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Association between agronomic characters and hay quality of sweet potato branches

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ABSTRACT

From the perspective of the use of sweet potato branches for animal feed, there is a lack of information on the influence of this action on hay quality. Therefore, the objective was to study the association of sweet potato yield attributes with chemical-bromatological characteristics of hay. Ten sweet potato clones were evaluated, conducted in randomized blocks with five replications. Green and dry mass yield, dry mass content, leaf and stem ratio, total and commercial root yield, and chemical and bromatological characteristics of hay from the branches were determined. Phenotypic correlation and trial analysis between characteristics were estimated. Selection for the highest yield of roots and commercial roots may provide increased hay of crude protein, neutral detergent fiber and acid and total soluble sugars. However, selection for the highest root yield has a negative effect on the starch content of hay and deserves special attention from the breeder.

Keywords: *Ipomoea batatas*, animal feed, trial analysis.

RESUMO

Associação entre caracteres agrônômicos e qualidade de feno de ramas de batata-doce

Sob perspectiva do uso das ramas de batata-doce para a alimentação animal, há carência de informações da influência desta ação sobre a qualidade do feno. Logo, objetivou-se estudar a associação dos atributos de produtividade da batata-doce com características químicas-bromatológicas do feno. Foram avaliados dez clones de batata-doce, conduzidos em blocos ao acaso com cinco repetições. Determinou-se as produtividades de massa verde e seca, teor de matéria seca e a relação folha e haste das ramas, a produtividade total e comercial de raízes, e, características químico-bromatológicas dos fenos a partir das ramas. Estimou-se a correlação fenotípica e a análise de trilha entre as características. A seleção para a maior produtividade de ramas e de raízes comerciais pode proporcionar o aumento no feno da proteína bruta, fibra de detergente neutro e ácido e açúcares solúveis totais. Porém, a seleção para a maior produtividade de raízes tem efeito negativo no teor de amido do feno, merecendo atenção especial do melhorista.

Palavras-chave: *Ipomoea batatas*, alimentação animal, análise de trilha.

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The search for supplies for grazing animals in the dry season is constant, as there is usually a great shortage of pastures, causing animal mortality due to lack of food (Viana *et al.*, 2011). This fact determines the demand by the producer of food alternatives in order to supply the low forage availability for ruminant animals thus establishing a nutritive efficiency for their growth and development (Ferreira *et al.*, 2014).

Thus, sweet potato (*Ipomoea batatas*) may be an alternative because, despite being traditionally

cultivated for the production of roots for human consumption, its branches have satisfactory characteristics for animal feed, because they are rich in sugars, vitamins and have high crude protein content, total digestive nutrients and digestibility (Pedrosa *et al.*, 2015). Sweet potato is a tuberous vegetable with wide adaptation to different environments, characterized by its rusticity, low production cost and mainly cultivated by small producers (Andrade Junior *et al.*, 2016).

Due to their high protein content,

sweet potato branches can be fed to various animal species such as pigs and cattle (Veiga *et al.*, 2009; Ly *et al.*, 2010). Branches can be supplied to animals in fresh form, dried or preserved in silage (Andrade Junior *et al.*, 2014; Pedrosa *et al.*, 2015). However, one form of use in animal feed is the use of hay branches.

The haymaking technique is based on the principle of conservation of the forage nutritive value through rapid dehydration, in the face of paralysis of the respiratory activity of the plant

and of microorganisms, baling and storage (Calixto Júnior *et al.*, 2012). For good quality hay production it is necessary to take into account the use of plants with high nutritive value, easily dehydratable, which is related to cuticle thickness, stem diameter and length and leaf/stem ratio among others (Andrade *et al.*, 2006).

This haying process has not been reported for the conservation of sweet potato branches, which indicates the need for research aimed at increasing the producer's alternatives for animal feed throughout the year. Thus, studies of cultivars with high yield of roots for human consumption and branches for animal feed become important in order to obtain information on both agronomic and hay quality characteristics. Therefore, the objective of the present research was to study the relationships between the agronomic characteristics of sweet potatoes for the municipality of Diamantina-MG and the qualitative characteristics of hay.

MATERIAL AND METHODS

The work was conducted in the Olericulture sector of the Department of Agronomy of the Universidade Federal dos Vales do Jequitinhonha e Mucuri (UFVJM), in Diamantina-MG (18°12'11"S, 43°34'20"W, 1,400 m altitude), from September 2015 to April 2016. The soil of the experimental area is classified as a typical Arctic Quartzarenic Neossol (Embrapa, 2013).

The experimental design was a randomized complete block with 10 treatments (genotypes) and five replications, totaling 50 experimental plots of two rows, 4.5 m each. Spacing was 1.0 m between rows and 0.30 m between plants. The evaluated clones (UFVJM-07, UFVJM-10, UFVJM-13, UFVJM-15, UFVJM-23, UFVJM-35, UFVJM-37, UFVJM-45, UFVJM-46, UFVJM-54) belong to the sweet potato germplasm bank of UFVJM, and presented potential for use in animal feed, mainly in the form of silage (Andrade Júnior *et al.*, 2016). The germplasm bank is formed by specimens from various Brazilian

regions, including the Jequitinhonha Valley.

Planting fertilization consisted of 10 t ha⁻¹ organic compost and 30 kg ha⁻¹ nitrogen. Selected and standardized branches with eight knots were planted, burying from 3 to 4 knots. At 30 days after planting the branches, 30 kg ha⁻¹ nitrogen was applied as ammonium sulfate. Planting, mulching, irrigation and weeding were made as recommended for the crop (Filgueira, 2008).

Characteristics evaluated

Branches and roots were harvested 150 days after planting, when the roots were developed. The analyzed characteristics were: a) green mass yield of branches (BGMY) (t ha⁻¹) determined by weighing the harvested branches; b) dry mass content of the branches (DMB), quantified by samples of the newly harvested branches. Homogeneous samples of 500 g in each experimental unit were placed in paper bags and kept in an oven with forced ventilation at 60°C, until reaching constant mass; c) branch dry mass yield (BDMY) (t ha⁻¹), obtained by the product between green mass yield and root dry mass content; d) leaf and stem ratio (LS), determined by the ratio of leaf dry mass to stem dry mass, of a representative sample of branches, approximately 500 g of fresh material, separated into leaf and stem fractions that were weighed and placed into an oven with forced ventilation at 60°C until constant weight; e) total root yield (TRY) (t ha⁻¹), obtained by weighing the roots; f) commercial root yield (CRY) (t ha⁻¹), selection of roots with mass between 100 and 800 grams, without cracking, deformed, greenish, perforated or with veins.

For hay production, the sweet potato branches were crushed into pieces, approximately 3 to 5 cm, later taken to the greenhouse and distributed to the experimental plots over plastic canvas in uniform layers of 2 to 3 cm for drying until reducing the moisture content of fresh branches to less than 18%, during about four days.

After obtaining the hay, 500 g of material were collected in each sample unit, taken to the oven with forced air ventilation and kept at 60°C for drying until constant mass. The material was

then sent for chemical-bromatological analysis to obtain 1) neutral detergent fiber (NDF); 2) acid detergent fiber (ADF) and 3) lignin (LIG) according to Detmann *et al.* (2012); 4) crude protein (CP) obtained by the LECO® CHNS / O elemental analyzer and the value multiplied by the conversion factor 6.25; 5) total soluble sugars (TSS) and 6) starch, through Mc Cready *et al.* (1950) with values expressed as percentage of dry mass.

Statistical analysis

Statistical analyzes were performed using Genes software (Cruz, 2013). A correlation matrix between the characteristics was estimated, which was tested for multicollinearity by the matrix condition number (NC) proposed by Montgomery *et al.* (2012). To unfold the correlation into direct and indirect effects, we resorted to trial analysis. When multicollinearity (NC>1000) was identified, the crest or communal trial analysis methodology was used (Cruz *et al.*, 2012). The dependent (basic) variables considered were the characteristics associated with hay quality: CP, ADF, NDF and starch. The explanatory variables were the characteristics that presented significant phenotypic correlation with the basic variable according to the t test ($p \leq 0.05$).

RESULTS AND DISCUSSION

Phenotypic correlations between agronomic characteristics and sweet potato hay quality

Estimates of significant phenotypic correlations ranged from -0.37 (total soluble sugars and leaf-stem ratio) to 0.97 (green mass yield and dry mass yield) (Figure 1). In general, phenotypic correlations were of low magnitude and not significant. This indicates that selection for one characteristic tends not to affect the others.

Estimates of positive and significant phenotypic correlation between characters show that in practice, it is necessary to evaluate only the most easily determined character. This means that selection will be performed indirectly on the other associated character, thus reducing the time spent

the plant. These associations can be observed with the two characteristics for hay quality, ADF and NDF, which resulted in significant correlations with CRP, 0.46 and 0.54, respectively (Figure 1).

The analysis of lignin is extremely important to verify the degradation of forages and thus the nutritional utilization of animal feed. The amount of lignin present in food is a critical factor regarding digestibility, as it is associated with fibrous carbohydrates in plant cell walls, thus limiting cellulose and hemicellulose digestibility (Norton, 1982). Thus, indirect selection of the trait *LIG* or *NDF* (significant correlation 0.47) (Figure 1) may be able to provide higher consumption by the animal, since low levels of these two characteristics are desirable.

Positive estimates between the

yield characteristics of green or dry mass of sweet potato branches with chemical-bromatological characteristics are desirable for better use of plants in the field and also for animal feed. Thus, indirect selection of *BDMY* may lead to *NDF* quality and total soluble sugars (*TSS*), which presented significant coefficients of 0.33 and 0.55 respectively (Figure 1). *TSS* are of great importance as they are concentrated sources of rapidly degrading energy supplied to microorganisms in ruminant animals (Medeiros & Marino, 2015). The relationship between *TSS* and *BGMY* was also found (0.57) (Figure 1), showing that the selection of high *BGMY* values will lead to higher levels of *TSS* in sweet potato hay.

On the other hand, when the phenotypic correlation is negatively significant, one character is favored

over the other, which may provide undesirable gains for characteristics, as found in: *LS* with *BGMY* (-0.52), (-0.44) and *TSS* (-0.37); *TSS* and *DMB* (-0.48); starch with *TRY* (-0.74), *CRY* (-0.56) and *CP* (-0.61) (Figure 1). Thus, it becomes difficult to determine which characteristics measure the relative importance of agronomic characters with the quality of sweet potato hay. Therefore, an alternative is to adopt another statistic, the trial analysis, to quantify the direct and indirect effects on the (basic) characteristic of interest (Cruz *et al.*, 2012).

Contribution of components for direct and indirect effects between yield characteristics and quality of sweet potato hay

Only those characteristics that were significant with the basic variables [crude protein (*CP*), neutral detergent fiber (*NDF*) and acid and starch] were considered. The phenotypic correlation matrix between the characters resulted in weak multicollinearity ($NC < 100$) when considering *ADF* and *NDF* as basic variables (Table 1). When basing *CP* and starch as basic variables, it was necessary to use crest trial analysis. The coefficients of determination were moderately satisfactory for the trial analyzes, with estimates over 67% indicating that there is a direct effect of the explanatory variables (Table 1).

The chemical-bromatological evaluations of hay are important because in animal feed the nutritional state of the animal depends mainly on this composition (Van Soest, 1994). When the basic variable was crude protein (*CP*), the leaf-stem ratio (*LS*) (0.58) resulted in the largest direct effect on *CP* because it was equal to the residual effect value (0.58) (Figure 2a), showing that this variable is the main determinant of *CP* variation providing greater impact in terms of selection gain. For total root yield (*TRY*) and starch it was observed in the unfavorable direction, -0.4 and -0.58 respectively (Figure 2a). This indicates the absence of cause and effect, ie, *TRY* and starch characteristics are not the main determinants of changes in the basic variable *CP*.

The *CP* content is a good measure of hay quality. It allows higher

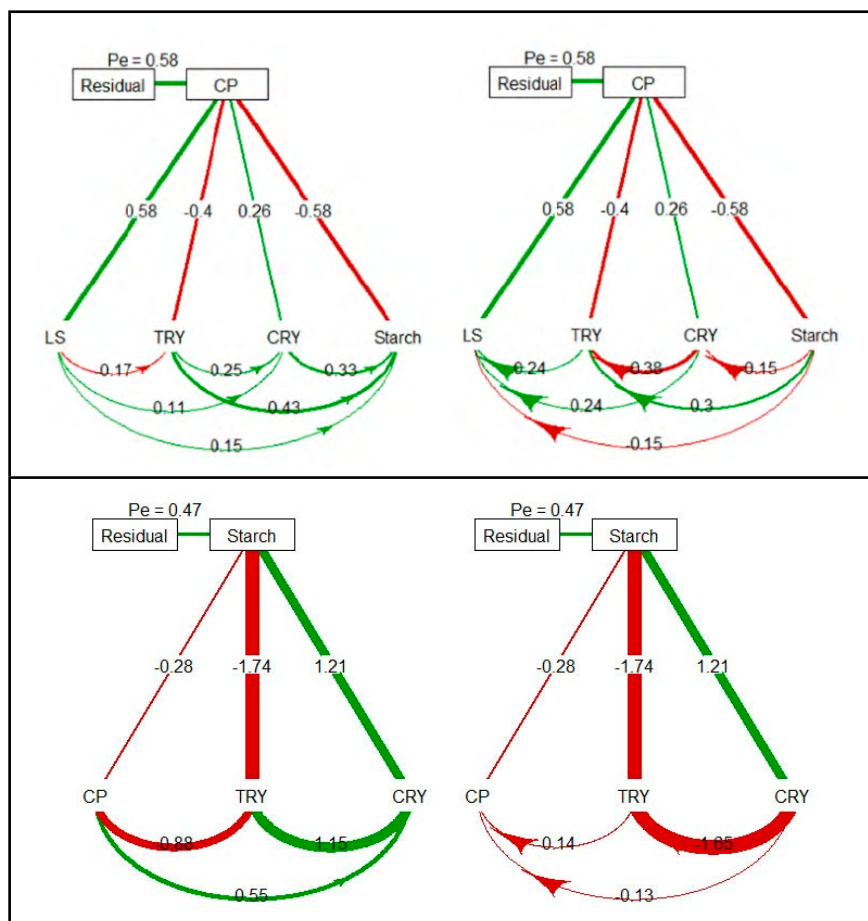


Figure 2. Unfolding of phenotypic correlations in direct (straight line) and indirect (arrow line) effects components in sweet potato hay involving a) dependent main variable (*CP*) and explanatory independent variables (*LS*, *TRY*, *CRY*, starch), b) dependent main variable (starch) and the explanatory independent variables (*CP*, *TRY*, *CRY*). Diamantina, UFVJM, 2015/2016.

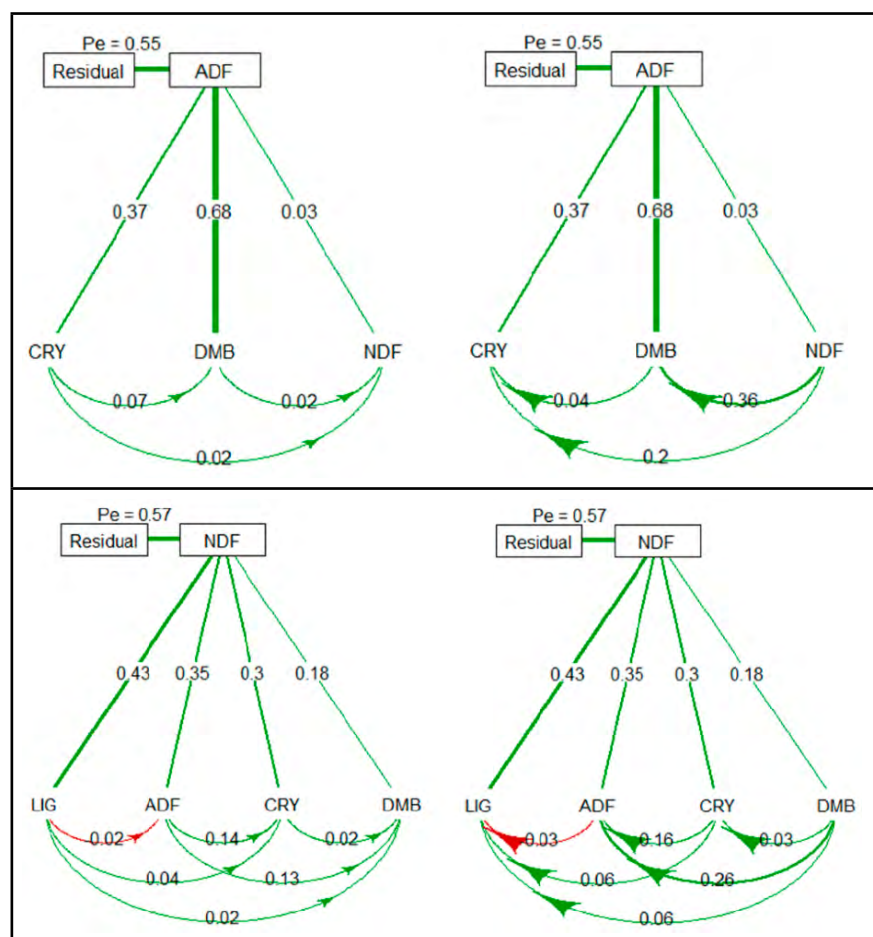


Figure 3. Unfolding of phenotypic correlations in direct effects (straight lines) and indirect effects (arrow lines) components in sweet potato hay, involving: a) dependent main variable (ADF) and explanatory independent variables (CRY, DMB, NDF), b) dependent main variable (NDF) and the explanatory independent variables (LIG, ADF, CRY, DMB). Diamantina, UFVJM, 2015/2016.

consumption of dry mass by animals, as the rumen nitrogen deficiency results in less growth of the rumen microbiota. This deficiency does not meet nutritional requirements, with decreased cell wall digestion and consumption (Wilson & Kennedy, 1996). Thus, crude protein is the most required ingredient after energy for the development of ruminant metabolic functions (Paiva *et al.*, 2013).

The presence of starch in the food is important because it plays a significant contribution in the rumen fermentation products. This improves the quality of the food, since the greater inclusion of concentrate in the diet tends to decrease ruminal pH and rumination and, consequently, buffering through saliva (Van Soest, 1994). However, sweet potato hay starch as the basic variable showed only a direct effect

with the characteristic commercial root yield (1.21) because its value is higher than the residual effect (0.47) (Figure 2b). However, the indirect effects of the CP and TRY characteristics were significantly negative, being these of greater relevance that determined the high correlation with starch.

For the basic variable acid detergent fiber (ADF), only the variable dry mass of branches (DMB) had some direct influence (0.68), since its value was higher than the residual effect (0.55) (Figure 3a). This relationship is desired in hay quality because dry mass content is useful for predicting or correcting storage problems and ADF content refers to food digestibility (Silva *et al.*, 2013). The other characteristics showed small positive direct and indirect effects on ADF content. Thus, in selecting

the dry mass characteristic, it is also selected directly for ADF.

Although the characteristics LIG, ADF, CRY and DMB were positively correlated with the basic variable NDF, they did not determine direct effect with it. This was due to the fact that these explanatory variables presented values below the residual effect (0.57) (Figure 3b). This shows that these characteristics had small indirect effects among them, being essential to predict these phenotypic correlations with NDF.

Differences between the direct and indirect effects of hay agronomic and chemical-bromatological characteristics may be due to the non-commercial genetic materials tested for the traits of interest. Therefore, results of different performances show the need for further research of these genotypes to achieve higher yields of roots, twigs and quality of sweet potato hay according to their suitability.

From the results presented, it is important to identify an association of sweet potato yield attributes with hay chemical characteristics. Thus, the association of highly correlated variables with the basic variable of greatest direct effect in favor of selection is preferable for the correlated response through indirect selection to be efficient. Therefore, the characteristics that positively correlated were CRY with CP, NDF, ADF; and the BDMY of NDF and TSS branches. As for the significantly positive direct effects: 1) in the basic variable PB with the variable LS; 2) ADF as basic variable as DMB content; and 3) basic variable starch CRY variable. However, when direct positive as well as high and negative indirect effects are observed, indirect selection may not provide satisfactory gains, as in the basic NDF variable and other characteristics, and in the starch basic variable with CP and TRY.

Thus, we concluded that selection for higher yield of roots and commercial roots can provide increased crude protein, neutral and acid detergent fiber, and total soluble sugars in the hay. Selection for the highest root yield has a negative effect on the starch content of hay, deserving special attention from the breeder.

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Evaluation of weed changes according to different fertilization management systems, through phytosociological analyzes in lettuce and carrot

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Abstract

The population dynamics of weeds due to different fertilization management systems is essential in the agricultural areas for the understanding of their interference and possible damages. The objective of this study was to evaluate the influence of different fertilization management systems on the weed community through phytosociological analyzes in lettuce and carrot crops grown in succession. The experimental design was a randomized block design, with eight treatments and four replications in each plant, following the same experimental layout. The treatments, referring to different management of fertilization were: Conventional; With Weeds; No Weeds; Compound; Crotalaria; Crotalaria more Compound; Lab-Lab and Lab-Lab + Compound. During cultivation of lettuce and carrot, we collected more than 3,000 weed specimens, representing 25 species distributed in 11 families, 88% dicotyledonous and 22% monocotyledonous. The weed families with the highest value of importance in all stages of collection were Asteraceae, Brassicaceae and Poaceae. The most representative species in the area were *Eleusine indica*, *Cyperus rotundus* L., *Galinsoga parviflora*, *Richardia brasiliensis*, *Oxalis latifolia*, *Cynodon dactylon* and *Conyza canadensis*. The different forms of fertilization and use of cover crops were able to promote changes in the weed community and decrease in the population density during the experimental period. The treatments contributed to reduce the daily amplitudes of thermal and water changes and the incidence of sunlight on the surface layer of the soil, delaying the emergence of these weeds and contributing to other soil benefits inherent to the use of each type of fertilization.

Keywords: hedge plants, lettuce, carrot, greenery, compost.

Abbreviations: UFVJM_ Federal University of Jequitinhonha e Mucuri Valleys; Den_Density; Der_ Relative density; Fre_frequency; Frr_Relative frequency; Abu_abundance; Abr_Relative abundance; IVI_ Importance value index

Introduction

In crop management studies, evaluations of weed dynamics and the impacts caused by the practices used in their control are fundamental to understand the interference and damage caused in agricultural areas. The presence of weeds is one of the factors that most compromises the environment in the growing areas, resulting in reductions in the production and quality of the final product. The weed species require the same factors that are also essential the cultivated crops for their development. Therefore, they establish a competitive process, when they develop with crops (Meneckelli et al., 2016). The establishment of a weed community depends on several factors, related to the crop (cultivated species, cultivar and spacing), the weed

community (specific composition, density and distribution) and the environment (climate, soil and crop management) (Pitelli, 1985). Therefore, the negative effects caused by the presence of these plants should not be attributed exclusively to competition, but rather to environmental pressures, which may be direct (competition, allelopathy, crop interference and others) and indirect (relation to pest insects, diseases and others) (Karam et al., 2006). In this way, it is important to invest in methods that help in the knowledge of these communities, so that they provide the culture with better conditions for growth and development and, at the same time, unfavorable to germination, emergence and addition of weeds. Thus, as a sustainable alternative has been increasingly recommended for weed

management and practices that promote conservation and improve the environment in a continuous way, maintaining ecosystem equilibrium (Borges et al., 2014). From the practices, the use of organic fertilizers and the cultivation of plants for the purpose of generating living and or dead cover for protection of the soil (straw), known as hedge plants can be highlighted (Silva et al., 2009; Correia et al., 2013). These cover crops provide soil benefits, since they protect against the impact of raindrops, improve their structure the water infiltration capacity, favor nutrient cycling and cause changes in the weed population (Borges et al., 2014).

To analyze the dynamics of growth and occupation of infested communities on the impact of management systems phytosociological indexes are sometimes used (Concenço, 2015; Pitelli, 2000). These were so important in the production areas, but were intentional to identify the intensity, frequency and dominance, and consequently, favor the choice of the best times and weed management strategies for each agro-ecosystem (Pitelli, 2000; Carvalho et al., 2007).

Researches on different forms of fertilization to assist in weed management are still incipient, evidencing the need for more consistent information in this regard. The population dynamics of weeds due to different fertilization management systems is essential in the agricultural areas for the understanding of their interference and possible damages. In addition, economic, social and ecological pressures to limit the use of chemical pesticides in production systems are currently driving research in the search for alternative procedures that promote less environmental and social impact.

In this context, it is expected that more conservationist practices, such as less soil rotation, the maintenance of its cover with plants and organic fertilization can reduce the density of weeds in olive crops in a way harmful to the environment. Thus, in the present work, we tried to evaluate the influence of different fertilization management systems on the weed community through phytosociological analyzes in lettuce and carrot crops. Thus, providing information that can be used more practically in the management of weeds is useful, aiming to reduce the use of herbicides and contributing positively to a more sustainable management.

Results and discussion

In the weed community in the studied area, 25 species were identified in the different treatments, distributed in 11 botanical families: Asteraceae (nine species), Brassicaceae (three species), Poaceae, Oxalidaceae and Amaranthaceae (two species each) and Cyperaceae, Lamiaceae, Rubiaceae, Brassicaceae, Caryophyllaceae, Commelinaceae, Portulacaceae (one species each) (Table 1). There was a greater predominance of families of dicotyledonous plants (88%) than monocotyledons (22%) in population weed species (Table 1).

The weed families found in this study resemble those identified in the soybean crop (Benedetti et al., 2009), cassava (Marques et al., 2010; Cardoso et al., 2013) and coffee (Maciel et al., 2010). The first three authors reported that the Asteraceae family was the owner of a large number of species. Maciel et al. (2010) performed a

phytosociological survey on organic coffee plant and found similar results like this study on Poaceae weed family.

The high number of families of dicotyledon weeds was also verified by Cunha et al. (2016) who found that 66% of dicotyledonous weeds were cultivated in conventionally cultivated papaya. Evangelista et al. (2015) studied spontaneous plants in vegetables grown on organic system and found eight families of dicotyledonous class and two monocotyledons.

It was observed that although dicotyledons had a higher occurrence than monocotyledons, they had higher percentages of quantified individuals such as grasses and cyperaceae. This is because most of them are C4 plants with narrow leaves and deeper root system, presenting greater initial competitiveness. These plants are adapted to environmental conditions such as high light intensity, high temperature and drought (Christin et al., 2014), except for the *Amarantus* sp. species, which does not have the above mentioned characteristics common to most C4 species.

In the initial periods of coexistence, the species that had higher densities were *Cyperus rotundus*, *Eleusine indica* and *Cynodon dactylon* (Fig. 1). In the evaluation period before planting of crops, it was verified that besides the species *Cyperus rotundus* there was an increase in the number of plants of *Galinsoga parviflora* and *Oxalis latifolia*. For the evaluation period after lettuce planting, the species with the highest density was *Oxalis latifolia*, followed by the species *Cyperus rotundus*. In the last evaluation period, after planting the carrot, *Cyperus rotundus* remained the species with the highest density of weeds, followed by *Galinsoga parviflora*, *Oxalis latifolia* and *Conyza canadensis*.

The above-mentioned species, found in the initial period of coexistence, also presented representativeness in onion (Soares et al., 2004), okra (Santos et al., 2010; Bachega et al., 2013) and eggplant. These species may have been benefited at the beginning of cultivation because they have more available environmental factors, such as water, high temperature, light and naked soil. In this initial evaluation period (Fig. 7), temperatures varied between 15 and 29°C, with low precipitation in the area and high relative humidity, conditions. In such conditions C4 species can develop better compared to C3, since they present fast initial growth and vigorous canopy, making them highly competitive with higher rates of photosynthesis (Christin et al., 2014).

For the periods after planting lettuce and carrot, we observed that condition more favored the development of C3 species. This may have occurred due to the shading caused by the crops and also to the milder temperatures in these evaluation periods, since C3 species are favored by lower availability of radiation (Christin et al., 2014).

During the evaluation periods, there was a decrease in the density of weed species. For example, density of *Cyperus rotundus* as the species with the highest density was dropped (Fig. 1). Kumar et al. (2012) reported that in natural infestations of weeds, *Cyperus rotundus* appears in larger numbers. However, in contact with other weeds, grasses or broad leaves, its vigor and growth can be reduced by the pressure of other species. Thus, in the experimental area, when the crops were planted, they shaded the area, hindering the development of this species.

The density of weeds in the initial period of coexistence was the period that presented the highest values in all the

treatments (Fig. 2). This is due to the competition effects of weeds in the early stage of the crop development cycle, which with early germination will be able to compete for the resources of the environment, hampering development and productivity (Meneckelli et al., 2016). In this aspect, weeds with greater vegetative canopy become dominant and can develop better in the area, becoming a major problem for the development of crops. On the other hand, weeds with lower vegetative canopy are suppressed or die, leading to crops advantage over their development. It should be noted that in the initial period of evaluation, there was still no crop planting and neither the plots that would be applied to the chemical fertilizers. So, it had low weed density in relation to the treatments that used in the plots with same source of soil nutrient availability. In the plots with cover crops as treatments, they were still under development in this period, having no effect as a soil cover. However, the legumes used as cover plants may have presented higher values of weeds, due to the potential of these species used as a source of nutrients for the soil. This is because the crotonaria forms symbiotic association with soil bacteria (rhizobia) and takes advantage of the nitrogen fixed in the air by these microorganisms, providing a reduction in the need for nitrogen fertilizer application (Pereira et al., 2005). This may have contributed to better development.

However, the high density observed for the weed treatment (Fig. 2) may have occurred due to the presence of the weed communities in the area, since these were kept as cover in the plots. They have ability to regrow faster than other treatments, for example in the treatments, in which weeds were removed from the plots during the control. Development of weeds may only seem beneficial to the crop if they can be considered as cover plant.

Galvão et al. (2013) showed that the system of organic weeding of lettuce on straw of weeds is efficient for providing superior productivity and less requirement in organic fertilization. Bezerra et al. (2004) reported the efficacy of weeds in reducing agricultural pests. Sakonnakhon et al. (2006) favored the biomass and nutrients cycling by weeds with improvements in soil physical conditions.

It was verified that all the treatments contributed to the reduction of weeds in the area. The fertilizations caused physical changes in the soil, which delayed the emergence of weeds. In addition, they provided favorable environmental conditions for weed control, such as reduction of daily amplitudes of thermal and water changes and the incidence of sunlight on the surface layer of the soil. This reduction has a great impact on the germination of seeds of invasive plants, which occur in olive groves, thus contributing directly to their control (Pitelli, 1985).

Weed species that presented the highest phytosociological indexes (relative frequency, relative abundance, relative species dominance and importance value index) in the area in the evaluation period prior to planting of crops were *Cyperus rotundus*, *Galinsoga parviflora*, *Oxalis latifolia*, *Eleusine indica*, *Conyza canadensis*, *Cynodon dactylon* and *Richardia brasiliensis* (Fig. 3). In general, it was observed that in the treatments with cover crops, the C3 metabolic species had the highest relative frequency, relative density and relative abundance indices in the area (Fig. 3E, 3F, 3G and 3H), in addition to the C4 species *Cyperus rotundus*.

Although *Cyperus rotundus* was a species with higher index of importance value for the treatments without the use of cover plants, it was verified that for the treatments Without weeds and With weeds, the species with C4 metabolism (*Cynodon dactylon*) also presented relative frequency index, relative density and relative abundance. This fact may be related to the empirical florals for the development of species with a type of photosynthetic metabolism, since the year of study was occurred in the summer, and that the type of growth was higher and the relative ratio was high (Fig. 7). Deuber et al. (2004) reported that this is an invasive species in beet culture and has also occurred in other vegetables (Zanatta et al., 2006). For the evaluation period after lettuce planting, we observed a decrease in the density of weed species and a change in the importance of the species in the area (Fig. 4). In the Conventional treatment, *Cyperus rotundus* and *O. latifolia* (Fig. 4A) were the species that presented the highest importance value, differently from the previous evaluation (Fig. 3A), in which *Galinsoga parviflora* had been the most representative species. In the CPD treatment (Fig. 4B), *Cyperus rotundus* remained with a high importance value index, but we observed a decrease of the C4 species, as previously identified. This difference between the number of weeds sampled can be explained by the architecture of the cultivated plants, because the plants shading more like the lettuce, discourage the emergence of weeds. For the treatment Without weeds (Fig. 4C) an increase in the importance value index of the species *Cynodon dactylon* was observed, and its metabolism was benefited in this treatment. For the treatments using compound (Fig. 4D, 4E and 4H) and cover plants (Fig. 4E, 4F, 4G and 4H), a higher index value was found, mainly for *Oxalis latifolia* (C3 species). Its development was favored by shading, lower temperatures and better chemical and physical soil conditions. Thus, both the treatments using organic compost, and those using cover crops were beneficial for the development of these plants. The presence of organic fertilization may have contributed to the improvement of soil structure and microbiological activation. With increase in organic matter content, plant resistance to pest and disease attack, cation retention (Ca, Mg and K) and the effect of soil moisture protection were increased. For the control of weeds, the effect of Crotonaria is related to the variations in the thermal and soil amplitudes. The amount of light filtered by the straw affects the dormancy and, consequently, the germination of the weeds (Borges et al., 2014). Lab-Lab, because of its indeterminate, low growth, confers greater capacity to its branches and leaves that distribute better and closer to the soil, presenting a greater capacity to smoothing the soil, forming an environment more conducive to the development of C3 plants (Favero et al., 2001). Regarding the evaluations made in the final period, after planting the carrot, we observed another change in the importance of weeds (Fig. 5). For the Conventional treatment (Fig. 5A), the species *Cyperus rotundus* again presented the highest importance value index and the *Galinsoga parviflora* was the second species with the highest importance value index. For the treatments using cover plants we observed an increase in frequency, density and relative abundance indexes for *Cyperus rotundus* species and also for *Conyza canadensis* species.

Table 1. List of weeds found in the experimental area, identified by scientific name, family, common name, botanical classification and metabolism.

Species	Family	Popular name	Classification	Metabolism
<i>Eleusine indica</i>	Poaceae	Chicken foot	Monocotyledonou	c4
<i>Cyperus rotundus</i>	Cyperaceae	Tiririca	Monocotyledonou	c4
<i>Galinsoga parviflora</i>	Asteraceae	Buttercup	Dicotyledonou	c3
<i>Bidens pilosa</i>	Asteraceae	Picão	Dicotyledonou	c3
<i>Leunurus sibiricus</i>	Lamiaceae	Ruby	Dicotyledonou	c3
<i>Richardia brasiliensis</i>	Rubiaceae	Poaia	Dicotyledonou	c3
<i>Oxalis latifolia</i>	Oxalidaceae	Clover	Dicotyledonou	c3
<i>Amarantus sp.</i>	Amaranthaceae	Caruru	Dicotyledonou	c4
<i>Cynodon dactylon</i>	Poaceae	Silk grass	Monocotyledonou	c4
<i>Siegesbeckia orientalis</i>	Asteraceae	Buttercup	Dicotyledonou	c3
<i>Conyza canadensis</i>	Asteraceae	Buva	Dicotyledonou	c3
<i>Taraxacum officinale</i>	Asteraceae	Dandelion	Dicotyledonou	c3
<i>Coronopus didymus</i>	Brassicaceae	Mastruço	Dicotyledonou	c4
<i>Lepidium virginicum</i>	Brassicaceae	Mastruço/mentruz	Dicotyledonou	c3
<i>Raphanus raphanistrum</i>	Brassicaceae	Nabiça	Dicotyledonou	c3
<i>Stellaria media</i>	Caryophyllaceae	Finch herb	Dicotyledonou	c3
<i>Commelina benghalensis</i>	Commelinaceae	Ragged	Dicotyledonou	c4
<i>Portulaca oleracea</i>	Portulacaceae	Purslane	Dicotyledonou	cam
<i>Chenopodium ambrosioides</i>	Amaranthaceae	Herb of Santa Luzia	Dicotyledonou	c3
<i>Ageratum conyzoides</i>	Asteraceae	Mentrasto	Dicotyledonou	c3
<i>Bidens subalternans</i>	Asteraceae	Black picket	Dicotyledonou	c3
<i>Emilia fosbergii</i>	Asteraceae	False mountain	Dicotyledonou	c3
<i>Parthenium hysterophorus</i>	Asteraceae	Losna	Dicotyledonou	c3
<i>Sonchus oleraceus</i>	Asteraceae	Milkweed	Dicotyledonou	c3
<i>Oxalis corniculata</i>	Oxalidaceae	Trevinho	Dicotyledonou	c3

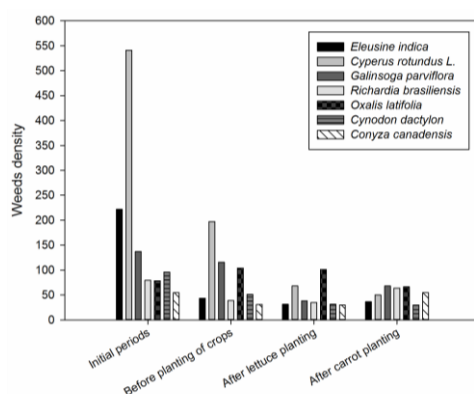


Fig 1. Relationship between weed density and coexistence period of the most representative species of the experimental area.

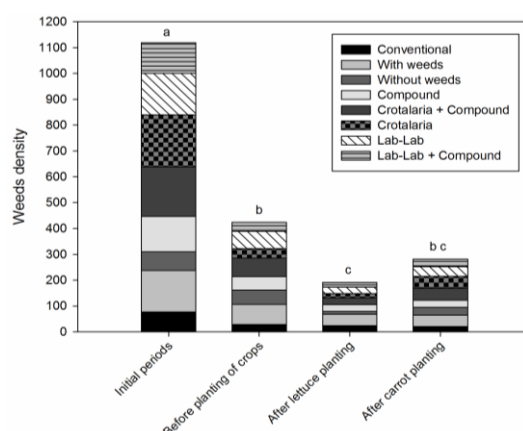


Fig 2. Density of weeds for the different periods of coexistence of plants of each treatment. The treatments with equal letters do not present significant difference according to the Tukey test ($p < 0.05$).

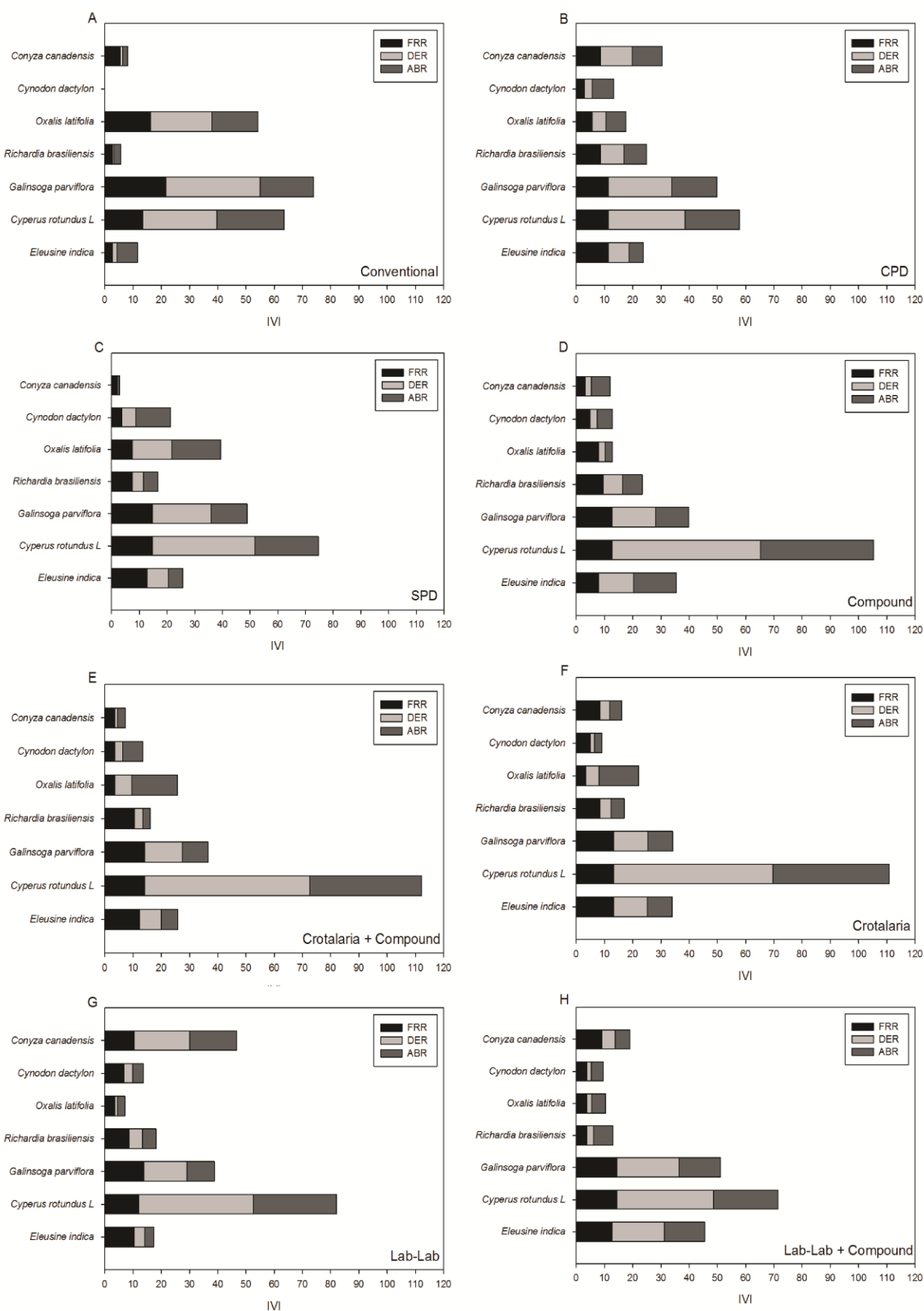


Fig 3. Relative frequency (FRR), relative density (DER), relative abundance (ABR) and importance value index (IVI) of weeds prior to planting of lettuce, according to treatments: (A) Conventional; (B) CPD- with weeds; (C) SPD- without weeds; (D) Compound; (E) Crotalaria + Compound; (F) Crotalaria; (G) Lab-Lab + Compound; and (H) Lab-Lab.

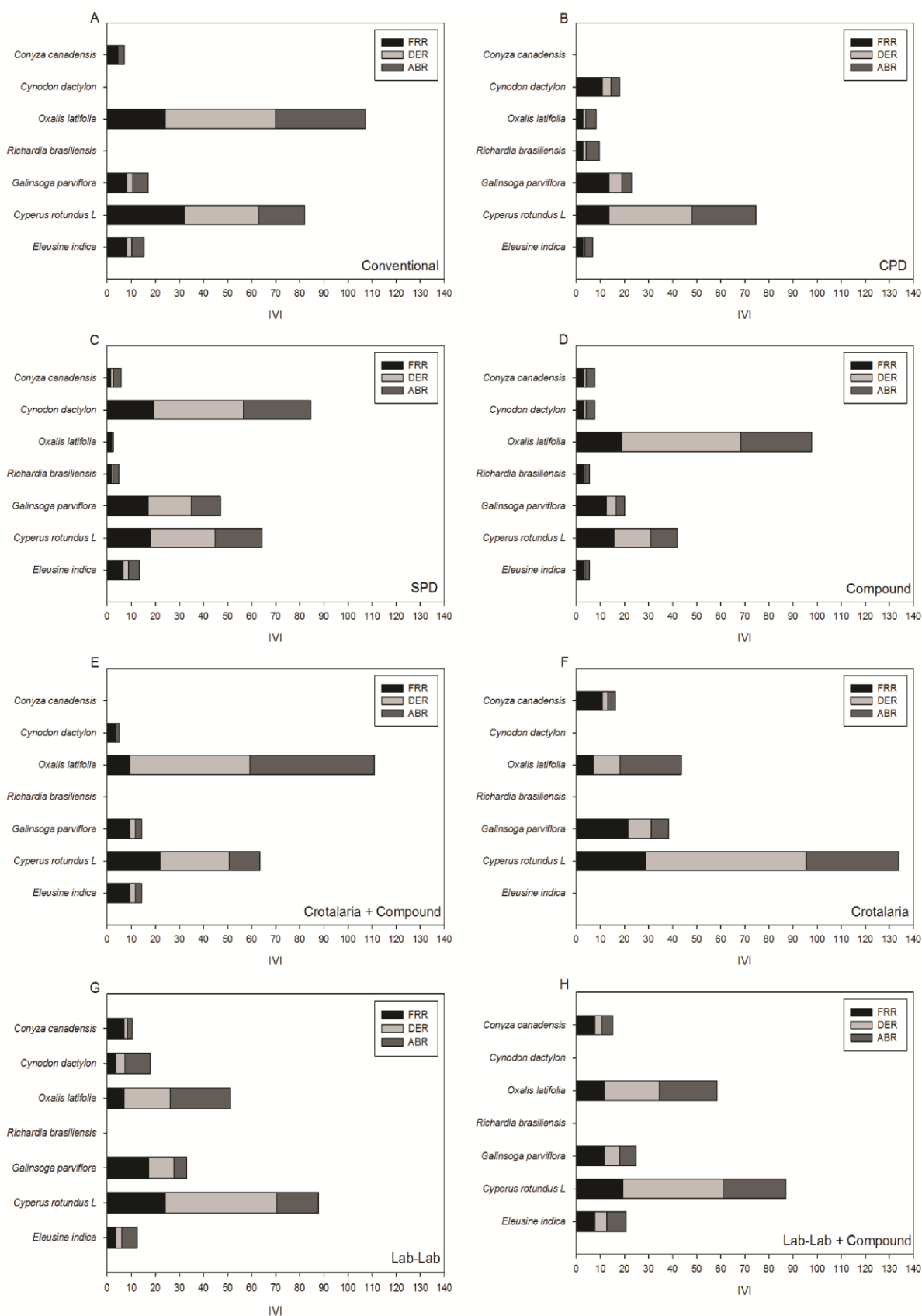


Fig 4. Relative frequency (FRR), relative density (RER), relative abundance (ABR) and importance value index (IVI) of weeds after planting lettuce, according to the treatments: (A) Conventional; (B) CPD- with weeds; (C) SPD- without weeds; (D) Compound; (E) Crotalaria + Compound; (F) Crotalaria; (G) Lab-Lab + Compound; and (H) Lab-Lab.

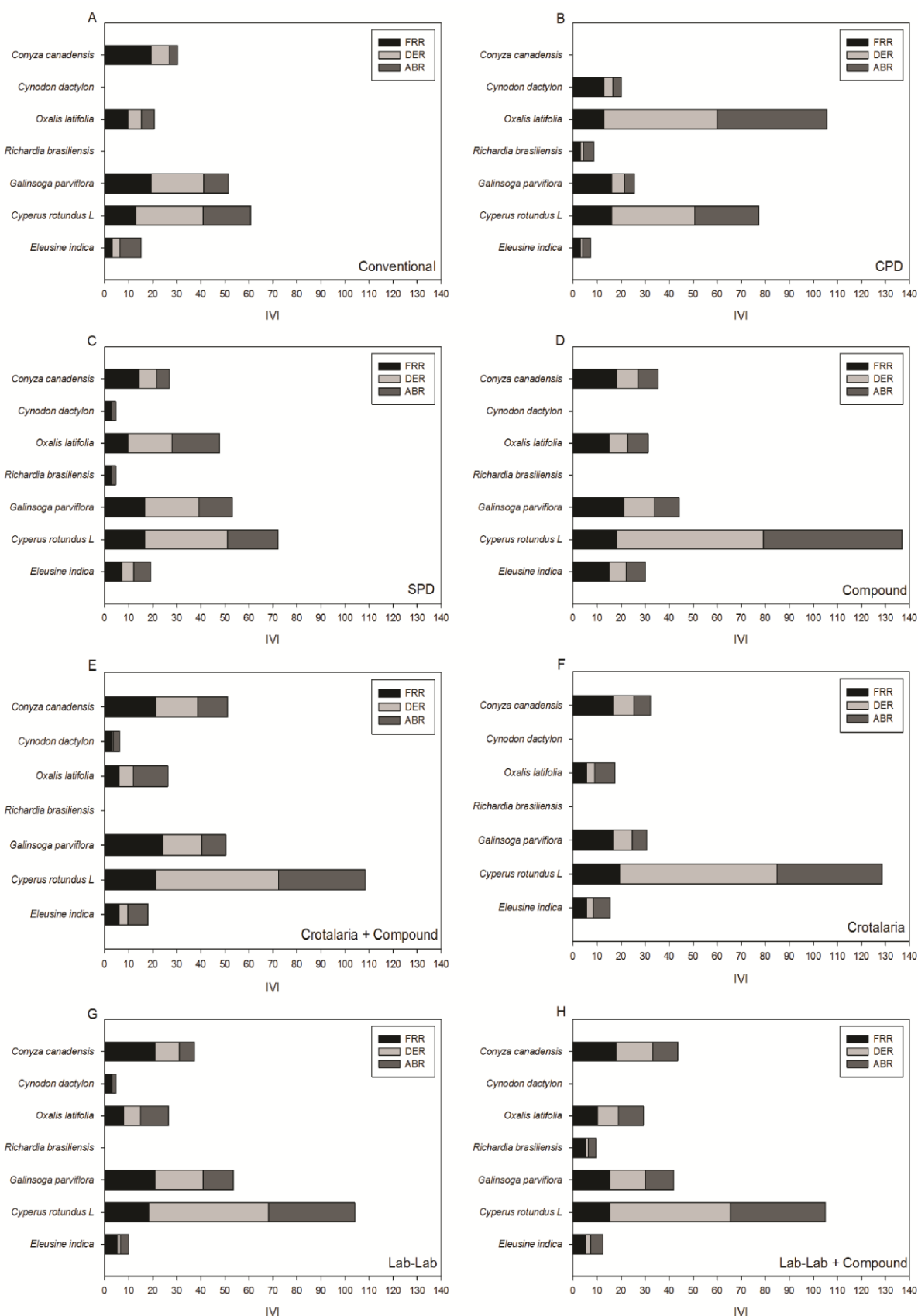


Fig. 5. Relative frequency (FRR), relative density (RER), relative abundance (ABR) and importance value index (IVI) of the weeds after planting the carrot, according to the treatments: (A) Conventional; (B) CPD- with weeds; (C) SPD- without weeds; (D) Compound; (E) Crotalaria + Compound; (F) Crotalaria; (G) Lab-Lab + Compound; and (H) Lab-Lab.

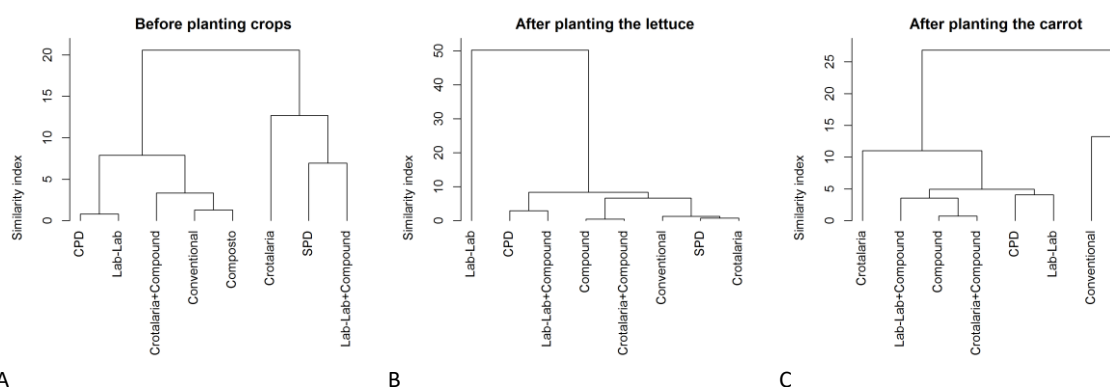


Fig 6. Similarity index among the eight treatments (Areas) in the different evaluation periods. (A) Before planting crops; (B) After planting the lettuce; (C) After planting the carrot.

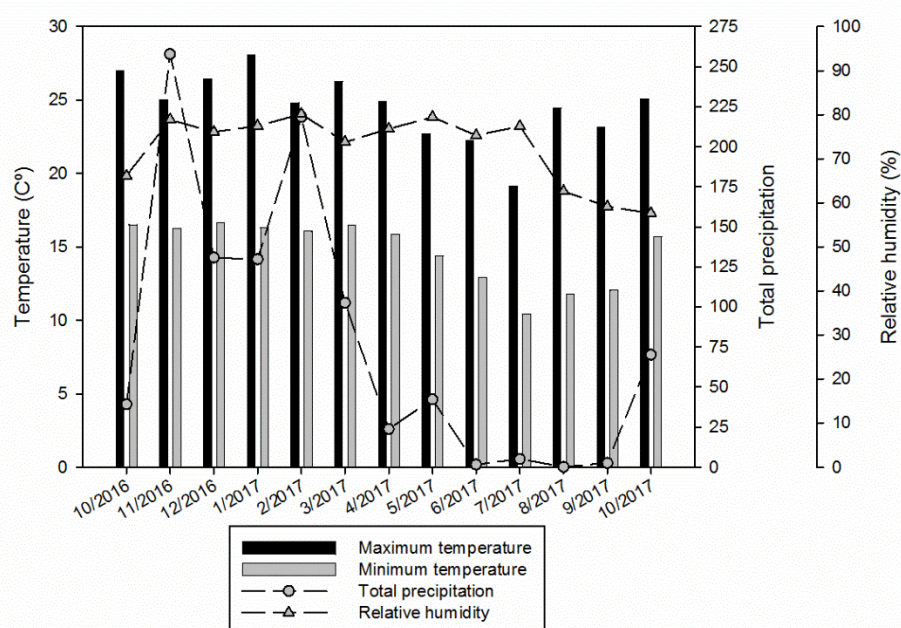


Fig 7. Maximum, minimum temperature, total precipitation and relative humidity of the experimental area during the work period of conduction.

This fact could have occurred due to climatic and environmental conditions favorable to the development of these species and also to the power of covering the soil of the legumes used. It is known that cover crops provide improvements in the chemical and physical conditions of the soil and that when using the resources of the medium for its growth can reduce the development and the production of weeds seeds, contributing to the exhaustion of the seed banks (Borges et al., 2014).

For all evaluated periods and among the species identified in each treatment, *C. rotundus* was the one that presented the highest value of importance in all surveys, being the most representative species in this study. Species of the genus *Cyperus* have a great competitive capacity, being able to affect several cultures (Monquero, 2014). It presented wide adaptation and good dissemination, found in all types of soil and climate, having both sexual and asexual reproduction (Panozzo et al., 2009). These factors are well evidenced in the present work, since the genus was present in all treatments, noting that the high relative density of this species in the different treatments may be related mainly to

its biology, which may have been benefited by environmental conditions.

In a given crop, it is difficult to estimate which species of weeds were most damaging to the crop, but it is assumed that those with the highest phytosociological indexes are the most problematic. Usually in a community, all species cannot present the same intensity in the interference imposed on the crop development. Therefore, we verified that *Cyperus rotundus*, *Galinsoga parviflora* and *Oxalis latifolia* were the species with the highest numerical representativity in almost all the evaluations made in the different periods. It shows that for these species, greater attention should be paid to the management and control, because they can even make farming unfeasible in the infested area.

The treatments that had the greatest similarity in the period before planting the crops according to the floristic similarity index were with weeds and Lab-Lab (Fig. 6A), as previously seen, these treatments showed very close plant densities. At the same time, the lowest species similarity was observed for the Conventional and Crotalaria treatments.

In the evaluations made after planting the lettuce (Fig. 6B), it was verified that the greatest similarity of species occurred for the treatments Compost and Crotalaria + Compost. The treatments that presented the lowest similarity of species were the Conventional and Lab-Lab treatments. After the sowing of the carrot, there was a higher species similarity (Fig. 6C) for the treatments Compost and Crotalaria + Compost. Conventional and Crotalaria treatments had the lowest species similarity.

According to Carvalho and Pitelli (1992), similarity indexes are not only related to the soils or the distance between areas, but also to the forms of management used in these areas. These changes may influence the germination and development of weeds and, consequently, weed management strategies considered more important. It should also be emphasized that the similarity index is usually calculated according to the individual species present.

Thus, it was observed that the highest similarity throughout the evaluations were occurred for the treatments Compost and Crotalaria + Compost, evidencing that the management of fertilization of these treatments may have aided in the emergence of similar weeds, besides the effects of the crops, since these results were obtained in post-planting evaluations of lettuce and post-planting of the carrot.

Therefore, this study was able to provide more information about the weed community through the evaluation of phytosociological parameters, along with the evaluation of weed density and similarity. It is possible to perceive differences of emergence of weed species according to different season and fertilization management in lettuce and carrot crops in succession.

Materials and methods

Plant materials

Two different cultures, carrot and lettuce, were used for the experimental trial. The cultivar of lettuce was Veneranda, which is characterized as tolerant to the LMV virus, early tillage and edge burning. The carrot cultivar used was Nantes Milena, which is characterized as fall/winter cultivar, cylindrical in shape, dark orange and high in carotene content.

Treatments

The treatments represent the use of different management of fertilization in lettuce and carrot crops, in succession.

The management of the fertilizers consisted of organic fertilizers (organic compost), minerals (mineral fertilizer) and green manure (legume residues), totally eight treatments:

- i. Treatment 1 (T1) = Conventional fertilization according to technical recommendations for lettuce and carrot cultivation, according to the '5ª aproximação' (Ribeiro, 1999);
- ii. Treatment 2 (T2) = With weeds, without fertilization and control of weeds only in the crop lines, remaining in the soil in the surrounding area;
- iii. Treatment 3 (T3) = No Weeds, control treatment, without fertilization and weed control in all areas;
- iv. Treatment 4 (T4) = Compound, organic fertilizer, having as feedstock quail bed and crushed dry grass (1:10);

- v. Treatment 5 (T5) = Crotalaria + Compost, use of *Crotalaria juncea* as soil cover plant and compost as organic fertilizer;
- vi. Treatment 6 (T6) = Crotalaria, with the use of the leguminous species *Crotalaria juncea* as ground cover plant;
- vii. Treatment 7 (T7) = Lab-Lab, using the leguminous species *Lab-Lab purpureus* as a soil cover plant; and,
- viii. Treatment 8 (T8) = Lab-Lab + Compound, using *L. purpureus* as a soil cover plant and the compound as organic fertilizer.

Experimental design and assay

The experiment was conducted from October 2016 to November 2017 in the experimental field area of the Juscelino Kubitschek Campus, Federal University of the Jequitinhonha and Mucuri Valleys (UFVJM), in Diamantina/MG - Brazil, located at 18°12'01 "S, 43°36'20"W at 1,400 m altitude.

The climate of the region is characterized as temperate humid, with dry winter with mild temperatures and mild summer with more rainy periods. The average annual precipitation is approximately 1,404 mm with a rainy period from October to March, when 88% of the precipitate total occurs during the year. The minimum and maximum temperatures found during the experiment were 14.1 °C and 23.7 °C, respectively (Fig. 7). The soil of the experimental area is classified as Quarantine Neosol (Santos et al., 2013), with 83% sand, 10% clay and 7% silt.

The experiment in the field was conducted in a randomized complete block design with four replications. Each replicate contained eight crop lines (beds) to allocate the eight treatments spaced 0.5 m apart, with each plot containing 1.0 m wide and four rows 5 m long.

Before the implementation of the field experiment, the lettuce seedlings were previously produced by the direct sowing method in styrofoam trays in inverted pyramid format, containing 128 cells with commercial substrate under greenhouse conditions, with three lettuce seeds per cell. After emergence, one seedling was maintained per cell, being able to transplant in the field when they had 4 to 6 leaves (approximately 30 days).

The lettuce seedlings were planted in the field, with spacing of 0.25 x 0.25 m, totally 80 plants per plot. After 66 days, their harvesting was performed. After the lettuce was harvested, the carrot was planted directly in the beds, in grooves in the direction of the width of the bed with depth of 1 cm. The grooves used for the sowing of the carrot were made with spacing's of 25 cm, where the seeds were evenly distributed. After 25 days of sowing, thinning was done in the crop, leaving a spacing of 6 cm between the plants. The carrot harvest was occurred on October 4, 2017, 96 days after sowing.

Ten days before transplanting of lettuce seedlings in to the field and after the fallow period of cover plants used, the fertilization of planting was carried out with NPK and more organic fertilization with bovine manure (50 t ha⁻¹) and cover fertilizations with N and K₂O at 15, 30 and 40 days. For the treatment with Weeds, the area was maintained with weeds as vegetation cover, and for the treatment Without Weeds, these plants were totally removed from the area. In the treatment of organic compost, 6 L m⁻² of organic compost was applied to the plot. *Crotalaria juncea* (Crotalaria) and

Lab-lab purpureus (Lab-Lab) legumes were used for the treatments with the use of plants as plant cover, and these were planted according to Embrapa's recommendations (2014), at depths of 2 to 3 cm, with spacing between the grooves of 20 cm and density of 40 seeds per linear meter of groove. When these species presented 50% flowering, they were cut close to the soil and arranged on the beds, without incorporation in to the soil. The legumes were left fallow in the beds for approximately 30 days. After that period, it was transplanted with lettuce seedlings. When the treatment was the organic compound with some leguminous, the compound was applied to the soil only at the time of planting the green manures, and after the flowering of these, they were cut close to the soil and placed as mulch and reapplied again as the organic compound, 6 L m⁻².

Weed community assessment

The phytosociological study was carried out every 20 days, from the sowing period of the cover crops until the carrot harvest period. Before the consolidation of the experiment, weeds were sampled in the total area. The classification was based on the Angiosperm Phylogeny Group III (2009) system, with assistance in the delimitations of families and the ordering of some genera, according to Souza and Lorenzi (2005). In addition, specific literature was used to identify and quantify weed species present in any experimental area (Kissman and Groth, 2000; Lorenzi, 2008), as well as bibliographies of medicinal plants, ornamental plants, dissertations and theses related to the subject.

For each treatment, weed samples were collected using a 0.25 m² area, cast randomly twice in each plot (Braun-Blanquet, 1979; Erasmo et al., 2004), to be identified, quantified and separated by species and families.

From the counting of the present species, the phytosociological indexes were calculated: i) Density (Den): total number of individuals per species/total area collected; (ii) Relative density (Der): density of species x 100/total frequency of all species; iii) frequency (Fre): number of parcels containing species/total number of parcels used; iv) relative frequency (Frr): species frequency x 100/total frequency of all species; v) abundance (Abu): total number of individuals per species/total number of plots with the species; vi) relative abundance (Abr): abundance of species x 100/total abundance of all species; vii) Import Value Index (IVI): Frr + Der + Abr.

For the evaluation of the weed community in the area, the different periods of development of the experiment were considered, so the periods evaluated were separated into four: i) period prior to planting of the crops, when the treatments had not yet been applied in the area; ii) period prior to lettuce planting, referring to the development period of the cover plants; iii) period after the planting of lettuce; and iv) period after planting the carrot.

Statistical analysis

The Shapiro-Wilk test ($p < 0.05$) and analysis of variance was performed according to the F-test for all treatments ($p < 0.05$), considering the block design and analysis in time subdivided plots. After detecting the significance of the

treatments, the averages were compared using the Tukey test at 5% level of significance.

In order to compare weed communities established in each evaluation period, considering each treatment group distinctly, the Sorensen floristic similarity index (Ss) was used: $2a/(2b + b + c)$, where: a = number of species common to both plots or communities; b = number of species occurring in plot 2 or community 2; and, c = number of species occurring in plot 1 or community 1. After that, a two-dimensional diagram (dendrogram) was constructed, using the middle link method (UPGMA) as hierarchical grouping method and the distance measure was Euclidian. All statistical analyzes were performed using the R (R Core Team, 2017) software.

Conclusion

The main weed species found in all evaluation periods were *Eleusine indica*, *Cyperus rotundus*, *Galinsoga parviflora*, *Richardia brasiliensis*, *Oxalis latifolia*, *Cynodon dactylon* and *Conyza canadensis*. *Cyperus rotundus* was the species with the highest phytosociological indexes, being characterized as the weed with the greatest potential of competition with the lettuce and carrot crops, under different management of fertilization. In the studied olive cultivation, there was a predominance of dicotyledonous weeds, although monocotyledonous species had higher species density. It was verified that the cultivation and the use of cover crops contributed to the reduction of weed infestation in lettuce and carrot crops, and are therefore recommended for use in the control and suppression of weeds in olive groves.

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Agronomic characteristics and postharvest quality of strawberry in a semi-hydroponic cultivation system

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Abstract – The objective of this work was to evaluate the influence of using a semi-hydroponic system on the agronomic and postharvest variables of strawberry cultivars. The experiment was conducted in a randomized complete block design, with cultivars Aromas, Camarosa, Festival, Merced, Oso Grande, and San Andreas, with eight plants per plot and five replicates. Agronomic and postharvest variables were evaluated. Cultivar San Andreas showed the highest values for the agronomic variables number of commercial fruits and total and commercial yield per plant, with the highest yield in October, November, and December. The postharvest variables moisture, firmness, pH, titratable acidity, and reducing sugars did not differ between cultivars. In a semi-hydroponic system, the San Andreas cultivar presents the best results for the agronomic variables related to fruit yield, with the highest yield in October and November.

Index terms: *Fragaria x ananassa*, cultivars, protected cultivation, yield.

Características agrônômicas e qualidade pós-colheita de morango em sistema de cultivo semi-hidropônico

Resumo – O objetivo deste trabalho foi avaliar a influência do uso de sistema semi-hidropônico sobre as variáveis agrônômicas e de pós-colheita de cultivares de morangueiro. O experimento foi conduzido em delineamento de blocos ao acaso, com as cultivares Aromas, Camarosa, Festival, Merced, Oso Grande e San Andreas, com oito plantas por parcela e cinco repetições. Foram avaliadas variáveis agrônômicas e de pós-colheita. A cultivar San Andreas apresentou os maiores valores para as variáveis agrônômicas número de frutos comerciais e produção total e comercial por planta, com as maiores produtividades em outubro, novembro e dezembro. As variáveis de pós-colheita umidade, firmeza, pH, acidez titulável e açúcares redutores não diferiram entre as cultivares. Em sistema semi-hidropônico, a cultivar San Andreas apresenta os melhores resultados para as variáveis agrônômicas de produção de frutos, com as maiores produtividades em outubro e novembro.

Termos para indexação: *Fragaria x ananassa*, cultivares, cultivo protegido, produtividade.

Introduction

Strawberry (*Fragaria x ananassa* Duch.) is cultivated worldwide, with China being its largest producer (Lima et al., 2021; FAO, 2023).

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However, in South America, Brazil is responsible for most of the production of strawberries, the main species of small fruits grown in the continent (Chiomento et al., 2021; Santos et al., 2021). Strawberries are valued due to their typical flavor, aroma, and color, also being a healthy diet option, providing essential nutrients and high levels of vitamin C and folic acid when consumed in natura or in processed foods (Galvão et al., 2017; Hernández-Martínez et al., 2023).

Strawberries are currently grown in soil or in a hydroponic system with or without substrate (Oliveira et al., 2017). In conventional cultivation, soil is the used growth medium, providing support, nutrients, air, and water to the plants; however, the presence of pathogenic organisms, nematodes, poor drainage, and compaction are some of the problems reported in this system (Fussy & Papenbrock, 2022).

In the hydroponic system, cultivation is carried out either without soil or any aggregates or with the presence of inert substrates, in which plant roots reach an aerated nutrient solution that can be fluid or static (Fussy & Papenbrock, 2022). Within soilless cultivation, the use of a substrate as an inert support for plant roots differentiates the semi-hydroponic system from the hydroponic one (Fernandes et al., 2021).

The production of strawberries through soilless cultivation has increased as it is a relatively simple technique, characterized by the lack of soil diseases and a reduced incidence of pests, minimizing or eliminating the use of pesticides, as well as by readily-available nutrients to the plants and no mechanical impediment for the development of their root system

(Sharma et al., 2018; Ameri et al., 2020). Furthermore, soilless cultivation is more practical since gardening can be done on benches above ground level (Miranda et al., 2014).

In this scenario, a key factor to be studied is the interaction between soilless cultivation system and planted cultivar, whose selection, in addition to consumer preference and location, also depends on the type of production system used (Lima et al., 2021; Hernández-Martínez et al., 2023). According to Wortman et al. (2016), most strawberry cultivars available to farmers are developed under soil-based field conditions in traditional strawberry production regions (Wortman et al., 2016). Therefore, the yield and fruit quality of strawberry cultivars produced in a soilless cultivation system need to be better evaluated, as these are necessary information for regions where producers are interested in this production system (Guimarães et al., 2015; Wortman et al., 2016; Diel et al., 2018).

The objective of this work was to evaluate the influence of using a semi-hydroponic system on the agronomic and postharvest variables of strawberry cultivars.

Materials and Methods

The experiment was carried out in a greenhouse, with an arched roof and open sides, at the farm of the Mape Frutas Ltda company, located in the municipality of Datas, in the Alto Jequitinhonha region, in state of Minas Gerais, Brazil (18°26'44"S, 43°39'21"W, 1,244 m above sea level). Maximum, average, and minimum temperatures during the 2018-2019 experimental period in the greenhouse are shown in the Figure 1. The shelter, without temperature control, contained benches suspended 1.0 m from the ground, on which plastic bags, filled with substrate composed of coconut fiber (slabs), were placed for the seedlings to be planted in. The climate of the region is warm to temperate, classified as Cwb according to Köppen-Geiger, with 1,416 mm precipitation.

Postharvest analyses were performed at the Cerrado Technology Laboratory of Universidade Federal dos Vales do Jequitinhonha and Mucuri (UFVJM), in the municipality of Diamantina, in the state of Minas Gerais, Brazil.

The Aromas, Camarosa, Festival, Merced, Oso Grande, and San Andreas strawberry cultivars were evaluated in a randomized complete block design, with eight plants (spaced 12 cm from each other) per plot, with five replicates. Cultivars Aromas and San Andreas are classified as neutral day, and Camarosa, Festival, Merced, and Oso Grande as short day (Chiomento et al., 2021). The commercial fruit yield was evaluated monthly per harvest in a split-plot arrangement, with the cultivars as the main plot and the harvest season as the subplot.

Class 2 strawberry seedlings, with a crown diameter between 5.1 and 8.0 mm, were used (Guimarães et al.,

2015). The seedlings were planted in slabs on 6/15/2018 and fertigated with nutrients applied automatically using the HidroFerti direct injection (Hidrosense, Jundiaí, SP, Brazil), with an electrical conductivity of 1.2 mS cm⁻¹, maintaining the nutritional levels recommended for the crop (Portela et al., 2012). The fertilizers were diluted in separate boxes due to their incompatibility and to avoid precipitation and nutrient unavailability (Table 1).

The strawberry plants were irrigated three to seven times a day, using the HidroFerti autonomous irrigation controller (Hidrosense, Jundiaí, SP, Brazil), with pulses of approximately 2 min and 40 s. Pests and diseases were controlled with pesticides registered for the strawberry crop. The stolons of the strawberry plants were removed, whenever necessary, to reduce their effect on plant development.

Strawberry fruits, at the stage of 75 to 100% maturation, were harvested weekly from 63 days after planting, between August 2018 and January 2019, and transported to the laboratory of the Olericulture Sector of UFVJM. The total yield of each plot was obtained by weighing all fruits. To determine the commercial yield of the strawberry plants, only the fruits weighing more than 10 g were considered, while the others were discarded (Guimarães et al., 2015).

The evaluated variables were: number of total and commercial fruits per harvest and experimental plot; yield per plant (g), obtained by dividing the average yield of the plot by the number of plants in the plot; commercial yield per plant (g), calculated by dividing commercial yield by the number of plants per plot; average fruit mass (g), determined by dividing yield per plant by the number of fruits; average commercial fruit mass (g), obtained by dividing the commercial yield per plant by the number of commercial fruits; total yield, considered the fruit yield per plot and treatment

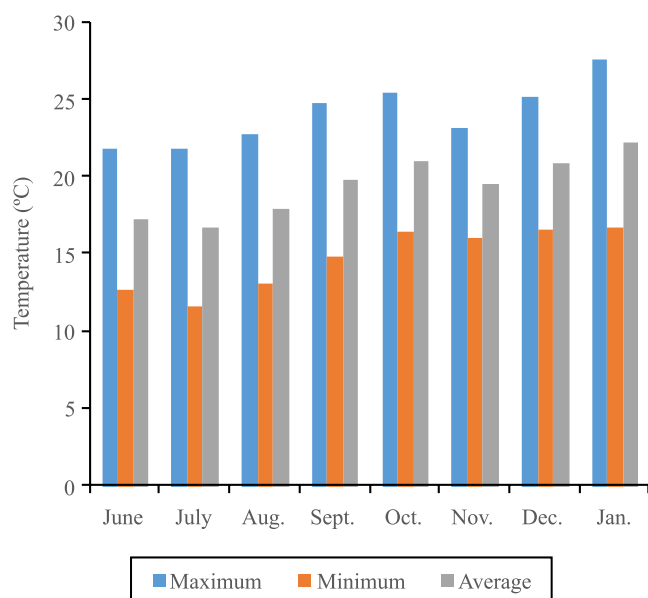


Figure 1. Maximum, average, and minimum temperatures during the 2018–2019 experimental period in a greenhouse at the farm of the Mape Frutas Ltda company, in the municipality of Datas, in the state of Minas Gerais, Brazil.

Table 1. Composition of the nutritious solution for a volume of 1,000 L applied by fertigation to a strawberry (*Fragaria x ananassa*) crop in a semi-hydroponic cultivation system.

Planting box		Nutrient content ⁽¹⁾
Box A		60 kg calcium nitrate and 3.0 kg iron chelate
Box B	40 kg magnesium sulfate, 30 kg potassium nitrate, 23 kg potassium sulfate, 20 kg monopotassium phosphate, 8.0 kg monoammonium phosphate, 0.278 g boric acid, 0.227 g zinc sulfate, 0.185 g manganese sulfate, 0.074 g copper sulfate, and 0.054 g sodium molybdate	

Source: Mape Frutas Ltda (Datas, MG, Brazil).

in all harvests; commercial fruit yield (Mg ha^{-1}), i.e., the commercial fruit yield per plot and treatment in all harvests; and fruit diameter and length (mm), measured with a digital caliper in the longitudinal and transversal directions of three fruits randomly selected among the commercial ones per plot, cultivar, and harvest.

The postharvest analyses were performed on strawberry fruits harvested in November 2018, to determine: moisture, firmness, pH, soluble solids (SS), titratable acidity (TA), total reducing sugars, and vitamin C. Moisture (%) was obtained by draining the strawberries in an oven with forced-air circulation, at 105°C , until reaching a constant weight (Horwitz, 2000), and, then, placing them in a desiccator. Firmness was measured using with the FT 327 portable analog penetrometer (T.R. Turoni srl, Forlì, Italy), with an 8.0 mm tip, by drilling four fruits per cultivar at two opposite points in their equatorial region, with results expressed in pounds and transformed into Newton. pH was determined using the PHB 500 digital benchtop pH meter (Ionlab Equipamentos Laboratoriais e Hospitalares Ltda., Araucária, PR, Brazil), calibrated with a pH 4.0 and 7.0 buffer solution, by immersing electrodes in the pulp of each strawberry cultivar. The content of SS, expressed in $^{\circ}\text{Brix}$, was obtained with the r^2 mini digital refractometer (Reichert Analytical Instruments, Depew, NY, USA), which was calibrated with a drop of distilled water using a scale measured at zero. TA, expressed as percentage of citric acid, was

determined by titrating the sample in a titrating solution of sodium hydroxide (NaOH) at a concentration of 0.1 N, standardized with potassium biphthalate and using phenolphthalein as a turning indicator. The SS/TA ratio represented the relationship between the values of SS and TA. Total reducing sugars, expressed in gram per 100 g of strawberry pulp, were quantified by the Somogy method, with readings performed in a spectrophotometer (Nelson, 1944). Vitamin C (milligram of ascorbic acid per 100 g of strawberry) was determined by the colorimetric method, based on the reduction of 2,6-dichlorophenolindophenol-sodium standardized with ascorbic acid (Horwitz, 2000).

Data on the agronomic and postharvest variables were subjected to the analysis of variance, and means were compared by Tukey's test, at 5%, probability, using the GENES software (Cruz, 2013).

Results and Discussion

Of all cultivars, San Andreas showed the highest number of total and commercial fruits, total and commercial yield per plant, and total and commercial yield. The total fruit mass of the San Andreas cultivar was greater than that of Aromas, Festival, and Oso Grande; however, commercial fruit mass did not differ between cultivars. Fruit length and diameter were also greater in cultivar San Andreas, when compared with Merced, Festival, and Oso Grande (Table 2).

The better performance of the San Andreas cultivar is attributed to its greater adaptability to photoperiod

Table 2. Agronomic variables evaluated in a strawberry (*Fragaria x ananassa*) crop in a semi-hydroponic cultivation system⁽¹⁾.

Parameter ⁽²⁾	Cultivar					
	Aromas	Camarosa	Festival	Merced	Oso Grande	San Andreas
NTF (fruits per plant)	25.65ab (3.07)	20.48b (4.19)	16.99b (4.34)	12.77b (1.17)	21.68ab (4.46)	39.55a (6.77)
NCF (fruits per plant)	13.10b (1.32)	11.90b (2.79)	8.65b (2.18)	7.75b (0.80)	9.83b (2.22)	27.20a (4.80)
TYP (g per plant)	301.47b (32.34)	265.10b (61.37)	200.57b (50.19)	170.51b (12.86)	225.02b (48.44)	581.53a (95.35)
CYP (g per plant)	253.04b (43.10)	201.83b (48.94)	141.31b (36.23)	134.90b (10.85)	150.11b (33.92)	494.26a (81.91)
TY (Mg ha^{-1})	26.44b (2.84)	23.25b (5.38)	17.59b (4.40)	14.96b (1.13)	19.74b (4.25)	51.01a (8.36)
CY (Mg ha^{-1})	22.20b (3.78)	17.70b (4.29)	12.40b (3.18)	11.83b (0.95)	13.17b (2.98)	43.36a (7.19)
TFM (g per fruit)	11.82bc (0.21)	12.85ab (1.22)	11.93bc (0.61)	13.93ab (0.22)	10.29c (0.21)	14.91a (0.35)
TCF (g per fruit)	19.26a (2.61)	16.72a (0.76)	16.62a (0.25)	18.27a (0.46)	15.21a (0.44)	18.45a (0.46)
Fruit length (mm)	30.60ab (1.70)	32.10ab (2.00)	23.55b (3.21)	25.95b (1.44)	27.68b (1.94)	39.05a (1.56)
Fruit diameter (mm)	26.31ab (1.34)	24.88ab (1.83)	20.02b (2.66)	21.34b (1.07)	21.06b (1.52)	29.96a (1.24)

⁽¹⁾Means followed by equal lowercase letters, in the lines, do not differ by Tukeys test, at 5% probability. Values in parentheses are the standard error of the mean. ⁽²⁾NTF, number of total fruits; NCF, number of commercial fruits; TYP, total yield per plant; CYP, commercial yield per plant; TY, total yield; CY, commercial yield; TFM, average total fruit mass; and TCF, average commercial fruit mass.

and climatic conditions, such as temperature (Castro et al., 2017), as well as to its robustness as a day-neutral cultivar. Day-neutral cultivars, due to their genetic characteristics, show a better yield of fruits, which are characterized by a large size and good firmness (Ruan et al., 2013), and can flower in any photoperiod condition as long as the temperature is below 30/26°C day/night (Castro et al., 2015). However, high temperatures can decrease the percentage of pollen germination, inhibit plant growth and yield, and reduce the quality of strawberry fruits (Cui et al., 2021).

The commercial fruit yield of the San Andreas cultivar was the highest in October, November, and December. However, in December, cultivar Aromas did not differ significantly from San Andreas (Table 3). The highest yield of these two day-neutral cultivars may be associated with their lower sensitivity to climate variations (Scott et al., 2021), as they are more tolerant to heat and have prolonged harvest periods (Zeist & Resende, 2019). Therefore, day-neutral strawberry

cultivars can produce fruit continuously throughout summer and autumn under favorable conditions (Castro et al., 2015).

Fruit moisture content, firmness, pH, TA, and total reducing sugars were similar between cultivars, with values ranging from 88.67 to 90.19 for Oso Grande and Aromas, 5.27 to 8.67 for Festival and Merced, 3.20 to 3.53 for San Andreas and Aromas, 0.75 to 0.88 for Camarosa, Festival, and Oso Grande, and 2.07 to 4.22 for Merced, Festival, and San Andreas (Table 4). These similar values may be associated with the used cultivation system, in which the availability and absorption of nutrients by the plant increase the quality parameters of the fruits in comparison with the conventional system, in which there are greater losses of nutrients to the soil (Shirko et al., 2018). In this sense, Bidaki et al. (2019) added that consumers prefer fruits with a better flavor and firmness. Moreover, in the semi-hydroponic system, there is a greater uniformity of the plant roots submerged in water or in

Table 3. Commercial fruit yield by harvest period of six strawberry (*Fragaria x ananassa*) cultivars in a semi-hydroponic cultivation system⁽¹⁾.

Period	Aromas	Camarosa	Festival	Merced	Oso Grande	San Andreas
August	2.80Aba (0.56)	2.43Aba (1.12)	2.48Aa (0.73)	0.40Aa (0.20)	1.46Aa (0.25)	3.27CDa (0.83)
September	1.90Bab (0.53)	1.54ABab (0.43)	0.88Aab (0.52)	1.38Aab (0.65)	0.37Ab (0.20)	5.05BCa (0.43)
October	3.43ABb (0.65)	4.89Ab (2.04)	2.15Ab (1.32)	1.24Ab (1.20)	2.70Ab (0.72)	12.37Aa (2.51)
November	3.33ABb (0.78)	3.53ABb (1.04)	2.90Ab (0.94)	1.82Ab (0.46)	3.06Ab (0.88)	8.06Ba (1.53)
December	6.57Aab (2.99)	2.57Abbc (0.85)	1.75Ac (0.49)	1.78Ac (0.64)	3.16Abc (1.22)	8.41Ba (2.24)
January	3.88Aa (1.06)	2.38Aba (0.75)	2.20Aa (0.81)	2.40Aa (1.06)	2.24Aa (0.81)	5.79BCa (1.31)

⁽¹⁾Means followed by the equal letters, uppercase in the columns and lowercase in the rows, do not differ by Tukey's test, at 5% probability. Values in parentheses are the standard error of the mean.

Table 4. Values for postharvest variables of strawberry (*Fragaria x ananassa*) cultivars evaluated in a semi-hydroponic system⁽¹⁾.

Variable ⁽²⁾	Cultivar					
	Aromas	Camarosa	Festival	Merced	Oso Grande	San Andreas
Moisture	90.19a (1.16)	89.82a (0.65)	88.70a (0.37)	89.29a (1.30)	88.67a (1.14)	89.50a (0.76)
Firmness	6.13a (1.49)	8.34a (1.37)	5.27a (1.03)	8.67a (2.55)	6.62a (1.23)	7.91a (1.40)
pH	3.53a (0.35)	3.26a (0.04)	3.29a (0.07)	3.24a (0.06)	3.21a (0.08)	3.20a (0.05)
TA ⁽³⁾	0.82a (0.06)	0.75a (0.01)	0.75a (0.06)	0.68a (0.07)	0.88a (0.06)	0.87a (0.02)
RS	3.99a (0.45)	3.29a (0.60)	2.07a (0.42)	2.07a (0.35)	3.27a (0.69)	4.22a (0.56)
SS (°Brix)	6.25b (0.67)	7.93ab (0.19)	7.65ab (0.70)	8.78a (0.17)	8.20ab (0.39)	7.58ab (0.17)
SS/TA	7.60b (0.40)	10.58ab (0.26)	10.28ab (0.97)	13.06a (1.33)	9.41b (0.54)	8.69b (0.06)
Vitamin C	73.53a (1.72)	65.13ab (2.72)	60.16ab (2.97)	58.51ab (2.12)	54.16b (3.85)	52.13b (4.57)

⁽¹⁾Means followed by equal lowercase letters, in the lines, do not differ by Tukey's test, at 5% probability. Values in parentheses are the standard error of the mean. ⁽²⁾TA, titratable acidity, expressed in gram of citric acid per 100 g strawberry; RS, reducing sugars, expressed as g 100 g⁻¹ sample; and vitamin C, expressed as milligram ascorbic acid per 100 g fruit.

solution with nutrients, keeping the root zone hydrated and nourished (Diel et al., 2017; Sharma et al., 2018).

The SS content of the cultivars ranged from 6.25 to 8.78, with a higher value for Merced and a lower one for Aromas (Table 4). Consequently, the SS/TA ratio of cultivar Merced was higher than that of Aromas, Oso Grande, and San Andreas. The higher SS content and SS/TA ratio observed for Merced may be related to the lower total fruits of this strawberry cultivar, considering that fruits act as drains that reduce the accumulation of photoassimilates (Correia et al., 2011). In this line, Bertin et al. (1998) observed that an increase in the number of tomatoes (*Solanum lycopersicum* L.) decreased the individual weight and the total SS content in the pulp of each fruit. Although variations in the SS content between cultivars can be explained by genetic factors, fruit quality is also affected by environmental conditions, including climate, water management, and other cultivation practices (Cao et al., 2015). In the example of tomato, the genetic basis of its cultivars increases the potential for high levels of SS, but pre- and postharvest factors can reduce this parameter (Beckles, 2012). However, according to Shirko et al. (2018), the relationship between SS/TA is more important than each of these parameters individually, because the balance between sweet and acid, used in the evaluation of fruit flavour, is higher. This means that higher values for the SS/TA ratio are associated with the flavor preferred by consumers (Gude et al., 2021).

Vitamin C content was higher in cultivar Aromas than in Oso Grande and San Andreas (Table 4), a result related to the genotype, as the different parents that are used to develop the cultivars determine their nutritional quality (Olsson et al., 2004; Capocasa et al., 2008; Rocha et al., 2008). In addition, the vitamin C content of vegetable fruits can be increased or decreased by pre- and postharvest factors, such as climatic conditions, cultural practices, and maturation at harvest, as well as by relative humidity and storage temperature (Lee & Kader, 2000). Strawberry has been reported to be one of the richest fruits in vitamin C, with an average of 80 mg 100 g⁻¹ fruit (Franke et al., 2004). For cultivar Aromas, Rocha et al. (2008) found a similar value of 81.14 mg 100 g⁻¹.

Among the evaluated cultivars, San Andreas is the most promising for cultivation in a semi-hydroponic system, as it presents the best results for the studied

agronomic and postharvest variables, showing a high yield in the period between winter and spring.

Conclusion

In a semi-hydroponic system, the San Andreas cultivar presents the best results in terms of agronomic variables for fruit production, with the highest yield in October and November.

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Dormência em aquênios de morango (*Fragaria x ananassa* Duch)

Dormancy in strawberry achenes (*Fragaria x ananassa* Duch)

Latencia en aquenios de fresa (*Fragaria x ananassa* Duch)

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RESUMO

Os aquênios de morango apresentam dormência tegumentar, sendo necessário para a sua germinação estratégias de superação de dormência. Objetivou-se com esse trabalho verificar o efeito das concentrações e tempos de imersão de ácido sulfúrico na superação de dormência de aquênios em morango, cultivar San Andreas. O experimento foi conduzido na Universidade Federal dos Vales do Jequitinhonha e Mucuri - UFVJM, utilizando o delineamento experimental inteiramente casualizado, em esquema fatorial (4 x 2), com quatro concentrações de ácido sulfúrico (0%, 25%, 50% e 98%) e dois períodos na solução (3 e 10 minutos) com quatro repetições de 25 aquênios cada. Foram determinados a porcentagem de plântulas normais, de plântulas anormais, sementes dormentes, sementes mortas e o índice de velocidade de germinação. Concluiu-se que a escarificação com ácido sulfúrico na concentração de 98% e tempo de imersão de 10 minutos proporcionou maior quebra de dormência dos aquênios de morango da cultivar San Andreas.

Palavras-chave: tegumento, escarificação química, germinação, plântulas normais.

ABSTRACT

Strawberry achenes present integumentary dormancy, requiring strategies to overcome dormancy for their germination. The objective of this work was to verify the effect of concentrations and



immersion times of sulfuric acid on overcoming achene dormancy in strawberry, cultivar San Andreas. The experiment was conducted at the Federal University of Vales do Jequitinhonha and Mucuri - UFVJM, using a completely randomized experimental design, in a factorial scheme (4 x 2), with four concentrations of sulfuric acid (0%, 25%, 50% and 98%) and two periods in the solution (3 and 10 minutes) with four repetitions of 25 achenes each. The percentage of normal seedlings, abnormal seedlings, dormant seeds, dead seeds and the germination speed index were determined. It was concluded that scarification with sulfuric acid at a concentration of 98% and an immersion time of 10 minutes provided a greater break in dormancy of the strawberry achenes of the San Andreas cultivar.

Keywords: tegument, chemical scarification, germination, normal seedlings.

RESUMEN

Los aquenios de fresa presentan latencia tegumentaria, requiriendo estrategias para superar la latencia para su germinación. El objetivo de este trabajo fue verificar el efecto de las concentraciones y tiempos de inmersión de ácido sulfúrico en la superación de la latencia del aquenio en fresa, cultivar San Andreas. El experimento se realizó en la Universidad Federal de Vales do Jequitinhonha y Mucuri - UFVJM, utilizando un diseño experimental completamente al azar, en esquema factorial (4 x 2), con cuatro concentraciones de ácido sulfúrico (0%, 25%, 50% y 98%) y dos periodos en solución (3 y 10 minutos) con cuatro repeticiones de 25 aquenios cada una. Se determinó el porcentaje de plántulas normales, plántulas anormales, semillas latentes, semillas muertas y el índice de velocidad de germinación. Se concluyó que la escarificación con ácido sulfúrico a una concentración del 98% y un tiempo de inmersión de 10 minutos proporcionó una mayor ruptura de la latencia de los aquenios de fresa del cultivar San Andreas.

Palabras clave: tegumento, escarificación química, germinación, plántulas normales.

1 INTRODUÇÃO

O morango se destaca como uma das frutas mais apreciadas pelos consumidores em diversas regiões do mundo, devido sua coloração, sabor, aroma e sua versatilidade na gastronomia e culinária, pois sua utilização pode ser tanto na forma *in natura*, como ingrediente de sobremesas (Antunes *et al.*, 2011). Por estas razões é altamente demandado para consumo *in natura* quanto para processamento industrial.

A propagação do morangueiro, quando se busca o melhoramento genético, deve ser feita por aquênios, popularmente chamados de sementes. No entanto, a germinação de aquênios de morango é dificultada devido a presença de dormência (Zeist *et al.*, 2021), ocasionada pela impermeabilidade da água na testa e no pericarpo. A dormência física ocorre quando o tegumento



duro da semente é incapaz de absorver água e oxigênio (Contreras *et al.*, 2015). O pericarpo duro age como uma barreira física, impedindo a expansão e germinação do embrião (Kim *et al.*, 2024).

Devido a essas condições é necessário que se realize um processo que possibilite a germinação da semente. Diversos tratamentos químicos têm sido relatados para melhorar a germinação de aquênios de morango, incluindo o uso de giberelina, etrel, nitrato de potássio, peróxido de hidrogênio e ácido sulfúrico (Galvão *et al.*, 2014). A utilização do ácido sulfúrico (H_2SO_4) é a mais indicada para quebrar a dormência das unidades de dispersão (sementes, núculas, aquênios etc.) de algumas espécies (Lopes; Nascimento, 2012). Segundo diversos autores, na germinação dos aquênios do morango o ácido sulfúrico atua melhorando o desempenho das sementes durante a germinação (El Hamdouni *et al.*, 2001; Galvão *et al.*, 2014; Chapieski, 2017).

A eficiência do ácido sulfúrico já foi observados na germinação das sementes de morango. A aplicação de 20 a 50 minutos de H_2SO_4 em sementes híbridas F1 ‘Chiba go’ proporcionou um aumento de 84% na germinação sete dias após a semeadura, os quais proporcionaram desaparecimento ou afinamento da camada externa do pericarpo (Ito *et al.*, 2011). No entanto, quanto maior o tempo de contato dos aquênios com o ácido sulfúrico, mais reduzida é a porcentagem de germinação (Lata *et al.*, 2018), podendo afetar a qualidade fisiológica do embrião.

Dessa forma, foi observado que a escarificação com ácido sulfúrico (98%) por 5 minutos maximiza e sincroniza a germinação dos aquênios de morango da Cultivar ‘Monterey’ armazenados em geladeira por 60 dias (Gusmão, 2018). Em trabalho realizado por Eidam, (2012), foi verificado que a escarificação de aquênios frescos (momento da colheita) com lixa comercial e imersão em solução de ácido sulfúrico 10% por 10 minutos proporciona 84,3% de germinação de aquênios da Cultivar Caminho Real. De acordo com o mesmo autor, quando os aquênios foram imersos em ácido sulfúrico 10% por 10 minutos e com adição de 0,5 mg L GA3 no meio de cultura após o armazenamento por dois meses, a emergência reduziu para 53,1% respectivamente.

A necessidade de estudos envolvendo a superação de dormência e germinação de sementes de morangueiro representa fundamental importância, pois são escassos os trabalhos relacionados ao tema, e crescente os investimentos no desenvolvimento de novas cultivares. Nesse contexto, objetivou-se com esse trabalho verificar o efeito das concentrações e tempo de



imersão de ácido sulfúrico na superação de dormência de aquênios em morango.

2 MATERIAL E MÉTODOS

A pesquisa foi conduzida no Laboratório de Sementes da Universidade Federal dos Vales do Jequitinhonha e Mucuri, Diamantina, MG. Foram utilizados aquênios de frutos maduros de morango da cultivar San Andreas, adquiridos na Fazenda Mape Frutas, Datas – MG.

A extração dos aquênios foi realizada com uso de liquidificador, contendo de 5 a 8 frutos inteiros juntamente com 1 litro de água, ligado em baixa velocidade por 30 segundos, a fim de evitar que os aquênios fossem danificados. Estes foram coados em uma peneira, colocados sobre papel toalha para secagem em temperatura ambiente por 18 horas.

O grau de umidade dos aquênios foi determinado utilizando o método da estufa a 105° C por 24 horas, com duas repetições de 0,3 g de sementes (Brasil, 2009).

Os aquênios foram acondicionados em béqueres e submetidos ao tratamento com ácido sulfúrico (H_2SO_4) nas concentrações de 25%, 50%, 98% e controle (somente água no substrato) nos períodos de tempos de 3 minutos e 10 minutos. Após a imersão, os aquênios foram então lavados com água destilada por 1 minuto e submetidos ao teste de germinação.

Para o teste de germinação, as sementes foram alocadas em caixas gerbox sobre papel germitest, umedecidas com água destilada na proporção de 2,5 vezes o peso do papel, acondicionados em câmara de germinação do tipo BOD, sob temperaturas alternadas de 20°C - 30°C e fotoperíodo de 8 horas de luz por um período de 28 dias (Brasil, 2009) computando-se a porcentagem de plântulas normais, plântulas anormais deformadas, sementes dormentes e sementes mortas. Foi determinado o índice de velocidade de germinação (IVG) conforme a fórmula proposta por Maguire (1962).

O delineamento experimental utilizado foi o inteiramente casualizado (DIC), em esquema fatorial (4 x 2), com quatro concentrações de ácido sulfúrico 25%, 50%, 98% e o controle, dois períodos de tempo (3 e 10 minutos) com quatro repetições de 25 aquênios cada.

Os dados foram submetidos à análise de variância, identificando-se a diferença significativa pelo teste F, as médias dos tratamentos foram comparadas entre si pelo teste de Tukey a 5% de probabilidade, utilizando o software R versão 4.3.1 (R core team, 2023). A análise discriminante canônica foi feita com auxílio do pacote candisc (Friendly; Fox, 2021).



3 RESULTADOS E DISCUSSÕES

O grau de umidade dos aquênios após a secagem dos frutos foi de 17%. Resultado semelhante também foi observado por Chapieski (2017) que obtiveram para aquênios de morango da cultivar Albion grau de umidade de 16,9%. Os tempos de imersão do ácido sulfúrico proporcionaram diferença estatísticas para as variáveis plântulas normais (PN), plântulas anormais (PA) e índice de velocidade de germinação (IVG) (Tabela 1).

Tabela 1. Efeito do tempo em minutos (min) de imersão em ácido sulfúrico (H_2SO_4) na quebra de dormência de aquênios de Morango (*Fragaria x ananassa* Duch), cultivar San Andreas, sobre a porcentagem de Plântulas Normais (PN); Plântulas Anormais (PA) e Índice de velocidade de Germinação (IVG).

Tempo (min.)	Testes		
	PN (%)	PA (%)	IVG
3	4 b	4 b	0,12 b
10	7 a	7 a	0,31 a
CV (%)	20,57	23,47	12,60

Médias seguidas de mesma letra, em cada coluna, não diferem estatisticamente pelo teste de Tukey ao nível de 5% de probabilidade. C.V: Coeficiente de Variação

Fonte: Elaborado pelos autores

No geral, o tempo de imersão de 10 minutos proporcionou uma maior germinação dos aquênios, uma vez que, obteve os maiores resultados de porcentagem de plântulas normais, plântulas anormais e índice de velocidade de germinação. Diante desses resultados, podemos observar que o tempo de imersão dos aquênios no ácido sulfúrico influencia na germinação morango na cultivar San Andreas, no entanto, é preciso tomar cuidados ao expor os aquênios por um período que vá interferir negativamente no desenvolvimento das plântulas e evitar a formação de plântulas anormais. Os resultados deste trabalho divergem dos encontrados por Gusmão (2018), onde avaliando diferentes tempos de imersão de aquênios de morango *Fragaria x ananassa* cv. Monterey em ácido sulfúrico, obtiveram os melhores resultados com o tempo de 5 minutos. Contudo, o mesmo autor relata que o tempo de 10 minutos foi considerado excessivo, acarretando efeitos negativos na germinação. Diante disso, o presente estudo elucida que é preciso avaliar o tempo adequado de escarificação com ácido sulfúrico para cada cultivar.

Nas concentrações de ácido sulfúrico para a quebra de dormência dos aquênios da cultivar San Andreas, houve diferença estatística para as variáveis, plântulas normais (PN), plântulas anormais (PA), sementes dormentes (SD), sementes mortas (SM) e índice de velocidade de germinação (IVG) (Tabela 2).



Tabela 2: Efeito das concentrações de ácido sulfúrico na quebra de dormência de aquênios de morango (*Fragaria x ananassa* Duch), cultivar San Andreas, sobre a porcentagem de Plântulas Normais (% PN); Plântulas Anormais (% PA); Sementes Dormentes (% SD); Sementes Mortas (% SM) e Índice de velocidade de Germinação (IVG) após 28 dias.

Concentrações (%)	Testes				
	PN (%)	PA (%)	SD (%)	SM (%)	IVG
0	3.00 b	1.00 b	67.00 b	28.00 a	0.05 c
25	5.00 ab	3.00 b	92.00 a	2.00 b	0.09 bc
50	7.00 a	1.00 b	86.00 a	2.00 b	0.13 b
98	4.00 ab	15.00 a	82.00 a	2.00 b	0.34 a
CV (%)	19.12	20.46	6.43	21.71	17.85

Médias seguidas de mesma letra, em cada coluna, não diferem estatisticamente pelo teste de Tukey ao nível de 5% de probabilidade. C.V: Coeficiente de Variação

Fonte: Elaborado pelos autores

Para a porcentagem de plântulas normais (PN), houve melhor resultado na concentração de 50% do ácido sulfúrico, diferindo significativamente do tratamento controle (Tabela 2). Mesmo não havendo diferença estatística entre as concentrações (25%, 50%, 98%), é possível observar que houve um acréscimo de plântulas normais somente até a concentração de 50%, seguido de um decréscimo quando aumentou a concentração do ácido para 98%. Tal observação, nos dá um indicativo que em concentrações altas de ácido sulfúrico pode influenciar na qualidade fisiológica dos aquênios, podendo aumentar o número de plântulas anormais.

A maior porcentagem de plântulas anormais (PA) foi observada com a utilização da concentração de 98% do ácido sulfúrico (98%), sendo estatisticamente superior aos demais tratamentos. Já a concentração de 50% foi idêntica ao tratamento controle, proporcionando uma menor quantidade de plântulas anormais. Além de uma boa germinação, o desenvolvimento de plântulas normais e vigorosas são fundamentais para assegurar expressivamente a probabilidade de sucesso no estabelecimento da lavoura (Krzyzanowski *et al.*, 2018).

Ao avaliar as sementes não germinadas, verificou-se maior quantidade de sementes dormentes (SD) na concentração de 25% do ácido, demonstrando baixo efeito corrosivo dessa concentração para quebrar a barreira física ocasionada pelo tegumento. Já em relação as sementes mortas (SM), foi encontrado uma maior porcentagem no tratamento controle. Tais resultados demonstram que as concentrações de ácido sulfúrico (25%, 50%, 98%) não influenciaram na morte das sementes. Ao avaliar o índice de velocidade de germinação (IVG), verifica-se que a concentração de 98% proporcionou uma maior velocidade de germinação, seguido da concentração de 50%, sendo estatisticamente superior ao controle.

Para as concentrações de ácido sulfúrico, as duas primeiras variáveis canônicas explicaram 99,62%, das variáveis porcentagem de plântulas normais (PN); plântulas anormais



(PA); sementes dormentes (SD); sementes mortas (SM) e índice de velocidade de germinação (IVG) (Tabela 3). A canônica 1 está correlacionada mais fortemente com a PA, SD, SM e IVG explicando 74,27% da variância original, enquanto a canônica 2 está mais fortemente correlacionada com a PN, explicando 25,35% da variância original.

Tabela 3. Coeficientes, autovalores e variância explicada pelas variáveis canônicas para as variáveis de aquênios de morango (*Fragaria x ananassa* Duch), cultivar San Andreas submetidas a submetidas a imersão em diferentes concentrações de ácido sulfúrico (0, 25, 50, 98%).

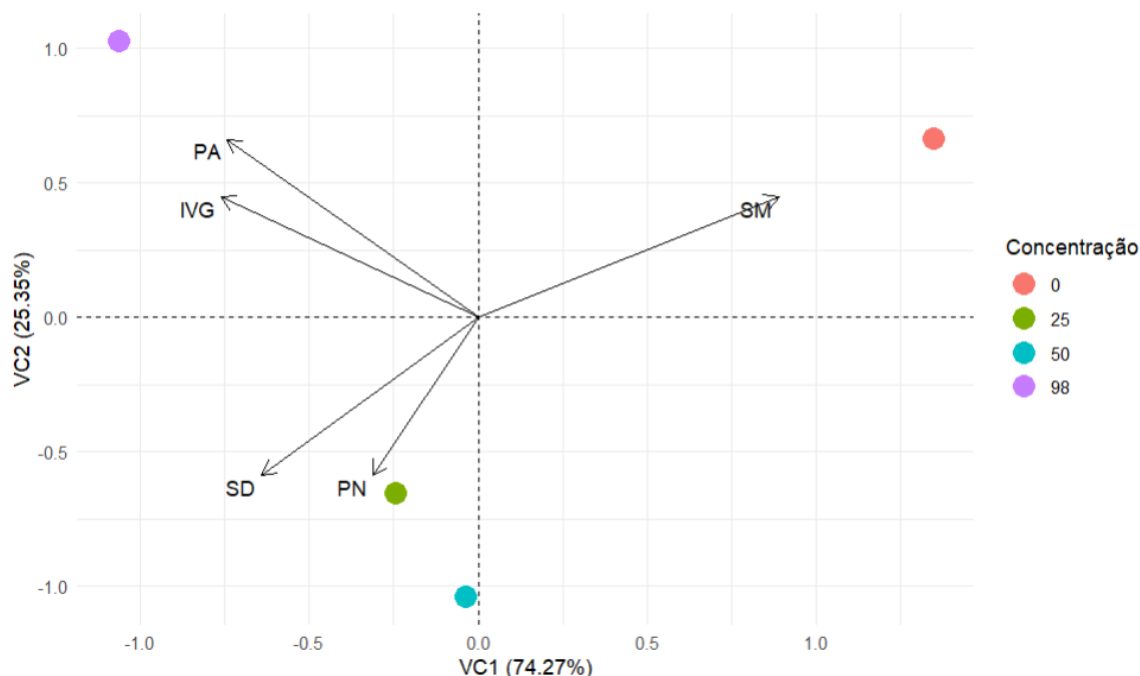
Variáveis	H ₂ SO ₄	
	Canônica 1	Canônica 2
Plântulas normais (PN)	-0,4251	-0.7914
Plântulas anormais (PA)	-0,7485	0.6612
Sementes dormentes (SD)	-0,7119	-0.6454
Sementes mortas (SM)	0,8940	0.4479
Índice de velocidade de germinação (IVG)	-0,8295	0.4854
Autovalor	117,12	39,98
Variância explicada (%)	74,27	25,35
Variância cumulativa (%)	74,27	99,62

Fonte: Elaborado pelos autores

Na figura 1, podemos observar que a concentração de 98% de ácido sulfúrico foi a que proporcionou maior porcentagem de plantas anormais (15,00%) e índice de velocidade de germinação (0,34). Já as concentrações de 25% e 50% apresentaram os maiores valores de plântulas normais e sementes dormentes. Já o controle, apresentou os maiores valores de sementes mortas. No geral, esses resultados reforçam a ideia que mesmo proporcionado uma germinação rápida, a concentração de 98% influência negativamente no desenvolvimento inicial das plântulas, provavelmente nos aquênios que apresentam menor vigor, acarretando uma maior porcentagem de plântulas anormais.



Figura 1. Análise discriminante canônica para porcentagem de plântulas normais (PN); plântulas anormais (PA); sementes dormentes (SD); sementes mortas (SM) e índice de velocidade de germinação (IVG) de aquênios de morango (*Fragaria x ananassa* Duch), cultivar San Andreas imersas em diferentes concentrações de ácido sulfúrico (0, 25, 50, 98%).



Fonte: Elaborado pelos autores

A ação do ácido sulfúrico na superação da dormência é pela corrosão química do tegumento, o que é favorável para alterar a permeabilidade da membrana, permitindo que a água, fator essencial à germinação, seja absorvida, dando início ao processo germinativo, além de permitir as trocas gasosas, e assim, permitindo que o embrião tenha as condições necessárias para se desenvolver (Dousseau *et al.*, 2007; Costa *et al.*, 2013). Entretanto, de acordo com os resultados deste trabalho, a eficiência do ácido sulfúrico para superar a dormência de aquênios de morango cultivar San Andreas, vai depender de sua concentração. Vale ressaltar que a eficiência do tratamento deve estar diretamente relacionado com o aumento da porcentagem de germinação com a consequente formação de plântulas normais.

A interação entre fatores (tempo x concentração) na porcentagem de sementes dormentes (SD) estão na Tabela 4. Podemos observar que houve diferença entre os tempos de imersão somente no tratamento controle (0%), sendo que no tempo de 10 minutos obteve a maior porcentagem de sementes dormentes (76%). Ao analisar a influência das concentrações dentro de cada tempo, verificou-se que no tempo de 3 minutos, as maiores porcentagens de sementes



dormentes foram obtidas com as concentrações de H_2SO_4 (25, 50 e 98%). Já para o tempo de 10 minutos, não foram observadas diferenças significativas entre as concentrações e o controle.

Tabela 4: Efeito do tempo (minutos – min) de imersão e concentrações em ácido sulfúrico (H_2SO_4) na quebra de dormência de aquênios de Morango (*Fragaria x ananassa* Duch), cultivar San Andreas, sobre a porcentagem de Sementes Dormentes (% SM) após 28 dias.

Tempo (min)	Concentrações de H_2SO_4 (%)			
	0	25	50	98
3	67.00 Bb	92.00 Aa	86.00 Aa	82.00 Aa
10	76.00 Aa	85.00 Aa	86.00 Aa	79.00 Aa
CV (%)	6.50			

Médias seguidas pelas mesmas letras maiúsculas na coluna e minúsculas na linha não diferem entre si pelo teste de Tukey ao nível de 5% de probabilidade. C.V: Coeficiente de Variação

Fonte: Elaborado pelos autores

Ao avaliar a influência das concentrações de H_2SO_4 em cada tempo de imersão (3 e 10 minutos), as duas primeiras variáveis canônicas explicaram 84,89% da variância total contida entre as variáveis porcentagem de plântulas normais (PN); plântulas anormais (PA); sementes dormentes (SD); sementes mortas (SM) e índice de velocidade de germinação (IVG) (Tabela 5). A canônica 1 está correlacionada mais fortemente com a PN, PA, SM e IVG, explicando 58.09% da variância original. A canônica 2 está mais correlacionada com SD, explicando 26,79% da variância.

Tabela 5. Coeficientes, autovalores e variância explicada pelas variáveis canônicas para as variáveis de aquênios de morango (*Fragaria x ananassa* Duch), cultivar San Andreas submetidas a submetidas a imersão, em diferentes tempos (3 e 10 minutos), em concentrações de ácido sulfúrico (0, 25, 50, 98%).

Variáveis	H_2SO_4 x Tempo	
	Canônica 1	Canônica 2
Plântulas normais (PN)	-0,46	0,14
Plântulas anormais (PA)	-0,43	0,32
Sementes dormentes (SD)	-0,48	0,72
Sementes mortas (SM)	0,98	-0,13
Índice de velocidade de germinação (IVG)	-0,52	-0,00
Autovalor	4,62	2,13
Variância explicada (%)	58,10	26,79
Variância cumulativa (%)	58,10	84,89

Fonte: Elaborado pelos autores

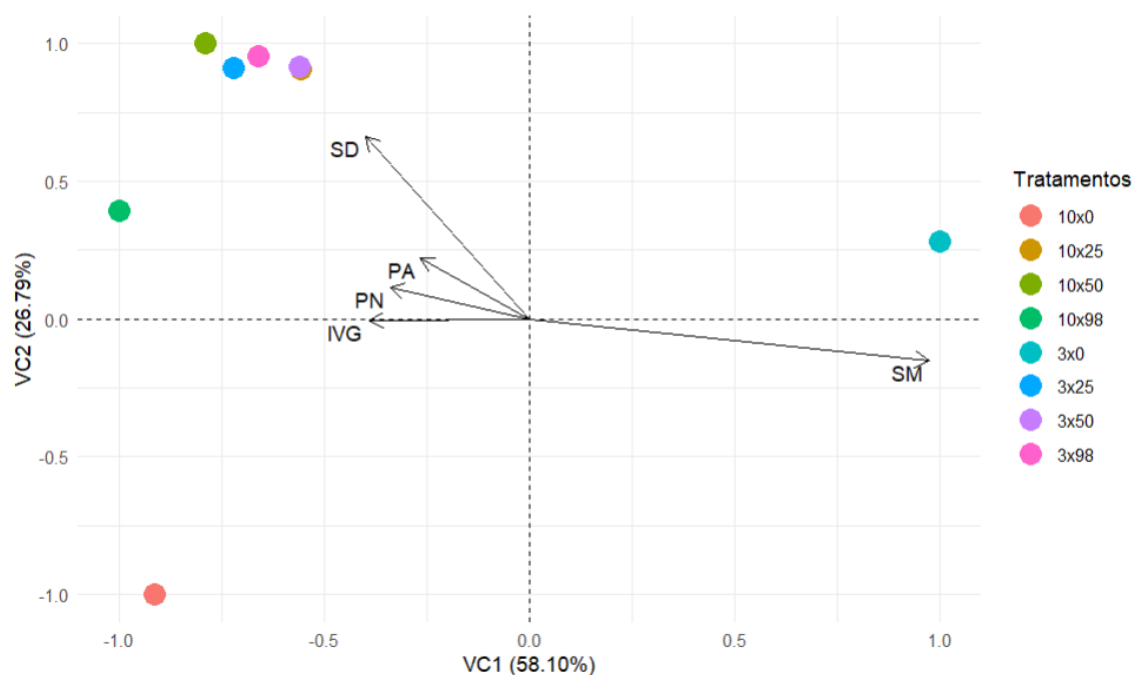
Ao avaliar a influência das concentrações de H_2SO_4 (0, 25, 50 e 98%) em cada tempo de imersão (3 e 10 minutos) no teste de germinação de aquênios de morango (*Fragaria x ananassa* Duch), cultivar San Andreas, observou-se altas porcentagens de sementes mortas (SM) e sementes duras (SD). Para a porcentagem de sementes mortas (SM), o maior valor foi obtido



com o tratamento controle com 3 minutos de imersão (3x0). Já em relação a porcentagem de sementes duras (SD), verificou-se maiores valores na concentração de 25% por 10 minutos (10x25) e na concentração de 50% por 3 minutos (3x50).

A concentração de 98% no tempo de 10 minutos (10x98) proporcionou as maiores porcentagens de plântulas normais (PN); plântulas anormais (PA) e índice de velocidade de germinação (IVG). A permanência das sementes por períodos prolongados no ácido em alta concentração, embora favoreça a superação do fenômeno da dormência, aumenta a porcentagem de sementes deterioradas e de plântulas anormais (Oliveira *et al.*, 2010).

Figura 2. Análise discriminante canônica para porcentagem de plântulas normais (PN); plântulas anormais (PA); sementes duras (SD); sementes mortas (SM) e índice de velocidade de germinação (IVG) de aquênios de morango (*Fragaria x ananassa* Duch), cultivar San Andreas submetidas a imersão, em diferentes tempos (3 e 10 minutos), em concentrações de ácido sulfúrico (0, 25, 50, 98%).



Fonte: Elaborado pelos autores

No geral, os aquênios de morango da cultivar San Andreas apresentam baixa germinação, confirmando os relatos de outras pesquisas que consideram a germinação de aquênios de morango muito baixas, não uniforme e muito lento (Yanagi *et al.*, 2006; Gemeli, 2016). Com os dados obtidos neste estudo e comparados aos de outros trabalhos, com diferentes concentrações de H_2SO_4 , tempos de escarificação e cultivares de morangueiro (Eidam, 2012; Galvão *et al.*,



2014; Lata et al., 2018), observa-se que a concentração do H_2SO_4 e o tempo adequado de imersão para superar a dormência de aquênios de morango podem variar de acordo com as cultivares.

5 CONCLUSÃO

A escarificação química com H_2SO_4 na concentração de 98% e imersão de 10 minutos promove uma maior porcentagem de plântulas normais, plântulas anormais e índice de velocidade de germinação de aquênios de morango da cultivar San Andreas.

Estudos futuros podem se concentrar em novas concentrações de ácido sulfúrico e tempos de imersão, visto que, a concentração de 98% de H_2SO_4 pode aumentar a quantidade plântulas anormais e a concentração de 50% favorece o aumento da porcentagem de plântulas normais de aquênios de morango da cultivar San Andreas.



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Strawberries in a warming world: examining the ecological niche of *Fragaria* × *ananassa* Duch – Across different climate scenarios

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Abstract.

BACKGROUND: Strawberry (*Fragaria* × *ananassa* Duch.) is a species of great economic and nutritional importance. It is widely cultivated in different regions of the world. However, climatic factors have a significant influence on its production.

OBJECTIVE: To evaluate the ecoclimatic suitability and growth index of *F. × ananassa* in the face of the impacts of climate change in Brazil and the world.

METHODS: The potential global distribution of *F. × ananassa* it was based on predicted global climate changes using CLIMEX and the A1B and A2 emissions scenario for the years 2050 and 2100. CLIMEX weekly growth index (GIw) was applied, and productivity data in commercial strawberry cultivation in Brazilian areas were collected.

RESULTS: The results indicate a progressive reduction in areas suitable for strawberry cultivation globally, mainly on the African continent, Australia, China, and the Americas for the years 2050 and 2100. In Brazil, only the South region and part of the Southeast will continue to be suitable for strawberry production.

CONCLUSIONS: The CLIMEX model predicts a reduction in the suitable area for cultivating *Fragaria* × *ananassa* Duch between 2050 and 2100 due to climate change. The generated maps can help identify new cultivation areas and support genetic improvement programmes to develop cultivars more tolerant to heat.

Keywords: CLIMEX, improvement, modeling, strawberry

1. Introduction

Strawberry (*Fragaria* × *ananassa* Duch.) is a crop cultivated worldwide due to its economic importance, mainly for China, the United States and much of Europe [1, 2]. In addition to their beauty, aroma and sweetness,

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