Acta Scientiarum. Agronomy
ISSN: 1807-8621
Editora da Universidade Estadual de Maringá - EDUEM

Mouzinho Carvalho, Marina; Coelho Carvalho, Leidiane; Oliveira de Freitas Bueno, Regiane Cristina
Quantitative impacts of different planting arrangements on the populations of natural enemies in soybean
Acta Scientiarum. Agronomy, vol. 41, e42605, 2019
Editora da Universidade Estadual de Maringá - EDUEM

DOI: https://doi.org/10.4025/actasciagron.v41i1.42605

Acta Scientiarum
http://periodicos.uem.br/ojs/acta
ISSN on-line: 1807-8621
Doi: 10.4025/actasciagron.v41i1.42605

CROP PROTECTION

Quantitative impacts of different planting arrangements on the populations of natural enemies in soybean

Marina Mouzinho Carvalho[1*], Leidiane Coelho Carvalho[2] and Regiane Cristina Oliveira de Freitas Bueno[1]

[1]Departamento de Proteção Vegetal, Faculdade de Ciências Agronômicas, Universidade Estadual Paulista "Júlio de Mesquita Filho", Rua Jose Barbosa de Barros, 1780, 18610-307, Botucatu, São Paulo, Brazil. [2]Centro de Ciências Agrárias, Universidade Estadual do Oeste do Paraná, Marechal Candido Rondon, Paraná, Brazil. *Author for correspondence. E-mail: mouzinho.marina@gmail.com

ABSTRACT. Natural biological control is an important alternative for the control of insect pests using natural enemies that occur naturally in agroecosystems. The potential of these insects can increase when they are adequately managed. Thus, the objective of this study was to quantify the populations of natural enemies in soybean cultivars with different growth habits planted in different arrangements. The experiment consisted of eight treatments: four planting arrangements and two soybean cultivars, with four replicates. The populations of natural enemies were evaluated from the vegetative stage V3 to crop harvest using a shaking-cloth. A population survey of the beneficial arthropods present on the soil surface was performed in the reproductive stages R2 and R3 with the installation of modified pitfall traps. The main natural enemies that occurred in the culture were Class Arachnida, Order Heteroptera, Order Hymenoptera, Order Coleoptera and Order Dermaptera. The populations of the natural enemies assessed using the shaking-cloth did not show significant differences. However, in the evaluations with the modified pitfall traps in the reproductive stage R3 in the crossed arrangement, the populations of the Coleoptera and Dermaptera orders were higher in the determinate cultivar than in the indeterminate cultivar.

Keywords: *Glycine max* (L.) Merril; beneficial arthropods; biological control; cultural control.

Received on October 10, 2017.
Accepted on March 20, 2018.

Introduction

The success of pest control following the principles of integrated pest management (IPM) depends on the adoption of efficient control tactics and low environmental impact (Goulart, Bueno, Bueno, & Diniz, 2011a). In this sense, natural enemies perform an important environmental service as regulators of the populations of insect pests, resulting in greater stability in ecosystems of different cultures. This service, however, is often not considered during decision making in pest management. In addition, the use of broad-spectrum insecticides can reduce the populations of natural enemies and is inefficient (Zhang & Swinton, 2009).

As a result, it is important to search for new technologies that reduce the high use of pesticides and have fewer adverse effects on the environment (Silva, Batista, & Brito, 2009). As the purpose of pest control is to maximize agricultural productivity, the approach of IPM should always be interdisciplinary and multidisciplinary, seeking the integration of different control methods (Goulart, Bueno, Bueno, & Vieira, 2011b).

Based on this perspective, a promising alternative to achieve high levels of productivity is the modification of soybean planting arrangements, which has been showing good results in terms of productivity in production regions in Brazil (Mato Grosso, Bahia, Piauí, Maranhão, Paraná, Tocantins, Goias, Minas Gerais, Mato Grosso do Sul, and São Paulo) and the United States of America (USA). This occurs because soybean is highly adaptable to different environmental conditions and management strategies, such as increasing plant populations and changing spacing (Pires, Costa, & Thomas, 1998; Rambo, Costa, Pires, Parcianello, & Ferreira, 2003).

Given the importance of natural biological control agents, the new possibilities for planting arrangements and the relevance of IPM in the management of insect pests, the objective of this study was to assess the influences of conventional, double row, crossed and reduced planting arrangements on the populations of natural enemies in soybean.

Material and methods

The experiment was performed during the 2012/2013 season at the experimental farm of the Faculdade de Ciências Agronômicas, Universidade Estadual Paulista "Julio de Mesquita Filho" - UNESP, Botucatu, São Paulo State, Brazil, located at 22º 53' 25” S and 48º 27' 19” W.

The experimental design consisted of randomized complete blocks with treatments distributed in a 4 × 2 factorial scheme (four planting arrangements: conventional 40 cm, double row, crossed planting, and reduced spacing of 20 cm; two soybean cultivars, one of determinate growth habit and the other indeterminate) with four replicates. The plot dimensions were 12 × 7 m.

BRS 295RR (determinate habit) and Vmax RR (indeterminate habit), belonging to maturity groups 6.5 and 6.2, respectively, were planted. The planting in different arrangements used the same plant population (350,000 plants ha^{-1}) and was conducted using a direct sowing system. The soybean seeds were treated with fungicide (60 g a.i. carboxin + 60 g a.i. thiram) and insecticide (70 g a.i. thiamethoxam) per 100 kg of seed. The seeds were subsequently inoculated with a *Bradyrhizobium* suspension (60 g 50 kg^{-1} of seeds).

Monitoring the natural enemies present in the aerial part of the soybean plants began in the vegetative phonological stage V3 and was conducted weekly until the reproductive stage R8 (Fehr & Caviness, 1977) using a shaking-cloth. Sampling was conducted at four locations per plot. The population survey of beneficial arthropods present on the soil surface was performed in reproductive stages R2 and R3 by installing three modified pitfall traps arranged in a diagonal transect in each plot. The modified pitfall traps consisted of two-liter plastic bottles of 9 cm in diameter cut to 8 cm in length. The bottles were buried in the ground to their tops, anda solution of water and mild detergent (2 mL) was added to trap the insects and prevent their escape.

The entire complex of soybean insect pests was also monitored during the crop cycle, and the pesticide application was performed only when the population reached the management threshold proposed by Hoffmam-Campo, Correa-Ferreira, and Moscardi (2012), which occurs when there is an average of 20 large caterpillars (> 1.5 cm) per meter or when defoliation reaches 30% in the vegetative stage and 15% in the reproductive stage. For stink bugs, the proposed management threshold is two bugs per meter (Hoffmam-Campo, Correa-Ferreira, & Moscardi, 2012).

The data on the average number of natural enemies collected using the shaking-cloth and modified pitfall traps were assessed for normality assumptions based on the residuals, the homogeneity of treatment variance, and model additivity to allow the application of ANOVA followed by Tukey tests when differences were detected ($p < 0.05$) using the program Sisvar (Ferreira, 2000). The relative abundance was calculated according to the mathematical formula % Spi = n * (100 / N), where % Spi is the percentage of the species of interest, n is the number of species, and N is the total number of individuals in the sample.

Results

The populations of natural enemies sampled in the evaluations using the shaking-cloth were composed primarily of spiders and, to a lesser extent, predatory bugs (*Podisus* spp.), the beetle *Calosoma granulatum* Perty, 1830 (Coleoptera: Carabidae) and the ladybug *Cycloneda sanguinea* Linnaeus, 1763 (Coleoptera: Chrysopidae).

There were no significant differences in the population density of predators sampled throughout the crop cycle (Table 1). In the vegetative stage V3, natural enemies were present in the samples, but only a small number, which was close to zero. The population showed a slight increase in V7, but this increase occurred continuously only in R4, reaching a peak in the population in R5.2. In R5.3, the population began to decline to zero at the end of the cycle, in R8 (Table 1).

The diversity of predators occurring in the soil varied with the planting arrangement, the cultivar and the phenological stage. In the conventional treatment with the indeterminate cultivar, the double rows with both cultivars, the crossed with the determinate cultivar and the reduced treatment with both cultivars, insects belonging to the order Diptera were the most abundant. The "Other" category had the highest relative abundance in the conventional treatment with the determinant cultivar, the double row treatment with the indeterminate cultivar and the reduced treatment with both cultivars in R2. The Arachnida class was most abundant in the conventional treatment with the determinate cultivar, the double row treatment with both cultivars in R3, and the crossed treatment with the determinate cultivarin R2 (Table 2).

Table 1. Average number (±SE) of natural enemies (spiders, *Podisus* sp., *Calosoma granulatum*, and *Cycloneda sanguinea*) in soybean plants with different growth habits, planted in different arrangements, and in different assessment phases in the field. Botucatu, São Paulo State, Brazil, harvest of 2012/2013.

Treatments	V7		V8		R1	
	Indeterminate growth habit	Determinate growth habit	Indeterminate growth habit	Determinate growth habit	Indeterminate growth habit	Determinate growth habit
Conventional	0.81 ± 0.33	0.75 ± 0.32	0.31 ± 0.12	0.31 ± 0.06	0.19 ± 0.12	0.06 ± 0.06
Double row	0.50 ± 0.24	0.81 ± 0.19	0.50 ± 0.10	0.44 ± 0.16	0.13 ± 0.07	0.19 ± 0.06
Crossed	0.19 ± 0.12	0.19 ± 0.19	0.25 ± 0.18	0.56 ± 0.26	0.38 ± 0.24	0.19 ± 0.06
Reduced	0.69 ± 0.28	0.13 ± 0.13	0.81 ± 0.28	0.63 ± 0.13	0.13 ± 0.07	0.25 ± 0.10
CV (%)	21.32		11.63		9.20	
Treatments	R2		R3		R4	
	Indeterminate growth habit	Determinate growth habit	Indeterminate growth habit	Determinate growth habit	Indeterminate growth habit	Determinate growth habit
Conventional	0.06 ± 0.06	0.31 ± 0.16	0.13 ± 0.07	0.06 ± 0.06	0.19 ± 0.12	0.31 ± 0.16
Double row	0.31 ± 0.06	0.38 ± 0.22	0.19 ± 0.06	0.06 ± 0.06	0.44 ± 0.19	0.25 ± 0.18
Crossed	0.25 ± 0.10	0.13 ± 0.07	0.50 ± 0.27	0.38 ± 0.30	0.19 ± 0.12	0.31 ± 0.16
Reduced	025 ± 0.10	0.25 ± 0.14	0.25 ± 0.14	0.31 ± 0.12	0.44 ± 0.16	0.25 ± 0.10
CV (%)	9.94		12.21		11.56	
Treatments	R5.1		R5.2		R5.3	
	Indeterminate growth habit	Determinate growth habit	Indeterminate growth habit	Determinate growth habit	Indeterminate growth habit	Determinate growth habit
Conventional	0.75 ± 0.25	0.38 ± 0.16	11.25 ± 0.75	10.25 ± 0.25	0.06 ± 0.06	0.13 ± 0.07
Double row	0.50 ± 0.20	0.44 ± 0.12	11.25 ± 0.75	10.25 ± 0.25	0.06 ± 0.06	0.31 ± 0.12
Crossed	0.75 ± 0.25	0.38 ± 0.16	11.25 ± 0.75	10.25 ± 0.25	0.06 ± 0.06	0.13 ± 0.07
Reduced	0.25 ± 0.10	0.69 ± 0.06	10.75 ± 0.48	10.50 ± 0.50	0.13 ± 0.07	0.19 ± 0.19
CV (%)	10.14		8.47		8.24	

Table 2. Relative abundance (%) of soil pests caught in modified pitfall traps in soybean plants with different growth habits, planted in different arrangements, and in two different assessment phases (R2 and R3) in the field. Botucatu, São Paulo State, Brazil, harvest of 2012/2013.

Treatments	R2		R3	
	Diptera			
	Indeterminate growth habit	Determinate growth habit	Indeterminate growth habit	Determinate growth habit
Conventional	45.94	22.50	100.00	28.45
Double row	46.77	71.40	45.84	58.54
Crossed	29.04	16.61	90.96	86.60
Reduced	24.89	30.37	66.67	66.67
Treatments	Hymenoptera			
	Indeterminate growth habit	Determinate growth habit	Indeterminate growth habit	Determinate growth habit
Conventional	0.00	19.40	0.00	28.45
Double row	0.00	0.00	16.62	8.29
Crossed	0.00	5.54	0.00	0.00
Reduced	0.00	0.00	0.00	20.08
Treatments	Arachnida			
	Indeterminate growth habit	Determinate growth habit	Indeterminate growth habit	Determinate growth habit
Conventional	5.36	16.10	0.00	43.10
Double row	39.92	7.10	0.00	0.00
Crossed	63.26	27.85	9.04	0.00
Reduced	25.04	0.00	0.00	0.00
Treatments	Other*			
	Indeterminate growth habit	Determinate growth habit	Indeterminate growth habit	Determinate growth habit
Conventional	48.70	42.00	0.00	0.00
Double row	13.31	21.51	37.53	33.17
Crossed	7.70	50.00	0.00	13.40
Reduced	50.08	69.63	33.33	13.25

*Other: Coleoptera + Dermaptera.

Throughout the study, the average total catch of arthropods in the modified pitfall traps showed significant differences only in the "Other" category in the crossed treatment, in which the determinate cultivar showed a greater number of individuals than the indeterminate cultivar (Table 3).

Table 3. Average values (±SE) of soil pests caught in modified pitfall traps in soybean plants with different growth habits, planted in different arrangements, and in two different assessment phases (R2 and R3) in the field. Botucatu, São Paulo State, Brazil, harvest of 2012/2013.

Treatments[1]	R2		R3	
	Diptera			
	Indeterminate growth habit	Determinate growth habit	Indeterminate growth habit	Determinate growth habit
Conventional	0.71 ± 0.34	0.58 ± 0.37	0.58 ± 0.34	0.08 ± 0.08
Double row	0.29 ± 0.17	0.83 ± 0.61	0.46 ± 0.16	0.58 ± 0.58
Crossed	1.42 ± 1.21	0.25 ± 0.16	0.83 ± 0.61	2.67 ± 2.45
Reduced	0.41 ± 0.16	0.58 ± 0.28	0.33 ± 0.19	0.42 ± 0.21
CV (%)	30.82		22.31	
Treatments[1]	Hymenoptera			
	Indeterminate growth habit	Determinate growth habit	Indeterminate growth habit	Determinate growth habit
Conventional	0.00 ± 0.00	0.50 ± 0.50	0.00 ± 0.00	0.08 ± 0.08
Double row	0.00 ± 0.00	0.00 ± 0.00	0.17 ± 0.10	0.08 ± 0.08
Crossed	0.00 ± 0.00	0.08 ± 0.08	0.00 ± 0.00	0.00 ± 0.00
Reduced	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.13 ± 0.13
CV (%)	21.42		11.29	
Treatments[1]	Arachnida			
	Indeterminate growth habit	Determinate growth habit	Indeterminate growth habit	Determinate growth habit
Conventional	0.08 ± 0.08	0.42 ± 0.25	0.00 ± 0.00	0.13 ± 0.13
Double row	0.25 ± 0.16	0.08 ± 0.08	0.00 ± 0.00	0.00 ± 0.00
Crossed	3.08 ± 2.97	0.42 ± 0.21	0.08 ± 0.08	0.00 ± 0.00
Reduced	0.42 ± 0.25	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
CV (%)	26.55		8.73	
Treatments[1]	Other*			
	Indeterminate growth habit	Determinate growth habit	Indeterminate growth habit	Determinate growth habit
Conventional	0.75 ± 0.60	1.08 ± 0.71	0.00 ± 0.00aA	0.00 ± 0.00aA
Double row	0.08 ± 0.08	0.25 ± 0.25	0.37 ± 0.04aA	0.33 ± 0.13aA
Crossed	0.38 ± 0.38	0.75 ± 0.28	0.00 ± 0.00aA	0.41 ± 0.25aB
Reduced	0.83 ± 0.61	1.33 ± 0.49	0.17 ± 0.10aA	0.08 ± 0.08aA
CV (%)	30.80		15.04	

*Other: Coleoptera + Dermaptera; [1]Means (± SE) followed by the same letters: lowercase letters in a column comparing the treatments in each column and capital letters comparing the different growth habits do not differ statistically based on the Tukey test at 5% probability ($P < 0.05$). All data were square root (X+1) transformed prior to analysis.

Discussion

Fluctuation in the populations of natural enemies depends on the planting density, crops involved, predator culture adaptability, prey density, predator specificity, availability of other food sources (e.g., pollen), soil moisture and the microclimate of the crops (French, Elliott, & Berberet, 1998). This reinforces the need for studies that consider the complexity of plant-insect interactions in diverse systems to facilitate a greater understanding of these population dynamics.

The experiment was directly influenced by the density of prey because during their deployment, despite the low population of natural enemies sampled with shaking-cloth monitoring in the early stages of the culture, there was a dramatic increase in R5.2, which was related to the increase in lepidopteran defoliation in the soybeans, and lepidopterans are the main prey of the predators studied. This high population occurs primarily in the most advanced stages of soybean (Lourenção, Reco, Braga, Valle, & Pinheiro, 2010). This relationship is explained in other works that define predation as a complex process that can be affected by several factors, with the prey being a basic density factor (Holling, 1961). After high-population lepidopteran defoliation, it is necessary to adopt a method of control that will result in a reduction in the population of insect pests and, consequently, the predators. Thus, there is usually an increase in predators when there is a larger amount of available prey (Oliveira, Bortoli, Miranda, Torres, & Zanuncio, 2008).

The populations of beneficial arthropods in the soil are also very important for the management of insect pests, and it has been reported that the identification of these dominant species has been considered to be essential for the management of natural biological control agents due to their potential as predators (Ellsbury, Pikul Junior, & Woodson, 1998). The dominant species observed in population and faunal studies can act as natural control agents of phytophagous insects, with the potential to be used in biological control programs through conservation (Cividanes & Cividanes, 2008). Even though they were observed at low populations in this study, the species in the modified pitfall trap are all cited as important predators in soybean.

Conclusion

The populations of beneficial arthropods in the soil will be especially important in order to further develop biological control strategies, where the low tolerance for pests is currently a stumbling block for natural enemy establishment. It was possible with that work to assess the influences of different planting arrangements on those populations of natural enemies in soybean because some differences in insect population densities were detected among treatments. These findings merit further investigation to determine the potential for pest insect suppression by beneficial arthropods.

Acknowledgements

We thank the São Paulo Research Foundation (FAPESP) for supporting the first author by granting the master's scholarship, process no. 2013/03851-1. We are also grateful to Gerry Auel for her valuable comments, which improved this manuscript.

References

Cividanes, F. J., & Cividanes, T. M. S. (2008). Flutuação populacional e análise faunística de Carabidae e Staphylinidae (Coleoptera) em Jaboticabal, São Paulo. *Arquivos do Instituto Biologico São Paulo*, *75*(4), 449-456.

Ellsbury, M. M., Pikul Junior, J. L., & Woodson, W. D. (1998). A review of insect survival in frozen soils with particular reference to soil-dwelling stages of cornrootworms. *Cold Regions Science and Technology*, *27*(1), 49-56. DOI: 10.1016/S0165-232X(97)00023-2

Fehr, W. R., & Caviness, C. E. (1977). *Stages of soybean development*. Ames, US: State University of Science and Technology. (Special report, 80).

French, B. W., Elliott, N. C., & Berberet, R. C. (1998). Reverting conservation reserve program lands to wheat and livestock production: effects on ground beetles (Coleoptera: Carabidae) assemblages. *Environmental Entomology*, *27*(6),1323-1335. DOI: 10.1093/ee/27.6.1323.

Ferreira, D. F. (2000). *Sistema de análises de variância para dados balanceados*. Lavras, MG: UFLA (SISVAR 4. 1. Pacote computacional).

Goulart, M. M. P., Bueno, A. F., Bueno, R. C. O. F., & Diniz, A. F. (2011a). Host preference of the egg parasitoids *Telenomus remus* and *Thichogramma pretiosum* in laboratory. *Revista Brasileira de Entomologia*, *55*(1), 129-133. DOI: 10.1590/S0085-56262011000100021

Goulart, M. M. P., Bueno, A. F., Bueno, R. C. O. F., & Vieira, S. S. (2011b). Interaction between *Telenomus remus* and *Thichogramma pretiosum* in the management of *Spodoptera* spp. *Revista Brasileira de Entomologia*, *55*(1), 121-124. DOI: 10.1590/S0085-56262011000100019

Hoffmann-Campo, C. B., Correa-Ferreira, B. S., & Moscardi, F. (2012). *Soja:* manejo integrado de insetos e outros artrópodes-praga. Londrina, PR: Embrapa Soja.

Holling, C. S. (1961). Principles of insect predation. *Annual Review of Entomology*, *6*(1), 163-182. DOI: 10.1146/annurev.en.06.010161.001115

Lourenção, A. L., Reco, P. C., Braga, N. R., Valle, G. E., & Pinheiro, J. B. (2010). Produtividade de genótipos de soja sob infestação da lagarta-da-soja e de percevejos. *Neotropical Entomology*, *39*(2), 275-281. DOI: 10.1590/S1519-566X2010000200020

Oliveira, J. E. M., Bortoli, S. A., Miranda, J. E., Torres, J. B., & Zanuncio, J. C. (2008). Predação por *Podisus nigrispinus* (Heteroptera: pentatomidae) sob efeito da densidade de *Alabama argilácea* (Lepidoptera: noctuidae) e idades do algodoeiro. *Científica Journal of Agrarian Sciences*, *36*(1), 1-9. DOI: 10.15361/1984-5529.2008v36n1p1+-+9

Pires, J. L. F., Costa, J. A., & Thomas, A. L. (1998). Rendimento de grãos de soja influenciado pelo arranjo de plantas e níveis de adubação. *Pesquisa Agropecuária Gaúcha*, *4*(2), 183-188.

Rambo, L., Costa, J. A., Pires, L. F., Parcianello, G., & Ferreira, F. G. (2003). Rendimento de grãos da soja em função do arranjo de plantas. *Ciência Rural*, *33*(1), 405-411. DOI: 10.1590/S0103-84782003000300003

Silva, A. B., Batista, J. L., & Brito, C. H. (2009). Aspectos biológicos de *Euborellia annulipes* sobre ovos de *Spodoptera frugiperda*. *Engenharia Ambiental*, *6*(3), 482-495.

Zhang, W., & Swinton, S. M. (2009). In corporating natural enemies in an economic threshold for dynamically optimal pest management. *Ecological Modelling*, *22*(17), 1315-1324. DOI: 10.1016/j.ecolmodel.2009.01.027