa hopper, *Spissistilus festinus* (Say), and the green cloverworm, *Plathypena scabra* (F.), are common soybean

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[2]To whom correspondence should be addressed.

[3]Statistical and Computer Services, USDA/ARS, Coastal Plain Experiment Station, P.O. Box 748, Tifton, GA 31793

[4]Department of Horticulture, University of Georgia Hoke Smith Bldg., Athens, GA 30602.

[5]Attapulgus Research Center, University of Georgia P.O. Box 189, Attapulgus, GA 31715.

insect pests (Higley and Boethel 1994) and occur in soybeans produced in Georgia every year. Managing these pests can be difficult because these arthropod communities experience constant dynamic change as a consequence of changing crop production practices and the adaptability of the insect species (Kogan and Turnipseed 1987).

Planting date (McPherson and Bondari 1991), row width (Mayse 1978, McPherson et al. 1988), soybean maturity grouping (McPherson et al. 1996, McPherson 1996), and tillage systems (Deighan et al. 1985, Ferguson et al. 1984) are production practices that impact soybean arthropod communities. Irrigation is another cultural practice being utilized in soybean production throughout the U.S. to reduce yield variation due to rainfall deficits (Boquet 1994). It also has been reported to impact the diversity and density of certain foliage-inhabiting arthropods in late-maturing soybeans (Felland and Pitre 1991a), especially the survivorship and development of some Lepidoptera (Felland and Pitre 1991b). However, these studies did not report on the seasonal abundance of stink bugs and velvetbean caterpillars, two of the most serious arthropod pests on soybeans in Georgia. Also, these studies were limited to late-maturing soybeans, and the trend in Georgia soybean culture is to plant more early-maturing (Group IV and V) soybeans (Woodruff 1995). Thus, this study was conducted to examine the effects of irrigation and soybean maturity on the seasonal abundance of soybean foliage-inhabiting arthropods, soybean phenology, and yield.

Materials and Methods

'Forrest' (Maturity Group V) and 'Braxton' (Maturity Group VII) soybeans were planted in field plots at the Attapulgus Research Center, Decatur Co., GA, between 18 May and 26 May in 1987 through 1990 (Table 1). Plots measuring 25.6 m wide (28 rows) × 45.7 m long, were randomly assigned by variety into adjacent field terraces that were either irrigated (center pivot) or non-irrigated. Each terrace contained five plots of a specific variety. Treatments were arranged in a 4-way factorial design with year, irrigation, variety, and sampling date as the variables factored into the analysis. Between 15 May and 30 Sep of each year the irrigated terraces received 2.54 cm of water whenever there were at least 7 consecutive days without rainfall and plant

Table 1. Planting date, rainfall records and total number of irrigations (2.54 cm) applied in the soybean test plots, Attapulgus Research Center, 1987-90.

Year	Planting date	Total (cm) rainfall (15 May-31 Oct)	Days receiving ≥0.25 cm (15 May-31 Oct)	Days receiving ≥0.64 cm (15 May-31 Oct)	Total irrigations* (15 May-30 Sept)
1987	20 May	49.2	32	20	6
1988	18 May	62.5	28	18	5
1989	26 May	85.7	39	31	3
1990	24 May	53.4	29	25	4

* Irrigations made as follows: 1987—2 June, 9 June, 14 July, 4 Aug., 25 Aug., 29 Sept.; 1988—24 May, 31 May, 21 June, 9 Aug., 27 Sept.; 1989—30 May, 4 Aug., 12 Sept.; 1990—5 June, 12 June, 12 Sept., 25 Sept.

stress was observed. The number of irrigations per year varied from 3 to 6 (Table 1). Standard tillage, fertilization and herbicide programs were followed. All terraces were essentially weed free (some weeding by hand was done when necessary), and no pre-plant or post-emergence insecticides were applied to the plots.

Daily rainfall was recorded at the official weather station located at the Center. Information on irrigation dates and amounts were recorded by Center personnel. Soybean phenology (Fehr and Caviness 1977) was measured weekly from early July through mid-October. Canopy closure (the amount of space remaining open between adjacent rows) and plant height (the distance from the soil surface to the last or newest, trifoliolate node) were measured in 1987 and 1989 after vegetative growth had ceased and pods were beginning to fill with seeds. At maturity, two center rows from each plot were harvested with a self-propelled plot combine. Yields were calculated and adjusted to 13% moisture.

All plots were sampled weekly, from early July to mid-October using a standard 38-cm diam sweep net by taking a 25-sweep sample down a single row in the middle of each plot (5 samples per treatment) (Kogan and Pitre 1980). Each sample was placed into a labeled clear plastic bag, returned to the laboratory, frozen, and counted at a later date. Adult and nymph stink bugs (primarily the southern green stink bug, *N. viridula*) and threecornered alfalfa hoppers, and velvetbean caterpillar, soybean looper, and green cloverworm larvae were counted. Also, the numbers of adult and nymph nabids (*Nabis* spp.), bigeyed bugs (*Geocoris* spp.), and spiders (all species combined) were recorded and pooled as the total arthropod predators.

The overall (4 year) arthropod population densities were analyzed as a 4-way factorial using the General Linear Models (GLM) procedure of the Statistical Analysis System with $P = 0.05$ (SAS Institute 1989). The model variables were Year (Y), Irrigation (I), Variety (V), Sampling Date, and Error. The analysis considered year and sampling date as random effects and irrigation and variety (maturity group) as fixed effects, as well as the interaction terms Y*I, Y*V, I*V, and Y*I*V. The Fisher's rule of interactions test was used to determine the appropriate error sources to test the main effects (SAS Institute 1989). The residual error term was used to test the Sampling Date and Y*I*V, Y*I*V to test I*V, Y*V to test V and Y*I to test I. A Chi-square test for irrigation and variety effects across all sampling dates was performed on insect count data each year to examine the trends in arthropod abundance (SAS Institute 1989). A nested effects analysis of variance also was performed to determine the relative contribution of Year, Irrigation, Variety, Date, and Residual Error to the total variation (SAS Institute 1989). Both the actual count and the log transformation were analyzed for all insect count data. Canopy closure, plant height, and yield were not repeatedly measured over time and, thus, the Sampling Date variable was not included in the GLM procedure.

Results

Irrigation and rainfall. Between 3 and 6 irrigations (2.54 cm each) were applied each season during this study to the irrigation plots (Table 1). In this study, the earlier maturing Forrest variety generally displayed drought stress before the Braxton variety occurring 7 to 9 days after any rainfall (or irrigation). In 1987, rainfall was a limiting factor during most of the season. Only 49.2 cm of rain fell during the 139 days between 15 May and 31 Oct 1987. Six irrigations were applied—at least one every month—from June through Sep. The 1988 season was also a dry season with at least

Table 2. Date of full bloom, plant height, yield, and canopy closure index (cc index, space remaining open between adjacent rows) in irrigated (Irr.) and non-irrigated (NI) soybeans, Attapulgus, GA, 1987-1990.

Variety	1987				1988		1989				1990	
Irrigated (IRR) or Non-Irr. (NI)	Plant height (cm)	CC Index (cm)	Bloom date	Yield kg/ha	Bloom date	Yield kg/ha	Plant height (cm)	CC Index (cm)	Bloom date	Yield kg/ha	Bloom date	Yield kg/ha
'Braxton' Irr.	89.6*	8.2	21 Jul	1912*	26 Jul	1502*	90.8	0.8	25 Jul	3248	26 Jul	1689*
'Braxton' NI	73.7*	10.5	21 Jul	1684*	26 Jul	1300*	85.1	3.0	2 Aug	3011	26 Jul	1361*
'Forrest' Irr.	73.2*	12.6*	14 Jul	1766*	19 Jul	1845*	80.6	8.0	20 Jul	3227	18 Jul	1731*
'Forrest' NI	59.9*	21.8*	14 Jul	1489*	19 Jul	1495*	80.0	12.5	20 Jul	2984	18 Jul	1112*

Column mean comparison for specific varieties followed by an * are significantly different using χ^2 test ($P < 0.05$). Overall plant height—'Braxton' (84.8 cm) taller than 'Forrest' (73.4 cm); Overall canopy closure—'Forrest' (13.7 cm) greater than 'Braxton' (5.6 cm); χ^2 test ($P < 0.05$) for both parameters.

one irrigation necessary in the irrigated plots every month except during July when 25.7 cm of rain fell during 10 days of the month. In 1989, rainfall was not a limiting factor, with over 85 cm falling during the season. Only 3 irrigations were made to the irrigated plots that year just after planting (30 May), and on 4 Aug and 12 Sep. June and Sep in 1990 were very dry with average rainfall amounts in July (14 cm) and Aug (18 cm). A total of 4 irrigations were made during the 1990 season, 2 in June and 2 in Sep.

Soybean yield and physiological responses. Yields were most severely affected by soil moisture deficits in Braxton and Forrest soybeans in 1987, 1988, and 1990 (Table 2). Both varieties had lower yields in the non-irrigated plots compared to the irrigated plots every year except 1989 (wet year). In general, the late-maturing Braxton and the early-maturing Forrest produced comparable yields every year during this 4-year study.

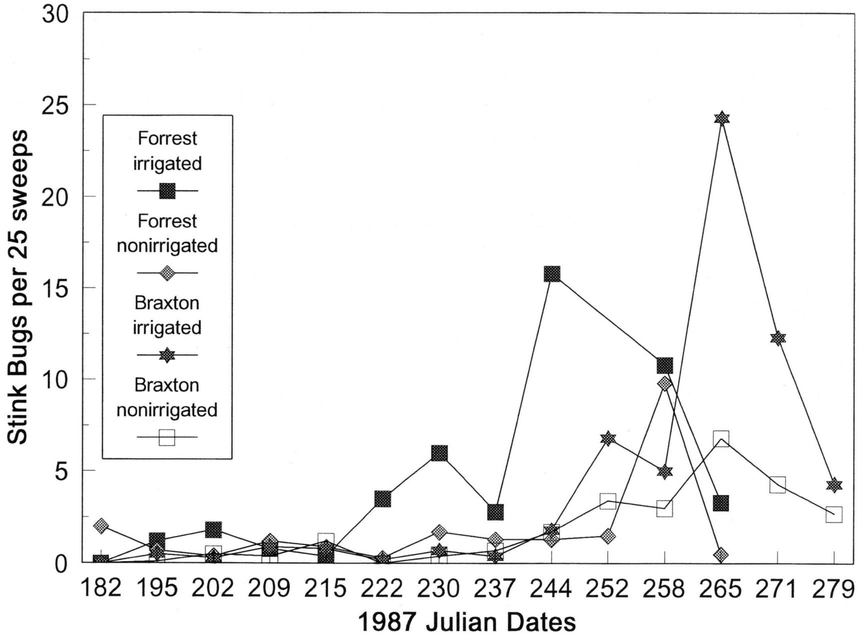
Both irrigated Braxton and Forrest were taller, and Forrest had less open canopy remaining between adjacent rows than corresponding non-irrigated varieties in 1987 (Table 2). No significant differences were noted in these growth parameters between the irrigated and non-irrigated plots in 1989, when soil moisture was adequate. Irrigation had no effect on the date of full bloom for each variety. However, the blooming period tended to last longer under the non-irrigation production system, extending from 7 to 10 days longer in some years. This extended period of blooming was probably a plant growth response to deficit rainfall conditions.

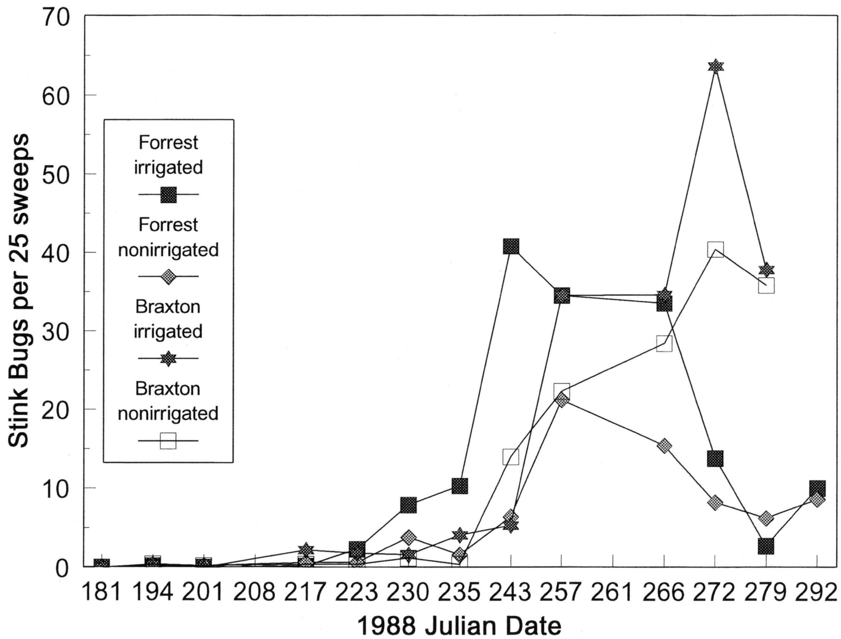
Stink bugs. There was a significant (P = 0.02) Year × Irrigation × Variety interaction for stink bug abundance on soybeans. There were significant differences between Braxton and Forrest either irrigated or non-irrigated each year (Table 3). Seasonal mean stink bug populations per 25 sweeps were higher in Forrest (5.1) than in Braxton (2.8) in 1987 and higher in Braxton (12.6) than in Forrest (9.1) in 1988 (Fig. 1). In all years, stink bug densities were higher in the early-maturing Forrest from julian days 215-250, then higher in the later-maturing Braxton after julian day 250 (Fig. 1). Irrigation influenced stink bug populations in both varieties each year, except in Forrest in 1990 when season-long populations were low (Table 3). The overall

Table 3. Chi-square tests for yearly irrigation and varietal effects on stink bugs (SB), velvetbean caterpillars (VBC) and threecornered alfalfa hoppers (TCAH) from all sampling dates each year.*

	Irrigation vs no irrigation				'Braxton' vs 'Forrest'			
Year	Variety	TCAH	SB	VBC	Irrigation	TCAH	SB	VBC
1987	'Braxton'	NS	0.01	0.01	Irrigated	0.01	0.01	0.01
1987	'Forrest'	0.01	0.01	0.01	Non-irrig.	0.01	0.01	0.01
1988	'Braxton'	0.02	0.01	0.01	Irrigated	0.01	0.01	0.01
1988	'Forrest'	NS	0.01	0.01	Non-irrig.	0.01	0.01	0.01
1989	'Braxton'	NS	0.01	0.05	Irrigated	0.01	0.01	0.01
1989	'Forrest'	0.02	0.01	0.03	Non-irrig.	0.01	0.01	0.01
1990	'Braxton'	0.01	0.01	0.01	Irrigated	NS	0.01	0.01
1990	'Forrest'	NS	NS	NS	Non-irrig.	NS	0.05	0.01

* Sampling dates for each year are presented in Fig. 2-4. NS represents a non-significant χ^2 test with $P > 0.05$.





mean stink bug density pooled over all years and dates was 31% higher in irrigated plots (6.3 per 25 sweeps) than in the non-irrigated plots (4.8 per 25 sweeps). Peak populations were higher in both irrigated varieties than in corresponding non-irrigated varieties in all years, except in 1989 when non-irrigated Braxton contained higher

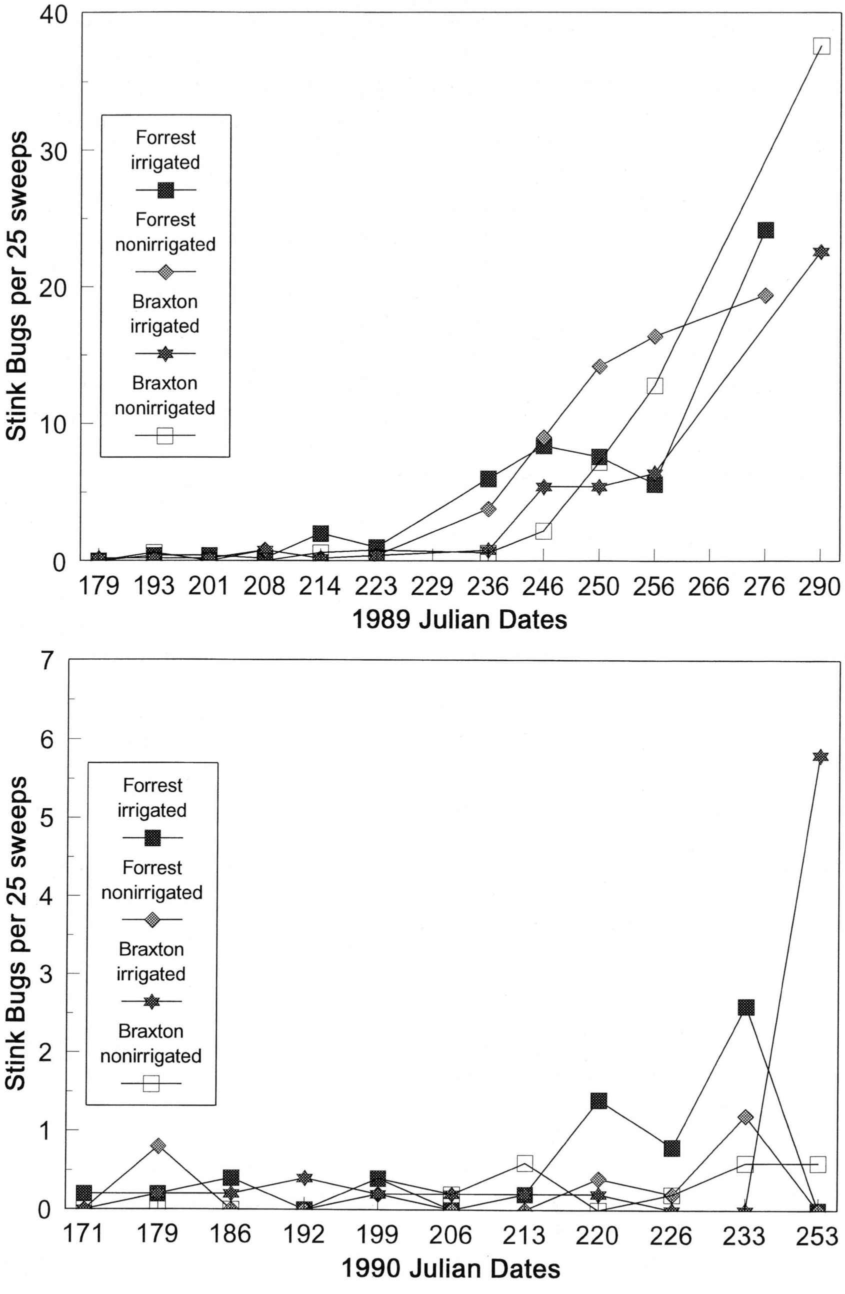


Fig. 1. Seasonal abundance of stink bugs, primarily *Nezara viridula*, on irrigated and non-irrigated 'Forrest' (Maturity Group V) and 'Braxton' (Maturity Group VII) soybeans, Attapulgus, GA, 1987-1990.

stink bug densities than did irrigated Braxton (Fig. 1). Stink bug populations varied greatly among years, with peak populations reaching around 25, 60, 35, and 6 per 25 sweeps in 1987 to 1990, respectively. The date of peak population also varied greatly among varieties and years, ranging from julian date 243 to julian date 290. It is reported that stink bugs colonize the earliest maturing soybeans in an area, reproduce, then the subsequent generation moves to the later-maturing soybeans (McPherson 1996). The fact that higher stink bug populations occurred on irrigated soybeans, particularly the early-maturing 'Forrest', implies that this production system (irrigation) could actually enhance late-season pest populations on later-maturing soybeans. In the nested analysis of variance, year, irrigation, sampling date, and random error contributed 11.4, 4.8, 62.1, and 21.3% of the total variance (mean 5.5 per 25 sweeps and SEM 1.9), while variety contributed a total of only 0.4%. Although *N. viridula* accounted for over 90% of the stink bug complex, the brown stink bug, *Euschistus servus* (Say), and the green stink bug, *Acrosternum hilare* (Say), were also commonly encountered on most sampling dates each year.

Velvetbean caterpillars. The 3-way interaction also was noted for velvetbean caterpillars. Population peaks varied greatly among years, ranging from over 80 per 25 sweeps in 1987 to under 8 per 25 sweeps in 1990 (Fig. 2). There were varietal differences each year (Table 3); however, the overall mean velvetbean caterpillar populations were similar between the two varieties. Irrigation also influenced population densities each year in both varieties (Table 3). Peak populations were higher in the irrigated variety compared to the non-irrigated variety each year, except in 1988 when peak densities were higher in non-irrigated Braxton than in irrigated Braxton (Fig. 2). Over all sampling dates, there were more velvetbean caterpillars per 25 sweeps in irrigated Braxton (7.6) than in non-irrigated Braxton (5.6), but no difference was observed between irrigated and non-irrigated Forrest (6.1 and 5.3 per 25 sweeps, respectively). In the nested analysis, year, date, and random error contributed 5.9, 82.7, and 11.3% of the total variance (mean 6.1 per 25 sweeps, SEM 2.0).

Soybean loopers. The Irrigation*Variety interaction was significant ($P = 0.05$) for soybean loopers. Soybean looper population densities were relatively low at this test site all 4 years, with population peaks ranging from around 2 to 8 per 25 sweeps (Fig. 3). Overall, there were more loopers per 25 sweeps on Forrest (0.7) than on Braxton (0.5) and more on irrigated (0.8) than on non-irrigated (0.4) soybeans. Irrigated Braxton had higher looper populations (0.6 per 25 sweeps) than non-irrigated Braxton (0.3). Irrigated Forrest soybeans also had higher looper population densities (1.0 per 25 sweeps) than non-irrigated Forrest (0.4). In the nested analysis, year, irrigation, date, and random error contributed 4.1, 7.0, 43.8, and 45.1% of the total variance (mean 0.6 per 25 sweeps, SEM 0.2).

Green cloverworms. Season mean population densities of green cloverworm were low, ranging from 0.2 to 0.8 per 25 sweeps for all 14 sampling dates. Peak populations ranged from 2 (1988) to 5.5 (1989) per 25 sweeps. This pest also had a significant ($P = 0.01$) Irrigation*Variety interaction in the analysis. There was no overall varietal effect; however, green cloverworm larvae were more numerous in the irrigated plots (0.5 per 25 sweeps) than on the non-irrigated plots (0.3 per 25 sweeps). Irrigated Forrest had more cloverworms (0.7) than non-irrigated Forrest (0.3), but this response was not apparent in the Braxton variety (0.3 and 0.4 on irrigated and non-irrigated, respectively). In the nested analysis, year, irrigation, date, and random error contributed 2.8, 0.9, 51.1, and 45.1% of the total variance (mean 0.4 per 25 sweeps, SEM 0.11).

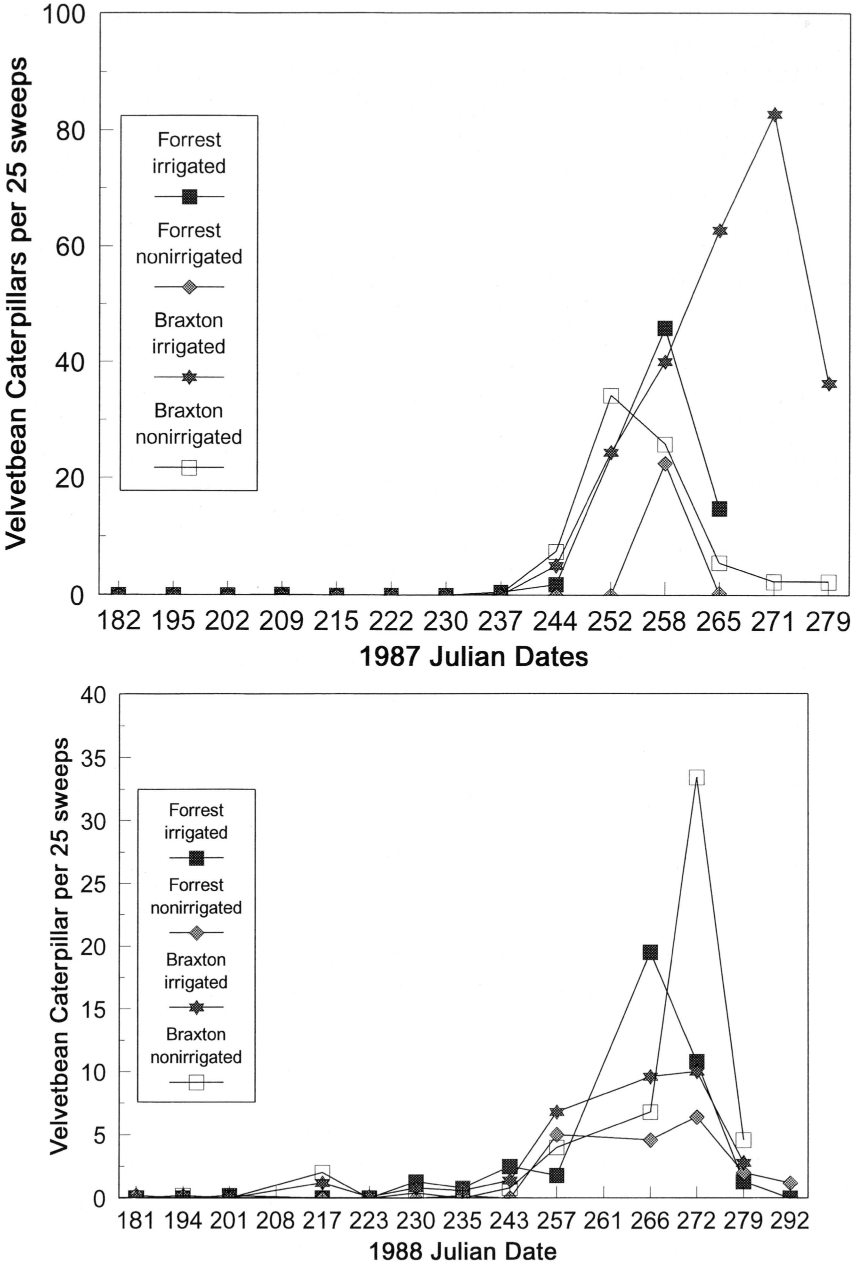
Threecornered alfalfa hoppers. Threecornered alfalfa hoppers also were more numerous on Forrest (2.1 per 25 sweeps) than Braxton (1.6 per 25 sweeps), and on irrigated soybeans (2.1) than non-irrigated soybeans (1.6), but there was a significant 3-way interaction. There were significant varietal differences each year except 1990 when population densities were the lowest (Table 3). Irrigation effects also were significant except for Braxton in 1987 and 1989 and in Forrest in 1988 and 1990 (Table 3). Populations were similar on all four years of this study with peaks ranging from 2.5 (1990) to 8 (1987) per 25 sweeps. Overall, threecornered alfalfa hopper populations were higher on irrigated Forrest (2.5 per 25 sweeps) than on non-irrigated Forrest (1.7), while overall populations were similar on irrigated (1.7) and non-irrigated (1.5) Braxton. In the nested analysis, year, irrigation, variety, date, and random error contributed 1.8, 0.3, 2.4, 51.7, and 43.8% of the total variance (mean 1.8 per 25 sweeps, SEM 0.24).

Arthropod predators. Like most of the pest species, total arthropod predators (nabids, bigeyed bugs, and spiders) also had a significant 3-way interaction. Total predator populations varied greatly within plots of the same variety on most sampling dates. Predators were more numerous on Braxton than on Forrest in 1988 (3.9 and 2.8 per 25 sweeps, respectively) and 1990 (4.1 and 3.3, respectively). Like the pest species counted, over all dates, predators were more abundant on soybeans under irrigation (3.6 per 25 sweeps) than without irrigation (3.0 per 25 sweeps). This pattern was also consistent with varieties; arthropod predators were more numerous on irrigated Braxton (3.9) than on non-irrigated Braxton (3.2) and more abundant on irrigated Forrest (3.3) than on non-irrigated Forrest (2.8). In the nested analysis, irrigation, variety, date, and random error contributed 1.7, 1.1, 30.2, and 66.9% of the total variance (mean 3.3 per 25 sweeps, SEM 0.14).

Discussion

This study demonstrated the impact of irrigation and soybean maturity group on arthropod communities. In particular, irrigating soybeans periodically throughout the growing season when plant drought stress becomes apparent tends to increase the populations of several commonly encountered insect pest and beneficial species. The canopy structure in these soybean production systems appears to affect the foliage-inhabiting arthropods, especially predatory arthropods (Felland and Pitre 1991a). Survivorship and developmental rates are also improved for certain insect pests, particularly *P. includens* and *Spodoptera frugiperda* (J. E. Smith), on irrigated vs dryland soybeans (Felland and Pitre 1991b). Irrigation also has been correlated with size of *P. includens* larvae, plant injury, and insect-induced yield reduction in both a susceptible and resistant soybean genotype (Lambert and Heatherly 1995).

Soybean maturity group has been shown to impact the population peaks of velvetbean caterpillars and Mexican bean beetles, *Epilachna varivestis* Mulsant, with peaks occurring at the same time in all varieties but higher peaks in the later-maturing varieties without irrigation (McPherson et al. 1996). The results reported herein tend to agree with earlier reports when only data from non-irrigated plots are examined. However, when comparing the four cropping systems evaluated in this study, i.e., Braxton irrigated, Braxton non-irrigated, Forrest irrigated, and Forrest non-irrigated,



then a distinctly different outcome is apparent. The irrigated late-maturing Braxton had more velvetbean caterpillars than the other three systems, while irrigated early-maturing Forrest had more stink bugs, soybean loopers, green cloverworms and threecornered alfalfa hoppers than the other systems. Numbers of natural enemies

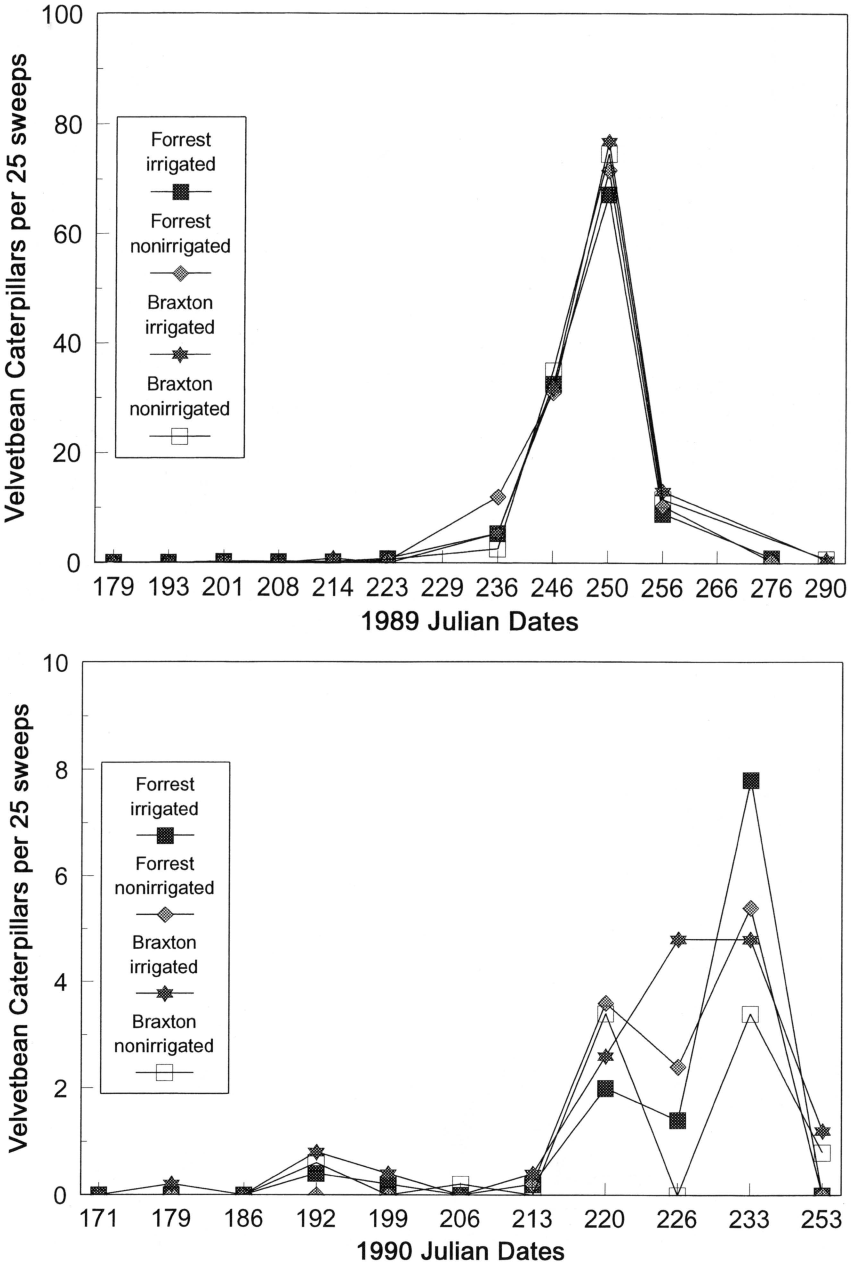
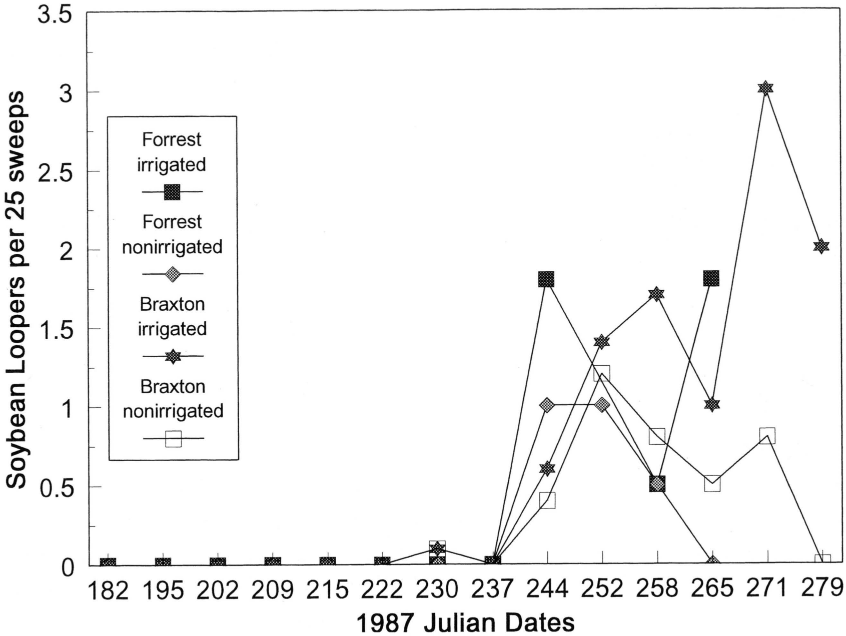
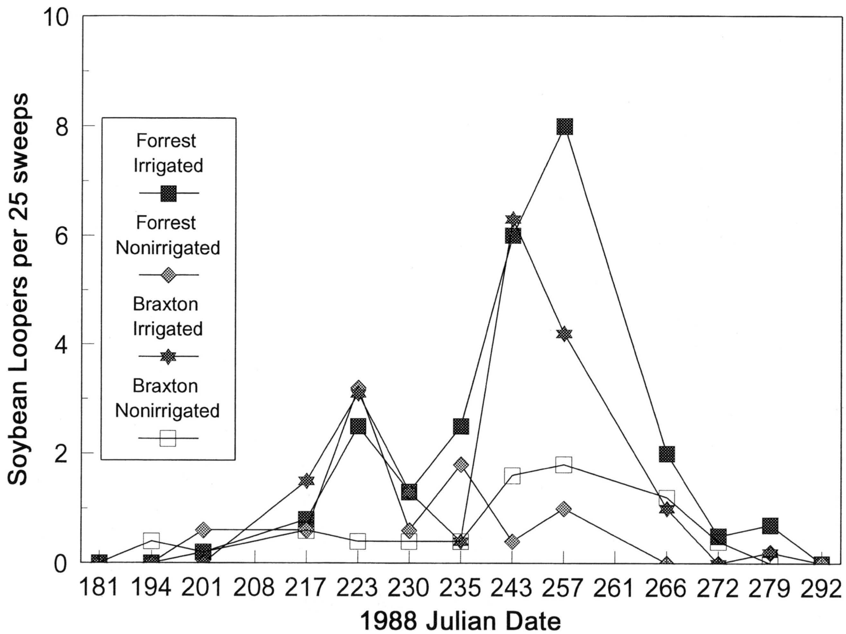


Fig. 2. Seasonal abundance of velvetbean caterpillars, *Anticarsia gemmatalis*, on irrigated and non-irrigated 'Forrest' (Maturity Group V) and 'Braxton' (Maturity Group VII) soybeans, Attapulgus, GA, 1987-1990.





also were higher in the irrigated plots. These higher numbers were probably influenced most by prey density; however, a more favorable environment (closed canopy with possibly more moisture and lower temperatures) also could have resulted in higher predator populations.

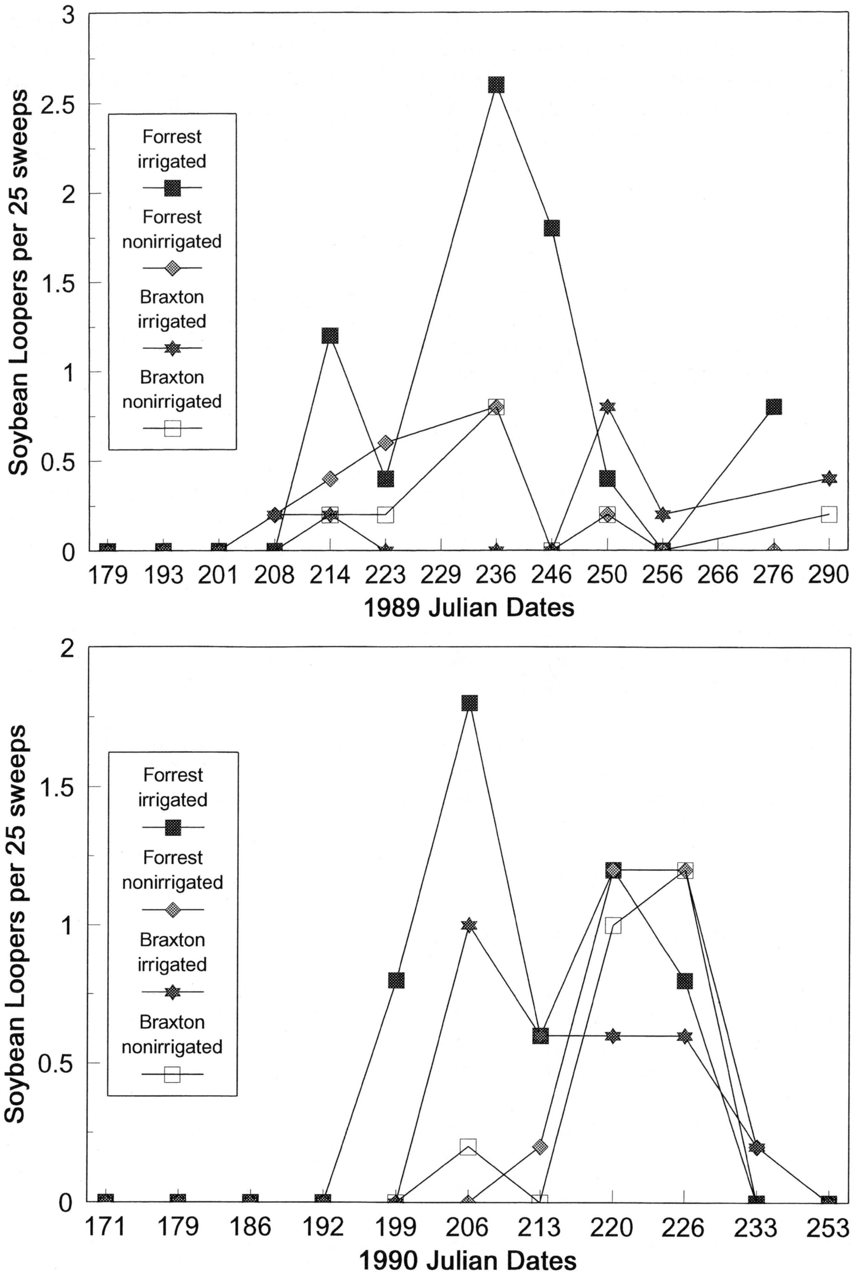


Fig. 3. Seasonal abundance of soybean loopers, *Pseudoplusia includens*, on irrigated and non-irrigated 'Forrest' (Maturity Group V) and 'Braxton' (Maturity Group VII) soybeans, Attapulgus, GA, 1987-1990.

In conclusion, irrigating soybeans during water deficit periods of the growing season affects the density of several insect pests. In particular, stink bug, velvetbean caterpillar, soybean looper, green cloverworm, and threecornered alfalfa hopper populations were all higher under irrigated vs non-irrigated production systems. Soybeans produced in areas where any of these pests are potential threats to the crop need to be extensively monitored for pest infestations, particularly when irrigation is used.

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