Relationship Between Soybean Maturity Group and the Phenology and Abundance of Stink Bugs (Heteroptera: Pentatomidae): Impact on Yield and Quality[1]

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ABSTRACT Soybean, *Glycine max* (L.) Merrill, varieties in maturity groups IV-VIII were sampled weekly for stink bugs from mid-June to mid-October in 1993 and 1994. Plots were either treated with tralomethrin to control stink bugs or left untreated to measure yield and seed quality losses to the pests. In 1993, stink bug populations peaked at 8.3 per 25 sweeps in the Group IV NK S4884 in late-August, 6 wks after the R_4 growth stage (full pod without seeds). As they were declining in the Group IV soybean, populations were rapidly increasing in the later-maturing varieties, reaching population peaks 5 to 6 wks after R_4 in all maturity groups. Population peaks in the later-maturing varieties were higher than in the maturity groups IV and V. Similar seasonal population distributions were observed in 1994, although populations peaked 4 to 6X higher than in 1993. Both *Nezara viridula* (L.) and *Acrosternum hilare* (Say) were common in 1993 when populations were relatively low. In 1994, *N. viridula* was the most abundant species. *Euschistus servus* (Say) was present at low population densities both years. Tralomethrin treatments significantly decreased the stink bug damage to seeds. Seed weights and yield also were higher in the treated plots of most varieties. Significant correlations occurred for stink bug population peaks with percentage kernel damage, yield reductions and 100-seed weight reductions.

KEY WORDS Soybean, *Nezara viridula, Acrosternum hilare, Euschistus servus,* population dynamics, economic injury.

The stink bug complex on soybean, *Glycine max* (L.) Merrill, significantly reduces yield and quality, particularly in the southern United States (Jensen and Newsom 1972, McPherson et al. 1979, McPherson et al. 1995a). This pest complex is an annual economic threat in Georgia costing soybean producers over $13 million in chemical control and crop losses in some years (Douce and McPherson 1991). Stink bugs can damage soybean from the time of early pod-fill until harvest (Minor 1966). Feeding results in discolored and shriveled seeds, reduced seed germination, transmission of certain pathogens, and reduced yield (McPherson et al. 1995b). Stink bugs feed preferentially on soybean seeds in the upper half of the plant until high populations develop (Russin et al. 1987). Seeds with no stink bug injury have higher seed weights than damaged seeds (McPherson et al. 1979).

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The stink bug complex occurring on soybean in the United States consists primarily of the southern green stink bug, *Nezara viridula* (L.), the brown stink bug, *Euschistus servus* (Say), and the green stink bug, *Acrosternum hilare* (Say) (McPherson et al. 1995b). However, when stink bug-related damage occurs on Georgia soybean, it usually results from high populations of *N. viridula*, while *A. hilare* and *E. servus* remain relatively low from year to year (McPherson et al. 1993).

Stink bug populations increase on soybean as pods begin to fill with seeds; peaks occur in the fall as the crop begins to mature (McPherson et al. 1993). Stink bugs can be attracted to small plantings of early-maturing soybean (i.e., trap crop) and controlled before they infest a major planting of later-maturing soybean (McPherson and Newsom 1984). However, in Georgia, there is a wide range of maturity groups of soybeans being planted, primarily Group V-VIII (Adams 1987). The maturity grouping for each variety is determined by the daylength required to stimulate flowering and maturity. The earlier-maturing varieties require longer daylengths (Teare and Hodges 1995). Interest in planting earlier varieties of Group IV has increased in Georgia in recent years (Woodruff 1995). It is doubtful that a trap crop will remain effective all season long in fields planted with varieties representing a wide range of maturity groups. Also, the impact of such a wide range in the physiological/phenological plant characteristics (date of blooming and date of setting pods) on immigrating stink bug pests is not fully understood.

A better understanding of the phenology of stink bugs on different maturity group soybeans, and the resultant yield and quality losses in these soybeans, would allow for improved predictions of when and where economically-damaging populations will occur. This information would also improve the decision guidelines for management of these pests. Thus, this study was undertaken to determine the seasonal abundance of stink bugs in maturity group IV-VIII soybeans, to determine if peak populations are associated with certain phenological plant responses, and to compare the yield and quality responses of these soybeans when infested with stink bugs.

Materials and Methods

'Northrup King S4884' (Group IV), 'Essex' (Group V), 'Davis' (Group VI), 'Braxton' (Group VII), and 'Cobb' (Group VIII) soybeans were planted in field plots at the Bowen Research Farm in Tift Co., GA, on 8 June 1993 and 17 June 1994. These dates are within the ideal planting time for soybean production in south Georgia (Adams 1987). Plots were 12 rows wide (0.9 m row spacing) by 60 m long and planted in a randomized block design with 4 replications, with 1.8 m alleys between adjacent replications. The fields were conventionally moldboard plowed and a pre-plant tank mix of pendimethalin (American Cyanamid, Wayne, NJ) at 2.4 L/ha and vernolate (Drexel Chemical Co., Memphis, TN) at 2.7 L/ha was incorporated with a tillivator into the soil for grass and broadleaf weed control. No insecticides were applied in 1993 because stink bug populations were low. In 1994, each plot was split and 6 rows were treated with tralomethrin (Roussel Uclaf, Montvale, NJ) at 0.026 kg AI/ha on 22 August and 6 rows were left untreated. The tralomethrin was applied with a CO_2-powered backpack sprayer with four TX-12 nozzles on a 1.8-m boom (2 nozzles per row) at 276 kPA (40 psi) that delivered 161.5 L/ha. The Davis, Braxton, and Cobb plots were treated a second time on 5 September because of pest insect occurrence on these later-maturing varieties.

All plots were sampled every 6 to 10 days, from mid-June to mid-October using a standard 38-cm diam sweep net (25 sweeps per plot) (Kogan and Pitre 1980). The number of adults and nymphs of each stink bug species was recorded on each sampling date and the mean number per 25 sweeps on each sampling date was plotted on a seasonal distribution curve. The plant phenological growth stage also was determined on each date using guidelines established by Fehr and Caviness (1977). All plots were harvested with a small plot combine for yield and seed quality evaluations. Seeds from four random 100 seed samples per plot were individually examined and categorized as having either light, moderate, heavy or no stink bug damage (McPherson et al. 1979). The percent damaged seeds and weights of 100 seeds were determined.

Data were analyzed by analysis of variance ($P = 0.05$), and means were separated by the Least Significant Difference. Data from the treated and untreated plots for each variety were compared using a paired t-test (SAS Institute 1985). A general linear model (PROC GLM, SAS Institute 1985) was used to analyze the overall linear relationship between the peak stink bug population and the percentage of total damaged kernels, percentage of moderate plus heavy damaged kernels, yield reductions, and 100-seed weight reductions.

Results and Discussion

The seasonal distribution of adult and nymphal stink bugs in soybean varieties from five maturity groups is presented in Fig. 1a. Stink bugs peaked in the Group IV NK S4884 variety at 8.3 per 25 sweeps on 24 August, 2 months after this variety was in full bloom (R_2 development) and 6 wks after the full pod stage (R_4 development). Populations were very low in the other varieties on this date, except the Group V Essex in which the populations had suddenly risen from 0.6 per 25 sweeps on 17 August to 6.7 per 25 sweeps on 24 August, nearly 5 wks after the R_4 stage of plant development. As the stink bug populations declined in the NK S4884 variety in late August and early September, due to plant senescence, populations increased in the Group V-VIII entries. All these entries had full pods by this time, although the Group VIII entry had reached this stage on 24 August. Populations peaked in the Essex plots on 14 September at 9.3 stink bugs per 25 sweeps, 7 wks after the R_4 stage was reached. The Essex plants were almost at harvest maturity on this date and no further samples taken. The Group VI Davis and Group VII Braxton also had peak stink bug populations on 14 September, with a density of 8.0 and 7.2 stink bugs per 25 sweeps, respectively, 6 and 5 wks after R_4 development. The Group VIII entry, Cobb had the highest stink bug populations. They occurred late in the season as the other entries were maturing, peaking at 10.8 per 25 sweeps on 29 September, 5 wks after R_4 development, and remaining relatively high until 13 October.

The green stink bug was the most numerous species in the Groups IV-VI varieties in 1993 during the early part of the season, when overall populations

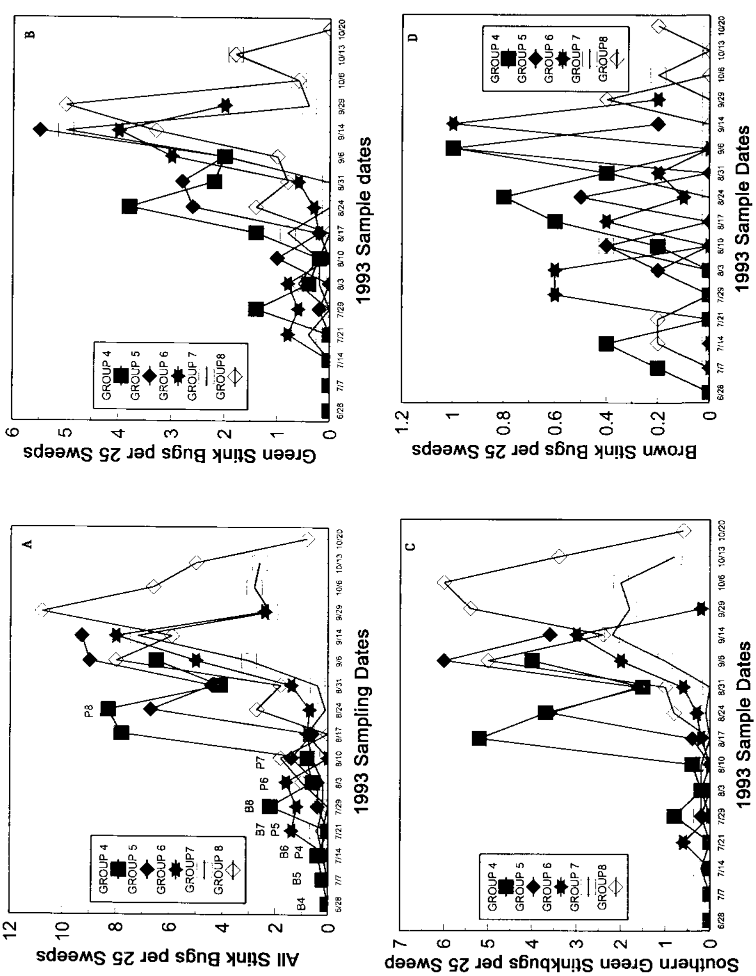

Fig. 1. Seasonal distribution of stink bugs (1a), green stink bugs (1b), southern green stink bugs (1c), and brown stink bugs (1d) on soybeans in maturity groups IV-VIII, 1993. The 'B' above certain points identifies the date that each maturity group (4-8) was in full bloom while the 'P' indicates the date that each maturity group (4-8) had full pods without seeds.

were low (Fig. 1b). From mid-August through mid-October, both the southern green and green stink bugs were commonly collected (Fig. 1b and 1c). Brown stink bugs were in low numbers throughout the season in all five varieties and their presence was very sporadic (Fig. 1d).

Stink bug populations were much higher in 1994 (Fig. 2a). Although populations were low during June and July, by mid-August there were 18.4 stink bugs per 25 sweeps in the Group IV NK S4884, 5 wks after the R_4 development was reached. They peaked in NK S4884 on 31 August at 26.4 bugs per 25 sweeps, 7 wks after R_4. However, stink bug populations also peaked in the Group V Essex on this date at 32.8 per 25 sweeps, 6 wks after this variety reached the R_4 stage of development. The stink bug population peak in the Group VI Davis occurred 9 days later, on 8 September, at 52.3 per 25 sweeps, 4.5 wks after R_4. The peak in the Group VII Braxton occurred on 16 September at 52.0 stink bugs per 25 sweeps, (5.5 wks after R_4 development), while they peaked in the Group VIII Cobb on 26 September at 41.5 per 25 sweeps (4½ weeks after R_4 development).

Overall, the green stink bug populations were higher in 1994 than in 1993, with the highest populations occurring in the Group IV NK S4884 on 31 August (10.8 per 25 sweeps) and the Group VI Davis (15.8 per 25 sweeps) on 8 September (Fig. 2b); however, populations were low in all varieties until late August. The southern green stink bug was the most abundant species in 1994 (Fig. 2c), reaching population densities of 34.5, 43.5, and 35.2 per 25 sweeps in the Group VI, VIII, and VII varieties, respectively. Brown stink bugs also were more numerous in 1994 (Fig. 2d), increasing in the Group V Essex during August and peaking at 3.0 per 25 sweeps on 8 September. Population peaks in the Group VII and VIII varieties were 2.0 and 2.5, respectively.

The seasonal stink bug peak population density occurred around 4 to 6 wks after the plants had full pods that were not beginning to fill with seeds (R_4 stage), regardless of the Maturity Group. Because the early-maturing varieties (Group IV and V) began flowering and setting pods earlier, they had full pods earlier in the season than the other varieties, but the peak stink bug population still occurred around 4 to 6 wks after the R_4 stage was reached. Thus, extensive field monitoring for stink bugs should begin at around R_4 stage of development, even though stink bug populations are low, because they will rapidly increase in the subsequent 4 to 6 wks before reaching their peak population densities.

The low stink bug population densities in 1993 caused some seed injury in all five of the varieties examined (Table 1). The Group IV NK S4884 and Group V Essex had significantly more heavily damaged kernels than the other entries. The Group IV variety also had more moderate seed damage than the Group VI-VIII varieties. The moderate and heavily-damaged seeds were discolored and shrivelled and would be identified by seed graders as stink bug-damaged kernels, resulting in a reduction of the price received. Many of the severely damaged seeds were probably blown out of the combine with the pod and stem residue that results during the threshing process. It appears that the mid-season stink bug populations that are present at 8 to 9 per 25 sweeps during early pod formation were more damaging to the seed quality than the later developing populations that were higher in the Group VII and VIII varieties. However, these populations were present after the seeds were fully formed. Differences in 100 seed weights and yields were significant among the varieties in 1993.

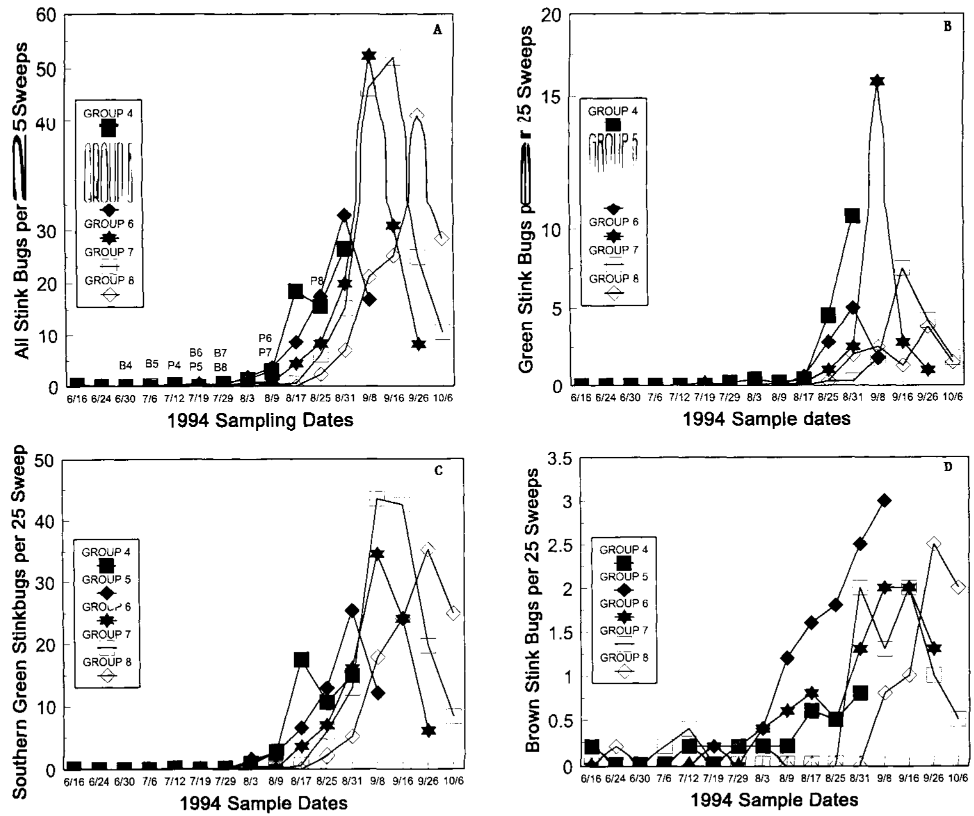

Fig. 2. Seasonal distribution of stink bugs (2a), green stink bugs (2b), southern green stink bugs (2c), and brown stink bugs (2d) on soybeans in maturity groups IV-VIII, 1994. The 'B' above certain points identifies the date that each maturity group (4-8) was in full bloom while the 'P' indicates the date that each maturity group (4-8) had full pods without seeds.

Table 1. Stink bug damage and yield characteristics of soybean varieties of varying maturity groups grown in Tift Co., GA, in 1993.

Soybean variety	Maturity group*	% Stink bug damaged seeds**				100-seed wt. (gm)	Yield (kg/ha)
		None	Light	Mod.	Heavy		
NK S4884	IV	66.9	11.8	12.3	9.0	14.5	2044.1
Essex	V	70.4	13.3	8.8	7.5	14.1	2583.0
Davis	VI	77.5	15.4	4.9	2.2	15.8	2136.1
Braxton	VII	78.3	14.7	3.9	3.1	16.8	2090.1
Cobb	VIII	72.5	21.3	2.8	3.4	17.2	2405.6
LSD (P = 0.05)		NS	9.2	7.1	5.2	1.9	374.6

* Teare and Hodges 1995.

** Light damage includes seeds with stink bug-feeding punctures with some discoloration but no shrivelling, moderate damage includes seeds with feeding punctures, discoloration, and minor shrivelling around the feeding site, and heavy damage includes seeds with feeding punctures and extensive discoloration and shrivelling.

However, these are agronomic characteristics that vary among varieties, and thus cannot be soley attributed to stink bug injury because no insecticides were directed at controlling stink bugs due to their low natural infestation levels in 1993.

Much more stink bug-induced seed damage was observed in 1994 when stink bug populations were about 5X higher than in 1993. From 85 to 90% of the seeds from each variety were damaged with stink bug punctures (Table 2). Davis and Braxton, which both had stink bug population peaks of over 50 bugs per 25 sweeps, had significantly more heavily-damaged seeds than the other varieties. NK S4884 had significantly more moderately damaged seeds than the other varieties. The 100 seed weights were not different among varieties; however, every variety had a lower seed weight in 1994 than in 1993 when stink bug populations and damaged seeds were much lower.

The tralomethrin treatments significantly increased the number of seeds with no stink bug damage on all five of the soybean varieties (Table 3). The treated NK S4884 had a lower incidence of moderate seed damage and an increased 100 seed weight than the untreated NK S4884. The treated Essex also had lower numbers of light and moderate seed damage and a higher seed weight (though not significant) than the untreated Essex. The treated Davis plots had lower numbers of heavy stink bug damaged seeds and an increased yield than in the untreated plots. The Braxton and Cobb plots that were treated with two applications of tralomethrin had lower numbers of moderate and heavy damage seeds and higher seed weights and yields than their respective untreated plots.

Table 2. Stink bug damage and yield characteristics of soybean varieties of varying maturity groups grown in Tift Co., GA, in 1994.

Soybean variety	Maturity group*	% Stink bug damaged seeds**				100-seed wt. (gm)	Yield (kg/ha)
		None	Light	Mod.	Heavy		
NK S4884	IV	9.1	41.1	40.2	9.6	13.6	2267.6
Essex	V	15.3	64.1	16.2	4.4	13.8	2116.4
Davis	VI	10.8	66.7	7.9	14.5	14.8	2300.5
Braxton	VII	8.8	40.1	22.0	17.9	14.0	2517.4
Cobb	VIII	12.9	70.6	10.1	6.5	14.0	1754.9
LSD (P = 0.05)		NS	16.5	15.8	4.2	NS	407.5

* Teare and Hodges 1995.

** Light damage includes seeds with stink bug-feeding punctures with some discoloration but no shrivelling, moderate damage includes seeds with feeding punctures, discoloration, and minor shrivelling around the feeding site, and heavy damage includes seeds with feeding punctures and extensive discoloration and shrivelling.

Significant linear regressions (y = bx + a), where y equals the stink bug population peak and x is the plant response measured were obtained for total damaged kernels (x_1), yield reductions (x_2), and 100-seed weight reductions of soybeans exposed to varying natural stink bug population peaks (Table 4). The percentage of moderately and heavily damaged kernels was not correlated with stink bug peak population ($P > 0.05$). This indicates that moderate and heavy damage is independent of the population level. The young tender seeds are susceptible to moderate and heavy damage even if low stink bug populations are present, while older seeds require heavier feeding pressure before more seed shrivelling and discoloration occurs.

It appears that soybean maturity group affects the timing and magnitude of the stink bug populations in Georgia. The early-maturing varieties are initially infested 3 to 4 wks before the later-maturing varieties. However, as the populations declined in the early varieties, they rapidly increased in the later varieties, reaching population peaks around 4 to 5 wks after the R_4 plant development for all maturity groups. Population peaks occur later in the season in the later-maturing varieties and are higher than those present in the early varieties. Seed quality and yield losses occurred across all maturity group soybeans. Yield losses tended to be higher in the later-maturing varieties where stink bug populations were more abundant. There is a correlation with peak population and amount of kernel injury, yield reduction and 100-seed weight reduction. Thus, it is important that each soybean field be sampled weekly, primarily during the 4 to 6 wks after the R_4 plant developmental stage is reached, and control measures applied if stink bug populations begin to rapidly increase during this period.

Table 3. Stink bug damage and yield characteristics of five soybean varieties either treated with Tralomethrin (Trt) or left untreated (Untrt), Tift Co., GA, in 1994.

Soybean variety	Treatment Category	% Stink bug damaged seeds**				100-seed wt. (gm)	Yield (kg/ha)
		None	Light	Mod.	Heavy		
NK S4884	Trt	45.6*	34.4	12.8	7.2	14.6*	2589.7
	Untrt	9.1	41.1	40.2*	9.6	13.6	2267.6
Essex	Trt	39.2*	47.2	8.3	5.2	14.4	2405.6
	Untrt	15.3	64.1*	16.2*	4.4	13.8	2116.4
Davis	Trt	35.8*	55.8	5.3	3.1	15.7	2668.5*
	Untrt	10.8	66.7	7.9	14.5*	14.8	2300.5
Braxton	Trt	40.5*	48.9	6.5	4.1	15.8*	2984.0*
	Untrt	8.8	40.1	22.0*	17.9*	14.0	2517.4
Cobb	Trt	45.5*	50.9	1.5	2.1	18.3*	2261.0*
	Untrt	12.9	70.6*	10.1*	6.5*	14.0	1854.9

* The mean comparison between the treated and the untreated variable for a particular variety is significantly different, paired t test ($P = 0.05$).

** Light damage includes seeds with stink bug-feeding punctures with some discoloration but no shrivelling, moderate damage includes seeds with feeding punctures, discoloration, and minor shrivelling around the feeding site, and heavy damage includes seed with feeding punctures and extensive discoloration and shrivelling.

Table 4. Linear relationship between the peak stink bug population on soybean and the percentage of total damaged kernels, percentage of moderate plus heavy damaged kernels, yield reductions (kg/ha) and 100-seed weight reductions (gm), Tift Co., GA.*

Variable tested	*F* Value	*P* level	b (slope)	a (Y-inter.)	r^2
Total damaged kernels	10.35	0.01	0.52	-5.01	0.828
Mod. + heavy damage	2.75	N.S.	–	–	–
Yield reductions	22.03	0.01	0.11	1.10	0.901
100-seed wt. reductions	6.11	0.03	11.07	14.5	0.426

* Each linear model had 58 error degrees of freedom for total damaged kernels and moderate plus heavy damaged kernels, and 18 error degrees of freedom for yield reductions and 100-seed weight reductions. N.S. represents a nonsignificant linear relationship ($P > 0.05$).

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