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ORIGINAL RESEARCH ARTICLE

Relationship between stink bug populations and soybean (*Glycine max* L.) phenology

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Abstract

The populations of phytophagous stink bugs may vary with cultivar and crop management. The aim of this study was to know the population dynamics of stink bugs *Euschistus heros*, *Nezara viridula*, and *Piezodorus guildinii* at different soybean phenological stages. Samples of each stink bug species were collected from three soybean (Syn1059, P97R01, and M7110IPRO) cultivars conducted in two seasons. For three cultivars and two seasons, *E. heros* was the most abundant, followed by *P. guildinii* and *N. viridula*. The soybean phenology influenced stink bug population dynamics, mainly in the reproductive stages. For soybean cultivars, Syn1059 and M7110IPRO were high colonized by stink bugs, while colonization in P97R01 was low suggesting susceptible differences between cultivars. The number of collected insects was positively related between reproductive soybean phonological stages, suggesting that stink bugs population can compromise crop production.

Keywords Insect pest · Plant-insect interactions · Population dynamics · Soybean pest

Introduction

The soybean, *Glycine max* (L.) Merril (Fabaceae) is a native plant from China and grown in large areas worldwide. Abiotic and biotic factors reduce soybean yield (Justiniano et al. 2014). Among biotic factors, stink bugs (Hemiptera: Pentatomidae) are phytophagous insects in soybean cultivars (Pan et al. 2013). Damages caused by stink bugs in soybean reduce seed yield and quality, low germination rate, foliar retention, delay in maturation and abnormal plant growth (Tuelher et al. 2016; Bentivenha et al. 2018; Mantia et al. 2018). The green bug, *Nezara viridula* Linnaeus, small green bug, *Piezodorus guildinii* Westwood and brown stink bug, *Euschistus heros* Fabricius are the main soybean pest (Bortolotto et al. 2015).

Stink bugs are phytophagous by nature and are present in soybean crops during the vegetative and reproductive stages (Table 1). Vegetative stages are described by the letter V of C to n (VC, V1, V2, V3, Vn). Emergence to open cotyledons (VC) and the number of nodes with fully developed leaves above the cotyledons (V1 to Vn) (Fehr et al. 1971). Reproductive stages are described by the letter R from 1 to 8, describing the maturation of the flowering period. Flowering of plant (R1 and R2), development of pods (R3 and R4), development of seeds (R5 and R6) and physiological maturity (R7 and R8) (Fehr et al. 1971).

In Brazil, farmers can use the pest control methods at the control level (NC) and before reaching the level of economic damage (NDE) to reduce the negative impacts and to improve profits from sustainable soybean production (Bortolotto et al. 2015). However, factors such as climate, transgenic crops, and insecticide use can alter the soybean pest population level. Also, the high genetic variability of insect pests favors them to adaption to seasonal variations and food habits by moving

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Table 1 Growth stages of soybeans divided into vegetative (v) and reproductive (R) stages

Vegetative Stages	Reproductive Stages
vE = emergence	R1 = beginning bloom
vC = cotyledon	R2 = full bloom
v1 = first node	R3 = beginning pod
v2 = second node	R4 = full pod
v3 = third node	R5 = beginning seed
v4 = fourth node	R6 = full seed
v5 = fifth node	R7 = beginning maturity
v6 = nth node	R8 = full maturity

to other niches and searching for host plants at different phenological stages (Venugopal et al. 2014). Consequently, a study was conducted on soybean crops, to monitoring natural infestations of stink bugs phytophagous and relationship between different phenological stages, in order to support stink bugs pest management programs.

Materials and methods

Study areas

The study was carried out in the county of Rio Paranaíba (19°14’ S and 46°12’ W, 1088 m) in Minas Gerais, Brazil, with an average temperature of 20.04 ºC, 57% relative humidity, and 2,008 mm annual rainfall. Field studies were conducted in the 2013/2014 and 2014/2015 seasons involving the determinate soybean cultivars pest/disease resistant ‘M7110’ (Monsoy®, Sao Paulo, Brazil), disease resistant ‘SYN1059’ (Syngenta®, Sao Paulo, Brazil), and non-resistant ‘P97R01’ (Pioneer®, Sao Paulo, Brazil); also, general agronomic practices were followed throughout the two seasons. Soybean plants were planted between 0.5 × 0.05 m (20 plants per linear meter).

Field experiments

Within 2 weeks before experiment initiation, the entire field was treated with methomyl (600 mL/ha), α-cypermethrin (120 mL/ha), and acephate (500 g/ha) to eliminate any resident stink bugs. Evaluations were done in two fields of 10 ha each, subdivided into five plots, each with 10 evaluation points spaced at 100 m. Each evaluation point was a sample unit, totaling 50 sampling points/plot. Nymphs and adults of stink bugs were sampled weekly during soybean phenological stages. The samplings were carried out with white beat cloth of 1 m.

Statistical analyses

Descriptive statistics (Means ± SD) of population densities of each stink bug species between the soybean phenological stages were summarized weekly to the end of the season. Also, estimated stink bug population and soybean phenological stages were correlated using Pearson correlation coefficient analysis. The population densities of stink bug species were estimated by counting the number of insects per beat cloth of each soybean cultivars, depending on the phenological plant stages and submitted by analysis of variance at the end of the season. For population density in field conditions, a Kolmogorov-Smirnov test verified the data normality to meet the normality assumptions and ANOVA was conducted as a mixed model. A Tukey’s Honestly Significant Difference (HSD) test was also used for comparison of means at the 5% significance level. Data were analyzed using SAS User software (v. 9.0) for Windows.

Results

Mean weekly samples of *E. heros*, *N. viridula*, and *P. guildinii* for each of the soybean phenological stages are shown in Fig. 1. In first season, *E. heros* reached population peaks in development of pods and physiological maturity (R4, R7, and R8) with 7.2, 7.1, and 3.1 stink bugs/beat cloth to SYN1059, P97R01, and M7110IPRO, respectively. *Nezara viridula* reached population peaks in developed leaves (v2) and development of pods (R3, and R4) with 1.5, 5.2, and 2.1 stink bugs/beat cloth to SYN1059, P97R01, and M7110IPRO, respectively. *Piezodorus guildinii* reached population peaks in flowering of plant (R1) and development of seeds (R5) with 0.5, 5.1, and 2.8 stink bugs/beat cloth to SYN1059, P97R01, and M7110IPRO, respectively. In second season, *E. heros* reached population peaks in development of seeds (R5) with 7.2, 0, and 8.4 stink bugs/beat cloth to SYN1059 and M7110IPRO, respectively; *E. heros* not found in P97R01. *Nezara viridula* reached population peaks in development of seeds (R5 and R6) with 5.9, 1.1, and 5.1 stink bugs/beat cloth to SYN1059, P97R01, and M7110IPRO, respectively. *Piezodorus guildinii* reached population peaks in development of seeds (R5) with 7.0, 1.1, and 3.2 stink bugs/beat cloth to SYN1059, P97R01, and M7110IPRO, respectively.

The analysis of the correlation between stink bug population and soybean phenological stages revealed significant and positive correlations ($r = 0.85$, $P < 0.05$). The positive correlation was found between the stages v3, R3, R4, R5, and R6 stages, but the correlation was not significant by others stages (Table 2).

The population densities of stink bugs were different on three soybean cultivars. In first season, populations of

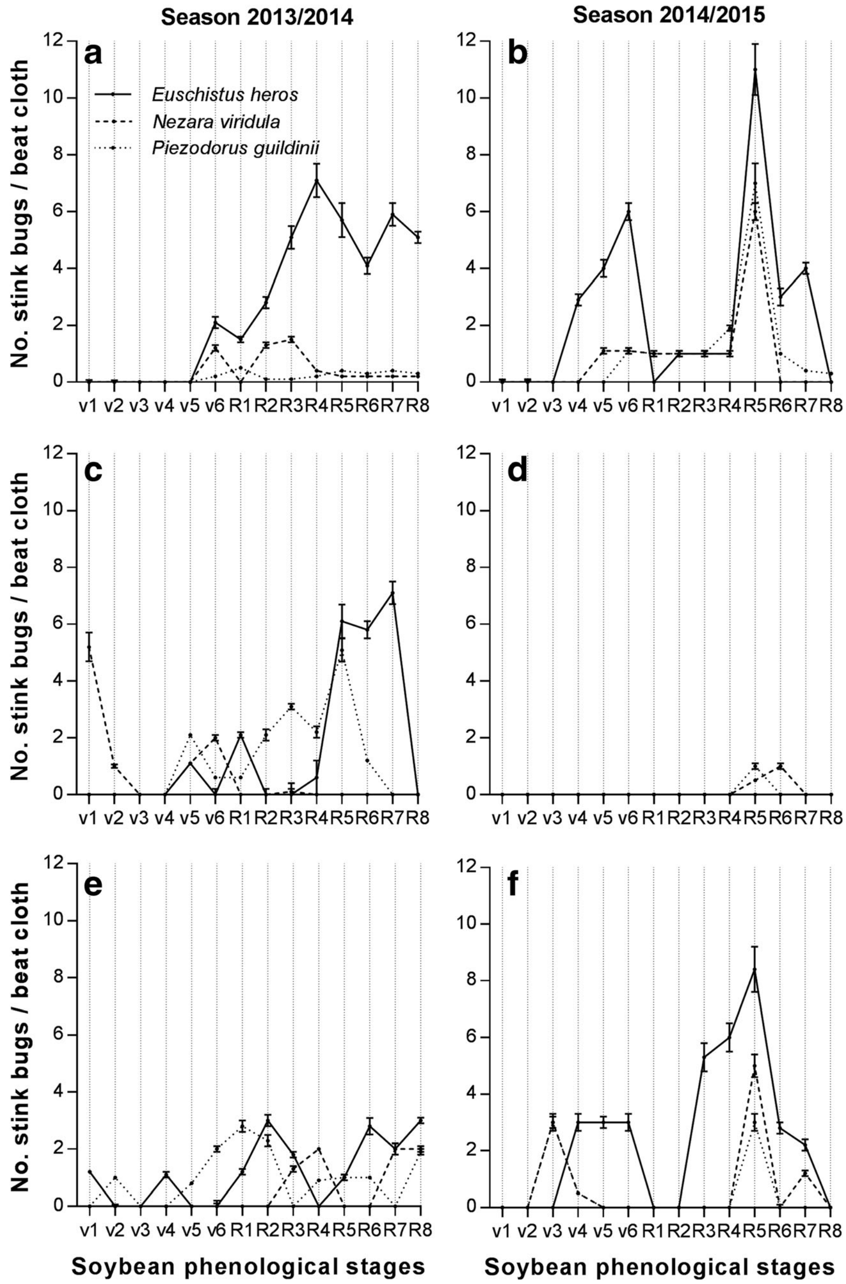

Fig. 1 Seasonal population trends of stink bugs in relation to soybean phenological stages. Soybean cultivars (SYN 1059, P97R01, and M7110IPRO) and two seasons (2013/2014 and 2014/2015). Season 2013/2014 (A, C, E) and season 2014/2015 (B, D, F)

E. heros was high in SYN1059, *N. viridula* in M7110IPRO, and *P. guildinii* in P97R01cultivar. In second season, populations of *E. heros* was high in SYN1059 an M7110IPRO, *N. viridula* in SYN1059, and *P. guildinii* in SYN1059 cultivar (Table 3).

Discussion

The phenological plant stage was the dominant factor explaining variability in stink bug densities; this suggests an extrinsic association between stink bug populations and soybean phenological stages. In this sense, colonization of soybean by stink bugs was related to reproductive stages and was predictable. Preliminary studies indicate that up to 1stink bug per plant (of each species), during 21 days, affect the vigor and seed viability (Smith et al. 2009). Threshold densities of stink bugs were encountered mainly in R5, although densities observed before R5 soybean were slightly less. Densities decline at R8, but damages and economic impacts of stink bugs can occur until soybean seed quality (Fonseca et al. 2014). In particular, stink bug species start the colonization during the end of the growing to the beginning of flowering, therefore, can reach high populations in the reproductive soybean stages (Fonseca et al. 2014).

Table 2 Correlation between the populations of stink bugs and soybean phenological stages according to the Pearson correlation coefficient (r = 0.85, $P < 0.05$). Values in bold indicate significance at 5% level

Stage	v1	v2	v3	v4	v5	v6	R1	R2	R3	R4	R5	R6	R7	R8
v1	1	0.63	-0.04	0.079	0.20	0.36	-0.33	-0.27	-0.28	-0.30	-0.33	-0.25	-0.25	-0.22
v2		1	-0.25	-0.15	0.28	0.63	0.28	-0.05	-0.49	-0.29	-0.33	-0.26	-0.36	-0.14
v3			1	**0.71**	-0.37	0.11	0.21	**0.71**	0.65	0.51	0.25	0.47	0.41	**0.84**
v4				1	-0.25	-0.33	0.14	0.51	0.12	-0.17	-0.07	0.30	0.12	0.39
v5					1	0.09	0.16	0.00	-0.02	-0.08	0.47	0.10	-0.11	-0.47
v6						1	0.20	0.30	0.21	0.38	0.04	-0.11	-0.13	0.27
R1							1	0.43	-0.05	0.15	0.45	0.62	0.42	0.33
R2								1	0.63	0.42	0.28	0.26	0.02	0.63
R3									1	**0.86**	0.52	0.28	0.31	0.65
R4										1	0.57	0.35	0.49	**0.73**
R5											1	**0.80**	**0.71**	0.19
R6												1	**0.90**	0.35
R7													1	0.42
R8														1

The stink bug species showed a synchronic fluctuation with the soybean reproductive stages. *Euchistus heros* was found from R4 to R8, *N. viridula* from R3 to R6, while *P. guildinii* from R1 to R5 stages. For three soybean cultivars, phenological stages coincide with the time when economic loss is greatest from stink bug feeding. Although damage estimates were not conducted in this study, the development of stink bugs thresholds is warranted. Studies confirm that population fluctuations of *E. heros*, *N. viridula*, and *P. guildinii* can vary at different soybean reproductive stages (Marsaro Júnior et al. 2010; Husch et al. 2014; Bueno et al. 2015; Tuelher et al. 2016).

The density of stink bug species on three soybean cultivars was recorded as shown in this study. High population densities of stink bugs occurred by SYN1059 and M7110IPRO cultivars suggesting susceptibility to these insect pests. The phenology of the crop may strongly influence pest colonization as shown by the significant densities for soybean cultivars. In contrast, P97R01 cultivar was less susceptible and suggests that some soybean cultivars may reduce the stink bug species pressure. Stink bugs have developed resistance to most of the insecticides recommended for its control, and alternative control strategies are required, including the development of pest-resistant cultivars with secondary metabolites that these insects cannot detoxify (Olson et al. 2011; Souza et al. 2015; Graça et al. 2016).

The soybean phenology may influence stink bug population dynamics, mainly in the reproductive stages. The stink bugs, *E. heros* was the most abundant, followed by *P. guildinii* and *N. viridula* in three soybean cultivars. The results can be implications in cropping management to reduce pesticide dependence and maximize pest control in population peaks associate with sensitive soybean phenological stages. The predictable colonization in soybean reproductive stages by stink bugs continues to encourage research to population's management, with possible new cultivars options.

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Table 3 Means of population density of stink bugs of different cultivars in Lagoa Formosa and Rio Paranaíba. Density (Means ± SD) of *Euschistus heros*, *Nezara viridula*, and *Piezodorus guildinii* in three soybean cultivars during two seasons

Cultivar	First season			Second season		
	E. heros	*N. viridula*	*P. guildinii*	*E. heros*	*N. viridula*	*P. guildinii*
SYN1059	2.71 ± 0.10a	0.29 ± 0.02b	0.17 ± 0.07c	2.78 ± 0.11a	1.00 ± 0.06a	1.11 ± 0.06a
P97R01	1.64 ± 0.09b	0.21 ± 0.02b	1.57 ± 0.07a	0.17 ± 0.01b	0.06 ± 0.01c	0.06 ± 0.01c
M7110IPRO	1.21 ± 0.04c	0.57 ± 0.04a	1.00 ± 0.04b	2.94 ± 0.10a	0.72 ± 0.05b	0.56 ± 0.03b

Compliance with ethical standards

Conflict of interest The author declares no conflict of interest.

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