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Effects of different levels of artificial defoliation on the vegetative and reproductive stages of soybean

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Abstract. Any factor that may limit the leaf area of the crop in soybean may compromise its development and, consequently, its productivity. The aim of the study was to evaluate the effect of different levels of artificial defoliation performed in the vegetative and reproductive stages of two soybean cultivars, FT Campo Mourão and Brasmax Potência. The treatments consisted in: 1) Without defoliation throughout the culture cycle; 2) 16.7% defoliation in the vegetative stage; 3) 33.3% on vegetative stage; 4) 16.7% on reproductive stage; 5) 33.3% on reproductive stage; 6) 16.7% throughout the soybean cycle; 7) 33.3% defoliation throughout the soybean cycle. Regardless of the level of defoliation performed on soybeans, it was found that the cultivar Brasmax Potência presented the higher values of plant height, number of pods/plant and green weight of the aerial part, when compared to cultivar FT Campo Mourão. However, the number of pods/plant, green weight of the areal part, grain yield and weight of the seeds were not influenced by the defoliation intensities applied to the soybean. Based on the results, the threshold level of 30% of defoliation in the vegetative stage or 15% in the reproductive stage of soybean is still considered valid for the control of defoliating caterpillars in soybean crop.

Keywords: *Glycine max* (L.); level of action; phenological stage; productivity.

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In the beginning of the 70's, the area cultivated with soybeans in Brazil was approximately 1,300,000 ha, and already in the 2019/2020 season, this area surpassed 35 million hectares in the country (Lima *et al.* 2019; CONAB 2020). Standing out in world agribusiness, placing Brazil in second place in terms of production, and regarding exports of this legume, the country occupies first place (Toloi *et al.* 2021). The soybean yield is directly related to the photosynthetic rate performed by their leaves (Borém *et al*. 2015). Therefore, any factor that limits the leaf area of this crop could compromise its final yield. Defoliation caused mainly by caterpillars and diseases are the main agents responsible for the loss of leaf area in soybean plants (Peluzio *et al.* 2002; Li *et al.* 2006). Most of the insects that attack soybean plants are caterpillars, which significantly reduce the photosynthetic area of the plants, causing economic damage depending on the intensity and the time when this defoliation occurs in the crop (Bueno *et al.* 2010; Moscardi *et al.* 2012).

Among the main species of caterpillars occurring in soybean crop, velvet bean, *Anticarsia gemmatalis* Hübner (Lepidoptera: Erebidae), and soybean looper, *Chrysodeixis includens* (Walker) (Lepidoptera: Noctuidae), are the most importants (Bortolotto *et al.* 2015; Murúa *et al.* 2018). These caterpillars act by modifying the architecture of the soybean canopy, reducing its leaf area, reducing light interception, plant growth rate as well as dry mass accumulation, which consequently negatively affects grain yield of the crop (Haile *et al.* 1998). However, soybean plants have a natural tolerance to the defoliation which is directly linked to the phenological stage of the crop, the cultivar's ability to tolerate or compensate for this damage, as well as the action of environmental factors, such as volume and regularity of precipitation and the amount of light intercepted by the leaf canopy (Parcianello *et al.* 2004; Bahry *et al.* 2013; Taiz *et al.* 2017).

In order to determine the critical periods of attack of these defoliation insects in the soybean crop and to establish the criteria for control decision making and the rational use of chemical insecticides in this crop, the economic threshold for the management of this group of insects is very important. The economic threshold recommended to initiate the control of defoliation caterpillars in the soybean crop, based on their defoliation, is 30% defoliation in the vegetative stage and 15% defoliation in the reproductive stage (Lourenção *et al.* 2019). Several studies have shown that soybean plants can withstand high defoliation intensities, especially during the vegetative stage, without significant grain yield loss (Todd & Morgan 1972; Turnipseed 1972; Gazzoni & Moscardi 1998; Haile *et al.* 1998, Ribeiro & Costa 2000). However, most of these works were developed in the 70's to 90's, using production systems and cultivars that are no longer used. Thus, new soybean cultivars of soybeans, with greater productive potential have been used by growers, especially those with indeterminate growth, as well as other changes in crop production systems such as different plant spacing and a lower sowing density (Balbinot Jr. *et al.* 2015; Zanon *et al.* 2015).

These facts justify the need for further studies to reassess whether the current economic threshold for defoliating caterpillars in soybean are still valid. This information can guarantee a safer recommendation regarding the ideal time to start controlling this group of pests in the crop. The economic threshold determined from the artificial defoliation method is a real possibility to estimate grain yield of the crop, since this simulation of the injuries applied in the crop is similar to the natural defoliation caused by the defoliation insects (Ribeiro & Costa 2000; Glier *et al.* 2015; Fernandes & Ávila 2016; Krinski & Foerster 2017).

Therefore, this study aimed to evaluate the effects of different levels of artificial defoliation performed during the vegetative and reproductive stages of two soybean cultivars over the main agronomic parameters of the crop.

MATERIAL AND METHODS

The trial was conducted under field conditions in the experimental area of Embrapa Agropecuária Oeste (22º13'16 ''S, 54º48'20''W, 430 m altitude) in the county of Dourados, MS, Brazil. The rainfall and average daily temperature data observed in the experimental area are recorded in Figure 1. Two soybean cultivars were used, "FT Campo Mourão", which shows vegetative growth until the beginning of flowering, characterized as determined growth and precocious cycle and "Brasmax Potência", which shows vegetative growth after the beginning of flowering, characterized as undetermined growth and semi-precocious cycle. The soybean seeds used were previously treated with the carboxin + thiram fungicides (75 + 75 g a.i./100 kg of seeds) and inoculated with *Bradyrhizobium*. At the time of sowing, fertilization was carried out using 350 kg/ha of the fertilizer 00-20-20 (NPK), being the crop installed in the conventional planting system with the soil preparation done with a plow and grade leveler.

After the complete emergency of the two soybean cultivars in the experimental area (Figure 2), artificial defoliation in the plants of 16.7% or 33.3% (Bahry *et al.* 2013), as shown by Figure 3 (A and B). Defoliation was performed during the vegetative and/or reproductive period of the soybean, establishing the following treatments: T1) Control: without defoliation throughout the soybean cycle; T2) 16.7% defoliation by removing 50% of one of the three leaflets of the soybean leaf only in the vegetative stage; T3) 33.3% of defoliation by removal of a leaflet only in the vegetative stage; T4) 16.7% of defoliation only in the reproductive stage; T5) 33.3% of defoliation only in the reproductive stage; T6) 16.7% of defoliation throughout the soybean cycle; and T7) 33.3% defoliation throughout the soybean cycle, thus consisting of the trial of seven treatments of defoliation in soybean.

The experimental design was the randomized blocks allocated in the 2 x 7 factorial schemes (two cultivars x seven defoliation conditions) in four replicates. The experimental units consisted of five rows soybeans with 4.5 meters long, spaced 45 cm between the rows. The plots were isolated by a corridor 0.5 m wide and had the three central lines as useful area. The insecticides flubendiamide (24 g a.i./ha) were applied weekly for the control of caterpillars and thiamethoxan + lambdaciabotrin (35.2 + 26.5 g a.i./ha) for the control of stink bugs in the two soybean cultivars of the trial in order to prevent the occurrence of injuries naturally caused by these insects in the crop, which could alter the intensity of the injuries imposed in the treatments of defoliation. The fungicide azoxystrobin + ciproconazole (10 + 40 g.i.a./ha) was used on seeds for the control of soil diseases and the glyphosate herbicide (1,440 g.i.a./ha) for the control of invasive plants when necessary.

The following agronomic parameters were determined: 1) plant height (cm), 2) green weight of the areal part (g), 3) number of pods/plant, 4) weight of 100 seeds (g), and 5) yield of soybean grains (kg/ha). The average height and green weight of the aerial part, as well as the average number of pods/plant were determined by sampling twenty soy plants at random in the three central rows of each plot. For the evaluation of the average grains yield (in kg/ha), the soybean produced in the plants of the three central rows of each plot were harvested, and later, these grains were cleaned and weighed. The average weight of 100 seeds of the soybean harvested in the different treatments was also determined.

The values of the variables evaluated in the trial were submitted to analysis of variance (ANOVA), and when was

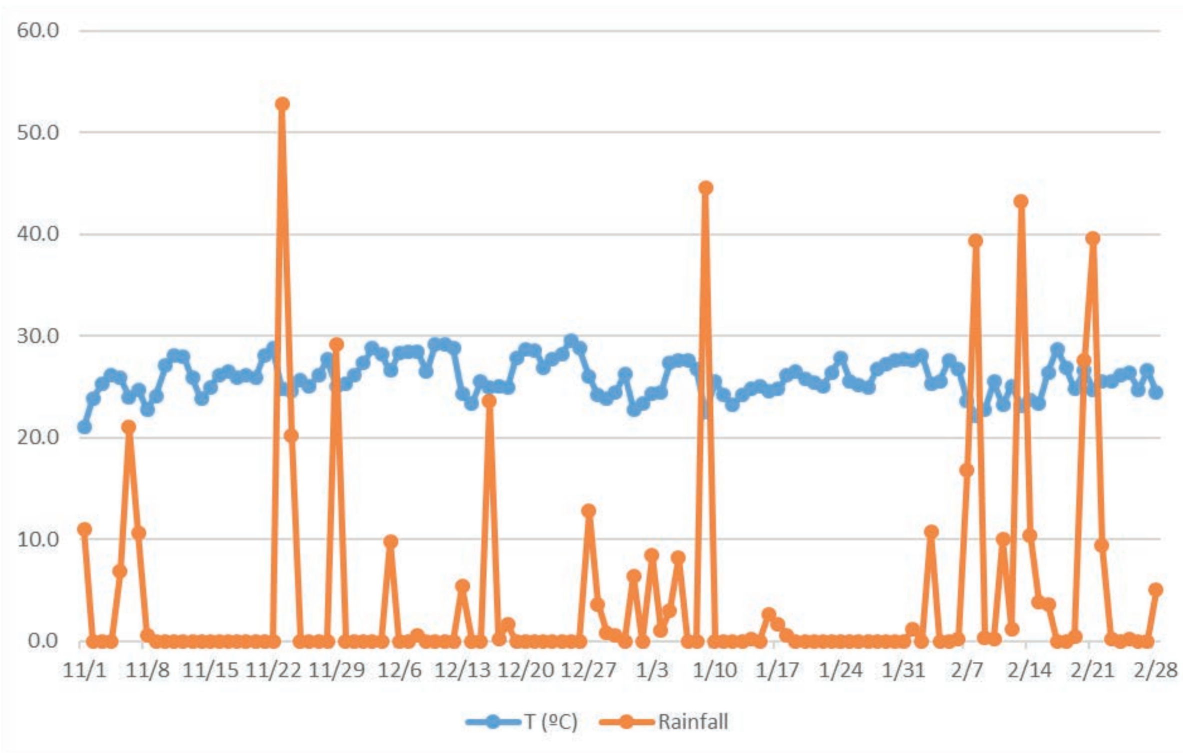

Figure 1. Rainfall and average daily temperature observed in the experimental area with the soybean crop. Dourados, MS.

Figure 2. Soybean experimental area after plant emergence. Dourados, MS.

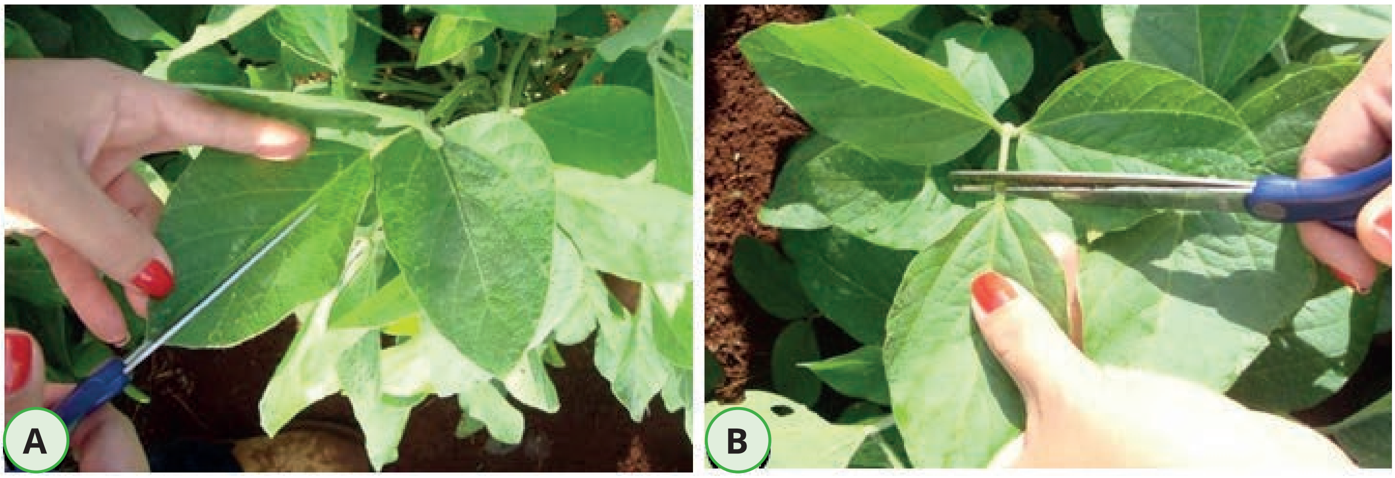

Figure 3. Defoliation simulation of 16.7% (A) and 33.3% (B) in the soybean crop. Dourados, MS.

verified significant effect of treatment, the means were compared by the Tukey's test at 5% probability, using de Rbio software (Bhering 2017).

These factors were interpreted separately by analyzing one of them and grouping another as shown in Tables 1 and 2.

RESULTS AND DISCUSSION

There was no significant interaction between the factors cultivar and defoliation conditions applied in the soybean plants, evidencing that the effects of these factors were expressed with independence for the different agronomic variables analyzed in the experiment. However, when the defoliation levels studied were disregarded, it was found that the cultivar Brasmax Potência had an average plant height higher than the cultivar FT Campo Mourão (Table 1). This agronomic characteristic is probably related to the type of growth of the soybean plants, that is, the cultivars of indeterminate growth, such as the Brasmax Potência cultivar has axillary inflorescence which allows the apical bud to maintain its vegetative growth even after beginning of flowering (Zanon *et al.* 2015), fact that explains its higher plant height. However, for genotypes with determined growth, such as the FT Campo Mourão cultivar, their inflorescences are characterized as racemes and their vegetative growth usually ceases after flowering (Perini *et al.* 2012; Borém *et al.* 2015; Zanon *et al.* 2015; Monteiro *et al.* 2017).

The Brasmax Potência cultivar also showed a higher average number of pods/plant and green weight of the areal part when compared to the FT Campo Mourão cultivar, although the two cultivars did not differ in grains yield (Table 1). Soybean crop has well defined agronomic traits and soybean plants with greater mass, as the cultivar Brasmax Potência presented, are not always the most productive (Perini *et al.* 2012). The weight of 100 seeds was higher in the FT Campo Mourão cultivar when compared to that obtained with the Brasmax Potência cultivar (Table 1). Probably, this greater weight of the seeds observed in the FT Campo Mourão cultivar is a way of this cultivar to present a compensation due to the smaller number of pods obtained in it, since

Table 1. Mean values of plant height (cm), number of pods/plant (np/p), green weight of areal part (g), grain yield (kg/ha) and weight of 100 seeds (g) for two soybean cultivars. Dourados, MS.

Cultivars	Plant height (cm)	Pods/Plant (np/p)	Green weight (g)	Grain yield (kg/ha)	Weight of 100 seeds (g)
FT Campo Mourão	81.70 b	38.29 b	615.71 b	2851 a	16.62 a
Brasmax Potência	86.62 a	63.32 a	787.10 a	2865 a	12.72 b
Cv (%)	**8.6**	**19.7**	**17.2**	**16.6**	**6.9**
Test F	***p = 0.014***	***p = 0.001***	***p = 0.001***	***p = 0.064***	***p = 0.001***

Averages followed by the same letter in the column do not differ statistically by the Tukey's test at 5% probability.

Table 2.Mean values of plant height (cm), number of pods/plant (np/p), green weight of areal part (g), grain yield (kg/ha) and weight of 100 seeds to the FT Campo Mourão and Brasmax Potência cultivars when submitted to different levels of defoliation in the vegetative and/or reproductive stages of the crop. Dourados, MS.

Treatments	Plant height (cm)	Pods/Plant (np/p)	Green weight (g)	Grain yield (kg/ha)	Weight of 100 seeds (g)
Control without defoliation in the soybean cycle	91.4 a	47.9 a	726.3 a	3096 a	15.1 a
16.7% of defoliation in the vegetative stage	83.6 ab	55.8 a	768.1 a	2928 a	14.6 a
33.3% of defoliation in the vegetative stage	84.2 ab	50.8 a	716.1 a	2988 a	14.9 a
16.7% of defoliation in the reproductive stage	87.1 ab	55.9 a	736.3 a	2868 a	14.8 a
33.3% of defoliation in the reproductive stage	81.5 ab	47.1 a	633.8 a	2430 a	13.9 a
16.7% of defoliation throughout the plant cycle	84.2 ab	50.9 a	708.1 a	2934 a	14.8 a
33.3% of defoliation throughout the plant cycle	77.2 b	47.2 a	621.3 a	2562 a	14.6 a
Cv (%)	**8.6**	**19.7**	**17.2**	**16.6**	**6.9**
Test F	***p = 0.001***	***p =0.0361***	***p =0.168***	***p = 0.169***	***p = 0.170***

Averages followed by the same letter in the column do not differ statistically by the Tukey's test at 5% probability.

the grain yield did not differ significantly between the two cultivars studied (Table 1).

By simulating artificial defoliate in a given crop, similar to the attack by defoliation insects, the results obtained can indicate the level of damage that these plants can tolerate at a given stage of development, as well as the losses in their final productivity (Glier *et al.* 2015; Fernandes & Ávila 2016; Krinski & Foerster 2017). In the treatments with different levels of defoliation, no significant effects on plant height were observed when defoliation occurred only at the vegetative or reproductive stages of the crop (Table 2). However, when defoliation of 33.3% was carried out throughout the soybean cycle, a significant reduction in plant height was observed when compared to the control treatment, in which there was no defoliation (Table 2). Similarly, in the treatments with different defoliation conditions for the two soybean cultivars studied, no significant effects were observed for the number of pods/plant, green weight of the areal part, grain yield and weight of 100 seeds (Table 2).

It is expected that soybean plants suffering from intense defoliation may be significantly smaller in size than non-defoliated ones (Ostlie & Pedigo 1985; Bueno *et al.* 2010) as observed in the present assay when the defoliation was 33.33% throughout the crop cycle (Table 2). However, these soybean plants that suffered 33.33% defoliation during the entire crop cycle, although with smaller size, had no significant effect on grain yield as well as on the number of pods/plant and green weight of the areal part (Table 2). Therefore, it can be affirmed that even with certain defoliation levels, soybean plants are still able to resume their development and produce normally, as observed in the present study, despite having reduced the height. Soybean is known to contain a leaf canopy superior to its need for development and productivity (Borém *et al*. 2015). Probably the defoliation applied in soybean plants did not has not reached the threshold to reduce photosynthetic production in the leaves and, consequently, did not significantly interfere in the grains yield of the crop (Taiz *et al.* 2017). In addition, it is known that the number of pods per plant, among other agronomic traits, is genetically determined by the genotype, and may thus undergo small changes depending on the cultivar's growth habit.

Generally, defoliation performed in the reproductive stage (R1 to R5) is more harmful to soybean culture, compared to the same defoliation performed in the vegetative stage (Glier *et al.* 2015). Defoliation in the reproductive stage can result in a reduction in the number of pods per plant, when these structures are aborted, due to the lack of photoassimilates required for the filling of the pods (Fazolin *et al.* 2001; Schmildt *et al.* 2010; Bahry *et al.* 2013). However, in our work these effects were observed only for the height of plants with 33.3% of defoliation throughout the plant cycle. Perhaps this fact can be explained by the excessive foliar canopy that soybean has or due to the great capacity of foliar replacement that the plants presented in this research.

It is known that the reduction in carbohydrate production activity is caused by soybean defoliation in the reproductive phase directly, that interferes with the redistribution of photoassimilates within the plant, changing the patterns of dry matter accumulation in the grains (Bahry *et al.* 2013; Borém *et al.* 2015; Taiz *et al.* 2017). Based on the results obtained in the present paper, it can be stated that the economic threshold of 30% of defoliation in the vegetative stage or 15% in the reproductive stage is still considered valid to guide the management of defoliators in soybean crop.

REFERENCES

Bahry, CA, EL Dantas, E Venske, M Nardino, PD Zimmer, VQ Souza & BO Caron, 2013. Efeito da desfolha na fase vegetativa em alguns caracteres agronômicos da cultivar de soja BMX Potência RR. Brazilian Journal of Agriculture, 88: 179-184.

Balbinot, JAA, SO Procópio, H Debiase, JC Franchini & F Panison, 2015. Semeadura cruzada em cultivares de soja com tipo de crescimento determinado. Semina: Ciências Agrarias, 36:1215-1226. DOI: https://doi.org/10.5433/1679-0359.2015v36n3p1215

Bhering, LL, 2017. Rbio: A tool for biometric and statistical analysis using the R platform. Crop Breeding and Applied Biotechnology, 17: 187-190. DOI: https://doi.org/10.1590/1984-70332017v17n2s29

Borém, A, T Sediyama & F Silva, 2015. Soja: do plantio a colheita. Viçosa: UFV.

Bortolotto, OC, A Pomari-Fernandes, RCOF Bueno, AF Bueno, YKS Kruz, AP Queiroz, A Sanzovo & RB Ferreira, 2015. The use of soybean integrated pest management in Brazil: A review. *Agronomy Science and Biotechnology,* 1: 25-32. DOI: https://doi.org/10.33158/ASB.2015v1i1p25

Bueno, AF, MJ Batistela & F Moscardi 2010. Níveis de desfolha tolerados na cultura da soja sem a ocorrência de prejuízos à produtividade. Circular Técnica 79. Embrapa Soja. Londrina.

CONAB, 2020. Acompanhamento da safra brasileira de grãos - Safra 2019/20 - Segundo levantamento, Brasília. Available in: <http://www.conab.gov.br>. [Access: 21.iii.2021].

Fazolin, M, JS Pessoa, Jr DL Amaral, WSA Oliveira & CR Costa, 2001. Determinação do Nível de Ação para o controle da vaquinha-do-feijoeiro no Acre. Comunicado Técnico 134. Embrapa Acre, Rio Branco.

Fernandes, ET & CJ Ávila, 2016. Efeito de diferentes tipos de injúrias causadas nos estádios iniciais de desenvolvimento da soja. EntomoBrasilis, 9 :193-196. DOI: https://doi.org/10.12741/ebrasilis.v9i3.643

Gazzoni, DL & F Moscardi, 1998. Effect of defoliation levels on recovery of leaf area, on yield and agronomic traits of soybeans. Pesquisa Agropecuária Brasileira, 33: 411-424.

Glier, CAS, JB Duarte Júnior, GM Fachin, ACT Costa, VF Guimarães & CR Mrozinski, 2015. Defoliation percentage in two soybean cultivars at different growth stages. Revista Brasileira de Engenharia Agrícola e Ambiental, 19: 567–573. http://dx.doi.org/10.1590/1807-1929/agriambi.v19n6p567-573

Haile, FJ, LG Higley & JE Specht, 1998. Soybean cultivars and insect defoliation: yield loss and economic injury levels. Agronomy Journal, 90: 344-352.

Krinski, D & LA Foerster, 2017. Simulated attack of defoliating insects on upland rice cultivated in new agricultural frontier from Amazon Rainforest region (Brazil) and its effect on grain production. Bioscience Journal, 33: 95-104. DOI: https://doi.org/10.14393/BJ-v33n1a2017-32743

Li, X, S An, AE Eneji & K Tanabe, 2006. Salinity and defoliation effects on soybean growth. Journal of Plant Nutrition, 29: 1499-1508. DOI: https://doi.org/10.1080/01904160600837642

Lima, M, CAS Junior, L Rausch, HK Gibbs & JA Johann, 2019. Demystifying sustainable soy in Brazil. Land Use Policy. 82: 349-352. DOI: https://doi.org/10.1016/j.landusepol.2018.12.016

Lourenção, ALF, ARG Bezerra, AM Melotto, DC Gitti & JFJ Grigolli, 2019 (eds). Tecnologia e Produção Soja. Safra 2017/2018. Curitiba: Midiograf.

Monteiro, MA, F Koch, FLL Nobre, FS Zulli, BOM Araújo, EG Borges, T Pedó, TZ Aumonde & EL Santos, 2017. Intensidade de desfolha e desempenho de plantas de soja com diferentes hábitos de crescimento. Scientia Agraria Paranaensis, 16: 265-269. DOI: https://doi.org/10.18188/1983-1471/sap.v16n1p265-269

Moscardi, F, AF Bueno, DR Sosa-Gomez, S Roggia, CB Hoffmann-Campo, A Pomari-Fernandes, IC Corso & SAC Yano, 2012. Artrópodes que atacam folhas da soja. In: CB Hoffman-Campo, BS Corrêa-Ferreira & F Moscardi (eds.). Soja: manejo integrado de insetos e outros artrópodes praga. Brasília, DF: Embrapa.

Murúa, MG, MA Vera, M Herrero, SV Fogliata & A Michel, 2018. Defoliation of soybean expressing Cry1Ac by lepidopteran pests. Insects, 9: 1-13. DOI: https://doi.org/10.3390/insects9030093

Ostlie, KR & LP Pedigo, 1985. Soybean response to simulated green clover worm (Lepidoptera: Noctuidae) defoliation: progress towards determining comprehensive economic injury levels. Journal of Economic Entomology, 78 :437-444.

Parcianello, G, JÁ Costa, JLF Pires, L Rambo & K Saggin, 2004. Tolerância da soja ao desfolhamento afetada pela redução do espaçamento entre fileiras. Ciência Rural, 34: 357-364. DOI: https://doi.org/10.1590/S0103-84782004000200004

Peluzio, JM, HB Barros, RNC Rocha, RR Silva & IR Nascimento, 2002. Influência do desfolhamento artificial no rendimento de grão e componentes de produção da soja [*Glycine max* (L.) Merrill]. Ciência e Agrotecnologia, 26: 1197-1203.

Perini, LJ, NSF Junior, D Destro & CEC Prete, 2012. Componentes da produção em cultivares de soja com crescimento determinando e indeterminado. Ciências Agrárias, 33: 2531-2544. DOI: https://doi.org/10.5433/1679-0359.2012v33Supl1p2531

Ribeiro, ALP & EC Costa, 2000. Desfolhamento em estádios de desenvolvimento da soja, cultivar BR 16, no rendimento de grãos. Ciência Rural, 30:767-771. DOI: https://doi.org/10.1590/S0103-84782000000500004

Schmildt, ER, JAT Amaral, D Pratissoli & EF Reis, 2010. Influência de desfolhas artificiais para simular perdas na produção do feijoeiro (*Phaseolus vulgaris* L. cv. xamego). Arquivos do Instituto Biológico, 77: 457-463.

Taiz, L, E Zeiger, I Moller & A Murphy, 2017. Fisiologia e desenvolvimento vegetal. 6.ed. Porto Alegre: Artmed.

Todd, JW & LW Morgan, 1972. Effects of hand defoliation on yield and seed weight of soybeans. Journal of Economic Entomology, 65: 567-570. DOI: https://doi.org/10.1093/jee/65.2.567

Toloi, MNV, SH Bonilla, RC Toloi, HRO Silva & IA Nääs, 2021. Development Indicators and Soybean Production in Brazil. Agriculture, 11: 1-15. DOI: https://doi.org/10.3390/agriculture11111164

Turnipseed, SG, 1972. Response of soybeans to foliage losses in South Carolina. Journal of Economic Entomology, 65: 224-229. DOI: https://doi.org/10.1093/jee/65.1.224

Zanon, AJ, NA Streck, GL Richter, CC Becker, TSM Rocha, LC Cera, JEM Winck, AP Cardoso, EL Tagliapietra & PS Webe, 2015. Contribuição das ramificações e a evolução do índice de área foliar em cultivares modernas de soja. Bragantia, 74: 279-290. DOI: https://doi.org/10.1590/1678-4499.0463

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