Defoliation Levels Supported in Soybean Crop With No Harm on Productivity in the Municipality of Parauapebas

L. J. Damasceno[1], V. F. A. Silva[1], J. N. da Silva[1], P. A. Silva[1], C. C. Lima[1], J. P. da Silva[1], J. R. Galvão[2], N. C. Melo[3] & G. F. Valente[1]

[1] Federal Rural University of Amazon, Parauapebas, Brazil

[2] Institute of Agricultural Sciences, Federal Rural University of Amazon, Belém, Brazil

[3] Department of Soil Science, Federal Institute of Amapá, Macapá, Brazil

Correspondence: V. F. A. Silva, Federal Rural University of Amazon, Bairro Cidade Nova (Caixa postal Nº 3017), 68515-000, Parauapebas, Brazil. Tel: 94-9-9156-9961. E-mail: vicente.silva@ufra.edu.br

Abstract

The reduction in the leaf area is one of the causes in the fall in soybean (*Glycine max*) productivity as it depends on the production of photoassimilates generated by the leaves, so any factor that interferes in its leaf area may affect the production. The attack of defoliating insects is among such factors. They cause a marked drop in grain yield due to its direct action, therefore, reducing the leaf area, consequently reducing the photosynthetic rate of the plant. The agronomic characteristics of the cultivars may interfere on the level of tolerance of the plant to this type of stress. The objective of this study was to evaluate the influence of defoliation levels on the vegetative and reproductive stages on the development and yield of grains in soybean cultivars. The experimental design was in randomized blocks, in a 2×11×2 factorial scheme, with four replicates. Factors consisted of defoliation stage (vegetative and reproductive), treatment levels (T1-control plant and ten treatments of artificial defoliation) and soybean cultivars (BRS 9090 RR and BRS 8890 RR). The following variables were evaluated: grain yield, dry mass of the pod, leaf dry mass, stem and root dry mass, plant height, stem diameter, number of leaves per plant, length and width of roots. It was observed that the defoliation had a negative effect on the productivity components of the cultivars, with the highest decrease in the reproductive stage, except for the treatment R5, 100% defoliation at the R5 stage, which was also reduced. In relation to the cultivars, the BRS 8890 RR was 27% better in grain yield in relation to BRS 9090 RR.

Keywords: *Glycine max*, leaf area reduction, productivity

1. Introduction

Soybean (*Glycine max* (L.) Merril) is one of the crops with the greatest growth in planted area in the Brazilian agro-industrial segment. Its expansion and establishment of agricultural frontiers was only possible due to the development of cultivars with high productivity, wide adaptation to the different edaphoclimatic conditions and resistance to pests and diseases (EMBRAPA, 2008).

The productivity of the soybean is directly related to the photosynthesis performed by the leaves, and the production of photoassimilates from the photosynthetic complex. However, the factor that limits the leaf area may compromise crop productivity (Peluzio et al., 2002; Li et al., 2006). The attack of a large variety of defoliating insects (Timsina et al., 2007), the incidence of diseases such as soybean rust (Debona et al., 2009) and the occurrence of inclement weather (Fazolin & Estrela, 2003) are some of the factor that limits its production.

Studies that evaluate the influence of early defoliation on soybean yield through the analyses of the phenological stages in which the soybean was found (from the initial vegetative stage to the end of the reproductive period) and levels of defoliation (ranging from 0 to 100%) have demonstrated since the non-occurrence of the response until 87% of grain yield (Ribeiro & Costa, 2000; Parcianello et al., 2004).

Chemical control of defoliating insects should be avoided as it results in environmental pollution, occupational diseases, and an increase in the final cost of production. Thus, the identification of the period(s) of greater

sensitivity of the crop to defoliation, resulting from the attack of the pest insects will result in a decrease in the number of pesticide applications, consequently, it will reduce environmental damage and the cost of production.

According to Gazzoni (1974), the most important characteristics in the reduction of grain production are the number of seeds per pod and the mass of the seeds. According to Santos (1980, 1983), total defoliation in full flowering causes a reduction in grain yield due to a reduction in the number of pods per plant.

The ability of soybean when submitted to defoliation depends very much on its genetic characteristics, on the stage of development of the plants, and on the intensity of the defoliation itself (Costa et al., 2003).

Some factors may compromise the appropriate photosynthetic process, such as the low radiation incident on the canopy, the attack of defoliating insects, diseases such as soybean rust, which causes early leaf fall, abiotic stresses such as drought, salinity and soil fertility (Pedigo et al., 1986; Li et al., 2006; Timsina et al., 2007; Debona et al., 2009).

The objective of this work was to evaluate the influence of defoliation levels on the vegetative and reproductive stages on the soybean yieldand to evaluate the agronomic characteristics of each stage.

2. Material and Methods

2.1 Characterization of Experimental Area

The experiment was conducted at the nursery at UFRA (Federal Rural University of Amazonia), in the municipality of Parauapebas, Pará, Brazil, from August 2017 to January 2018. The municipality is located at the geographical coordinates 49°51′19″ W latitude, 06°12′58″ S longitude, 197 m above sea level. The climate in the region is rated as Aw according to Koppen Geiger.

2.2 Characterization of Soil

A sample was collected for soil analysis. The material was air-dried, ground, homogenized and sieved through a 2-mm stainless steel mesh sieve. Then, three samples of compounds were collected, consisting of six simple samples. These samples were sent to the laboratory for the analysis.

The physical and chemical characteristics of the soil were as follows: pH (H_2O): 4.3; Ca^{2+}: 2.1 cmolc kg^{-1}; Mg^{2+}: 1.2 cmolc kg^{-1}; Al^{3+}: 4.09 cmolc kg^{-1}; $H^{++} Al^{3+}$: 4.29 cmolc kg^{-1}; K^+: 0.32 cmg kg^{-1}; Na^+: 0.33 cmolc kg^{-1}; P: 10.10 mg kg^{-1}; organic matter: 25.62 g kg^{-1}. Clay 3.8 g kg^{-1}, silt 2.2 g kg^{-1}, coarse sand 1.7 g kg^{-1} and fine sand 2.3 g kg^{-1}.

The chemical characteristics were determined according to EMBRAPA (1997) and the particle size was classified according to Gee and Bauder (1986). Soil classification and fertilizer sizing were carried out using the Agrophytos Solo SAAT software.

Soil amendment was performed 60 days before sowing using dolomitic limestone (PRNT 70%), by raising base saturation to 70%, with the standard dosage of 6.68 t ha^{-1} as recommended for soybean for the respective soil type (EMBRAPA, 2011). The basic fertilization was performed according to the recommendation of EMBRAPA (2011), with the standard dosage of 600 kg ha^{-1} in 5-25-15 NPK formulation.

2.3 Experimental Design

The experiment was carried out in a completely randomized block design, factorial scheme 2×11 consisting of two soybean cultivars (BRS 8890 RR and BRS 9090 RR) and 11 treatments (1 Control Plant and 10 artificial defoliation) (Table 1), with 5 treatments at the vegetative stage and 5 in the reproductive stage with four replications, totaling 88 experimental units. The artificial defoliation in the plants was made for each phenological stage by using pruning shears.

Table 1. Defoliation level treatments according to the phenologic stage of the plant

Treatment	Defoliation Level
T1	Control plant with no injuries
T2	01 cotyledon removal
T3	02 cotyledon removal
T4	Removal of trefoil at V5
T5	Total defoliation at V6 stage
T6	Removal of apical bud at V6 stage
T7	Total defoliation-One open flower at any node on the main stem-R1
T8	Removal of 02 trefoil at R3-Pod from 0.5 cm to 2.0 cm on one of the four higher nodes on the main stem
T9	50% defoliation at R5-beginning of grain filing (< 10% seed filling) on one of the four higher nodes on the main stem
T10	25% defoliation at R5-beginning of grain filing (< 10% seed filling) on one of the four higher nodes on the main stem
T11	Total defoliation at R5-beginning of grain filing (< 10% de seed filling) on one of the four higher nodes on the main stem

2.4 Experimental Plots

The experiment was conducted in a nursery using 50% shading. The seeds were placed to germinate in black polyethylene bags with holes, with the capacity of 11 kilograms. For sowing, three seeds per bag were placed for subsequent thinning and conduction of a single plant until the end of the experiment.

The cultivars used in the study were BRS 8890 RR-glyphosate-tolerant transgenic soybean; cycle (maturation): 101 to 115 days; and BRS 9090 RR-transgenic soybean cultivar, which shows tolerance to the herbicide glyphosate; cycle (maturation): 100 to 127 days, both of determined growth.

The soybean seeds were treated with the fungicide/insecticide Standak Top (1.5 mL per kg of seed) and then inoculated two hours prior to sowing with Total Nitro Ultra inoculant, Turfoso solids, on August 17, 2018. A dose of 60 mL of the total Nitro Ultra inoculant per 100 kg of seeds was used. Treatments were homogenized in polyethylene bags. Monitoring and measurements were performed every day over the experiment.

In order to assure the maintenance of the homogeneous defoliation in each treatment, weekly applications of insecticides were carried out or whenever it was necessary to prevent any influence of pests that could change the required levels of defoliation.

The fungicides were also used in all treatments, whenever it was necessary according to the usual practices used by soybean farmers.

Harvest was carried done manually by cutting the plants at ground level on December 20, 2017, when they reached the R8 stage (Fehr & Caviness, 1977), totaling 123 days after planting.

2.5 Evaluated Characteristics

The following variables were analyzed at the end of soybean crop cycle:

Plant height (PH): it was measured with tape measure from the ground level to the leaf rosette.

Principal stem diameter (SD): The diameter was obtained with the use of a digital caliper with an accuracy of 0.1 mm, measuring at 5 cm above ground level.

Number of leaves (NL): all leaves of each plant were counted.

Root length and width (RL and RW): The root system was measured by using a measuring tape. Length and width of the root were determined.

Seed production (kg ha^{-1}): Pods of the plants were collected from each replicate. Then, the seeds were removed and pods were weighed and the values extrapolated to kg ha^{-1}. After harvest, the seeds were placed in an oven until reaching the commercial humidity of 13%.

Pod dry mass: Pods were removed and weighed. An oven was used at 60 ºC for 36 hours.

Stem dry mass: The stems were removed and weighed, using a stove for 36 hours at 60 ºC. Leaf dry mass: An oven was used at 60 ºC for 36 hours.

Root dry mass: roots were removed, washed and weighed using an oven for 36 hours at 60 ºC.

2.6 Data Analysis

The statistical analysis of the results was performed using the Sisvar software (Ferreira et al., 2014), so that the data were submitted to analysis of variance and, if significant, the test of Tukey was used at 5% of probability for differentiation of means.

3. Results and Discussion

Table 2 shows that for the cultivars treatment there was an isolately significance only for the number of leaves (NL) and root width (RW). Regarding the levels of defoliation and interaction between cultivars and levels of defoliation, no significance was observed.

Table 2. Summary of analysis of variance and data average for plant height (PH), number of leaves (NL), stem diameter (SD), root length (RL), root width (RW), submitted to defoliation levels and soybean cultivars

Variation Factors		AP	NF	CR	RL	RW
		m	un	-------------------- cm --------------------		
Cultivars (C)	BRS 8890 RR	0.92	46.15a	44.30	17.64a	9.74
	BRS 9090 RR	0.91	30.21b	45.33	15.03b	9.99
Defoliation level (ND)	T1	0.97	42.50	52.83	18.28	11.15
	T2	0.95	41.00	48.17	17.36	10.48
	T3	0.90	41.83	45.33	16.45	10.30
	T4	0.86	41.00	41.67	16.05	10.40
	T5	0.80	41.16	45.33	16.18	8.78
	T6	0.87	40.50	45.67	16.71	9.82
	T7	0.87	36.67	40.17	15.88	9.06
	T8	0.86	42.00	42.83	14.91	9.99
	T9	0.71	44.00	44.00	16.36	10.39
	T10	0.83	40.33	43.33	15.03	9.25
	T11	0.70	38.00	43.67	16.48	9.09
Test F	C	0.02^{NS}	6.91^{*}	0.47^{NS}	19.35^{**}	0.28^{NS}
	ND	0.98^{NS}	0.51^{NS}	1.88^{NS}	0.93^{NS}	0.69^{NS}
	C×ND	2.29^{NS}	0.53^{NS}	0.87^{NS}	1.49^{NS}	0.88^{NS}
CV (%)		10.25	24.53	13.60	14.76	19.61

Note. CV = coefficient of variation; ^{NS} = not significant (p > 0.05); ** = significant (p ≤ 0.01); * = significant (p ≤ 0.05).

A greater influence of defoliation level treatments was observed on the reproductive stages particularly on total defoliation treatment (T5, T7 and T 11).

The objective of total defoliation treatment is to simulate the severe attack of soybean rust, whose main loss is the early fall of the leaves and, consequently, the reduction of the mass of grains, by the reduction in the source, thus damaging the productivity of the crop (Yang et al., 2001). Such situation was also observed at defoliation insects attack, as the limitation of leaf area causes a smaller production of photoassimilates, therefore, compromising the adequate grain filling (Timsina et al., 2007).

A higher reduction in the height was observed (28% in relation to the control treatment, without defoliation), when they underwent total defoliation at the R5 stage, and a reduction by 10 and 18% in the treatments (T7 and T11), respectively. In the other treatments, the mean values were lower, but not significant in relation to the control.

For plant height, interaction between cultivars and defoliation level (Figure 1). No difference was observed between BRS8890 RR and BRS 9090 RR cultivars, except for T3, T5 and T9 treatments, which showed a difference.
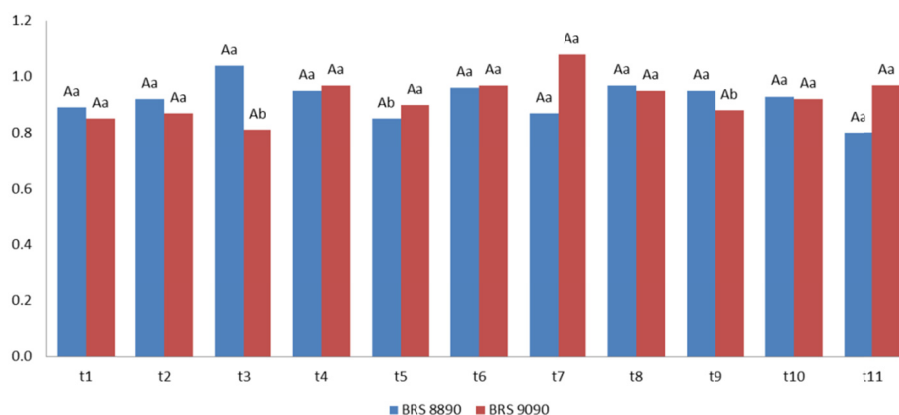
Figure 1. Unfolding between defoliation levels and cultivars for plant height variable

Note. Lower-case levels compare cultivars in each treatment and the upper-case letter compare treatments in each cultivar.

The reduction in plant height is directly related to the percentage of defoliation. Where the defoliation of the soybean in its vegetative period has little effect on its production, mainly due to the great capacity of recovery of the plant in that period, that emits many new leaves.

The soybean cultivars used in the experiment tolerate a certain defoliation index, providing the remaining leaves a greater efficiency in the photosynthetic rate when compared to the non-defoliation plants (Li et al., 2006).

The stem diameter (SD), as well as the plant height, showed statistically equal values for all treatments, plus a reduction of 14% in the T7 treatment (total defoliation-R1 stage) in relation to the control. This explains that besides the capacity of recovery of soybean, one must also consider that the plant has the characteristic of producing excess of leaf area.

For the cultivar factor, the number of leaves (NL) was significant, in which the cultivar BRS 8890 RR showed about 35% more leaves than BRS 9090 RR. This was also observed for width of roots, therefore, showing that besides the short-term changes in the distribution of photo-assimilates between the different drains (roots, nodules, expanding leaves, grains), the source metabolism adjusts to the altered conditions in long-term experiments.

Table 3 shows for the cultivar treatment a significance for the variables, productivity (PRODUT), dry stem mass (DSM) and root fresh mass (RFM). Nevertheless, for defoliation levels and interaction between cultivars, no significance was observed.

Table 3. Summary of analysis of variance and means of data on Productivity (PRODUT), Pod Fresh Mass (PFM), PDM-Pod Dry Mass; FSM-Fresh Stem Mass; DSM-Dry Stem Mass; FLM-Fresh Leaf Mass; DLM-Dry Leaf Mass; FRM-Fresh Root Mass; DRM-Dry Root Mass

Variation Factors		PRODUT	MVF	MVS	MCF	MCS	MFF	MFS	MRF	MRS
		kg ha^{-1}	--- g ---							
Cultivars (C)	8890	3954.30 a	51.7	12.99a	84.56	28.54a	55.93	13.63	55.12a	6.79
	9090	2894.42 b	51.2	9.14b	88.57	17.69b	54.08	13.69	47.10b	6.70
Defoliation level (ND)	T1	5053.00	47.8	15.81	110.87	38.57	78.96	26.97	60.86	7.81
	T2	4105.67	47.8	13.99	96.62	34.28	73.71	24.67	56.41	7.24
	T3	4091.67	47.1	12.69	95.62	27.19	58.79	14.98	54.98	5.13
	T4	3860.67	44.4	12.61	92.36	26.64	57.69	12.73	54.59	7.53
	T5	2271.67	38.4	8. 00	70.66	14.45	24.01	10.32	53.54	6.08
	T6	3586.67	43.7	11.51	88.86	22.65	52.67	11.86	53.54	6.08
	T7	2507.33	40.6	7.47	70.38	18.64	28.83	11.33	49.78	6.95
	T8	3576.33	44.3	9.41	80.66	19.28	38.82	10.75	49.20	7.20
	T9	3411.00	40.1	8.02	75.10	18.92	45.24	10.70	48.03	6.23
	T10	3193.00	39.6	8.02	69.73	17.29	43.02	8.12	45.12	5.96
	T11	2011.00	35	5.37	64.46	15.37	22.34	7.89	40.84	7.30
Test F	C	13115**	0.029^{NS}	6.65*	0.25^{NS}	16.24*	0.031^{NS}	0.00^{NS}	5.23*	0.06^{NS}
	ND	3406*	0.57^{NS}	1.36^{NS}	1.01^{NS}	1.63^{NS}	0.74^{NS}	1.54^{NS}	1.13^{NS}	1.79^{NS}
	C×ND	1923^{NS}	0.39^{NS}	0.61^{NS}	1.82^{NS}	1.24^{NS}	0.68^{NS}	1.30^{NS}	1.87^{NS}	2.40^{NS}
CV (%)		11.14	10.01	24.76	13.36	16.24	17.28	13.63	9.87	21.84

Note. CV = coefficient of variation; not significant (p > 0.05); ** = significant (p ≤ 0.01); * = significant (p ≤ 0.05).

Defoliation after vegetative stages resulted in a reduction in grain yield, in the dry mass of the pods, stems, leaves and roots. This reduction increased as the level of defoliation increased, except in the T5 treatment, which was a total defoliation at the end of the vegetative stage (Table 3).

Considering the level of defoliation within the period, it was verified that there were no significant reductions in grain yield, in relation to the control, for defoliation that occurred in the first stages of vegetative development. The exception was T5 treatment, which had a total defoliation.

The highest reductions, 60%, 55% and 50%, occurred when the defoliation was 100% in treatments T11-stage R5, T5-stage V6 and T7-stage R1 in relation to the control, identifying in the plants in the phenological phase of complete pod formation.

Defoliations after the vegetative stage caused, in general, a reduction in the grain yield. Such reduction increases as the level and the season of defoliation increases, in the defoliation treatments in relation to the control. Smaller productivity occurred in T11 total defoliation in R5-beginning of grain filling.

Authors point out the early defoliation, especially over the reproductive phase of the crop as an important factor and that it may limit the final productivity (Pratissoli et al., 2001; Parcianello et al., 2004; Peluzio et al., 2004; Fontoura et al., 2006).

The treatments performed in the vegetative stages submitted to defoliation presented higher productive index. Soybean tolerates defoliation, providing to the remaining leaves, a greater efficiency in the photosynthetic rate when compared to plants without defoliation, especially when submitted to some abiotic stress (Li et al., 2006). This higher photosynthetic efficiency contributed to the higher maintenance of vegetables near these more active leaves, which may have occurred in the study.

For Shibles et al. (1975), the defoliation changes the source/drain ratio, causing the plant to undergo a rearrangement of the physiological functions. Pissaia et al. (1982) mention that levels of defoliation cause competition in the plant between reproductive and vegetative parts. New leaves are formed at the expense of carbohydrates that would be used in the formation of the pods. This competition is more pronounced as defoliation levels increase, leading to further reductions in grain yield.

Studies have shown that defoliation of less than 50% before flowering does not normally reduce grain yield, whereas during reproductive stages, it has caused greater reductions in soybean yield (Bueno et al., 2010).

However, the capacity of the soybean to avoid reduction in the productivity after defoliation depends on factors such as the defoliation intensity itself, the phenological stage in which it occurs, the ability of the cultivar to tolerate or to compensate for defoliation (Costa et al., 2003; Parcianello et al., 2004) besides the environmental factors, among them, the solar radiation (Andrade et al., 2002).

4. Conclusions

In their early stages of development, soybean plants have a great recovery capacity in relation to defoliation, and reductions in the production are only caused when the defoliation is sufficient to cause the death of the plant, therefore, significantly reducing the plant stand. This reduction in the stand only happened with the occurrence of intense injuries, that is, when 100% defoliation occurs. Levels of defoliation and the period of leaf removal significantly influenced the number of pods per plant, the mass of one hundred seeds and the yield of grains. Thus, treatments T11, T7 and T5, where the total removal of leaves occurred, showed the largest decreases in grain yield.

It was found in this work that cultivar BRS 8890 RR showed the best results, approximately 27% more productive than the cultivar BRS 9090 RR.

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