

Potential of Species of Green Coverage in Entisol

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Received: February 24, 2019

Accepted: May 8, 2019

Online Published: July 31, 2019

doi:10.5539/jas.v11n11p263

URL: <https://doi.org/10.5539/jas.v11n11p263>

Abstract

The intensive use of the soil, associated with the application of chemical fertilizers, contribute to degradation processes that affect soil quality and crop production. The use of techniques that contribute to soil conservation and reduction of external inputs is important for the success of the agriculture, and hedging is an alternative. The objective of this study was to evaluate the phytomass production nutrient accumulation and contents, as well as rate of decomposition of different species used as cover plants. The experimental design was randomized blocks, with nine treatments distributed in three blocks. The treatments were: *Canavalia ensiformes* (L.) DC., *Crotalaria spectabilis* Roth, *Crotalaria ochroleuca* G. Don., *Crotalaria juncea* L., *Dolichos lablab* L., *Stizolobium niveum* (Roxb.) Kuntze, *Stizolobium aterrimum* Piper & Tracy, *Neonotonia wightii* (Wight & Arn.) J.A. Lackey and *Pennisetum glaucum* (L.) R.Br. The most recommended species as cover plants are *C. ochroleuca* and *C. spectabilis* for they produce more dry matter on the tops, 5.89 and 4.04 kg ha⁻¹, in addition to greater accumulation of nutrients. *C. ochroleuca* and *C. spectabilis* had higher accumulation of N, P, K, Mg and S, and soil coverage with those species can be a good source of green manure. The recommended species for the highest coverage rate are: *N. wightii*; *S. niveum* and *S. aterrimum*. The recommended species for the lowest rate of decomposition are: *S. aterrimum*; *S. niveum*; *P. glaucum* and *C. ochroleuca* (0.245; 0.260; 0.264 and 0.276% month⁻¹).

Keywords: decomposition, phytomass, graminea, legumes, macronutrients

1. Introduction

The Brazilian Northeast region is characterized by its climatic variability, which, alongside the reduced vegetation coverage, favors the erosive process, reducing the physical, chemical and biological quality of the soil. The use of cover crops has become an efficient practice in keeping the soil covered for longer, as well as promoting the improvement of chemical and physical properties, in addition to keep the soil protected against rainfall impacts. The decomposition and mineralization of this material improves soil fertility, reducing the amount of fertilizers, mainly nitrogen fertilizers, used in crops of economic value (Foloni, Catuchi, Barbosa, Calonego, & Tiritan 2016; Ordóñez-Fernández, Torres, Márquez-García, Moreno-García, & Cabonell-Bojollo, 2018).

Knowing the importance of cover crops in the rotation or succession of crops in semi-arid regions, is essential for the intensive use of the soil, high temperature, low precipitation and high evaporation, cover plants can be an important allied to reduce these factors. In the northeastern region of Brazil, there are already studies with cover plants, however it is necessary to know more about the contribution of phytomass, accumulation of nutrients and decomposition of the material. Among the factors that may contribute to the successful use of these plants are the cycle, climatic conditions and morphological characteristics.

The cycle of the species is an important aspect to be considered, since a shorter cycle will favor the species to be inserted in the system of rotation and succession of cultures, as well as species that have a fast growth, covering the ground thoroughly, which contributes to reduce the incidence of spontaneous plants and protecting the soil from sun exposure (Teodoro, Oliveira, Silva, Fávero, & Quaresma, 2011). This technique also directly contributes to the accumulation of dry matter and the nutrient supply (*i.e.*, nitrogen) more gradually in the soil (Santos, Nunes, Giongo, Barros, & Figueiredo, 2018).

The present study allows to determine the effect of biomass, nutrient extraction, decomposition, mineralization and nutrient release on the soil (Ambrosano et al., 2013). The non-replenishment or slow mineralization of the plant material will provide low nutrient availability in the soil, resulting in low nutrient contents in the plant material (Barbosa, Lazarini, Picoli, & Ferrari, 2011), while higher levels and phytomass production will result in greater accumulations of nutrients, in addition to maintaining soil moisture and reducing erosion.

Given this, the objective of this study was to evaluate the phytomass production, nutrient accumulations and contents and rate of decomposition of different species used as cover plants.

2. Material and Methods

The experiment was conducted from May to November 2015 in the experimental field of the Olericulture Module, located at the Experimental Farm of Olho D'Água, Areia-PB, belonging to the Federal University of Paraíba (UFPB). The climate of the region is Tropical wet (As, with dry summer), according to Köppen (Alvares et al., 2013).

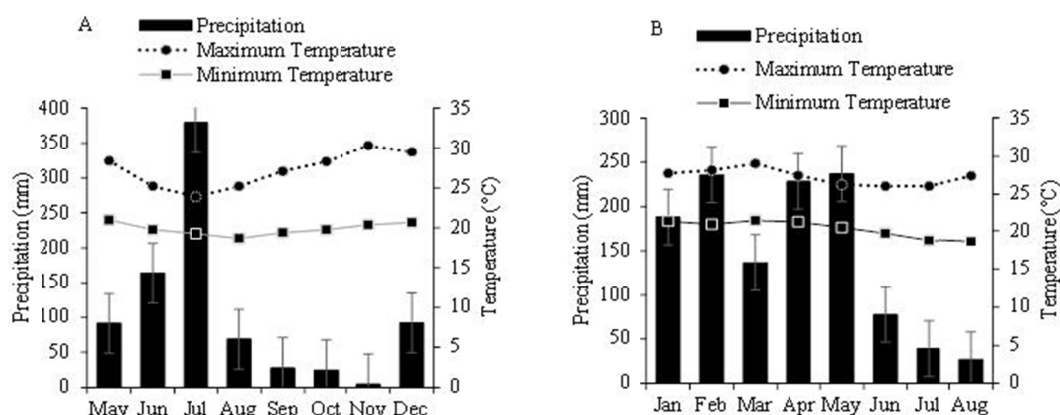


Figure 1. Precipitation, maximum and minimum temperature data for the years 2015 (A) and 2016 (B). Meteorological Station of CCA-UFPB-Areia-PB

The soil was a sandy Entisol (Soil Taxonomy, 2014), with the following properties in layers 0-10 and 10-20 cm: pH in water, 5.8 and 5.6; calcium, magnesium, potential acidity ($H^+ + Al^{3+}$), 1.91 and 1.94; 0.77 and 0.75; 3.06 and 3.26 $cmolc\ dm^{-3}$, respectively; sodium phosphorus and potassium, 0.03 and 0.03; 34.99 and 37.01; 102.30 and 78.27 $mg\ dm^{-3}$ in that order; organic matter, 10.97 and 10.72 $g\ kg^{-1}$.

The experiment will be conducted in the long term. The initial experiment was carried out in 2014, and 2015 was the second year of cultivation. The experimental design was in randomized blocks, with nine treatments and three replications. The treatments consisted of the following species: (*Canavalia ensiformes* (L.) DC.), (*Crotalaria spectabilis* Roth), (*Crotalaria ochroleuca* G. Don.), (*Crotalaria juncea* L.), (*Dolichos lablab* L.), (*Stizolobium niveum* (Roxb.) Kuntze), (*Stizolobium aterrimum* Piper & Tracy), (*Neonotonia wightii* (Wight & Arn.) J.A. Lackey) and (*Pennisetum glaucum* L.) R.Br. For the species *N. wightii*, it was chosen to work with regrowth. In the first year of cultivation, the plot with the species *C. juncea* was lost, being again inserted in the work in the year 2015, being the first year of cultivation while other species were in the second year.

Each plot consisted of a useful area of 24 m^2 (6 × 4 m), with 8 rows spaced 0.50 m between rows and 0.10 m between plants. Spacing between blocks 1.0 m and between plots 0.50 m. Seeding was performed considering a depth of 3 cm. The experiment was conducted in rainfed cultivation and the cultural treatments were carried out during initial period.

The soil cover rate was evaluated for the species *S. niveum*, *S. aterrimum*, *C. ensiformes*, *N. wightii* and *D. lablab* at 30; 45; 60; 75 and 90 DAS by the number method of intersections described by (Alvarenga, Costa, Moura Filho,

& Regazzi, 1995). The green phytomass was obtained when the plots were with 50% of the flowering plants, and a square of wood of 0.50×0.50 m was randomly released at 4 points of the plot. The material inside the square was collected and weighed. Based on the data, the dry weight of shoot, roots and total (t ha^{-1}) was calculated.

After weighing the samples, they were sent to the laboratory, where they were washed and conditioned in a forced circulation oven at 65°C for 72 hours. After drying, the material was weighed, ground and sent to the laboratory to determine macronutrient contents (Brazilian Agricultural Research Company [EMBRAPA], 1998). The accumulation of nutrients was obtained through product of the amount of dry mass by the content of the nutrients of the species.

After cutting the plants in the flowering period, material was collected to analyze the rate of dry matter decomposition. The material was dried in a forced circulation oven at 65°C until constant weight. The carbon in the material was determined by the muffle method (Goldin, 1987). Based on the C and N contents, the C/N ratio of the samples was determined (Table 1). Then, 30.0 g (corresponding to the material of each treatment) were separated and packed in nylon bags (litter bags), measuring 0.04 m^2 , made with a 1 mm mesh screen (Alves, Souto, Souto, & Holanda, 2006). Subsequently, five bags were distributed per treatment on the soil surface in each plot, totaling 135 bags in the experimental area.

The dry matter decomposed as a function of time was calculated by the difference between the initial weight (30.0 g) and the weight after oven drying at 65°C , thus obtaining the remaining dry weight percentage. With these data, decomposition rates were estimated by several regression models commonly used in decomposition studies. The model that provided the best fit for all species was the first-order exponential: $M_t = M_0 \cdot e^{-kt}$ (Barlocher et al., 2005), in which: M_t is the dry weight percentage remaining after t days and M_0 is 100% when t is equal to zero. Thus, for each cover plant, in each experimental plot, an equation was obtained. The half-life ($t_{1/2} = 0.693/k$) was calculated. Based on the adjusted model, the graphs were generated in the R[®] program, according to the calculation to determine the half-life ($T_{1/2}$) proposed by Paul and Clark (1989), where, $t_{1/2} = 0.693/k$, being $t_{1/2}$ the time required for 50% decomposition and constant decomposition.

Data were submitted to analysis of variance and, when significant, the Tukey test ($p \leq 0.05$) was performed using the SAS[®] statistical package (Cody, 2015).

3. Results and Discussion

In Figure 2A, the soil cover data of the species fitting the quadratic polynomial model are presented. At 90 DAS, *S. niveum* presented 100% coverage area, while *S. aterrimum* at 90 DAS covered 90.95% of the area. Greater soil coverage was attributed to the species with prostrate/climbing habit, *S. niveum*, *S. aterrimum* and *D. lablab*—100; 90.95 and 87.50%, respectively.

In figure 2B, the coverage rate data for *N. wightii* is presented. At 30 DAS, *N. wightii* presented 50% coverage, indicating its capacity for spontaneous suppression, since it has high competitiveness and fast coverage of soil. At 60 DAS, it reached 100% coverage. Mucunas and *C. ensiformes* are efficient in terms of greater soil coverage and suppression of weeds. Species with low growth habit have greater ability to smother and aggressivity, reducing the population of spontaneous plant species.

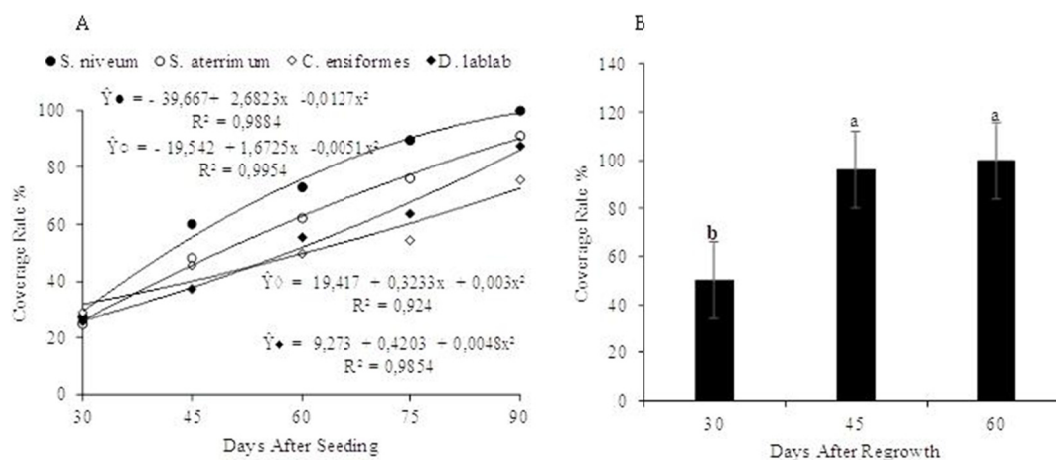


Figura 2. Rate of cover of species used as green manure *S. niveum*, *S. aterrimum*, *C. ensiformes*, *D. lablab*, at 30, 45, 60, 75 and 90 DAS (Figura 2A) *N. wightii* at 30, 45 and 60 DAR (Figura 2B)

During the conduction of the experiment, rainfall was irregular, delaying species' development; coverage rates were lower than those described by (Souza, Santos, Rios, & Souza, 2018). *C. ochroleuca* produced the highest amount of dry matter of tops 5.89 t ha^{-1} (Figure 3A). *C. spectabilis* produced 4.04 t ha^{-1} of dry mass, having the second highest production. The species *N. wightii* and *C. juncea* produced 3.12 and 2.98 t ha^{-1} , respectively.

The higher dry matter production of the area cultivated with *C. spectabilis* and *C. ochroleuca* can be explained by the fact that these species present a more woody stem when compared to the others that have more tender stems. The rainfed cultivation and the irregular rains in the region during the period (Figure 1A) may have contributed to a reduction in the mass production of the dry matter of the species *S. niveum*, *S. aterrimum*, *C. ensiformes*, *N. wightii*, *D. lablab*. According to Pacheco et al. (2011), among the factors that interfere in phytomass production are late sowing and low rainfall.

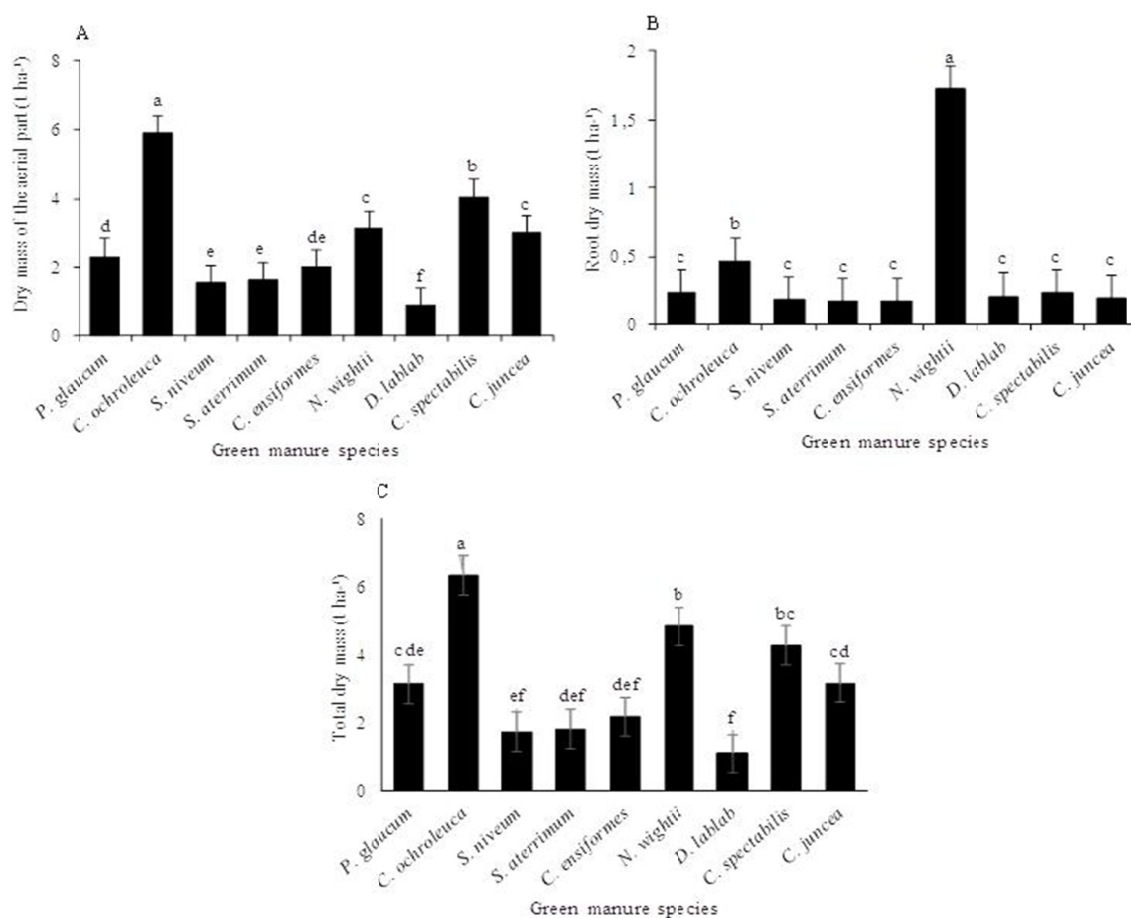


Figure 3. Mean mass values of dry matter of aerial (A) root (B) and total (C) of species used for green fertilization, in the stage which 50% of the plants were blooming. Means followed by the same letters do not differ by Tukey's test ($p \leq 0.05$)

Greater root dry mass (Figure 3B) was obtained for *N. wightii*, 1.73 t ha^{-1} , which has deep roots and high productivity, possibly associated with regrowth cultivation. *C. ochroleuca* presented the second highest value of the dry matter in the root, demonstrating its potential for the mass production of the roots and consequent increase of organic matter in the soil throughout its cultivation. The other species presented similar values, due to the similar characteristics of pivotal roots.

For the variable total dry matter (Figure 3C), the *C. ochroleuca* species produced the highest mass (6.35 t ha^{-1}), differing from the others, which can be explained by satisfactory yield in both shoot and root, followed by *N. wightii* (4.85 t ha^{-1}) and *C. spectabilis* (4.28 t ha^{-1}). Higher productivity may be associated with higher plant density per linear meter; in addition, productivity values may be influenced by planting season and climate, which may inhibit or stimulate vegetative development of the species.

(Macedo, Costa, Viana, & Freire, 2013) found out yield of *C. juncea* and *P. glaucum* (3.80 to 3.0 t ha^{-1}) were similar to this study (3.17 and 3.13 t ha^{-1}). The species *C. ensiformes* and *C. spectabilis* had nitrogen contents of 30.86 and 30.15 g kg^{-1} (Figure 4A), similar to the species *C. ochroleuca*, *S. niveum*, *N. wightii* and *D. lablab* (24.75 , 24.68 , 27.74 and 24.92 g kg^{-1} , respectively). The species *P. glaucum* presented lower content (12.39 g kg^{-1}).

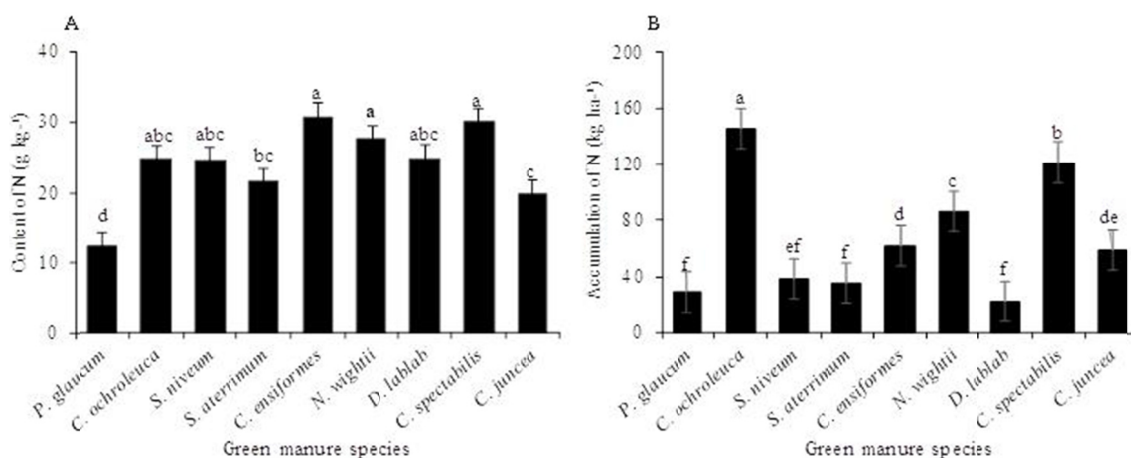


Figure 4. Average nitrogen content (A) and accumulation (B) in the dry matter of green manure, in the stage which 50% of the plants were flowering. Means followed by the same letters do not differ by Tukey test ($p \leq 0.05$)

C. ochroleuca accumulated $145.93 \text{ kg ha}^{-1}$ of N, differing from the other species (Figure 4B), while *C. spectabilis* accumulated the second largest N content. Santos et al. (2018) explains that cover crops, especially legumes, provide greater availability and maintenance of stable concentrations of nitrogen and carbon in the soil.

The legumes have a greater capacity of fixing the atmospheric N through the symbiosis performed with bacteria of the genus *Rhizobium*, and the N fixed by the legumes is immobilized in the plant material. After the cutting of the species, with the process of decomposition and mineralization of the material N will be released to the soil, attending the crop in succession (Ordóñez-Fernández et al., 2018). Leguminosae presented higher levels of N (except *C. juncea*), which can be explained by the fact that this was the first year of cultivation of this species in the experimental area, and there were no residues from the previous crop, provoking a lower content of this nutrient when compared to other legume species in the second year of cultivation.

P. glaucum had the highest P content, followed by *C. ensiformes* and *C. spectabilis* (4.63 ; 3.08 and 2.77 g kg^{-1} , respectively) (Figure 5A). With respect to the accumulation of P (Figure 5B), the species that accumulated the most were *C. ochroleuca*, *C. spectabilis* and *P. glaucum* (14.19 ; 11.31 and 10.71 kg ha^{-1} , respectively).

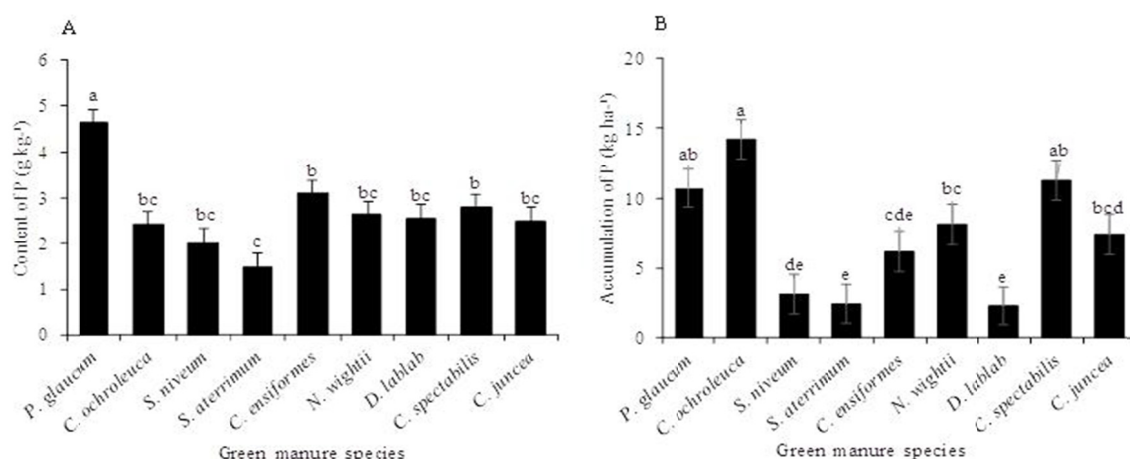


Figure 5. Content (A) and phosphorus accumulation (B) in the dry matter of green manures, in the stage which 50% of the plants were flowering. Means followed by the same letters do not differ by Tukey test ($p \leq 0.05$)

Some species presented low dry matter yield, however they presented satisfactory nutrient contents, which grants them the capacity to recycle nutrients. *P. glaucum*, although presenting low phytomass productivity, presented higher levels and accumulations of P, therefore this species could be considered efficient in recycling this nutrient (Rodriguez et al., 2012).

Boer et al. (2007) state that accumulation of nutrients varies according to species, phenological stage, dry matter production and planting season. In the present study, the climatic conditions during the experiment were irregular, which may have contributed to phytomass productivity and nutrient accumulations to be lower than those found in the literature.

P. glaucum had a K content of 23.75 g kg⁻¹, the highest content when compared to the other species (Figure 6A). *C. ochroleuca*, *N. wightii*, *C. spectabilis* and *C. juncea* did not differ among themselves, and their values were 16.88; 18.75; 16.87 and 16.67 g kg⁻¹, respectively. Regarding the accumulation, *C. ochroleuca* accumulated 99.26 kg ha⁻¹ of K, being superior to the other species (Figure 6B).

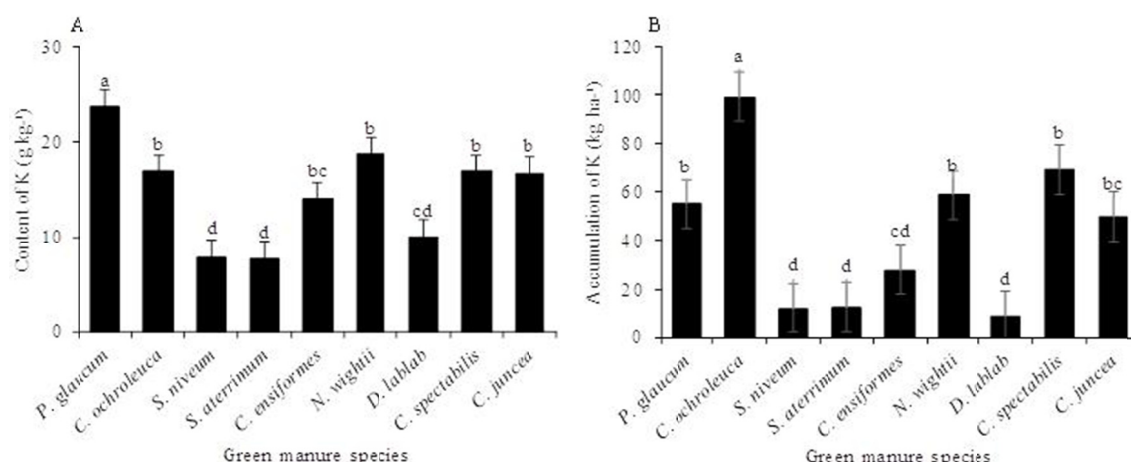


Figure 6. Content (A) and potassium accumulation (B) in the dry matter of green manures, in the stage which 50% of the plants were flowering. Means followed by the same letters do not differ by Tukey test ($p \leq 0.05$)

Soil type, temperature, humidity, plant density, consortium system, water availability and nutrients affect the production and nutrient uptake in cover crops. Results for the species with lower accumulation of K are related to lowest phytomass production and lower K content.

The highest Ca content was found in the plant tissue of *C. ensiformes* (22.07 g kg⁻¹), not differing from the species *C. spectabilis*, *S. aterrimum* and *D. lablab* (21.71; 19.20 and 7.78 g kg⁻¹, respectively) (Figure 7A). The highest accumulations of Ca were found in *Crotalaria spectabilis* and *C. ochroleuca* (87.38; 73.97 kg ha⁻¹),

differing from the others (Figure 7B). The results for *C. juncea* were superior to those of Barbosa et al. (2011), which verified accumulation of Ca of 26.04 and 17.01 kg ha⁻¹, in two sowing periods.

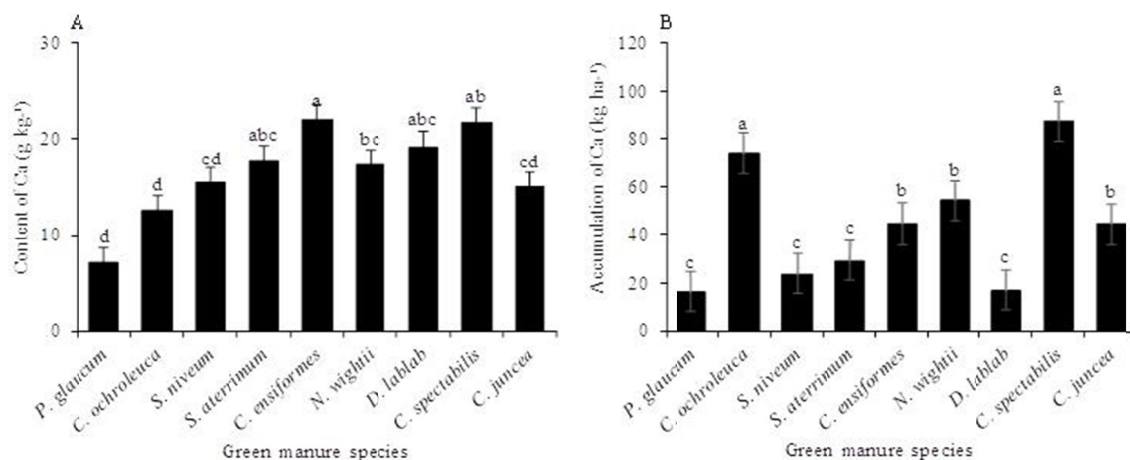


Figure 7. Calcium content (A) and accumulation (B) in the dry matter of green manures, in the stage which 50% of the plants were flowering. Means followed by the same letters do not differ by Tukey test ($p \leq 0.05$)

Mg contents are presented in Figure 8A. *C. ochroleuca* obtained a higher content, followed by *N. wightii*, *C. juncea* and *D. lablab* (5.14; 4.75; 4.27 and 4.06 g kg⁻¹). *C. ochroleuca* had higher accumulation of Mg (30.37 kg ha⁻¹) (Figure 8B).

Mg contents were similar to the study by Rodrigues et al. (2012) (Figure 1), for *C. juncea*, *S. aterrimum*, *C. ensiformes* and *P. glaucum* (4.1; 3.0; 3.6 and 4.5 g kg⁻¹). In order to increase nutrient accumulation, fertile soil and available nutrients are essential, in addition to adequate precipitation, for higher phytomass production (Pacheco et al., 2011).

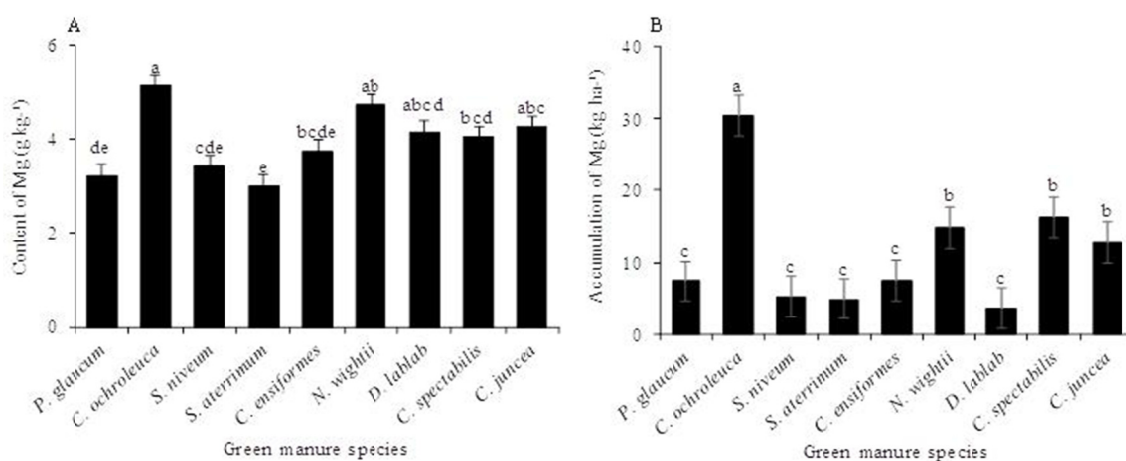


Figure 8. Content (A) and magnesium accumulation (B) in the dry matter of green manures, in the stage which 50% of the plants were flowering. Means followed by the same letters do not differ by Tukey test ($p \leq 0.05$)

P. glaucum had higher S content, 2.04 g kg⁻¹ (Figure 9A). For accumulation of S, *C. ochroleuca* was superior, but similar to *C. spectabilis*, *P. glaucum* and *N. wightii*, with 6.45; 5.49; 4.72 and 4.53 kg ha⁻¹, respectively (Figure 9B). S content observed for *P. glaucum* in this study was similar to the one observed by Foloni et al. (2016), 2.56 g kg⁻¹, and higher than described by Rodrigues et al. (2012), 1.2 g kg⁻¹.

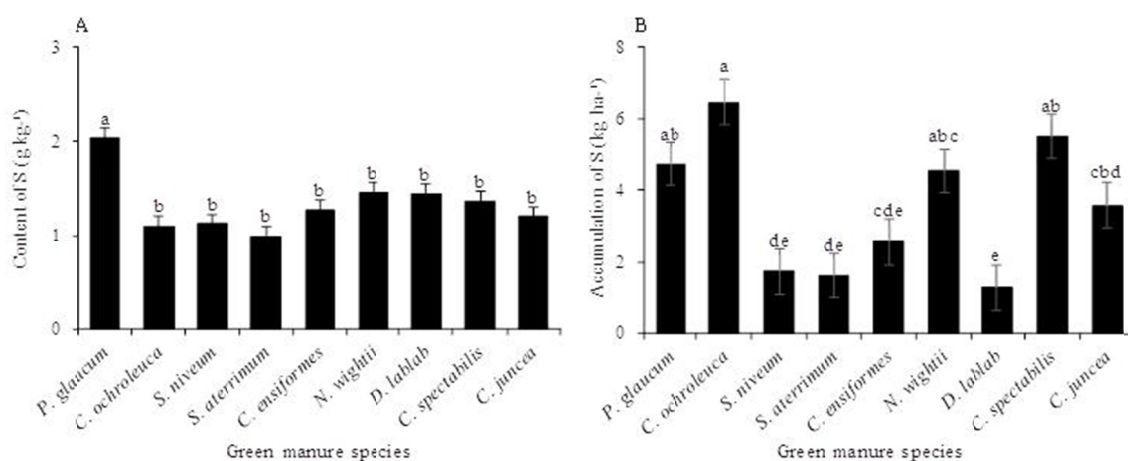


Figure 9. Content (A) and sulfur accumulation (B) in the dry matter of green manures, in the stage which 50% of the plants were flowering. Means followed by the same letters do not differ by Tukey test ($p \leq 0.05$)

Accumulation of nutrients is proportional to mass production, and in order to obtain significant results it is necessary to choose the species recommended for the region and, mainly, that the climatic conditions favors both its development and greater mass production by area (Pacheco et al., 2011). Coating plants can be efficient in accumulating nutrients in the plants dry matter, which, through chemical decomposition and mineralization, will provide chemical improvement of the soil, thereby reducing the use of fertilizers (Rodrigues et al., 2012).

Table 3 shows the values of M_0 (maximum decomposable potential, %); k (rate of decomposition, % month⁻¹); R^2 (coefficient of determination of the model); $T_{1/2}$ (half-life, or time required for 50% decomposition, months) and the C/N ratio of the species.

Table 3. Maximum decomposable potential, monthly decomposition rates, model parameters, number of months to occur 50% decomposition and C/N ratio of coverage plants

Species	M_0	K	R^2	$T_{1/2}$ months	C/N Ratio
<i>P. glaucum</i>	100	0.264	0.97	2.62	36
<i>C. ochroleuca</i>	100	0.276	0.98	2.61	19
<i>S. niveum</i>	100	0.26	0.99	2.66	19
<i>S. aterrimum</i>	100	0.245	0.99	2.82	22
<i>C. ensiformes</i>	100	0.352	0.98	1.96	15
<i>N. wightii</i>	100	0.299	0.99	2.31	17
<i>D. lablab</i>	100	0.317	0.98	2.18	18
<i>C. spectabilis</i>	100	0.44	0.98	1.57	15
<i>C. juncea</i>	100	0.335	0.98	2.06	23

Decomposition of the plant material depends on factors such as precipitation, temperature, humidity and the presence of organisms in the soil. Figure 10 shows the values and intervals of k with respect to the rate of decomposition of the species. The highest rate of decomposition was observed for *C. spectabilis* with $k = 0.44\%$ month⁻¹, which may be related to its higher N content and lower C/N ratio (15:1). The decomposition of *P. glaucum*, *C. ochroleuca*, *S. niveum* and *S. aterrimum* was similar with mean monthly decomposition of 0.264; 0.276; 0.26 and 0.245% of month⁻¹, differing from *C. ensiformes*, *N. wightii*, *D. lablab* and *C. juncea* (0.352; 0.299; 0.317 and 0.335% month⁻¹).

At 30 days, the species presented 25% of similarity and slower decomposition, which can be explained due to the low rainfall recorded in December (Figure 1A), except for the species *C. spectabilis*, of which approximately 35% of the initial material had already been decomposed at 30 days. From the 30 days, the decomposition rate was faster, compared to the other periods, which can be explained by an increase in precipitation recorded from January (Figure 1B).

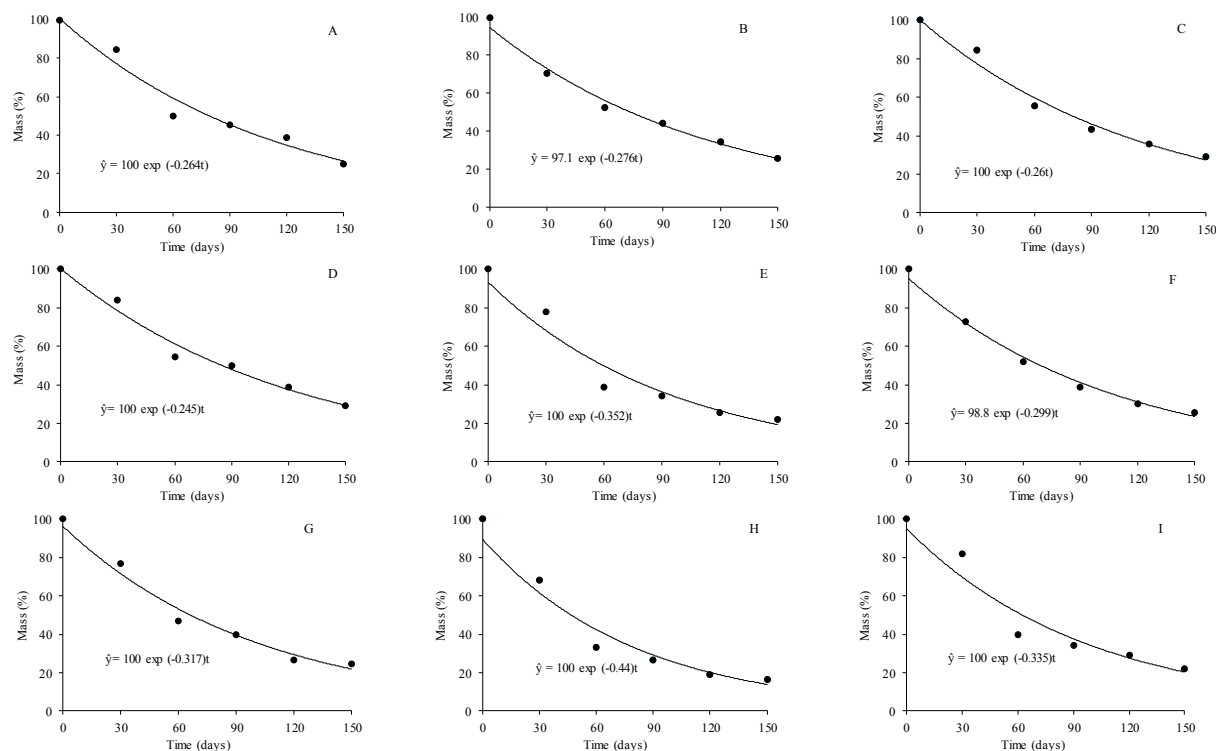


Figure 10. Percentage change of mass as a function of time in green manure species, *P. glaucum* (A.), *C. ochroleuca* (B.), *S. niveum* (C.), *S. atterrimum* (D.), *C.* (E.), *N. wightii* (F.), *D. lablab* (G.), *C. spectabilis* (H.), *C. juncea* (I.), evaluated at 0, 30, 60, 90, 120 and 150 days

The fact that the species present similarity in the rate of decomposition may be related to the values of the near C/N ratio, as well as the half-life time (Boer et al., 2007). The half-life ($T_{1/2}$), which means the time needed to reach 50% of the dry matter decomposition of each species, is presented in Table 3. Species with higher $T_{1/2}$ are presumed to be used when the objective is to keep the residues under the soil, and species with a lower $T_{1/2}$ when the succession is an agronomic crop, since nutrient decomposition and mineralization is faster (Viola et al., 2013). *C. spectabilis* presented the lowest $T_{1/2}$, and *S. atterrimum* presented higher $T_{1/2}$; the highest $T_{1/2}$ may be related to high lignin contents, making it difficult for microorganisms to act and, consequently, slowing decomposition (Viola et al., 2013).

The climate is a fundamental factor for the decomposition process, mainly precipitation and temperature, since both influence the environmental conditions of the soil, therefore, in the greater or lesser microbial activity. According to (Santana, Vieira, Souto, Gondim, & Fonseca, 2011), the type of management interferes with the rate of decomposition, and the incorporation of the material accelerates the decomposition process, as well as precipitation. In the present study, precipitation and temperature were higher from January to May (Figure 1B), during which time the samples were collected.

4. Conclusions

The most recommended species to be used as cover plants are: *C. ochroleuca* and *C. spectabilis*, since they produce more dry matter on the tops, 5.89 and 4.04 kg ha⁻¹, and also showed greater accumulation of nutrients.

C. ochroleuca and *C. spectabilis* had the highest accumulations of N, P, K, Mg and S, and soil cover may be a good source of green manure.

The species recommended for the highest coverage rate are: *N. wightii*; *S. niveum* and *S. atterrimum*.

The species recommended for the lowest rate of decomposition are: *S. atterrimum*; *S. niveum*; *P. glaucum* and *C. ochroleuca* (0.245; 0.260; 0.264 and 0.276% month⁻¹).

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