Action Thresholds for Managing *Megacopta cribraria* (Hemiptera: Plataspidae) in Soybean Based on Sweep-Net Sampling

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ABSTRACT The kudzu bug, *Megacopta cribraria* (F.), first discovered in the United States in 2009, has rapidly become a pest of commercial soybean, *Glycine max* (L.) Merrill, throughout much of the southeast. Because of its recent arrival, management practices and recommendations are not well established. To develop action thresholds, we evaluated insecticide applications targeted at different densities of adults and nymphs determined using the standard 38-cm diameter sweep net sampling method in 12 soybean field trials conducted in Georgia, North Carolina, and South Carolina from 2011 to 2013. Average peak densities of *M. cribraria* in the untreated controls reached as high as 63.5 ± 11.0 adults per sweep and 34.7 ± 8.0 nymphs per sweep. Insecticide applications triggered at densities of one adult or nymph of *M. cribraria* per sweep, two adults or nymphs per sweep, and one adult or nymph per sweep, with nymphs present, resulted in no yield reductions in most cases compared with plots that were aggressively protected with multiple insecticide applications. A single insecticide application timed at the R3 or R4 soybean growth stages also resulted in yields that were equivalent to the aggressively protected plots. Typically, treatments (excluding the untreated control) that resulted in fewer applications were more cost-effective. These results suggest that a single insecticide application targeting nymphs was sufficient to prevent soybean yield reduction at the densities of *M. cribraria* that we observed.

KEY WORDS invasive species, cumulative insect day, economic benefit, yield component

Megacopta cribraria (F.) (Hemiptera: Plataspidae), an invasive native of Asia, poses a new pest management challenge to producers of soybean, *Glycine max* (L.) Merrill, in the southeastern United States (Eger et al. 2010). Although the family Plataspidae is not native to the Western Hemisphere, *M. cribraria* was found in nine counties in Georgia in fall of 2009 (Suiter et al. 2010), with the Kyushu region of Japan as the likely point of origin (Hosokawa et al. 2014). The invasive distribution of *M. cribraria* now includes South Carolina, North Carolina, Alabama, Virginia, Tennessee, Florida, Mississippi (Gardner et al. 2013), Louisiana, Maryland, Delaware, the District of Columbia, Kentucky (W. Gardner, personal communication), and Arkansas (N.J.S., unpublished data). *M. cribraria* primarily feeds on plant sap on the main stems and petioles of the plant, with adults and nymphs often congregating at nodes and growing points (Tayutivutikul and Yano 1990, Thippeswamy and Rajagopal 2005, Suiter et al. 2010). Although several legumes can support development (Medal et al. 2013), soybean and the invasive weed kudzu, *Puereria montana* (Loureiro) Merrill variety *lobata* (Willdenow), are the most important developmental hosts in the United States (Zhang et al. 2012). The first of two generations in the southeastern United States typically develops on kudzu, while the second generation can develop on kudzu or soybean (Zhang et al. 2012, Seiter et al. 2013a). If soybean is available early in the season, development of the first generation on soybean is possible beginning with the early vegetative stages of the plant (Del Pozo-Valdivia and Reisig 2013).

Feeding by *M. cribraria* does not directly damage the seed. However, *M. cribraria* has the potential to reduce soybean yields if populations are sufficiently high (Seiter et al. 2013b). Soybean growth characteristics (Kikuchi and Kobayashi 2010) and yield (Zhixing et al. 1996) can be reduced by *M. cribraria* feeding in Asia. However, reports of its actual pest status in its native range are mixed (Hosokawa et al. 2007). Feeding can cause visually apparent necrotic lesions on stems and other feeding sites (Thippeswamy and Rajagopal 2005,

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Table 1. Location, variety, planting and harvest dates, and plot size for trials evaluating action thresholds for *M. cribraria* in soybean

Trial ID	Location	Planting date	Variety	Maturity group	Plot size	Harvest date
SC-1	Barnwell County, SC (EREC)	1 July 2011	AGS 758[a]	VII	12 rows × 12.2 m	7 Nov. 2011
SC-2	Barnwell County, SC (EREC)	16 May 2012	95Y70[b]	V	8 rows × 12.2 m	18 Oct. 2012
SC-3	Barnwell County, SC (EREC)	17 May 2012	95Y40[b]	V	8 rows × 12.2 m	11 Oct. 2012
SC-4	Barnwell County, SC (EREC)	17 May 2013	AG6931[c]	VI	8 rows × 12.2 m	30 Oct. 2013
SC-5	Barnwell County, SC (EREC)	17 May 2013	AG6931[c]	VI	8 rows × 12.2 m	6 Nov. 2013
NC-1	Edgecombe County, NC (UCPRS)	20 April 2012	AG5503[c]	V	4 rows × 13.7 m	1 Nov. 2012
NC-2	Montgomery County, NC (SRS)	18 April 2013	AG7502[c]	VII	4 rows × 12.2 m	6 Nov. 2013
GA-1	Burke County, GA (SGREC)	20 May 2011	95Y20[b]	V	24 rows × 30.5 m	7 Oct. 2011
GA-2	Burke County, GA (SGREC)	23 May 2012	AG5831[c]	V	6 rows × 12.2 m	25 Oct. 2012
GA-3	Tift County, GA (Tifton)	31 May 2012	AG5831[c]	V	6 rows × 12.2 m	22 Oct. 2012
GA-4	Burke County, GA (SGREC)	9 May 2013	95Y71[b]	V	6 rows × 12.2 m	31 Oct. 2013
GA-5	Tift County, GA (Tifton)	7 May 2013	AG5831[c]	V	6 rows × 12.2 m	10 Oct. 2013

[a] AGSouth Genetics, Albany, GA.
[b] DuPont Pioneer, Johnston, IA.
[c] Asgrow, St. Louis, MO.

Seiter et al. 2013b). The extent of functional tissue damage represented by these lesions is unknown. In the United States, *M. cribraria* reduced yield by up to 60% when they were artificially confined to soybean plants and allowed to complete a generation of development (Seiter et al. 2013b). Seeds per pod and individual seed weight were reduced, indicating plant stress during the pod fill stages of reproductive growth (Seiter et al. 2013b). While there is a clear potential for economic losses due to this insect, development and evaluation of management options have so far been limited due to its recent arrival in the United States.

Current recommendations for management of *M. cribraria* are based largely on informal observations. In 2011, growers in Georgia and South Carolina reported quick reentry of adults of *M. cribraria* into soybean fields after insecticide applications (unpublished data). Economic injury level curves were calculated for a range of soybean prices and management costs in terms of cumulative insect days per plant based on whole-plant counts (Seiter et al. 2013b). However, sampling of this highly mobile insect by whole-plant counts would likely be too time consuming and inefficient to be useful to most producers or crop advisors. Injury levels and thresholds based on a relative sampling method, such as sweep-net sampling, would be more applicable to field situations. A preliminary action threshold of one nymph per sweep using a 38-cm diameter sweep net was proposed based on observations from a variety of experimental trials (Greene et al. 2012, Stubbins et al. 2014). However, this and other possible thresholds have not yet been broadly tested. The objectives of this study were to evaluate management of *M. cribraria* in soybean with insecticides triggered at several densities and to develop management recommendations accordingly.

Materials and Methods

Soybean Field Trial Information. Twelve field trials using a similar experimental design and protocol were conducted from 2011 to 2013 at the Clemson University Edisto Research and Education Center (EREC) in Barnwell County, SC, the University of Georgia Southeast Georgia Research and Extension Center (SGREC) in Burke County, GA, the University of Georgia Tifton campus (Tifton) in Tift County, GA (2012–2013 only), the North Carolina State University Upper Coastal Plain Research Station (UCPRS) in Edgecombe County, NC (2012 only), and the North Carolina State University Sandhills Research Station (SRS) in Montgomery County, NC (2013 only). Varieties and planting dates were chosen to reflect those typically used by commercial soybean growers within the region (Table 1). Row spacing was 96.5 cm (EREC) or 91.4 cm (all other locations). Seeding rates were ≈255,000 seeds per ha at EREC, ≈287,000 seeds per ha at SGREC and Tifton, and ≈322,780 seeds per ha at UCPRS and SRS. Insecticide applications were made at a spray volume of 93.5 l/ha using a high-clearance self-propelled sprayer (EREC, SGREC, and Tifton) or a CO_2 backpack sprayer (UCPRS and SRS). A common insecticide was used for all treatment applications at each location. The insecticide used at EREC, SGREC, and Tifton was 0.035 kg/ha of λ-cyhalothrin and 0.046 kg/ha of thiamethoxam (Endigo ZC, Syngenta Crop Protection LLC, Greensboro, NC), and the insecticide used at UCPRS and SRS was 0.112 kg/ha of bifenthrin (Discipline 2EC, AMVAC, Los Angeles, CA). Both insecticides have shown consistent high efficacy for control of adults and nymphs (unpublished data). In addition, all trials at EREC in 2013 were sprayed on 24 July and 27 August with 0.077 kg/ha of spinosad (Tracer Naturalyte, Dow AgroSciences, Indianapolis, IN) to control potentially yield-limiting populations of soybean looper, *Chrysodeixis includens* (Walker), and corn earworm, *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae). This rate of spinosad was used because it has been observed to effectively control these and other lepidopteran pests with little to no impact on populations of *M. cribraria* (J.K.G., unpublished data).

Each experimental trial was arranged as a randomized complete block design with four replicate blocks. (Individual trials are numbered by state for reference; Table 1). Experimental units were plots of soybean that varied in size among trials but were at least four rows wide and 12.2 m in length (Table 1). Plots were sampled weekly (trial SC-1) or every other week (all other trials) from the time populations of *M. cribraria* were observed entering the plots, and soybean plants were large enough to allow sweep-net sampling (at least soybean growth stage V6; Fehr and Caviness 1977) until the time plants were too mature (late R6-R7) to be effectively swept. Plots were sampled using a standard canvas cloth 38-cm diameter sweep net by swinging the net from side to side in a 180° arc, keeping the net below the tops of the soybean plants, while walking down the row middle so that each swing passed through new areas of the canopy. Sweeping was conducted across one (GA trials) or two (SC and NC trials) rows of soybean. Samples consisted of 25 (SC-1), 20 (GA-1; SC-2,3,4,5; NC-1,2), or 10 (GA-2,3,4,5) sweeps per plot. Insecticide applications were made following a treatment protocol. In some treatments (referred to as "density-based" treatments), applications were made whenever a predetermined density of *M. cribraria* was reached within that treatment (averaged across all four replicate blocks) based on sweep-net sampling. These densities were chosen at the beginning of the experiment to reflect the range of densities commonly observed in soybean fields in South Carolina and Georgia in 2011 (N.J.S. unpublished data). Applications in the other treatments were made regularly or at a specific soybean growth stage, regardless of the sampled density of *M. cribraria*. The following core treatments were included in each field trial: 1) untreated control (no insecticide applications); 2) aggressively protected (applications were made weekly [trial SC-1] or every other week [all other experiments] throughout the sampling period); 3) application triggered at a density of one *M. cribraria* per sweep, regardless of life stage ("one per sweep"); 4) application triggered at a density of two *M. cribraria* per sweep, regardless of life stage ("two per sweep"); 5) application triggered at a density of one *M. cribraria* per sweep with at least some nymphs present in the plots ("one per sweep with nymphs"); and 6) a single insecticide application coinciding with the R3 or R4 (varied with trial) soybean growth stage. An additional treatment 7) of an application triggered at a density of one nymph per sweep (regardless of the presence of adults) was included in trials SC-4 and SC-5.

Just prior to harvest, yield component samples were collected from the five SC trials; pods per plant, seeds per pod, and weight per seed were measured from 10 randomly selected plants per plot collected from the center two rows. The center two (GA and NC trials) or four (SC trials) rows of each plot were harvested at full maturity (stage R8) using a two-row small-plot combine. Soybean yield and moisture content were measured, and yields were converted to kg/ha at 13% moisture prior to data analysis. Samples of 1,000 seeds per plot were collected from the trial GA-1, dried in a forced-air oven to standardize moisture, and weighed.

Economic benefits of each treatment were estimated at two hypothetical soybean prices. These prices, $0.4042/kg ($11.00/bushel at 13% moisture) and $0.5512/kg ($15.00/bushel), were chosen to encompass the range of average prices received by growers for soybeans from 2010 to 2012 (United States Department of Agriculture [USDA] Economic Research Service [ERS] 2014). An average insecticide cost of $16.24 (λ-cyhalothrin + thiamethoxam) or $13.55 (bifenthrin) per hectare (based on the average price among six agricultural input dealers in South Carolina in 2013) was added to estimated variable and fixed costs of $13.84 per hectare for operating a self-propelled high clearance sprayer (Clemson University Cooperative Extension [CUCE] 2014) to give a total estimated cost of $30.08 (λ-cyhalothrin + thiamethoxam) or $27.39 (bifenthrin) per hectare per application. For each experimental unit, total application costs per hectare (cost per application × number of applications) were subtracted from the marginal benefit of insecticide applications per hectare (difference in soybean yield between treated and untreated plots, multiplied by soybean price) to give the net marginal benefit of the treatment.

Data Analysis. Only trials in which populations of *M. cribraria* were sufficient to trigger all of the density-based treatments (i.e., 11 of 12 trials) were analyzed. Cumulative insect days, which combine the magnitude and duration of an insect infestation in a single measure (Ruppel 1983), were calculated for adults and nymphs of *M. cribraria* for the duration of sampling in each trial. Briefly, insect days were calculated for each sampling interval as the average density of two consecutive samples multiplied by the number of days between the two samples; insect days were accumulated at each sampling date to give a cumulative total for the season. Because application timing in the density-based treatments depended on the population sampling, trials were combined for analysis based on the number of soybean rows that were sampled. Thus, trials in which sweep samples were taken from a single row (GA trials) were combined, and trials in which samples were taken from two rows (SC and NC trials) were combined. Because applications were triggered based on the mean population across the four replicates in a given trial, individual plots were not truly independent when multiple trials were considered together (as used in Musser et al. 2009). Therefore, the mean of all four replicates of each trial for each response variable was used in combined analyses. Cumulative adult days, cumulative nymph days, yield, net marginal benefit at a soybean price of $0.4042 per kg, net marginal benefit at a soybean price of $0.5512 per kg, and number of applications were analyzed using a generalized linear mixed model (PROC GLIMMIX), with treatment as a fixed effect and trial as a random effect (SAS Institute 2010). Cumulative adult days and cumulative nymph days were analyzed using a Poisson distribution, while yield, net marginal benefits, and number of applications were analyzed using a normal distribution. Because net marginal benefits were calculated by comparison with the untreated control (making the value for the untreated control treatment fixed at zero), the analysis of net marginal benefits did not include the untreated control. Similarly, the analysis of number of applications did not include the untreated control or single application treatments, which had

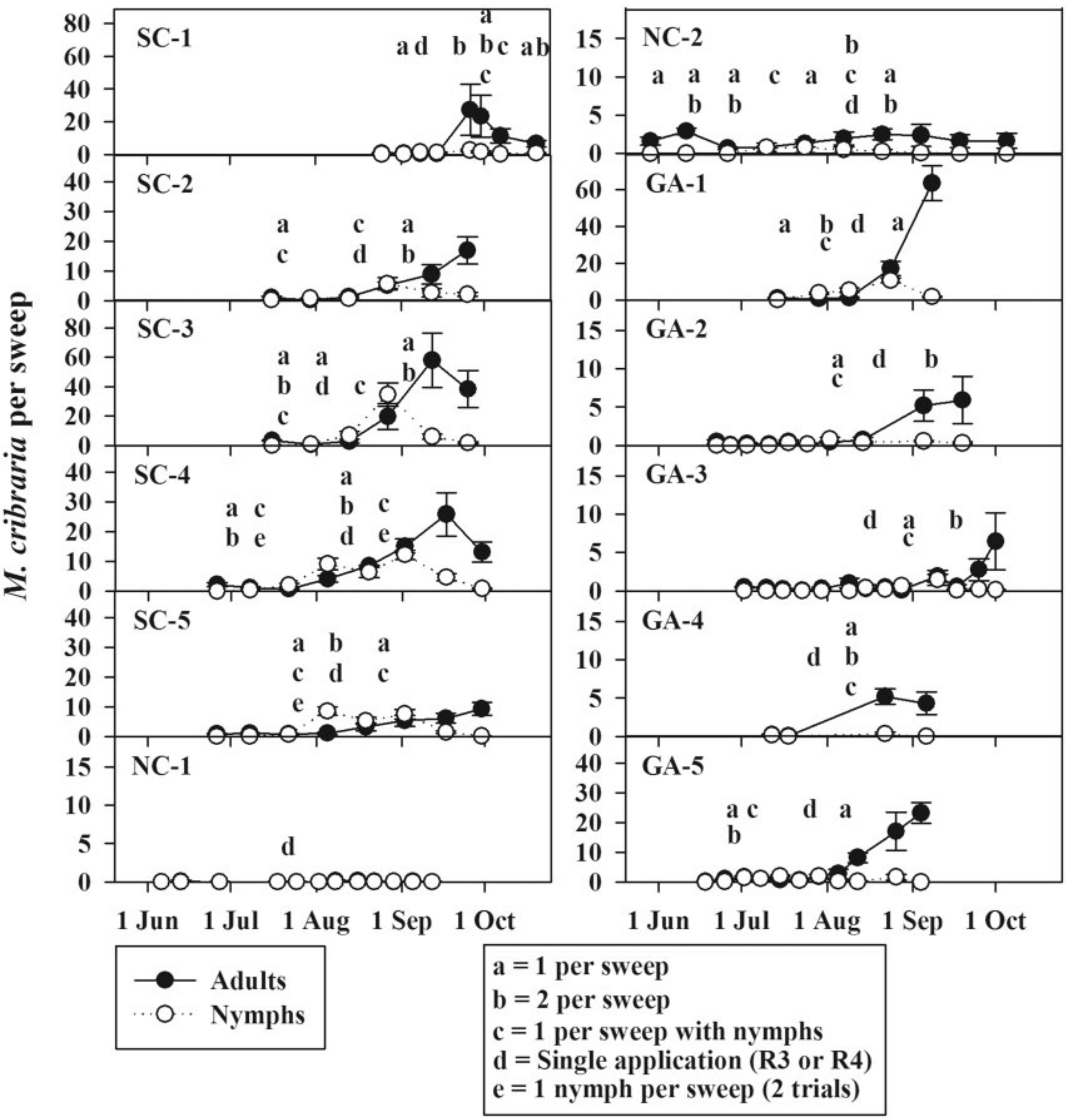

Fig. 1. Abundance of *M. cribraria* in untreated control plots in trials conducted in Georgia, North Carolina, and South Carolina from 2011 to 2013; each plot is an individual trial conducted in a single year. Letters indicate timing of insecticide applications triggered by density of *M. cribraria* or plant growth stage (applications in the aggressively protected plots occurred every other week or weekly [SC-1] and are not indicated).

fixed numbers of applications. Because this combined analysis did not allow testing of the effects of trial (which included location, year, variety, and other factors that likely influenced yield) or the trial by treatment interaction, each trial was also analyzed individually (PROC GLIMMIX). Treatment was the lone fixed effect in these models, and replicate block was included as a random effect. Similar to the combined analyses, cumulative adult days and cumulative nymph days were analyzed using a Poisson distribution, while yield, pods per plant, seeds per pod, seed weight, and net marginal benefits were analyzed using a normal distribution.

Results

Double-Row Sweeps (SC and NC Trials). Populations of *M. cribraria* in trial NC-1 were not sufficient to trigger any of the density-based treatments (Fig. 1), and this trial was excluded from all analyses. All other trials had populations that were sufficient to trigger all density-based treatments at least once (Fig. 1). Peak populations reached a minimum of 2.6 ± 0.6 (SEM) nymphs per sweep and 6.1 ± 1.7 adults per sweep in all SC trials, and none of the other major pests measured exceeded 0.9 ± 0.3 per sweep in these trials (Table 2). Populations of both nymphs and adults were highly influenced by treatment (Table 3), both when

Table 2. Seasonal population peaks of *M. cribraria* and other damaging insect pests in untreated control plots of threshold trials conducted in South Carolina and North Carolina (double-row sweeps) and Georgia (single-row sweeps) from 2011 to 2013

Trial	Mean (±SEM) per sweep across untreated plots at population peak (soybean growth stage in parentheses)							
	M. cribraria		Soybean looper	Corn earworm	Velvetbean caterpillar	Southern green stink bug	Brown stink bug	Green stink bug
	Adults	Nymphs						
SC-1	27.4 ± 15.6 (R6)	2.6 ± 0.6 (R6)	<0.1 (R7)	<0.1 (R2)	0.2 ± 0.1 (R6)	<0.1 (R6)	<0.1 (R6)	0.1 ± 0.1 (R6)
SC-2	17.0 ± 4.5 (R7)	5.7 ± 2.1 (R5)	0.8 ± 0.3 (R7)	0.1 ± 0.1 (R5)	0.6 ± 0.2 (R7)	0.4 ± 0.2 (R7)	0.1 ± 0.1 (R6)	0.1 ± 0.1 (R6)
SC-3	57.9 ± 18.4 (R6)	34.7 ± 8.0 (R6)	0.5 ± 0.2 (R6)	0.2 ± 0.1 (R6)	<0.1 (R6)	0.1 ± 0.1 (R6)	0.1 ± 0.1 (R6)	0
SC-4	25.8 ± 7.2 (R6)	12.2 ± 1.5 (R5)	0.9 ± 0.3 (R5)	0.1 ± 0.1 (R6)	<0.1 (R6)	0.3 ± 0.1 (R7)	0.1 ± 0.1 (R7)	0.2 ± 0.1 (R7)
SC-5	6.1 ± 1.7 (R6)	8.5 ± 1.4 (R2)	0.3 ± 0.1 (R5)	0.1 ± 0.1 (R5)	0.3 ± 0.1 (R5)	0.2 ± 0.1 (R7)	0.1 ± 0.1 (R7)	0.1 ± 0.1 (R7)
NC-1	0.2 ± 0.1[a]	0	—[b]	—	—	—	—	—
NC-2	2.9 ± 0.5 (V6)	1.3 ± 0.8 (R2)	—	—	—	—	—	—
GA-1	63.5 ± 11.0 (R7)	10.6 ± 1.4 (R6)	—	—	—	—	—	—
GA-2	5.9 ± 3.6 (R7)	0.5 ± 0.3 (R2)	—	—	—	—	—	—
GA-3	6.5 ± 4.3 (R7)	1.5 ± 0.8 (R5)	—	—	—	—	—	—
GA-4	5.2 ± 1.1 (R5)	0.4 ± 0.3 (R5)	—	—	—	—	—	—
GA-5	23.3 ± 4.0 (R6)	2.0 ± 0.4 (R3)	—	—	—	—	—	—

[a] Soybean growth stage not available.
[b] Additional insect pests not available from NC or GA trials.

Table 3. Generalized linear mixed model statistics for treatment effect in threshold trials for *M. cribraria* in soybean conducted in South Carolina and North Carolina, with sweep-net samples taken from two soybean rows

Dependent variable	SC-1			SC-2			SC-3			SC-4		
	F	df	*P*	*F*	df	*P*	*F*	df	*P*	*F*	df	*P*
Yield (kg/ha)	1.75	5, 15	0.183	3.17	5, 15	0.038	4.98	5, 15	0.007	1.44	6, 18	0.252
Pods per plant	0.16	5, 15	0.975	1.25	5, 15	0.334	0.68	5, 14	0.649	0.56	6, 18	0.755
Seeds per pod	1.21	5, 15	0.351	6.24	5, 15	0.003	3.79	5, 14	0.022	2.02	6, 18	0.116
Weight (g) per seed	1.15	5, 15	0.379	5.34	5, 15	0.005	13.43	5, 14	<0.001	2.13	6, 18	0.100
Adult days per sweep	322.68	5, 15	<0.001	173.65	5, 15	<0.001	1,209.44	5, 15	<0.001	778.16	6, 18	<0.001
Nymph days per sweep	60.38	5, 15	<0.001	181.70	5, 15	<0.001	598.27	5, 15	<0.001	499.38	6, 18	<0.001
Number of applications	—	—	—	—	—	—	—	—	—	—	—	—
Net marginal benefit (low price)	8.10	4, 12	0.002	2.30	4, 12	0.118	2.88	4, 12	0.070	1.89	5, 15	0.157
Net marginal benefit (high price)	5.42	4, 12	0.010	1.87	4, 12	0.180	2.36	4, 12	0.112	1.27	5, 15	0.328

	SC-5			NC-2			SC and NC trials (combined)		
	F	df	*P*	*F*	df	*P*	*F*	df	*P*
Yield (kg/ha)	0.33	6, 18	0.913	1.38	5, 15	0.285	4.39	5, 25	0.005
Pods per plant	0.98	6, 18	0.466	—	—	—	—	—	—
Seeds per pod	1.17	6, 18	0.364	—	—	—	—	—	—
Weight (g) per seed	0.69	6, 18	0.659	—	—	—	—	—	—
Adult days per sweep	153.88	6, 18	<0.001	23.32	5, 15	<0.001	622.51	5, 25	<0.001
Nymph days per sweep	247.94	6, 18	<0.001	[a]			499.17	5, 25	<0.001
Number of applications	—	—	—	—	—	—	42.44	3, 15	<0.001
Net marginal benefit (low price)	0.56	5, 15	0.726	0.25	4, 12	0.904	3.59	4, 20	0.023
Net marginal benefit (high price)	0.44	5, 15	0.813	0.29	4, 12	0.878	1.75	4, 20	0.179

[a] Model did not converge.

trials were analyzed individually (Table 4) or combined (Fig. 2). (Note: the models did not converge for nymphs in trial NC-2 [Table 3] because there were values of 0 for some treatments across the four replicates [Table 4].) Populations of both nymphs and adults were higher in the untreated control plots than in any of the other treatments in every trial (Table 4).

Treatment dramatically affected the number of insecticide applications (Table 3), and the aggressively protected treatment resulted in greater than double the number of insecticide applications in any of the density-based treatments (Table 5). There were no significant differences in the numbers of applications among density-based treatments. Often, density-based treatments that were triggered early in the season (e.g., before August 1) were triggered one or more subsequent times, while density-based treatments triggered after August 1 were rarely triggered again (Fig. 1). Trial SC-1 was an exception, as a large peak of mostly adults in late September triggered multiple applications in all density-based treatments.

Yield was affected by treatment in only two of the six trials when analyzed individually, but the effect of treatment on yield was highly significant when trials were combined (Table 3). The differences among treatments followed a similar pattern across trials, with the untreated control plots having the lowest yields and few or no differences among the other treatments

Table 4. Populations of adults and nymphs of *M. cribraria* in individual trials conducted in South Carolina and North Carolina (double-row sweeps) and Georgia (single-row sweeps) in cumulative insect days per sweep (mean ± SEM)

Trial	Life stage	Cumulative insect days per sweep						
		Untreated	Aggressively protected	1/sweep	2/sweep	1/sweep w/nymphs	Single appl. (R3/R4)	1 nymph/sweep
SC-1	Adults	403.7 ± 210.7A	74.8 ± 40.6E	90.5 ± 21.7D	133.0 ± 71.0C	177.0 ± 115.3B	97.6 ± 18.4D	—
	Nymphs	52.6 ± 2.7a	1.5 ± 0.8d	2.1 ± 0.7d	28.5 ± 8.8b	2.7 ± 1.5d	6.8 ± 3.9c	—
SC-2	Adults	177.6 ± 44.7A	22.0 ± 7.0E	40.1 ± 13.3CD	129.5 ± 37.8B	33.4 ± 10.3D	47.9 ± 10.1C	—
	Nymphs	129.6 ± 38.2a	5.6 ± 2.6d	10.3 ± 4.3c	141.1 ± 57.2a	6.5 ± 5.1cd	16.9 ± 5.1b	—
SC-3	Adults	831.5 ± 251.1A	62.5 ± 11.4C	59.7 ± 7.2C	77.0 ± 8.6B	75.7 ± 9.2B	54.3 ± 9.3C	—
	Nymphs	679.3 ± 161.1a	5.8 ± 3.7c	5.4 ± 3.0c	39.6 ± 20.7b	3.3 ± 1.3c	6.3 ± 1.0c	—
SC-4	Adults	621.6 ± 94.2A	32.3 ± 3.9F	49.8 ± 6.9E	51.6 ± 5.7DE	62.1 ± 6.7CD	157.1 ± 48.7B	72.2 ± 11.3C
	Nymphs	461.2 ± 35.3a	1.6 ± 0.8f	15.4 ± 7.1e	22.6 ± 10.0d	23.5 ± 6.8d	173.6 ± 71.9b	46.9 ± 19.6c
SC-5	Adults	211.2 ± 61.2A	20.4 ± 1.9F	51.8 ± 5.2E	66.9 ± 8.3CD	57.0 ± 7.9DE	70.7 ± 9.7C	87.9 ± 16.6B
	Nymphs	321.3 ± 40.8a	8.7 ± 7.4e	72.6 ± 39.0d	153.7 ± 42.2b	74.0 ± 56.5d	133.8 ± 24.6c	69.9 ± 35.0d
NC-2	Adults	198.4 ± 45.5A	108.5 ± 18.5D	145.4 ± 25.3C	170.1 ± 25.7B	141.6 ± 12.3C	159.4 ± 17.2BC	—
	Nymphs	34.5 ± 25.5	0.5 ± 0.3	0.0 ± 0.0	0.8 ± 0.3	1.2 ± 0.7	33.7 ± 15.3	—
GA-1	Adults	162.7 ± 28.2A	22.9 ± 1.5C	12.3 ± 3.3D	11.2 ± 3.7D	9.4 ± 1.2D	31.2 ± 9.4B	—
	Nymphs	196.6 ± 23.4a	0.2 ± 0.2d	22.8 ± 7.3c	24.0 ± 2.4c	25.7 ± 2.1c	81.2 ± 19.5b	—
GA-2	Adults	83.9 ± 29.6A	8.3 ± 1.7C	2.9 ± 1.0D	57.5 ± 27.6B	3.2 ± 1.1D	9.1 ± 4.1C	—
	Nymphs	25.3 ± 5.7a	0.2 ± 0.2d	3.3 ± 1.7c	13.1 ± 9.0b	3.5 ± 1.3c	6.4 ± 3.2c	—
GA-3	Adults	43.7 ± 14.2A	18.7 ± 4.7C	16.3 ± 2.3C	28.2 ± 5.2B	21.7 ± 6.2BC	9.2 ± 1.6D	—
	Nymphs	24.8 ± 12.7a	0.7 ± 0.4c	8.4 ± 2.1b	22.7 ± 3.8a	23.0 ± 7.7a	2.5 ± 0.5c	—
GA-4	Adults	164.7 ± 35.3A	5.5 ± 1.4B	8.1 ± 3.1B	7.0 ± 2.4B	9.2 ± 2.7B	8.5 ± 2.5B	—
	Nymphs	9.9 ± 5.1	0.5 ± 0.5	8.7 ± 5.4	3.2 ± 1.3	0.0 ± 0.0	0.4 ± 0.2	—
GA-5	Adults	419.2 ± 139.7A	39.8 ± 11.6DE	90.1 ± 51.5B	54.2 ± 13.7C	35.5 ± 7.3E	45.7 ± 14.5CD	—
	Nymphs	63.9 ± 21.0a	7.1 ± 4.2e	23.6 ± 11.8c	18.7 ± 11.5cd	15.7 ± 6.3d	34.3 ± 13.3b	—

Different letters indicate mean separation (within row; adults uppercase, nymphs lowercase) based on the Fisher method of least significant difference ($\alpha = 0.05$).

(Table 6, Fig. 2). Pods per plant were not affected by treatment in any of the trials in which they were measured (Table 3; data not shown). Seeds per pod were affected by treatment in two of the five trials in which they were measured, and seed weight was affected by treatment in two of the five trials in which it was measured (Table 3). All trials in which one or both of these yield components were affected by treatment also showed significant yield responses to treatment (Table 3). In all of these trials, the untreated control plots were in the lowest mean separation group in terms of numbers of seeds per pod and seed weights (Table 7). Seeds per pod were also reduced in the one per sweep, two per sweep, and single application treatments in trial SC-2 compared with the aggressively protected treatment (Table 7). The single application treatment had lower seed weights than the aggressively protected treatment in trial SC-2 (Table 7).

Net marginal benefit at a soybean price of $0.4042/kg was affected by treatment in only one of the six trials when they were analyzed individually but was affected by treatment when all trials were combined (Table 3). Net marginal benefit at a soybean price of $0.5512/kg was also affected by treatment in one of the six trials when analyzed individually but was not affected when trials were combined (Table 3). In trial SC-1 (the only individual trial in which net marginal benefits were affected), the aggressively protected treatment had the lowest net marginal benefit at both prices. The two per sweep treatment and the one per sweep with nymphs treatment had net marginal benefits that were reduced compared with the single application treatment at a soybean price of $0.4042 (Table 8). At a soybean price of $0.5512, the two per sweep treatment was reduced compared with the one per sweep treatment, the one per sweep with nymphs treatment, and the single application treatment. When trials were combined, the aggressively protected treatment had the lowest net marginal benefit at $0.4042/kg, while all density-based treatments and the single application treatment had higher net marginal benefits that were not statistically different from each other (Fig. 2).

Single-Row Sweeps (GA Trials). All of the trials that used single-row sweep net sampling had densities of *M. cribraria* that were sufficient to trigger all of the density-based treatments (Fig. 1). Populations of both nymphs and adults were highly influenced by treatment (Table 9), both when trials were analyzed individually (Table 4) or combined (Fig. 3). (Note: the models did not converge for nymphs in trial GA-4 [Table 9] because there were values of 0 for some treatments across the four replicates [Table 4].) Populations of both nymphs and adults were higher in the untreated controls than in any of the other treatments in every trial (Table 4).

Treatment dramatically affected the number of insecticide applications (Table 9), and the aggressively protected treatment resulted in greater than triple the number of applications in any of the density-based treatments (Table 5). As with the trials that used double-row sweeps, there was no statistical separation in the number of applications among the density-based treatments. In the trials that used single-row sweeps, only the one per sweep treatment was ever triggered more than once.

Yield was affected by treatment in four of the five trials when analyzed individually, and this effect was significant when trials were combined (Table 9). When

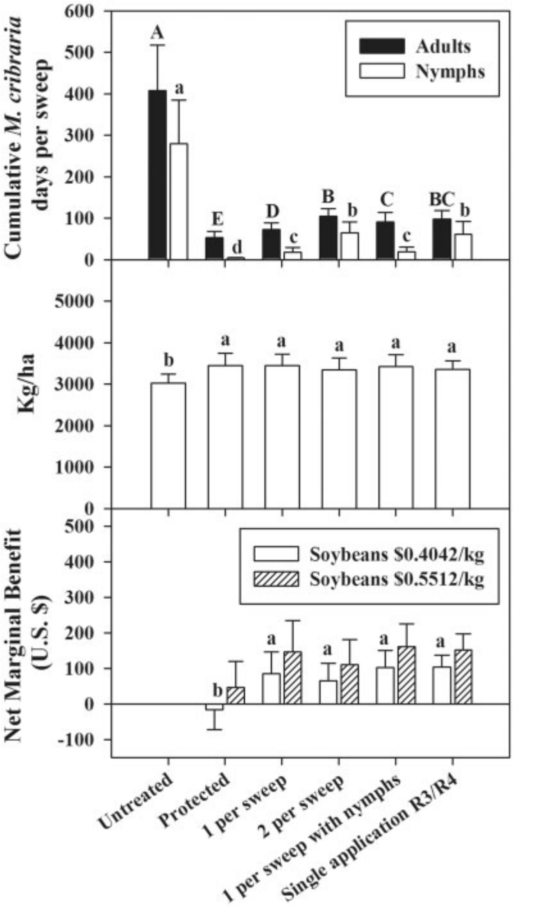

Fig. 2. Cumulative density, yield, and net marginal benefits for the SC and NC trials from 2011 to 2013 (averaged across years and locations). Population sampling of *M. cribraria* was conducted using sweep nets across two rows of soybean plants. Different letters above a column (adults uppercase, nymphs, yield, and net marginal benefits lowercase) indicate mean separation based on the Fisher method of LSD at α = 0.05.

Table 5. Number of insecticide applications (mean ± SEM) by treatment from 2011 to 2013 (averaged across years)

Treatment	SC and NC trials (double-row sweep)	GA trials (single-row sweep)
Aggressively protected	6.3 ± 0.5 a	6.8 ± 0.4 a
1 per sweep	2.8 ± 0.5 b	1.4 ± 0.2 b
2 per sweep	2.2 ± 0.5 b	1.0 ± 0.0 b
1 per sweep with nymphs	2.2 ± 0.2 b	1.0 ± 0.0 b

Treatments with a fixed number of applications (untreated control and single application at R3/R4) were excluded from analysis. Different letters indicate mean separation (within column) based on the Fisher method of least significant difference (α = 0.05).

trials were combined, yield in the untreated control was lower than in all other treatments (except for the one per sweep with nymphs treatment, which could not be distinguished from any of the other treatments) (Fig. 3). When the trials were analyzed individually, the untreated control was always in the lowest yielding treatment group (Table 6); differences among the other treatments were inconsistent, with every treatment at times being indistinguishable from the untreated control. Seed weight was affected by treatment in trial GA-1 (Table 9); the untreated control had the lowest seed weights, while the two per sweep and one per sweep with nymphs treatments had lower seed weights than the one per sweep treatment.

Net marginal benefits were not affected by treatment at either soybean price when the trials using single-row sweeps were combined (Table 9). When the trials were analyzed individually, net marginal benefits were affected by treatment in three of the five trials at a soybean price of $0.4042 and in two of the five trials at a soybean price of $0.5512 (Table 9). At a soybean price of $0.4042, the untreated control was always among the treatment group with the lowest net marginal benefits (Table 8). The single application treatment had among the highest net marginal benefits at both soybean prices in every trial in which the effect of treatment was significant (Table 8).

Discussion

All density-based treatments evaluated, as well as a single application timed at the R3 or R4 soybean growth stages, were sufficient to prevent soybean yield loss due to feeding by *M. cribraria* based on comparison with repeated applications (5–8 in the aggressively protected treatment). These results suggested that a single insecticide application would have been sufficient to prevent yield loss by *M. cribraria* at the densities observed in these trials. The densities evaluated in the GA trials were effectively higher than those tested in the SC and NC trials because the individual sweeps that the treatments were based on sampled less foliage (a single row compared with two rows). However, the yield relationships among treatments in the GA trials were equivalent to those in the SC and NC trials, with no significant reductions in yield among the density-based treatments.

The effectiveness of a single insecticide application in controlling *M. cribraria* was underscored by the elevated net marginal benefits observed in the single application timed at R3 or R4, as well as the two per sweep density and the density of one per sweep with nymphs present. These two densities typically resulted in one or two insecticide applications. The currently recommended preliminary threshold of one nymph per sweep (Greene et al. 2012) was evaluated in two trials, resulting in a single application in one trial and two applications in the other trial. However, yield could not be differentiated among treatments in either trial. Although the effects of treatment on net marginal benefits were not as apparent or consistent as the effects on population or yield, it is reasonable to assume that a single application is economically preferable to multiple applications if the additional applications have no yield advantage.

Seeds per pod and seed weight were different among treatments in several trials, and these trials also

Table 6. Soybean yield at 13% moisture content in kg/ha (mean ± SEM) for individual trials conducted in South Carolina and North Carolina (double-row sweeps) and Georgia (single-row sweeps)

Trial	Untreated	Aggressively protected	1 per sweep	2 per sweep	1 per sweep w/nymphs	Single application (R3/R4)	1 nymph per sweep
SC-1	2,172 ± 122	2,282 ± 121	2,478 ± 138	2,290 ± 141	2,329 ± 191	2,486 ± 111	—
SC-2	3,622 ± 175 b	4,049 ± 88 a	3,807 ± 119 ab	3,785 ± 59 ab	4,008 ± 72 a	3,932 ± 62 a	—
SC-3	2,882 ± 110 b	3,456 ± 236 a	3,780 ± 96 a	3,485 ± 175 a	3,419 ± 197 a	3,575 ± 325 a	—
SC-4	3,432 ± 112	3,768 ± 167	3,661 ± 146	3,669 ± 32	3,854 ± 117	3,505 ± 118	3,590 ± 153
SC-5	2,810 ± 289	2,988 ± 144	2,691 ± 113	2,726 ± 389	2,889 ± 325	3,048 ± 136	2,832 ± 92
NC-2	3,240 ± 282	4,159 ± 239	4,235 ± 571	4,100 ± 41	4,065 ± 319	3,589 ± 427	—
GA-1	2,460 ± 234 b	3,385 ± 105 a	3,357 ± 111 a	3,167 ± 76 a	3,259 ± 166 a	3,437 ± 68 a	—
GA-2	4,267 ± 144 c	4,567 ± 130 ab	4,348 ± 108 c	4,455 ± 50 abc	4,555 ± 46 abc	4,725 ± 50 a	—
GA-3	2,801 ± 98	2,981 ± 108	2,842 ± 53	2,785 ± 71	2,899 ± 75	2,861 ± 66	—
GA-4	4,926 ± 132 b	5,356 ± 92 a	4,988 ± 82 b	5,400 ± 129 a	4,751 ± 293 b	5,506 ± 138 a	—
GA-5	3,451 ± 283 c	4,788 ± 88 a	4,380 ± 165 ab	4,308 ± 317 ab	4,095 ± 306 abc	3,721 ± 400 bc	—

Different letters indicate mean separation (within row) based on the Fisher method of least significant difference (α = 0.05).

Table 7. Soybean seeds per pod and seed weight (wt.) expressed as the weight (g) per 1,000 seeds

Trial	Variable	Untreated	Aggressively protected	1 per sweep	2 per sweep	1 per sweep w/nymphs	Single application (R3/R4)	1 nymph per sweep
SC-1	Seeds/pod	1.91 ± 0.07	2.09 ± 0.12	1.96 ± 0.04	1.88 ± 0.08	2.03 ± 0.03	1.92 ± 0.08	—
	Seed wt.	112 ± 7	125 ± 3	121 ± 3	122 ± 8	119 ± 2	124 ± 2	—
SC-2	Seeds/pod	2.07 ± 0.03BC	2.19 ± 0.02 A	2.11 ± 0.03 B	2.01 ± 0.02 C	2.12 ± 0.02 AB	2.09 ± 0.04 B	—
	Seed wt.	129 ± 3 c	145 ± 2 a	139 ± 2 ab	143 ± 4 a	141 ± 2 ab	134 ± 3 bc	—
SC-3	Seeds/pod	2.21 ± 0.02 B	2.34 ± 0.01 A	2.35 ± 0.06 A	2.36 ± 0.03 A	2.39 ± 0.02 A	2.31 ± 0.02 A	—
	Seed wt.	135 ± 1 b	166 ± 4 a	164 ± 2 a	159 ± 3 a	161 ± 2 a	158 ± 5 a	—
SC-4	Seeds/pod	1.79 ± 0.02	1.90 ± 0.04	1.80 ± 0.03	1.83 ± 0.01	1.82 ± 0.02	1.86 ± 0.04	1.77 ± 0.04
	Seed wt.	174 ± 7	170 ± 8	175 ± 4	171 ± 5	178 ± 5	159 ± 7	176 ± 4
SC-5	Seeds/pod	1.78 ± 0.07	1.92 ± 0.06	1.88 ± 0.03	1.94 ± 0.05	1.90 ± 0.04	1.87 ± 0.04	1.85 ± 0.03
	Seed wt.	142 ± 10	158 ± 6	142 ± 7	151 ± 7	148 ± 5	147 ± 8	150 ± 4
GA-1	Seed wt.	100 ± 0.4 c	121 ± 0.4 ab	124 ± 2 a	117 ± 3 b	116 ± 3 b	120 ± 3 ab	—

Weights from the SC trials (double-row sweeps) were measured at harvest moisture, while weights for trial GA-1 (single-row sweeps) were determined after drying in a forced-air oven. Different letters indicate mean separation (within row; seeds/pod uppercase, seed wt. lowercase) based on the Fisher method of least significant difference (α = 0.05).

Table 8. Net marginal benefits in US dollars (mean ± SEM) at soybean prices of $0.4042 or $0.5512 for individual trials conducted in South Carolina and North Carolina (double-row sweeps) and Georgia (single-row sweeps)

Trial	Price/kg	Aggressively protected	1 per sweep	2 per sweep	1 per sweep w/ nymphs	Single application (R3/R4)	1 nymph per sweep
SC-1	$0.4042	−196 ± 36 C	33 ± 51 AB	−42 ± 60 B	−27 ± 39 B	97 ± 56 A	—
	$0.5512	−178 ± 49 c	78 ± 69 ab	−25 ± 82 bc	−4 ± 53 ab	143 ± 76 a	—
SC-2	$0.4042	22 ± 72	15 ± 69	36 ± 55	96 ± 92	95 ± 65	—
	$0.5512	85 ± 98	42 ± 94	60 ± 75	153 ± 126	141 ± 89	—
SC-3	$0.4042	82 ± 121	273 ± 52	184 ± 75	157 ± 79	250 ± 135	—
	$0.5512	166 ± 166	405 ± 71	272 ± 103	236 ± 107	352 ± 184	—
SC-4	$0.4042	−75 ± 39	33 ± 32	36 ± 47	140 ± 73	−1 ± 92	34 ± 75
	$0.5512	−25 ± 53	66 ± 44	71 ± 64	202 ± 100	10 ± 126	57 ± 102
SC-5	$0.4042	−108 ± 117	−108 ± 111	−64 ± 174	−28 ± 173	66 ± 152	−21 ± 123
	$0.5512	−82 ± 159	−126 ± 152	−76 ± 237	−16 ± 236	101 ± 208	−18 ± 168
NC-2	$0.4042	180 ± 208	265 ± 276	238 ± 129	279 ± 94	114 ± 188	—
	$0.5512	315 ± 284	411 ± 377	364 ± 176	400 ± 128	165 ± 256	—
GA-1	$0.4042	193 ± 112	302 ± 112	256 ± 68	293 ± 84	365 ± 98	—
	$0.5512	329 ± 152	434 ± 153	360 ± 92	410 ± 114	509 ± 133	—
GA-2	$0.4042	−89 ± 62 C	3 ± 86 BC	46 ± 42 B	86 ± 75 AB	155 ± 76 A	—
	$0.5512	−45 ± 85 c	15 ± 117 bc	74 ± 57 bc	129 ± 102 ab	222 ± 104 a	—
GA-3	$0.4042	−168 ± 27 B	−14 ± 41 A	−36 ± 44 A	9 ± 57 A	−6 ± 26 A	—
	$0.5512	−141 ± 37	−8 ± 55	−39 ± 60	24 ± 78	3 ± 35	—
GA-4	$0.4042	−7 ± 87 B	−5 ± 70 B	205 ± 35 A	−101 ± 11 B	161 ± 34 A	—
	$0.5512	57 ± 119 ab	4 ± 95 b	290 ± 47 a	−126 ± 15 b	231 ± 47 a	—
GA-5	$0.4042	330 ± 98	315 ± 90	316 ± 45	230 ± 195	79 ± 94	—
	$0.5512	526 ± 133	452 ± 122	442 ± 61	325 ± 266	119 ± 128	—

Different letters indicate mean separation (within row; $0.4042 uppercase, $0.5512 lowercase) based on the Fisher method of least significant difference (α = 0.05).

Table 9. Generalized linear mixed model statistics for treatment effect in threshold trials for *M. cribraria* in soybean conducted in Georgia, with sweep-net samples taken from a single soybean row

Dependent variable	GA-1			GA-2			GA-3			GA-4		
	F	df	*P*	*F*	df	*P*	*F*	df	*P*	*F*	df	*P*
Yield (kg/ha)	7.16	5, 15	0.001	2.90	5, 15	0.050	1.08	5, 15	0.411	5.38	5, 11	0.010
Seed dry weight (g)	29.25	5, 15	<0.001	—	—	—	—	—	—	—	—	—
Adult days per sweep	219.81	5, 15	<0.001	99.60	5, 15	<0.001	22.52	5, 15	<0.001	232.40	5, 15	<0.001
Nymph days per sweep	196.63	5, 15	<0.001	23.99	5, 15	<0.001	21.52	5, 15	<0.001	[a]		
Number of applications	—	—	—	—	—	—	—	—	—	—	—	—
Net marginal benefit (low price)	1.79	4, 12	0.196	6.82	4, 12	0.004	6.88	4, 12	0.004	5.09	4, 8	0.025
Net marginal benefit (high price)	1.16	4, 12	0.374	4.66	4, 12	0.017	3.04	4, 12	0.060	4.68	4, 8	0.031

	GA-5			GA trials (combined)		
	F	df	*P*	*F*	df	*P*
Yield (kg/ha)	4.23	5, 15	0.013	3.37	5, 20	0.023
Seed dry weight (g)	—	—	—	—	—	—
Adult days per sweep	550.18	5, 15	<0.001	285.57	5, 20	<0.001
Nymph days per sweep	49.61	5, 15	<0.001	74.74	5, 20	<0.001
Number of applications	—	—	—	161.27	3, 12	<0.001
Net marginal benefit (low price)	1.10	4, 12	0.399	1.00	4, 16	0.435
Net marginal benefit (high price)	1.35	4, 12	0.307	0.40	4, 16	0.808

[a] Model did not converge.

exhibited differences in yield. Reductions in these yield components were consistent with reductions that occurred when *M. cribraria* were artificially confined to soybean plots (Seiter et al. 2013b) and are indicative of stress during seed formation and pod fill. Reductions in these yield components generally mirrored reductions in yield, as the untreated control plots were reduced in every case. However, reductions in seeds per pod and seed weight were also observed among density-based treatments in two of these trials. Although these reductions among density-based treatments could be a reflection of reductions in yield that were too subtle to be picked up by our analysis, they only occurred in two of the six trials in which these components were measured. Yields were also reduced among density-based treatments in several trials when they were analyzed individually, but when all trials were considered together only the untreated controls had reduced yields.

Adult movement, though not directly evaluated here, appears to be a key factor in successful management of *M. cribraria*. Insecticide applications in the density-based treatments were often triggered multiple times when the initial trigger occurred early in the season, largely due to the continuing immigration of adults into the trials. Such movement into soybean fields can lead to greater densities of adults and nymphs along the edges (Seiter et al. 2013a). Insecticide applications targeting nymphs appear to be less vulnerable to repeated infestation based on our observations from field situations and multiple experimental trials in addition to this study. This is apparently due to seasonal variation in the population densities and flight activity levels of adults. Furthermore, development of nymphs is associated with soybean yield losses (Seiter et al. 2013b). Because of these factors, insecticide applications targeting the nymphs are likely to provide a longer duration of effective control. Future studies should test the current recommendation of one nymph per sweep along with higher thresholds based on nymphs alone or nymphs and adults.

Sweep-net sampling effectiveness can vary depending on factors such as environmental conditions, time of day, insect density (Schotzko and O'Keeffe 1989), and the individual conducting the sampling (Cothran et al. 1975). Sweep-net sampling of *M. cribraria* is biased toward adults and late instars (Seiter et al. 2013a), which could be problematic for pest management decision making considering the apparent importance of nymphs for management. Combining sweep-net sampling with visual examination of plants for nymphs could improve the accuracy of sampling. Another option is beat-cloth sampling. This method is more cost reliable than sweep-net sampling for pest management (Stubbins et al. 2014). However, it is not suitable for narrow-row soybeans (Pitre et al. 1987) and is also likely to underestimate the density of early instars due to their small size.

Our combined analysis of multiple trials was an attempt to account for the inherent variability in soybean yields among different trial locations due to a variety of agronomic and environmental factors. Different varieties were used among the trials, and weather, soil, and other environmental conditions varied, leading to inherent differences in yield potential. Because our experimental design did not allow testing of trial and the trial by treatment interaction as fixed effects in the combined analyses, we also analyzed the trials individually. Using this approach, no significant yield differences were observed among the treatments in 5 of the 12 trials. Overall densities of *M. cribraria* were highly variable among trials, and higher densities were often associated with yield differences among treatments. Underscoring the inherent variability in soybean yield,

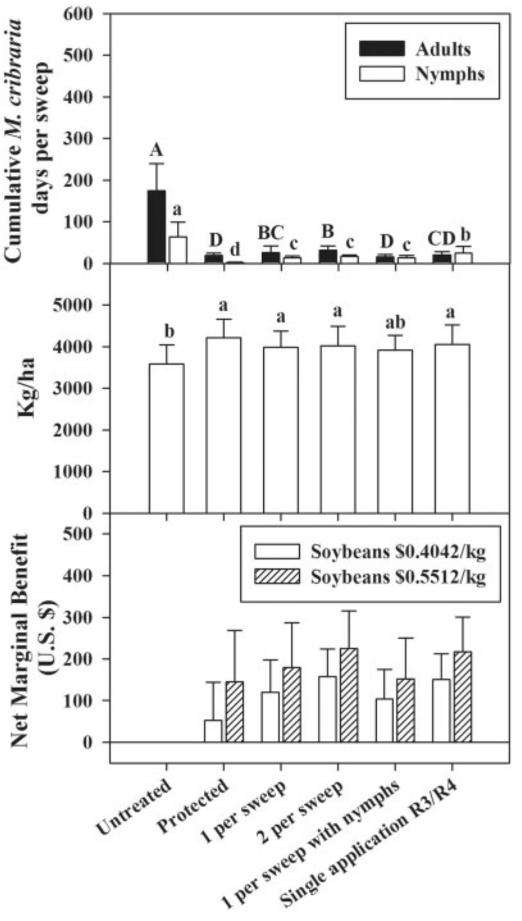

Fig. 3. Cumulative density, yield, and net marginal benefits for the GA trials from 2011 to 2013 (averaged across years and locations). Population sampling of *M. cribraria* was conducted using sweep nets across a single row of soybean plants. Different letters above a column (adults uppercase, nymphs and yield lowercase) indicate mean separation based on the Fisher method of least significant difference (LSD) at $\alpha = 0.05$.

trial GA-4 had yield differences among the three density-based treatments even though they were triggered only once on the same day. Another consideration is that the range of density-based treatments we evaluated might have been too low to allow population densities of *M. cribraria* to reach damaging levels. Although all densities were reached in every trial (except for NC-1, which had populations that were insufficient to trigger any density-based treatment and was excluded from analysis), yield differences among the density-based treatments were only rarely observed. This suggests that the true economic threshold for *M. cribraria* in soybean could be higher than those tested here.

Several other pests in addition to *M. cribraria* are important throughout the southeastern United States and could have played a role in reducing soybean yields in some of these trials. The insecticides used in our studies have a broad spectrum, affecting many of the pest and beneficial insects that might have been present (e.g., Baur et al. 2003, Snodgrass et al. 2005, Kamminga et al. 2009). Populations of these insects were likely coincidentally reduced by applications targeting *M. cribraria*, potentially contributing to yield differentiation among treatments. This is representative of field situations, where a single pest species is accompanied by a complex of pest, beneficial, and innocuous insect species and insecticide applications rarely (if ever) affect only the target insect (Tillman and Mulrooney 2000, Macfadyen and Zalucki 2012). Overall, the populations of other pests measured during sweep-net sampling in the SC trials were relatively low; only stink bugs ever exceeded the sweep-net threshold that is recommended for soybeans in South Carolina (1–2 per 10 sweeps; Greene 2013). Where several pest species cause the same or similar types of damage to the plant, they can be incorporated into action thresholds (e.g., hemipteran pests of cotton in the midsouthern United States; Musser et al. 2009). However, as a vascular fluid feeder of the stems, the mechanism of feeding damage caused by *M. cribraria* is unique among damaging soybean pests in the southeastern United States, and the thresholds we evaluated only included *M. cribraria*.

In conclusion, all density-based treatments evaluated were equivalent in protecting soybean yield from losses due to *M. cribraria*. Our results suggest that thresholds of one per sweep with nymphs present, two per sweep regardless of life stage, or one nymph per sweep regardless of adult presence all have potential to be used cost-effectively in commercial situations for management of *M. cribraria*. Although the lack of differences in yield that we observed among treatments suggests the true economic threshold could be higher than those tested here, higher threshold levels must be evaluated in field trials before we can recommend them for management. The currently recommended preliminary threshold of one nymph per sweep (Greene et al. 2012), while only tested explicitly in two trials, resulted in one or two insecticide applications with no yield reduction (however, no yield differences among treatments were observed in these trials). The consistent effectiveness of a single insecticide application at the R3 or R4 soybean growth stages suggests that additional applications that occurred in many of the density-based treatments were unnecessary. An elevated threshold for subsequent applications after the initial threshold has been reached could address this, but a single, well-timed insecticide application would have prevented yield losses in all trials at the densities of *M. cribraria* we observed. Because the development of nymphs is associated with soybean yield losses (Seiter et al. 2013b) and only one of the two generations of *M. cribraria* generally occurs in soybeans (Seiter et al. 2013a), targeting a single insecticide application with the occurrence of nymphs should prevent soybean yield losses due to *M. cribraria* in most cases.

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