




Agronomic performance of soybeans with the presence of volunteer RR corn¹

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ABSTRACT

The presence of volunteer corn plants among soybeans, both resistant to glyphosate, has increased in recent years in Brazil. The objective of this study was to quantify the impact on the agronomic performance in RR soybeans by the presence of volunteer RR corn in field conditions. The experiment was conducted in Tiradentes do Sul (RS), 2018/19 harvest. The experimental design used in the experiment was randomized blocks with four replications: control in the clean (only soybean) and eight densities of volunteer corn in soybean crop with 1, 2, 3, 4, 5, 6, 7 and 8 corn plants m⁻². In the physiological maturation of soybean, plant height, number of lateral branches, stem diameter, height of insertion of the first pod, number of pods plant⁻¹ and grain yield were evaluated. All variables analyzed were negatively affected by the increase in the density of volunteer corn infestation, where the variables grain yield and number of pods plant⁻¹ were the most affected, 63% and 81%, respectively. The presence of volunteer corn has a high capacity to reduce the yield of soybeans in the proportion of 500 kg ha⁻¹ plant⁻¹ of corn m⁻², and even at low densities, it needs control.

Keywords: Competition; *Glycine max*; Weed; *Zea mays*.

INTRODUCTION

A widely used cultivation alternative in Brazil, especially in intensive systems of commercial areas, is the succession of off-season soybeans after corn cultivation. However, with the emergence of technologies such as the use of Roundup Ready (RR) grains, the succession of crops results in a new problem for planting systems, such as weeds (Aguiar *et al.*, 2017). For example, the presence of volunteer RR corn plants in coexistence with soybean has been increasing since the introduction of glyphosate-resistant corn varieties on the market (Braz *et al.*, 2019).

Several weeds are commonly found in soybean crops in Brazil and their levels of economic damage are known. However, plants that were not considered harmful to crops now have this characteristic, as in the case of volunteer corn with RR technology that ends up competing with soybean in succession and has become a problem for post-emergence control in RR soy (Marquardt *et al.*, 2012).

The so-called volunteer corn originates from the germination of grains lost by mechanized harvesting that becomes a weed in the soybean crop competing for water, light, nutrients and CO₂ and cannot be eliminated by the application of the glyphosate herbicide, since it ends up being resistant to this type of herbicide.

The potential for volunteer corn to cause damage to soybean crops is high when compared to other weeds. For example, *Ipomoea grandifolia*, *Euphorbia heterophylla* or *Brachiaria plantaginea* plants in the density of one plant m⁻² have low potential for loss of soybean yield (Voll *et al.*, 2002). On the other hand, the high density of *Raphanus sativus* (55 plants m⁻²), in addition to the reduction of plant height and branch length, caused losses in soybean yield by 3 to 15% (Bianchi *et al.*, 2011). Volunteer corn plants have great capacity for competition for growth and development above the canopy of soybean plants (Page *et al.*, 2010), and can also cause metabolic changes due to the occurrence of oxidative stress in soybean plants (Piasecki *et al.*, 2018a),

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resulting in a reduction in plant growth and loss of grain yield. As a weed, volunteer corn reduces soybean yield by 10 to 22% plant⁻¹ m⁻² on average (Aguiar *et al.*, 2017). However, this can be over 40% with high densities (Marquardt *et al.*, 2012; Alms *et al.*, 2016; Aguiar *et al.*, 2017; Piasecki *et al.*, 2018b). Thus, the continuous use of RR cultivars tends to reduce crop yields, especially for off-season soybean in succession to corn. According to Piasecki *et al.* (2018b), the incorrect handling of herbicides and mechanical losses due to the previous harvest are the two main factors that are related to the presence of volunteer corn among soybean crops.

According to Braz *et al.* (2019), the level of volunteer corn interference as a weed in soybean crops depends on several factors such as infestation density, location, length of stay and crop stage. Also, there are few site studies, specifically the response to interference imposed by corn plants due to the sowing of soybean cultivars with different growth habits, development cycle, volunteer corn infestation densities and type of specific local climates (Nordby *et al.*, 2007; Braz *et al.* 2019). There are studies in the literature that assess the interference of volunteer corn in soybeans, but few verify the interference in conditions of local agroecosystems, short-cycle cultivars and low densities of volunteer corn. The hypothesis of this study is that, due to the competition capacity, low densities of volunteer corn plants are capable of promoting loss in the yield in soybean culture in the mesoclimate of the Northwest region of Rio Grande do Sul. Thus, the objective of this study was to quantify the impact on agronomic performance caused by the presence of volunteer RR corn in RR soybean under field conditions.

MATERIAL AND METHODS

The field experiment, in a crop area, was carried out in the 2018/19 harvest in the locality of Linha Formosa, in Tiradentes do Sul, State of Rio Grande do Sul (RS), latitude 27°23'51" south and longitude 54°05'02" west, 407 meters above sea level. According to the Köppen classification, the climate in the region where the experiment was conducted is humid subtropical (Cfa). The soil at the beginning of the experiment was evaluated for its physical-chemical composition (Table 1). The soil fertility levels were corrected following the recommendations of the CQFS RS/SC (2016).

The experiment was carried out in random blocks with four replications of the following treatments: Control - area in the clear (RR soybean only) and eight densities of RR corn in the soybean crop with 1, 2, 3, 4, 5, 6, 7 and 8 corn plants m⁻². Each experimental plot contained 16 lines of 6 meters in length with a spacing between lines of 45 cm, totaling 43.2 m⁻². The useful area considered for each plot was the eight central lines (3.6 m) with 3.0 m in length (10.8 m⁻²). Before the installation of the experiment, a dose of 2.5 L ha⁻¹ of glyphosate (356 g L⁻¹) and another subsequently after five days of 2.0 L ha⁻¹ of paraquat dichloride (200 g L⁻¹) were applied to total desiccation of the plants in the experimental area.

The sowing of the soybeans was carried out in succession to early corn crop on the same day as the application of paraquat dichloride. Before sowing, the seeds were treated with *Bradyrhizobium japonicum*, with peat-type inoculant, using 0.5 kg of inoculant for every 60 kg of soybean seeds. The soybean cultivar resistant to glyphosate (NA 5909 RG) of the undetermined-growth type and semi-early cycle, was sown with a mechanized seeder on the December 1st 2018, with a density of 292,000 plants ha⁻¹. Next, F2 volunteer corn, from the cultivar Coodetec 3410 RR, was sown manually and randomly distributed alleatory in between rows of each soybean plot, according to the respective density of treatments volunteer corn. The presence of weeds in the soybean crop, except for corn, was controlled manually. The application of fungicides and insecticides was carried out according to the technical recommendation of the soybean crop. The experiment was carried out under natural conditions and without irrigation (Figure 1).

At maturity, stage R8, ten soybean plants from the useful area of each plot were randomly selected for evaluation of the plant height, number of lateral branches, stem diameter, height of insertion of the first pod and number of pods plant⁻¹. To determine the height of the plants, a measuring tape was used for measuring from the surface of the soil to the apex of the plant. Determination of the height of insertion of the first pod was also used to measure the distance from the soil surface to the first pod. The diameter of the stem at ground level was measured with a digital caliper. Regarding the number of lateral branches, all the branches that had pods were counted, starting from the main stem of each plant. The soybean

Table 1: Chemical and physical characteristics of the soils in the area at the beginning of the experiment.

pH ^a	V	SOM	Clay	Ca	Mg	Al	H + Al	S	P	K	Cu	Zn	B
H ₂ O	%			mmol _c dm ⁻³			mg kg ⁻¹						
5.9	84.8	4.1	56.0	12.1	4.4	0.0	3.1	11.3	4.6	220.0	17.0	20.1	0.1

^a pH: Hydrogen potential; V: Base saturation; SOM: Soil organic matter; Ca: Calcium; Mg: Magnesium; Al: Aluminum; H + Al: Potential acidity; S: Sulfur; P: Phosphorus; K: Potassium; Cu: Copper; Zn: Zinc; B: Boron.

grain yield was determined by manual harvesting of the four central lines of each plot. The grain weight was adjusted to 13% moisture and the yield expressed in kg ha⁻¹.

The data were subjected to analysis of variance, and when significant, adjustments between models for corn populations were made using polynomial regression analysis. The computer program software Genes was used (Cruz, 2006).

RESULTS AND DISCUSSION

The presence of volunteer corn positively influenced the height of the soybean, the higher the density of corn, the greater the height of the soybean plants, in the proportion of 0.67 cm for each corn plant added in the area (Figure 2). Braz *et al.* (2019) also observed a positive correlation in the height of soybean plants as the density of corn plants. Aguiar *et al.* (2017), observed an increase of approximately 1 cm in the height of the soybean plants for each corn plant, 49% higher to the result obtained in our study. These changes in the morphology of the soybean plants, which are higher than the normal pattern, indicate that they are in a competitive environment with the weeds, although this competition is apparently not critical for

the development of both of them. According to Page *et al.* (2010), volunteer corn plants have a large growth capacity above the canopy of soybean plants, resulting in a reduction in the growth of soybean plants.

Radosevich *et al.* (1997), found that the weed, in the case also applied to volunteer corn, reflects light at a certain wavelength, which is recognized by the plants of the other crop, which causes soybean to increase its height to capture the maximum of solar radiation. Ballare & Casal, (2000) report that from that moment, the plant begins to adjust its growth according to the presence of weeds. Similar data from older studies recorded by Esehie (1992) had already registered a relationship between the height increase of the planted species in relation to the weed. Studies from the last 10 years (Silva *et al.*, 2009; Aguiar *et al.*, 2017; Braz *et al.*, 2019), report that, in addition to the competition for light and increase in plant height, with the coexistence between the cycle of species there will also be competition for soil nutrients, as well as for water, which may cause a drop in the crop yield.

The insertion of the first pod in the soybean corresponds to the height measurement in relation to the soil up to the point where the insertion of the first pod with grain appears in the main stem of the plant. The higher

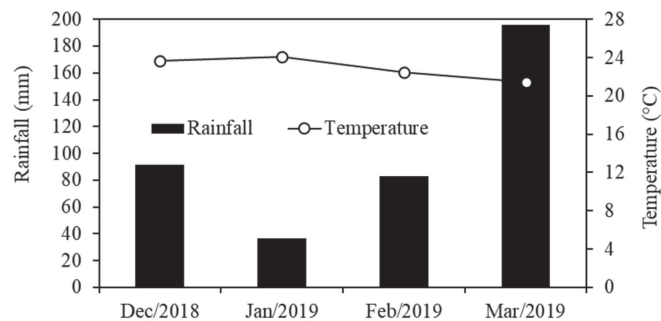


Figure 1: Rainfall and average air temperature over the experimental period. Tiradentes do Sul, RS, Brazil, 2018/19.

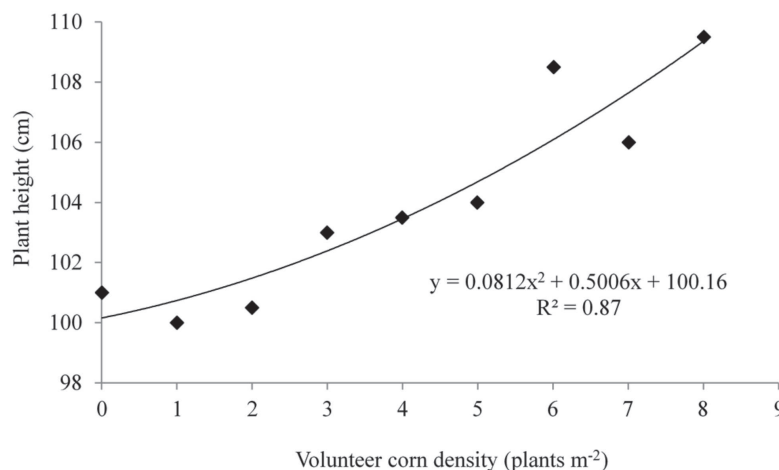


Figure 2: Height of soybean plants and density of volunteer corn plants.

the density of volunteer corn in soybeans, the higher the pods insertion (Figure 3). The insertion of the first pod was 21.8 cm, whereas in a competition environment, it was 0.35 cm higher for each volunteer corn plant in the area. Pires *et al.* (2012), state that plants with lower first pod insertion tend to have higher yield in grain production. In this sense, for the cultivar used, the result obtained indicates a reduction in grain production in soybean culture. According to Merotto *et al.* (2002), the interference to the passage of sunlight caused by the weed directly affects the insertion of the first pod in the soybean plant, as it reduces its photosynthetic efficiency. In addition, it is possible to observe a variation in the morphological behavior such as horizontal growth to increase the leaf area of the plant.

The measure of the stem diameter, measured on the main stem before the first branching of the plant, showed that the reduction in diameter was proportional to the increase in the density of volunteer corn plants (Figure

4). A density of three volunteer corn plants per square meter has already caused a decrease by 30% in the stem diameter of soybean plants. This decrease reached more than 50% with the insertion of eight corn plants. A study by Aguiar *et al.* (2017), showed an average reduction of 31% in the stem diameter of two soybean cultivars with corn density of 1 to 8 plants m^{-2} . This decrease in stem diameter is directly linked to the increase in the height of soybean plants, which increased by about 10 cm with the presence of eight corn plants m^{-2} (Figure 2). According to Braz *et al.* (2019), in general, etiolate plants tend to have a smaller stem diameter, which leaves them more exposed to lodging. Crotser *et al.* (2003), report that the elongation of the plant causes a decrease in the diameter of the stem, as weeds induce a change in the quality of light in the lower canopy, therefore, reducing the diameter of the stem.

The number of side branches also decreased with the presence of volunteer corn (Figure 5). While the stem

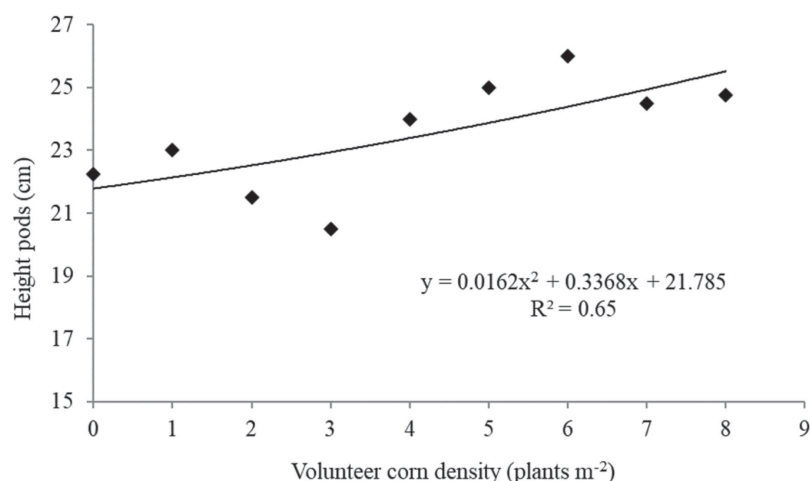


Figure 3: Insertion height of the first pod and density of volunteer corn plants.

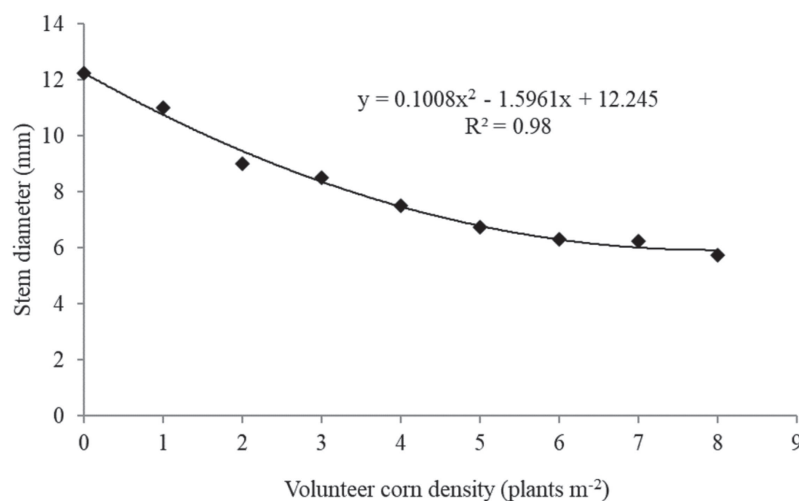


Figure 4: Stem diameter of soybean plants in relation to weed density of volunteer corn.

reduction reached just over 50% with eight plants of corn m^{-2} (Figure 4), the number of branches was reduced by almost 60% with this same plant density. This result corroborates with Braz *et al.* (2019), who observed a reduction of 15, 41 and 60% when competing with corn at densities of 2, 4 and 8 plants m^{-2} , respectively. In this context, the development of the soybean crop is delayed with the presence of a greater number of corn plants. Carvalho & Veline (2001) found a delay in the lateral growth of soybean plants when they competed for solar radiation and nutrients with weeds. Bianchi *et al.* (2011), showed that soybean cultivars in competition with *Raphanus sativus* reduced plant height, average branch length and soybean yield.

The number of pods plant^{-1} was the component most affected by the increase in the density of volunteer corn plants (Figure 6). Volunteer corn plants caused up to 81% reduction in the number of pods plant^{-1} when subjected to the densities of 8 plants m^{-2} . This result

corroborates those obtained by Aguiar *et al.* (2017), showing that the volunteer corn plants caused a reduction of 24 to 74% in the number of pods plant^{-1} when submitted to densities of 1 to 8 plants m^{-2} , respectively. Silva *et al.* (2008), found that in the areas of low, medium and high infestation of several species of weeds, at the end of the cycle, there was a reduction of 58, 71 and 78%, respectively in the number of soybean pod plant^{-1} . Juan *et al.* (2003), observed that among the components of the soybean yield, the number of pods plant^{-1} was the most affected by the competition of *Euphorbia dentata*, with reductions of 40% in relation to the treatment without weeds. However, according to Lamego *et al.* (2004) this effect is related to the soybean cultivar, showing that cultivars with highly competitive ability, in addition to tolerating competition, preserving the yield potential, also suppress the grain production of competing plants. The space limitation, both aerial and underground, promoted by the volunteer corn

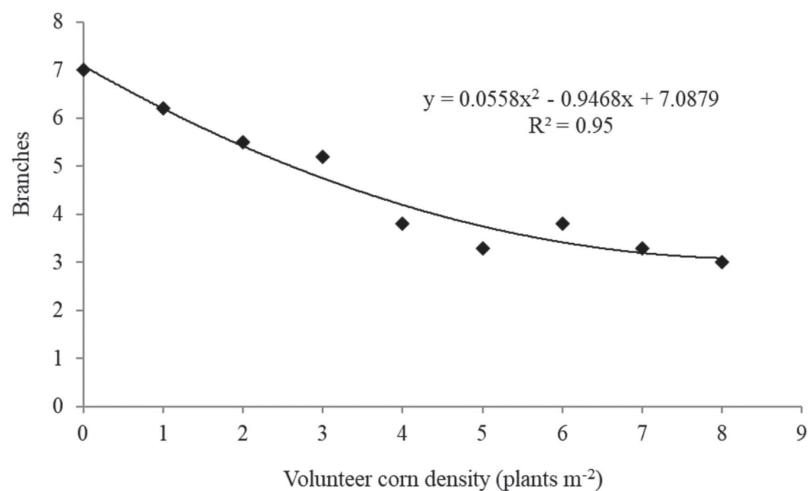


Figure 5: Number of lateral branches in soybean plants and density of volunteer corn plants.

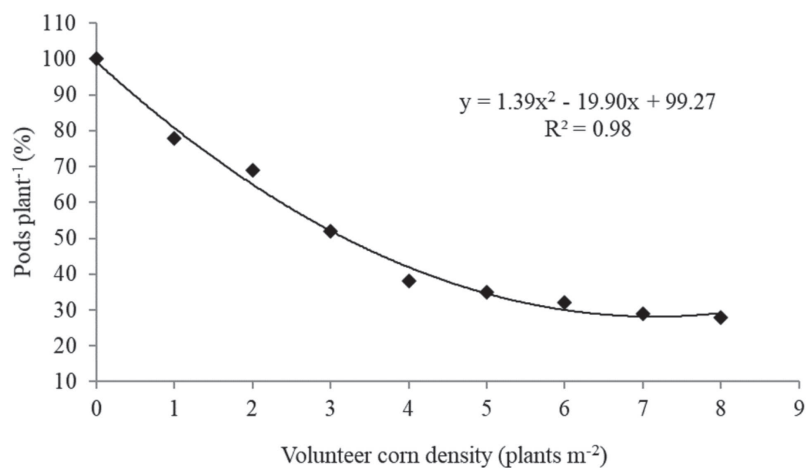


Figure 6: Percentage of soybean pods plant^{-1} according to the density of volunteer corn.

plants, could also affect the formation, growth and development of the reproductive structures of the soy plants; however, it is not possible to state which of the factors is the most relevant. The number of pods in a plant is a prior indication of the yield of soybeans in a given area. In our study, the number of pods showed a high degree of correlation with grain yield ($r^2 = 0.92$; $p < 0.05$). Juan *et al.* (2003), also observed high levels of correlation between grain yield, number of pods plant⁻¹ and weight of 1000 soybean seeds, 98 and 85%, respectively. Thus, according to Silva *et al.* (2008), the number of pod plant⁻¹ is one of the yield components most affected by weeds in the soybean crop.

Our study found that the final consequence of the presence of volunteer corn plants is the yield of soybean grains (Figure 7). It can be seen that the soybean yield decreased by 63% in the presence of 8 plants m⁻² of volunteer corn. Piasecki *et al.* (2018b) observed a maximum loss of 83% with 13 maize plants m⁻², which is 32% higher than that observed in our study. Aguiar *et al.* (2017), observed a reduction of up to 58% in soybean grain yield, also with 8 plants m⁻². Braz *et al.* (2019) found for each volunteer corn plant m⁻² a reduction of 9.3 and 13.5% for soybean cultivars BMX Potência RR and M8210 IPRO, respectively, in Brazilian Cerrado conditions. Marquardt *et al.* (2012), concluded that the reductions in soybean yield varied from 10 to 41%, where the densities of early-emerged volunteer corn varied from 0.5 to 16 plants m⁻², respectively. Alms *et al.* (2016), showed that 0.3 and 4.4 plants m⁻² of volunteer corn reduced 9 and 51% the soybean grain yield, respectively.

The reduction in grain yield is one of the factors most impacted by the presence of volunteer corn in soybeans. As already observed in the number of pods, grain yield has also been greatly reduced with the increase in the density of volunteer corn. Also, according to study by Piasecki *et al.* (2018a), in addition to the competition for

light, water and nutrients, the intense reduction in soybean yield under the influence of volunteer corn may be related to oxidative stress resulting from the greater production of reactive oxygen species (ROS), such as hydrogen peroxide (H₂O₂). This data is worrying when considering production costs, since the yield becomes less than 40% of the expected when the density is 8 plants m⁻² (Piasecki *et al.*, 2018a). Thus, it is important to carry out the proper management of crops and techniques to control volunteer corn plants to improve the grain yield of the soybean crop. The use of soybean cultivars with a semi-early cycle and indeterminate growth may have influenced the reduction in the number of pods and grain yield, even in low densities of volunteer corn, as cultivars with a shorter cycle are generally more susceptible to competition and stress.

It was also possible to estimate with our study, in addition to the negative effect of the presence of volunteer corn plants on soybean grain yield, the economic loss. The presence of only one corn plant per square meter resulted in a reduction of 500 kg of soybeans ha⁻¹ (Figure 7). The average price offered per bag of 60 kg of soybeans in March 2020 in Brazil was \$ 15.86 (CONAB, 2020). In financial terms, there would be a loss of \$ 132.16 plant⁻¹ of volunteer corn m⁻². Aguiar *et al.* (2017), in a more detailed study, with the expectation of high grain harvest, 5000 kg ha⁻¹ and \$ 27.3 per bag, presented an economic loss with 0.96 plants volunteer corn m⁻². Although the price of soybean and the cost of control are factors that affect the control decision, in practice, with one plant per square meter, it could indicate the level of need for controlling volunteer corn. Finally, it should be noted that the results obtained in our study come from and reflect the interference of low density of volunteer corn in a short-cycle soybean cultivar in mesoclimate and agroecosystem in the northwest region in the State of RS.

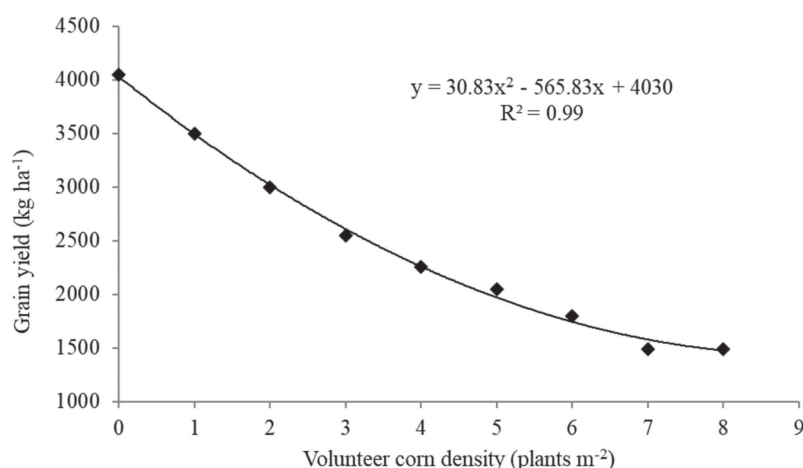


Figure 7: Grain yield and density of volunteer corn plants.

CONCLUSIONS

Plant height, number of side branches, stem diameter, height of insertion of the first pod, number of pods and soybean yield are negatively affected by the increase in the density of volunteer corn RR infestation.

The presence of volunteer corn RR has a high capacity to reduce the grain yield of soybeans in the proportion of 500 kg ha⁻¹ plant⁻¹ m⁻², and needs control, even at low densities.

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There is no conflict of interest in the execution and publishing this study.

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