PLANTA DANINHA
SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS
SBCPD
<http://www.sbcpd.org>
ISSN 0100-8358 (print)
1806-9681 (online)

Article

Criteria for Decision Making and Economic Threshold Level for Wild Radish in Wheat Crop

Critérios para Tomada de Decisão e Nível de Dano Econômico de Nabo na Cultura do Trigo

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ABSTRACT - Weed competition limits wheat yield by reducing the availability of essential resources for its growth and development. In this sense, this study aimed to estimate the economic threshold level (ETL) of wild radish (*Raphanus raphanistrum*) in competition with wheat cultivars. Treatments were arranged in a factorial scheme. The factor wheat cultivar consisted of early (BRS 328), medium (BRS 177), and late (BRS Umbu) cycles and the factor wild radish population ranged from 0 to 564 plants m^{-2} (10 populations) for the cultivar BRS 328, 0 to 472 plants m^{-2} for the cultivar BRS 177 (11 populations), and 0 to 724 plants m^{-2} for the cultivar BRS Umbu (10 populations). The early-cycle BRS 328 presented a higher competitive ability when compared to the medium-cycle BRS 177 and late-cycle BRS Umbu. Yield losses of wheat grains due to wild radish interference can be satisfactorily estimated by the rectangular hyperbola model using the variables plant population, shoot dry matter, soil cover, and leaf area of the weed. ETL values varied as a function of the cultivar cycle, being higher for the cultivar BRS 328 (early) > BRS 177 (medium) > BRS Umbu (late). Wild radish is competitive in wheat crop, requiring at least 1.6 plants m^{-2} for control to be justified.

Keywords: *Triticum aestivum* L., *Raphanus raphanistrum*, cultivars, populations.

RESUMO - A competição com plantas daninhas limita a produtividade do trigo, reduzindo a disponibilidade de recursos essenciais para o crescimento e desenvolvimento da cultura. Dessa forma, objetivou-se estimar o nível de dano econômico de nabo (Raphanus raphanistrum) em competição com cultivares de trigo. Os tratamentos foram arranjados em esquema fatorial, em que o fator cultivar de trigo apresentou três níveis: ciclo precoce (BRS 328), médio (BRS 177) e tardio (BRS Umbu); e o fator população da planta competidora variou de 0 a 564 plantas de nabo m^{-2} (10 populações), para o cultivar BRS 328; 0 a 472 plantas de nabo m^{-2}, para o cultivar BRS 177 (11 populações); e 0 a 724 plantas de nabo m^{-2}, para o cultivar BRS Umbu (10 populações). O cultivar BRS 328, de ciclo precoce, apresenta maior habilidade competitiva comparativamente ao cultivar BRS 177, de ciclo médio, e BRS Umbu, de ciclo tardio. As perdas de produtividade de grãos de trigo, devido à interferência de nabo, podem ser estimadas de modo satisfatório pelo modelo da hipérbole retangular, utilizando-se as variáveis população de plantas, massa de matéria seca da parte aérea, cobertura do solo e área foliar da planta daninha. Os valores de NDE variam em função do ciclo do cultivar, sendo maior para o cultivar BRS 328 (precoce) > BRS 177 (médio) > BRS Umbu (tardio). O nabo mostra-se competitivo na cultura de trigo, sendo necessário no mínimo 1,6 planta m^{-2} para que o controle se justifique.

Palavras-chave: *Triticum aestivum* L., *Raphanus raphanistrum*, cultivares, populações.

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Received: April 21, 2017
Approved: October 16, 2017

Planta Daninha 2019; v37:e019178898

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Doi: 10.1590/S0100-83582019370100004

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the basic components of the diet of several peoples, being responsible for much of the caloric diet of the population. The area planted with wheat in Brazil over the last 10 years was 2.24 million ha, reaching an average productivity of approximately 2,456 kg ha^{-1} (Conab, 2017a). The Rio Grande do Sul and Paraná are the main producing States, accounting for approximately 37 and 51% of the Brazilian production, respectively (Conab, 2017b).

Among the factors that limit wheat yield is the competition with weeds, which reduce the availability of essential resources for its growth and development and may cause changes in its morphological characteristics and yield (Floss, 2008; Melo et al., 2009). Several weed species cause economic losses to wheat, among which we can mention ryegrass (*Lolium multiflorum* Lam.) and wild radish (*Raphanus* spp.), which stand out as its main weeds, with an increased incidence in recent years due to their use of soil cover and winter pasture formation (Lamego et al., 2013).

The presence of "neighboring" plants alters the growth of their shoot as a way to improve the efficiency in the capture of the light radiation and avoid the shading (Lamego et al., 2015). The light stress caused by the competition may lead to different plant responses, one of the main ones characterized by alterations in the root system and reduction of the area of exploitation, which directly affect water and nutrient absorption rates (Taiz and Zeiger, 2017).

The use of tools that can quantify in advance and properly the damage caused by weed population on the growth and yield in a given crop is of great use for the decision-making on the adoption of management measures and enable the production potential of the crop. The economic threshold level (ETL) is a management strategy that aims to determine the population of a weed capable of causing economic loss based on parameters such as the weed population level, weed emergence period in relation to the crop, crop productive potential in the absence of the weed, price paid for producing the crop, cost for weed control, efficiency of the control method, and management practices (Galon et al., 2007; Kalsing and Vidal, 2010).

Characteristics such as higher emergence rate, size, dry matter production, and leaf area are related to a higher competitive ability (Schaedler et al., 2009). The wheat cultivars BRS Guatambu and BRS Timbaúva, with long and medium cycles, respectively, and a high plant height, stood out when in periods of coexistence with wild radish and ryegrass plants, presenting a higher competitive potential at the beginning of the cycle (Rigoli et al., 2009). Plants with high rates of emergence and initial growth have priority in the use of environmental resources and, therefore, take advantage of their use (Gustafson et al., 2004).

Studies on crop competition with weeds and determination of the economic threshold level allow developing management strategies to avoid losses of productivity since they can define characteristics that give a higher competitive ability to the crops and determine whether the adoption of control measures is viable. Considering the above, it is believed that the early cycle of the wheat cultivar increases its competitive ability and increases the wild radish ETL. Thus, the aim of this study was to estimate the economic threshold level of wild radish in competition with the wheat cultivars BRS 328 (early cycle), BRS 177 (medium cycle), and BRS Umbu (late cycle).

MATERIAL AND METHODS

The experiment was conducted under field conditions at the Agricultural Center of Palma (CAP) and in the Laboratory of Seed Analysis (LDAS), both belonging to the Federal University of Pelotas (UFPel). The experimental design was a completely randomized design with replications corresponding to different wild radish populations, providing the necessary variance to perform the statistical analysis by the hyperbolic model. The experimental units were composed of plots with 1.53 x 5 m, totaling 7.65 m^2. The soil of the area is classified as a sandy loam textured Ultisol (Argissolo Vermelho-Amarelo, Brazilian Soil Classification System), which belongs to the Pelotas mapping unit (Embrapa, 2013).

Wheat was sown under a conventional tillage system in an area previously desiccated with glyphosate (Atanor 48®) at a dose of 1.07 kg a.e. ha^{-1} and spray volume of 120 L ha^{-1} in order to eliminate weeds and standardize their emergence. Sowing was carried out at a density of 105 kg ha^{-1} of wheat seeds using a seed drill regulated for a row spacing of 0.17 m and distribution of 60 seeds per meter.

Base fertilization consisted of 288 kg ha^{-1} of the formula 04-11-09 following the soil chemical analysis, with topdressing nitrogen fertilization performed with 166 kg ha^{-1} of urea fractioned at the tillering stage and 15 days after. Weed and insect control and other management practices were performed according to the recommendations for the wheat crop (Informações..., 2011).

Treatments were arranged in a factorial scheme, in which the factor wheat cultivar consisted of early (BRS 328), medium (BRS 177), and late (BRS Umbu) cycles and the factor wild radish population ranged from 0 to 564 plants m^{-2} (10 populations) for the cultivar BRS 328, 0 to 472 plants m^{-2} for the cultivar BRS 177 (11 populations), and 0 to 724 plants m^{-2} for the cultivar BRS Umbu (10 populations).

The study was conducted in an area naturally infested with wild radish and the populations were fit according to the population levels of the treatments. The control of the excess of wild radish and other weeds was performed with herbicides applied seven days after emergence (DAE). Poaceae control was performed with the use of the herbicide clodinafop-propargyl at the dose of 60 g a.i. ha^{-1} with the mineral oil Assist® at a dose of 0.5% v/v. For wild radish plants in excess at each experimental unit, the herbicide bentazon was used at a dose of 720 g a.i. ha^{-1} with the mineral oil Assist® at a dose of 0.5% v/v. Regarding the procedure for the establishment of wild radish populations, plants were previously protected with plastic cups when in low populations or by kraft paper plates when in high populations so that they were not reached by the herbicide.

The variables assessed at 21 DAE were wheat plant population (PP), shoot dry matter (SDM), soil cover (SC), and leaf area (LA). The quantification of PP was performed by counting the individuals present in two areas of 0.25 m^2 (0.5 x 0.5 m) at each experimental unit. To determine SDM, plants were collected from an area of 0.25 m^2 (0.5 x 0.5 m), being dried in an oven at a constant temperature of 60 °C for 72 hours and weighed in an analytical balance. The determination of SC was performed by visual evaluation, assigning percent scores from 0 to 100%, where 0% means the absence of soil cover and 100% its complete coverage. After cutting the plants at the ground level, leaves were separated to assess the LA using a leaf area meter (model LI 3100C).

To determine grain yield, plants from the useful area of each experimental area were harvested (3.57 m^2). After threshing, grains were weighed, correcting their moisture content to 13% and the values were transformed into kg ha^{-1}. From the grain yield data, the percentage losses were calculated in relation to the plots maintained without weed infestation (control), according to Equation (1):

$$\text{Loss (\%)} = [(Ra - Rb)/Ra] \times 100 \qquad \text{(eq. 1)}$$

where Ra and Rb are the crop yields without or with the presence of wild radish, respectively.

The values of shoot dry matter (g m^{-2}), leaf area (cm^2 m^{-2}), and soil cover (%) were previously multiplied by 100, thus avoiding correcting these values in the model (Agostinetto et al., 2004; Galon et al., 2007).

The relationship between the percentage losses of wheat yield (Ly) as a function of the explanatory variables plant population (PP), shoot dry matter (SDM), and soil cover (SC) were calculated separately for each cultivar using a nonlinear regression model derived from the rectangular hyperbola, as proposed by Cousens (1985):

$$Ly = [i \times X/(1 + (i/a) \times X)] \qquad \text{(eq. 2)}$$

where Ly is the loss of yield (%), X is the explanatory variables PP, SDM or SC, and i and a are the yield losses (%) per wild radish unit for cases in which the value of the variable is close to zero or when it tends to infinity, respectively.

The fitting of the data to the model was performed through the procedure Proc Nlin procedure of the software SAS (SAS, 1989). For this procedure, we used the Gauss-Newton method, in which the values of the parameters in which the sum of squares of the deviations of observations, estimated through successive interactions and in relation to the fit values, is minimal (Ratkowsky, 1983). The value of the F statistic ($p \leq 0.05$) was used as the criterion for fitting the data to the model. The criterion of acceptance of the fitting of the data to the model was based on the highest value of the coefficient of determination (R^2) and in the lowest value of the mean squared residual (MSR).

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

$$ETL = [Cc/(P \times Y \times (i/100) \times (H/100))] \quad \text{(eq. 3)}$$

where *ETL* is the economic threshold level (plants m^{-2}), *Cc* is the control cost (herbicide and tractor application, in dollars ha^{-1}), *P* is the wheat price (dollars kg^{-1} of grains), *Y* is the yield of wheat grains (kg ha^{-1}), *i* is the loss (%) of wheat yield per unit of weed when the population level is close to zero, and *H* is the herbicide efficiency level (%).

Three values were estimated for the variables *Cc*, *Y*, *P*, and *H* of Equation (3). Thus, we considered for control cost (*Cc*) an average price of $ 46.78 ha^{-1} (100 g ha^{-1} of the herbicide iodosulfuron-methyl + 0.3% v/v of the adjuvant sodium lauryl ether sulfate), with the maximum and minimum costs changed by 25% in relation to the average cost. Wheat grain yield (*Y*) was based on the lowest (1,757 kg ha^{-1}), average (2,225 kg ha^{-1}), and higher (2,756 kg ha^{-1}) yield obtained in the State of Rio Grande do Sul in the last 10 years (Conab, 2014). Wheat price (*P*) was estimated from the lowest (US$ 8.46), average (US$ 11.46), and higher (US$ 14.46) wheat price paid per bag of 60 kg in the last 10 years (Agrolink, 2014). The values for herbicide efficiency (*H*) were established in the order of 80, 90, and 100% of control, where 80% is the minimum weed control considered as effective. Intermediate values were used for variables not calculated in the ETL simulations.

RESULTS AND DISCUSSION

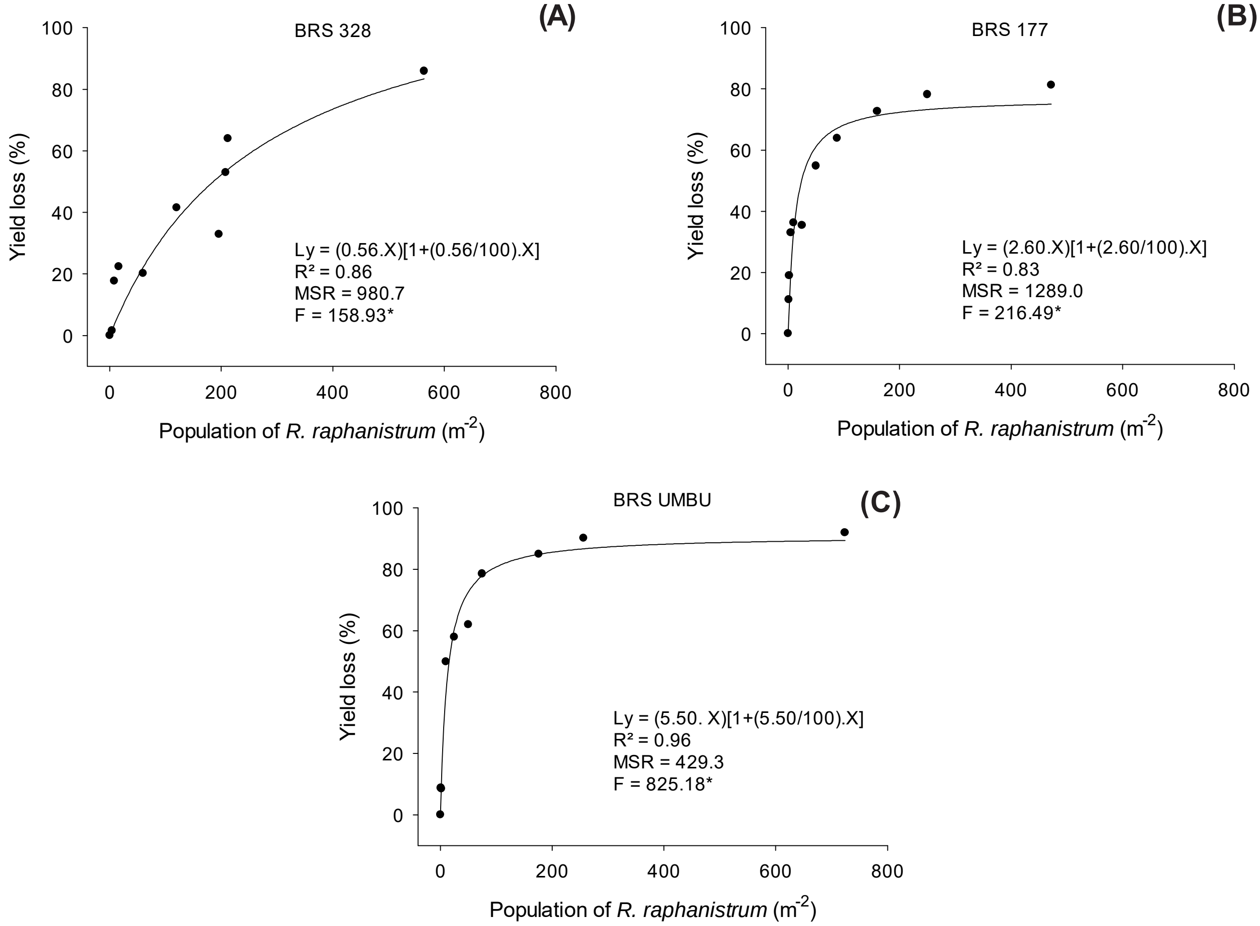
In the estimation of yield loss (Ly), based on the wild radish population at 21 DAE in the three cultivars (Figure 1), the cultivar BRS Umbu presented the best fit to the rectangular hyperbole model (Figure 1C), followed by the cultivars BRS 328 and BRS 177 (Figures 1A, B). In the variable PP, the unit loss *i* showed that for each unit of the weed per square meter, the cultivars BRS 177 and BRS Umbu lost 2.60 and 5.50% in grain yield, respectively, while the cultivar BRS 328 had a loss of only 0.56% (Figure 1 and Table 1). Some cultivars have a differentiated competitive ability in relation to weeds (Galon et al., 2007). Eslami et al. (2006) observed that high densities of wheat populations allowed a higher competitiveness with wild radish.

Regarding the estimation of yield loss based on SDM of wild radish plants at 21 DAE, the cultivar BRS 177 presented the best fit to the rectangular hyperbola model, followed by the cultivars BR Umbu and BRS 328 (Figure 2). The lowest and highest values for the parameter *i* were observed in the cultivars BRS 328 and BRS Umbu, respectively. The increase in weed population reduces wheat dry matter between 45 and 55% (Eslami et al., 2006).

The cultivar BRS 177 presented the best fit to the rectangular hyperbola model when considering the variable soil cover (Figure 3B). The estimated yield losses for the parameter *i* were 0.057, 0.071, and 0.037 for the cultivars BRS 177, BRS Umbu, and BRS 328, respectively (Figure 3).

The estimate of yield loss based on the leaf area of wild radish plants at 21 DAE in the three cultivars presented an R^2 equal to 0.92, adequately fitting to the rectangular hyperbole model. The estimated yield losses for the variable LA were 0.0030, 0.0045, and 0.0009 in the cultivars BRS 177, BRS Umbu, and BRS 328, respectively (Figure 4).

When comparing the competitive ability of wheat cultivars of different vegetative cycles with wild radish, the cultivar BRS 328 (early cycle) presented the lowest values for the parameter *i* and, consequently, a higher competitive ability when compared to the cultivars BRS 177 (medium



R^2: coefficient of determination; MSR: mean squared residual; *Significant at 5% probability.

Figure 1 - Loss of yield (Ly) of the wheat cultivars BRS 328 (A), BRS 177 (B), and BRS Umbu (C) as a function of population levels of wild radish at 21 days after emergence (DAE).

Table 1 - Loss of wheat grain yield as a function of plant population, estimated soil cover, shoot dry matter, and leaf area of wild radish at 21 days after emergence (DAE) in three wheat cultivars

Cultivar	Cycle	Yield loss (%)[1]	R^2	F*	MSR
Plant population					
BRS 328	Early	(0.56. X)[1+(0.56/100).X]	0.86	158.93	980.7
BRS 177	Medium	(2.60. X)[1+(2.60/100).X]	0.83	216.49	1289.0
BRS Umbu	Late	(5.50. X)[1+(5.50/100).X]	0.96	825.18	429.3
Shoot dry matter					
BRS 328	Early	(0.15. X)[1+(0.15/100).X]	0.91	263.90	603.5
BRS 177	Medium	(0.46. X)[1+(0.46/100).X]	0.94	581.32	493.7
BRS Umbu	Late	(0.67. X)[1+(0.67/100).X]	0.93	416.95	840.8
Soil cover					
BRS 328	Early	(0.037. X)[1+(0.037/100).X]	0.78	103.06	1469.7
BRS 177	Medium	(0.057. X)[1+(0.057/100).X]	0.86	261.18	1076.6
BRS Umbu	Late	(0.071. X)[1+(0.071/100).X]	0.86	216.15	1590.7
Shoot leaf area					
BRS 328	Early	(0.0009. X)[1+(0.0009/100).X]	0.92	287.61	555.3
BRS 177	Medium	(0.0030. X)[1+(0.0030/100).X]	0.92	480.35	595.4
BRS Umbu	Late	(0.0045. X)[1+(0.0045/100).X]	0.92	385.70	907.4

[1] Value obtained through the regression model of the rectangular hyperbola (COUSENS, 1985). * Significant at 5% probability. MSR: mean squared residual.

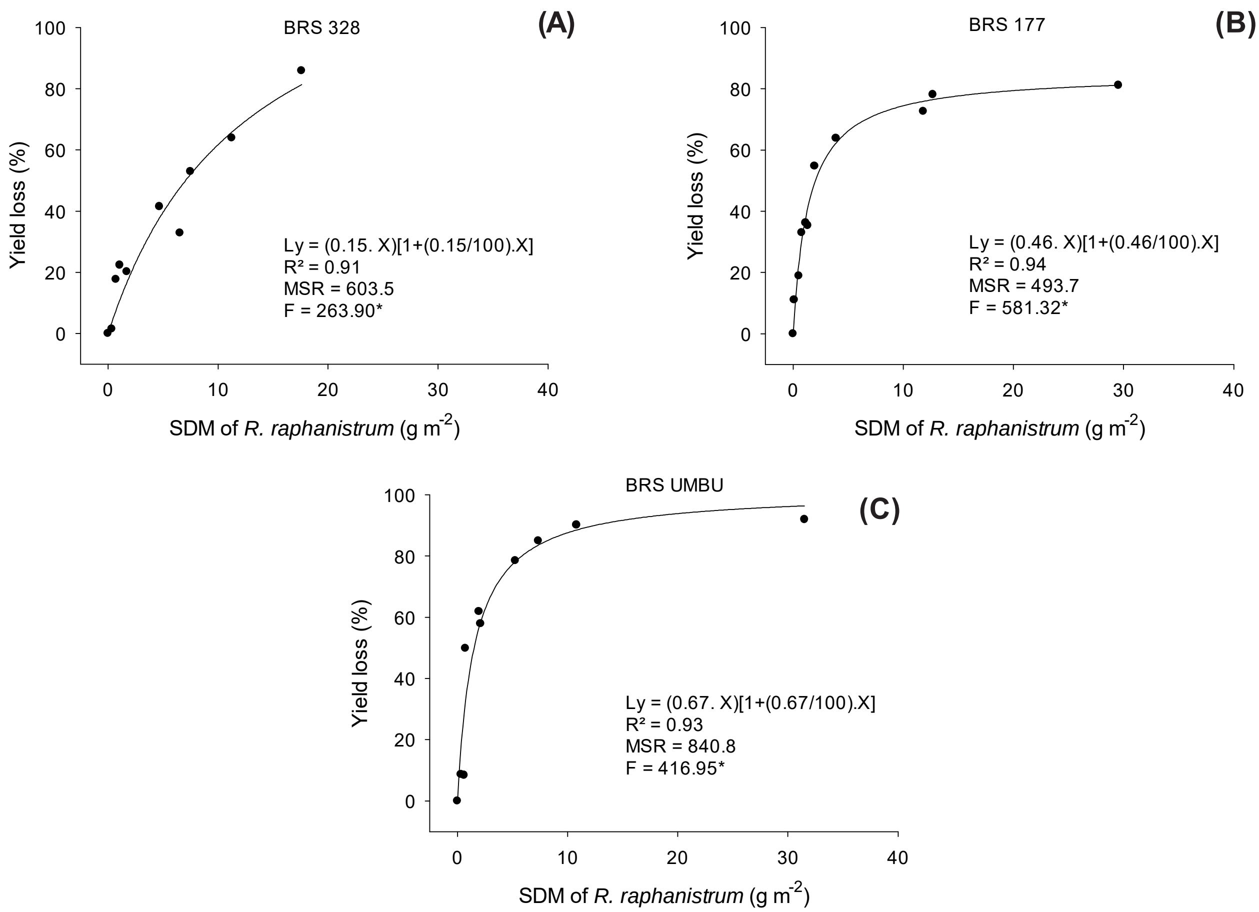
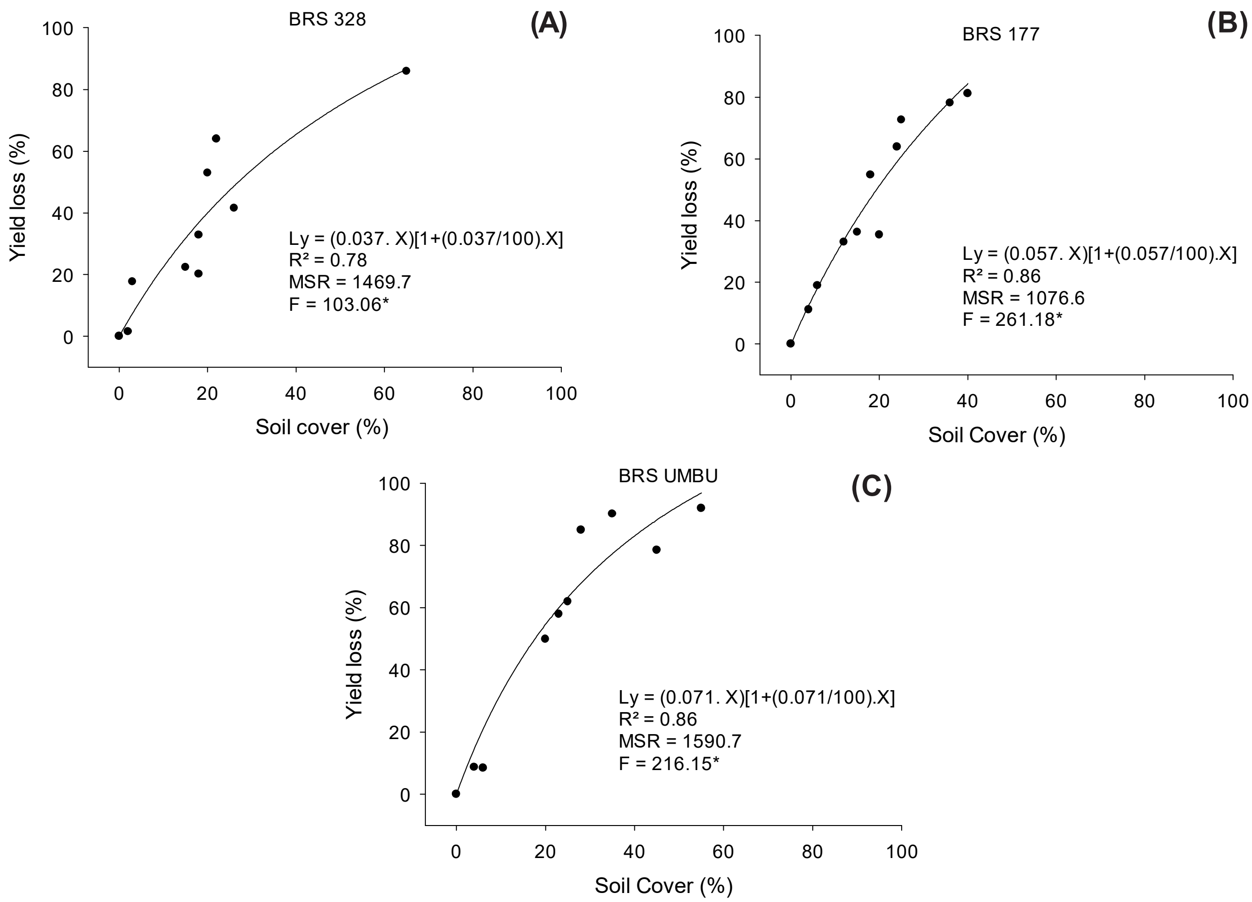


Figure 2 - Loss of yield (Ly) of the wheat cultivars BRS 328 (A), BRS 177 (B), and BRS Umbu (C) as a function of shoot dry matter at 21 days after emergence (DAE).

cycle) and BRS Umbu (late cycle), regardless of the used explanatory variable (Figures 1, 2, 3, and 4 and Table 1). In the average of the four explanatory variables (PP, SDM, SC, and LA), the order in relation to the competitiveness of the cultivars was BRS 328 > BRS 177 > BRS Umbu. The observed differences between the results of cultivars may occur due to the best use of the resources available in the environment. Early-cycle cultivars, such as BRS 328, have a rapid initial development and leaf area accumulation and hence intercept light more easily, reducing the incidence of solar energy in their neighbors and increasing their competitive ability against the presence of weeds (Fleck et al., 2003; Westendorff et al., 2013).

Plants with high rates of emergence and initial growing use of resources of the environment as a priority and in general become more competitive (Gustafson et al., 2004). The differential competitive ability among cultivars of a same cultivated species is a common feature, as observed for rice cultivars (Galon et al., 2007). Lamego et al. (2015) observed that the initial coexistence of the wheat cultivar Fundacep Cristalino is more affected by the presence of plants of the cultivar BRS Guamirim as a simulator of competing plant when compared to wild radish and ryegrass.

The parameter *a* of the rectangular hyperbola model represents the yield loss when weed population is maximum. This parameter allows comparing the maximum yield losses between cultivars of a given crop (Agostinetto et al., 2005). In our study, estimates of the parameter *a* for the weed variables PP, SDM, SC, and LA were overestimated by the model and their values were restricted to 100% (Figures 1, 2, 3, and 4). These results may have been obtained because weed populations were not high enough to estimate the maximum yield loss (Agostinetto et al., 2004). According to Cousens (1991), to obtain a reliable estimate of the parameter a, experiments must have sufficiently high populations, i.e. above those commonly found in the crops. Therefore, as in other studies, a maximum loss restriction was adopted since there is no biological explanation for losses higher than 100% (Askew and Wilcut, 2001; Agostinetto et al., 2004).



R^2: coefficient of determination; MSR: mean squared residual; *Significant at 5% probability.

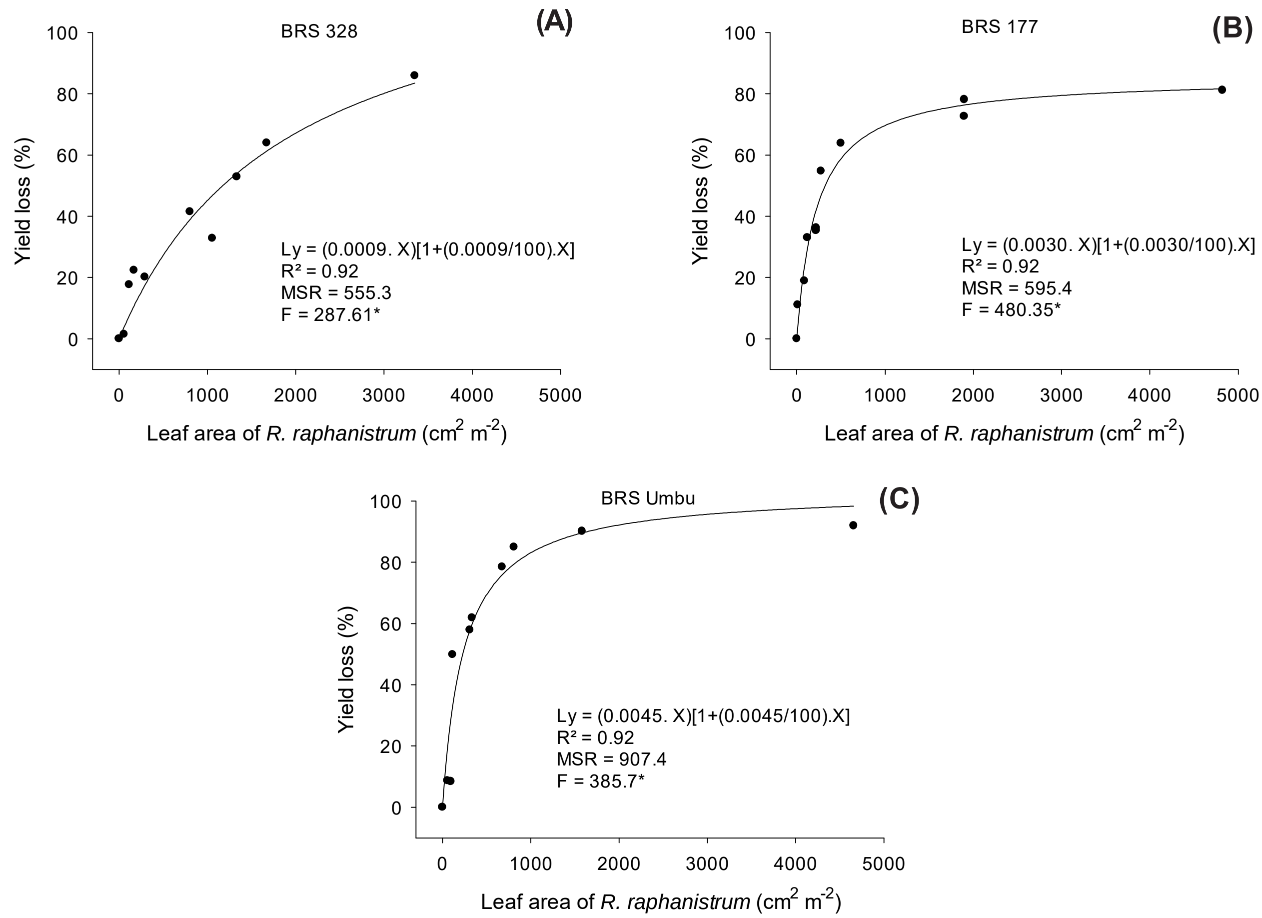
Figure 3 - Loss of yield (Ly) of the wheat cultivars BRS 328 (A), BRS 177 (B), and BRS Umbu (C) as a function of soil cover estimated by the wild radish shoot at 21 days after emergence (DAE).

The comparison between the explanatory variables PP, SDM, SC, and LA showed a good fit for the three studied cultivars, considering the highest average values of R^2 and the lowest average values of MSR (Table 1). However, for estimates of the economic threshold level (ETL), it is recommended that the variables used to determine yield losses be simple, easy to use, and preferably not destructive (Vitta and Fernandez Quintanilla, 1996; Rizzardi and Fleck, 2004). Thus, ETL estimates were made based on PP for the three cultivars since it had a high R^2, a relatively low MSR, and it is a variable that presents advantages over others, such as ease, speed, and low cost for determination.

Each cultivar presented a prediction order, which followed a certain hierarchy (BRS 328, early cycle: LA > SDM > PP > SC; BRS 177, medium cycle: SDM > LA > SC > PP; and BRS Umbu, late cycle: PP > SDM > LA > SC), assuming that the best fit is given by the highest coefficients of determination and lowest mean squared residuals (Figures 1, 2, 3, and 4 and Table 1). Thus, depending on the cultivar, the variable PP can be replaced for the decision-making.

The lowest economic threshold level of wild radish populations for the three wheat cultivars as a function of control cost (Figure 5A), herbicide efficiency (Figure 5B), grain yield (Figure 5C), and wheat price (Figure 5D) were obtained for the cultivar BRS Umbu, with a value of 1.64 plants m^{-2}. Considering the same criteria, ETL was reached with 3.48 and 16.15 wild radish plants m^{-2} in the cultivars BRS 328 and BRS 177, respectively. These results highlight the difference between wheat cultivars in relation to the competitive ability with wild radish plants.

Control cost, herbicide efficiency, grain yield, and the price paid per wheat bag influence ETL. For an increase in control cost of $ 23.39 (from $ 35.08 to $ 58.47), the wild radish population required to reach the ETL increased by approximately 67% for the cultivars BRS 328, BRS 177,



R^2: coefficient of determination; MSR: mean squared residual; *Significant at 5% probability.

Figure 4 - Loss of yield (Ly) of the wheat cultivars BRS 328 (A), BRS 177 (B), and BRS Umbu (C) as a function of the leaf area of wild radish shoot at 21 days after emergence (DAE).

and BRS Umbu (Figure 5A). On the other hand, with a reduction in herbicide efficiency by 20% (from 100% to 80%), the wild radish population required to reach the ETL increased by approximately 25% for the analyzed cultivars (Figure 5B).

For a reduction in grain yield by about 1,000 kg (from 2,756 to 1,758 kg ha^{-1}), the wild radish population required to reach the ETL increased by approximately 57% for the assessed wheat cultivars (Figure 5C). By increasing productivity expectations, the crop should be less influenced by environmental factors, such as the competition with weeds (Agostinetto et al., 2005). With a reduction in the price of wheat grain bag by \$ 6.00 (from \$ 14.46 to \$ 8.46), the wild radish population required to reach the ETL increased by about 71% for all the cultivars (Figure 5D).

Fluctuations between the highest and lowest control costs, herbicide efficiency, grain yield, and price per bag (60 kg) of wheat influenced the ETL in the average of the three cultivars, leading to variations of approximately 67, 57, 25, and 71%, respectively. The cultivars BRS 328, BRS 177, and BRS Umbu in the presence of competition with wild radish in the average of the four variables (control cost, herbicide efficiency, grain yield, and the price paid for wheat) caused an average ETL variation of about 55%.

When assessing the average of the three cultivars and comparing the lowest and highest control cost, a variation of about 67% was observed in the ETL (Figure 5A). A similar result was observed for rice grass when considering the same variable in the average of the cultivars IRGA 417 (short cycle) and BRS Fronteira (medium cycle), in which ETL variation was also of approximately 67% (Galon et al., 2007). For herbicide efficiency, an ETL variation of approximately 25% was verified in the average of the three cultivars when comparing the lowest and highest herbicide control efficiency (Figure 5B). Identical variations for the same variable were observed

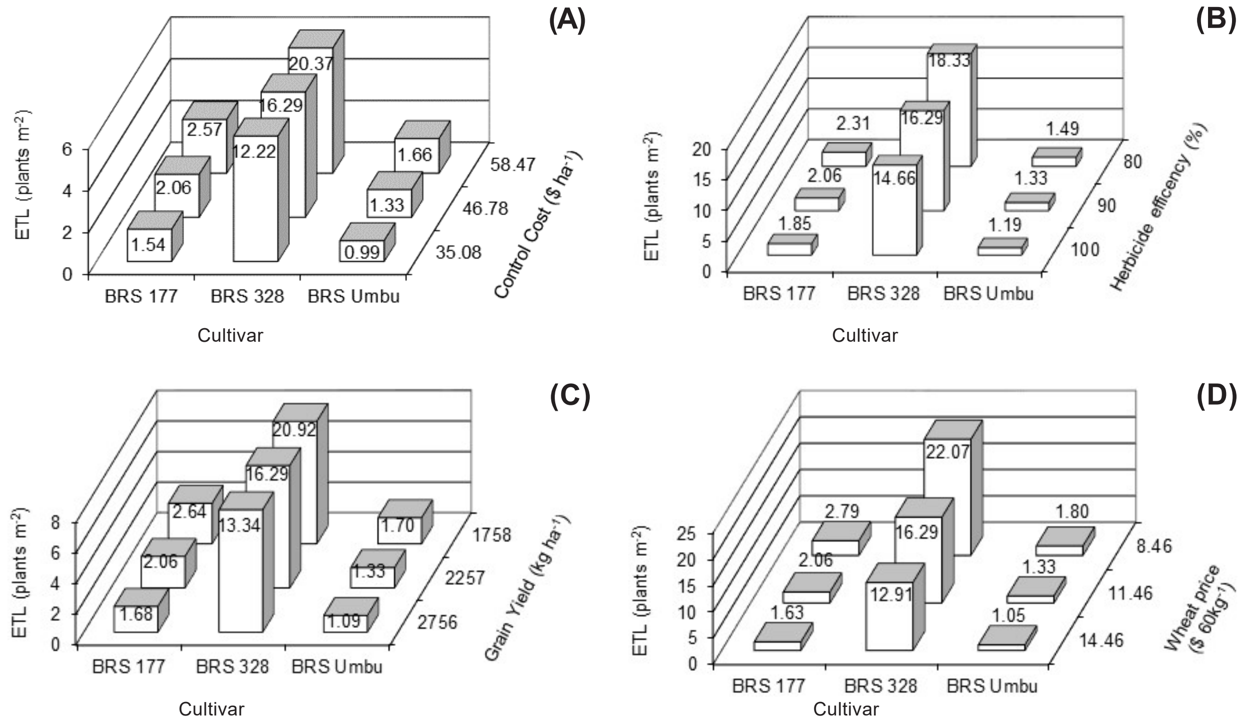


Figure 5 - Economic threshold level (ETL) of wild radish populations for three wheat cultivars as a function of cost control (A), herbicide efficiency (B), grain yield (C), and wheat price (D).

in the ETL of barnyardgrass for the average of the cultivars IRGA 417 and BRS Fronteira (Galon et al., 2007).

An ETL variation of 57% was observed for the variable grain yield when considering the average of the three cultivars and comparing the lowest with the highest yield (Figure 5C). Similarly, a variation of approximately 50% in the average yield of the cultivars IRGA 417 and BRS Fronteira was observed for barnyardgrass (Galon et al., 2007).

The ETL for the variable price paid per wheat bag varied in the average of the three cultivars by approximately 71% when comparing the lowest and highest prices (Figure 5D). For rice cultivation, the ETL for the price paid varied, on average, 135% for the cultivars IRGA 417 and BRS Fronteira (medium cycle) in competition with barnyardgrass (Galon et al., 2007).

The values of ETL varied according to the cultivar cycle, with the highest values for BRS 328 (early) > BRS 177 (medium) > BRS Umbu (late). Early cultivars have a more vigorous initial growth, lower vegetative stage, and hence a shorter period of photoassimilate accumulation to invest in plant structures (Bianchi et al., 2011), thus being more competitive with weeds when compared to those with medium and late cycles. Late cultivars grow slower at the initial stage, but maintain their growth for a longer period, becoming strong competitors in more advanced development stages (Nordby et al., 2007; Bianchi et al., 2011).

The ETLs were calculated based on a single agricultural season and do not include the factor associated with the possible increase of the seed bank in the soil in the following years. The inclusion of the factor seed production in the concept may reduce ETLs, increasing the need to adopt control measures (Coble and Mortensen, 1992). On the other hand, ETLs can represent an important tool to support weed control decision-making since their use is always associated with other cultural practices such as crop rotation, adequate fertilization, recommended crop population and arrangement, and competitive cultivars.

Based on the results, the early-cycle cultivar BRS 328 presents a higher competitive ability when compared to medium-cycle BRS 177 and late-cycle BRS Umbu. Yield losses of wheat grains due to the interference of wild radish can be satisfactorily estimated by the rectangular hyperbola model for the variables plant population, shoot dry matter, soil cover, and leaf area of the weed. ETL values varied as a function of the cultivar cycle, with the highest values for BRS 328 (early)

> BRS 177 (medium) > BRS Umbu (late). The weed wild radish is competitive with wheat crop, requiring at least 1.6 plants m^{-2} for control to be justified.

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