REVISTA SCIENTIA AGRARIA
Versão On-line ISSN 1983-2443
Versão Impressa ISSN 1519-1125
SA vol. 19 n°. 2 Curitiba abr/jun. 2018 p. 78-85

IMPACT OF THE COMPETITION DURATION ON LIGHT AND SOIL RESOURCES BETWEEN SOYBEAN AND VOLUNTEER CORN

Impacto da duração da competição por recursos da luz e solo entre soja e milho voluntário

Diecson Ruy Orsolin da Silva[1*], Adalin Cézar Moraes de Aguiar[2], Claudir José Basso[3], Luan Cutti[4], Hilda Hildebrand Soriani[5]

[1]Doutor em Fitossanidade; Professor em Universidade Federal de Santa Maria, Frederico Westphalen, RS: diecsonros@hotmail.com
[2]Engenheiro Agrônomo; Universidade Federal de Santa Maria, Frederico Westphalen, RS: adalin-cezar@hotmail.com
[3]Doutor em Ciência do Solo; Professor em Universidade Federal de Santa Maria, Frederico Westphalen, RS: claudirbasso@gmail.com
[4]Engenheiro Agrônomo; Universidade Federal de Santa Maria, Frederico Westphalen, RS: luancutti@hotmail.com
[5]Doutora em Biologia, Universidade Federal de Santa Maria, Frederico Westphalen, RS: hildasoriani@gmail.com
*Autor para correspondência

Artigo enviado em 13/04/2017, aceito em 24/04/2018 e publicado em 17/07/2018.

Abstract – The RR volunteer corn emerged as a problematic weed in the soybean rotation system. In the early crop stages, the requirement resources for growth is little and enough to crop and weeds, however the light competition could triggering morphological changes in response to changes in light reflected from neighboring. The objective of this study was to evaluate the impact of duration of competition for light and soil resources between soybean and volunteer corn. The treatments were competition conditions between soybean and corn as competitor: control, light competition and soil+light competition; and duration of competition: at V_3 and V_5 soybean growth stages. The results of this study demonstrate that duration and resource of competition with volunteer corn influenced the response on soybean growth and development. The soybean not displayed characteristic of shade avoidance syndrome in light competition. The light competition changes the soybean shoot: root length ratio and root length. In early competition, the soybean growth and development are unaffected for light or soil+light resource in competition. However, in later duration of competition, light and soil+light have similar reduction on effects on soybean growth, development and photosynthetic pigments.

Keywords – neighboring, growth stage, shade avoidance, pigments, plastochron.

Resumo – O milho voluntário RR surgiu como uma planta daninha problemática no sistema de rotação da soja. Nos estágios iniciais da cultura, a exigência de recursos para o crescimento é pequena e suficiente para a cultura e plantas daninhas, no entanto a competição por luz pode desencadear alterações morfológicas em resposta a mudanças na radiação refletida por plantas vizinhas. O objetivo deste estudo foi avaliar o impacto da duração da competição por recursos de luz e solo entre a soja e o milho voluntário. Os tratamentos foram condições de competição entre soja e milho como competidor: controle, competição por luz e solo+luz; e duração da competição: até os estádios V_3 e V_5 de soja. Os resultados deste estudo demonstram que a duração e o recurso da competição com milho voluntário influenciaram a resposta no crescimento e desenvolvimento da soja. A soja não apresenta características da síndrome para evasão ao sombreamento na competição por luz. A competição por luz altera a relação entre parte aérea:raiz e o comprimento da raiz da soja. Na competição precoce, o crescimento e desenvolvimento da soja não são afetados pela competição por luz ou solo+luz. No entanto, em uma duração posterior da competição, a competição por luz e solo+luz têm efeitos semelhantes na redução do crescimento, desenvolvimento e nos pigmentos fotossintéticos da soja.

Palavras-chave – plantas vizinhas, estádio de crescimento, evasão ao sombreamento, pigmentos, plastocrono.

REVISTA SCIENTIA AGRARIA
Versão On-line ISSN 1983-2443
Versão Impressa ISSN 1519-1125
SA vol. 19 n°. 2 Curitiba abr/jun. 2018 p. 78-85

INTRODUCTION

The RR volunteer corn emerged as a problematic weed in the rotation system between corn and soybean (MARQUARDT et al., 2012). The high adoption of Roundup Ready technology in crop succession has further aggravated the problems of volunteer corn in soybean crop (Alms et al., 2016). Reports in the literature have shown that volunteer corn causes damage to crop productivity. In soybean, one volunteer corn plant m^{-2} was able to reduce 25% of yield of soybean competing throughout the all crop cycle (MARQUARDT et al., 2012). Similarly, Alms et al. (2016) found a reduction of 22% in soybean yield with density of one volunteer corn plant per m^{-2}. If not controlling volunteer corn, the yield losses can reach up to 69.9% in the soybean grown in succession (LÓPEZ-OVEJERO et al., 2016). For other crops, such as cotton, the presence of one corn plant m^{-2} reduced crop yield by up to 8% and of the economic threshold level ranged from approximately 190 to 770 corn plants ha^{-1} (Thomas et al. 2007). The yield loss of sucrose was also verified in beet with 19% reduction per corn m^{-2} and the economic threshold level ranged from 0.03 to 0.08 plant m^{-2} (KNISS; SBATELLA; WILSON, 2012).

The competition between crop and weed is a negative interaction, in which the organisms involved use scarce supply, resulting in mutual loss of growth (RADOSEVICH; HOLT; GHERSA, 1997). The resources present below and above the surface of the soil, such as water, nutrients and solar radiation, are the main involved in the competition. In the early crop stages, the requirement resources for growth is little enough that both the soybean and volunteer corn can coexist without affecting each other, however the competition for light is an important factor in triggering morphological changes in response to the initial competition between plants (PAGE et al., 2010; GREEN-TRACEWICZ; PAGE; SWANTON et al., 2012). Thus, both quality and quantity of light are related as the first environmental resource that modifies the competition relations between crop and weed (AFIFI; SWANTON, 2012).

In both natural and agricultural plant communities, light can become a limiting resource under high densities plants. In this environment, the light incident on the canopy of the plants can be partitioned and attached differently between them, which induces the light competition. Low-quality solar radiation is reflected horizontally by plants and acts as a sign of the presence of neighbors, providing plant suitability to future competition (BALLARÉ; CASAL, 2000). In such a situation, plants may present mechanisms to tolerate or avoid shade, and the plants had a sets of responses, such as changes in leaf physiology, biochemistry, anatomy and morphology, and / or plant architecture (ROING- VILLANOVA; MARTÍNEZ-GARCÍA, 2016).

In this way, the plants developed two strategies in response to light competition: shade tolerance and shade avoidance. The first presents as a response to light competition, the optimization of carbon gain in low light conditions, which may be related to higher content of chlorophylls, greater specific leaf area, and the reduced Chlorophyll a / b ratio (NIINEMETS, 2010). The second strategy involves some morphological changes to reach light, such as increase in height, elongating, and branches reduction and plant tillers (FRANKLIN; WHITELAM, 2005). In addition, agronomic factors such as plant population and row spacing, the weeds presence at the early stage of crop development may alter plant morphology and crop yield (RAMBO et al., 2003).

Competition studies for resources below and above the soil surface are mostly carried out under controlled conditions because of the ease of their separation. The split vessel technique proposed by McPhee and Aarssen (2001) consists of the partition of space above and below the soil surface in which a partition separates the competition below and the other one that occurs above the soil surface. According to the technique, four competition situations can be generated: absence of competition, soil competition, competition for solar radiation and by both sources of resources (total competition).

The objective of this study was to evaluate the impact of duration of competition for light and soil resources between soybean and volunteer corn.

MATERIAL AND METHODS

An experiment was carried out in a greenhouse and laboratory. A soybean NA 5909 RR (GM 5.9 – early maturing cultivar) variety was selected for the experiment and volunteer corn (F2 plant of DKB 240 VT Pro Yieldgard) was used as a surrogate plant competitor. The experimental design was completely randomized with four replicates. The experimental arrangement was in a 3x2 factorial scheme, where the treatments were competition conditions: control, light competition and soil+light competition; and duration of competition: V_3 and V_5 soybean growth stages.

The experimental units consisted of plastic pots with a capacity of 5.5 L (23 cm diameter) filled with an agricultural substrate (Tecnomax®) and soil in a 4: 1 ratio, respectively. The soil characteristics were: pH in H_2O (1:1) 4.6; SMP index 5.1; clay 750 g kg^{-1}; organic matter 2.7 g kg^{-1}; P-mehlich 7.2 mg dm^{-3}; potassium 137 mg dm^{-3}; calcium 2.1 cmolcdm^{-3}; magnesium 1.2 cmolcdm^{-3}; H+Al 8.0 cmolcdm^{-3}; Al 2.1 cmolcdm^{-3}; CTC 11.6 cmolcdm^{-3}; and CEC bases and Al of 31.3 and 36.5% respectively.

To establish the competition treatments, a plastic tube (8 x 13 cm) was placed in the centre of a 5.5 L plastic pot on control and light competition treatments, in order to separate the root system of soybean seedling from that of the volunteer corn. To control and light competition treatments, soybean seeds were planted into the center of plastic cups (one seed per cup) and soil+light treatment, the seed were planted into the center of the plastic pots. The volunteer corn competitor were establish with four seedling

REVISTA SCIENTIA AGRARIA
Versão On-line ISSN 1983-2443
Versão Impressa ISSN 1519-1125
SA vol. 19 n°. 2 Curitiba abr/jun. 2018 p. 78-85

surrounding at six centimeters to the soybean seedling. The experimental units were irrigated two times per day and fertilized with 30, 50 e 50 kg ha^{-1} of the NPK, respectively.

Growth characteristics were performed at V_3 and V_5 stages of soybean development (control treatment as reference) measuring growth stage, by measured of the number of visible nodes, recorded daily during the experiment. At each harvest, soybean height and root was measured and the root were washed with tap water. Above-ground and below-ground biomass was separated, and dried to constant weight at 80ºC prior to weighing, and it was determined the shoot dry weight, leaf dry weight, root dry weight, and total dry weight.

The absolute growth rates (AGR) were determined of the shoot, root and total using the following equation AGR = (W2-W1)/(T2-T1), W1 and W2 are the mean dry weights (mg) in the first and second harvest, respectively, and T1 and T2 refer to days interval for each harvest. The plastochron was estimated by the inverse of the slope of the linear regression between of the accumulated daily thermal time (base temperature of 10 ºC) and the number of visible nodes on the main stem.

Chlorophyll index was measured with a hand-held chlorophyll content meter (ClorofiLOG 1030), which was performed in the central leaflet of the three trifoliate leaf of soybean, without them being removed. In the laboratory, the total extractable chlorophyll content of each sample of the central leaflet of the second trifoliate was taken for analysis by pigments extractable method (a, b and (a+b) chlorophyll and carotenoids). The samples were macerated in the presence of 80% (v / v) acetone and centrifuged at 4000 rpm for three minutes. The supernatant was transferred to test tubes and made up to 8 ml of 80% (v / v) acetone. Chrolophyll a, b and a+b and carotenoid levels were calculated using the equation Lichtenthaler (1987) from the absorbance of the solution obtained by spectrophotometry at 645, 663 and 480 nm, with the results expressed in mg g^{-1} of fresh mass.

The Shapiro-Wilk statistic was used to test the assumption of normality, with no need for transformation. Then, it was conducted the analysis of variance, according to the F test (p≤0.05); and when F test indicated difference, the means were compared by Duncan's test (p≤0.05).

RESULTS AND DISCUSSION

The soybean developing in the light competition not displayed characteristic shade avoidance responses, such as plant height. The plant height of soybean not increase when grew with volunteer corn at V_3 stage, however, the soybean height was decrease by soil+light competition at V_5 stage, which was reduced by 27% compared with control (Table 1).

Table 1. Shoot height, Root length, total dry weight and shoot height: root length in soybean exposed to light and soil+light competition with volunteer corn at V_3 and V_5 stage of soybean development

Competition conditions	Stage of soybean development			
	V_3		V_5	
	Shoot height (cm)			
Control	A	5.25	A	16.2 *
Light	A	4.80	AB	13.4 *
Soil+Light	A	5.50	B	11.9 *
CV(%)	16.6			
	Root length (cm)			
Control	B	33.6	AB	72.7 *
Light	A	66.7	A	85.7 ^{ns}
Soil+Light	B	32.5	B	64.8 *
CV(%)	8.8			
	Shoot height : Root lenght			
Control	A	0.16	A	0.22 *
Light	B	0.07	B	0.16 *
Soil+Light	A	0.17	A	0.18 ^{ns}
CV(%)	23.9			

The same uppercase letters, not differ between competition conditions treatments by Duncan's test (p<0.05). * or ^{ns} significant or not significant, respectively, between growth stage of competition treatments by t test (p<0.05).

No difference was observed in the plant height between control and light competition, and light and soil+light competition. The significant evolution was observed to plant height during period from V_3 to V_5 stage. The increase of plant height of soybean was 208% in control treatment, while in in light competition the evolution was 179% and while that for soil + light competition was 116%. Exposure to light competition until V_3 stage, the root length of soybean was significantly superior than others treatments. At V_5 stage, the disparity in the root length continued regarding to soil+light treatment, and there were no differences observed between control and soil+light treatments. The volunteer corn height on average was 8.8 and 16.6 cm, at V_3 and V_5 stage of soybean, respectively (data not show).

Differently of the expected, the shoot: root ratio was decreased in the light competition, due a result of higher root length. The larger increase of the root length is suggestive of a plastic root response to competition, since this is observed in roots associated with the superior of competitive ability (POORTER; LAMBER, 1986), which leads to tolerate future stresses in the competition for soil resources. No difference was observed on corn root dry weight between conditions competitions with soybean (data not show).

The plant height is an important component in the competitive ability for light competition, so it was expected response to neighboring presence in plant height, as observed in the competition of *Bidens* spp., *Sida rhombifolia* and *Raphanus sativus* with soybean (Bianchi et al., 2006). However, soybean did not present increase in height when

REVISTA SCIENTIA AGRARIA
Versão On-line ISSN 1983-2443
Versão Impressa ISSN 1519-1125
SA vol. 19 n°. 2 Curitiba abr/jun. 2018 p. 78-85

competing for light resources, the probable explanation being that both plants emerged at the same time, these responses suggest, that soybean not express shade avoidance symptom. These results are according with Caratti et al. (2016), found no differences when the soybean grew free from any light or soil+light competition with corn.

The shade avoidance is a phenomenon more pronounced when the plant develops in an environment with already established competitors, which impacts on the increase of the plant height, hypocotyl elongation rates, and increase shoot:root rate of the later plant established (GREEN-TRACEWICZ; PAGE; SWANTON et al., 2012; AFIFI; SWANTON, 2012). The changes in the quality and intensity of light, especially in the red and far red light (V / Ve), may affect the development of soybean plants (BALLARÉ; SCOPEL; SÁNCHEZ, 1990).

Significant differences were detected between two stages of competition in shoot, root, total dry weight (Table 2). In control treatment, shoot dry weight increase 6.5 times from of the V_3 to V_5 stage, while to light and soil+light competition the increase average was 3.6. The increase in root dry weight and total dry weight between competition periods was 32 and 38% lower than control treatment, respectively. Although the soybean shoot, root and total dry weights did not differ between control and competition treatment for light and soil+light competition conditions at V_3 stage, differences were found at V_5 stage between control treatment and volunteer corn presence (Table 2). Despite the large difference of soybean root length for light competition compared to soil+light treatments, this root length difference was not indicative of an increase in root and total dry weight. Even if soybean does not present morphological changes in early stages of competition due to the coexistence with other plants, physiological changes that occur in response to initial coexistence, even with the resources of the non-limiting environment, result in a cost to the plant, which results in a decrease in growth and development of the plants (AFIFI; SWANTON, 2012).

When compared with control treatment, both light and soil+light competition, reduced above and belowground biomass of soybean, without significant differences between them. The shoot dry weight was delayed, independently of the competition treatment (light and soil+light), as well as root and total dry weight (Table 2). The relatives reduction caused by light competition in soybean shoot, root and total dry weight ranged from 38 to 45%, and to soil+light the reduction was equally of the 38%. Although above and below ground dry weights differ between control and competitions treatments, differences were not found with the shoot: root dry weight ratio by treatments and period of competition. In this way, it is possible to infer that the light intercepted or reflected from the volunteer corn causes reduction in the accumulation of vegetal biomass.

Table 2. Shoot dry weight, root dry weight, total dry weight and shoot dry weight: root dry weight in soybean exposed to light and soil+light competition with volunteer corn at V_3 and V_5 stage of soybean development

Competition conditions	Stage of soybean development				
	V_3		V_5		
	Shoot dry weight (g)				
Control	A	0.180	A	1.169	*
Light	A	0.197	B	0.732	*
Soil+Light	A	0.207	B	0.735	*
CV(%)	32.7				
	Root dry weight (g)				
Control	A	0.208	A	0.928	*
Light	A	0.179	B	0.511	*
Soil+Light	A	0.177	B	0.582	*
CV(%)	21.7				
	Total dry weight (g)				
Control	A	0.387	A	2.096	*
Light	A	0.377	B	1.243	*
Soil+Light	A	0.384	B	1.318	*
CV(%)	27				
	Shoot dry weight : Root dry weight				
Control	A	0.90	A	1.25	ns
Light	A	1.11	A	1.41	ns
Soil+Light	A	1.19	A	1.25	ns
CV(%)	17.9				

The same uppercase letters, not differ between competition conditions treatments by Duncan's test ($p<0.05$). * or ns significant or not significant, respectively, between growth stage of competition treatments by t test ($p<0.05$).

Previous research also showed that, neighboring weeds presence changes of quality and quantity light, which will affect the biomass accumulation in crop plant (GREEN-TRACEWICZ et al., 2012; AFIFI; SWANTON, 2012). The competition for light and soil resources is not independent event, since the competition for light resources changes the photoassimilates allocation patterns to increase the ability of plants, however, the response in competitive ability for below ground resource will result the a fitness cost for aboveground resources (CAHILL Jr. 2002). Thus, Bianchi et al. (2006) argue that depending on the stage of development of the plant and the competition intensity, there may be alternating in the relative importance of competition resources located below and above the soil surface.

Previous studies prove that changes caused by weeds in light quality help the crop detect the proximity and spatial distribution of neighboring plants, and initiate a series of physiological changes that result in the expression of shade avoidance syndrome, such as stem elongating, the reduction of stem diameter, and a reduction in shoot and root biomass (AFIFI; SWANTON, 2012; BALLARÉ, 2009). However, these studies, the target plants are transplanted after the neighboring competitor had already

REVISTA SCIENTIA AGRARIA
Versão On-line ISSN 1983-2443
Versão Impressa ISSN 1519-1125
SA vol. 19 n°. 2 Curitiba abr/jun. 2018 p. 78-85

established several days ago. As a result, the early established of weed allow advantages from crop in later emergence. Nevertheless, our findings are according to previous results found by Page et al. (2010) and Green-Tracewicz, Page and Swanton et al., (2012), where it were demonstrated that crops plants in the presence of neighboring had considerably lower growth and development plant, with the exception of plant height that not differ in our study.

The absolute growth rate measure the daily accumulation in dry matter, and is an important indicator of the competitiveness of the plants. When the soybean compete with volunteer corn for light and soil+light resources, it is evident the damage in the shoot, root and total absolute growth rate, compared with control (Table 3). The soybean shoot growth rate was reduced about 42% regardless of the competition condition with volunteer corn. On the other hand, the soybean root growth rate was more affected when it competed with corn for light resources, which was 51% lower than the control, while competition for soil+light showed a reduction of 43%. As there were reductions in soybean shoot and root growth, the total absolute growth rate was reduced by 46% in competition for light resources, while competition for soil + light caused a 42% reduction.

Table 3. Absolut growth rate in soybean exposed to light and soil+light competition with volunteer corn

	Absolute growth rate (mg)					
	Shoot		Root		Total	
Control	44.30	A	34.07	A	78.37	A
Light	25.45	B	16.60	B	42.06	B
Soil+Light	25.78	B	19.40	B	45.19	B
CV(%)	32.7		21.5		26.8	

Means followed by same letter in the column do not differ for the Duncan's test ($p<0.05$).

The reduction in the absolute growth rate of both competition conditions demonstrates that the effect of the presence of volunteer corn as competitor (light competition) has similar impact to competition for water and nutrients (soil+light). This demonstrates the ability of plants to detect light quality very early, being the first form of negative interference between plants (VIDAL et al., 2012). In addition, light reflected by the presence of weeds is able to penetrate the soil and be detected by seed phytochrome, which initiates a series of molecular and physiological alterations that may delay germination and root growth (AFIFI et al., 2015).

The alterations can be further induced when the morphophysiological characteristics of weeds are more efficient under conditions of light competition, as is the case with corn, because it has C4-type carbon fixation metabolism and canopy architecture, which provides advantages when competing with soybean. The advantage of corn in faster growth, greater height and leaf area in relation to soybean, suggest that the solar radiation is the main resource disputed by the plants in the initial stages of development.

The estimation of soybean growth and development can be predictable by the speed of appearance of nodes in the main stem, characterizing the vegetative stage of soybean. The timing interval that elapsed between the appearances of successive nodes on the stem, in dicotyledons, is called plastochron (STRECK et al., 2008). The plastochron is related with the development of the leaf area of the plant, sequentially, determines the interception of solar light, photosynthesis and biomass (STRECK et al., 2008). The higher values of the soybean plastochron in competition indicate a lower plant development. When the soybean grew in different competitions conditions, the volunteer corn induced significant differences in plastochron than control treatment (Table 4). Soybean plants grown under light and soil+light competitions had higher sum of the thermic degree accumulation than control treatment, theses higher values indicate a lower plant development. The effects of light and soil+light competitions did not differ from each other and had very similar sum of the thermic degree accumulation, 72,3 and 74,9 ºC day node^{-1}, respectively. The values of plastochron of the light competition was 6% higher than control treatment, and soil+light competition was 10% higher than the control.

Table 4. Plastochron in soybean exposed to light and soil+light competition with volunteer corn

Competition conditions	Plastochron (ºC day node^{-1})	
Control	68.1	B
Light	72.3	A
Soil+Light	74.9	A
CV(%)	2.7	

Means followed by same letter in the column do not differ for the Duncan's test ($p<0.05$).

Throughout of the experiment, it was observed that the soybean entered a new stage of development on average 1 day earlier compared to the competition treatments with volunteer corn. When plants grew under soil+light competition, the onset of V_4 stage of soybean was 3 days later than control and light competition. At the end of the experiment, only the soybean on control treatment reached the V_5 stage (data not show).

High plastochron values indicate that a greater amount of accumulated thermal sum is required for the soybean to emit the next consecutive node on the main stem. This justifies the highest values of this variable in treatments submitted to the presence of competitor, since the development of the culture of interest is impaired. Similarly, Bianchi et al. (2006) reported that regardless of the light or soil+light competition condition, the soybean nodes emitted was reduced in intraspecific competition compared with null competition.

Another important factor in the development of plants under changes in the light quality and quantity is the opening and closing behavior of the stomata, which mainly affect the photosynthesis of the plants. The radiation reflected by neighboring plants is capable of inducing the closure of leaf stomata (AFIFI; SWANTON, 2012), which result in a reduction in the photosynthetic activity of the plants, and consequently, reduce soybean growth and development, as observed in the tables 2, 3 e 4.

The use of chlorophyll index is a indicate indirectly of status of leaf nitrogen, thus, it can be inferred that the conditions of competition with volunteer corn, either by light or soli + light, negatively affected the nitrogen utilization by soybean plants (Table 5). In the first soybean trifoliate, chlorophyll index values on control treatment was significantly higher from volunteer corn competition, but light and soil+light conditions did not differ from each other. In the second and third trifoliate, was observed a reduction of the 16 e 24% in chlorophyll index for light competition treatment, respectively. Whereas for soil+light competition, chlorophyll index was reduced from 30 at 43% for second and third trifoliate, respectively.

Table 4. Chlorophyhll index in soybean trifoliates exposed to light and soil+light competition with volunteer corn

Competition conditions	First trifoliate leaves		Second trifoliate leaves		Third trifoliate leaves	
	Chorophyll index					
Control	43.9	A	37.5	A	36.1	A
Light	37.6	B	31.4	B	27.3	B
Soil+Light	34.6	B	26.4	C	20.4	C
CV(%)	15					

Means followed by same letter in the column do not differ for the Duncan's test ($p<0.05$).

Soybean displaying reduced contents of chl a, chl b, chl a+b and carotenoids when did compete with volunteer corn for light or soil+light resources, but did not differ among them (Table 6). Furthermore, it was found that light and soil+light competition, the contents of all pigments decreased, demonstrating that both competition had similar effects on the pigments. The chlorophylls and carotenoids are associated to photosynthesis and, accordingly, to plant growth and adaptation to different environments (FOYER; NOCTOR, 2009). The photosystems consists of chlorophylls and carotenoids, and are responsible for the capture of solar radiation and transformation for biochemical energy. Thus, plants that have smaller amounts of chlorophylls and carotenoids can present restricted photosynthesis and possible oxidative damages to the cells of the plants, as well as decreasing growth plant (AFIFI; SWANTON, 2012).

Table 5. The effect of light and soil+light competition on soybean contends of Chlorophyll (chl *a*, chl *b*, chl *a+b*) e carotenoids in competition with volunteer corn

Competition conditions	Chlorophyll a		Chlorophyll b		Chlorophyll a+b		Carotenoids	
	(mg g^{-1} fresh mass)							
Control	3.78	A	1.13	A	4.92	A	0.86	A
Light	2.50	B	0.90	B	3.40	B	0.57	B
Soil+Light	2.42	B	0.89	B	3.32	B	0.54	B
CV(%)	17.7		13.8		16.2		18.3	

Means followed by same letter in the column do not differ for the Duncan's test ($p<0.05$).

Although there was no competition for water and nutrients in light competition, the effect was similar to soil+light competition. One probable explanation is that shading caused by volunteer corn, which could reduce nutrient and water uptake by soybean, and should have reduced effects on photosynthetic capacity, consequently negative impacts on growth and development soybean.

The effects showed on soybean growth and development by competition conditions are in accordance with the reduced chlorophyll index and contends of chlorophylls and carotenoids. The smaller amounts of pigments produced by the soybean in light and soil+light competitions are related to the higher plastochron in light and soil+light competition, which indicates that the use of light efficiency is less, causing the plants to need a greater accumulation of radiation so that they can develop their stages of competition. According to Fleck et al. (2003), plants with higher levels of photosynthetic pigments can provide plant support for better use of ambient light and greater photoassimilate liquid accumulation, in addition to a high growth rate.

The changes caused by the light competition between soybean and volunteer corn can cause a series of physiological changes that would result in reduced plant development. The changes caused by alteration in the quality and quantity of light in the early stages of soybeans may persist permanently throughout the crop cycle, contributing to an increase in yield loss of soybeans (GREEN-TRACEWICZ; PAGE; SWANTON, 2012).

CONCLUSIONS

The results of this study demonstrate that duration and resource of competition with volunteer corn influenced the response on soybean growth and development. Overall, the light and soil+light competitions had the similar effects on soybean. In early competition (until V_3 stage of soybean), the light competition with volunteer corn was more important, since it altered the soybean root length and the shoot height: root length ratio. In late competition (until V_5 stage of soybean), the volunteer corn competing for light

REVISTA SCIENTIA AGRARIA
Versão On-line ISSN 1983-2443
Versão Impressa ISSN 1519-1125
SA vol. 19 n°. 2 Curitiba abr/jun. 2018 p. 78-85

and soil+light resources with soybean, had a similar effect on the growth and development of crop.

REFERENCES

AFIFI, M.; LEE, E.; LUKENS, L.; SWANTON, C. Maize (*Zea mays*) seeds can detect above-ground weeds; thiamethoxam alters the view. *Pest Management Science*, v.71, n.9, p.1335-1345, set. 2015. Available in: <doi:10.1002/ps.3936> Accessed on: 10 Mar. 2016.

AFIFI, M.; SWANTON, C. Early physiological mechanisms of weed competition. *Weed Science*, v.60, n.4, p.542-551, oct. 2012. Available in: <http://dx.doi.org/10.1614/WS-D-12-00013.1> Accessed on: 8 jul. 2014.

ALMS, J.; MOECHNIG, M.; VOS, D.; CLAY, S.A. Yield loss and management of volunteer corn in soybean. *Weed Technology,* v.30, n.1, p.254-262, mar. 2016. Available in: <http://dx.doi.org/10.1614/WT-D-15-00096.1> Accessed on: 7 oct. 2016.

BALLARÉ, C. L. Illuminated behaviour: phytochrome as a key regulator of light forging and plant anti-herbivore defense. *Plant Cell Environmental*, v.32, n.6, p.713-725, jun. 2009. Available in: <doi:10.1111/j.1365-3040.2009.01958.x> Accessed on: 23 aug. 2015.

BALLARÉ, C. L.; CASAL, J. J. Light signals perceived by crop and weed plants. *Field Crops Research,* v.67, n.2, p.149-160, jul. 2000. Available in: <http://dx.doi.org/10.1016/S0378-4290(00)00090-3> Accessed on: 5 jul. 2016.

BALLARÉ, C.L.; SCOPEL, A.L.; SÁNCHEZ, R.A. Far-red radiation reflected from adjacent leaves: an early signal of competition in plant canopies. *Science*, v.247, n.19, p.329-332, jan. 1990. Available in: <doi:10.1126/science.247.4940.329> Accessed on: 8 jul. 2016.

BIANCHI, M.A.; FLECK, N.G.; FEDERIZZI, L.C. Características de plantas de soja que conferem habilidade competitiva com plantas daninhas. *Bragantia*, v.65, n.4, p.623-632, oct./dec. 2006. Available in: <http://dx.doi.org/10.1590/S0006-87052006000400013> Accessed on: 8 jul. 2016.

CAHILL JR, J. F. Interactions between root and shoot competition vary among species. *Oikos*, v.99, n.1, p.101-112, oct. 2002. Available in: <doi:10.1034/j.1600-0706.2002.990111.x> Accessed on: 8 jul. 2016.

CARATTI, F.F.; LAMEGO, F.P.; SILVA, J.D.G.; GARCIA, J.R.; AGOSTINETTO, D. Partitioning of competition for resource between soybean and corn as comeptitior plant. *Planta Daninha*, v.34, n.4, p.657-665, oct./dec. 2016. Available in: <http://dx.doi.org/10.1590/S0100-83582015000100002> Accessed on: 25 jan. 2017.

FLECK, N.G.; BALBINOT JR, A.A.; AGOSTINETTO, D.; RIZZARDI, M.A. Velocidade de estabelecimento em cultivares de arroz irrigado como característica para aumentar a habilidade competitiva com plantas concorrentes. *Ciência Rural*, v.33, n.4, p.635-640, jul./aug. 2003. Available in: <http://dx.doi.org/10.1590/S0103-84782003000400007> Accessed on: 12 jul. 2016.

FOYER, C.H.; NOCTOR, G. Redox regulation in photosynthetic organisms: signaling, acclimatation, and practical implication. *Antiredox Redox Signal*, v.11, n.4, p.861-905, apr. 2009. Available in: <doi:10.1089/ars.2008.2177> Accessed on: 12 jul. 2016.

FRANKLIN, K. A.; WHITELAM, G. C. Phytochromes and shade avoidance responses in plants. *Annals of Botany*, v.96, n.2, p.169-175, 2005. Available in: <https://doi.org/10.1093/aob/mci165> Accessed on: 12 jul. 2016.

GREEN-TRACEWICZ, E.; PAGE, E.R.; SWANTON, C.J. Light quality and the critical period for weed control in soybean. *Weed Science*, v.60, n.1, p.86-91, jan. 2012. Available in: <http://dx.doi.org/10.1614/WS-D-11-00072.1> Accessed on: 12 jul. 2016.

KNISS, A.R.; SBATELLA, M. G.; WILSON, R.G. Volunteer glyphosate-resistant corn interference and control in glyphosate-resistant sugarbeet. *Weed Technology*, v.26, n.2, p.348-355, apr. 2012. Available in: <https://doi.org/10.1614/WT-D-11-00125.1> Accessed on: 24 jul. 2016.

LICHTENTHALER, H.K. Chlorophylls and carotenoids: pigment photosynthetic biomembranes. *Methods in Enzymology*, v.148, n.34, p.350-382, 1987. Available in: <http://dx.doi.org/10.1016/0076-6879(87)48036-1> Accessed on: 17 oct. 2015.

LÓPEZ-OVEJERO, R.F.; SOARES, D.J.; OLIVEIRA, N.C.; KAWAGUCHI, I.T.; BERGER, G.U.; CARVALHO, S.J.P.; CHRISTOFFOLETI, P.J. Interferência e controle de milho voluntário tolerante ao glifosato na cultura da soja. *Pesquisa Agropecuária Brasileira*, v.51, n.4, p.340-347, abr. 2016. Available in: <DOI: 10.1590/S0100-204X2016000400006> Accessed on: 15 mar. 2017.

MARQUARDT, P.; KRUPKE, C.; JOHNSON, W.G. Competition of transgenic volunteer corn with soybean and the effect on western corn rootworm emergence. *Weed Science*, v.60, n.2, p.193-198, apr. 2012. Available in: <http://dx.doi.org/10.1614/WS-D-11-00133.1> Accessed on: 12 jul. 2016.

MCPHEE, C. S.; AARSSEN, L. W. The separation of above- and below-ground competition in plants. A review and critique of methodology. *Plant Ecology*, v.152, n.2, p.119-

REVISTA SCIENTIA AGRARIA
Versão On-line ISSN 1983-2443
Versão Impressa ISSN 1519-1125
SA vol. 19 n°. 2 Curitiba abr/jun. 2018 p. 78-85

136, feb. 2001. Available in: <doi:10.1023/A:1011471719799> Accessed on: 8 jul. 2016.

NIINEMETS, Ü. A review of light interception in plant stands from leaf to canopy in different plant functional types and in species with varying shade tolerance. *Ecological Research*, v.25, n.4, p.693-714, jul. 2010. Available in: <doi:10.1007/s11284-010-0712-4> Accessed on: 8 jul. 2016.

PAGE, E. R.; TOLLENAAR, M.; LEE, E.A.; LUKENS, L.; SWANTON, C.J. Shade avoidance: an integral component of crop weed competition. *Weed Research*, v.50, n.4, p.281-288, aug. 2010. Available in: <doi:10.1111/j.1365-3180.2010.00781.x > Accessed on: 12 jul. 2016.

POORTER, H.; LAMBERS, H. Growth and competitive ability of a highly plastic and marginally plastic genotype of *Plantago major* in a fluctuating environment. *Physiologia Plantarum*, v.67, n.2, p.217-222, jun. 1986. Available in: <doi: 10.1111/j.1399-3054.1986.tb02446.x> Accessed on: 23 aug. 2016.

RADOSEVICH, S. R.; HOLT, J.S.; GHERSA, C.M. Weed ecology: Implications for management. 2. ed. New York: John Wiley & Sons, 1997. 589p. Accessed on: 8 jul. 2016.

RAMBO, L.; COSTA, J.A.; PIRES, J.L.F.; PARCIANELLO, G.; FERREIRA, F.G. Rendimento de grãos da soja em função do arranjo de plantas. *Ciência Rural*, v.33, n.3, p.405-411, may./jun. 2003. Available in: <https://dx.doi.org/10.1590/S0103-84782003000300003> Accessed on: 3 set. 2016.

ROING-VILLANOVA, I.; MARTÍNEZ-GARCÍA, J. F. Plant responses to vegetation proximity: a whole life avoiding shade. *Frontiers in Plant Science*, v.7, art. 236, 10p, feb. 2016. Available in: <https://doi.org/10.3389/fpls.2016.00236 > Accessed on: 25 jan. 2017.

STRECK, N.A.; DE PAULA, G.M.; CAMERA, C.; MENEZES, N.M.; LAGO, I. Estimativa do plastocrono em cultivares de soja. *Bragantia*, v.67, n.1, p.67-73, jan./mar. 2008. Available in: <http://dx.doi.org/10.1590/S0006-87052008000100008> Accessed on: 8 jul. 2016.

THOMAS, W.E.; EVERMAN, W.J.; CLEWIS, S.B.; WILCUT, J.W. Glyphosate-resistant corn interference in glyphosate-resistant cotton. *Weed Technology*, v.21, 2, p.372-377, apr. 2007. Available in: <http://dx.doi.org/10.1614/WT-06-007.1> Accessed on: 23 aug. 2016.

VIDAL, R.A.; TREZZI, M.M.; KOZLOWSKI, L.A.; PRATES, M.V.B.; CIESLIK, L.F.; MEROTTO Jr, A. Initialism as a mechanism of weed interference: can a crop plant be blinded? *Planta Daninha,* v.30, n.3, p.469-475, jul./ set. 2012. Available in: <http://dx.doi.org/10.1590/S0100-83582012000300002> Accessed on: 23 aug. 2016.