Interference and Economic threshold level of Alexander Grass in Soybean as a Function of Cultivars and Weed Populations

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Abstract**—** *In the soybean crop occurs high losses of grains production, in function of weeds. It is noteworthy that among the most damaging weeds in the soybean crop is the alexander grass (Urochloa plantaginea). The objective of the project was to test mathematical models and identify explanatory variables to determine the level of control of alexander grass in the soybean crop estimated in function of cultivars and populations of the competitor. The experiment was installed in the UFFS experimental area in Erechim, RS in the agricultural year 2016/17. The treatments were composed of soybean cultivars (NS 5445 IPRO, NS 5959 IPRO, SYN 13561 IPRO, SYN 1059 RR e BMX Elite IPRO) and 12 alexander grass populations that competed with each soybe an cultivar. We evaluated plant population, leaf area, ground cover and dry mass of the aerial part of alexander grass. The plant population presents a better fit to the model of the rectangular hyperbole, and this model can estimate the grain productivity losses due the alexander grass interference. The cultivars SYN 1059 RR, BMX Elite IPRO and NS 5445 IPRO were the most competitive in comparing with the others in the presence of alexander grass. The values of economic threshold level ranged from 0.96 to 2.16 plants m2. The increase in grain productivity, commercial price of soybeans, herbicide efficiency and reduction in control cost decrease the economic threshold level for weed control, justifying application of control measures for lower densities of al exander grass.*

Keywords**— *Glycine max, Urochloa plantaginea, Integrated Weed Management.***

I. INTRODUCTION

The soybean (*Glycine max* (L) Merril) is a specie with world importance, because contains high protein (40%) and oil (20%) contents, used for animal feed, oil production, soybean meal, biodiesel e disinfectants (Sediyama, 2009). In Brazil, the soybean cultivated area in the latest crop year 2016/17 was around 33.8 million hectares. The main soybean producing states are those of the South Region (Rio Grande do Sul - RS, Santa Catarina - SC e Paraná - PR) and Midwest (Mato Grosso, Mato Grosso do Sul, Goiás e Distrito Federal). In the South region the seeded area was 11.4 million hectares, with average productivity of 3537 kg ha-1, being the highest productivity average in Brazil (CONAB, 2017).

The soybean crop is very demanding in nutrients for its development and at the 30 days after emergence initiates the greater absorption, remaining with a high rate of translocation until the phase of the grain filling (Carmello, 2006). Is required from 450 to 850 mm of water during the crop cycle, varying according to the management adopted during the conduction of the crop, the cultivar, the climate and even the interference of weeds (Carvalho et al., 2013).

For any agricultural crop, the productivity is dependent on many factors, such as those already reported previously, and when it comes to soybean, this productivity is much below than those obtained in experimental areas or crops that adopt high technologies. Among the probable causes for this low productivity are

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the factors of production, such as cultivars, soil fertility, insect management, diseases and weeds, related in such a way that any of them can be limiting to the production (Bastiani et al., 2016). The negative effects of weed interference are manifested on the quantity and quality of agricultural production in consequence of competition for environmental resources, allelopathy, or for being agents that host pests and diseases (Kalsing and Vidal, 2010; Galon et al., 2011).

Among the weeds that infest soybeans, one of the most competitive is the alexander grass (*Urochloa plantaginea*), belonging to the Poaceae family. This specie is found with greater abundance in the cultivated soils of the South and Central regions of the country, being introduced in Brazil in colonial times (Kissmann, 1997).

Weeds compete with crops for the resources available in the environment, such as: water, light and nutrients (Bianchi et al., 2006; Bastiani et al., 2016), Gal et al. (2015), when studying the effect of red light reflection by weeds on soybean, concluded that the crop presented a decrease in root volume, nodulation, root length, among other factors related to gene expression and flavonoid production

For the control of weeds, especially the alexander grass that infests soybean and other annual and perennial crops, we use herbicides in function of the practicality, efficiency and lower cost when compared to other methods of control (Christoffoleti et al., 2006). However, the use of herbicides has generated environmental contamination and also in the food produced, thereby necessitating other forms of weed management in soybean, such as cultural, preventive, biological, mechanical management, among others methods.

Research work involving the competitiveness of crops versus weeds provides the development of alternative strategies based on competition of cultivars, spacing, sowing density, among others (Jha et al., 2017; Datta et al., 2017). Thus, it is possible to define the characteristics that the crops suffer with the damages caused by weeds (Agostinetto et al., 2010; Bianchi et al., 2006; Machado et al., 2015; Galon et al., 2016). Among the available options for the study of competition between plants in a community, we have the nonlinear equation of the rectangular hyperbola, this equation makes the relation between the loss of crop productivity, using the variables plant population, dry mass, ground cover and leaf area of weeds (Rizzardi et al., 2003a; Agostinetto et al., 2010). The model of the rectangular hyperbola is composed by the parameters (i and a) that have biological and agronomic meaning, they can be used as signs of competitiveness between plants when living together in communities (Cousens, 1985).

Nowadays, more productive and sustainable control models are sought for a lower environmental impact, safer food production and reduction of herbicide intoxications to the applicators. In this fundament, the application of herbicides according to the concept of economic threshold level (ETL), is characterized by adopting the control method only when the damage caused by weeds is higher than the cost of the control method used in the management (Agostinetto et al., 2010; Vidal et al., 2010; Galon et al., 2011).

The hypothesis of the work is that there is differentiation in the competition between soybean cultivars with populations of alexander grass plants and this will impact in the decision-making of the economic threshold level.

With this, the research's objective was to test mathematical models and to identify explanatory variables aiming to determine the economic threshold level of alexander grass in the soybean crop, estimated in function of cultivars and weed populations.

II. MATERIAL AND METHODS

The experiment was conducted in the field, in the experimental area of the Federal University of Fronteira Sul, Campus Erechim, in soil classified as Typical Aluminoferric Red Latosol (EMBRAPA, 2013). The rainfall during the conduction of the experiment is presented in Figure 1.

The experimental design was completely randomized, without repetition. The treatments were constituted of five soybean cultivars (NS 5445 IPRO, NS 5959 IPRO, SYN 13561 IPRO, SYN 1059 RR and BMX Elite IPRO) and twelve plant populations of Alexandergrass (0, 2, 6, 8, 18, 26, 18, 30, 36, 94, 70 and 104; 0, 2, 4, 4, 6, 22, 24, 36, 58, 58, 94 and 124; 0, 2, 4, 4, 8, 12, 18, 18, 28, 76, 94 and 116; 0, 4, 2, 4, 8, 12, 14, 14, 24, 30, 84 and 114; 0, 2, 12, 20, 24, 26, 28, 36, 40, 48, 62 and 104, plants m-2) for each tested cultivar, respectively.

In reason of alexander grass is derived of the soil seed bank, the establishment of the populations was variable, because factors as infestation, vigor, humidity, and others, prevent the establishment of exactly the same plants number for area (experimental unit).

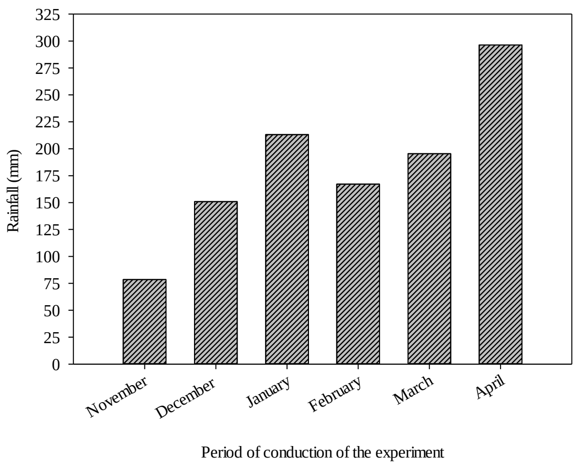

Fig.1: The rainfall (mm) in the period of conduction of the experiment. Data from the Automatic station of Passo Fundo – RS. Font: Inmet, 2018.

The populations of weeds were established from the soil seed bank, by the application of the herbicide glyphosate (3 L ha^{-1}), when the crop had three trefoils and the weed, in the four-leaf stage to a tiller. The period was chosen for being the most suitable for the application of herbicides in post emergence in the soybean crop. The alexander grass plants were protected with plastic cups, in order to not be harmed by the herbicide. The other remnant weeds in the experimental units, which were not part of the experiment, were controlled by weeding.

The experiment was conducted in no-tillage system in the straw, and the vegetation that was composed of black oat + radish was desiccated with the glyphosate herbicide (1080 g ha^{-1} of acid equivalence) before the soybean seeding with the seeder/fertilizer. The experimental units were composed of an area of 15 m^2, being the seeding conducted in six lines, of 5 m long and separated by 0.50 m, making 3 m wide. The sowing density of the soybean cultivars was 14 viable seeds per linear meter or 280,000 ha-1 seeds, which allowed the establishment of 28 m-2 plants.

The evaluated variables of the crop and weed 30 days after emergence - DAE (period that coincides with the application of herbicides in post-emergence of weeds) were: plants population (PP), dry mass (DM), leaf area (LA) and ground cover (GC). The quantification of the explanatory variable PP was performed by counting the plants present in two areas of 0.25 m² (0.5 x 0.5 m) in each parcel. The GC by alexander grass and soybean plants was visually evaluated, individually, by two evaluators using percentage scale in which the value zero corresponds to the absence of GC and a value of 100 represents full coverage of the soil. The quantification of the LA of the species was affected with a portable electronic leaf area integrator, model CI-203, from CID BioScience, using the leaves of the plants present in an area of 0,25 m^2 (0,5 x 0,5 m) and after the determination of this variable, these leaves were used to measure DM. The DM of soybean and alexander grass plants (g m^{-2}) was dried in forced air circulation oven at the temperature of 60±5ºC, until it reached a constant mass.

At the end of the cycle, the grains productivity of the soybean cultivars was quantified, obtained by the harvest of the plants in usable area of 6 m² (3 x 2 m) of each experimental unit, when the humidity level of the grains reached approximately 15 %. After weighing the grains, its humidity was determined and, subsequently, the masses were corrected to 13% of humidity and the values extrapolated to kg ha^{-1}.

The loss percentage of the productivity of soybean cultivars in relation to experimental units free of competing plants were calculated according to Equation 1.

$$\text{Loss (\%)} = \left(\frac{Ra - Rb}{Ra} \right) x100 \qquad \text{Equation 1}$$

where: Ra and Rb: productivity of the crop without or with the presence of competitor plants (alexander grass) respectively. The obtained data were adjusted to the nonlinear regression model of the rectangular hyperbola (Cousens, 1985), according the Equation 2:

$$Pp = \frac{(i * X)}{(1 + (\frac{i}{a}) * X)} \qquad \text{Equation 2}$$

where: Pp = productivity loss (%); X = alexander grass population, dry mass of the aerial part, leaf area or ground cover; *i* and *a* = losses in productivity (%) per unit of alexander grass plants when the variable value is close to zero and when it tends to infinite, respectively.

For the mathematical modeling procedure in order to estimate the competitive ability of the species and for the ETL calculation, the adjustment of the data to the model was performed with the Proc Nlin procedure of the SAS computer program (SAS, 1989) the variables PP, DM, LA and GC was used for this. For the calculation procedure, the Gauss-Newton method was used, which, by successive iterations, estimates the parameter values, in which the sum of the squared deviations of the observations, in relation to the adjusted values, are minimum (Ratkowsky, 1983). The value of the F statistic ($p \leq 0,05$) was used as an analysis criterion for the data adjustment to the model. The acceptance criteria of the adjustment of the data to the model was due to the higher value of the coefficient of determination (R^2) and the lower value of meddle error square (MES).

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For the calculation of the economic threshold level (ETL), was used the estimates of the parameter *i* obtained from Equation 2 (Cousens, 1985), and the adapted equation of Lindquist and Kropff (1996) – Equation 3:

$$ETL = \frac{(Cc)}{(R*P*(\frac{i}{100})*(\frac{H}{100}))} \quad \text{Equation 3}$$

where: ETL = economic threshold level (plants m-2); Cc = control cost (herbicide and tractorized terrestrial application, in dollars ha^{-1}); R = soybean grain productivity (kg ha^{-1}); P = soybean price (dollars kg^{-1} of grains); *i* = loss (%) in productivity of soybean per unit of competitive plant when the population level is close to zero and H = herbicide's efficiency level (%).

For the variables Cc, R, P and H (Equation 3), was estimated three values. Thus, for the control cost (Cc), the average price was considered, being the maximum and minimum costs altered in 25%, in relation to the average cost. The soybean grain productivity (R) was based in the smallest, average and the biggest productivities obtained in Rio Grande do Sul in the last 10 years. The product price (P) was estimated from the smallest, average and biggest prices of soybean paid per 60 kg sack in the last 10 years.

The values for the herbicide efficiency (H) were established in the order of 80, 90 and 100% of control, being 80% the minimum control considered effective in the weed. (SBCPD, 1995). For the ETL simulations, was used the intermediate values for the variables that were not the object of the calculation.

III. RESULTS AND DISCUSSION

The explanatory variables plant population (PP), leaf area (LA), ground cover (GC) and dry mass of the aerial part (DM) for all the evaluated soybean cultivars presented significant values of F-statistics showing significant differences between the treatments (Table 1, 2, 3 e 4). The obtained results showed that for the soybean cultivars NS 5445 IPRO, NS 5959 IPRO, SYN 13561 IPRO, SYN 1059 RR and BMX Elite IPRO, the rectangular hyperbola model adjusted properly to the data presenting R^2 values over 0,54 e low MES, which characterizes an elevated adjustment to the rectangular hyperbola model.

It was observed, for the majority of evaluated variables, that the values estimated for the parameter tended to be smaller for the cultivars SYN 1059 RR, BMX Elite IPRO and SYN 13561 IPRO, respectively, thus demonstrating greater competitiveness than the others. The smaller competitiveness was verified for the NS 5959 IPRO cultivar, for the variables PP, LA and DM variables, and the NS 5445 IPRO for the LA, which presented the biggest losses of grain productivity, compared to the others (Tables 1, 2, 3, and 4).

The relative competitiveness of the species is defined based on the parameter, that is, the smaller it is, more competitive the specie is, this parameter is used to compare the relative competitiveness between crops and weeds (Swinton et al., 1994; Dieleman et al., 1995).

Table 1. Adjustments obtained for the loss of grain productivity, according to the population of alexandergrass (Urochloa plantaginea) and soybean cultivars, NS 5445 IPRO, NS 5959 IPRO, SYN 13561 IPRO, SYN 1059 RR and BMX Elite IPRO. UFFS, Erechim, 2016.

Cultivars	Parameters[1]		R^2	MES	F
	I	*A*			
NS 5445 IPRO	1.39	89.20	0.95	35.30	161.84*
NS 5959 IPRO	2.50	54.28	0.67	82.29	61.54*
SYN 13561 IPRO	1.58	71.04	0.72	111.60	38.81*
SYN 1059 RR	1.10	81.20	0.85	11.59	250.91*
BMX Elite IPRO	1.26	85.46	0.58	355.80	13.60*

[1] *i* and *a*: productivity losses (%) per unit of alexandergrass when the variable value approaches zero or tends to the infinite, obtained by the equation $Y=(i.X)/(1+(i/a).X)$; respectively; * Significant in $p\leq 0,05$.

The results for the parameter *a* estimate were lower than 100% for the PP explanatory variable for all cultivars, presenting that crop productivity losses can be adequately simulated, based on this parameter for this variable. However, for the other explanatory variables GC, LA and DM the values were higher than 100% or overestimated by the model. These results may be due to the fact that the largest populations of alexandergrass plants were insufficient to adequately estimate the maximum productivity loss. According to Cousens (1991), to obtain a reliable estimate for the parameter *a* it is necessary to include in the experiment very high populations of weeds, over those commonly found in agriculture.

An alternative to avoiding overestimates of productivity losses would be to limit the maximum loss in 100%. However, the limitation will influence the estimation of parameter *i*, which may result in less predictability in the model of the rectangular hyperbola (Streibig et al., 1989).

In addition, productivity losses greater than 100% are biologically unrealistic and occur when the amplitude of weed populations are too narrow and/or when the highest population values are not sufficient to produce asymptotic responses of productivity loss (Cousens, 1985; Yenish et al., 1997; Galon et al., 2007).

For the explanatory variable PP, the estimated values for the parameter *i* were lower for the cultivars SYN 1059 RR and BMX Elite IPRO, which characterizes greater competitiveness when compared with the others. The lowest competitiveness was verified for cultivars NS 5959 IPRO and SYN 13561 IPRO. This fact occurs because the cultivars have genetic characteristics differentiated related to stature and development cycle, which makes them more or less competitive. This result was also verified by Agostinetto et al., (2013) when evaluated the relative competitive ability of Southern Crabgrass in coexistence with irrigated rice and soybean.

The cultivars BMX Elite IPRO and SYN 13561 IPRO presented values of the parameter *i* equal to 0.01 demonstrating greater competitiveness in relation to the others as a function of GC (Table 2). The highest values for parameter *a* were presented by cultivars NS 5959 IPRO and BMX Elite IPRO, stating higher productivity losses for them. The lower competitiveness of these cultivars may occur due to the slower initial growth, allowing a higher incidence of sunlight on weeds. Consequently, occur loss of competitiveness, a fact also related by Bastiani et al., (2016) when working with soybean cultivars living with barnyard grass.

Table 2. Adjustments obtained for grain productivity loss due to the ground cover of alexandergrass (Urochloa plantaginea) and soybean cultivars, NS 5445 IPRO, NS 5959 IPRO, SYN 13561 IPRO, SYN 1059 RR and BMX Elite IPRO. UFFS, Erechim, 2016.

Cultivars	Parameters[1]		R^2	MES	F
	I	*A*			
NS 5445 IPRO	0.02	181.29	0.73	182.50	31.69*
NS 5959 IPRO	0.02	283.20	0.76	30.48	173.38*
SYN 13561 IPRO	0.01	204.30	0.71	34.03	131.59*
SYN 1059 RR	0.02	164.90	0.77	21.51	132.90*
BMX Elite IPRO	0.01	206.40	0.62	135.90	23.27*

[1] *i* and *a*: productivity losses (%) per unit of alexandergrasss when the variable value approaches zero or tends to the infinity, obtained by the equation Y= (*i*.X)/(1+(*i* / *a*).X); respectively; * Significant in p≤0,05.

For the results of the LA the cultivars SYN 13561 IPRO and SYN 1059 RR presented the lowest values for the parameter *i* being 0.00004 for the two, as well as presented the highest values of the parameter *a* of 114.80 and 155.80% respectively (Table 3). Demonstrating that, although they are more competitive, they also presented the highest maximum losses, in comparison with the other cultivars. This situation may be related to the conduction of the field experiment, as previously reported. Galon et al., (2016) also verified this fact when evaluating the interference and the economic threshold level of beggartick on bean cultivars.

Table 3. Adjustments obtained for the loss of grain productivity, according to the alexander grasss leaf area (Urochloa plantaginea) and soybean cultivars, NS 5445 IPRO, NS 5959 IPRO, SYN 13561 IPRO, SYN 1059 RR and BMX Elite IPRO. UFFS, Erechim, 2016.

Cultivars	Parameters[1]		R^2	MES	F
	I	*A*			
NS 5445 IPRO	0.00900	82.47	0.86	65.54	85.34*
NS 5959 IPRO	0.00008	68.89	0.71	112.60	42.10*
SYN 13561 IPRO	0.00004	114.80	0.66	150.30	26.98*
SYN 1059 RR	0.00004	155.80	0.61	77.26	33.64*
BMX Elite IPRO	0.00010	64.43	0.62	11.67	394.70*

[1] *i* e *a*: productivity losses (%) per unit of alexander grasss when the variable value approaches zero or tends to the infinity, obtained by the equation Y= (*i*.X)/(1+(*i* / *a*).X); respectively; * Significant in p≤0,05.

The cultivar SYN 1059 RR presented the lowest value for the parameter *i* and the highest value for the parameter *a* in the explanatory variable DM, this demonstrates that the cultivar presented the greatest competitiveness and also the greatest loss, in comparison to the others, this fact also occurred in the explanatory variable LA (Table 3 and 4). On the other hand, the lowest competitiveness was found for cultivars NS 5959 IPRO and BMX Elite IPRO with values of the parameter *i* equal to 0.01, being these that presented the lowest values for the parameter *a* being 60.27 and 63.21% respectively. That is, in addition to presenting the smallest competitions, also showed the lowest maximum losses compared to the others.

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Table 4. Adjustments obtained for the loss of grain productivity, according to the dry mass of alexander grasss (Urochloa plantaginea) and soybean cultivars, NS 5445 IPRO, NS 5959 IPRO, SYN 13561 IPRO, SYN 1059 RR and BMX Elite IPRO. UFFS, Erechim, 2016.

Cultivars	Parameters[1]		R^2	MES	F
	I	*a*			
NS 5445 IPRO	0.008	93.94	0.79	106.60	50.73*
NS 5959 IPRO	0.010	60.27	0.91	118.70	39.80*
SYN 13561 IPRO	0.007	79.80	0.63	154.30	26.83*
SYN 1059 RR	0.005	118.50	0.77	92.43	27.38*
BMX Elite IPRO	0.010	63.21	0.54	11.12	408.40*

[1] *i* e *a*: productivity losses (%) per unit of alexander grass when the variable value approaches zero or tends to the infinity, obtained by the equation $Y= (i.X)/(1+(i / a).X)$; respectively; * Significant in $p\leq0,05$.

The demonstration of the values of economic threshold level (ETL) was carried out using the explanatory variable PP of the alexander grass, because it presented one of the best adjustments to the model of the rectangular hyperbola and for being the most utilized in experiments with this objective (Fleck et al., 2002; Galon et al., 2007; Agostinetto et al., 2010; Kalsing et al., 2010; Galon et al., 2016).

In the average of all the cultivars and comparing the lowest with the highest productivity of grains, it was observed a difference in the ETL in the order of 84% (Figure 2). The greater the productive potential of the cultivars, the lower the PP of alexander grass will be necessary to surpass the ETL, resulting in the adoption of measures of control of the alexander grass so that the profitability of the producer is compensated. Galon et al. (2016), when evaluating the interference and ETL of beggartick on bean cultivars, also observed that the ETL varies according to the bean cultivars that have a greater productive potential, since they can present smaller ETL.

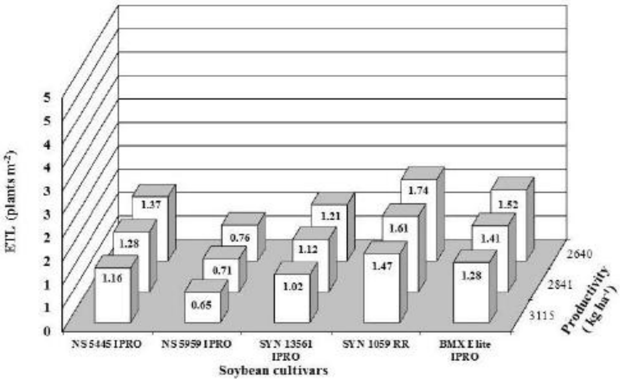

Fig.2: Economic threshold level (ETL) of alexander grass in soybean as a function of grain productivity. UFFS, Erechim/RS 2016/17.

The average results of all cultivars tested, from the highest versus the lowest price paid for soybean, varied 1.6 times higher to the ETL value (Figure 3). Thus, the lower the price paid to the soybean bag, the higher the population needed to exceed the ETL and compensate for the adoption of control measures. When fixed the amount paid per ton of soybean at US$ 470.00, Song et al. (2017), found values of economic level of 0.70 plants m^{-2} for a community of weeds living with soybean, that is, very close to those found for cultivar NS 5959 IPRO (soybean price US$ 482.5 ton^{-1}). In the work done with rice crop, competing with Southern Crabgrass, the authors observed the same effect, the lower the price paid by the sack, the greater the population of the weed necessary to exceed the ETL (Agostinetto et al., 2010).

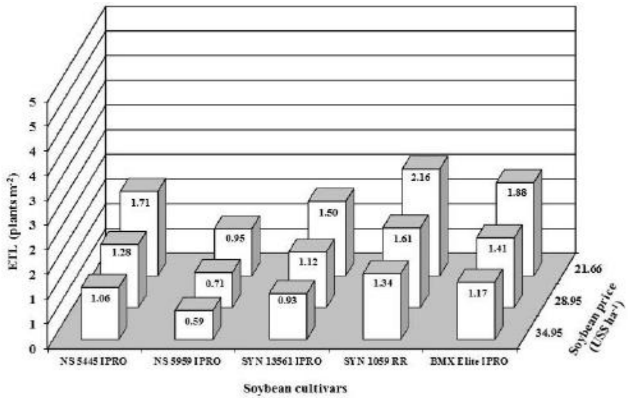

Fig.3. Economic threshold level (ETL) of alexander grass in soybean as a function of the price of soybean sack. UFFS, Erechim/RS 2016/17.

When comparing the average cost of control of alexander grass in all cultivars, which takes into account the cost of application and the price of the herbicide, was verified a decrease of 40% in ETL between the minimum cost when comparing with the maximum cost (Figure 4). In function of the control cost, the higher it is, the greatest are the ETL and larger populations of alexander grass

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plants m^{-2} are necessary to compensate the adoption of control measures. Fleck et al. (2002), when evaluating the ETL of arrow leaf *Sida* in soybean, observed that the higher the cost of control is, the higher the ETL will be, which is in line with that observed in the present study.

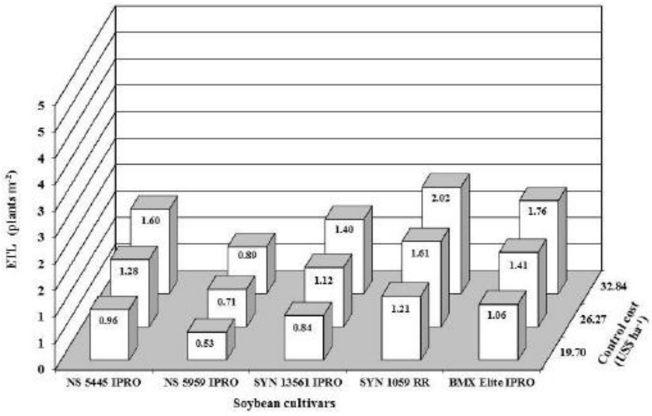

Fig.4. Economic threshold level (ETL) of alexander grass in soybean as a function of the cost of control. UFFS, Erechim/RS 2016/17.

The results demonstrate that the average efficiency (90%) when compared in relation to the highest (100%) or lower (80%) occur changes in ETL values in the order of 11% (Figure 5). The efficiency level of the herbicide influences the ETL, the higher the efficiency, the lower infestations of alexander grass plants m^{-2} are necessary to overcome the ETL and justify the adoption of control. For a control efficiency of 90%, Song et al., (2017), found ETL values ranging from 0.66 to 1.45 plants m^{-2}, for the weeds *Ambrosia artemisiifolia*, *Echinochloa crus-galli*, *Sonchus oleraceus*, *Chenopodium album* and *Beckmannia syzigachne* in competition with soybean, results very close to those observed for the alexandergrass.

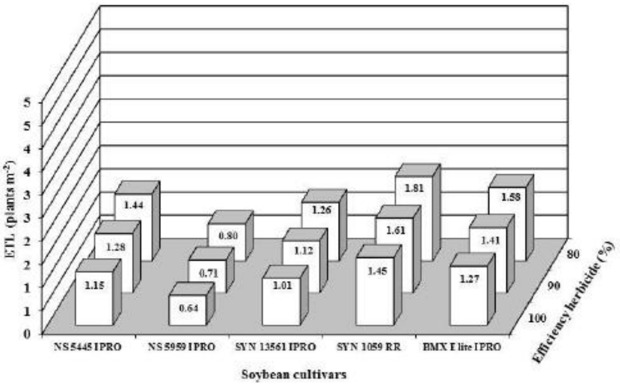

Fig.5. Economic threshold level (ETL) of alexander grass in soybean as a function of herbicide efficiency. UFFS, Erechim/RS 2016/17.

The factors involved in the ETL calculation (herbicide cost, application cost and value of the product sack of the commercialized crop) can be easily estimated by the farmers themselves, but the crop yield potential, herbicide efficiency, loss of productivity per unit of weed, are more difficult to predict accurately, due to variability of environmental conditions, weed size, set of weed species and the effect of cropping modes on them (Fleck et al., 2002).

The ETL quantify crop losses only in a single growing season, with calculations based on a single year (Kalsing and Vidal 2010). However, we do not take into account the factor associated with the possible increase in the weed seed bank, on the long-term profitability in the decisions of the weed control forms, since, due to the ETL that only present the direct damage caused by the weeds and do not the potential damage that can be caused by seed production. (Rizzardi et al., 2003a,b).

However, there are difficulties in approaching ETL use, due to the confrontation of the farmer at the moment of the management decision, for not knowing previously what will be the productivity of grains weed free, thus estimating only in the productivities of previous years and the yield target for the crop. ETL adoption becomes justifiable in crop situations that are managed with other weed management practices, such as the use of appropriate plant arrangement, crop rotation, application of efficient herbicide doses, use of adequate fertilization, use of more competitive cultivars, among others (Galon et al., 2011; Rizzardi et al., 2003b; Galon et al., 2016).

Therefore, the difficulties encountered in adopting the ETL approach serve as a challenge to research, so that weed management systems are developed and optimized for the rational and economical use of chemical control measures, which are normally used, with little or no technical justification. In this sense, the understanding of weed biology and ecology, results in integrated weed management strategies, minimizing the cases of resistance and providing more sustainable technologies in comparison to the current model that is currently failing (Westwood et al., 2017).

IV. CONCLUSION

The results obtained allow us to conclude that the nonlinear regression model of the rectangular hyperbola adequately estimates the unit and maximum productivity losses of soybean grains when infested with alexander grass. The cultivars SYN 1059 RR and SYN 13561 IPRO presented the highest competitiveness with alexander grass, with ETL values ranging from 0.84 to 2.16 plants m^{-2}. The increase in soybean grain productivity, soybean price, herbicide efficiency, and reduction in control cost, causes a decrease in the economic threshold level, thus justifying the adoption of control methods in low densities of alexander grass.

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