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Agronomic performance of soybean according to stages of development and levels of defoliation

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Insect pests have led to decreases in grain yield; yet this occurrence depends on the level of defoliation and the reproductive stage of the plant when defoliation occurs. Thus, the aim of this study was to evaluate the agronomic performance of the cultivar BRS Favorita RR® according to the stages of reproductive development of the plant at defoliation and the levels of defoliation. A randomized block experimental design was used in a 6 × 3 + 1 factorial arrangement, composed of six reproductive stages at the time of defoliation [R_1 (Beginning flowering), R_2 (Full flowering), R_3 (Beginning pod formation), R_4 (Full pod formation), R_5 (Beginning seed filling), R_6 (Full seed filling -100% pod filling), and three levels of defoliation (33, 66 and 99%), as well as one additional treatment without defoliation, with three replications. The following features were evaluated: Plant height, number of pods per plant, number of grains per pod, harvest index, thousand seed weight, and grain yield. It was observed that all the levels of defoliation had a significant effect on the other variables studied, with the exception of plant height. The phenological stages at the time of defoliation had a significant effect on plant height, number of pods per plant, harvest index, and grain yield. There was a decline in grain yield with levels of defoliation as of 66%, and this decline was more significant with defoliation at the more advanced stages of the crop reproductive cycle.

Key words: Leaf area, BRS Favorita RR®, *Glycine max* (L.) Merrill, damage level.

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill] is the main oilseed crop grown in the world. Brazil is the second largest producer and exporter worldwide, with a planted area of 30173.1 thousand ha^{-1} and mean grain yield of 2854 kg ha^{-1} in the 2013/2014 crop year (CONAB, 2014). The Brazilian soybean production chain has gone through modernization processes, which have led to an increase in grain yield.

Among the factors that have brought about declines in yield, the occurrence of insect pests stands out. This constitutes one of the main problems faced by soybean producers in achieving high grain yields (Sediyama, 2009). Significant pests are the velvetbean caterpillar (*Anticarsia gemmatalis*, Lepidoptera: Noctuidae), the soybean looper (*Chrysodeixis includens*, Lepidoptera: Noctuidae), and some species of Spodoptera, due to

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Table 1. Chemical and physical composition of the dystrophic red latosolsoil (0-0.20 m) before setting up the experiment. Lavras, MG, Brazil. 2013/2014 crop season.

pH	Ca^{2+}	Mg^{2+}	Al^{3+}	$H^{+}+Al^{3+}$	SB	CEC	P	K	OM	V
H_2O			cmol$_c$ dm^{-3}				mg dm^{-3}		dag/kg^{-1}	%
6.4	5.0	1.4	0	2.9	6.7	9.6	11.46	118	3.41	69,82
Zn	**Mn**	**Cu**	**B**	**Fe**	**S**	**Clay**	**Silt**	**Sand**	**Texture class**	
		mg/dm^3					dag/kg			
4.97	31.70	1.40	0.17	34.81	4.75	64	20	16	Clayey	

H + Al, Potential acidity; SB, sum of bases; CEC, cation exchange capacity at pH 7.0; OM, organic matter; V, base saturation.

their wide distribution in Brazilian territory (Hoffman-Campo et al., 2012). Recently, the caterpillar *Helicoverpa armiger*a (Hübner) (Lepidoptera: Noctuidae) has led to expressive damage in the crop (Czepak et al., 2013; Specht et al., 2013).

Under field conditions, the leaf-eating pests cause damage by reducing leaf area and, consequently, the photosynthetic capacity of the plant. The level of damage depends on the time the pest remains on the plant, the percentage of defoliation, and the phenological stage of the plant (Hoffman-Campo et al., 2012).

Thus, producers have adopted the use of chemical products as a means of control so as to minimize the damage arising from leaf-eating insects. Nevertheless, according to Barros et al. (2002), the use of chemical products should be avoided, due to environmental consequences and the increase in production costs. Thus, identifying the period(s) of greatest sensitivity of the crop to defoliation is of great relevance in planning applications of these agricultural chemicals.

Some studies have been carried out regarding the behavior of soybean cultivars in response to damage caused by these pests (Jesus et al., 2013). A general rule is to control the leaf-eating pests when they cause 30% damage in the vegetative phase or 15% damage in the reproductive phase (Hoffmann-Campo et al., 2000), considering that above these levels, the pests cause economic losses. Therefore, agronomic performance of soybean plants undergoing defoliation is a function of the reproductive stage of the soybean and the levels of defoliation since, in some studies (Bahry et al. 2013; Souza et al. 2014), it was observed that defoliation up to 66.7% in the vegetative stages does not lead to loss in grain yield. Yet, in other studies (Diogo et al., 1997; Pelúzio et al., 2004), defoliation at any level led to reduction in yield and in yield components.

A more detailed study is necessary in respect to plant stages and the levels of defoliation tolerated by the cultivar BRS Favorita RR® (chosen for being among the cultivars most used in the south of the Brazilian state of Minas Gerais) so as to increase the effectiveness of current technologies of pest control and reduce losses.

Thus, the aim of this study was to evaluate the agronomic performance of the soybean cultivar BRS Favorita RR® under defoliation in accordance with the stages of reproductive development and levels of defoliation.

MATERIALS AND METHODS

The experiment was carried out at the Crop and Livestock Scientific and Technological Development Center – Muquém Farm/UFLA (Universidade Federal de Lavras) in the municipality of Lavras, MG, Brazil (21°14' latitude south, 45°00'W longitude west, and altitude of 918 m), in the 2013/2014 crop season. Soil in the experimental area is classified as dystrophic red latosol. The chemical and physical composition of the soil is shown in Table 1.

Climate in the region is type Cwa (wet moderate subtropical), according to the Köppen classification, with mean annual temperature of 19.3ºC and normal annual rainfall of 1530 mm (Dantas et al., 2007). The climatic data were collected at the meteorological station of the Instituto Nacional de Meteorologia (INMET) at the Universidade Federal de Lavras - UFLA and are shown in Figure 1.

A randomized block experimental design was used in a 6 × 3 + 1 factorial arrangement, composed of six reproductive stages at the time of defoliation [R_1 (Beginning flowering), R_2 (Full flowering), R_3 (Beginning pod formation), R_4 (Full pod formation), R_5 (Beginning seed filling), R_6 (Full seed filling - 100% pod filling), and three levels of defoliation (33, 66 and 99%), as well as one additional treatment without defoliation, making for a total of 19 treatments, with three replications. Defoliation was characterized by the removal of one part (terminal leaflet), two parts (opposed leaflets), and three parts (all the leaflets) of all the leaves developed on the plant, with the aid of a scissors. Each plot consisted of 4 planted rows of 5 m length, spaced at 0.50 m, for a total area of 10 m^2 (5 m × 2 m) for each plot. The two center rows were considered as a useful area for the experiment, excluding a 1 m border area from each extremity.

Soybeans were planted on December 15, 2013 and the seeds were treated with pyraclostrobin + thiophanate methyl + fipronil at the commercial product rate of 2 mL kg^{-1} of seed, and inoculated with *Bradyrhizobium japonicum* at the commercial product rate of 3 mL kg^{-1} of seed using the strains SEMIA 5079 and 5080. Fertilization consisted of 350 kg ha^{-1} of formulaic N-P_2O_5-K_2O (02-30-20) applied in the plant furrow according to recommendations of the Comissão de Fertilidade do Estado de Minas Gerais (1999). The soybean cultivar used was BRS Favorita RR® at a planting density of 12 plants/meter, which was subjected to the established levels of defoliation.

The following management was used during plant development: (i) Application of the herbicide Glyphosate (Roundup Ready®) at the rate of 1080 g e.a. ha^{-1} after crop emergence, 25 days after emergence (DAE); (ii) Preventive applications of fungicides, pyraclostrobin + epoxiconazole (Opera®) at the commercial

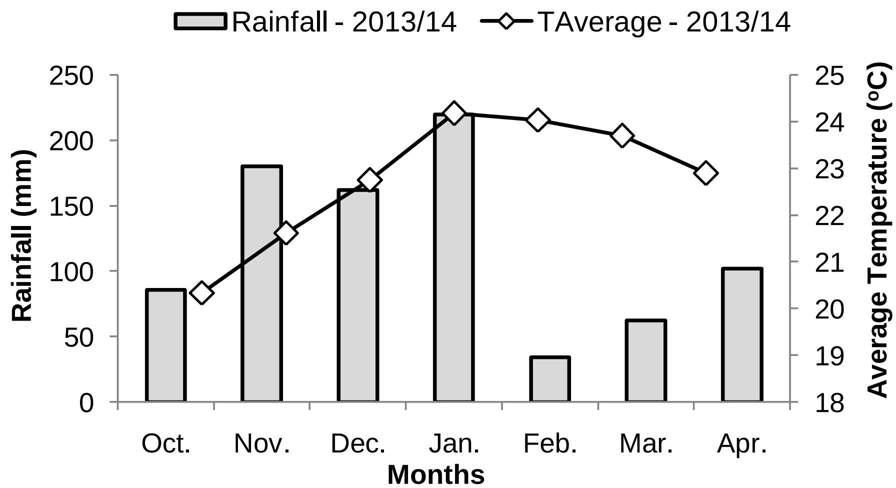

Figure 1. Monthly averages of rainfall and air temperature in Lavras during 2013/2014 cropping season. Lavras, MG, Brazil in the 2013/2014 crop season.

product rate of 500 mL ha^{-1}, applied in the R_1 stage, and azoxystrobin + cyproconazole (Priori Xtra®) at the commercial product rate of 300 mL ha^{-1} + an additional 0.5% of the adjuvant Nimbus, applied in the R_3 stage (beginning pod formation) and iii) three applications of insecticide, Teflubenzuron (Nomolt®) at the commercial product rate of 50 mL ha^{-1}, Cypermethrin (Nortox 250 EC®) and Chlorpyrifos (Fersol 480 EC®) at the commercial product rates of 120 and 250 mL ha^{-1}, respectively.

At the time of harvest (R_8 stage) the following observations were made: Plant height - determined from the soil surface to the apex of the apical meristem with the aid of millimeter ruler; after that, ten plants were collected per plot to evaluate first pod height, number of pods per plant, number of grains per pod, and thousand seed weight. The plants with in the useful area of the plot were collected manually, and threshed mechanically. The yield was transformed into kg ha^{-1} of grain, at standard 13% moisture. The grain harvest index (GHI) was also determined in the following manner: GHI = grain yield/ biological yield.

After collection and tabulation of the data, analysis of variance was carried out on the data obtained in all the parameters evaluated. For comparison of the defoliation treatments, the Tukey test at 5% probability was used. Each mean value of the defoliation treatment and the value in the additional treatment (control) were compared by the Scott-Knott test at 5% probability. The statistical program Sisvar® (Ferreira, 2011) was used to carry out the analyses.

RESULTS AND DISCUSSION

With the exception of plant height, it may be seen that the levels of defoliation had a significant ($p \leq 0.01$) effect on the other variables studied (Table 2). The phenological stages at the time of defoliation had a significant effect on the number of pods per plant, the harvest index, and grain yield. The effects of the level of defoliation and of the phenological stage at the time of defoliation on soybean production components were documented by Barros et al. (2002) and Pelúzio et al. (2002). Significant interaction between both factors occurred for grain yield. Thus, with the exception of grain yield, an isolated study of the factors of level of defoliation and the stage of the plant at defoliation was carried out for the other parameters.

Plant height

According to Table 3, this trait was not affected by the factors evaluated. Upon comparing the mean values of the treatments with the control, no statistical difference is seen. These results differ from those obtained by Diogo et al. (1997); these authors observed reductions of 26.75% in plant height when the mean values were compared with the control.

The fact that the level of defoliation and the stage of the plant at defoliation did not affect the soybean plants was expected since the cultivar used has a determined growth habit and the cultivars with these particular features tend to define this growth habit during the vegetative cycle. Therefore, after this period, the photo-assimilates produced are redistributed mainly for pod and grain formation, and a smaller portion for plant maintenance.

Number of pods per plant

Upon comparing the mean values of the treatments with the control, a significant reduction is seen for this trait at all levels of defoliation and stages in which defoliation was carried out (Table 4). The greatest reduction in the number of plant pods (51.38%) in relation to the control occurred at the 99% level of defoliation in the R_4 stage, when the pods were already completely developed. These results are similar to those seen in the study of Pelúzio et al. (2002), who also verified a significant

Table 2. Analysis of variance of the data in regard to plant height (PH), number of pods per plant (NPP), number of grains per pod (NGP), harvest index (HI), thousand seed weight (TSW),and grain yield (GY)obtained in the trials of levels of defoliation and different reproductive stages at the time of defoliation in the soybean crop of the cultivar Favorita. Lavras, MG, Brazil. 2013/2014 crop season.

Sources of variation	DF	Mean squares					
		PH	NPP	NGP	HI	TSW	GY
		cm	unit			g	Kg ha^{-1}
Blocks	2	4.73	6.50	0.16	0.0003	46.02	91048.09
Defoliation (D)	2	57.45^{ns}	352.28**	0.76**	0.30**	1827.80**	6012007.84**
Stage (S)	5	30.14^{ns}	74.09**	0.14^{ns}	0.01**	186.49^{ns}	253877.79**
D x S	10	18.50^{ns}	16.67^{ns}	0.17^{ns}	0.001^{ns}	109.22^{ns}	104324.64*
Factorial *vs* Additional	1	116.28**	591.75**	591.75*	1284.48**	599.21*	1387275.47**
Treatments	18	31.97^{ns}	138.19**	0.23^{ns}	0.05**	347.39**	870450.96**
Residue	36	24.06	10.61	0.11	0.002	125.42	45349.94
Corrected Total	56	-	-	-	-	-	-
CV (%)	-	5.37	7.77	18.56	11.55	8.06	11.80

** and * significant at the level of 1 and 5% probability by the F test, respectively. ^{ns}, not significant; DF, degrees of freedom; CV, coefficient of variation.

Table 3. Mean values of plant height (cm) obtained in the trials of levels of defoliation and different reproductive stages at the time of defoliation in the soybean crop of the cultivar FavoritaRR. Lavras, MG, Brazil. 2013/2014 crop season.

Defoliation (%)	Reproductive stages						Mean
	R_1	R_2	R_3	R_4	R_5	R_6	
33	82.26	99.66	93.46	93.33	92.20	90.53	93.48^{A}
66	89.46	96.00	90.40	86.06	92.46	86.53	90.71^{A}
99	91.80	92.26	89.53	89.60	92.66	90.40	90.68^{A}
Mean	91.17^{a}	94.86^{a}	91.13^{a}	89.66^{a}	92.44^{a}	90.48^{a}	91.62

In the column, mean values followed by the same uppercase letter, and in the row, by the same lowercase letter belong to the same group by the Tukey test at 5% probability.* Mean values statistically different from the mean value of the control without defoliation (85.00 cm) by the Scott Knott test at 5% probability.

Table 4. Mean values of the number of pods per plant (unit) obtained in the trials of levels of defoliation and different reproductive stages at the time of defoliation in the soybean crop of the cultivar Favorita. Lavras, MG, Brazil. 2013/2014 crop season.

Defoliation (%)	Reproductive stages						Mean
	R_1	R_2	R_3	R_4	R_5	R_6	
33	51.80*	44.53*	41.93*	43.33*	44.44*	56.53*	45.41^{A}*
66	46.13*	42.40*	42.66*	42.96*	43.46*	43.86*	43.58^{A}*
99	40.53*	36.46*	32.33*	30.60*	40.30*	41.86*	37.00^{B}*
Mean	45.16^{a}*	41.13^{bc}*	38.97^{c}*	38.96^{c}*	42.66^{ab}*	44.08^{ab}*	41.99

In the column, mean values followed by the same uppercase letter, and in the row, by the same lowercase letter belong to the same group by the Tukey test at 5% probability. *Mean values statistically different from the mean value of the control without defoliation (62.93 unit) by the Scott Knott test at 5% probability.

reduction in the number of pods per plant in the total defoliation carried out in the R_4 stage.

Furthermore, significant differences are detected between the levels of defoliation and the stages at which defoliation was carried out. Namely, when carried out in the R_3 and R_4 stages, greater reduction occurred for this variable, although no statistical difference occurred in the R_2 stage. Upon analyzing the levels of defoliation, it may be seen that total defoliation has the most severe impact on formation of the number of plant pods. Nevertheless,

Table 5. Mean values of the number of grains per pod (unit) obtained in the trials of levels of defoliation and different reproductive stages at the time of defoliation in the soybean crop of the cultivar Favorita. Lavras, MG, Brazil. 2013/2014 crop season.

Defoliation (%)	Reproductive stages						Mean
	R_1	**R_2**	**R_3**	**R_4**	**R_5**	**R_6**	
33	1.97	2.13	2.26	2.12	1.96	1.95	2.07^{A}
66	2.33	1.96	1.99	1.31	1.67	1.80	1.85^{AB}
99	1.62	1.83	1.49	1.70	1.41	1.87	1.65^{B}
Mean	1.98^{a}	1.97^{a}	1.91^{a}	1.71^{a}	1.68^{a}	1.87^{a}	1.86

In the column, mean values followed by the same uppercase letter, and in the row, by the same lowercase letter belong to the same group by the Tukey test at 5% probability. *Mean values statistically different from the mean value of the control without defoliation (2.09 unit) by the Scott Knott test at 5% probability.

Table 6. Mean values of thousand seed weight (g) obtained in the trials of levels of defoliation and different reproductive stages at the time of defoliation in the soybean crop of the cultivar Favorita. Lavras, MG, Brazil. 2013/2014 crop season.

Defoliation (%)	Reproductive stages						Mean
	R_1	**R_2**	**R_3**	**R_4**	**R_5**	**R_6**	
33	154.36	152.50	156.90	156.90	152.00	148.83	153.58^{A}
66	148.16	145.63	136.56*	133.66*	129.22*	148.60	140.31^{B}*
99	143.20	139.90*	137.76*	131.00*	125.83*	125.16*	133.81^{B}*
Mean	148.57^{a}	146.01^{a}	143.74^{a}	140.52^{a}*	135.70^{a}*	140.86^{a}*	142.57

In the column, mean values followed by the same uppercase letter, and in the row, by the same lowercase letter belong to the same group by the Tukey test at 5% probability. *Mean values statistically different from the mean value of the control without defoliation (154.36 g) by the Scott Knott test at 5% probability.

all the levels of defoliation negatively affect this trait. Working with the same levels of defoliation in soybean, Barros et al. (2002) observed significant reductions for this trait only at a 99% level of defoliation.

Reduction in the number of pods per plant is nothing more than a reflection of reduction in leaf area because it is in this structure that photosynthesis occurs for production of photo-assimilates, which, during the reproductive phase, are prioritized for the formation of pods and filling of grain. Thus, since there are fewer photo-assimilates, the plant tends to reduce the sinks (pods) to complete its cycle. Soybean has good capacity for leaf expansion (Procópio et al., 2003), but under total defoliation conditions, this capacity is not sufficient to compensate for defoliation. In addition, Pelúzio et al. (2002) report the occurrence of peaks of photosynthetic activity, which indicates greater demand of photo-assimilates in the reproductive stages for the plant to produce pods.

Number of grains per pod

This trait was significantly affected only for levels of defoliation (Table 5). Comparing all the defoliation treatments with the control, statistical differences were not observed for the number of grains per pod. These data corroborate those obtained by Diogo et al. (1997), in which the authors observed a smaller number (1.90) of seeds per pod in total defoliation (99%).

In light of these results, it may be seen that plants under defoliation were subject to reductions in the number of pods per plant compared to the control (Table 4). Nevertheless, upon reducing the number of sinks (number of pods) at all the plant stages and levels of defoliation, even with reductions in their leaf area, plants managed to produce photo-assimilates in a sufficient quantity to meet the demands of grain filling. In contrast, the control obtained a greater number of pods and, consequently, greater sinks for distributing its photo-assimilates. Thus, the number of grains was identical to the defoliation treatments. For Mauad et al. (2010), the total number of grains per pod is related to the total number of pods per plant. Therefore, a reduction in the total number of pods directly affects the number of grains per pod. However, that behavior was not observed in this study (Table 6).

Thousand seed weight

For this variable, a significant decrease was observed in the thousand seed weight in relation to the control for the treatments with 66% defoliation in the R_3, R_4, and R_5

Table 7. Mean values of the harvest index obtained in the trials of levels of defoliation and different reproductive stages at the time of defoliation in the soybean crop of the cultivar Favorita. Lavras, MG, Brazil. 2013/2014 crop season.

Defoliation (%)	Reproductive stages						Mean
	R_1	R_2	R_3	R_4	R_5	R_6	
33	0.70*	0.60*	0.61*	0.57*	0.55*	0.61*	0.60^{A}*
66	0.50*	0.47*	0.45*	0.45*	0.46*	0.48*	0.47^{B}*
99	0.42*	0.36*	0.32*	0.31*	0.33*	0.31*	0.34^{C}*
Mean	0.54^{a}*	0.48^{ab}*	0.45^{c}*	0.44^{c}*	0.45^{c}*	0.47^{ab}*	0.47

In the column, mean values followed by the same uppercase letter, and in the row, by the same lowercase letter belong to the same group by the Tukey test at 5% probability. *Mean values statistically different from the mean value of the control without defoliation (0.80) by the Scott Knott test at 5% probability.

stages. For total defoliation, in addition to the stages mentioned, defoliation carried out in the R_2 and R_6 stages also resulted in lower thousand seed weight (Table 7). The results of thousand seed weight as a function of levels of defoliation and plant stages for defoliation are contradictory in the literature since Pelúzio et al. (2002) observed reduction in this trait at the levels of 66 and 99% of defoliation only in the R_5 and R_6 stages, whereas Barros et al. (2002) observed reductions at all levels (33, 66 and 99%) and all stages (R_4, R_5, R_6) evaluated. Both results partially corroborate those obtained in this study.

Upon considering the mean values of levels of defoliation, a reduction is detected in thousand seed weight when there was removal of 66 and 99% of the leaves. Nevertheless, differences are not observed among the plant stages in which defoliation is carried out (Table 7).

Such findings are probably related to the low production and translocation of photo-assimilates during grain filling, which occurs in the R_4, R_5, and R_6 stages, requiring a greater quantity of leaves to increase efficiency during this process. For Sediyama et al. (1985), the increase in sinks in the reproductive period causes an increase in photosynthetic activity, highlighting the importance of leaves as a source of photo-assimilates. Therefore, the greater the percentage of defoliation occurring in the R_4, R_5, and R_6 stages of the crop, the lower the efficiency of grain filling. These observations reaffirm the importance of the presence of leaves during these stages, having a direct impact on crop yield.

Grain harvest index

The values obtained for this characteristic exhibit response patterns similar to those observed for the number of pods per plant. All the treatments showed significant difference from the control, indicating changes in plant biomass conversion to grain (Table 7). These changes may lead to losses in productive potential and utilization of resources during soybean growth, as well as losses in yield. It should be noted that even the lowest level of defoliation applied caused significant changes in the mean values of both the variables reported, and these parameters are directly related to grain yield. According to Petter et al. (2012), the grain harvest index expresses crop efficiency in converting plant biomass into grain yield, that is, there is positive correlation between the index and the harvest (Fageria and Santos, 2008).

Grain yield

The values obtained for grain yield exhibited the same tendency of response to treatments observed for thousand seed weight (Table 8). Nevertheless, only the treatments with defoliations of 66 and 99% differed significantly from the control (Table 7). These results are similar in part to those obtained by Diogo et al. (1997), who observed reductions from the defoliations of 66% in the R_4 and R_5 stages, and from total defoliation in all the reproductive stages studied (R_2, R_4, and R_6). Ribeiro and Costa (2000) also observed drastic reductions in yield with defoliations greater than 67% at all the developmental stages evaluated, and yields were even weaker if defoliations were applied in the reproductive stages of development. Likewise, in similar trials, Fontoura et al. (2006) observed that the treatment with 100% defoliation in the R_5 stage led to the lowest grain yield, with reduction of 76% in relation to the control.

It is important to highlight that this variable is dependent on the other parameters already evaluated, such as number of pods per plant, number of grains per pod, and the seed weight. Thus, it is possible to observe that the variation shown for grain yield may be explained by the variations observed previously for the other traits. Any variation not explained by the previous parameters may be related to the Defoliation X Plant Development Stage interaction (D x S), which was significant for grain yield.

The soybean plant is characterized by high compensation capacity (Hoffman-Campo et al., 2012), especially when the damage levels are low, and its

Table 8. Interaction effect between levels of defoliation and different reproductive stages at the time of defoliation for grain yield (kg ha^{-1}). Lavras, MG, Brazil. 2013/2014 crop season.

Defoliation (%)	Reproductive stages						Mean
	R_1	R_2	R_3	R_4	R_5	R_6	
33	2638.44Aa	2498.48 Aa	2238.44 Aa	2295.10 Aa	2194.56 Aa	2421.27 Aa	2381.05
66	2084.86 Ba*	1828.31 Ba*	1779.55 Ba*	1801.66 Ba*	2067.73 Aa*	1913.77 Ba*	1912.65
99	1774.48 Ba*	1310.60 Cab*	1295.33 Cab*	1193.91 Ca*	1008.04 Ba*	807.99 Ca*	1231.72
Mean	2165.92	1879.13	1771.11	1763.56	1756.78	1714.34	1841.81

In the column, mean values followed by the same uppercase letter, and in the row, by the same lowercase letter belong to the same group by the Tukey test at 5% probability. *Mean values statistically different from the mean value of the control without defoliation (2526.26 kg ha^{-1}) by the Scott Knott test at 5% probability.

Table 9. Percentage variation of grain yield (%) obtained due to in the trials of levels of defoliation and different reproductive stages at the time of defoliation in the soybean crop of the cultivar Favorita. Lavras, MG, Brazil. 2013/2014 crop season.

Defoliation (%)	Reproductive stages					
	R_1	R_2	R_3	R_4	R_5	R_6
33	+ 4.44	- 1.09	- 11.31	- 9.15	- 13.13	- 4.15
66	- 17.47*	- 27.62*	- 29.55*	- 28.68*	- 18.15*	- 24.24*
99	- 29.75*	- 48.12*	- 52.74*	- 52.74*	- 60.09*	- 68.01*

Mean values statistically different from the mean value of the control without defoliation according to the mean values shown in Table 8.

recovery without losses in grain yield is possible. It shows good plasticity, which allows it to change its morphology in accordance with the damages that occur.

This behavior of defoliation at a lower intensity carried out at the beginning of the reproductive cycle may be softened by the compensation effect of the plant, which puts forth new leaflets. In contrast, upon analyzing the yield of the control (2526.26 Kg ha^{-1}), it may be seen that performance is below the mean yield for the crop in the state of Minas Gerais (2687 Kg.ha^{-1}) achieved in the 2013/2014 crop season (CONAB, 2014). This is related to the low rainfall amounts, which probably hurt recovery of the plants that received the most severe defoliations (Figure 1).

According to Larcher (2004), plant cover functions as an assimilation system in which layers of leaves are overlaid and provide mutual shading and in which solar radiation arrives in the plant cover in various manners: directly through openings in the plant cover or from the margins, and as diffuse radiation derived from reflection of the leaves and the soil surface, or even as radiation transmitted through the leaves.

Thus, small levels of defoliation do not affect plant production. This occurrence is probably based on the increase in photosynthetic production of the plant promoted by greater penetration of radiation at the lower layers of the plants. For Bueno et al. (2010) and Souza et al. (2014), depending on the intensity of the attack of leaf-eating insects, the leaf area of the remaining leaves are able to carry out photosynthesis at a sufficient level to ensure energy production for the plant, in addition to remobilization of the reserves.

Regardless of the stage at which defoliation takes place, the treatments involving total removal of the leaves showed greater yield reductions (Table 9). At this level of defoliation, greater losses in yield are observed to the extent that leaf removal was carried out in more advanced stages, especially evident in the loss of 68.01% of grain yield with defoliation in the R_6 stage. These results are in agreement with those observed by Diogo et al. (1997), Pelúzio et al. (2002), Barros et al. (2002) and Carvalho et al. (2012), who also detected greater reductions in grain yield upon carrying out total removal of the leaves at more advanced reproductive stages of the crop.

It should be emphasized that the decreases in yield at the levels of defoliation of 66 and 99% reflects the lower number of pods per plant (Table 3), and reduction in the thousand seed weight at these levels of defoliation (Table 6). The reduction in yield as a result of defoliation of 66% in the R_3, R_4, and R_6 stage, and in total leaf removal in these stages mentioned plus the R_2 stage is directly related to the thousand seed weight (Table 6).

The results show a large impact from the plant reproductive stage at the time of defoliation and the level of defoliation on the agronomic development of the crop and on yield. However, there are some practices suggested in the literature for the purpose of lessening the damages. According to Costa and Daros (2006), reduction in the spacing between plant rows may decrease the effects caused by defoliation. From the results, it is possible to see that the cultivar BRS Favorita® exhibits sensitivity to defoliation, with alteration in all the traits evaluated, except for plant height.

There was a decrease in grain yield as of levels of defoliation of 66%, and these losses were more significant when defoliation occurred at the more advanced stages of the reproductive cycle of the crop.

Conflict of Interest

The authors have not declared any conflict of interest.

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