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Biomass yields, soil cover, content and accumulation of nutrients of some green manure legumes grown under conditions of north of Minas Gerais, Brazil

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The potential of green manure crops as conservation practice play an important role in soil quality and sustainability of agricultural systems. This field experiment was conducted in 2009 season to evaluate the performance of different green manures cultivated under Minas Gerais conditions, southeast Brazil. The treatments, in randomized blocks with three replications, were: Spontaneous vegetation (control), Sunhemp (*Crotalaria juncea*), Pigeonpea (*Cajanus cajan*), Velvetbeans (*Mucuna aterrima*, *Mucuna pruriens*, *Mucuna deeringiana*), Lablab (*Lablab purpureus*), Jackbean (*Canavalia ensiformis*), Cowpea (*Vigna unguiculata*) and mixture (all treatments). From the green manures screened, *M. pruriens* and the spontaneous vegetation presented the highest soil covering potential. The largest productions of fresh shoot biomass were recorded from the spontaneous vegetation, *C. juncea* and *C. ensiformis*. *C. juncea* and spontaneous vegetation also had the largest production of dry shoot biomass. The green manures presenting more nutrients in the shoot were the *C. juncea*, with higher contents of N, P, Ca, Mg and B, and spontaneous vegetation with the highest contents of K and Mg. In conclusion, the use of these green manures is promising and an appropriate technology for the reduction of chemical fertilizer use.

Key words: Agroecology, *Canavalia ensiformis*, crop rotation, family farming, green manures.

INTRODUCTION

Green manuring is considered to be a good management practice in all agricultural production systems because of its increasing sustainability cropping system through reducing soil erosion, improving soil physical properties, increasing soil organic matter and fertility level, especially nitrogen (Tejada et al., 2008). Furthermore, the crop rotation through the green manures use are between the key mechanisms for more effective soil nutrient cycling that are so critical to soil productivity, and so, essential to the sustainability development of low-input and organic farming systems around the world (Mohammadi et al., 2011a; Branco et al., 2013).

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Table 1. Sowing seed density used in the experiment.

Green manures	Amounts of seeds	
	Linear meter	kg ha^{-1}
Crotalaria juncea	20	40
Cajanus cajan	18	50
Mucuna aterrima	6-8	60-80
Mucuna pruriens	6-8	60-90
Mucuna deeringiana	6-8	80-100
Lablab purpureus	8	45
Canavalia ensiformis	5-6	150-180
Vigna unguiculata	20	60-75

The cultivation of green manures, notably the legumes, the gives the farmer certain autonomy in relation to the availability of organic matter and has a role in management of soil fertility under the low-input resource-management conditions (Wortmann et al., 2000; Pereira, 2007). The legume family of have an advantage due to their symbiotic associations with N_2 fixing bacteria, resulting in the contribution of considerable amounts of that nutrient to the soil-plant system (Perin et al., 2003), which can be available in subsequent cultivations.

The soil covering is an important measure for the tropical and subtropical soils, since it protects from the direct effects of the sun, rain and wind, thus favoring the maintenance of soil moisture and reducing the temperature oscillation, which consequently favors the microbial activities (Ribeiro, 2008). In addition, principal issues as soil organic matter management in different cropping areas for improving soil health and residues management concerning recycling and environmental protection need to be addressed in future (Mohammadi et al., 2011b). Therefore, due to the high soil conservation efficiency provided by the plant covering of green manures (Telhado, 2007), there is the possibility of high biomass contribution to the cultivated areas.

Although several researches have proved the beneficial effect of green manuring in agriculture, the cultivation ways of several species depend a lot on the edapho-climatic conditions in an area. Therefore, the objective of this work was to evaluate the behavior of some legumes, for their potential as soil covering and in the contents and accumulation of nutrients, in the North region of Minas Gerais, southeastern Brazil, with a view to establish the use of green manures as a management practice that is more relevant to local conditions.

MATERIALS AND METHODS

Site characteristics

The study was conducted in a family rural property (Community of Planalto), near the Montes Claros town, Minas Gerais, Southeast Brazil located approximately 16°54'6"S latitude and 43º52'32" W longitude, altitude 978 m, during April to November, 2009. The main climate, according to the Koppen classification, is Aw – tropical of savannah with dry winter and wet summer. The native vegetation was the Brazilian savannah (also known as Cerrado). The soil of the experimental site is classified as Haplic Cambisol, which physical and chemical properties in the 0 to 20 cm layer prior conducting the experiment were (Embrapa, 1997): pH H_2O (1:2.5) = 6.1; P Mehlich (mg dm^{-3}) = 40.6; K (cmol$_c$ dm^{-3}) = 0.11; Ca^{2+} (cmol$_c$ dm^{-3}) = 3.0; Mg^{2+} (cmol$_c$ dm^{-3}) = 0.8; Al^{3+} (cmol$_c$ dm^{-3}) = 0.00; H + Al (cmol$_c$ dm^{-3}) = 1.41; SB (cmol$_c$ dm^{-3}) = 3.91; t (cmol$_c$ dm^{-3}) = 3.91; T (cmol$_c$ dm^{-3}) = 5.31; V (%) = 74; MO (dag kg^{-1}) = 2.93; Sand (78%); Silt (8%) and Clay (14%).

Experimental design and treatments

The experiment was set up in the random block experimental design, with ten treatments and 3 repetitions. The green manures used were Spontaneous vegetation (control), Sunhemp (*Crotalaria juncea*), Pigeonpea (*Cajanus cajan*), Velvetbeans (*Mucuna aterrima*, *Mucuna pruriens*, *Mucuna deeringiana*), Lablab (*Lablab purpureus*), Jackbean (*Canavalia ensiformis*), Cowpea (*Vigna unguiculata*) and mixture (all treatments). Regarding the treatment with the spontaneous vegetation, a characterization of the area was carried out to verify the main species. The most frequently cultivated species were: *Brachiaria plantaginea* (Link) Hitchc, *Bidens pilosa* L., *Crotalaria incana* L., *Senna obtusifolia* (L.) H. S. Irwin & Barneby, *Sida* spp., *Eleusine indica* (L.) Gaertn, *Acanthospermum hispidum* DC., *Conyza canadensis* (L.) Cronquist, *Commelina diffusa* Burm. f. and *Blainvillea rhomboidea* Cass. The plot size was of 2 m length by 4 m width with four rows per plot, and spacing 1 m between the rows. The sowing density was used according to recommendations for each species (Table 1). The useful sampling area was represented by the two central rows, neglecting 0.5 m on each extremity.

Field practices and management

The soil was prepared for planting through plowing and light harrowing, considered conventional production practices, but did not receive any type of fertilizer or acidity correction. Until the summer of 2009, the area had been cultivated in crop-rotation system, through the planting of annual cultures in the summer and some vegetables (such as green beans, eggplant and okra) in the winter. It is very common to the farmer to use fertilizers at the planting of all cultures and coat fertilization only for vegetables. Furthermore, practices to control eventual pests and diseases of each culture were carried out. In this field experiment, before sowing, bacterias *Rhizobium* spp. from the Embrapa Agrobiologia, specific for each species, were inoculated in the seeds of the green manures. All seeds of the green manures species did not receive any treatment type to overcome the impermeability of the tegument. There was not any culture practice during the field experiment. However, cleaning was conducted in the planting rows after the emergence of the green manures for the removal of the spontaneous plants. The experiment was only irrigated in the initial period of plant establishment, when there was no rainfall.

Measurements

In the reproductive phase of the plants or coinciding with the sampling of the shoot fresh biomass, only the height of the green manures that presented erect behavior was evaluated, such as *C. juncea, V. unguiculata, C. cajan, L. purpureus* and *C. ensiformis.* For such, five plants from each useful area were taken, measured at 1 cm from the soil until insertion of the last leaf of the stem. In the evaluation of the plant coverage (soil cover), it as made an average

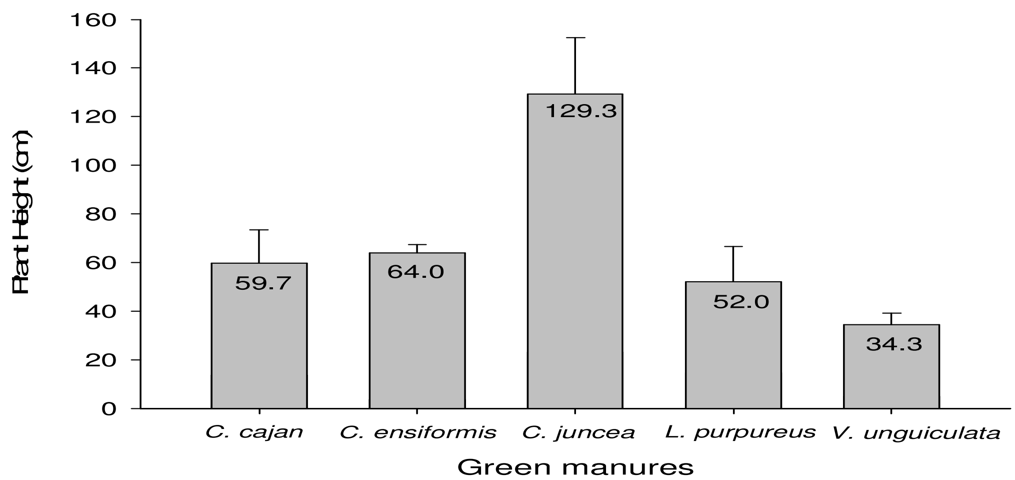

Figure 1. Plant height (cm) of green manures with erect growth habit measured during full flowering (above 50% flowering). Each data is mean of three replications.

of two samplings per plot at 59, 80 and 125 days after sowing (DAS) of the green manures. For this, a 50 × 50 cm wooden frame was used, with a string network spaced 2 cm, where the presence of coverage provided by the green manures and the spontaneous plants at the intersections of the string network was observed. The green manures biomass and their contents and accumulated nutrient in the shoot were appraised between the full flowering phase and the formation of the pods, between 120 and 137 DAS. The vegetation contained in 1 m^2 of the useful area of the parcels was cut close to the soil level and weighed immediately to determine the fresh biomass. The collected shoot material was separated and dried in a forced-air oven at 65°C, until constant weight, for the determination of the dry biomass and accumulation of macronutrient (N, P, K, Ca, Mg and S) and micronutrient (B, Zn, Fe, Mn and Cu). Vegetal tissue samples, after nitric acid (HNO_3) / perchloric acid ($HClO_4$) digestion, P was determined by calorimetry; Ca, Mg, Cu, Fe, Mn and Zn by flame atomic absorption spectrophometry (FAAS); K by flame atomic emission spectrometry (FAES) and S by turbidimetry. Boron (B) was obtained by dry-ashing digestion in a muffle furnace in 500°C for 1.5 h and determined by colorimeter of Azometin H (Malavolta et al., 1997). For the determination of the N content, the ground material was subjected to the sulfuric acid digestion and distillation in a Kjeldahl method. The accumulation of nutrients was determined by the relation between the amount of dry biomass and the nutrient content in the plant tissue.

Statistical analysis

The data obtained regarding the height, soil cover rate, fresh biomass, dry biomass and accumulation of nutrients in the shoot were subjected to the analysis of variance (ANOVA), average of the variables were compared using the Scott - Knott test at 5% level of probability.

RESULTS AND DISCUSSION

Plant height

The average height of the *C. juncea* was longer than the other green manures, presenting 129.3 cm (Figure 1). The superiority of the *C. juncea* was expected, since it is a short-day and fast growing plant compared to the other plants included in this trial (Burle et al., 2006). The similar result was observed by Neto et al. (2008) who found a plant height of 92.4 and 86.5 cm respectively after using bovine manure and humus as substrate source in the Northeastern Brazil (semiarid), although shorter plant height was also observed by Dourado et al. (2001), in savannah soil, in the absence of phosphate fertilizer.

Soil cover

The spontaneous vegetation provided the highest ($p < 0.05$) soil cover over the three appraised times, with 53.7% at 59 DAS, 80.3% at 80 DAS and 97.3% at 125 DAS. However, at 125 DAS, the *M. pruriens* also produced the same soil covering vegetation (98.7%) (Figure 2).

At 59 and 80 DAS, the lowest coverage percentages were observed in the *C. cajan*, *M. deeringiana,* and *M. aterrima*. The *C. cajan* is an erect annual or short-lived perennial, therefore, it might have contributed to the lower coverage values. Besides that, its slow initial growth, as observed up to the 80 DAS, might also have favored that result. Favero et al. (2001) studied the modifications in populations of spontaneous vegetation in presence of green manures and found a slow growth habit for *C. cajan*.

However, for the *M. aterrima*, problems were verified in the emergence of the plantules, besides it having presented slow development. Suzuki and Alves (2006) studied the production of biomass of cover crops in different successions of cultures and cultivation systems and also recorded slow initial development of the *M. aterrima* providing the establishment of spontaneous plants in the plots. Such facts might have culminated in

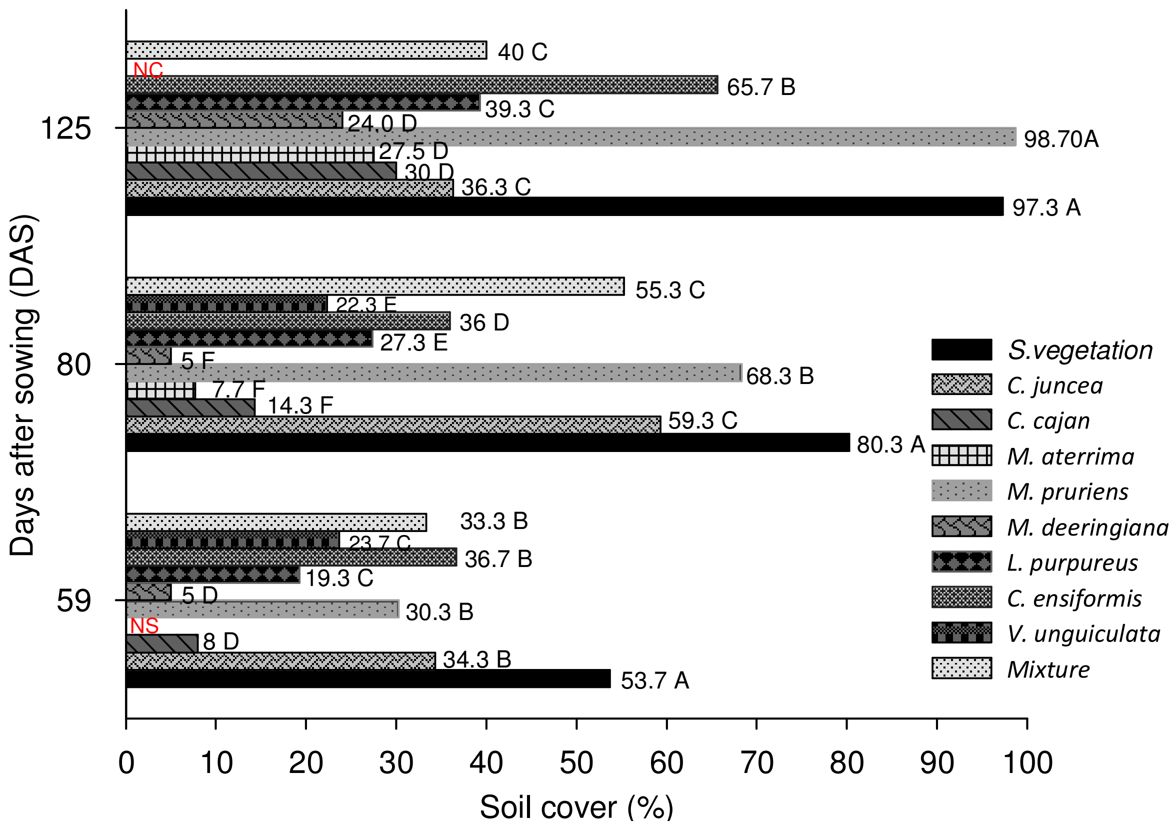

Figure 2. Soil cover (%) of the green manures at 59, 80 and 125 days after sowing (DAS). Values followed by the same letters under each DAS do not differ significantly (Scott - Knott test, P ≤ 0.05). NS, Plant emergence was no sufficient to sample. NC, there was no coverage. Each data is mean of three replications.

unevenness of plantules after 80 DAS. On the other hand, Sodré Filho et al. (2004), in a study conducted with sequential cover crops after maize in Savannah soil, obtained the highest soil cover values in the areas planted with *Mucuna cochinchinensis* at 30 and 60 days after sowing. Therefore, the great advantage of the *M. aterrima* in performing efficient vegetative development and accentuated rusticity is that it enables its good adaptation to water deficiency and high temperature conditions (Amabile et al., 2000). Such a fact, however, was not verified in this research.

It is important to point out that due to the difference between the growth stages of one green manure species in relation to another, certain variation in the soil cover values occurred, not only among the treatments, but also among the sampling periods. At 125 DAS, for instance, the plants were in the following development stages: *C. cajan* - flowering state, already beginning grain filling; *M. aterrima* - in the vegetative development stage; *M. prurients* – end of vegetative development stage to beginning of flowering; *M. deeringiana* and *C. ensiformis* - over 50% flowering; *L. purpureus* - end of grain filling to beginning of maturation; *V. unguiculata* - maturation to complete maturation stage of the grains (presence of dry green beans) and mixture “cocktail” - presence of those previously described stages. The difference in the behavior of the vegetable species, besides those inherent to the species itself, as to the soil cover, can be due to climatic, edaphic and environmental factors, which interfere in the growth and adaptation of the species in that locality.

The prevailing of the spontaneous vegetation with the highest soil covering values can be attributed to the fact that those plants are already adapted to the local climate and soil conditions, besides the possible larger seed bank in the soil. Regarding the legumes, the *M. pruriens* stood out as potential for soil cover at 125 DAS, being important specie to be recommended as fallow or succession in this study condition. Therefore, this green manuring species should be planted at the end of the rainy season. Bueno et al. (2007) admit the benefits provided by the *Mucuna* spp., among them: Fast growth, high fresh biomass production capacity and soil cover.

Productivity of fresh and dry biomass of the shoot

The spontaneous vegetation, *C. juncea* and *C. ensiformis* produced significantly ($p < 0.05$) higher shoot fresh biomass (SFB) production at 12.5, 11.6 and 10.5 Mg ha^{-1} respectively than the other green manures (Figure 3). The

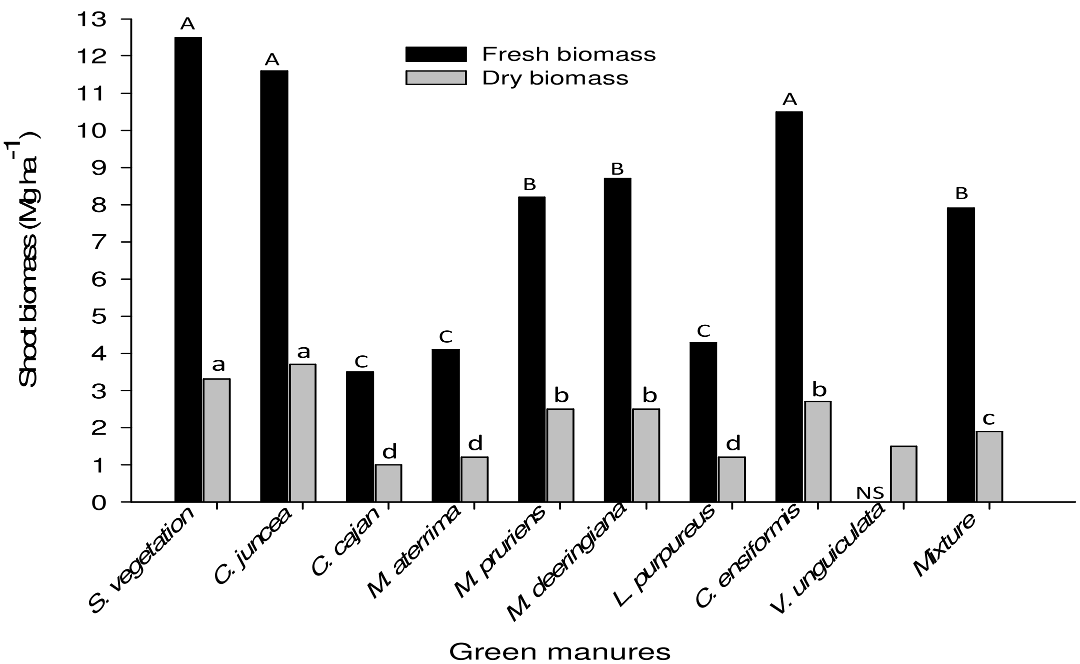

Figure 3. Shoot fresh and dry biomass in the full flowering phase of the green manures. Values followed by the same upper case letters (fresh biomass) and followed by the same lower case letters (dry biomass) do not differ significantly (Scott - Knott test, P ≤ 0.05). NS, No sufficient to sample. Each data is mean of three replications.

highest SFB observed for the spontaneous vegetation can be justified by the presence of plants already adapted to the local environmental conditions, mainly low rainfall and limited soil nutrients. The highest SFB recorded from *C. ensiformis* and *C. juncea* legumes can be related to factors such as nodulation (nodule development was observed) and differences in root development between plants which may have contributed to the variation in the result. In addition to these factors, environmental conditions such as temperature, pH, nutrient availability and soil conditions can have a significant influence on nitrogen fixation by the legumes (Mohammadi et al., 2012).

Shoot dry biomass (SDB) of *C. juncea* (3.7 mg ha^{-1}) and spontaneous vegetation (3.3 Mg ha^{-1}) increased significantly ($p < 0.05$) over the other green manures (Figure 3). Nascimento and Silva (2004) analysed legumes for using as soil covering who found over 2.0 mg ha^{-1} dry biomass of *C. juncea*, a value inferior to that found in the present experiment. Perin et al. (2004) also shown *C. juncea* as a species with potential higher biomass production than the spontaneous vegetation in an experiment conducted in a Cambisol. The *C. juncea*, sown in April in Savannah soil, in succession to the maize culture also produced 2.1 mg ha^{-1} of dry biomass under conventional planting and 2.4 mg ha^{-1} under no-tillage (Sodré Filho et al., 2004). In general, green manuring legumes can produce over 5 mg ha^{-1} of dry biomass during a short period of time during the summer and take up large weeding between rows may also reinforce for this low fresh biomass. Besides, in spite of the *C. cajan* being amounts of N and K (Ambrosano et al., 2010).

Comparatively lower fresh and dry biomass of *L. purpureus*, *M. aterrima* and *C. cajan* legumes (Figure 3) may be due to the change of the planting time of the species. Amabile et al. (2000) suggested that vegetative phase of species, like the *C. cajan*, can reduce if it is sown in a marginal time that possess short days instead sowing in a favorable time (beginning of November). The lowest fresh biomass production by *C. cajan* can be associated to its slow development, where such behavior, has enabled the appearance of spontaneous plants that compete with the *C. cajan* for water, sunlight and nutrients as reported by Suzuki and Alves (2006). No a species already planted within the local conditions, its establishment in the field was appeared later, coinciding with the highest temperatures and the lowest rainfall.

Content and accumulation of nutrients

Macronutrients content, except S, were significantly ($p<0.05$) different among the green manures (Table 2). The highest N contents were observed for the *C. juncea* (46.7 g kg^{-1}) and significantly higher P for *V. unguiculata* (4.2 g kg^{-1}), *L. purpureus* (4.0 g kg^{-1}), *C. juncea* (3.9 g kg^{-1}) and the spontaneous vegetation (3.7 g kg^{-1}). The highest contents were found in the spontaneous vegetation (26.5

Table 2. Content of macronutrients (nitrogen, phosphorus, potassium, calcium, magnesium and sulfur) in the aerial part (shoot) of the green manures; each data is mean of three replications¹.

Green manures	Macronutrients (g kg^{-1})					
	N	P	K	Ca	Mg	S
Spontaneous vegetation	23.1^{d}	3.7^{a}	26.5^{a}	17.1^{c}	4.1^{a}	2.1^{ns}
C. juncea	46.7^{a}	3.9^{a}	9.9^{c}	27.9^{a}	4.0^{a}	2.5^{ns}
C. cajan	34.2^{b}	2.6^{b}	11.8^{b}	17.0^{c}	3.2^{b}	2.0^{ns}
M. aterrima	36.2^{b}	2.7^{b}	5.8^{d}	24.7^{a}	2.1^{c}	2.1^{ns}
M. pruriens	36.4^{b}	2.7^{b}	6.7^{d}	22.0^{b}	2.5^{c}	2.1^{ns}
M. deeringiana	37.7^{b}	2.0^{b}	5.6^{d}	22.9^{b}	1.8^{c}	1.9^{ns}
L. purpureus	30.4^{c}	4.0^{a}	13.2^{b}	21.4^{b}	2.7^{c}	2.7^{ns}
C. ensiformis	38.2^{b}	2.4^{b}	9.1^{c}	22.4^{b}	3.0^{b}	2.5^{ns}
V. unguiculata	35.0^{b}	4.2^{a}	13.9^{b}	25.0^{a}	3.4^{b}	3.2^{ns}
Mixture	38.4^{b}	3.1^{b}	9.9^{c}	28.3^{a}	3.1^{b}	2.7^{ns}
CV (%)	**9.8**	**16.9**	**10.7**	**10.5**	**14.9**	**20.0**

[1]Values followed by same lower case letters in columns do not differ significantly (Scott - Knott test, P ≤ 0.05); ^{ns}, Not significant; CV - Coefficient of variation.

Table 3. Content of micronutrients (boron, zinc, iron, manganese and copper) in the aerial part (shoot) of the green manures; each data is mean of three replications¹.

Green manures	Micronutrients (mg kg^{-1})				
	B	Zn	Fe	Mn	Cu
Spontaneous vegetation	29.0^{b}	34.0^{c}	1006.0^{c}	46.3^{b}	8.6e
C. juncea	42.3^{a}	47.6^{b}	332.6e	55.0^{b}	13.0^{d}
C. cajan	38.0^{a}	35.0^{c}	482.6^{d}	61.6^{b}	16.3^{c}
M. aterrima	28.0^{b}	33.0^{c}	457.0^{d}	67.0^{b}	17.0^{c}
M. pruriens	31.3^{b}	35.3^{c}	325.0e	101.3^{a}	19.6^{b}
M. deeringiana	23.0^{b}	28.0^{d}	334.0e	90.0^{a}	26.0^{a}
L. purpureus	51.3^{a}	42.3^{b}	1353.6^{a}	50.0^{b}	10.0e
C. ensiformis	29.6^{b}	22.0^{d}	227.0e	51.6^{b}	8.0e
V. unguiculata	43.3^{a}	54.0^{a}	1181.3^{b}	78.0^{a}	9.6e
Mixture	35.0^{b}	32.3^{c}	502.3^{d}	84.3^{a}	11.3^{d}
CV (%)	**18.3**	**13.5**	**10.6**	**22.8**	**7.6**

[1]Values followed by same lower case letters in columns do not differ significantly (Scott - Knott test, P ≤ 0.05); CV - Coefficient of variation.

g kg^{-1}) while Ca in Mixture "cocktail" (28.3 g kg^{-1}), *C. juncea* (27.9 g kg^{-1}), *V. unguiculata* (25.0 g kg^{-1}) and *M. aterrima* (24.7 g kg^{-1}). Significantly higher, Mg was found in the spontaneous vegetation (4.1 g kg^{-1}) and *C. juncea* (4.0 g kg^{-1}).

The highest N values found in the *C. juncea* can be related to the good plant efficiency for biological nitrogen fixation, which can be verified in the field by the presence of nodules on the plants. The N (46.7 g kg^{-1}) and P (3.9 g kg^{-1}) contents in the *C. juncea* were above what observed by Cazetta et al. (2005) who evaluated the exclusive and intercropped cultivation of *C. juncea*, and Carvalho et al. (2008) who evaluated covering plants cultivated in succession to maize in Savannah soil. Pereira et al. (2007) also found significant difference ($p<0.05$) in N, P, K, Ca and Mg contents, even for autumn-winter conditions (sowing on 30th March), P content being the highest in the *Crotalaria juncea* (1.5 g kg^{-1}). The K values were highest in the spontaneous vegetation. The reason could be the presence of those plants was more efficient in the absorption of nutrients Perin et al. (2004), although the species found in ours study are different. Our results on Ca and Mg values corroborated the results found by Perin et al. (2004).

The micronutrient contents varied significantly among the green manures used in this experiment (Table 3). Comparatively higher B contents found ranged between 38.0 (*C. cajan*) to 51.3 (*L. purpureus*) mg kg^{-1} and Mn contents ranged from 78.0 (*V. unguiculata*) to 101.3 (*M. pruriens*) mg kg^{-}1. Significantly higher Zn (54.0 mg kg^{-1}),

Table 4. Accumulation of macronutrients (nitrogen, phosphorus, potassium, calcium, magnesium and sulfur) in the aerial part (shoot) of the green manures; each data is mean of three replications[1].

Green manures	Macronutrients (kg ha^{-1})					
	N	P	K	Ca	Mg	S
Spontaneous vegetation	76.9^{b}	12.4^{b}	88.3^{a}	56.8^{b}	13.8^{a}	7.0^{b}
C. juncea	175.8^{a}	14.9^{a}	37.4^{b}	105.1^{a}	15.0^{a}	9.6^{a}
C. cajan	34.7^{c}	2.6^{d}	12.0^{c}	17.3e	3.2^{c}	2.0^{d}
M. aterrima	42.3^{c}	3.1^{d}	6.7^{c}	28.9^{d}	2.4^{c}	2.4^{d}
M. pruriens	89.9^{b}	6.6^{c}	16.5^{c}	54.3^{b}	6.2^{b}	5.1^{c}
M. deeringiana	92.7^{b}	4.9^{c}	13.7^{c}	56.3^{b}	4.4^{c}	4.6^{c}
L. purpureus	36.6^{c}	4.9^{c}	16.0^{c}	26.1^{d}	3.2^{c}	3.4^{d}
C. ensiformis	103.3^{b}	6.5^{c}	24.4^{c}	60.8^{b}	8.2^{b}	6.7^{b}
V. unguiculata	53.8^{c}	6.3^{c}	21.1^{c}	38.0^{c}	5.1^{b}	4.9^{c}
Mixture	74.1^{b}	5.8^{c}	18.5^{c}	52.0^{b}	6.2^{b}	5.0^{c}
CV (%)	**15.9**	**15.2**	**18.8**	**11.3**	**23.3**	**16.5**

[1]Values followed by same lower case letters in columns do not differ significantly (Scott - Knott test, P ≤ 0.05). CV - Coefficient of variation.

Fe (1353.6 mg kg^{-1}), Cu (26.0 mg kg^{-1} contents were observed in *V. unguiculata, L. purpureus* and *M. deeringiana,* respectively. From these results, it can be inferred that most of the appraised green manures correspond positively to micronutrient recycling as reported by Pereira (2007). The nutrient cycling capacity should be, consequently, considered as an essential form for the choice of a green manuring legume.

The *C. juncea* was statistically superior ($p < 0.05$), for the accumulation of the macronutrients N, P, Ca, Mg and S (175.8, 14.9, 105.1, 15.0 and 9.6 kg ha^{-1}, respectively), compared to the other green manures. In addition, the *C. juncea* also had higher accumulation of Mg (15.0 kg ha^{-1}) which is statistically similar to spontaneous vegetation. However, the spontaneous vegetation presented significantly higher K accumulation (88.3 kg ha^{-1}) compared to the other green manures (Table 4).

The highest amounts of macronutrients accumulated by the *C. juncea* (Table 4) demonstrate that it can be cultivated in fallow systems or succession to the cultures of commercial interest, because it will add various nutrients, like N, P, Ca, Mg and S, for subsequent plantings. Furthermore, the highest dry biomass production of the *C. juncea* is an added plus (Figure 3), being essential for the covering and consequent soil protection. Castro et al. (2004) also found the highest total N values accumulated in the *C. juncea* (126 kg ha^{-1}) before the culture (pre-cultivation) of the eggplant (*Solanun melongena*). Thus, the high N accumulation capacity, in a short time span, makes *C. juncea* high potential specie for using as a green manuring crop (Perin et al., 2004). Moreover, the nutrient accumulation capacity in the aerial part of the green manures enables those plants to be used for soil nutrient cycling and biological nitrogen fixation processes (Barroso et al., 2009).

Regarding the spontaneous vegetation, in function of the plant diversity, further study should be needed as various species contributed with great amounts of K and S accumulated (Table 4), compared with the legumes. Thus, one of the suggestions to the family farmer would be the maintenance of the recently harvested area for a long enough periods for the development of the spontaneous plants with consequent biomass production and soil cover. However, care should be taken not to allow those species to produce seeds in the same area as the culture will be cultivated.

According to Table 5, accumulated amounts (g ha^{-1}) of boron (B), zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu) in the shoot of the green manures were significantly different among the treatments. The *C. juncea* presented significantly higher accumulation of B and Zn (159.1 and 179.2 g ha^{-1} ha^{-1} respectively). For the other micronutrients, the spontaneous vegetation presented higher accumulation of Fe (3331.92 g ha^{-1}) while *M. pruriens* and the *M. deeringiana* (250.2 g ha^{-1} and 221.4 g ha^{-1}, respectively) provided the highest accumulation of Mn. The *M. deeringiana* also presented a of higher value accumulated Cu (63.9 g ha^{-1}).

The accumulation of B, Zn and Cu (Table 5) was similar to that observed by Oliveira et al. (2002) who intercropped legumes (*M. aterrima* and *C. ensiformis*) with grasses (corn, sorghum and millet). In contrast, Teixeira et al. (2008) recorded higher values for the micronutrients B, Cu and Fe than our values when they evaluated the micronutrient accumulation in *C. ensiformis*, *C. cajan* and *Pennisetum typhoides* (millet) in single and intercropped cultivation. They found accumulation values of Zn (158.8 g ha^{-1}) and Mn (187.3 g ha^{-1}) in the *C. ensiformis* in single cultivation which are much higher than those values observed for the same species in the present study. However these Zn and Mn contents in *C. ensiformis* observed by them were much lower than the values

Table 5. Accumulation of micronutrients (boron, zinc, iron, manganese and copper) in the aerial part (shoot) of the green manures; each data is mean of three replications[1].

Green manures	Micronutrients (g ha^{-1})				
	B	Zn	Fe	Mn	Cu
Spontaneous vegetation	96.2^{b}	112.7^{b}	3331.9^{a}	152.5^{b}	28.7^{c}
C. juncea	159.1^{a}	179.2^{a}	1250.8^{c}	206.8^{a}	48.8^{b}
C. cajan	38.6^{d}	35.6e	490.7e	62.6^{c}	16.6^{d}
M. aterrima	32.7^{d}	38.6e	534.6e	78.3^{c}	19.8^{c}
M. pruriens	77.3^{b}	87.2^{c}	802.7^{d}	250.2^{a}	48.5^{b}
M. deeringiana	56.5^{c}	68.8^{c}	821.6^{d}	221.4^{a}	63.9^{a}
L. purpureus	60.9^{c}	52.1^{d}	1651.5^{b}	60.7^{c}	12.2^{d}
C. ensiformis	79.8^{b}	59.5^{d}	617.8e	143.2^{b}	21.7^{c}
V. unguiculata	65.7^{c}	82.0^{c}	1793.0^{b}	118.9^{b}	14.7^{d}
Mixture	64.6^{c}	60.8^{d}	961.1^{d}	151.2^{b}	22.9^{c}
CV (%)	**14.1**	**12.0**	**14.6**	**19.1**	**14.4**

[1]Values followed by same lower case letters in columns do not differ significantly (Scott - Knott test, $P \leq 0.05$). CV, Coefficient of variation.

observed for *C. juncea* in our study.

Based on the above results, it should be mentioned that the green manures are quite promising for the rural producer, because they can present good efficiency in extracting soil nutrients in addition to their low cost of cultivation, which can contribute to an increase of culture productivity.

Conclusions

Of the green manures screened, the *C. juncea* was the species that provided the greater height based on erect growth. On the other hand, *M. pruriens* and the spontaneous vegetation presented the highest soil covering potential. The largest productions of fresh biomass were reached by the spontaneous vegetation, *C. juncea* and *C. ensiformis. C. juncea* and spontaneous vegetation also showed largest production of dry biomass.

C. juncea, green manuring crop had higher contents of N, P, Ca, Mg and B while spontaneous vegetation had the largest contents of K and Mg. Thereby, the use of these green manures will be a promising technology for reducing on the usage of chemical fertilizers in the Brazil conditions.

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