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Effects of planting systems and lime doses on corn-forage intercropping during off-season

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Abstract

This research was conducted to evaluate the effects of the planting systems and lime dosages on the corn and forage (*Urochloa brizantha*) yield, the weed control system and soil seed bank of the corn-forage intercropping system. The experiment was conducted under field conditions in a randomized complete block design, with four replications. We adopted a split plot 2×4 arrangement, consisting of a combination of two planting systems (tillage and no-tillage) as plots with four lime doses (0, 0.83, 1.25 and 2.50 t ha^{-1}) as the subplot. Maximum plant height, stem diameter, dry matter and corn yield were recorded in the no-tillage system, with 311% higher productivity in the no-tillage system compared with the conventional system, regardless of the limestone application. The high production is mainly due to the ability of the no-tillage to retain and provide the corn plants with water. The results showed that liming influenced only the corn grown in the conventional system. Weed infestation was higher in the non-tillage system whereas, the tillage system enabled greater diversity and quantity of viable seeds in the soil. The no-tillage is, therefore, an excellent alternative to the intercropping corn-forage production during the late summer cultivation.

Keywords: Non-tillage; Soil acidity; Soil seed bank; *Urochloa brizantha*; Weeds; *Zea mays*.

Abbreviations: 100GW_100 grain-weight; BDM0_*Urochloa brizantha* dry matter at harvest corn; BDM45_45 days after harvest corn; CEIH_corn ear insertion height; CT_tillage; DAP_days after planting; IVI_importance value index; NT_no-tillage; PH_plant height; PROD_productivity; SD_stem diameter; SDM60_shoot dry matter at 60 DAP; SDM120_ shoot dry matter at 120 DAP; SI_similarity index; SSB_soil seed bank; WDM30_weeds dry matter at 30 DAP; WDM60_weeds dry matter at 60 DAP.

Introduction

Pasture degradation has been reported to be one of the main problems for the development of the Brazilian cattle, directly affecting the production and system stability. To recover these areas involves an increase in the forage yield, support of the largest animal production and maintenance of the natural resources. In this context, the use of annual crops along with the grasses is an excellent alternative to establish and recover the pasture (Jakelaitis et al., 2005). This practice also permits the use of less intensive inputs, resulting in greater and more sustainable practices over time (Assmann et al., 2003); it also decreases the investments required for the establishment of the pastures (Jakelaitis et al., 2004). The crop-forage intercropping system implementation during the late planting period shows great potential for the recovery of degraded pastures by enabling the producer to introduce the cultivation of a new crop of an annual plant species at the end of the rainy season, bringing in higher income for the farmers. However, the low rainfall period during the "off-season", in some regions, has been proven to be an obstacle for this system to be efficient. Therefore, the tillage system has been recommended in such situations, as greater conservation of the soil moisture is possible due to the coverage with straw, which prevents the direct sunlight from falling on the soil (Choudhary et al., 2013).Several annual species have been used in the implementation of this integrated crop-forage system; however, maize (*Zea mays L.*) has been the preferred crop because of its rapid initial growth, which results in greater competition with its smaller size (Jakelaitis et al., 2004), great ability to adapt to the Brazilian regions (Jakelaitis et al., 2005), high market value, high productivity and its excellent performance when intercropped with the forage plants. As an alternative to forage in intercropping with corn, *Urochloa brizantha* has been used the most, because of its capacity to withstand the shading caused by culture, without incurring pasture production losses (Martuscello et al., 2009). The negative interference imposed by the weeds may influence the establishment of the intercropped forage, crop grain yield and product quality. These plants can be propagated by seed chamber or vegetative methods and these propagules form what is termed the soil seed bank. Utilizing this knowledge, we can adopt more rational and economic methods to exert, in particular, chemical control, and several authors have reported differences in the soil seed bank based on the spacing adopted (Clements et al., 1996; Ferreira et al., 2008).

In this context, this work aimed at evaluating the effects of the cropping system and lime dosing rates on the growth and yield of corn and *Urochloa brizantha*, at the time of intense weed infestation and the soil weed seed bank.

Results and Discussion

Effects of liming and planting systems on corn

Higher growth was observed in the corn crop using the tillage system, regardless of lime application (Table 1). The increases observed were 225% in plant height, 114% in stem diameter, 287% in dry matter at 60 Days After Planting (DAP) in field and 184% in dry matter at 120 DAP (after harvest corn silage). These results directly represent the variability of the productivity components including weight and grain yield, which were 157% and 311% higher, respectively, in the no-tillage system when compared with the tillage system. Tsunechiro et al. (2006) and Furlaneto and Esperancini (2010) stipulate, as an economic balance, the productivity of 2,500 kg ha^{-1} for the monoculture system of corn cropping in the Autumn–Winter growing season (off-season), which proves the inefficiency of the tillage system under these conditions of this experiment (Table 1). Although the corn yield had dropped below the national average, considering the off-season cultivation and intercropping, the production can be considered satisfactory; other studies have also reported similar yields (Brambilla et al., 2009) or even lower (Farinelli et al., 2003). Part of these results can be explained as being due to the low rainfall received during the growing season, which is a drought period, and which contributed to the large difference between the systems; also, the non-tillage system showed a higher capacity to store and deliver water to the plants, due to the presence of the straw (Albuquerque, 2001). This shows that this system is an excellent alternative for corn production during low rainfall periods, a common situation in the off-seasons. These results were quite unexpected, in the very first year of cultivation with tillage, as other authors reported higher yields only in the stable system and that too only after more than two years (Ismail et al., 1994; Hernani, 1997). Plant height and dry matter of corn evaluated at 60 DAP were the only variables that indicated the influence of liming in the non-tillage system, and the regressions highlighted a positive and linear behavior (Fig 1). This difference can be attributed to the increased availability of the calcium and magnesium in the superficial soil layers, a common situation in the case of liming. The initial crop development could have been influenced by the higher absorption of these nutrients, which was not evident at the end of the crop cycle. Castro and Crusciol (2013) too, working with beans, did not report the influence of liming on non-tillage in the first cropping year; however, in the following year, an increased production was noted, with the use of this input. Conyers et al. (2003) showed that liming has low efficiency on the crops during drought, and there is very little product reaction on low soil moisture; the no-tillage system causes even more concern, because the effect of the liming activity occurs only at very low depths in the soil. Other factors which are the biggest index of organic matter in this system are those which can reduce the harmful effects of exchangeable Al on the soil. The tillage system showed a higher response of the corn to liming (Fig 1). The growth pattern of the height, stem diameter and dry matter was linear, suggesting the necessity of liming on the tillage. The 100-grain weight, ear insertion height and production were significant, adopting quadratic equations with the greater values of 1.94, 1.46, 1.79 kg ha^{-1}, respectively, of lime. This is an indication that for the tillage system, during the off-season cropping, the liming recommendation necessitates reviewing, because the necessity for liming in this system is lower, as Duarte and Cantarella (2007) report the lack of studies specific to off-season cropping. The grain yield in tillage without liming was about 240 kg ha^{-1} and the ears corn were inserted up to only 40 cm of height (Fig 1). Under such conditions the corn harvest was not viable, and the operational costs for the same were high; also, the low insertion of the ears would make the mechanical harvesting difficult, as the large bushing harvesters would need to be adjusted to this height, besides the damage caused by the harvester to the forage.

Effects of liming and planting systems on forage

The higher corn production observed in the no-tillage system can also be attributed to the greater development of weeds in the tillage system (Table 1). Higher development of weeds intensifies the competition for resources and environmental conditions. Several authors highlight that the increased ability of weeds to withdraw and use water during drought conditions (Griffin et al., 1989; Venancio et al., 2014) can contribute to the low availability of water for the corn plants. Furthermore, the low corn growth can positively influence the weed growth, in addition to the characteristics of tolerance and adaptation exhibited by the weeds during drought conditions. The low development of weeds in the no-tillage system can be indicative of the possibility of cropping without chemical control, when this intercropping system is adopted, as the cultural control study realized that utilizing the straw management on the soil can be satisfactory. The forage production in the twice evaluated program was not significantly influenced by the planting systems (Table 1). In general, the performance of *U. brizantha* is only slightly influenced by the management of crop-livestock integration, as revealed by Pequeno et al. (2006), who reported no difference in the development of this species during different sowing dates (16, 32 and 48 days after planting) in intercropping. The forage production in the no-tillage system was increased in both assessments according to the increase of the lime dose applied (Fig 2). Although *U. brizantha* can be considered as being tolerant to soil acidity, studies regarding liming have obtained conflicting results when dealing with tropical forages (Cantarutti and Novais, 2005). However, other studies also reported an increase in this forage productivity after liming (Guedes et al., 2012), mainly regarding the calcium supplied (Fonseca et al., 2011). In the tillage system, the lime influenced the dry matter of the brachiaria when evaluated only at 45 days after the corn harvest; the behavior of dry matter accumulation was quadratic, showing higher results without liming and with the highest dose (Fig 2). This behavior is quite contrary to that found for the corn grain production (Fig 1), and on the further intercropping of two species, the greater development of one crop can result in the lesser development of the other. Carvalho et al. (2011) reported that corn has certain aggressiveness in competition with *U. brizantha*, thus limiting the scope of the forage to make use of the resources available in the area.

Effects of liming and planting system on weed

Regarding dry matter accumulation of the weed, the influence of limestone was noted in the assessment only immediately before the atrazine application (Fig 2), as in the non-tillage system the weed dry matter increased according to the lime

Table 1. Values regarding the plant height (PH) and stem diameter (SD) 60 days after planting (DAP), shoot dry matter at 60 (SDM60) and 120 (SDM120) DAP, productivity (PROD), 100 grain-weight (100GW) and corn ear insertion height (CEIH), *Urochloa brizantha* dry matter at harvest corn (BDM0) and 45 days after (BDM45) and weeds dry matter at 30 (WDM30) and 60 (WDM60) days after corn emergence on intercropping systems.

Planting system	PH (cm)	SD (cm)	SDM60 ($kg\ ha^{-1}$)	SDM120 ($kg\ ha^{-1}$)	PROD ($kg\ ha^{-1}$)	100GW (g)	CEIH (cm)
No Tillage	80.86 A[1]	1.94 A	1,453.16 A	7,337.81 A	3,083.21 A	17.67 A	95.03 A
Tillage	35.93 B	1.70 B	507.00 B	3,979.69 B	991.15 B	11.27 B	55.41 B
CV (%)	42.20	3.37	35.79	34.09	73.72	26.17	19.54

Planting system	BDM0 ($kg\ ha^{-1}$)	BDM45 ($kg\ ha^{-1}$)	WDM30 ($kg\ ha^{-1}$)	WDM60 ($kg\ ha^{-1}$)
No Tillage	1,592.33 A	2,827.50 A	38.13 B	108.42 B
Tillage	1,976.20 A	3,275.00 A	407.64 A	596.65 A
CV (%)	82.37	17.81	101.43	30.93

[1]Averages followed by the same letter in the column do not differ by F test at p≤0.01 probability.

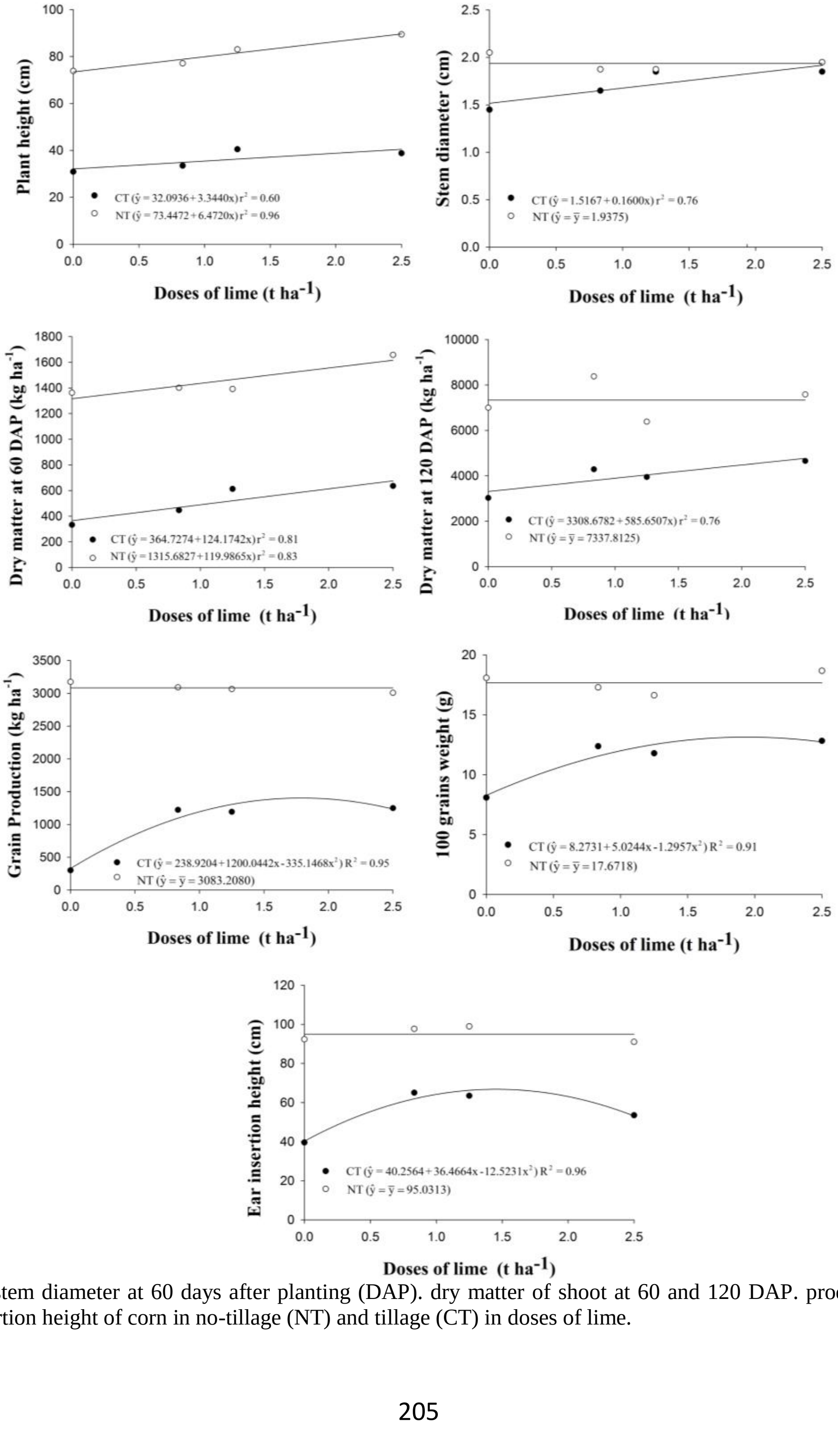

Fig 1. Height and stem diameter at 60 days after planting (DAP). dry matter of shoot at 60 and 120 DAP. productivity. 100-grain weight and ear insertion height of corn in no-tillage (NT) and tillage (CT) in doses of lime.

Table 2. Number of weed species and the similarity index (SI) between systems of no-tillage (NT) and tillage (CT) on intercropping corn-forage.

Lime doses (t ha^{-1})	CT ∩ NT[(1)]	CT	NT	SI (%)
0	5	7	6	76.92
0.833	3	6	7	46.15
1.250	7	7	9	87.50
1.000	5	5	6	90.91

[(1)]CT ∩ NT: intercession between areas. IS (%): [2*(CT ∩ NT)/(CT+NT)]*100

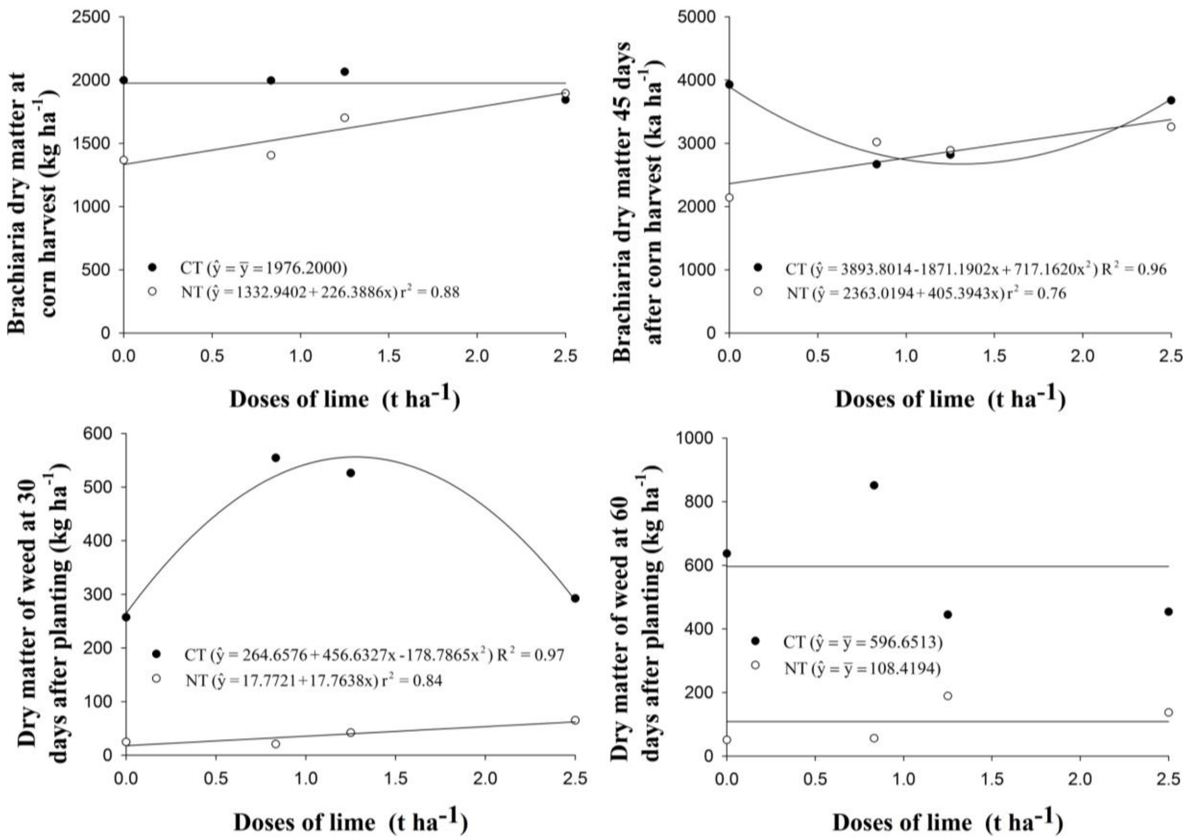

Fig 2. *Urochloa brizantha* dry matter at corn harvest and 45 days after, and weed at 30 and 60 days after planting corn in no-tillage (NT) and tillage (CT) on different doses of liming.

dose applied, whereas in the tillage system, the weed dry matter increased in response to the application of the intermediate doses but decreased with the higher doses. Braga et al. (2012) also reported greater weed emergence after liming. When the Soil Seed Bank (SSB) was assessed 12 plant species were found (Table 2), all of which are considered weeds, which often cause higher competitive capacity, disuniform germination, hardiness and production of a large number of seeds or propagules. In the plots under the tillage and no-tillage systems, the 9 and 10 species of weeds emerged, respectively. In general, a higher germination of these species was observed in the no-tillage system. Therefore, a greater emergency in the totality and diversity of weeds was observed in the no-tillage system. It is likely that in the tillage system the plowing and disking stimulated the emergence of the seedlings and as the soil sampling was performed at 60 DAP, most of the seeds in the soil in this system had already germinated, which was confirmed by the higher quantity of dry matter of the weeds reported in the tillage system after the soil sampling time (Table 1). Furthermore, Voll et al. (2001) reported that no amount of soil and vegetation cover decreased the immediate germination of the weed species, thus increasing the diversity and number of seeds in this system, which indicates the potential for future emergence. The Importance Value Index (IVI) of the species in the soil seed bank was influenced by the liming and planting systems (Fig 3). The species *Urochloa decumbens*, *Acanthospermum australe* and *Portulaca oleracea* were present in all the treatments and exhibited different behaviors with respect to their phytosociological indices. *A. australe* and *B. decumbens* showed higher IVIs in the tillage system whereas *P. oleracea* and *Cynodon dactylon* revealed them in the no-tillage system. All the treatments demonstrated that the species with the highest IVI showed relatively low frequency and high levels of density and relative abundance. This indicates that by establishing these conditions to germinate in the field, these will be presented as "Reboleira", in which the density and abundance represent the number of plants of each species per area and the concentration of these plants in the same area, respectively (Tuffi Santos et al., 2004). Thus, the control of these species can be performed only when they are present and not as is usually done in total area. On comparing the planting systems, the similarity index can be considered high

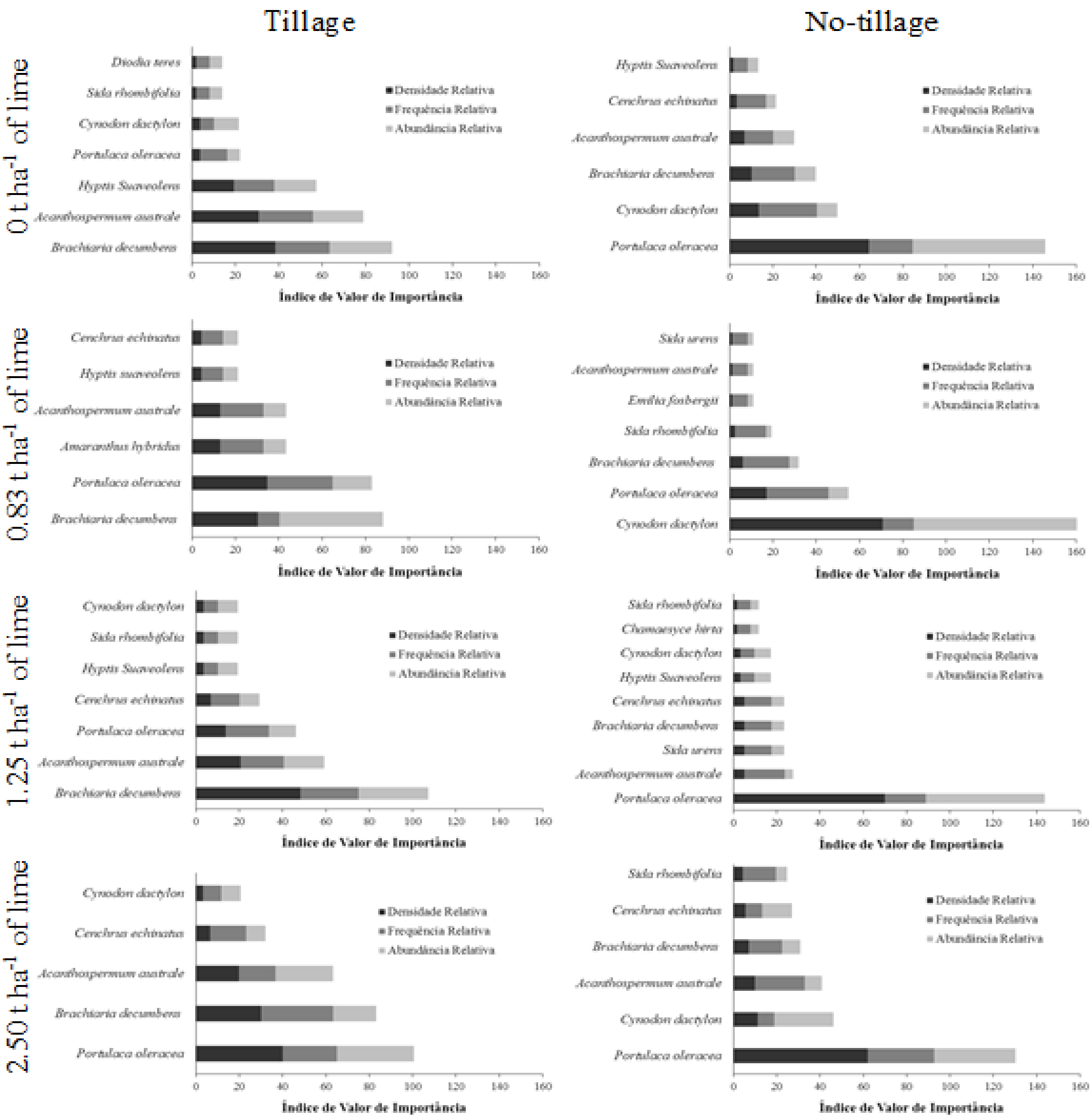

Fig 3. Phytosociological indexs of the soil seed bank in samples that were collected at 60 days after planting crops.

(Table 2), indicating that they have little influence on the potential of the SSB in the first year of adoption of both the systems. The exception was to apply 1/3 of the lime requirement, bearing a similarity of just 46%. In general, the development and yield of brachiaria and corn are more influenced by the planting system than the lime doses during late cropping. Perhaps, on cropping in more than a few years of each of the systems the liming response will be more pronounced. Another important fact is that the experimental area already showed pH values close to the ideal for corn cropping and the contribution of the limestone dosing was basically to supply the calcium and magnesium. However, controlling the weed and soil seed bank dynamics can be an important factor to be considered to ensure the economic sustainability of the system.

Material and Methods

Experimental conditions

The experiment was conducted during the period between January and July of 2009 at the Fazenda Experimental do Moura of Universidade Federal dos Vales do Jequitinhonha e Mucuri – UFVJM in Curvelo-MG, on soil classified as Red Yellow Latosol. Previously, the experimental area had been cultivated with forage for cattle. The clay, silt and sand contents are in the range of 71, 21, 8 dag kg^{-1}, respectively. The chemical analysis of the soil showed the following results: pH (water) of 5.5; organic matter content of 1.8 daq kg^{-1}; P and K of 1.8 and 80.0 mg dm^{-3}, respectively; Ca, Mg, Al , H+Al and CEC 1.0, 0.8, 0.8, 3.3 and 2.8 $cmol_c$ dm^{-3}, respectively.

Statistic design and treatments

The experiment was done in a randomized complete block design with four replications. Treatments were arranged in a scheme of 2x4 split plots, and the plots were composed of both tillage systems (direct and conventional) with subplots of the four limestone treatments of 0, 0.83, 1.25 e 2.50 t ha^{-1} (RNV = 80%). The dose of 2.50 t ha^{-1} is recommended for the corn crop in Minas Gerais state. The total area of each plot was 40 m^2 (5 x 8 m in width and length, respectively) with an area of 18 m^2.

Treatment applications and plant materials

Liming was performed 30 days before planting the crops and limestone was incorporated by plowing and disking in the tillage and in no-tillage systems applied superficially. From 15 days before planting, the area of no-tillage was subjected to desiccation with glyphosate (1.44 kg ha^{-1}). The planting fertilization was performed with 570 kg ha^{-1} of 4-14-8 (N-P_2O_5-K_2O). We opted for the corn sowing variety Al 25, with a 1 m spacing between the rows and 6 plants m^{-1} with a density of 60,000 plants ha^{-1}. The forage plant was *Urochloa brizantha* cv. Marandu sown in two rows of 50 cm among the rows of maize (25 cm apart from the line of corn), using 3.5 kg ha^{-1} of viable seeds planted simultaneously with corn sowed at 2 cm depth. At 30 days after planting, nitrogen fertilization was performed with coverage at a dose of 100 kg N ha^{-1} as urea and at this time the herbicide atrazine was applied (3.3 kg ai. ha^{-1}) in the total area for the control of the weed species.

Agronomical measurements

At 60 Days After Planting (DAP) the plant height, stem diameter and dry matter of shoots were evaluated, whereas at 120 DAP only the dry matter shoot was evaluated, and finally at 150 DAP the ear insertion height, weight of 100 grains and corn yield adjusted to 13% moisture were measured. The dry matter of weeds was obtained at 30 and 60 days after planting, and that of *U. brizantha* was performed at the time of the corn harvesting and after 45 days. The evaluation of both weeds as brachiaria were performed by the method of inventory square with the measurement of 0.5 m per side, done twice in a representative area of each plot. After collection, the plant material was oven dried with forced air circulation at 65°C to constant weight. Evaluation of the Soil Seed Bank was done 60 days after planting the crops. A sample was collected from each plot, 20 cm in depth and 16 cm in diameter. The soil was shade dried, fragmented and homogenized manually. Subsequently, the soil was placed in 3 L capacity pots being irrigated daily with a sprayer. Plant emergence was evaluated at intervals of 30 days, completing four cycles, the objective being to exhaust the soil seed bank. Plants were identified to the species level and the frequency, density and relative abundance were calculated, as well as the importance value index (Muller-Dombois and Ellenberg, 1974) and similarity index (Sorense, 1972).

Statistical analysis

Data were subjected to the analysis of variance, being the qualitative factor (planting system) tested by F test at $p \leq 0.01$ and the quantitative factor (lime doses) analyzed by regression.

Conclusions

The greater corn development and production were found in the no-tillage system regardless of lime application. *Urochloa brizantha* production was less influenced by the type of management adopted in the intercropping corn-forage system. Infestation of weeds was higher in the tillage system, although the no-tillage planting system maintained greater diversity and quantity of viable seeds in the soil.

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