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Morning glory species interference on the development and yield of soybeans

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ABSTRACT: Plants from the genus *ipomoea* are among the most important weeds in Brazil. The objective of this study was to determine the impact of different densities of 2 species of *Ipomoea* (*I. grandifolia* and *I. purpurea*) under different environments (counties of Pato Branco and Renascença, Paraná state, Brazil) on soybean biometric variables, yield components and crop yield loss. Field experiments in 2 distinct places were conducted in a randomized block design, where 1 factor consisted of 8 plant densities (0, 2, 4, 6, 8, 10, 15 and 20 plants·m^{-2}), whereas the other factor consisted of the 2 *Ipomoea* species. Joint analysis of the data was performed considering the factors environment, *Ipomoea* densities and species. The impact of one *Ipomoea* plant·m^{-2} was very high, reaching 26%, on average, of species and environments. The maximum soybean yield loss experienced with the *Ipomoea* density of 20 plants·m^{-2} was close to 80%. The impact of *Ipomoea* density was more important than the species and environment. This result highlights the importance of correct management of plants of these weed species in soybean crop.

Key words: interspecific competition, *Ipomoea* spp., *Glycine max*, biometric variables, yield components.

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INTRODUCTION

Weeds are among the worst limiting factors of the crop yield potential and can decrease 34% of the grain production of several crops, contrasted with 18 and 16% yield loss caused by pests and diseases, respectively (Oerke 2006). The degree of weed interference on the crops depends on the time of weed infestation, on the environment and on characteristics of the weed species (Kiaer et al. 2012; Hugo et al. 2014).

The genus *Ipomoea* is the most numerous on the Convolvulaceae family and comprises around 500 species (McDonald and Mabry 1992). *Ipomoea* plants have a voluble growth habit with flexible and robust stems, which allows them to climb the crop plants, decreasing the availability of light and reducing the mechanical harvest efficiency. The impact of *Ipomoea lacunosa* plants on soybean grain yields may reach 80% (Norsworthy and Oliver 2002). The species *I. purpurea* and *I. grandifolia* infest large crop areas in Brazil on many crop species. They are considered some of the most important species in soybean. The species are differentiated primarily by the size and shape of the leaf blade and the reproductive structures (Moura and Morim 2015). It is believed that the morphological differences between species can directly influence the competitive ability of plants, providing distinct damage on the development of soybean. There is no specific research investigating the competitive ability of the species *I. grandifolia* and *I. purpurea* within the soybean crop.

The environment consists of biotic and abiotic factors, which influence the degree of interference between crops and weeds (Pitelli 1985). The environment directly influences the development of the plants, changing its growth capacity and hence the competitive ability. Environmental conditions favorable to the development of crop plants will make them more competitive, while less favorable conditions for crops encourage the development of weeds (Zimdahl 2004; Radosevich et al. 2007). Cultivated plants were selected mainly by productive potential. Therefore they tend to be more sensitive to environmental variation, while weeds have higher plasticity adaptive to environmental changes (Radosevich et al. 2007).

The classical method to evaluate the yield losses caused by a certain species considers different plant weed density within a fixed crop density (Cousens 1985; Dodamani and Das 2013; Tanveer et al. 2015). For example, soybean yield infested with *Cyperus rotundus* (0-200 pl·m^{-2}) was decreased by 47% (Das et al. 2014), while soybean yield loss can reach 21% due infestation with *Trianthema portulacastrum* (0-200 pl·m^{-2}) (Hazra et al. 2011). *Bidens* spp. infestation (0-150 pl·m^{-2}) can decrease soybean yield by 40% (Rizzardi et al. 2003). The effect of each weed plant on the crop yield is highest under low weed density and it is defined as the parameter *i*. Indeed, the parameter *i* represents the percentage of yield loss caused by each weed, at limited weed densities, and it is used to estimate the weed economic threshold (Das et al. 2014; Trezzi et al. 2015).

The hypothesis is that the species *I. grandifolia* and *I. purpurea* provide differentiated damage on the development and yield of soybean grain when are grown in two different environments. The objective of this study was to determine the impact of different densities of two species of *Ipomoea* (*I. grandifolia* and *I. purpurea*) and different environments (counties of Pato Branco and Renascença, Paraná state, Brazil) on soybean biometric variables, yield components and crop yield loss.

MATERIAL AND METHODS

Two field experiments were conducted during the years 2011/2012 and 2012/2013. The first was held in the county of Pato Branco (lat 26°18′S, long 52°69′O, altitude of 760 m above sea level) and the second in the county of Renascença (lat 26°19′S, long 52°86′O, altitude of 780 m above sea level), both located in the Paraná state, Brazil. The soil type is classified as Distroferric Red Latosol (Oxisol) and its characteristics are shown in Table 1. The climate is classified as humid subtropical (Cfa). Environmental conditions during the experiments are shown in Figure 1.

The experiments followed very similar procedures and are described together. Limited differences between them are highlighted. The experimental design was a randomized block in split plot with three replications. The main plots contained the *Ipomoea* species (*I. grandifolia* and *I. purpurea*), whereas the subplots had the weed densities (0, 2, 4, 6, 8, 10, 15 and 20 plants·m^{-2}). Each experiment consisted of 48 subplots, with size of 2.25 × 4 m (5 soybean rows with 0.45 cm spacing), totalizing 9 m^2 each. For 9 years, the soybean crop was cultivated during the summer. Approximately 20 days before the crop sowing, the weeds were controlled with glyphosate (960 g·ha^{-1}).

Table 1. Soil texture and chemical attributes of Distroferric Red Latosol (Oxisol). Pato Branco, PR, 2011/2012, and Renascença, PR, 2012/2013.

Soil texture			Chemical attributes		
Properties	Pato Branco	Renascença	Properties	Pato Branco	Renascença
	Values (%)			Values*	
Clay	55.7	78.50	OM[1]	49.50	48.25
Sand	3	2.40	P_2O_5[2]	14.32	68.46
Silt	41.3	19.10	K_2O[3]	0.70	0.35
			CEC[4]	17.63	12.76
			pH[5]	5.6	5.10
			H + Al[6]	5.35	6.21

*[1]Organic matter (g·dm^{-3}); [2]Phosphorus (mg·dm^{-3}); [3]Potassium (cmolc·dm^{-3}); [4]Cation exchange capacity; [5]Soil pH; [6]Exchangeable acidity (cmol$_c$·dm^{-3}).

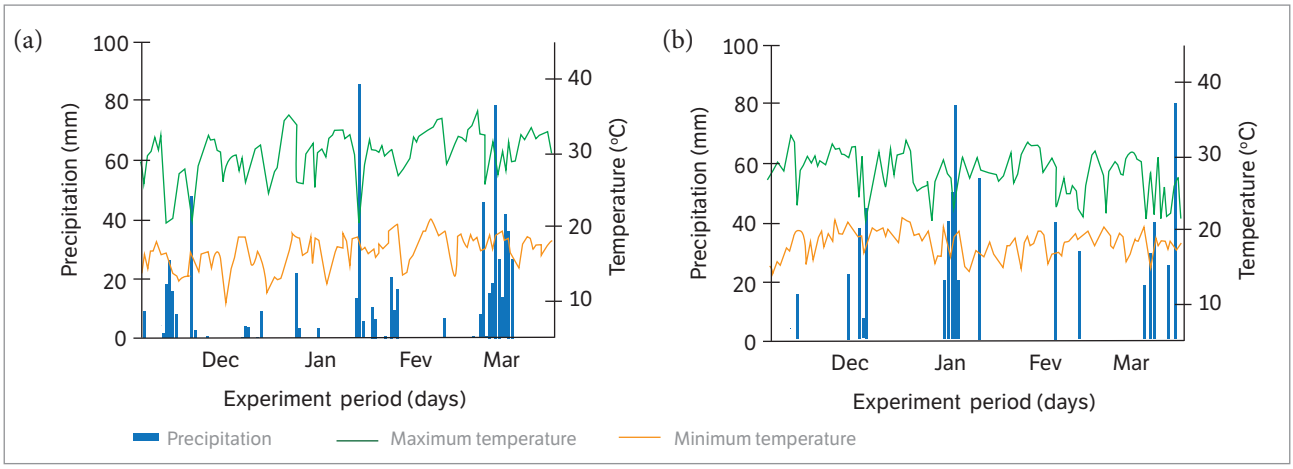

Figure 1. Precipitation, minimum and maximum temperature during periods in which the experiments were conducted in (a) Pato Branco and (b) Renascença. Pato Branco, 2011/2012 and Renascença, 2012/2013.

The first experiment started on 05 November 2011, whereas the second trial started on 15 November 2012. The soybean sowing was carried out mechanically with a density of 289,000 plants·ha^{-1}, using the cultivar BMX Turbo with indeterminate growth habit and maturity group 5.8. The *Ipomoea* seeds were purchased from Agrocosmos Ag Company (São Paulo, Brazil) and multiplied on the field in the years prior to the use. The dormancy of *Ipomoea grandifolia* seeds was overcome according to the method described by Pazuch et al. (2015). Afterwards, the *Ipomoea* seeds were sown manually on the field using 3 times the amount of seed needed for each density and excess seedlings were removed approximately 10 days after their emergence.

During the crop development, the plants from other weed species were removed manually. Soybean diseases were controlled through three applications of fungicides azoxystrobin + cyproconazole (60 + 24 g·ha^{-1}). Pests were controlled on 3 occasions using the insecticides profenofos + lufenuron (75 + 7.5 g·ha^{-1}), thiamethoxam + lambda-cyhalothrin (28 + 21 g·ha^{-1}) and acephate (750 g·ha^{-1}). To facilitate the harvest of *Ipomoea* and soybean crop, the herbicide paraquat (600 g·ha^{-1}) was sprayed at the end of the plant life cycle.

When the soybean plants were at the R_5 growth stage, it was collected 10 plants randomly distributed in the plot to evaluate the following biometric variables: leaf area (LA), fresh leaf mass (FLM) and fresh stem mass (FSM). The LA was determined with an integrator (Licor model LI-3100C). The FLM and FSM were determined in a scale immediately after plant sampling. The data were expressed in unit per plant.

During the soybean physiological maturity, 10 plants were collected randomly to determine: plant height (PHT); first pod height (FPH); and the yield components: pods per plant (PPP) and beans per pod (BPP). In each sub-plot, all the plants from the 2.7 m^2 were hand harvested to determine the grain yield. The grain yield was corrected to →

13% moisture. The soybean grain mass was determined in 400 seeds from the bulk harvested and converted to 1,000-grain mass (TGM). The soybean grain yield obtained in each subplot was converted to percentage yield loss (YL) in relation to weed-free treatments.

The data were submitted to the analysis of variance using the statistical program SOC - NTIA (Embrapa 1997). When no significant ($p \leq 0.05$) environment (place of the experiment) effect was detected, it was conducted a joint analysis of the experiments. The relationship between the *Ipomoea* density and the other dependent variables was explained using nonlinear sigmoidal model (Eq. 1) and 3-parameter logistic models (Eq. 2). The relation between the weed density and soybean grain yield loss was adjusted using a hyperbolic model (Eq. 3).

$$Y = A / [1 + \exp - (X - D_{50} / B)] \quad (1)$$

$$Y = A / [1 + (X / D_{50}) \wedge B] \quad (2)$$

$$YL = (A \times X) / (D_{50} + X) \quad (3)$$

where: Y is the dependent variable; X represents *Ipomoea* density; A means maximum asymptote of the curve; B is the curve slope; D_{50} represents weed density that reduces 50% of the dependent variable; YL is the soybean yield loss (%).

The ratio between the parameters A and D_{50} in Eq. 3 results in the parameter "i", which represents the yield loss when the weed density is 1 plant·m^{-2} (Cousens 1985).

RESULTS AND DISCUSSION

The analysis of variance indicated significant interaction for the following variables: place × species × densities for FPH and PPP; place × density for LA, FLM and FSM; species × density for LA and FSM; and place × species to YL. There were significant simple effects for density to PHT, TGM, BPP and YL; species to PHT; and place for PHT, TGM, BPP and YL.

Biometric variables

The soybean PHT decreased in response to increase of *Ipomoea* density (Figure 2). On the experiment located at Pato Branco, the soybean PHT was 13% higher than at Renascença (Table 2). Interference with *I. grandifolia* resulted in soybean PHT approximately 5% lower compared to *I. purpurea* (Table 2).

Interference with *I. purpurea* decreased LA and FSM at a higher magnitude than the observed with *I. grandifolia* (Figures 3a,b). Thus, lower densities of *I. purpurea* than *I. grandifolia* were required for 50% reduction of these variables (D_{50}) (Table 3). Indeed, the D_{50} for the variables LA and FSM measured on *I. purpurea* were 17 and 42 plants·m^{-2}, whereas for *I. grandifolia*, 89 and 65 plants·m^{-2}, respectively.

On the experiment located in Renascença, the *Ipomoea* plants had a greater impact on the variables LA and FLM, compared to the data from the experiment in Pato Branco (Figures 4a,b,c). Again, the D_{50} values reflected these results (Table 3).

There was density-dependent plastic response of the weed species on the soybean crop. For instance, FPH increased in direct proportion to the weed density (Figure 5). However, the impact of the weed species was also location-dependent. →

Table 2. Soybean plant height as affected by the interference of 2 *Ipomoea* species on experiments conducted in Pato Branco and Renascença. Pato Branco, 2011/2012, and Renascença, 2012/2013.

Environments	Soybean plant height (cm) Species		
	I. purpurea	*I. grandifolia*	Average
Pato Branco	76.52	71.30	73.9 a*
Renascença	64.63	63.19	63.9 b
Average	70.6 a*	67.2 b	

*Means with the same letter do not differ by the Tukey test ($p \leq 0.05$). Data represent the average of all *Ipomoea* densities.

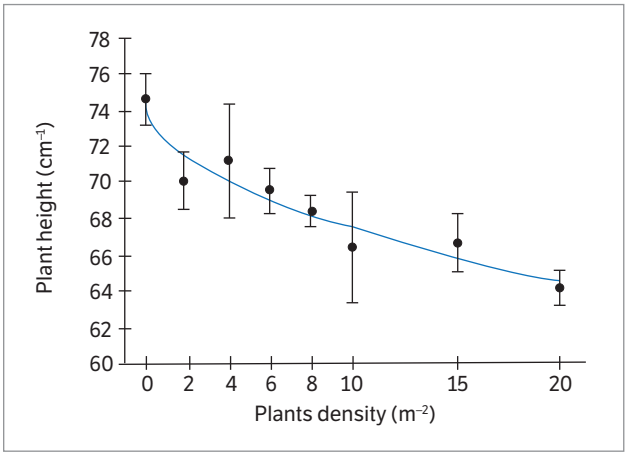

Figure 2. Plant height of the soybean plants cultivar BMX Turbo assessed at harvest time as affected by different Ipomoea densities. Data averaged across *Ipomoea grandifolia* and *I. purpurea* species as well as the environments: Pato Branco, 2011/2012, and Renascença, 2012/2013. Each dot corresponds to the average of 3 repetitions and the bars represent its standard error. Parameters are shown on Table 3.

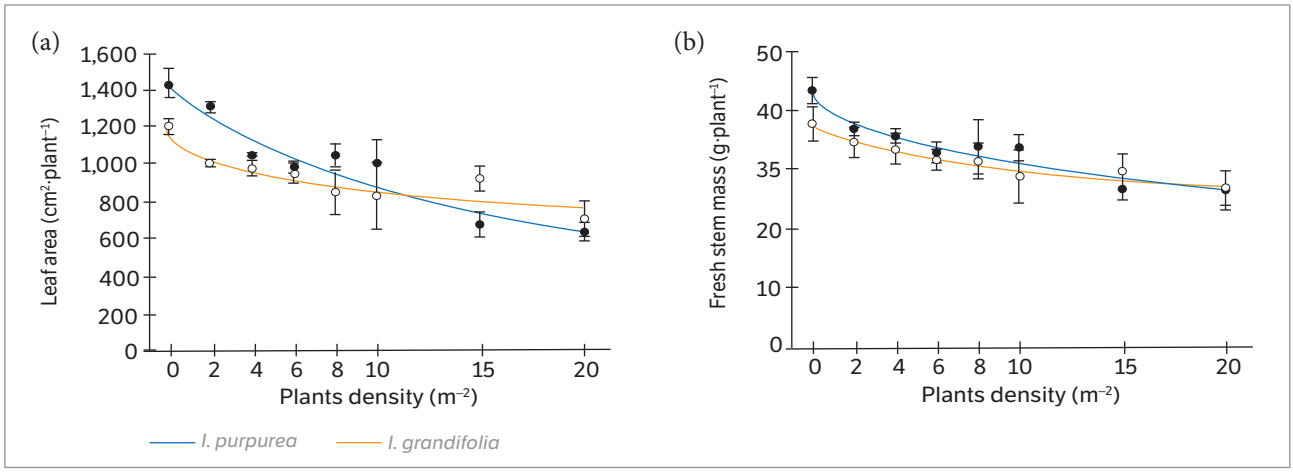

Figure 3. (a) Leaf area and (b) fresh stem mass in soybean plants cultivar BMX Turbo under densities of *Ipomoea purpurea* and *I. grandifolia* in 2 environments: Pato Branco, 2011/2012, and Renascença, 2012/2013. Each dot corresponds to the average of 3 repetitions and the bars represent its standard error. Parameters are shown on Table 3.

Table 3. Parameters of the equation, coefficient of determination, mean square error and probability of the equation for the variables plant height, leaf area, fresh leaf mass, fresh stem mass and first pod height of soybean plants. Pato Branco, 2011/2012, and Renascença, 2012/2013.

Variable	Treatments	Parameters			R^2	MSE	p
		A	B	D_{50}			
PHT		74.43 (0.99)**	0.55 (0.14)**	604.54 (525.44)ns	0.90	1.02	< 0.01
LA	*I. purpurea*[1]	1,422.76 (84.27)**	0.97 (0.24)**	16.91 (3.22)**	0.89	7,714.77	< 0.01
	I. grandifolia[1]	1,199.64 (62.85)**	0.50 (0.18)*	65.33 (43.78)ns	0.81	3,992.08	< 0.01
LA	Pato Branco[1]	1,464.86 (64.83)**	2.10 (0.83)*	25.02 (4.23)**	0.80	9,405.11	< 0.01
	Renascença[1]	1,132.78 (64.27)**	0.31 (0.12)*	6.94 (3.18)ns	0.91	4,132.06	< 0.01
FLM	Pato Branco[1]	26.87 (1.90)**	2.06 (1.26)ns	24.76 (6.51)*	0.60	7.94	0.04
	Renascença[1]	24.19 (1.35)**	0.29 (0.11)ns	7.21 (3.52)ns	0.91	1.82	< 0.01
FSM	*I. purpurea*[1]	43.49 (1.75)**	0.67 (0.16)**	41.82 (13.42)*	0.90	3.15	< 0.01
	I. grandifolia[1]	38.26 (0.86)**	0.63 (0.12)**	88.70 (30.57)*	0.94	0.77	< 0.01
FSM	Pato Branco[1]	46.16 (1.35)**	2.26 (1.28)ns	36.47 (13.80)*	0.67	4.74	0.02
	Renascença[1]	33.30 (1.73)**	0.20 (0.11)ns	40.29 (44.75)ns	0.89	3.01	< 0.01
FPH	Pato Branco: *I. purpurea*[2]	23.58 (1.09)**	5.65 (2.86)ns	−6.62 (3.36)ns	0.77	0.94	0.01
	Pato Branco: *I. grandifolia*[2]	29.32 (3.23)**	9.93 (4.33)ns	−4.33 (1.56)*	0.90	0.98	< 0.01
	Renascença: *I. purpurea*[2]	27.57 (1.02)**	8.74 (1.68)**	−5.64 (0.84)**	0.97	0.18	< 0.01
	Renascença: *I. grandofolia*[2]	25.55 (0.46)**	5.77 (0.85)**	−4.89 (0.77)**	0.98	0.15	< 0.01

[1]Three-parameter logistic model; [2]Three-parameter sigmoidal model; The values in parentheses indicate the standard error of the parameter estimate; *p ≤ 0.05; **p ≤ 0.01; nsNon-significant. A = Maximum equation asymptote; B = curve slope; D_{50} = Density needed for 50% reduction of the analyzed variable; R^2 = Coefficient of determination; MSE = Mean square error; p = Probability; PHT = Plant height; LA = Leaf area; FLM = Fresh leaf mass; FSM = Fresh stem mass; FPH = First pod height.

Whereas in Pato Branco the impact of *I. grandifolia* density on FPH was higher than the observed for *I. purpurea* densities in Renascença, the differences between species *Ipomoea* were very limited (Figure 5).

The soybean biometric variables LA, FLM and FSM were inversely related to the density of *Ipomoea* plants, whereas FPH increased proportionally to the *Ipomoea* density. It is reasonable to speculate that the coexistence between *Ipomoea* and soybean plants throughout their life cycle may trigger physiological processes that will result in shoot development. For instance, the "shade avoidance" syndrome can increase the FPH in response to the decrease in the proportion of red light (R) in relation to the far-red light (FR) caused by the increased density

of the weed population (Ruberti et al. 2012; Vidal et al. 2012; Gundel et al. 2014).

Overall, *I. purpurea* plants had a greater impact on soybean than *I. grandifolia* plants. The biometric variables most affected by that weed species were LA and FSM. Also, the FPH in soybean plants was higher in the presence of *I. grandifolia* than *I. purpurea*. This result is probably a consequence of differences on morphological and physiological characteristics between *I. grandifolia* and *I. purpurea* plants, specially the higher leaf area of *I. purpurea* plants in relation to *I. grandifolia* plants (Lorenzi 2006; Moura and Morim 2015).

The weed-crop interference would reduce the availability of water, nutrients and light. The soil chemical analysis from the experimental sites document medium to high levels of nutrients (Tedesco et al. 2004) on both environments (Pato Branco and Renascença) (Table 1), suggesting that the productivity differences between environments are not related to soil fertility. Thus, rainfall distribution and intensity and air temperatures (Figure 1) constitute the main differences between both experiments. Compared to Pato Branco, the experiment in Renascença had greater cumulative rainfall during the soybean development cycle. However, there was better rainfall distribution in Pato Branco than in Renascença (Figure 1). Environmental conditions favorable to the development of the crop increase the competitive ability of the plants in relation to the weeds. Nevertheless, more competitive weed species are expected under unfavorable environmental conditions (Radosevich et al. 2007). It is possible to speculate that the less favorable conditions for the development of soybean plants in Renascença reflected in lower development of the crop in this environment and increased competitive ability of the weeds, when contrasted to Pato Branco conditions.

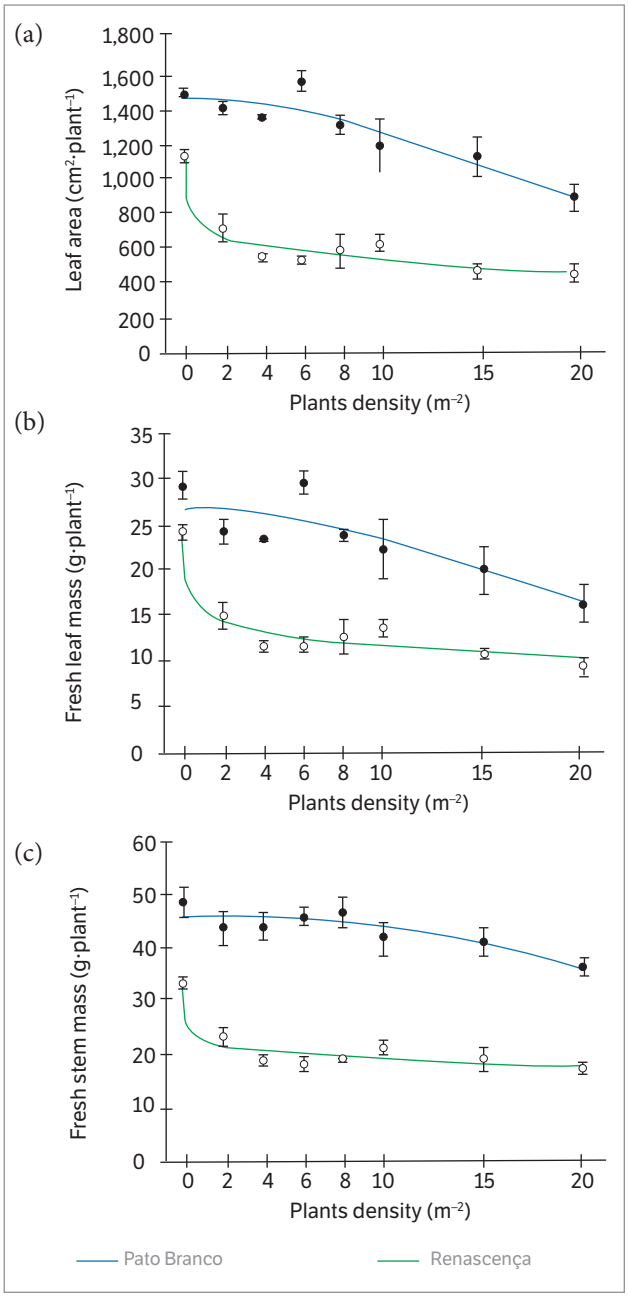

Figure 4. (a) Leaf area, (b) fresh leaf mass and (c) the fresh stem mass in soybean plants, cultivar BMX Turbo under *Ipomoea* densities (average of *Ipomoea grandifolia* and *I. purpurea*) in Pato Branco and Renascença environments. Pato Branco, 2011/2012, and Renascença, 2012/2013. Each dot corresponds to the average of 3 repetitions and the bars represent its standard error. Parameters are shown on Table 3.

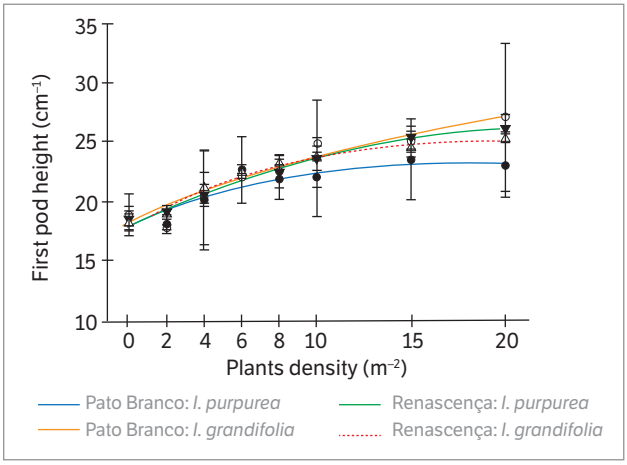

Figure 5. The soybean first pod height in response to densities of *Ipomoea purpurea* and *I. grandifolia* in Pato Branco and Renascença environments. Pato Branco, 2011/2012, and Renascença, 2012/2013. Each dot corresponds to the average of 3 repetitions and the bars represent its standard error. Parameters are shown on Table 3.

Yield components and yield losses

The number of PPP responded in inverse proportion to the *Ipomoea* plant density. Nonetheless, both the place of the experiment and the *Ipomoea* species had an impact on the PPP (Figure 6a and Table 4). In Renascença, the differences between *I. grandifolia* and *I. purpurea* were limited, whereas in Pato Branco, *I. purpurea* plant density had a greater impact on the PPP than *I. grandifolia* density (Figure 6a and Table 4).

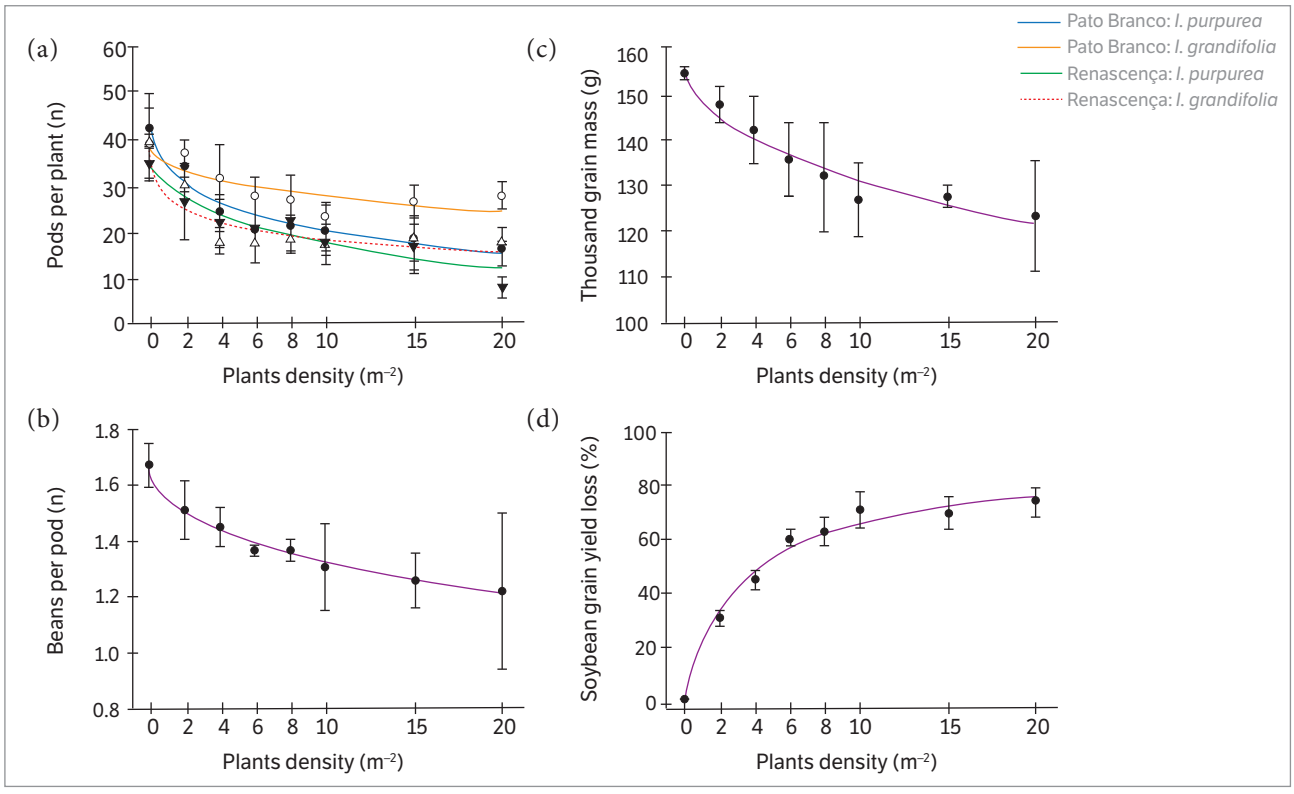

Figure 6. Impact of (a) plant density (either for *Ipomoea grandifolia* and *I. purpurea* and in Pato Branco and Renascença) on the number of pods per plant; Impact of weed density (averaged for *I. grandifolia* and *I. purpurea* and 2 places) on (b) number of beans per pod; (c) 1,000-grain mass; (d) Soybean grain yield loss. Pato Branco, 2011/2012, and Renascença, 2012/2013. Each dot corresponds to the average of 3 repetitions and the bars represent its standard error. Parameters are shown on Tables 4,6.

Table 4. Parameters of the equation, the coefficient of determination (R^2), mean square error (MSE) and probability (p) of the equation for the variables pods per plant, beans per pod and thousand grain mass. Pato Branco, 2011/2012 and Renascença, 2012/2013.

Variable	Environment and weed species	Equation parameters			R^2	MSE	p
		A	B	D_{50}			
PPP[1]	Pato Branco: *I. purpurea*	42.99 (2.32)[3]/**	0.64 (0.13)**	8.45 (1.87)**	0.93	5.41	< 0.01
	Pato Branco: *I. grandifolia*	39.86 (3.21)**	0.51 (0.26)[ns]	51,15 (44.77)[ns]	0.65	10.40	0.03
	Renascença: *I. purpurea*	34.56 (2.85)**	0.87 (0.25)*	10.54 (2.80)*	0.86	8.40	< 0.01
	Renascença: *I. grandofolia*	39.89 (3.65)**	0.42 (0.20)[ns]	6.94 (3.88)[ns]	0.80	13.31	< 0.01
BPP[1]		1.67 (0.01)**	0.53 (0.04)**	124.55 (21.97)**	0.99	0.0002	< 0.01
TGM[1]		156.07 (2.75)**	0.59 (0.11)**	170,27 (77.25)[ns]	0.94	7.81	< 0.01

[1]Three-parameter logistics; [2]D_{50} (density needed for 50% reduction of the analyzed variable); [3]Values in parentheses indicate the standard error of the parameter estimate; *p ≤ 0.05; **p ≤ 0.01; [ns]Non-significant. PPP = Pods per plant; BPP = Beans per pod; TGM = 1,000-grain mass; A = Maximum equation asymptote; B = curve slope.

Ipomoea density, at 20 plants·m^{-2}, decreased 27% the number of BPP and reduced 21% the TGM (Figures 6b,c). However, the differences in the number of BPP and TGM were dependent on the locations of the experiments (Table 5). These variables were, respectively, 29 and 34% smaller in Renascença, when compared to Pato Branco (Table 5).

On the experiment carried out at Pato Branco, the yield component most important to explain the crop yield was PPP (Figure 6). Probably, the contributing factors that explain this result is the limited reduction of LA in this experimental site (Figure 4a) and weed species (Figure 3a). Also, limited reduction of FLM and FSM (Figures 4b,c) in this experiment may explain, in part, the results. Weed competition affects FLM, FSM and branching in dicotyledonous plants (Silva et al. 2014). Reduced branch numbers can decrease the number of flowers per plant, thus decreasing the PPP. In other studies, PPP is the crop yield component most affected by the interference among plants (Green-Tracewicz et al. 2011).

The impact of weed density on some variables measured at soybean plant maturity was not homogeneous. Indeed, the D_{50} value observed for PHT, BPP and TGM was high (Tables 2,3), suggesting that weed density has limited impact on these variables. However, for other variables such as LA, FLM, FSM and PPP, the D_{50} values were very low, which imply that interference of *Ipomoea* strongly impact them.

The crop YL was directly proportional to *Ipomoea* plant density, reaching about 80% at the maximum weed density tested (Figure 6d). For the variable YL, the D_{50} (Table 6) averaged for the 2 weed species and 2 places was only 3.45 plants·m^{-2}. The critical level of damage (parameter "i") estimated with the hyperbolic equation was approximately 26, indicating that each plant of either *I. purpurea* or *I. grandifolia* was able to reduce the soybean productivity by 26%.

The place by species interaction (Table 7) indicates that *I. purpurea* was more competitive in the experiment located in Pato Branco than in Renascença, whereas in Renascença, soybean YL caused by both weed species were not different from each other.

As was previously speculated it is possible that the less favorable conditions for the development of the soybean plants in Renascença reflected in lower development of the crop in this environment and increased the competitive ability of the weeds, when contrasted to Pato Branco conditions. As a consequence, there was a greater reduction on the yield components and grain yield loss in Renascença than in Pato Branco (Figure 6a and Tables 5,7).

The relationship between YL and *Ipomoea* plant density followed the classical hyperbolic model (Figure 6d) (Cousens 1985). The maximum YL documented in this research was in accordance to the observed in other studies. For instance, *I. lacunosa*, at the density of 62 plants·m^{-2}, reduced 80% the soybean grain yield (Norsworthy and Oliver 2002).

Overall *Ipomoea* species and experimental sites, the impact of each plant on the soybean grain yield (parameter "i") was 26% (Table 6). This value is considered very high compared to other weed species in soybean, such as *Cyperus rotundus*, with i = 1.0 (Das et al. 2014) and *Conyza bonariensis* with i = 0.97% (Trezzi et al. 2015). At limited weed densities, the impact of each weed on the crop yield is additive and proportional to the number →

Table 5. Number of beans per pod and soybean grain mass evaluated on 2 environments. The data represent the average of all densities and for *Ipomoea grandifolia* and *I. purpurea* species. Pato Branco, 2011/2012, and Renascença, 2012/2013.

Environments	Beans per pod		Seed mass (g·1,000 seeds^{-1})	
Pato Branco	1.63	a*	165.08	a
Renascença	1.16	b	107.93	b

*Means followed by the same letter in the column do not differ by the Tukey test ($p \leq 0.05$).

Table 6. Parameters of the equation to determine the impact of *Ipomoea* densities and the soybean yield. The data represent the average of all densities for *I. grandifolia* and *I. purpurea* species as well as Pato Branco and Renascença environments. Pato Branco, 2011/2012, and Renascença, 2012/2013.

	Equation parameters*			R^2	p
	A	D_{50}	i		
Soybean yield loss (%)	89.23	3.45	25.86	98.47	< 0.01

*Hyperbolic equation $Y = (A \times D) / (D_{50} + D)$ based on data converted to percentage yield loss in relation to weed-free treatments. A = Maximum equation asymptote; D = weed density (independent variable); D_{50} = Density where 50% of the yield loss occurs; $i = A / D_{50}$ = Percentual impact of each weed on the crop yield at the density of 1 plant m^{-2}; R^2 = Coefficient of determination; p = Probability.

Table 7. Soybean yield loss caused by the interference of 2 *Ipomoea* species and evaluated on 2 environments. The data represent the average of all *Ipomoea* densities. Pato Branco, 2011/2012, and Renascença, 2012/2013.

Species	Soybean yield loss (%)			
	Pato Branco		Renascença	
I. purpurea	51.49	a*	57.76	a
I. grandifolia	38.72	b	58.82	a

*Means with the same letter in the column do not differ by the Tukey test ($p \leq 0.05$).

of weeds per area. However, at high weed densities, resource limitation makes the crop yield independent of plant population (Radosevich et al. 2007). The difference between the estimated value of the maximum YL (Table 6 parameter) exceeds the value of maximum loss depicted in Figure 6d, due to the fact that the densities used in the research were not sufficient to explain the maximum YL observed (Trezzi et al. 2015).

The results demonstrate that *Ipomoea* weed density is the most important factor affecting the biometric variables, yield components and soybean yield. In contrast, the crop environment (place of the experiment) and *Ipomoea* species impacted these variables in a lower degree of magnitude.

This research highlights the importance of appropriate control of plants from *Ipomoea* species, especially on modern soybean cultivars. Weed management practices to prevent the emergence of plants of these species in the off-season periods are also very important. Winter plants such as rye (*Secale cereale* L.) and radish (*Raphanus sativus* L.) can reduce the emergence of *I. grandifolia* (Bittencourt et al. 2013). Crop rotation allows the use of herbicides with an alternative mechanism of action, avoiding the evolution of herbicide resistant weeds.

CONCLUSION

The impact of the *Ipomoea* densities is more important than the environment and species. One *Ipomoea* plant·m^{-2} can reduce the soybean yield by approximately 26%. The impact in soybean development is more intensive in Renascença than Pato Branco environment. The negative impact of *Ipomoea purpurea* on soybean growth and yield is greater than *Ipomoea grandifolia*.

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