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Research Article

Vegetative development and biomass production of *Sesbania herbacea* in a wet floodplain environment[1]

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ABSTRACT

Green manure provides countless benefits to the chemical, physical and biological quality of soils. This study aimed to evaluate the *Sesbania herbacea* potential, regarding growth and biomass production parameters, as a green manure option in wet floodplain environments. A completely randomized experimental design was used, with measurements repeated over time and six replications. The parameters were evaluated every 20 days (20, 40, 60, 80, 100 and 120 days after emergence - DAE), namely: mean plant height, root and shoot fresh and dry matter biomass, and total plant matter biomass. The legume showed a good development in soil under waterlogged condition, which led to high amounts of phytomass accumulation (approximately 139 t ha^{-1} of total plant matter biomass and mean height of 4 m at 120 DAE).

KEYWORDS: Green manure, waterlogged soil, aquatic legume.

RESUMO

Desenvolvimento vegetativo e produção de biomassa de *Sesbania herbacea* em ambiente de várzea úmida

A adubação verde apresenta inúmeros benefícios para a qualidade química, física e biológica do solo. Objetivou-se avaliar o potencial de *Sesbanea herbacea*, quanto a parâmetros de crescimento e produção de biomassa, como alternativa para adubação verde em ambiente de várzea úmida. Utilizou-se delineamento experimental inteiramente casualizado, com medidas repetidas no tempo e 6 repetições. Os parâmetros foram avaliados a cada 20 dias (20, 40, 60, 80, 100 e 120 dias após a emergência - DAE), sendo eles: altura média das plantas, biomassa da matéria fresca e seca da raiz e parte aérea, e biomassa da matéria total das plantas. A leguminosa apresentou bom desenvolvimento em condição de encharcamento do solo, resultando no acúmulo de elevadas quantidades de fitomassa (cerca de 139 t ha^{-1} de biomassa da matéria total das plantas e altura média de 4 m aos 120 DAE).

PALAVRAS-CHAVE: Adubação verde, solo encharcado, leguminosa aquática.

INTRODUCTION

The use of green manures is a millenary technique adopted by Greeks and Romans (Granato 1924, Duarte 2010). In Brazil, this technique has brought enormous benefits to agriculture. It consists in using ground cover plants, whether incorporated or not, in pre-planting, intercropping or post-planting stages of annual and perennial-annual crops. Plants used as green manure also have other functions, such as the production of seeds, fibers and animal feed (Costa et al. 1993).

Green manures offer many advantages to the chemical, physical and biological properties of soils (Amabile et al. 2000). Research results confirmed the effects of green manures on soil protection, such as the increase in the cation exchange capacity and nutrient cycling at greater depths, bringing them to the surface, and their nitrogen-fixing form, especially in legumes (Passos 2012). In addition to their contribution with an elevated presence of biomass in cultivated areas (Espindola et al. 2005), green manures can provide the control of spontaneous plants (Lopes 1994, Busscher et al. 1996, Espindola et al. 2001, Duarte 2010).

The selection of green manure species into production systems depends on the adaptation to climatic conditions in the region, as well as the

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producers interests. The selected species must develop well in low-to-medium fertility soils and have the ability to adapt to acidic soils (Alvarenga et al. 2001, Chaves & Calegari 2001, Ernani et al. 2001, Silva & Rosolem 2001).

The mass production of green manure species depends on climatic, edaphic and phytosanitary conditions (Amado et al. 2002). These species must have certain characteristics such as rusticity, fast early growth and high phytomass production (Carvalho & Sodré Filho 2000).

The *Sesbania* genus belongs to the *Papilionoideae* subfamily of *Leguminosae* and *Robinieae* tribe. With approximately sixty tropical and subtropical species, it comprises annual and perennial plants, which are divided into four subgenera: *Agati*, *Daubentonia*, *Pterosesbania* and *Sesbania* (Monteiro 1984, Veasey et al. 1999).

Sesbania herbacea is an aquatic legume with a good nodule development in poorly drained soils. It is also considered a spontaneous plant in irrigated rice production systems (Wang & Martínez-Romero 2000). Its adaptive traits allow this legume to develop well in flooding conditions. This species has a nitrogen-fixing ability, which enables a fast growth in nitrogen-deficient soils and, consequently, its use as a green manure in intercropping and ground cover (Ndoye et al. 1990).

This study aimed to evaluate the performance of *S. herbacea*, regarding growth and biomass production, and identify the most appropriate management stage (cutting or incorporation into the soil) for its potential as a green manure option in wet floodplain environments.

MATERIAL AND METHODS

The experiment was conducted between November 2019 and March 2020, at an experimental field of the Embrapa Arroz e Feijão (16º26'08.27"S, 49º23'47.73"W and altitude of 728 m), in Goianira, Goiás state, Brazil.

The dominant climate in the region is classified as Aw, tropical sub-hot, according to the Köppen climate classification. It is characterized by two well-defined seasons, being rainy from October to April and dry from May to September (Kottek et al. 2006). The average annual temperature is 22.6 ºC, with the lowest average minimum temperature in June (14.2 ºC) and the highest average maximum temperature in September (31.7 ºC) (Oliveira & Rodrigues 2012). The average annual rainfall is 1,485 mm, and the average annual relative humidity is 71 %. Figure 1 shows the maximum and minimum temperatures and the rainfall data during the experiment period.

The soil of the experimental area is classified as Gleissolo Háplico Eutrófico neofluvissólico (Santos et al. 2018), which is equivalent to Gleysols (FAO 2015), medium-textured gravelly, moderate A, flat terrain, hydrophilic floodplain field (Oliveira & Rodrigues 2012). Its chemical analysis (0-20 cm depth) before the experiment is present in Table 1.

The experimental design was completely randomized, with six replications, and the treatments were represented by sampling periods, performed in six evaluations: 20, 40, 60, 80, 100 and 120 days after emergence (DAE).

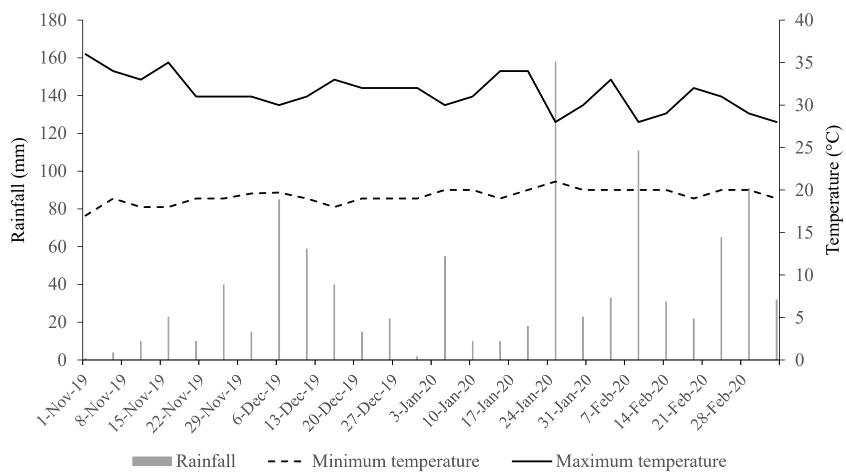

Figure 1. Rainfall, maximum and minimum temperatures, in Goianira (Goiás state, Brazil), during the experiment (2019/2020).

Table 1. Soil chemical attributes (0-20 cm depth) at the experimental area, prior to planting.

pH	Ca	Mg	Al	H + Al	P	K	Cu	Zn	Fe	Mn	OM[1]
(H_2O)	——— cmol$_c$ dm^{-3} ———				——— mg dm^{-3} ———						dag kg^{-1}
4.9	2.07	0.66	0.6	5.6	30.1	56	1.4	2.4	139	10.4	4.19

[1] OM: organic matter.

Sowing was conducted on November 01 (2019), with the same seeder used for rice cultivation. The soil was prepared with harrowing and leveling operations. The distance between rows was 0.17 m and the planting density comprised 10 kg ha^{-1} of previously scarified seeds. Neither fertilizers nor soil correctives were used in the experiment.

The seed scarification was carried out with equipment used for rice polishing, a rice testing machine (model MT 2014). This process is essential to overcome tegument impermeability, by breaking dormancy and, consequently, improving germination.

No weed, insect pests and diseases control methods were used during the experiment, nor any type of irrigation, only the rainfall that occurred during the experiment (Figure 1).

The sampling comprised 1 m^2 of the area, and it was done by placing a metallic rectangle in each quadrant of the total experimental area. Subsequently, plants were manually removed with their shoot and root and counted. Five of them were separated and their mean height was taken using a measuring tape. Their roots and shoots were separated on site using a machete, stored in cloth bags and weighed with a precision scale for the determination of shoot fresh weight, root fresh weight and total plant weight. The material was then taken into a forced ventilation oven, at 65 ºC, until reaching a constant weight, for the determination of shoot dry weight, root dry weight and total dry weight, calculated as the sum of shoot dry weight and root dry weight. The 1,000-seed mass of the *S. herbacea* was obtained using a precision scale, with 8 replications of 100 seeds (Brasil 2009). The plants removed every 1 m² were quantified to determine the number of plants per hectare.

The data were first subjected to tests of normality and homogeneity of variances for each variable and, then, to analysis of variance (Anova), F-test, with averages adjusted to regression models at 5 % of probability, using the Sisvar statistical analysis system (Ferreira 2019).

RESULTS AND DISCUSSION

The *S. herbacea* had a good vegetative development and adaptation to waterlogged soils, according to evaluated variables such as plant mean height, shoot fresh weight, shoot dry weight, root fresh weight, root dry weight, total dry weight and total plant weight (Table 2).

Table 2. Analysis of variance for mean plant height (MPH), shoot fresh weight (SFW), shoot dry weight (SDW), root fresh weight (RFW), root dry weight (RDW), total dry weight (TDW) and total plant weight (TPW).

Source of variation	DF	Mean square						
		MPH	SFW	SDW	RFW[1]	RDW[1]	TDW[1]	TPW
		cm	——— kg ha^{-1} ———					
Days	5	8.746**	3.21**	566,320,983.47**	1.112**	2.172**	1.357**	1.329**
Error	30	0.043	67,440,342.33	9,750,716.82	0.017	0.031	0.011	377,119,190.83
CV (%)		8.11	18.73	23.22	3.01	4.71	2.50	25.03
Mean		2.56	43,839.21	13,450.63	4.32	3.76	4.20	74,618.52
Days		Means[2]						
20		0.79	13,688.37	2,392.25	4,906.98	855.82	3,248.07	18,595.35
40		1.59	27,376.74	4,784.50	9,813.95	1,711.63	6,496.13	37,190.70
60		2.53	34,862.32	8,840.58	17,839.13	4,696.23	13,536.81	52,701.45
80		2.91	48,128.94	16,017.58	34,959.71	13,462.27	29,479.85	83,088.64
100		3.42	63,172.22	22,122.22	53,252.78	21,627.78	43,750.00	116,425.00
120		4.10	75,806.67	26,546.67	63,903.33	25,953.33	52,500.00	139,710.00

** Significant at 0.01, by the F-test. [1] Each variable is replaced with a log(x); [2] means are indicated with the original data.

The number of plants was counted, even though it was not statistically evaluated. The obtained result shows that, out of 500,000 seeds, approximately 460,000 plants ha^{-1} grew, indicating that germination occurred in approximately 92 % of the seeds, thanks to the scarification process.

A low incidence of unwanted plants was observed during the experiment. This probably occurred due to the *S. herbacea* fast adaptability, what, according to Fernandes et al. (1999), has a strong influence on weed control, because of greater or lesser shading.

The *S. herbacea* growth and biomass production values during the cycle (Figure 2) suggest a correlation between these variables. As the plants grow, the biomass accumulation increases. At 20 DAE, the mean plant height was 0.79 cm, the shoot dry weight was 2,392 kg ha^{-1} and the root dry weight was 856 kg ha^{-1}. At 40 DAE, the mean plant height was 1.59 cm, the shoot dry weight was 4,785 kg ha^{-1} and the root dry weight was 1,712 kg ha^{-1}. At 60 DAE, the plants reached a mean height of 2.53 cm, shoot dry weight of 8,841 kg ha^{-1} and root dry weight of 4,696 kg ha^{-1}. At 80 DAE, the mean plant height was 2.91 cm, the shoot dry weight was 16,018 kg ha^{-1} and the root dry weight was 13,462 kg ha^{-1}. At 100 DAE, the plants showed a mean height of 3.42 cm, shoot dry weight of 22,122 kg ha^{-1} and root dry weight of 21,628 kg ha^{-1}. Finally, at 120 DAE and in the phenological stage of full flowering, the plant mean height was 4.10 cm, the shoot dry weight was 26,547 kg ha^{-1} and the root dry weight was 25,953 kg ha^{-1}.

The greatest development was observed at 40-60 DAE, when the mean plant height was 0.94 cm, the shoot dry weight was 7,177 kg ha^{-1} and the root dry weight was 8,766 kg ha^{-1}.

The total dry weight, total plant weight and mean plant height data are shown in Figure 3. The evaluations performed at 120 DAE resulted in an accumulation of total plant weight and total dry weight of 139,710 and 52,500 kg ha^{-1}, respectively, and mean plant height of 4.10 m.

This study with *S. herbacea* revealed better results, when compared to those of Chanda et al. (2020), in which fertilizer doses and plant density per m² were evaluated using the *S. bispinosa* species at 60 DAE. Regarding the N fertilizer application, the obtained values were 0.66 m for height, 5.7 and 2.5 t ha^{-1} for fresh and dry biomass, respectively, when applying 20 kg ha^{-1} of N, and 0.61 m for height, 6.7 and 2.7 t ha^{-1} for fresh and dry biomass, respectively, when applying 30 kg ha^{-1} of N, as well as 1.13 m for height, 2.9 and 1.7 t ha^{-1} for fresh and dry biomass, respectively, at a density of 240 plants m^{-2}.

The results and analyses for *S. herbacea* in this study show its potential to be used as a green manure, especially in rice production systems in wet floodplains. However, future studies are still necessary to confirm some hypotheses about the legume use, such as fixed amount of N ha^{-1} and potential use as a component for animal feed.

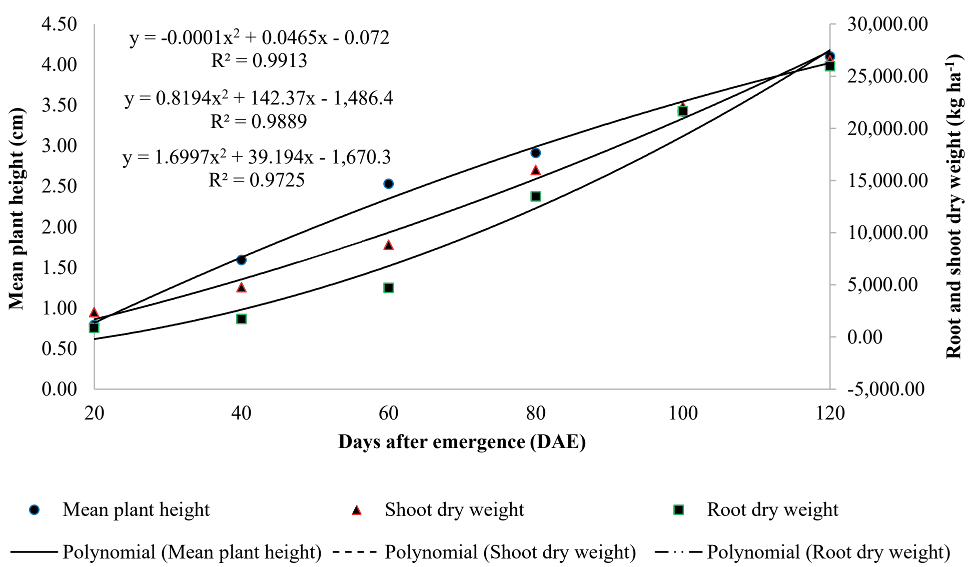

Figure 2. Regression analysis for mean plant height, shoot dry weight and root dry weight.

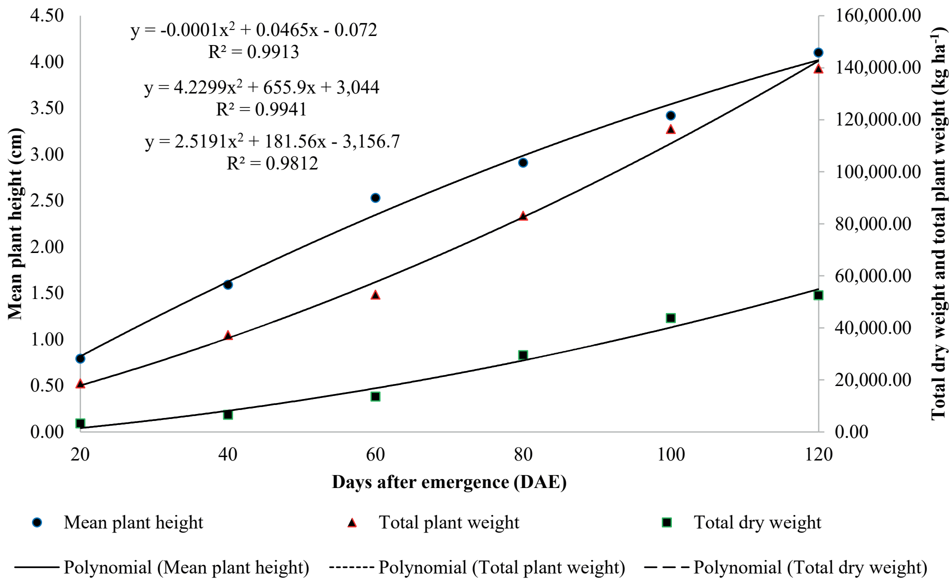

Figure 3. Regression analysis for mean plant height and total plant weight.

CONCLUSIONS

1. *Sesbania herbacea* has a high potential for cultivation in wet floodplains, serving as a green manure alternative;
2. The legume cutting or incorporation into the soil are recommended at the flowering period, at 120 days after emergence, due to the higher values for total plant weight and total dry weight (139.7 and 52.5 t ha^{-1}, respectively).

REFERENCES

ALVARENGA, R. C.; CABEZAS, W. A. L.; CRUZ, J. C.; SANTANA, D. P. Plantas de cobertura de solo para sistema plantio direto. *Informe Agropecuário*, v. 22, n. 208, p. 25-36, 2001.

AMABILE, R. F.; FANCELLI, A. L.; CARVALHO, A. M. Caracterização de espécies de adubos verdes em diferentes épocas de semeadura e espaçamentos na região dos Cerrados. *Pesquisa Agropecuária Brasileira*, v. 35, n. 1, p. 47-54, 2000.

AMADO, T. J. C.; MIELNICZUK, J.; AITA, C. Recomendações de adubação nitrogenada para o milho no RS e SC adaptada ao uso de culturas de cobertura do solo, sob sistema plantio direto. *Revista Brasileira de Ciência do Solo*, v. 26, n. 1, p. 241-248, 2002.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. *Regras para análise de sementes*. Brasília, DF: MAPA/ACS, 2009.

BUSSCHER, W. J.; REEVES, D. W.; KOCHHANN, R. A.; BAUER, P. J.; MULLINS, G. L.; CLAPHAM, W. M.; KEMPER, W. D.; GALERANI, P. R. Conservation farming in southern Brazil: using cover crops to decrease erosion and increase infiltration. *Journal of Soil and Water Conservation*, v. 51, n. 3, p. 188-192, 1996.

CARVALHO, A. M.; SODRÉ FILHO, J. *Uso de adubos verdes como cobertura de solo*. Planaltina, DF: Embrapa Cerrados, 2000. (Boletim de pesquisa, 11).

CHANDA, S. C.; RAZZAK, M. A.; HOSSAIN, M. A.; SARWAR, A. G. Biomass yield enhancement of dhaincha (*Sesbania* especies) through cultural practices. *Cercetari Agronomice în Moldova*, v. 53, n. 2, p. 160-176, 2020.

CHAVES, J. C. D.; CALEGARI, A. Adubação verde e rotação de culturas. *Informe Agropecuário*, v. 22, n. 212, p. 53-60, 2001.

COSTA, M. B. B.; CALEGARI, A.; MONDARDO, A.; BULISANI, E. A.; WILDNER, L. P.; ALCÂNTARA, P. B.; MIYASAKA, S.; AMADO, T. J. *Adubação verde no Sul do Brasil*. 2. ed. Rio de Janeiro: AS-PTA, 1993.

DUARTE, R. F. *Avaliação de adubos verdes no norte de Minas Gerais*. 2010. Dissertação (Mestrado em Ciências Agrárias) - Instituto de Ciências Agrárias, Universidade Federal de Minas Gerais, Montes Claros, 2010.

ERNANI, P. R.; BAYER, C.; FONTOURA, S. M. V. Influência da calagem no rendimento de matéria seca de plantas de cobertura e adubação verde, em casa de vegetação. *Revista Brasileira de Ciência do Solo*, v. 25, n. 2, p. 897-904, 2001.

ESPINDOLA, J. A. A.; GUERRA, J. G. M.; ALMEIDA, D. L. Uso de leguminosas herbáceas para adubação verde. *In*: AQUINO, A. M.; ASSIS, R. L. (org.). *Agroecologia*: princípios e técnicas para uma agricultura sustentável. Brasília, DF: Embrapa Informação Tecnológica, 2005. p. 435-451.

ESPINDOLA, J. A. A.; OLIVEIRA, S. J. C. R.; CARVALHO, G. J. A.; SOUZA, C. L. M.; PERIN, A.; GUERRA, J. G. M.; TEIXEIRA, M. G. *Potencial alelopático e controle de plantas invasoras por leguminosas herbáceas perenes consorciadas com bananeira*. Seropédica: Embrapa Agrobiologia, 2001.

FERNANDES, M. F.; BARRETO, A. C.; EMÍDIO FILHO, J. Fitomassa de adubos verdes e controle de plantas daninhas em diferentes densidades populacionais de leguminosas. *Pesquisa Agropecuária Brasileira*, v. 34, n. 9, p. 1593-1600, 1999.

FERREIRA, D. F. Sisvar: a computer analysis system to fixed effects splitplot type designs. *Revista Brasileira de Biometria*, v. 37, n. 4, p. 529-535, 2019.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO). *International soil classification system for naming soils and creating legends for soil maps*. Rome: FAO, 2015.

GRANATO, L. *Adubação verde*: arte antiga e ciência moderna: uma revolução na economia agrícola nacional. São Paulo: Monteiro Lobato, 1924.

KOTTEK, M.; GRIESER, J.; BECK, C.; RUDOLF, B.; RUBEL, F. World map of Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift*, v. 15, n. 3, p. 259-263, 2006.

LOPES, A. S. Manejo: aspectos químicos. *In*: PEREIRA, V. P.; FERREIRA, M. E.; CRUZ, M. C. P. (ed.). *Solos altamente suscetíveis à erosão*. Jaboticabal: Unesp/SBCS, 1994.

MONTEIRO, R. *Taxonomic studies on Brazilian legumes with forage potential*: Sesbania, Lupinus. 1984. Thesis (Ph.D. in Biology) - University of St. Andrews, St. Andrews, 1984.

NDOYE, I.; TOMEKPE, K. D. B.; DOMMERGUES, Y. R. Sesbania and Rhizobium symbiosis: nodulation and nitrogen fixation. *In*: MACKLIN, B.; EVANS, D. O. (ed.). *Perennial sesbania species in agroforestry systems*. Wamanalo: Nitrogen Fixing Tree Association, 1990.

OLIVEIRA, V. A.; RODRIGUES, C. *Levantamento detalhado dos solos da fazenda Palmital, município de Goianira - GO*. Goiânia: Viasat, 2012.

PASSOS, A. V. *Estudo de épocas de colheita e desenvolvimento de vagens de feijão guandu (cajanus cajan (L.) Millsp.), para obtenção de grãos e sementes não comerciais em pequenas unidades de produção familiar*. Dissertação (Mestrado em Agricultura Orgânica) - Instituto de Agronomia, Universidade Federal Rural do Rio de Janeiro, Seropédica, 2012.

SANTOS, H. G.; JACOMINE, P. K. T.; ANJOS, L. H. C.; OLIVEIRA, V. Á.; LUMBRERAS, J. F.; COELHO, M. R.; ALMEIDA, J. A.; ARAÚJO FILHO, J. C.; OLIVEIRA, J. B.; CUNHA, T. J. F. *Sistema brasileiro de classificação de solos*. 5. ed. Brasília, DF: Embrapa, 2018.

SILVA, R. H.; ROSOLEM, C. A. Crescimento radicular de espécies utilizadas como cobertura decorrente da compactação do solo. *Revista Brasileira de Ciência do Solo*, v. 25, n. 2, p. 253-260, 2001.

VEASEY, E. A.; SCHAMMASS, E. A.; VENCOVSKY, R.; MARTINS, P. S.; BANDEL, G. Morphological and agronomical characterization and estimates of genetic parameters of *Sesbania* Scop. (*Leguminosae*) accessions. *Genetics and Molecular Biology*, v. 22, n. 1, p. 81-93, 1999.

WANG, E. T.; MARTÍNEZ-ROMERO, E. *Sesbania herbacea-Rhizobium huautlense* nodulation in flooded soils and comparative characterization of *S. herbacea*-nodulating rhizobia in different environments. *Microbial Ecology*, v. 40, n. 1, p. 25-32, 2000.