Can Row Spacing Influence Arthropod Communities in Soybean? Implications for Early and Late Planting

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ABSTRACT Row spacing in agricultural systems can influence crop yield as well as pest and predator abundances. Soybean (*Glycine max* L. Merrill) growers in Maryland typically plant in narrow (∼19 cm), medium (∼38 cm), or wide (∼76 cm)-spaced rows, and there is a general lack of information on how these row-spacing schemes influence arthropod abundance and soybean yields. A study was conducted during two growing seasons to determine the effect of soybean row spacing and planting date (early and late) on soybean arthropods and yield. Despite a great deal of variation in arthropod responses to row spacing, and interactions between row spacing and study year, leaf-feeding herbivores were generally more abundant in narrow-spaced soybeans. All arthropod functional groups were more abundant, and yield was greater in early-planted soybeans relative to late-planted soybeans. Potential causes and implications of these finding are discussed.

KEY WORDS *Glycine max*, soybeans, row spacing, crop pests

The spatial distribution of organisms can have a profound effect on species with which they interact. Spatial distribution can be particularly influential for sessile organisms such as plants, as their spatial distribution is generally fixed for their lifetime. In domesticated plant systems, plant spatial structure can be easily manipulated by altering row spacing, which is generally chosen based on optimal yield potential or equipment limitations. Planting narrower rows has been shown to increase yields in soybean (McPherson and Bondari 1991), rice (Chauhan and Johnson 2010), and cacao (Dias et al. 2000) crops. In soybean (*Glycine max* L. Merrill), narrow rows are associated with faster canopy closure (McPherson and Bondari 1991), where earlier shading out of the understory (Anderson and Yeargan 1998) leads to greater weed suppression and crop yield (Peters et al. 1965). While row spacing in soybean can have profound effects on weed communities, it has been shown to have little influence on the distribution of soil nutrients or soil pH, even after several years of treatments (Bauer et al. 2002).

Row spacing can also influence arthropod abundance within crops. Planting soybeans in narrow rows, for example, can increase abundance of green cloverworms (*Plathypena scabra* F.) (McPherson et al. 1988), velvetbean caterpillars (*Anticarsia gemmatalis* Hübner), and southern green stink bugs (*Nezara viridula* L.) (McPherson and Bondari 1991), all of which are pest species on soybean. However, soybean row spacing does not always influence arthropods. Anderson and Yeargan (1998) found no effect of soybean row spacing on predator abundance or egg parasitism of the corn earworm (*Helicoverpa zea* Boddie). Similarly, Lam and Pedigo (1998) found no overall effect of soybean row spacing on herbivorous and predatory insects. Because each of the aforementioned studies controlled for plant density, any effects (or lack thereof) of row spacing on arthropods abundance can be attributed to plant spatial structure.

In the state of Maryland, soybean growers generally plant in narrow (∼19 cm), medium (∼38 cm), or wide (∼76 cm)-spaced rows. Past studies examining the influence of row spacing on arthropods have compared two row-spacing configurations ("narrow" and "wide") ranging from 25 to 100 cm (McPherson et al. 1988, McPherson and Bondari 1991, Anderson and Yeargan 1998, Lam and Pedigo 1998). Research findings suggest that narrower rows suppress weeds and increase yield (Peters et al. 1965), a general perception also held by Maryland soybean producers. However, there is no quantification of how the three soybean-spacing schemes used by Maryland farmers influence the abundance of soybean arthropods or yield. This study was conducted to address that need. Additionally, because Maryland soybean producers generally choose between two distinct planting times, effects of row spacing on soybean arthropods were examined in early- and late-planted soybeans.

Materials and Methods

Experimental Design. Field studies were conducted in 2009 and 2010 at the Central Maryland Research and Education Center (Upper Marlboro,

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MD) to examine the effects of row spacing and planting date on soybean arthropod abundance. Early- and late-planted soybeans were seeded in different fields during each study year. In 2009, soybeans were seeded on June 3 (early) and July 20 (late), and in 2010, they were seeded on May 31 (early) and July 12 (late). Each row-spacing treatment was replicated four times in a randomized complete block design. Row-spacing treatments were narrow (~18 cm between rows), medium (~36 cm between rows), and wide (~71 cm between rows). Asgrow Round-Up© Ready soybeans, variety AG 3905 (Monsanto Co., St. Louis, MO), Maturity Group 3.9 were seeded for each field study, using a Great Plains no-till drill (model 1005). Each treatment was planted at ~140,000 seeds per acre. Treatment plots were 15 m by 15 m and separated by 8 m of bare soil. To mimic commercial practices of soybean growers in Maryland, Round-Up© or a generic equivalent was applied to control weeds prior to planting and during the growing season.

Arthropod abundance was sampled weekly with a 38-cm-diameter sweep net. Sweep samples began approximately one month after seeding for a total of 10 (early-planted) and 13 (late-planted) sweeps in 2009, and 8 (early) and 7 (late) sweeps in 2010. Two sweep samples were collected per treatment plot on each sampling occasion; a sample consisted of five sweeps, down and across two rows of soybeans (Hooks et al. 2011). Sweep-collected arthropods were transferred to plastic zip-top bags and temporarily placed on ice, then stored in a freezer for later identification. Arthropods were sorted and identified to lowest taxonomic level possible. Prior to statistical analysis, arthropods were re-classified from species into four functional groups: leaf-feeding herbivores (LEAF), stem-feeding herbivores (STEM), pod-feeding herbivores (POD), and predatory arthropods (PRED).

To assess crop yield, soybeans were harvested with a Massey Ferguson 8XP plot combine. The combine made two passes through each plot and computed separate yields for each pass while making adjustments for seed moisture. Because soybeans flower in response to day length, harvest dates for early- and late-planted soybeans generally coincide, so harvesting all plots within a period of a few days is a reasonable approximation of typical grower practices. Soybean plots in the 2009 experiment were harvested January 6 (early-planted) and January 7 (late-planted), 2010. In the 2010 experiment, all plots were harvested on November 12, 2010.

Statistical Analyses. The cumulative abundance of each functional group, reflecting the total number of each arthropod type found in each treatment throughout the season, was analyzed separately for early- and late-planted soybeans. Because of skewed data distributions, permutation tests were used to analyze arthropod abundance in response to row spacing, year, and spacing-by-year interactions. When analyses gave significant results for row spacing, Wilcoxon rank sum tests were performed for *a priori* pair-wise comparisons between medium versus narrow spacing, and medium versus wide spacing. Yield in response to row spacing, year, and spacing-by-year interaction was analyzed separately for early and late plantings using analysis of variance (ANOVA). When interactions were not significant, they were eliminated from the model. Where final models gave significant results for row spacing, Tukey's honestly significant difference tests were performed for pair-wise comparisons. All analyses were conducted in R 3.0.1 (R Core Development); nonparametric analyses used the lmPerm package. Treatment comparisons were considered significant when $P < 0.05$.

Results

Table 1 reports the arthropod species encountered in sweeps, and each species' associated functional type. Overall, green cloverworms (*Plathypena scabra* F.) were the most abundant arthropod (36% of the total collected), followed by spiders (various species, 21%) and big-eyed bugs (*Geocoris punctipes*, 12%). The relative abundances of these three groups were similar across all row-spacing treatments in early-planted soybean. In late-planted soybeans, however, green cloverworm and spiders were equally abundant (27% of the total collected), and cucumber beetles (*Diabrotica undecimpunctata* and *Acalymma vittatum*) were the next most abundant (11%). In 2009, spiders (33%) and big-eyed bugs (16%) were most abundant, while green cloverworms made up 13% of the arthropods collected. In 2010, the most abundant arthropods sampled were green cloverworms (52%), spiders (11%), and big-eyed bugs (10%). All other species made up less than 10% each of the total abundance.

Row spacing did not have a significant effect on soybean yield (early planting: $F_{2,20} = 0.329$, $P = 0.723$; late planting: $F_{2,20} = 0.377$, $P = 0.691$) during either study year (Table 2). Yield was higher in 2010 in both early- and late-planted soybean (early-planted: $F_{1,20} = 29.2$, $P < 0.0001$; late-planted: $F_{1,20} = 28.1$, $P < 0.0001$) (Table 2). Row spacing influenced the density of LEAF and POD (Table 3). More LEAF were found in narrow than in medium or wide row treatment plots for early and late plantings (early planting: $SS_{2,18} = 3278$, $P < 0.0001$; late planting: $SS_{2,20} = 741$, $P < 0.0001$) (Fig. 1A and B). A row spacing-by-year interaction was present in the early planting ($SS_{2,18} = 3002$, $P < 0.0001$; Fig. 1A), where row spacing influenced LEAF abundance in 2010 but not in 2009. POD abundance was significantly influenced by row spacing in early-planted soybeans ($SS_{2,18} = 133$, $P = 0.017$), where POD were most abundant in the widest rows. Additionally, a row spacing-by-year interaction ($SS_{2,18} = 214$, $P = 0.001$) shows that this increase in POD abundance was driven by responses in 2010 (Fig. 2).

There was a year effect on all measured functional groups, and a particularly strong effect on LEAF and predators (Table 2, Fig. 3). Herbivore and predator abundances responded differently during each year of the experiment; predator abundance was high in 2009 relative to 2010, while the opposite was found for herbivore functional groups (Fig. 3).

Table 1. List of common arthropods found in sweeps

Common name	Scientific name	Functional group
Green cloverworm	*Plathypena scabra*	Leaf feeder
Soybean looper	*Pseudoplusia includens*	Leaf feeder
Corn earworm	*Helicoverpa zea*	Leaf feeder
Japanese beetle	*Popillia japonica*	Leaf feeder
Blister beetle	*Epicauta* spp.	Leaf feeder
Silver spotted skipper	*Epargyreus clarus*	Leaf feeder
Lepidopteran larvae	Multiple species	Leaf feeder
Yellow striped armyworm	*Spodoptera ornithogalli*	Leaf feeder
Cucumber beetle	*Diabrotica undecimpunctata*, *Acalymma vittatum*	Leaf feeder
Green stink bug	*Chinavia hilaris*	Pod feeder
Pentotomid	Multiple species	Pod feeder
Threecornered alfalfa hopper	*Spissistilus festinus*	Stem feeder
Dectes stem borer	*Dectes texanus*	Stem feeder
Big eyed bug	*Geocoris punctipes*	Predator
Spider	Multiple species	Predator
Damsel bug	Nabidae	Predator
Ladybeetle	Coccinellidae	Predator
Minute pirate bug	*Orius tristicolor*	Predator
Syrphid fly	Multiple species	Predator
Lacewing	*Chrysopa* spp.	Predator

Table 2. ANOVA table for yield responses in early- and late-planted soybeans

Response	Source	df	*F* value	*P*
Yield-early	Row spacing	2	0.329	0.723
	Year	1	29.217	<0.0001
	Residuals	20	0.00523	
Yield-late	Row spacing	2	0.377	0.691
	Year	1	28.067	<0.0001
	Residuals	20	0.00710	

Table 3. Results of permutation test for arthropod sweep counts in early- and late-planted soybean

Functional group	Source	df	Type III SS	*P*
LEAF-early	Row spacing	2	3,278	<0.0001
	Year	1	46,200	<0.0001
	Row spacing × year	2	3,002	<0.0001
	Residuals	18	1,461	
STEM-early	Row spacing	2	10.33	0.406
	Year	1	0.375	0.725
	Residuals	20	122.25	
POD-early	Row spacing	2	132.58	0.0168
	Year	1	551.04	<0.0001
	Row spacing × year	2	214.08	0.0014
	Residuals	18	252.25	
PRED-early	Row spacing	2	680.1	0.1198
	Year	1	10,333.5	<0.0001
	Residuals	20	2,887.7	
LEAF-late	Row spacing	2	741.0	<0.0001
	Year	1	6,902.0	<0.0001
	Residuals	20	540.6	
STEM-late	Row spacing	2	5.583	0.09364
	Year	1	32.667	<0.0001
	Residuals	20	25.583	
POD-late	Row spacing	2	14.33	0.8348
	Year	1	322.67	<0.0001
	Residuals	20	382.83	
PRED-late	Row spacing	2	316.8	0.2452
	Year	1	6,272.7	<0.0001
	Residuals	20	1,959.1	

See Table 1 for species associated with each arthropod functional group.

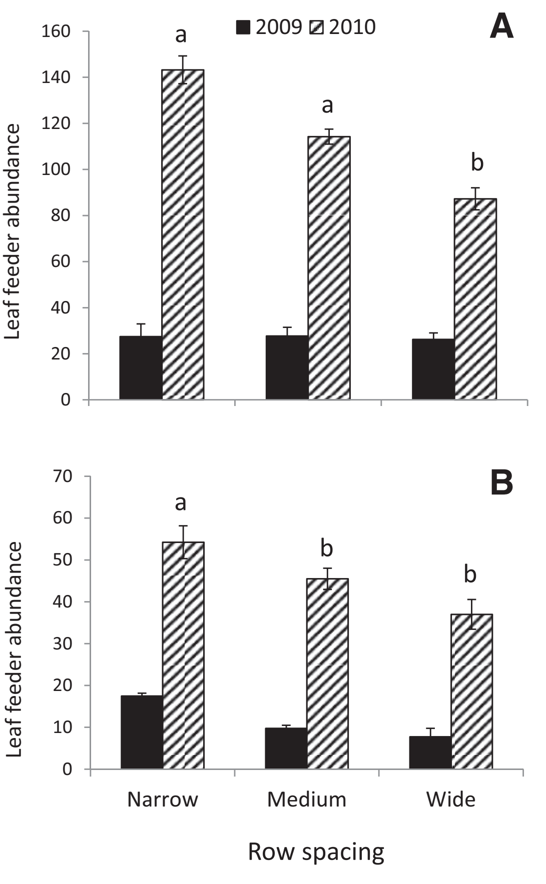

Fig. 1. Number of leaf-feeding insects found in (A) early- and (B) late-planted soybean in 2009 and 2010. The inter-row spacing for narrow, medium, and wide rows was ~18, 36, and 71 cm, respectively. Treatments are considered significant when the permutation test gave $P \leq 0.05$. Letters above the bars indicate differences to a $P \leq 0.05$ in *a priori* Wilcoxon rank sum tests. Error bars show standard error.

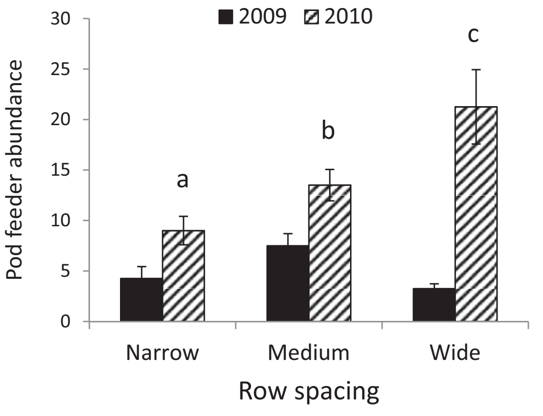

Fig. 2. Number of pod-feeding insects found in early-planted soybean in 2009 and 2010. Pod feeders were more abundant in wide rows in 2010 and showed a row spacing-by-year interaction. The inter-row spacing for narrow, medium, and wide rows was ∼18, 36, and 71 cm, respectively. Treatments are considered significant when the permutation test gave $P \leq 0.05$. Letters above the bars indicate differences to a $P \leq 0.05$ in *a priori* Wilcoxon rank sum tests. Error bars show standard error.

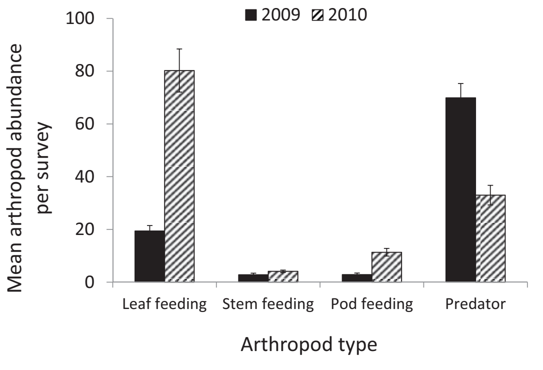

Fig. 3. Year effects on arthropod abundances, pooled across early- and late-planted soybeans. Year influenced all arthropod types in both planting times, except stem feeders in early-planted soybeans. Year is considered significant when $P < 0.05$. Error bars show standard error.

Discussion

Row spacing did not have a significant effect on soybean yield in this experiment. Although a previous study conducted in Georgia reported greater yield in narrow relative to wide rows (McPherson and Bondari 1991), that study did not use the three row-spacing schemes used in this study, including a much wider (90 cm) maximum spacing. Because there was no effect of row spacing on soybean yield, plant quality was likely not influenced by row spacing. Any arthropod responses to row spacing are therefore most likely owing to changes in habitat structure or microclimate.

Row spacing did influence arthropod abundance, but effects were not consistent across all arthropod functional groups. Leaf-feeding insects were most abundant in narrow rows in early- and late-planted soybeans (Fig. 2), similar to previous work finding an increase in caterpillar abundance in narrow rows (McPherson and Bondari 1991, McPherson et al. 1988). Pod-feeding insects, however, were most abundant in wide rows in early-planted soybeans (Fig. 2). In contrast, previous work found more stink bugs in narrow rows (McPherson and Bondari 1991). In similar research investigating a wide range of soybean-associated insects, Lam and Pedigo (1998) also found that some insect populations responded to row spacing, while others did not. In addition to different responses among arthropod functional groups, row spacing-by-year interactions for both LEAF and POD (Figs 1A and 2) show that responses to soybean row spacing differed across years. These interactions likely indicate that the yearly variation in abiotic factors that influence microclimate within the crop habitat has an important influence on pest populations. Unfortunately, this makes it difficult for growers to predict how any given row spacing will influence arthropod abundances from year to year. However, if growers are most concerned with LEAF, this study suggests that despite increased abundance of LEAF in narrow-row soybeans, there was no accompanying reduction in yield.

While this study was not designed to compare the influence of planting date on arthropod numbers, it is worth noting that all observed arthropod functional groups were more abundant in the early-planted soybean, and yield was greater in early-planted soybean. The perception among Maryland growers is that early-planted soybeans will have higher yield owing to greater precipitation during critical periods of soybean growth, which is a major factor in soybean performance (Calviño and Sadras 1999). Late-planted soybeans may face additional water stress, as they are typically planted in a double-cropping scheme following a small grain such as barley or wheat, which can deplete available water reserves (Lehrsch et al. 1994 and references therein).

While several studies have investigated the influence of soybean planting date on arthropods, few clear patterns of arthropod responses have emerged. Two studies found that early-planted soybeans supported more green stink bugs (*Chinavia hilaris* (Say)) (McPherson et al. 1988) and southern green stink bugs (*Nezara viridula* (L.)) (McPherson and Bondari 1991), while another study found the late-planted soybeans contained more stink bugs (combined abundances of green, southern green, and brown (*Euschistus servus* (Say)) stink bugs) (Gore et al. 2006). Similarly, McPherson and Bondari (1991) found that late-planted soybeans contained more velvetbean caterpillars. Other studies found no effect of planting date on predator populations or corn earworm egg predation (Anderson and Yeargan 1998), or stink bugs (combined abundances of green, southern green, and brown stink bugs) (Smith et al. 2009). Those studies that explicitly analyzed interactions between planting date and row spacing (McPherson et al. 1988, McPherson and Bondari 1991) found no planting date-by-row spacing interactions.

Previous research has speculated that early-planted soybean could reduce pest problems in late-planted soybean by serving as a trap crop to attract herbivores (McPherson and Bondari 1991), or as a nurse crop supporting predators. However, the strong effect of row spacing on leaf feeders in this study, which were also the most abundant of all feeding guilds, suggests that early-planted soybeans in narrow rows could simply support high abundances of herbivores that could spill over into other crops. Yearly, ∼60–70% of the soybeans grown in Maryland are planted early (late May to early June) and the remaining are planted late (month of July). The current study shows that despite supporting higher numbers of LEAF in narrow-row soybeans, yield is similar to wider-row plantings. This suggests that the effects of row spacing on arthropods should not be a consideration when Maryland producers are deciding a row-spacing scheme for early- or late-planted soybeans.

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