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Soybean response to different injury levels at early developmental stages

Resposta da cultura da soja a diferentes intensidades de injúria nos estágios iniciais de desenvolvimento

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ABSTRACT

This study evaluated the effects of different soybean injury levels at early growth stages of the plants. The experiments were carried out in two different growing seasons, using a randomized complete block design, with 11 treatments in the first and 10 treatments in the second season, and four replications. The 'BRS 133' soybean cultivar was used, and the injury levels tested were: 1-Control; 2-Removal of 1 cotyledon; 3-Removal of both cotyledons; 4-Removal of both cotyledons + 1 unifoliate leaf; 5-Removal of both cotyledons + both unifoliate leaves; 6-Removal of 1 unifoliate leaf; 7-removal of both unifoliate leaves; 8-Cut below unifoliate leaves; 9-Removal of trifoliate leaf sprouts; 10-Total defoliation; 11-Total defoliation + removal of apical bud (only in the first trial). Injury was manually imposed, and insecticides were applied weekly to prevent injury by insects. The results showed that the soybean yield was reduced only when the injury was severe enough to cause plant stand reductions as a consequence of plant death. This occurred for treatments 5, 10 and 11. Under the other treatments, the soybean plants were able to recover. These findings show that the recommended economic threshold of 30% defoliation to initiate pest control is safe, and should be accepted by growers.

Key words: ***Glycine max***, *pest insect, economic injury level, economic threshold, defoliation.*

RESUMO

Este estudo avaliou os efeitos de diferentes níveis de injúria nos estádios iniciais de desenvolvimento das plantas de soja. Os experimentos foram realizados em duas diferentes safras agrícolas em delineamento de blocos completos casualizados, com 11 tratamentos na primeira e 10 tratamentos na segunda safra, e quatro repetições. A cultivar utilizada foi a 'BRS 133' e os níveis de injúria foram: 1-Testemunha; 2-Remoção de 1 cotilédone; 3-Remoção de ambos os cotilédones; 4-Remoção de ambos os cotilédones + 1 folha unifoliolada; 5-Remoção de ambos cotilédones + ambas as folhas unifolioladas; 6-Remoção de 1 folha unifoliolada; 7-Remoção de ambas as folhas unifolioladas; 8-Corte abaixo das folhas unifoliadas; 9-Remoção do broto das folhas trifolioladas; 10-Desfolha total; 11-Desfolha total + remoção da gema apical (apenas no primeiro ensaio). A injúria foi realizada manualmente e inseticidas foram aplicados semanalmente para impedir injúria por insetos. Os resultados evidenciaram que a produção de soja foi reduzida somente quando a injúria foi severa o suficiente para provocar a redução do estande em consequência da morte de plantas. Isso ocorreu nos tratamentos 5, 10 e 11. Nos demais tratamentos, as plantas foram capazes de se recuperar, o que comprova que o nível de ação de 30% de desfolha que é recomendado para iniciar o controle é seguro e deve ser respeitado pelos sojicultores.

Palavras-chave: ***Glycine max***, *nível de dano econômico, nível de ação, desfolha.*

INTRODUCTION

Integrated Pest Management (IPM) programs are fundamentally different from control approaches for managing pest problems, because it focus on the tolerance of pest effects (FUNDERBURK et al., 1993). This tolerance is based on the premise that

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not all species of insects require control and that some levels of pest infestation are tolerable since they cause no economically important reduction in yield (TURNIPSEED, 1971). Therefore, insecticides must not be applied before economic damage occurs; and consequently, the economic injury level (EIL) concept was developed, defined as the lowest population density of pests that will cause economic damage to plants (STERN et al., 1959). However, in order to avoid reaching this EIL, mainly when considering different factors such as the time required for a control measure to be efficient, sampling precision, or climate factors that may interfere with the accomplishment of the control measure, among others, the decision to either control or not control the pest population must be taken within a safety margin in relation to the EIL. To take this consideration into account, the economic threshold (ET) was developed, defined as the pest population density at which control measures must be initiated to prevent an increasing pest population from reaching the EIL (PEDIGO et al., 1986).

Accurately established ETs are essential to increase yield and maintain environmental quality by reducing unnecessary use of management measures, especially insecticides (PEDIGO et al., 1986). Nowadays, the recommended ET for defoliators on soybeans ***Glycine max*** L. Merril may be based on the number of insects per area, or alternatively, on the extent of defoliation (%). ET values differ slightly around the world; in Brazil, pest-control measures are initiated when 20 large ($\geq$1.5cm) caterpillars are counted per sample-cloth (1-m-soybean row), or the plants are 30% defoliated (in the vegetative stage) or 15% defoliated (in the reproductive stage) (TECNOLOGIAS, 2010). In the United States, it is stated that soybean plants can withstand as much as 35% of foliage loss up to the blooming period. However, during this stage and when the pods begin to form and fill out, any foliage loss greater than 20% will decrease yield (ANDREWS et al., 2009).

Although yield losses from soybean defoliation during vegetative growth are often negligible (HINTZ et al., 1991) and the safety of the recommended ETs is stated in several publications (GAZZONI & MOSCARDI, 1998; REICHERT & COSTA, 2003; COSTA et al., 2003; PARCIANELLO et al., 2004), many soybean growers have been reluctant to wait for an insect outbreak to reach these ETs in order to begin control procedures. This skepticism about the ET has resulted in an increased use of insecticides, often erroneously and abusively (PALUMBO et al., 2001). Insecticides have not been applied based on the pest population, following the recommended ET, but instead have been applied based on subjective criteria as perceived by the farmers, who use pre-programmed insecticide applications, often attempting to take advantage of other cultural practices, such as joint applications with herbicides and/or fungicides (BUENO et al., 2010).

This skepticism by the soybean growers is even higher during early soybean stages, when the plants bear only the cotyledonary leaves or the first trifoliate leaves, and according to the growers' perception, the plants are at the most sensitive stage. However, there is no scientific confirmation for this hypothesis (COSTA et al., 2003; REICHERT & COSTA, 2003; PARCIANELLO et al., 2004). Therefore, the present study evaluated the effect of different injury levels at early soybean stages and the possible consequences of these injuries for yield reduction, in order to verify the safety of the 30%-defoliation ET recommended during vegetative growth.

MATERIALS AND METHODS

The experiments were carried out under field conditions during two crop seasons at the Embrapa Soja experimental station, in Londrina, Paraná, Brazil, in a randomized complete block design with 11 treatments in the first growing season and 10 treatments in the second growing season, and four replications. Each replication consisted of six soybean rows (cv. BRS 133), 6m long and 0.45 m apart, with 18 seeds per linear meter. The treatments were: 1) control (plants with no injury); 2) removal of one cotyledon; 3) removal of both cotyledons; 4) removal of both cotyledons and one unifoliate leaf; 5) removal of both cotyledons and both unifoliate leaves; 6) removal of one unifoliate leaf; 7) removal of both unifoliate leaves; 8) cut below the unifoliate leaves; 9) removal of the trifoliate leaf sprouts; 10) total defoliation (including trifoliate leaves); and 11) total defoliation with additional removal of the apical bud.

In all plots, the artificial defoliation was performed manually to assure homogeneous defoliation in each replication of the treatments. Insecticides were applied weekly to prevent any external influence of pests on plant defoliation. The insecticides used were from the insect growth regulator (IGR) group (methoxyfenozide or lufenuron) and pyrethroids (beta-cyflutrin) at the recommended rates for soybeans (TECNOLOGIAS, 2010). The herbicides and fungicides were applied equally to each treatment, according to the cultural practices commonly utilized for soybeans (two herbicide sprayings between the third and sixth weeks after emergence of plants; and three fungicide sprayings in the reproductive phase, starting between R1 and R2, followed by additional sprayings at 20 to 30-day intervals).

At the end of the crop cycle, the following parameters were evaluated: final stand before harvest; final plant height; height of first pod insertion; and yield of each plot, with 13% moisture content of seeds. The results were subjected to exploratory analysis to evaluate the assumed normality of residues, variance homogeneity of treatments, and additivity of the model to allow ANOVA application. Means were compared by the Tukey test, at 5% probability (SAS Institute, 2001).

RESULTS AND DISCUSSION

Similar results were obtained in both years (Tables 1 and 2). In the first trial, plants from treatment 5 - in which both cotyledons and also both unifoliate leaves were removed - were significantly smaller than plants in the other treatments, except when the defoliation was total (treatment 10), and when the defoliation was total in addition to the removal of the apical bud (treatment 11) (Table 1). The same results were observed in the second trial for treatment 5; however, did not differ from treatment 10 (total defoliation), 4 (removal of both cotyledons + one unifoliate leaf), 6 (removal of one unifoliate leaf), and 7 (removal of both unifoliate leaves) (Table 1). The reduction of plant height was linearly correlated with defoliation, as previously reported for soybeans by OSTLIE & PEDIGO (1985), although with a small effect on yield, mainly due to the recovery capacity of soybean plants, which produce many new leaves during vegetative growth (BOARD et al., 1994).

In addition to the recovery capacity, it is necessary to consider that the soybean plant is intrinsically capable of producing excess foliar area, also a characteristic of other plant species, which produce more foliar area than is actually needed. This excess of foliage captures the maximum possible solar radiation and consequently produces more photoassimilates to generate energy for the plants (BROUGHAM, 1956, 1958; DAVIDSON & DONALD, 1958; WATSON, 1958; MURATA, 1961; STERN & DONALD, 1962). Also, the treatments with extreme defoliation evaluated in these experiments represent a level of defoliation that occurs in soybeans only occasionally, when some caterpillars are at late developmental stages and/or when high populations of defoliator beetles attack young plants (TECNOLOGIAS, 2010).

Table 1 - Plant height and first pod insertion (Mean±SE) after artificial injury manually performed at different intensities on soybean (cv. ‘BRS 133’). Embrapa Soybean, Londrina, Paraná.

Injury intensity	Plant height (cm) at harvest		Height (cm) of the 1st pod insertion	
	Experiment 1	Experiment 2	Experiment 1	Experiment 2
1- Control (without injury)	63.4 ± 1.4 a*	66.5 ± 4.3 a	14.1 ± 0.6 a	15.0 ± 0.8 a
2-Removal of 1 cotyledon	57.4 ± 3.2 ab	62.4 ± 3.0 ab	12.1 ± 1.3 ab	15.7 ± 0.6 a
3-Removal of both cotyledons	53.6 ± 1.4 b	66.2 ± 2.6 a	10.2 ± 0.6 bcd	14.8 ± 0.5 a
4-Removal of both cotyledons + 1 unifoliate leaf	51.0 ± 1.7 b	51.0 ± 4.2 abc	10.3 ± 0.2 bc	13.5 ± 0.3 a
5-Removal of both cotyledons + both unifoliate leaves	22.6 ± 2.2 c	38.4 ± 7.1 c	6.6 ± 0.4 de	8.5 ± 1.5 b
6-Removal of 1 unifoliate leaf	55.1 ± 2.9 ab	57.4 ± 3.6 abc	12.7 ± 1.2 ab	13.7 ± 0.4 a
7-Removal of both unifoliate leaves	52.4 ± 4.5 b	54.5 ± 2.2 abc	11.6 ± 0.8 ab	14.0 ± 0.4 a
8-Cut below unifoliate leaves	55.6 ± 2.1 ab	58.5 ± 3.1 ab	12.6 ± 1.3 ab	14.2 ± 0.1 a
9-Trifoliate leaf sprout cut	59.9 ± 1.8 ab	58.2 ± 5.0 ab	13.2 ± 0.4 ab	14.1 ± 1.3 a
10- Total defoliation	19.0 ± 2.1 c	44.2 ± 6.2 bc	6.9 ± 0.3 cde	13.3 ± 0.4 a
11-Total defoliation + apical bud removal	20.5 ± 0.5 c	**	5.4 ± 0.8 e	**
CV (%)	8.4	14.3	14.1	9.0
$df_{residual}$	30	27	30	25
F	58.76	4.68	13.07	6.73
P	<0.0001	0.0004	<0.0001	<0.0001

*Means followed by the same letter in each column are not significantly different (Tukey, P=0.05); **Treatment not performed.

Table 2 - Stand before harvest and yield (13% moisture) (Mean±SE) after artificial injury manually performed at different intensities on soybean plants (cv. ‘BRS 133’). Embrapa Soybean, Londrina, Paraná.

Injury intensity	Final stand at harvest (6m row)		Yield (kg ha^{-1})	
	Experiment 1	Experiment 2	Experiment 1	Experiment 2
1- Control (without injury)	79.5 ± 3.2 a*	89.3 ± 1.4 a	1844.8 ± 243.0 a	2795.7 ± 166.6^{ns}
2-Removal of 1 cotyledon	76.5 ± 2.2 a	88.8 ± 6.0 a	2534.1 ± 351.7 a	2690.5 ± 186.3
3-Removal of both cotyledons	63.3 ± 4.1 a	85.3 ± 2.0 a	1883.3 ± 156.6 a	2743.8 ± 156.1
4-Removal of both cotyledons + 1 unifoliate leaf	63.8 ± 4.4 a	85.0 ± 9.3 a	2087.8 ± 78.1 a	2067.5 ± 166.6
5-Removal of both cotyledons + both unifoliate leaves	24.0 ± 7.1 b	37.3 ± 1.3 b	0.0 ± 0.0 b	1947.1 ±395.3
6-Removal of 1 unifoliate leaf	76.3 ± 4.3 a	91.0 ± 3.6 a	2004.9 ± 265.7 a	2441.7 ± 287.4
7-Removal of both unifoliate leaves	71.8 ± 2.6 a	80.0 ± 4.0 a	1773.3 ± 264.3 a	2409.0 ± 179.8
8-Cut below unifoliate leaves	77.3 ± 4.0 a	93.3 ± 2.8 a	1612.0 ± 370.8 a	2523.5 ± 86.6
9-Trifoliate leaf sprout cut	81.0 ± 0.9 a	85.0 ± 2.8 a	2096.6 ± 148.1 a	2438.6 ± 299.1
10- Total defoliation	22.8 ± 3.8 b	94.0 ± 2.8 a	0.0 ± 0.0 b	2252.4 ± 256.2
11-Total defoliation + apical bud removal	36.8 ±13.9 b	**	0.00 ± 0.00 b	**
CV (%)	16.6	8.1	29.2	18.0
$df_{residual}$	30	25	27	27
F	15.75	14.91	16.42	1.84
P	<0.0001	<0.0001	<0.0001	0.09

P*Means followed by the same letter in each column are not significantly different (Tukey, P=0.05); **treatment not performed; ^{ns}Non-significant.

Treatment 5 (removal of both cotyledons + both unifoliate leaves) induced the plant, to be shorter, with a statistically lower insertion of the first pod in both the first and second years (Table 1). In the first year, a lower insertion of the first pod was also observed for treatments 3, 4, 10 and 11, which consisted of the removal of both cotyledons, removal of both cotyledons and one unifoliate leaf, total defoliation (including trifoliate leaves), and total defoliation with additional removal of the apical bud, respectively. The lower insertion of the first pod may be a physiological response of the plant to the injury, in an attempt to reduce the damage and thus guarantee seed production. This hypothesis could be tested in future trials.

With respect to the final stand at harvest, the results showed that the treatments with more intense defoliation (treatments 5, 10, and 11) had the lowest plant stand, with values statistically lower than the remaining treatments in the first year (Table 2). In the second year, the results were similar but no differences were observed in the yield (Table 2). This higher tolerance observed in the second year might be due to different climate conditions, which are closely related to the capacity of plants to tolerate injury (PEDIGO et al., 1986).

Yield reductions associated with plant injury tend to be greater during reproductive than during vegetative development stages (WEBER, 1955; FEHR et al., 1983; CONLEY et al., 2008). The stage considered the most critical for soybean plants ranges from R3 to R6, a phase in which the plants need the highest production of photoassimilates (TURNIPSEED, 1972: GAZZONI & MINOR, 1979; GAZZONI & MOSCARDI, 1998; HAILE et al., 1998; RIBEIRO & COSTA, 2000). However, stem damage that leads to node removal is related to significant soybean yield reduction after the vegetative stages (HINTZ et al., 1991; HINTZ & FEHR, 1990).

In the results reported here, yield losses occurred only in the first year of the trial (experiment 1) in treatments 5 (removal of both cotyledons + both unifoliate leaves), 10 (total defoliation - including trifoliate leaves), and 11 (total defoliation + apical bud removal), the same treatments that reduced the plant stand (Table 2). In the second year, most probably because of better weather, none of the treatments impaired yield (Table 2). Stand reduction can be correlated to defoliation, and may reduce yield as a consequence of the decrease in the total number of plants per hectare (PARCIANELLO et al., 2004). This probably occurred in the treatments with 100% defoliation (Table 2). Similar results are reported in the literature. HINTZ et al. (1991) reported 7 to 18% yield loss when 33 to 66% of the nodes were removed, respectively, at the V3 and V6 stages. HINTZ & FEHR

(1990) reported 5 and 15% yield loss when 33% and 66% of the nodes was removed at the V3 and V6 stages, respectively. Yield loss increased to 20 and 39% respectively when 100% defoliation accompanied the 33% and 66% node removal treatments (HINTZ & FEHR, 1990).

In conclusion, this results indicate that the soybean plants, even at the initial developmental stages, have a high capacity to recover from defoliation. Yield reductions occurred only when the defoliation was severe enough to cause plant death, hence reducing the final stand. This occurred when the injuries consisted of removal of both cotyledons + both unifoliate leaves (including trifoliate leaves), total defoliation, and total defoliation + removal of the apical bud. This shows that the use of the 30% defoliation ET, as recommended for soybeans at the vegetative growth stage, is indeed safe and allows yields to be obtained that are equal to those obtained with plants that did not undergo this level of defoliation during the vegetative growth stages. Preventive application of insecticides before the ET is reached is unnecessary, and would only increase production costs to the farmers, with no benefit to yield.

CONCLUSION

The results obtained here lead to conclude that soybeans, even at early stages, have a high capacity to recover from defoliation, and yield reductions occur only when the defoliation is sufficiently severe to cause plant death, consequently reducing the stand. Therefore, the use of the 30% defoliation threshold level, recommended for soybeans at the vegetative growth stage, is safe and allows yields equal to those obtained with plants that did not undergo this level of defoliation during the vegetative growth stage; and any preventive application of insecticides before reaching the 30% threshold defoliation level recommended for soybeans is unnecessary, and only increases production costs, with no benefit to yield.

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