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Biomass production by legumes for green manure in Santarém, Pará, Brazil

Produção de biomassa por leguminosas para a adubação verde em Santarém, Pará, Brasil

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ABSTRACT

The practice of green manuring, involving the cultivation of plant species with beneficial characteristics for the soil, stands out as an effective strategy for improving soil fertility. The objective of the present study was to evaluate the biomass production of three species recommended for use as green manure (sun hemp - *Crotalaria juncea*; black velvet bean - *Mucuna aterrima*; stylo - *Stylosanthes macrocephala*). The research was carried out in Santarém, Pará, using a randomised block design with six replications. Data collection was carried out 90 days after planting and included measurements of plant height, fresh aerial part mass (FAPM), dry aerial part mass (DAPM), dry root mass (DRM), total dry mass (TDM), root length and stem diameter at the root collar. It was observed that sunny hemp stood out among the species with the highest production of fresh (1.43 ± 1.2 t ha^{-1}) and dry biomass (0.46 t ha^{-1} and 0.21 t ha^{-1}) in the aerial part of the plant. Black velvet bean was remarkable for its root length with an average of 33.2 cm. These results are highly relevant to sustainable agriculture, as green manuring plays a crucial role in promoting soil health, conserving natural resources and increasing agricultural productivity. The cultivation of species such as sun hemp and black velvet bean could provide significant benefits to crops.

KEYWORDS: Sustainable agriculture; agroecology; nutrient cycling; biological nitrogen fixation.

RESUMO

A prática de adubação verde, que envolve o cultivo de espécies vegetais com características benéficas para o solo, destaca-se como uma estratégia eficaz para a melhoria da fertilidade do solo. O presente estudo teve como objetivo avaliar a produção de biomassa de três espécies indicadas para utilização como adubação verde (crotalária - *Crotalaria juncea*; mucuna preta - *Mucuna aterrima*; estilosante - *Stylosanthes macrocephala)*. O trabalho foi realizado em Santarém, Pará através de um delineamento inteiramente casualizado, seis repetições e instalação do experimento em propriedade rural familiar. A coleta de dados foi realizada 90 dias após a semeadura e incluiu a medição da altura das plantas, massa fresca da parte aérea (MFPA), massa seca da parte aérea (MSPA), massa seca das raízes (MSR), massa seca total (MST), comprimento das raízes e diâmetro do colo da raiz. Observou-se que a crotalária se destacou em relação às demais espécies, apresentando a maior produção de biomassa fresca (1,43 ± 1,2 t ha^{-1}) e seca (0,46 t ha^{-1} e 0,21 t ha^{-1}) na parte aérea da planta. A mucuna preta se destacou para o comprimento de raiz com média de 33,2 cm. Esses resultados são de grande relevância para a agricultura sustentável, pois a adubação verde desempenha um papel fundamental na promoção da saúde do solo, na conservação dos recursos naturais e no aumento da produtividade agrícola. O cultivo de espécies como crotalária e mucuna preta poderá proporcionar benefícios significativos para os cultivos.

PALAVRAS-CHAVE: agricultura sustentável; agroecologia; ciclagem de nutrientes; fixação biológica de nitrogênio.

INTRODUCTION

With large-scale agricultural production, soil degradation processes in Brazil occur more rapidly, making it necessary to seek alternatives that promote proper soil management (ALVES 2021). In this context, adding organic matter to the soil is crucial, serving as an alternative to mitigate soil degradation (CHERUBIN et al. 2023).

Among the aforementioned practices, green manuring stands out as a management technique that positively influences soil fertility. This technique involves planting specific plant species that provide benefits after cutting, and is recognized as a viable option for sustainable crop production (ALCÂNTARA et al. 2000, LEITE et al. 2017, SILVA et al. 2014).

Green manuring involves adding fresh plant biomass, with or without incorporation, to restore soil fertility and productivity (RAMPIM et al. 2020). The incorporation of plants used as green manure enhances soil porosity, water infiltration, and retention capacity, due to increased organic matter and proper root development (SOUZA 2012, HENDGES et al. 2015).

Plant species from the Fabaceae family, also known as legumes, are the most commonly used for green manuring due to their hardiness, high dry matter production, deep root systems, and ability to form symbiotic associations with nitrogen-fixing bacteria (ALCÂNTARA et al. 2000). Moreover, these species can reduce atmospheric carbon emissions, helping to mitigate greenhouse gases (DOS SANTOS BRANCO & PRATES JÚNIOR 2022).

Crotalaria (*Crotalaria juncea*), velvet bean (*Mucuna aterrima*), and stylo (*Stylosanthes macrocephala*), selected for this study, stand out as promising species for green manure practices due to their hardy nature, rapid growth, and adaptation to low fertility conditions and high temperatures (AGUIAR JÚNIOR et al. 2011, TEODORO et al. 2011).

Nutrient cycling is crucial because it maintains soil fertility by replenishing nutrients lost through rainfall. Given the importance of soil restoration in areas affected by extensive and degrading activities, as well as the significance of using green manure species in this process, this study aimed to evaluate the biomass production of species used as green manures. The aim is thus to promote better planting and soil management practices in the Amazon region.

MATERIAL AND METHODS

To assess biomass production, three green manure species were selected (Table 1). These species were selected based on their known growth and development characteristics, including rapid growth, hardiness, and accelerated decomposition (OLIVEIRA et al. 2016).

Table 1. Main characteristics (vernacular name, scientific name, uses, family, habit and life cycle) of the species used in the biomass production experiment, from the Fabaceae family, in Santarém, Pará.

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Vernacular name	Scientific name	Features and applications	Custom	Cycle
Crotalaria	*Crotalaria juncea* L.	Soil fertility enhancement Fibers can be used in cellulose production	Upright shrub	Yearly
Velvet bean	*Mucuna aterrima*	Hardy plant Aluminum toxicity tolerant Helps control nematodes	Climber	Annual or biennial
Stylos plant	*Stylosanthes macrocephala*	Drought-resistant biological nitrogen fixation Disease resistance such as anthracnose Alternative approaches to land restoration	Herbaceous	Yearly

Source: Based on TEODORO et al. (2011).

The experiment was conducted in the Bom Jardim quilombo located on the shores of Lake Maicá, approximately 29 km from the city of Santarém, Pará (Figure 1). The municipality has a tropical monsoon climate (Am) according to the Köppen climate classification, with annual rainfall between 1,900 and 2,200 millimeters (mm) and average annual temperatures ranging from 25 to 27°C (ALVARES et al. 2013). The region has an average relative humidity of 85%, with two distinct seasons: a dry season typically lasting from July to November and a rainy season from December to June (INMET 2023).

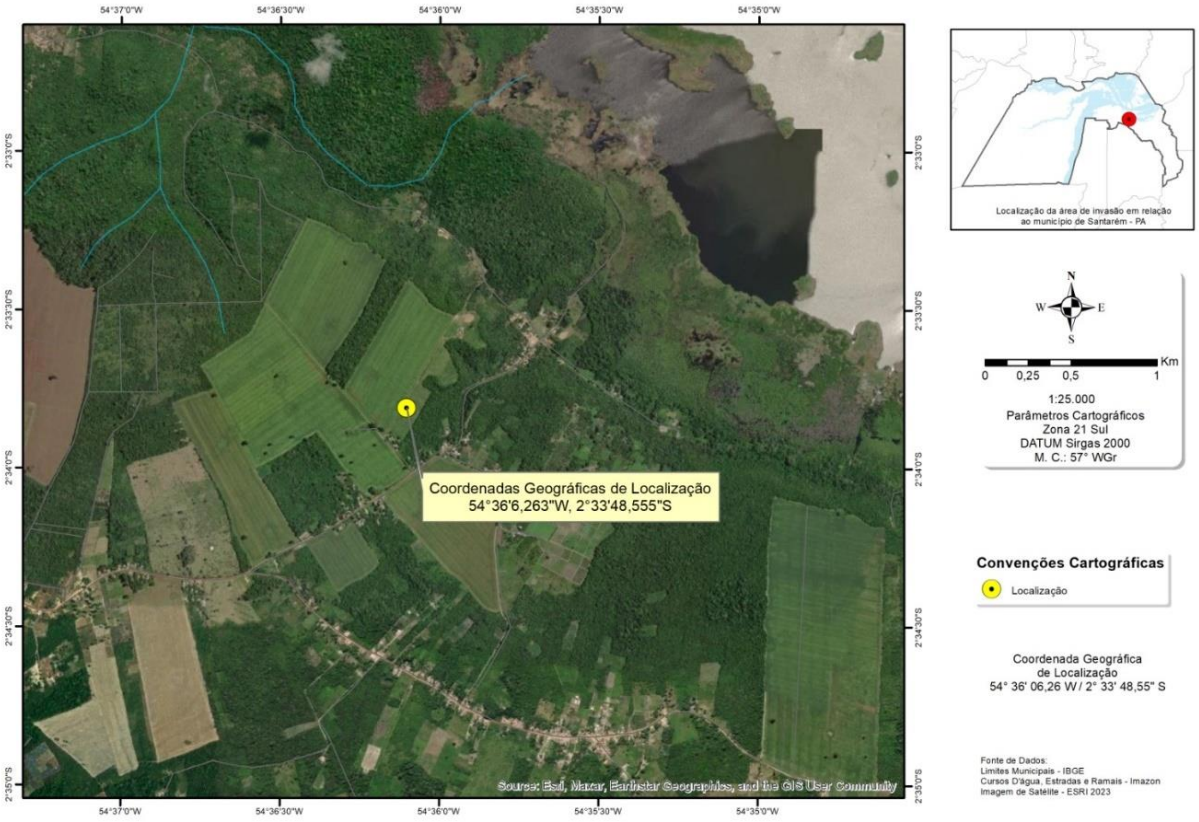

Figure 1. Location of the experimental area in the Bom Jardim community, in the municipality of Santarém, Pará.

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The selected area for the experiment had been used for cattle ranching for 10 years, with extensive management of about one animal unit per hectare, using *Brachiaria ruziziensis* forage pasture. For the experiment setup, mechanized soil preparation was carried out using a disc harrow with 14 28-inch discs, with three operations performed in February 2021. The soil in the area is described as a typical Dystrophic Yellow Argisol with moderate A horizon and medium clayey texture (DOS SANTOS et al. 2002). Due to limited research project resources, soil samples were not collected from the study area for more detailed analysis of soil physical and chemical properties.

The planting was carried out 15 days after clearing the area, in February 2021, by digging holes with hoes and placing seeds in the soil, with 1.0 m spacing between rows and 0.5 m between plants.

The experimental design adopted was a completely randomized design with six replications for each treatment. Strips for growing green manure species, measuring four meters wide by 57 meters long, were established interspersed with rows of tonka bean trees (*Dipteryx odorata*). The cumaru seedlings were also planted in February 2021, with 240 saplings distributed across 12 single rows, spaced six meters apart with three meters between each plant.

Data collection was carried out 90 days after sowing, when the velvet bean plants were flowering and fruiting, the crotalaria plants were flowering, and the stylos plant plants were in the vegetative stage. For data collection, six randomly established 3 m x 3 m (9 m²) plots were set up for each species. This approach was taken due to the visibly uneven growth observed among the introduced species. This phenomenon may have

occurred due to changes in land use, from pasture to perennial crops. The use of heavy machinery during the tilling process led to the formation of soil clumps, which were not properly broken down due to the lack of a leveling harrow in soil preparation.

In each plot, during fieldwork, two variables were assessed: average plant height (using a measuring tape) and weighing of all fresh aerial part mass (FAPM). For this purpose, the plants were manually cut using a machete and then weighed on a scale set up at the experiment site.

For the laboratory procedure, three samples were collected from each species, for a total of fifteen plants. The entire plant was used to quantify the dry aerial part mass (DAPM), dry root mass (DRM) and total dry mass (TDM) The samples were placed in paper bags and then dried in an oven at a constant temperature of 70°C until reaching a constant mass. To remove the plant without damaging or breaking the root, cutting tools (hoe and machete) were used to clear the soil around the plant. This process proved to be feasible, as the collection was carried out during the rainy season and the soil had been tilled before planting, making it easier to remove the entire plant from the ground.

To measure the length of plant roots, a ruler graduated in centimeters was used, measuring from the root collar apex to the lower end of the main root. The diameter of the stem was also measured using a digital caliper.

The Lilliefors normality test was performed, followed by linear association analysis using Pearson's correlation coefficient. For the comparison of variables across different treatments, analysis of variance (ANOVA) and Tukey's test were performed at a 5% significance level using Bioestat software (AYRES et al. 2007).

RESULTS AND DISCUSSION

The results show statistically significant differences in plant height among the three species studied (Table 2). The crotalaria showed the best performance in terms of height, with an average of 1.01 m. On the other hand, velvet bean reached an average height of 0.4 m, while stylosanthes averaged 0.28 m.

Table 2. Descriptive statistics for the height variable of Crotalaria, black mucuna, and stylo plants cultivated in Santarém, Pará.

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Species/height	Crotalaria	Velvet bean	Stylos plant
Lowest (cm)	54.5	35.43	23.7
Maximum (cm)	140.8	44	33.2
Average (cm)	101.0 a	40.0 b	28.0 b
Standard Deviation (cm)	36.1	35.5	33.9
Coefficient of Variation (CV)	35.5	8.9	12.3

Means followed by the same letter within a row are not significantly different at the 5% level.

Studies conducted by TEODORO et al. (2011) and OLIVEIRA et al. (2016) reported crotalaria heights of 1.23 m and 1.92 m, respectively, results similar to those obtained in this study, where the species had an average height of 1.01 m.

Table 3 shows the results for the following variables: FAPM, DAPM, DRM and TDM expressed in tonnes per hectare (t ha^{-1}). The statistical test shows no significant difference for these variables. The stylos plants was second only to the crotalaria in most attributes.

The results show statistically significant differences in the means of dry mass and fresh mass among treatments, with a significance level of 5% (p-value = 0.0229 and 0.0191, respectively). The Tukey test showed that, regarding fresh mass, both crotalaria and velvet bean achieved the best results, with no statistically significant difference between them (Table 3). On the other hand, stylos plant showed the lowest average compared to the other species.

Table 3 Mean and standard deviation of fresh and dry mass production of the aerial, root, and total parts of three leguminous species cultivated in Santarém, Pará.

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Species	FAPM	DAPM	DRM	TDM
	t ha^{-1}			
Crotalaria	1.43 a ± 1.2	0.46 a ± 0.38	0.17 a ± 0.07	0.64 a ± 0.44
Velvet bean	0.90 ab ± 0.38	0.21 ab ± 0.09	0.02 b ± 0.01	0.23 ab ± 0.10
Stylos plant	0.06 b ± 0.03	0.04 b ± 0.03	0.02 b ± 0.01	0.05 b ± 0.03

Means followed by the same letters within each column are not significantly different from each other, according to Tukey's test ($p < 0.05$). For fresh aerial part mass (FAPM), dry aerial part mass (DAPM), dry root mass (DRM), and total dry mass (TDM).

These findings are significant as incorporating green manure into the soil can enhance crop yields and modify soil conditions. This practice allows crop residues to remain on the soil surface, minimizing erosion while increasing soil aggregation, water infiltration and storage, and soil resistance to erosion (WILDNER 2014).

It was observed that crotalaria had the highest average aboveground fresh biomass of 1.43 ± 1.2 t ha^{-1}, followed by velvet bean with 0.90 ± 0.38 t ha^{-1} and stylo with 0.06 ± 0.05 t ha^{-1}. These figures show that crotalaria significantly outperformed the other species in terms of fresh biomass production.

Similarly, when considering DAPM, crotalaria also stands out, with an average of 0.46 ± 0.38 t ha^{-1}, followed by velvet bean with 0.21 ± 0.09 t ha^{-1} and stylos plant with 0.04 ± 0.03 t ha^{-1}. Once again, these findings indicate that crotalaria produced more aboveground dry matter compared to the other species.

However, when it comes to DRM, the values are more consistent across species. Crotalaria recorded an average of 0.17 ± 0.07 t ha^{-1}, followed by black mucuna and stylos plant, which showed averages of 0.02 ± 0.01 t ha^{-1} each. These findings indicate that root dry matter production varied among the species studied. Ponciano's (2022) study showed that under low rainfall conditions, crotalaria exhibited greater water retention. Most likely, this feature accounts for crotalaria's superior performance.

Finally, considering the total dry matter, which includes the dry mass of both aerial parts and roots, crotalaria once again stood out, with an average of 0.64 ± 0.44 (t ha^{-1}). Velvet bean recorded an average of 0.23 ± 0.10 t ha^{-1}, while stylos plant showed the lowest average, with 0.05 ± 0.03 t ha^{-1}.

The values obtained for these species were lower than those reported by WILDNER (2014) in their study of the same species, where crotalaria and velvet bean yielded 2.2 and 4.5 t ha^{-1}, respectively. Similarly, data found by COSTA et al. (2019) reported fresh biomass values of 19.4 t ha^{-1} for Crotalaria and 13.6 t ha^{-1} for velvet bean, which are higher than those obtained in this study.

Regarding dry matter, the species exhibited behavior similar to that of fresh matter, with crotalaria and velvet bean showing the highest values (0.46 and 0.21 t ha^{-1}, respectively), which were statistically equivalent. In this study, the average biomass production values for green manures were lower than those reported by other researchers. WUTKE et al. (2014) reported that dry matter production ranged from 6 to 8 t/h. In the work of LIMA et al. (2012), dry masses of 18.1 and 9.9 t ha^{-1} were obtained for crotalaria and velvet bean, respectively.

The dry matter production of the Crotalaria species is attributed to the morphological structure of its woody stem, which, depending on the plant's developmental stage, has a high water content, resulting in increased fresh plant mass and substantial plant growth (BETTIOL et al. 2015).

It is worth noting that water content can influence plant growth, development, and resistance processes (SOUZA et al. 2014). Species with higher water content may have a greater capacity to store water, which can be beneficial under water stress conditions (COSTA et al. 2015). On the other hand, species with lower water content may be more drought-resistant, but may also have a reduced ability to recover after extended periods without water (DA COSTA et al. 2021).

Regarding root length, velvet bean showed the highest average at 33.2 cm, followed by crotalaria at 25.3 cm and stylos plant at 15.1 cm (Figure 2). These findings suggest that velvet bean exhibited greater root growth compared to the other two species. This relevance is highlighted by the study of FOLONI et al. (2006), which showed that this species demonstrated greater tolerance to soil compaction compared to crotalaria, which proved to be relatively more susceptible.

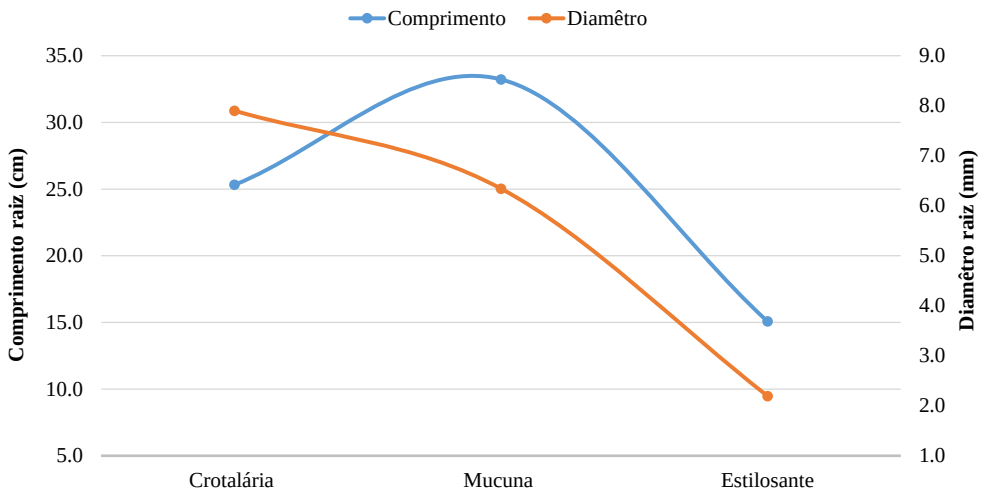

Figure 2. Average length and diameter of the root neck of crotalaria, mucuna preta and stylosante species in biomass production in Santarém, Pará.

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Deep-rooted legumes play a crucial role in enhancing soil physical properties (SILVA et al. 2017). These plants can loosen the soil, increase its porosity and permeability, and promote channel formation, facilitating the growth of successive species (BONFIM-SILVA et al. 2012).

The findings obtained in this study for the crotalaria species were lower than those reported by QUEIROZ NETO et al. (2019), who reported a root length of 29.7 cm, indicating that this legume is capable of exploring a large volume of soil. Regarding root diameter, crotalaria had the highest average at 7.9 mm, followed by velvet bean at 6.3 mm and stylos plant at 2.2 mm.

For black velvet bean, which exhibited larger roots in this study, it is expected to have the capacity to increase soil porosity and permeability (SOUZA et al. 2014). This feature also offers various benefits, such as improved water infiltration, reduced erosion risk, and enhanced water management efficiency in the system (WILDNER 2014). Thus, this deep root penetration ability allows velvet bean to more efficiently utilize available resources, such as water and nutrients, leading to better uptake of these elements by the root system.

No significant correlations were found between root diameter and length for the three species studied ($r = 0.23$ to 0.32; $p = 0.14$ to 0.38), although in the literature FOLONI et al. (2006) reported a positive correlation between these variables for crotalaria in compacted soil.

Furthermore, regarding root diameter, crotalaria showed the highest average, followed by velvet bean and stylos plant. These findings suggest that crotalaria developed thicker roots compared to the other two species.

CONCLUSION

The assessment of biomass production of species used as green manure in Santarém, Pará, shows that crotalaria and velvet bean are the most promising species. Crotalaria outperformed the other species, producing the highest fresh and dry biomass in the plant's aerial parts. Furthermore, black velvet bean excelled in root length and dry mass, suggesting a greater ability to explore the soil for water and nutrients.

Esses resultados são de grande relevância para a agricultura sustentável, pois a adubação verde desempenha um papel fundamental na promoção da saúde do solo, na conservação dos recursos naturais e no aumento da produtividade agrícola. Growing cover crops such as crotalaria and velvet bean can significantly benefit crop production.

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REFERENCES

AGUIAR JÚNIOR RA et al. 2011. Relação entre produção de biomassa e biometria de Gliricídia (Gliricidia sepium (Jacq.). Cadernos de Agroecologia 6: 1-5.

ALCÂNTARA FA et al. 2000. Adubação verde na recuperação da fertilidade de um Latossolo Vermelho-Escuro degradado. Pesquisa Agropecuária Brasileira 35: 277-288.

ALVARES CA et al. 2013. Köppen's climate classification map for Brazil. Meteorologische zeitschrift. 22: 711-728.

ALVES RE. 2021. A relação entre agricultura, degradação do solo e tempestades de areia. Revista Ayika 1: 50-66.

AYRES M et al. 2007. Aplicações estatísticas nas áreas das ciências bio-médicas. Instituto Mamirauá 364.

BETTIOL JVT et al. 2015. Plantas de cobertura, utilizando Urochloa ruziziensis solteira e em consórcio com leguminosas e seus efeitos sobre a produtividade de sementes do feijoeiro. Uniciências 19: 3-10.

BONFIM-SILVA EM et al. 2012. Establishment of Xaraés and Marandu grasses under levels of soil compaction. Engenharia Agrícola 32: 727-735.

CHERUBIN MR et al. 2023. Matéria orgânica do solo em áreas de pastagens no Brasil. Entendendo a matéria orgânica do solo em ambientes tropical e subtropical. Brasília: Embrapa. p.601-625.

COSTA LC et al. 2019. Produção de biomassa por leguminosas em diferentes épocas de semeadura na região Agreste de Alagoas. Revista Ambientale 11: 102-111.

COSTA N et al. 2015. Acúmulo de nutrientes e tempo de decomposição da palhada de espécies forrageiras em função de épocas de semeadura. Bioscience Journal 31: 818-829.

DA COSTA JS et al. 2021. Condições químicas e físicas do solo da unidade de adubos verdes da fazenda água limpa-Universidade de Brasília. In: Anais do VIII ECOPET-Encontro Centro-Oeste dos Grupos PET.

DOS SANTOS BRANCO J & PRATES JÚNIOR P. 2022. Fixação biológica de nitrogênio na produção sustentável de forragem. Revista Edutec 3: 101-114.

DOS SANTOS PL et al. 2002. Mapa de reconhecimento dos solos do Planalto de Santarém, Estado do Pará. Disponível em https://ainfo.cnptia.embrapa.br/digital/bitstream/item/105520/1/Doc-115-mapa.pdf

FOLONI JSS et al. 2006. Crescimento aéreo e radicular da soja e de plantas de cobertura em camadas compactadas de solo. Revista Brasileira de Ciência do Solo 30: 49-57.

HENDGES JAR. et al. 2015. Efeito da adubação verde nas propriedades químicas de um neossolo quatzarênico distrófico. Global Science and Technology 8: 9-18.

INMET. 2023. Instituto Nacional de Meteorologia. Normas climatológicas. Disponível em: http://www.inmet.gov.br/portal/. Acesso em: 18 jun. 2023.

LEITE MFA et al. 2017. Organic nitrogen rearranges both structure and activity of the soil-borne microbial seedbank. Scientific Reports 7: 42634.

LIMA JD et al. 2012. Produção de biomassa e composição química de adubos verdes cultivados no Vale do Ribeira. Bioscience Journal 28: 709-717.

OLIVEIRA MW et al. 2016. Época de semeadura altera o crescimento e a produção de biomassa da *Crotalaria juncea*. In: Anais do I Congresso Internacional das Ciências Agrárias. Recife: COINTER.

PONCIANO VFG et al. 2022. Retenção da água no solo sob diferentes adubos verdes como cobertura vegetal em neossolo litólico distrófico. Revista Ciência Agrícola 20: 1-10.

QUEIROZ NETO AP et al. 2019. Características agronômicas de crotalária ochroleuca. Informe Econômico. Teresina: UFPI. 39p.

RAMPIM L et al. 2020. Influence of mechanical management and green manure on physical attributes of Oxisol. Research, Society and Development 9: e173953258.

SILVA EC et al. 2014. Adubação verde como fonte de nutrientes às culturas. In: LIMA FILHO OF et al. Adubação verde e plantas de cobertura no Brasil: fundamentos e prática. Brasília: EMBRAPA.

SILVA MP et al. 2017. Plantas de cobertura e qualidade química e física de Latossolo Vermelho distrófico sob plantio direto. Revista Brasileira de Ciências Agrárias 12: 60-67.

SOUZA LAG. 2012. Guia da biodiversidade de fabaceae do Alto Rio Negro. Alto Rio Negro: INPA.

SOUZA LS et al. 2014. Adubação verde na física do solo. In: LIMA FILHO OF et al. Adubação verde e plantas de cobertura no Brasil: fundamentos e prática. Brasília: EMBRAPA.

TEODORO RB et al. 2011. Aspectos agronômicos de leguminosas para adubação verde no Cerrado do Alto Vale do Jequitinhonha. Revista Brasileira de Ciência do Solo 35: 635-640.

WILDNER LP. 2014. Adubação verde: conceitos e modalidades de cultivo. In: FILHO OFL et al. (Ed.). Adubação verde e plantas de cobertura no Brasil: Fundamentos e Prática. Brasília: EMBRAPA. p.219-244.

WUTKE EB et al. 2014. Espécies de adubos verdes e plantas de cobertura e recomendações para seu uso. In: LIMA FILHO OF et al. Adubação verde e plantas de cobertura no Brasil: fundamentos e prática. Brasília: EMBRAPA.