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Morpho-physiological responses of potato cultivars under weed competition

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Abstract

Among the factors that affect potato productivity, the interference caused by weeds stands out as they may compete with the crop, release allelopathic substances to soil and host insects and diseases. Therefore, the objective of this work was to assess the competitive ability of white (Aghata) and pink (Asterix) potato cultivars when infested by Alexandergrass (*Urochloa plantaginea*) or wild poinsettia (*Euphorbia heteroplylla*). The experiment was carried out into greenhouse in randomized blocks design, with four replications. A single potato plant faced competition by either Alexandergrass or wild poinsettia, ranging from 0 to 64 plants per plot. Fifty days after seedling transplanting, variables related to the morphophysiology of potato cultivars and weeds were assessed. Potatoes have low competitive ability with both weed species, with wild poinsettia being the most aggressive in reducing the accumulation rates of leaf area and aboveground dry mass. Potato photosynthetic rate is negatively influenced by the presence of both weeds. Internal CO_2 concentration, stomatal conductance, carboxylation efficiency and transpiration rates of potato varied depending on weed species and density. Morphological parameters are reduced when potato competed with Alexandergrass or wild poinsettia; however the physiological parameters are most sharply affected when under competition with wild poinsettia.

Keywords: *Euphorbia heterophylla, Solanum tuberosum, Urochloa plantaginea*

Introduction

Like other agricultural crops, potato has its growth, development and productivity influenced by abiotic and biotic factors. Among the biotic factors, the interference caused by weeds is preponderant due to competition for environmental resources such as water, light, nutrients and CO_2 (Souza et al., 2016; Shehata et al., 2019; Galon et al., 2021). In addition, weeds can release allelopathic compounds that interfere with crop's growth and development, and also may host insect pests and diseases (Galon et al., 2021). Weeds can cause direct and indirect damage to potato plants, reducing tuber productivity by more than 55% or even negatively affecting the quality of the harvested product when not properly controlled (Kołodziejczyk, 2015; Shehata et al., 2019).

Tubers are usually used for planting potato fields; these need a longer time to germinate compared to seed-planted potato, thus weed infestation tend to be most serious. There is a longer time span between planting and crop canopy formation in tuber-planted potato, and weeds can almost freely establish, demanding control practices until crop's canopy formation (Bankoti et al., 2021).

The impacts generated by weeds on potato plants when they coexist lead to both quantitative and qualitative losses; furthermore, the cost of chemically controlling them is usually high (Kolodziejczyk et al., 2015; Nourollahi, 2019). In this way, management techniques must be thought and planned in order to reduce herbicide demand in order to reduce the occurrence of resistant weeds, environmental contamination, control costs, and increase farmer's income (Nourollahi, 2019).

Among the weeds that infest potato crops, Alexandergrass (*Urochloa plantaginea*) and wild poinsettia (*Euphorbia heterophylla*) stand out as the

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most commonly reported. Both species present high shading ability and thus interfere with growth and initial development of crops, as seen when infesting soybeans (Galon et al., 2019), maize (Frandoloso et al., 2020) and beans (Franceschetti et al., 2019), among others, being one of the most important weed species in Brazil. Wild poinsettia presents annual cycle, being difficult to control due to the occurrence of multiple resistance to ALS-, PROTOX- and EPSPs- inhibiting herbicides (Brusamarello et al., 2020; Ulguim et al., 2017).

The coexistence and growth of species in community is directly related to their ability to absorb or capture scarce environmental resources. Plant ability to compete with each other depends on the species, cultivar, row spacing, seeding density and spatial distribution, and also crop management (Galon et al., 2021).

For the potato crop studies aimed at the interference of Alexandergrass and/or wild poinsettia in morphophysiological parameters are scarce. Given the lack of information on this subject, the present work becomes important for the adoption of most conservationist weed management methods in potato. Research related to crop competitiveness with weeds allows the development of new and most sustainable weed management strategies, also contributing for food safety.

The hypothesis of the work is that there is difference in competitive ability of potato cultivars when infested by Alexandergrass or wild poinsettia. Therefore, the objective of this work was to evaluate the competitive ability of potato cultivars, pink (Asterix) and white (Agatha) when infested by Alexandergrass and wild poinsettia.

Material and Methods

Plant material

The experiment was carried out in a greenhouse at the Universidade Federal da Fronteira Sul (UFFS), Campus Erechim/RS, Brazil, at the geographic coordinates 27° 43' 32" S; 52° 17' 27" W, 670 m ASL, from September to December, 2018. Experimental units consisted of plastic pots with capacity of 15 dm^3, filled with soil from an agricultural area, characterized as humic Aluminoferric Red Latosol (EMBRAPA, 2013).

The chemical and physical soil traits were: pH_{Water}: 4.8; OM: 3.3%; P: 6.3 mg dm^{-3}; K: 106 mg dm^{-3}; Al^{3+}: 0.9 $cmol_c$ dm^{-3}; Ca^{2+}: 5.1 $cmol_c$ dm^{-3}; Mg^{2+}: 3.3 $cmol_c$ dm^{-3}; CTC_t: 9.8 $cmol_c$ dm^{-3}; $CTC_{T\_pH=7}$: 17.6 $cmol_c$ dm^{-3}; H+Al: 8.7 $cmol_c$ dm^{-3}; BS: 9.2 $cmol_c$ dm^{-3}; V: 51%; Clay: 62%.

Seeds of Alexandergrass and wild poinsettia were previously collected in areas of commercial grain farming at Erechim/RS, Brazil, at physiological maturity. Afterwards, they were taken to the laboratory for Sustainable Management of Agricultural Systems at UFFS, Campus Erechim, where they were cleaned, placed in shaded and ventilated location for natural drying, and later stored in refrigerator at 7 °C for later use in the experiment.

Experimental design and treatments

The experiment was installed in randomized blocks design, with four replications. The potato cultivars tested were Agatha (white potato) and Asterix (pink potato), which competed with increasing densities of Alexandergrass and wild poinsettia (**Figure 1**).

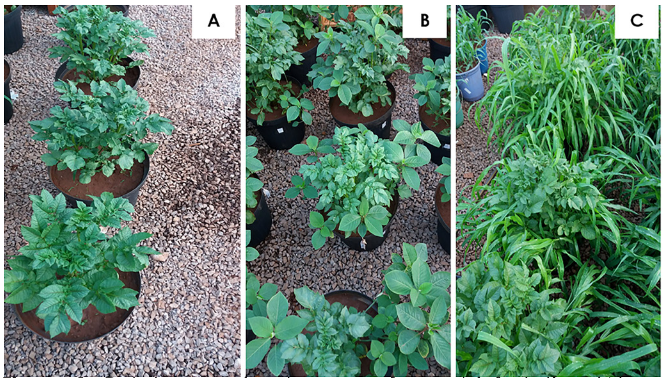

Figure 1. Potato crop in absence of weed infestation (A), or coexisting with wild poinsettia (B) or Alexandergrass (C). UFFS, Campus Erechim/RS, 2018.

The experiment was carried out in additive series according to the methodology proposed by Radosevich et al. (2007). Alexandergrass or wild poinsettia (according to the treatment), were planted in the experimental units, that were irrigated for weed germination and emergence. Ten days after emergence, with weeds ~ 1-2 cm tall, they were thinned by hand to the weed densities established for the treatment: 0, 2, 4, 8, 16, 32 or 64 plants $plot^{-1}$. Right after weed density thinning, in the center of each experimental unit, a single seedling of potato from the cultivar attributed to the treatment (Agatha or Asterix) was planted. Potato seedlings to be transplanted were previously established from seeds, in alveolar polystyrene trays, and cultivated under the same environmental conditions as the experiment.

Assessed variables

Morphological

Fifty days after transplanting (DAT), plant height, stem diameter, leaf number and area and aboveground dry mass of potato plants were evaluated. Plant height was determined with a ruler graduated in centimeters from the ground level to the apex of the last fully expanded leaf. Stem diameter was measured using a digital caliper 5 cm above ground. For leaf area determination, a portable meter model CI-203 (BioScience, Inc.) was used, quantifying leaves of the potato plant in each plot. After measuring the leaf area, plants were sectioned close to ground level, placed in Kraft paper bags and placed into forced air circulation oven at 60 ± 5 °C until constant weight, for aboveground dry mass determination.

Physiological

Fifty DAT, parameters related to potato physiology were evaluated: internal concentration of CO_2 (Ci-μmol mol^{-1}), transpiration rate (E-mol H_2O m^{-2} s^{-1}), stomatal conductance (Gs-mol m^{-1} s^{-1}), photosynthetic rate (A-μmol m^{-2} s^{-1}), water use efficiency (WUE - mol CO_2 mol H_2O^{-1}) and carboxilative efficiency (EC - mol CO_2 m^{-2} s^{-1}). These variables were determined in the middle third of the potato plants, in the first fully expanded leaf of the cultivars. Physiological parameters were measured between 8 am and 11 am using an infrared gas analyzer (IRGA, LCA PRO, Analytical Development Co. Ltd, Hoddesdon, UK).

Statistical analysis

The data set was subjected to tests of normality and homogeneity of errors, and later the analysis of variance was performed using the F-test, with the cultivars being considered distinct when Fc > Ft at 5% probability. Subsequently, linear and non-linear regressions were fitted to the original data to evaluate the effects of weed densities on potato cultivars. The choice of models was based on statistical significance (F-test), on the best fit - coefficient of determination (R^2) and on the biological significance of the model, as proposed by Adati et al. (2006). All regressions were also presented with the respective 95% confidence interval, and the curves on the same graph were considered distinct at sections where their confidence intervals did not overlap.

Results and Discussion

The results showed interaction between factors tested (weed species x densities) for all variables. The competition promoted decreases in aboveground dry mass production as the density of Alexandergrass or wild poinsettia increased (**Figure 2**). For wild poinsettia, there is no difference between from 52 plants m^{-2} onward, and Asterix accumulated more dry mass than Agatha. Sweet potato cultivars Beauregard and Carolina Bunch showed reduction of 38 and 65%, respectively, in aboveground dry mass when under competition with weeds (Harrison & Jackson, 2011), results that are similar to those found in this study.

Plant height of potato cultivars did not differ in competition with Alexandergrass (**Figure 3**). The wild poinsettia, on the other hand, influences the height of each cultivar differently, with Agatha showing higher tolerance to competition and Asterix being most affected as weed density increased, similarly to the reported for aboveground dry mass (Figure 2).

Contrasting with this study, Yadavi et al. (2016) reported that increasing the density of *Amaranthus retroflexus* significantly increased the height of potato plants. Other authors have also related this effect, with the crop presenting greater plant height due to etiolation, an ecological strategy to obtain light when in competition with weeds (Silva et al. 2009).

However, other researches indicate that weed interference can reduce the height of potato plants (Nelson & Thoreson, 1981; Kumar et al., 2017). And in the present study, only Asterix showed smaller plant height in the presence of wild poinsettia (Figure 3). This indicates the impact of the competitor on potato plants depends both on cultivar and weed species involved. This is mainly due to the genetic differentiation between cultivars related to development cycle, root volume, plant architecture, leaf area index, better use of space or availability of available resources, among others (GALON et al., 2019).

The stem diameter of Agatha decreased as Alexandergrass density increased, while Asterix was not significantly affected by any density of this weed (**Figure 4**). In the presence of wild poinsettia, the stem diameter did not show differences between cultivars weed density (Figure 4). The number of leaves of Asterix was reduced as Alexandergrass density increased; for Agatha there was stability in the weed effect from the density of eight plants per experimental unit onward.

Cultivars behavior was similar in the presence of wild poinsettia; however Agatha stabilized the number of leaves from the density of 28 plants m^{-2} onward (**Figure 5**). The number of leaves is a parameter that directly influences the leaf area (Monteiro et al., 2005), and great reductions in these parameters may limit the maximum photosynthesis ability of the plant.

Regarding the leaf area, there was decreasing differences between them as Alexandergrass or wild poinsettia density increased (**Figure 6**). It is worth mentioning the peculiarity of each cultivar in the morphological aspect, in which Asterix presents greater leaf area than Agatha in any density or weed in which they coexist. This comes from the genetic variability among potato cultivars, and thus their competitive ability varies as well.

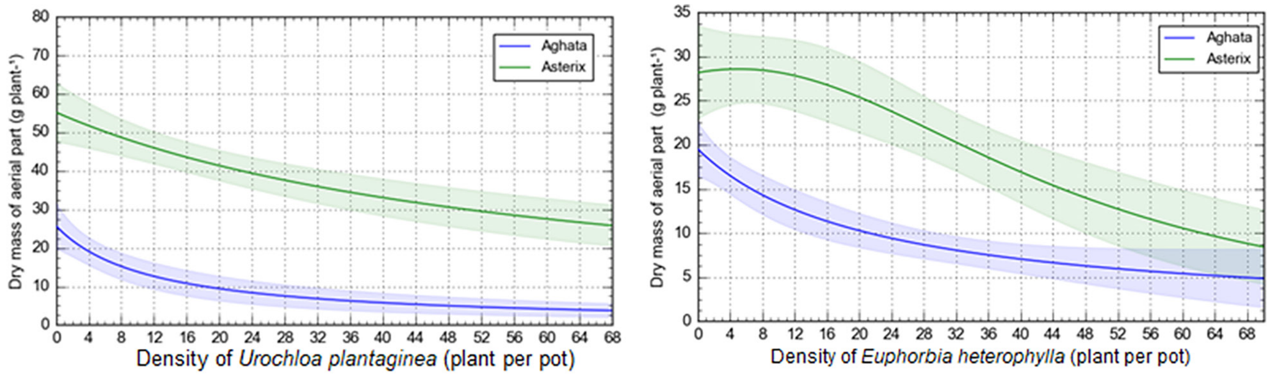

Figure 2. Aboveground dry mass (g plant-1) of potato cultivars Agatha and Asterix under competition with increasing densities of Alexandergrass (*Urochloa plantaginea*) and wild poinsettia ((Euphorbia heterophylla). UFFS, Campus Erechim/RS, 2018.

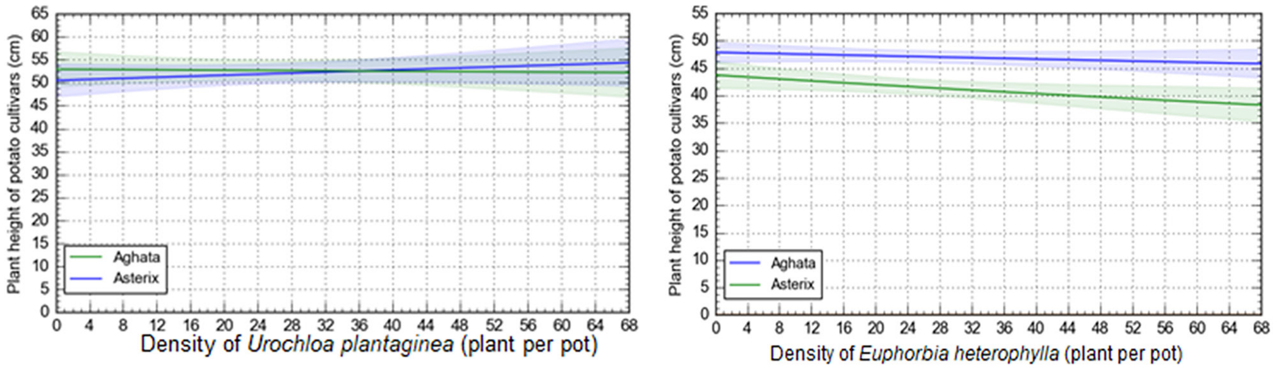

Figure 3. Plant hight (cm) of potato cultivars Agatha and Asterix under competition with increasing densities of Alexandergrass (*Urochloa plantaginea*) and wild poinsettia (*Euphorbia heterophylla*). UFFS, Campus Erechim/RS, 2018.

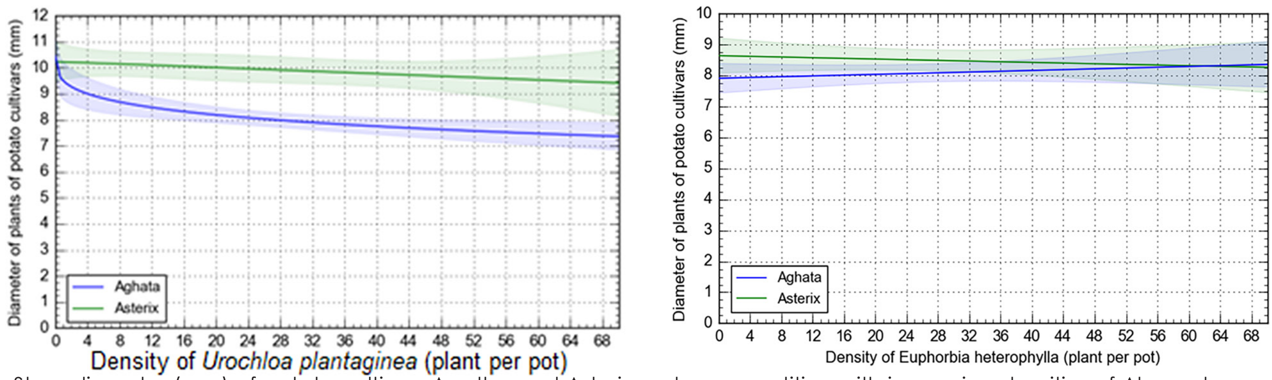

Figure 4. Stem diameter (mm) of potato cultivars Agatha and Asterix under competition with increasing densities of Alexandergrass (*Urochloa plantaginea*) and wild poinsettia (*Euphorbia heterophylla*). UFFS, Campus Erechim/RS, 2018.

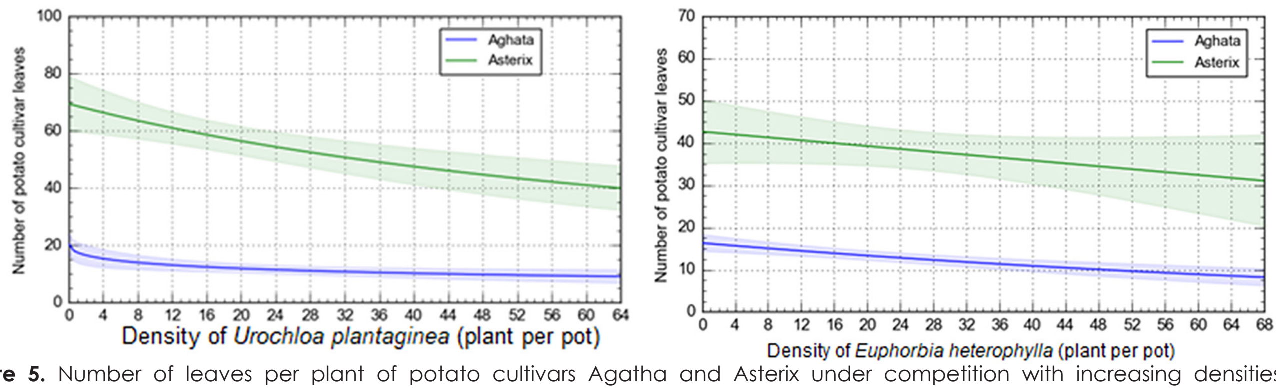

Figure 5. Number of leaves per plant of potato cultivars Agatha and Asterix under competition with increasing densities of Alexandergrass (*Urochloa plantaginea*) and wild poinsettia (*Euphorbia heterophylla*). UFFS, Campus Erechim/RS, 2018.

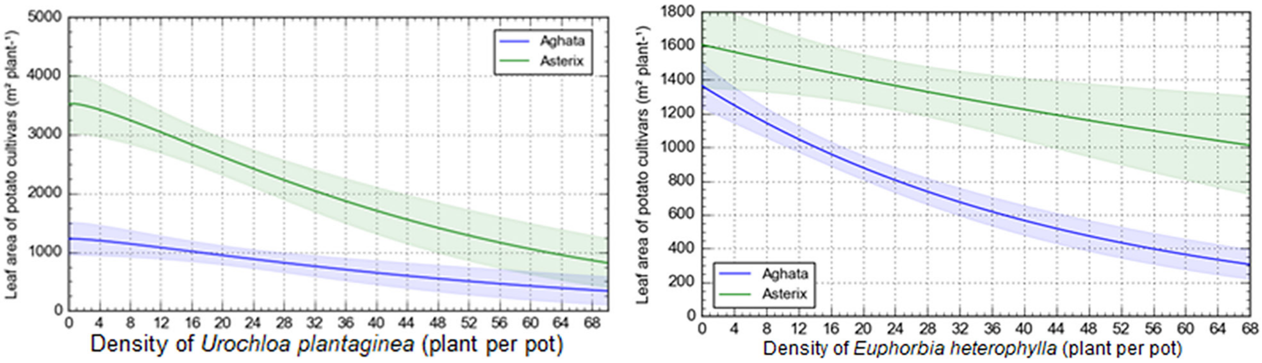

Figure 6. Leaf area (m^2 plant^{-1}) of potato cultivars Agatha and Asterix under competition with increasing densities of Alexandergrass (*Urochloa plantaginea*) and wild poinsettia (*Euphorbia heterophylla*). UFFS, Campus Erechim/RS, 2018.

This work corroborates the results reported by Colquhoun et al. (2009) when working with potato cultivars infested by weeds. Competitive differences between cultivars in the presence of weeds were also reported by Hutchinson et al. (2011), in which the cultivar Russet Norkotah was less competitive than Russet Burbank in the presence of hairy nightshade (*Solanum sarrachoides*). Similarly, Yadavi et al. (2016) found high losses in biological and tuber productivity of English potato under increasing densities and early emergence of Amaranthus retroflexus in relation to the crop. Thus, it is clear that yield losses in potato crop are particularly related to the cultivar, the weed species and its density, besides the factors related to soil, environment and management.

Losses in dry mass accumulation rates can directly influence potato production as when these reductions occur, physiological variables such as photosynthetic activity or even plant water use efficiency are also affected. This leads to a lower influx of CO_2 into leaves and increase in transpiration. This same fact was reported by Nelson & Thoreson (1981) who reported reduction in plant biomass when under competition with weeds. Other researches show the negative effect of weeds throughout the cycle and consequently on potato productivity (Hutchinson et al., 2011; Mushtaq et al., 2018).

The photosynthetic rate (A) was reduced in both potato cultivars in the presence of both weeds (**Figure 7**). When increasing the weed density, the loss in photosynthetic rate of both cultivars was greater (Figure 7). Assessing the photosynthetic rate, since it is one of the most important primary metabolic processes, can contribute to determine or explain the productive behavior of potato; this physiological parameter is strongly affected by the interference of biotic and abiotic factors such as competition with weeds (Germ, 2008; Ferreira et al., 2015).

Karimmojeni et al. (2014) report that the effect of competition between potato and other species often reduces photosynthesis, which consequent reduced growth and biomass accumulation and negatively impact on plant yield. The two evaluated weeds reduced the aboveground dry mass, number of leaves and leaf area of potato (Figures 2, 5 and 6). This evidences that these morphological variables are directly related to photosynthetic rate.

The internal concentration of CO_2 (Ci) showed no difference between weeds or densities, regardless of potato cultivar (**Figure 8**). When evaluating cassava crop in the presence of weeds, Aspiazú et al. (2010) reported that certain weeds influence Ci in a different way from what happened in the present study, in which potato cultivars were not impacted by weeds in Ci. In soybean, with increasing weed density, A reduced while Ci increased as a way for the crop to overcome the stress generated by competition (Ferreira et al., 2015). A and Ci are generally considered as inversely proportional due to the consumption of carbon for photosynthesis (Concenço et al., 2008); however, this fact did not happen in the present study. Physiological parameters should be considered in batches as increase in a given parameter may be compensated by reduction in others while a third group of parameters may be unaffected (Floss et al., 2008; Aspiazú et al., 2010).

The results demonstrate that the stomatal conductance (Gs) of Agatha in the presence of Alexandergrass reduced as weed density increased. Asterix was not affected by weed density. In the presence of wild poinsettia, Agatha was not affected while Asterix reduced Gs as weed density increased (**Figure 9**). Weed competition can generate a cascade of physiological changes in crops. And with regard to stomatal conductance, it was most likely not the limiting factor for photosynthesis for both cultivars in the presence of Alexandergrass.

The results demonstrate that the carboxylation

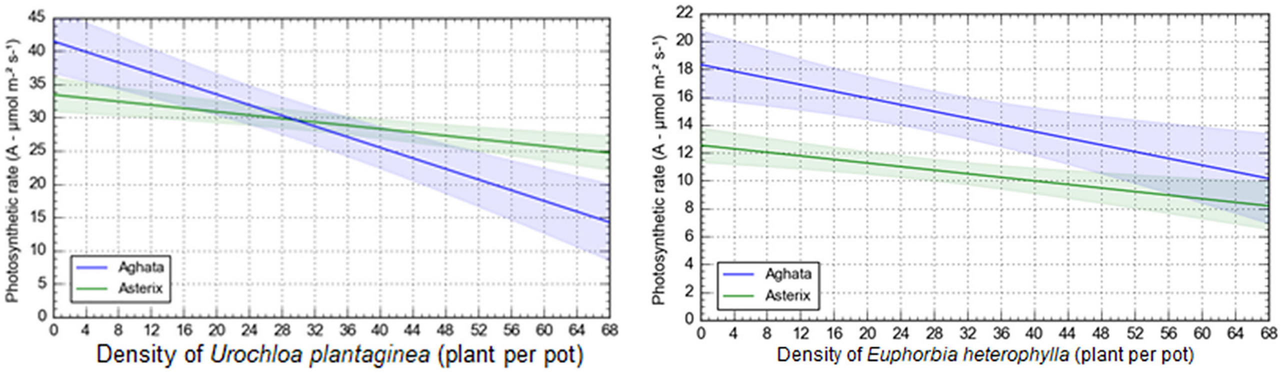

Figure 7. Photosynthesis rate (*A* - µmol m^{-2} s^{-1}) of potato cultivars Agatha and Asterix under competition with increasing densities of Alexandergrass (*Urochloa plantaginea*) and wild poinsettia (*Euphorbia heterophylla*). UFFS, Campus Erechim/RS, 2018.

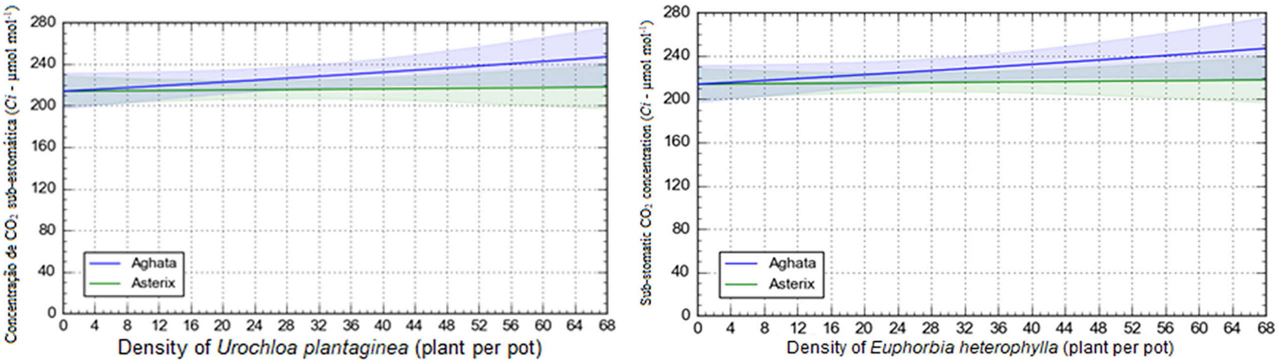

Figure 8. Substomatal CO_2 concentration (*Ci* - µmol mol^{-1}) of potato cultivars Agatha and Asterix under competition with increasing densities of Alexandergrass (*Urochloa plantaginea*) and wild poinsettia (*Euphorbia heterophylla*). UFFS, Campus Erechim/RS, 2018.

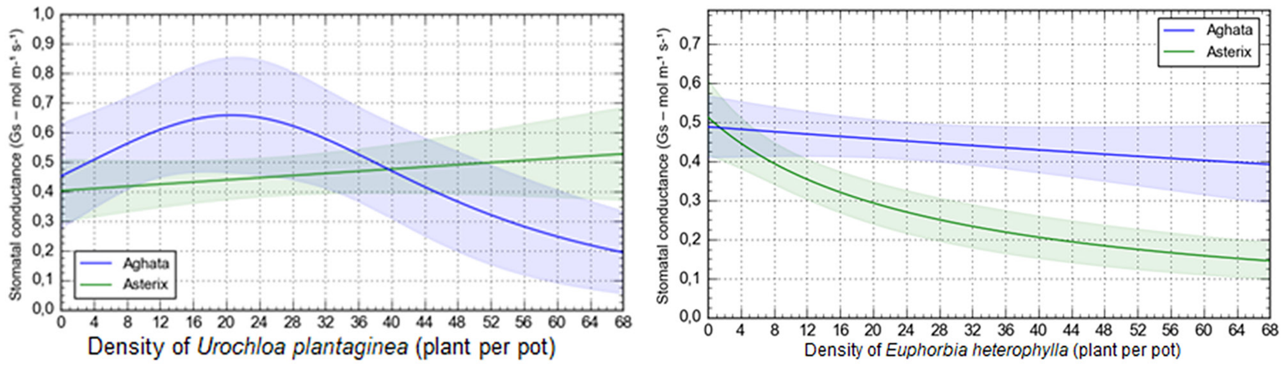

Figure 9. Stomatal conductance (*Gs* – mol m^{-1} s^{-1}) of potato cultivars Agatha and Asterix under competition with increasing densities of Alexandergrass (*Urochloa plantaginea*) and wild poinsettia (*Euphorbia heterophylla*). UFFS, Campus Erechim/RS, 2018.

efficiency (EC) for Asterix showed no difference in the presence of any Alexandergrass density. However, Agatha reduced EC as the density of this weed increased. For wild poinsettia, Agatha decreased EC at weed densities ≥ 20 plants plot^{-1} and Asterix showed no difference wild poinsettia densities (**Figure 10**).

For transpiration rate (E), under competition with Alexandergrass, cultivars greatly differed; Agatha decreased E with increasing densities while Asterix increased this parameter in the same situation. In the presence of wild poinsettia, there was no difference in EC for both cultivars as weed density increased (**Figure 11**).

There was reduction in water use efficiency (WUE) for Agatha as Alexandergrass density increased, while Asterix was not impacted (**Figure 12**). For wild poinsettia, the increase in weed density did not affect both potato cultivars.

Gs influences gas exchange, and its relationship on other physiological parameters is vastly reported in the literature (Aspiazú et al., 2010; Ferreira et al., 2015). In this way, while the crop tends to close stomata the photosynthetic rate and transpiration tend to fall, and this effect occurs as a means of avoiding stress (Nascimento et al., 2011).

Water use efficiency (WUE) represents the amount of CO_2 fixed by photosynthesis in a given time

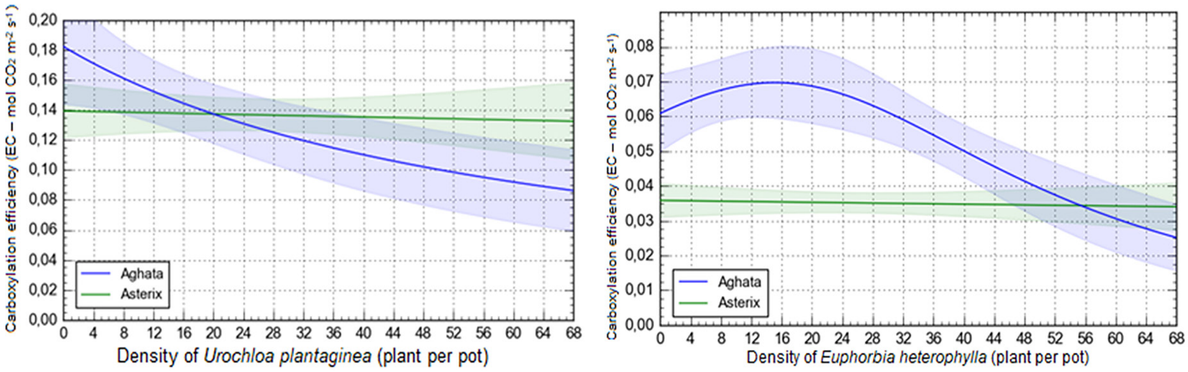

Figure 10. Carboxilative efficiency (EC – mol CO_2 m^{-2} s^{-1}) of potato cultivars Agatha and Asterix under competition with increasing densities of Alexandergrass (*Urochloa plantaginea*) and wild poinsettia (*Euphorbia heterophylla*). UFFS, Campus Erechim/RS, 2018.

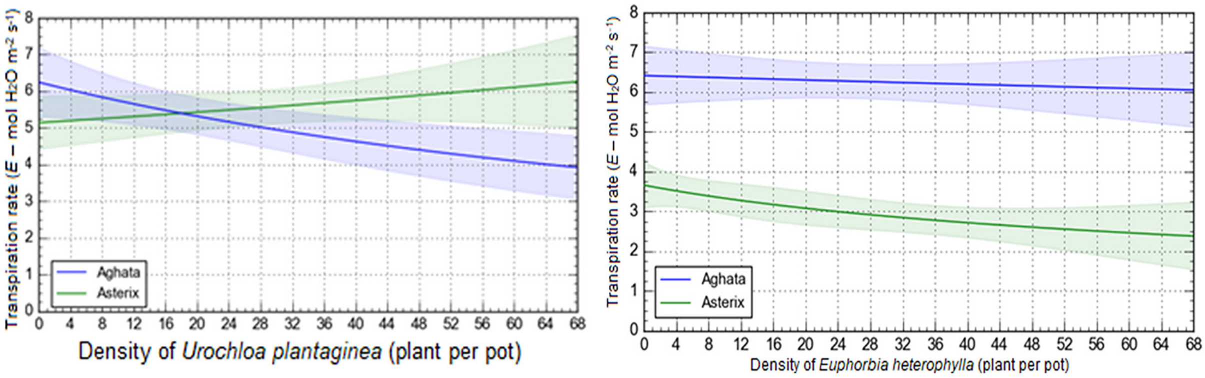

Figure 11. *Transpiration rate* (*E* – mol H_2O m^{-2} s^{-1}) potato cultivars Agatha and Asterix under competition with increasing densities of Alexandergrass (*Urochloa plantaginea*) and wild poinsettia (*Euphorbia heterophylla*). UFFS, Campus Erechim/RS, 2018.

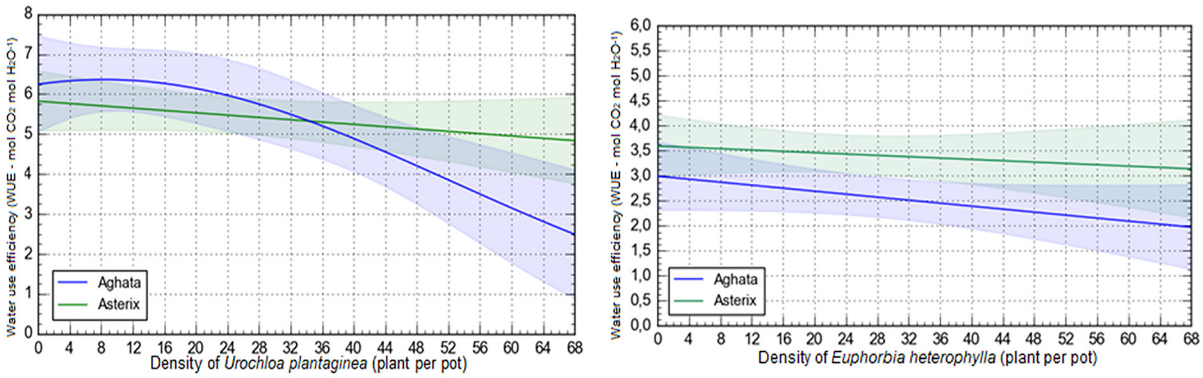

Figure 12. Water use efficiency (WUE - mol CO_2 mol H_2O^{-1}) of potato cultivars Agatha and Asterix under competition with increasing densities of Alexandergrass (*Urochloa plantaginea*) and wild poinsettia (*Euphorbia heterophylla*). UFFS, Campus Erechim/RS, 2018.

in relation to the amount of water used in the same time span (Floss, 2008). WUE is generally seen as an ideal mechanism for an environment where water is limited (Tardieu, 2013), considering that the presence of weeds and the competition between species for resources, including water, can affect the crop. However, the fact that, regardless of weed density, they did not interfere negatively in WUE of potato crop, allows to infer that there is no interference of Alexandergrass and wild poinsettia on WUE. However, to confirm this hypothesis, additional studies with other plant species are demanded.

There was decrease in soybean WUE in competition with *Bidens pilosa* and *Urochloa brizantha* (Ferreira et al., 2015). The authors considered these species highly aggressive, especially *B. pilosa*. However, this effect did not occur in potato cultivars, for both studied cultivars.

Potato cultivars showed differences in certain morphophysiological parameters under weed competition. Germ (2008) reports that the effects of drought and selenium are distinct in different potato cultivars; therefore, the results of a particular cultivar cannot be stretched for the whole set of cultivars of a given species. Accordingly, Cavalcante et al. (2017) report that competition between weeds and sweet potato genotypes can be extremely variable. The authors attribute this to an interaction of factors such as weed species, sweet potato genotype, climatic conditions, soil and environmental traits, among others.

The knowledge of the ability of weeds to interfere in the potato crop is important for the decision to carry out the control, which depends on factors linked to the weed community itself (specific composition, density and distribution), to the crop (species or cultivar, row spacing and seeding density) which can be altered by soil and climate conditions as well as by cultural practices. Thus, the identification of the most competitive cultivar, or the most impacting weed species, is not easy but becomes important for the adoption of more sustainable management for the control of Alexandergrass and/ or wild poinsettia, using herbicides only when really necessary.

Conclusions

The potato cultivar Agatha is less tolerant to competition with Alexandergrass or wild poinsettia, compared to Asterix;

The morphological and physiological parameters of potato, cultivars Agatha and Asterix, were reduced in the presence of Alexandergrass or wild poinsettia;

Wild poinsettia has greater competitive ability than Alexandergrass against potato cultivars Agatha and Asterix, being thus a most troublesome weed.

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