Sowing date influence on the soybean tolerance to defoliation at the beginning of pod formation[1]

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ABSTRACT

Late sowings anticipate flowering and decrease the soybean vegetative plasticity. These changes may limit the ability of plants to tolerate leaf area losses. The objective of this research was to evaluate the sowing date effect on soybean tolerance to defoliation at the beginning of pod formation. The experiment was set in Lages (Santa Catarina State, Brazil) during the 2016/2017 growing season. Two sowing dates were tested: November 2, 2016 (preferential) and December 15, 2016 (late). Five levels of defoliation (0%, 17%, 33%, 50% and 67%) of cultivar NA 5909 RG were imposed at the R3 growth stage. Grain yield showed a quadratic response to defoliation, ranging from 4,313 to 6,478 kg ha^{-1} in the preferential sowing date and from 3,374 to 4,443 kg ha^{-1} in the late sowing date. The plants tolerated up to 45.6% of defoliation in early sowing and 55.8% in late sowing, without yield losses, in comparison to the control. The highest level of defoliation reduced grain yield by 26.9% and 13.4% in early and late sowings, respectively, compared to the control. The delay of sowing date did not increase the sensitivity of cultivar NA 5909 RG to defoliation at the beginning of pod formation.

Keywords: *Glycine max*; leaf area; management practices; grain yield; abiotic stress.

INTRODUCTION

Soybean may be attacked by defoliating pests from seedling emergence to grain physiological maturity (Grigolli, 2015). The main insects that cause direct defoliation are the velvetbean caterpillar *Anticarsia gemmatalis* Hübner, 1818 (Lepidoptera, Noctuidaea) and the soybean looper *Chrysodeixis includens* Walker, 1858 (Lepidoptera, Noctuidae). Some species of the genus *Spodoptera* spp. are also important due to the decline in the use of integrated pest management (IPM) and a consequent increase in the number of insecticide applications (Bueno *et al.*, 2013).

The rationale for IPM is based on the premise that not all insect species need control and that plants tolerate some levels of infestation and injury without reducing grain yield (Hoffmann-Campo *et al.*, 2012). Thus, control of defoliating insects should start when the levels of economic injury reach 30% defoliation in the vegetative phase and 15% in the reproductive phase. At the same time, the IPM recommends that the insect population density should be monitored using the drop cloth method, considering the need for chemical intervention when there are up to 20 caterpillars (> 1.5 cm) per meter (Bortolotto *et al.*, 2015).

The effects of leaf area loss depend on defoliation percentage, injury duration and the crop growth stage (Hoffmann-Campo *et al.*, 2012). In addition to the attack of defoliating insects, crops may be under abiotic stress conditions throughout their growth when sowing does not

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occur within the optimal time. There may be deficiency or excess of atmospheric factors, such as solar radiation, temperature, air humidity and precipitation (Board & Kahlon, 2011).

Late sowing dates carried out after the end of November accelerate soybean growth. They anticipate flowering due to high temperatures and the decline of the photoperiod after December 21^{rst}. These meteorological conditions result in a shorter vegetative cycle, limiting canopy growth (Trentin *et al.*, 2013; Frigeri *et al.*, 2019). By interfering with the plant architecture, late sowings can reduce their ability to produce new leaves and recover their leaf area after defoliation.

Several studies have reported the negative impacts of late sowing dates (Cruz *et al.*, 2010a; Amorim *et al.*, 2011; Meotti *et al.*, 2012; Balena *et al.*, 2016; Carmo *et al.*, 2018) and defoliation (Glier *et al.*, 2015; Zuffo *et al.*, 2015; Monteiro *et al.*, 2017; Damasceno *et al.*, 2019; Durli *et al.*, 2020) on the productive performance of soybean crops. However, no research assessing the combined effects of these two factors on the crop agronomic performance was found. Therefore, there is a lack of information related to the influence of sowing time on soybean tolerance to defoliation.

The present experiment was based on the hypothesis that soybean tolerance to defoliation is lower when the sowing time is delayed. The objective of this research was to evaluate the effects of sowing date on soybean tolerance to defoliation performed at the beginning of pod formation.

MATERIAL AND METHODS

The experiment was carried out in seed beds, at the Santa Catarina State University, in Lages, SC, Brazil, during the growing season of 2016/2017. Each bed was 16 m long and 1.45 m wide. The location has the following geographical coordinates: 27°48’58”S south latitude and 50°19’34”W west longitude. The climate of the region, according to the classification of Köppen & Geiger (1928), is Cfb, mesothermal, with mild summers, average temperatures of the hottest month below 22 ºC and well-distributed rainfall.

The soil of the experimental area is classified as typical Distroferric Red Nitisol (Embrapa, 2006). The soil had the following characteristics at the 0-20 cm layer: 405 g kg^{-1} clay; pH in water 5.1; 24.9 mg dm^{-3} of P; 223 dm^{-3} of K; 3.7 g kg^{-1} organic matter; 4.7 cmol$_{ç}$ dm^{-3} Ca; 1.9 cmol$_{ç}$ dm^{-3} Mg; 1.0 cmol$_{ç}$ dm^{-3} of Al and 20.9 cmol$_{ç}$ dm^{-3} of CTC.

The experiment used a randomized split-plot block design with three replications per treatment. Two sowing dates were tested in the main plots: November 2, 2016 (preferential) and December 15, 2016 (late). Five defoliation levels were evaluated in the split plots: 0%, 17%, 33%, 50% and 67% of the leaf area presented by the crop at the R3 growth stage (beginning of pod formation), according to the phenological scale proposed by Fehr & Caviness (1977). Each split plot comprised four rows of 1.25 m in length with the inter-row spacing of 0.25 m. The two central rows were considered as usable area and the two external rows as borders.

The 0% defoliation level was equivalent to the control. The 17% and 33% rates were close to the economic injury levels (EIL) proposed by the IPM approach for the reproductive and vegetative phases, respectively. The 50% and 67% levels were above the EIL at any crop growth stage. Defoliation was performed with the aid of scissors. The leaflets from all trifoliolate leaves were removed or cut lengthwise according to the level of each treatment, as shown in Figure 1.

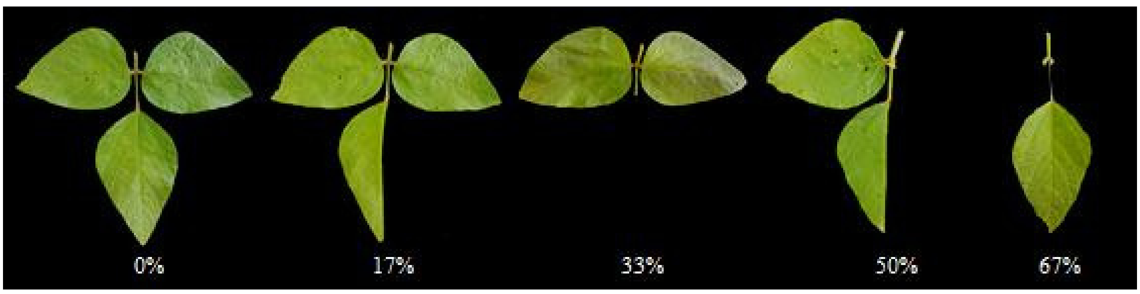


Figure 1: Defoliation levels imposed on each trifoliolate leaf of the soybean plants.

The experiment was manually sown dropping three seeds per hill of cultivar NA 5909 RG. This cultivar belongs to the 6.2 maturity group, has an indeterminate growth habit and is largely grown in southern Brazil.

The seeds were treated with 2 ml kg^{-1} cyantraniliprole + thiamethoxam (Fortenza Duo®) and with 3 ml kg^{-1} inoculant (Masterfix Soja®). Fertilization used 310 kg ha^{-1} triple superphosphate and 155 kg ha^{-1} potassium chloride, as recommended by CQFS (2016) to obtain grain yield of 6,000 kg ha^{-1}. The fertilizers were distributed superficially, close to the crop rows, after sowing. When the plants were at stage V1, thinning was carried out to adjust the population to 30 plants m², at both sowing times. The experiment was irrigated daily in the absence of precipitation to keep the soil moisture close to field capacity.

Post-emergent weed chemical control was performed with 5 ml L^{-1} of the herbicide glyphosate (Roundup®) when the plants were at the V2 growth stage. Preventive disease control was performed with 1.5 ml L^{-1} azoxystrobin + cyproconazole (Priori Xtra®), 1 g L^{-1} azoxystrobin + benzovindiflupyr (Elatus®), 2.6 ml L^{-1} trifloxystrobin + prothioconazole (Fox®). Fungicides were sprayed at stages V8, R1 and R5, respectively. Pest control was performed with 1.2 ml L^{-1} profenofos + lufenuron (Curyom®), 0,5 ml L^{-1} lambda-cyhalothrin + chlorantraniliprole (Ampligo®) and 1 ml L^{-1} thiamethoxam + lambda-cyhalothrin (Engeo Pleno®). The insecticides were applied at stages V4, V8, R1, R3 and R5.

Leaf area was determined by measuring the length and the largest width of the central leaflet of each trifoliolate leaf. The equation proposed by Richter *et al.* (2014) was used: LA = a. (L. W), where: LA is leaf area (cm²), L is leaflet length (cm), W is the largest leaflet width (cm), and *a* is the slope of 2.0185. Leaf area per plant was determined adding the leaf area of all trifoliolate leaves. Leaf area index (IAF) was calculated dividing the leaf area of five plants in each split plot by the soil surface occupied by them. Two assessments of LAI were carried out; the first one on the day defoliation was imposed at stage R3, and the second one at the R5 growth stage (beginning of grain filling). LAI differences were also determined between stages R3 and R5.

The harvests were carried out on April 10, 2017 and April 24, 2017, for the preferential and late sowing dates, respectively. The plants were hand-picked and threshed in a stationary thresher. Five plants from each split plot were collected to determine the number of pods per plant and grains per pod. These plants were later placed next to the others of the usable area to determine 1,000-grains weight and grain yield.

The data were evaluated by the analysis of variance using the F-test at a 5% significance level ($P < 0.05$). When the significance levels were reached, the means of the qualitative factor (sowing date) were compared using Tukey's test while those of the quantitative factor (defoliation) were compared by polynomial regression, both at 5% significance ($P < 0.05$). The choice of linear and quadratic equations in the figures was made according to the coefficient of determination that best fit the tested models.

RESULTS AND DISCUSSION

Table 1 shows the F-values and their levels of significance for the study variables. There was an interaction between sowing date and defoliation factors for the following variables: leaf area index at the R5 growth stage, grain yield, number of pods per plant and biological yield.

Leaf area index (LAI) at the R3 growth stage, before the imposition of defoliation levels, was influenced by the main effect of sowing time (Table 1). LAI was lower when soybean was sown in mid-December (Table 2).

Zanon *et al.* (2015a) also found a similar result. The authors reported a reduction in LAI with delayed sowing time, regardless of the maturity group and growth habit of the cultivar. Similarly, Balena *et al.* (2016) found a reduction from 3.7 to 2.8 for LAI when sowing was postponed from October to December, at the inter-row spacing of 0.25 and 0.50 m. When sowing is delayed, the plants accelerate their growth cycle and are induced to earlier flowering due to high temperatures and reduced photoperiod after December 21rst (Trentin *et al.*, 2013). These meteorological conditions favor the crop LAI reduction, as found in the present work.

A LAI value of 3.5 at flowering is necessary to obtain grain yields above 4,500 kg ha^{-1}, in cultivars with indeterminate growth habits (Tagliapietra *et al.*, 2018). This is the critical LAI so that the crop can intercept at least 95% of solar radiation. The evolution of LAI throughout the soybean growth cycle depends on the sowing time, genotype, plant density, inter-row spacing and pest management (Zanon *et al.*, 2015a). LAI values at both preferential and late sowings were above the critical value. The reduced inter-row spacing (0.25 m) used in the experiment favored the achievement of high IAF values, as this index is obtained through the relationship between the leaf area and the soil surface occupied by the plant.

Table 1: F-values according to the analysis of variance for the variables: leaf area index before defoliation at R3 (LAI R3), leaf area index at R5 (LAI R5), leaf area index between R3 and R5 (LAI R3-R5), grain yield (GY) 1,000-grains weight (TGW), number of pods per plant (PP), number of grains per pod (GP), biological yield (BY) and harvest index (HI), as affected by sowing dates (Nov. 2, 2016 and Dec. 15, 2016) and defoliation levels (0, 17, 33, 50 and 67%), at the R3 stage of soybean development[1]

Source of variation[2/]	DF	LAI R3	LAI R5	LAI R3-R5	GY	TGW	PP	GP	BY	HI
Blocks	2	8.2ns	0.1ns	0.2ns	0.8ns	3.3ns	1.0ns	1.4ns	0.5ns	0.8ns
Sowing date (SD)	1	73.2*	54.7*	0.3ns	98.2*	1,006.4*	916.2*	6.1ns	511.4*	23.8*
Error A	2									
Defoliation (D)	4	--	220.6*	31.6*	14.8*	8.6*	19.0*	1.0ns	4.9**	4.2*
S X D	4	--	23.9*	0.4ns	2.3*	1.3ns	10.8**	1.2ns	3.0*	2.5ns
Error B	16									
Total	29									

[1/]Stages R3 (beginning of pod formation) and R5 (beginning of seed filling) according to the scale proposed by Fehr & Caviness (1977). [2/] ** significant at the 1% probability level ($p < 0.01$) * significant at the 5% probability level ($p < 0.05$); ns - non-significant ($p > 0.05$).

Table 2: Leaf area index at the R3 growth stage, 1,000-grains weight and harvest index of soybean as affected by the sowing date, on the average of five defoliation levels at the R3 growth stage[1/]. Lages, SC, 2016/2017

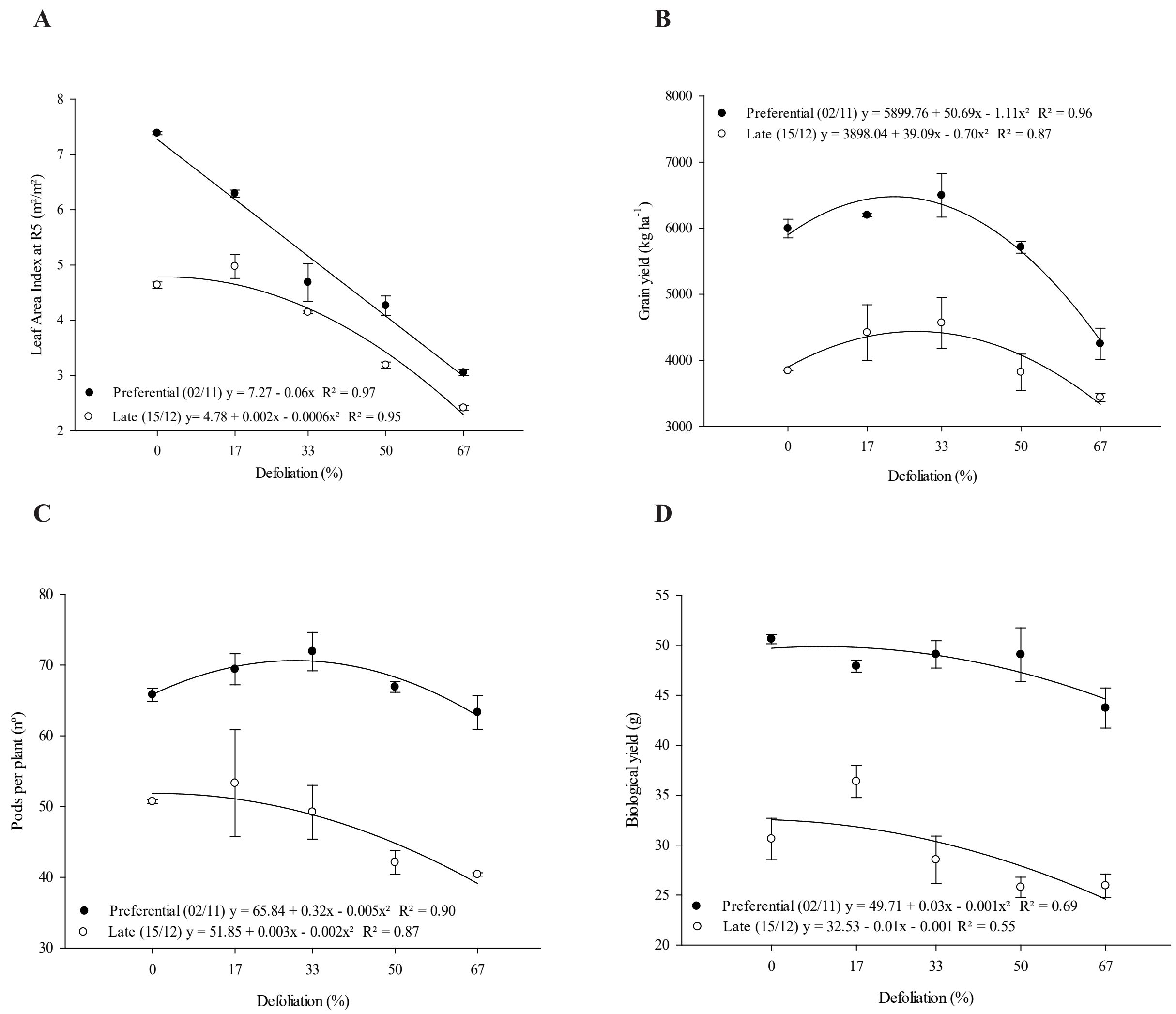
	Sowing Date		CV (%)
	Preferential (11/02/2016)	Late (12/15/2016)	
Leaf area index at R3[2/]	8.1 a*	6.1 b	9.1
1,000-grain weight (g)	200.3 a	179.1 b	2.6
Harvest index (g/g)	0.54 b*	0.56 a	3.7

[1/]Defoliation levels: 0%, 17% 33% 50% and 67% of the total leaf area of the plant.[2/]Leaf area index measured before defoliation at the R3 growth stage (beginning of pod formation) according to the phenological scale proposed by Fehr & Caviness (1977). *Means followed by different lowercase letters on the row differ from each other by Tukey's test at the 5% significance level.

LAI at the beginning of grain filling (R5) was influenced by the interaction between sowing date and defoliation (Table 1). There was a linear and quadratic reduction in LAI as defoliation percentage increased, with a decrease by 55.2% and 53.5% of the highest defoliation level, in comparison to the control, at the preferential and late sowing, respectively (Figure 2A). A similar result was also reported by Durli *et al.* (2020), who, when evaluating the leaf area at R5, after defoliation at R3, found that the reduction in leaf area was proportional to the level of defoliation imposed, regardless of the maturity group of the cultivar.

High IAF values were kept at R5, after defoliation at the R3 growth stage. Likewise, IAF values lower than 3.5 were found only at the levels of 64% and 49% defoliation in preferential and late sowings, respectively. The high LAI value recorded at stage R3 (Table 2) allowed the leaf area to remain high at R5, even after defoliation of up to 67%.

LAI between stages R3 and R5 was influenced by the main effect of defoliation (Table 1). There was a quadratic increase in LAI with an increase in the percentage of defoliation up to the level of 50% (Figure 3A).



The bars indicate the means of the treatment ± the standard error.

Figure 2: Leaf area index at R5 (beginning of grain filling) (A), grain yield (B), number of pods per plant (C) and biological yield (D) of soybean as affected by sowing date and defoliation at the R3 growth stage (beginning of pod formation). Lages, SC, 2016/2017.

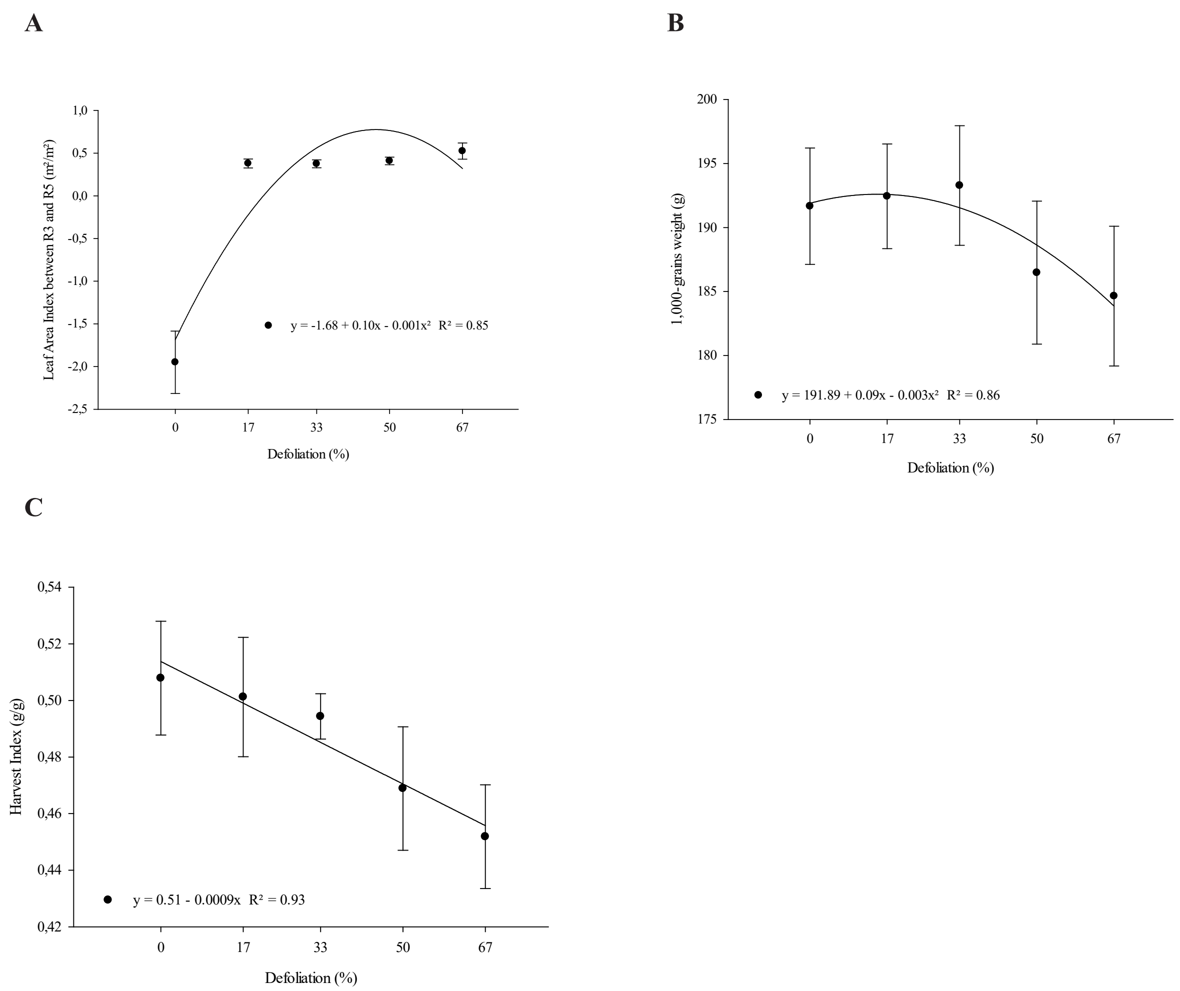
The control showed greater senescence than leaf increment, as LAI between the stages R3 and R5 was negative. This response is associated with high IAF values and, consequently, greater leaf shading. Shaded leaves reduce investment in photosynthetic proteins and decrease the respiration rate to minimize carbon use. Thus, with intense shading, the carbon balance is negative, leading to nutrient reallocation and leaf senescence (Brouwer *et al.*, 2012).

The greatest increase in LAI from R3 to R5 occurred between the control and the treatment with 17% of defoliation. After this level of defoliation, there was little variation in the LAI values between R3 and R5, regardless of the percentage of leaf area removed. One of the hypotheses of this research was that the plants have smaller ability to expand new leaves in late sowings, due to their shorter crop cycle (Trentin *et al.*, 2013). This behavior was not confirmed because the sowing date did not have a significant effect on leaf expansion (Table 1).

Grain yield was influenced by the interaction between sowing date and defoliation (Table 1). It showed a quadratic response to defoliation, ranging from 4,313 kg ha^{-1} to 6,478 kg ha^{-1} in the preferential sowing and from 3,374 kg ha^{-1} to 4,443 kg ha^{-1} in the late sowing date (Figure 2B). The grain productivities were higher than the average Brazilian yield value, which was approximately 3,300 kg ha^{-1} in the growing season of 2019/2020 (Conab, 2020), even in late sowing and with defoliation of up to 67%.

There was a reduction of 2,001 kg ha^{-1} of grain yield in the control when sowing was carried out in 12/15/2016. This result represents a decrease of 33.9%, in comparison to the yield in the control sown in the beginning of November. Cruz *et al.* (2010a) and Amorim *et al.* (2011) found the same trend. These authors reported lower grain yield when the sowing was carried out in Mid-December, and marked losses when it was postponed to late December and early January, regardless of cultivar cycle.

In late sowings, the high temperatures and the shorter day length during the initial plant growth period accelerate crop development, resulting in a shorter vegetative cycle, early flowering and low canopy growth. These phenological changes lead to yield losses (Trentin *et al.*, 2013; Frigeri *et al.*, 2019), as found in the present study.



The bars indicate the mean of the treatment ± the standard error.

Figure 3: Leaf area index (LAI) between stages R3 (beginning of pod formation) and R5 (beginning of grain filling) (A), 1,000-grains weight (B) and harvest index of soybean (C) as affected by defoliation at the R3 growth stage, on the average of two sowing dates (Nov. 2, 2016 and Dec. 15, 2016). Lages, SC, 2016/2017.

The maximum points of the quadratic functions fitted to the data indicate that there was an increase in grain yield up to the level of 22.8% of defoliation in the preferential sowing date (6,478 kg ha^{-1}) and 27.9% defoliation in the late sowing date (4,443 kg ha^{-1}). This result shows that moderate loss of leaf area does not reduce soybean grain yield because it can be compensated by the greater penetration of solar radiation into the lower layers of the canopy, leading to increased production of photoassimilates (Zuffo *et al.*, 2015).

The crop tolerated 45.6% defoliation in the preferential sowing and 55.8% in the late sowing, without presenting yield losses. Compared to the control, the highest level of defoliation reduced grain yield by 26.9% and 13.4% at the preferential and late sowings, respectively. These results did not confirm the hypothesis of the present study that soybean tolerance to defoliation is lower in late sowing.

The high tolerance of plants to defoliation is probably due to the LAI recorded at the beginning of grain filling. Defoliation levels of 45.6% and 55.8% provided LAI values of 4.5 and 3.0 in the preferential and late sowings, respectively. Therefore, even with a high percentage of defoliation, LAI was close to the critical value proposed by Tagliapietra *et al.* (2018) to accomplish high productivities (Figure 2A). A similar result was found by Owen *et al.* (2013). These authors reported that 67% defoliation kept the LAI close to 3.5 and that there were significant losses in grain yield only when defoliation exceeded 63% at the growth stages R3 and R5.

Soybean was more tolerant to defoliation in the late sowing date because the LAI values were closer to the ideal to intercept solar radiation when the crop was sown in Mid-December (Table 2, Figure 2A). Likewise, the reduced intra-row spacing used in the experiment help the crop to withstand high defoliation levels, increasing the interception of solar radiation (Board *et al.*, 2010). Moreover, cultivars with indeterminate growth habits, such as NA 5909 RG, have a longer overlapping period between the vegetative and reproductive growth stages (Zanon *et al.*, 2015b). This makes them more able to recover from short periods of stress. The high level of soil fertility and the use of irrigation also favored the plant tolerance to defoliation in the late sowing date.

The main effects of sowing date and defoliation (Table 1) influenced the 1,000-grains weight. The delay in sowing date from 11/2/2016 to 12/15/2016 reduced grain weight (Table 2). A similar behavior was found by Frigeri *et al.* (2019), who reported a reduction in seed weight with late sowing, regardless of cultivar and plant density. This response is associated with the decrease in temperature and solar radiation availability during grain filling when sowing is performed late. Low temperatures and lower light incidence reduce photosynthetic activity and the ability of plants to translocate photoassimilates from the source to the sink, thus reducing seed weight (Rodrigues *et al.*, 2006).

The 1,000-grains weight showed a quadratic reduction after defoliation, remaining practically stable until the level of 33% and decreasing as the defoliation increased (Figure 3B). There was a reduction of 7.4 g in grain weight with the greatest defoliation level compared to the control, representing a decrease of 3.9%.

This result corroborates the data reported by Zuffo *et al.* (2015), who found that 33% defoliation from the growth stages R1 to R6 did not reduce 1,000-seed weight. The low influence of defoliation on grain weight was also found by Glier *et al.* (2015), who reported an average reduction of 6.2% only with 100% defoliation, regardless of the growth stage when the stress was imposed (V4, V9, R3 and R5).

The photoassimilates accumulated during flowering probably helped to avoid a sharp decrease in grain weight when defoliation was performed in the beginning of pod formation. At this growth stage, soybean accumulates dry weight and nutrients in the vegetative parts of the plant, including leaves, petioles and branches (Mundstock & Thomas, 2005).

The number of pods per plant was influenced by the interaction between sowing date and defoliation (Table 1). There was a reduction of 13.9 pods per plant in the control when the sowing date was delayed, representing a decrease of 21.2% (Figure 2C). The number of pods per plant was smaller in all treatments with defoliation in the late sowing, in comparison to the preferential sowing date.

This result corroborates the findings of Cruz *et al.* (2010a), who reported an average reduction of 30% in the total number of pods between preferential and late sowing times. This response is associated with the occurrence of early flowering in late sowing times. This contributes to the formation of fewer nodes and productive branches, reducing the number of flowers and pods produced per plant (Zanon *et al.*, 2018).

In the preferential sowing date, the number of pods per plant increased up to the level of 33% of defoliation. The number of pods per plant between the control and the highest level of defoliation was similar. The high leaf area index of the crop at R3 and R5 (Table 2, Figure 2A) allowed the plants to maintain a similar number of pods to that of the control, even when it underwent the highest level of defoliation.

On the other hand, in the late sowing date, the number of pods per plant decreased as the percentage of defoliation increased. There was a reduction of 8.7 pods per plant with the highest level of defoliation, representing a decrease of 16.9%. This behavior was also reported by Durli *et al.* (2020), who found a decrease in the number of pods per plant with increasing defoliation at the R3 growth stage in cultivars NA 5909 RG and TMG 7262 RR. The reduction in leaf area may affect negatively soybean yield components due to the decrease in the plant photosynthetic capacity (Damasceno *et al.*, 2019). Thus, the plant aborts part of the pods and maintains those that have the capacity to translocate photoassimilates from the remaining leaves (Silva *et al.*, 2015).

The number of grains per pod ranged from 2.0 to 2.3 and was not significantly influenced by sowing time and defoliation (Table 1, data not shown). This was the yield component that has the lowest effect on grain yield, since it is little influenced by the cropping environment (Silva *et al.*, 2015).

The biological yield was influenced by the interaction between sowing date and defoliation (Table 1). It was lower at all defoliation levels in the late sowing date (Figure 2D). Ludwig *et al.* (2010) reported a reduction in the biological yield of 11 soybean cultivars when sowing was postponed from November to January, regardless of sowing density. Likewise, Cruz *et al.* (2010b) found sharp decreases in soybean dry matter accumulation when sowing was delayed from November 29 to January 12, in five cultivars with different cycles. The reduction of LAI, number of pods per plant, 1,000-grain weight and grain yield contributed to the lower biological yield observed in the late sowing date.

Biological yield had a quadratic decrease as defoliation percentage increased at the two sowing dates (Figure 2D). There were 5% and 15.8% reductions in biological yield with the highest level of defoliation, compared to the control, at early and late sowing dates, respectively.

Rezaei *et al.* (2012) did not find changes in dry weight accumulation with defoliation of 25%, 50% and 75% during soybean reproductive phase. Stresses or injuries caused by defoliating agents can influence both the rate and the duration of plant dry weight accumulation (Taiz *et al.*, 2017). Defoliation affects dry weight accumulation because it decreases the leaf area for interception of solar radiation and carbon fixation, resulting in lower biological yield by source reduction.

The main effects of sowing date and defoliation (Table 1) influenced the harvest index. It was higher in late sowing than preferential sowing (Table 2). Ludwig *et al.* (2010) also reported higher harvest index values when late sowing was carried out. As in the present study, the authors emphasized that the higher harvest index in late sowing did not result in higher grain yield, because the biological yield was lower in the Mid-December sowing date.

The harvest index decreased linearly with increased defoliation percentage (Figure 3C). There was an 11.8% reduction in the harvest index from the control to the highest level of defoliation, on the average of the two sowing dates. Board *et al.* (2010) also reported a decrease in the harvest index with increasing defoliation, in a study with weekly defoliation of 33%, 66% and 100% performed at stages R5 and R6. Similarly, Zuffo *et al.* (2015) found a reduction in the harvest index as the defoliation levels increased from 33% to 99%. This effect was stronger at the R3, R4 and R5 growth stages.

Defoliation decreased the harvest index at both sowing times. However, when sowing took place in December, the plants were more efficient to remobilize photoassimilates to the grains (Table 2). This prevented a further decrease in yield when sowing was delayed to Mid-December.

CONCLUSIONS

The delay of sowing date from November 2 to December 15 reduces grain yield of cultivar NA 5909 RG, regardless of defoliation level.

Moderate defoliation of up to 33% carried out at R3 increases the grain yield of cultivar NA 5909 RG, both in early and late sowings.

Delaying sowing date from early November to mid-December does not increase the grain yield sensitivity to defoliation of cultivar NA 5909 RG.

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