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

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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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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 (16°26'08.27"S, 49°23'47.73"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 °C, with the lowest average minimum temperature in June (14.2 °C) and the highest average maximum temperature in September (31.7 °C) (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).
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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 m$^2$ 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 1. Soil chemical attributes (0-20 cm depth) at the experimental area, prior to planting.

<table>
<thead>
<tr>
<th>pH (H$_2$O)</th>
<th>Ca</th>
<th>Mg</th>
<th>Al</th>
<th>H + Al</th>
<th>P</th>
<th>K</th>
<th>Cu</th>
<th>Zn</th>
<th>Fe</th>
<th>Mn</th>
<th>OM$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.9</td>
<td>2.07</td>
<td>0.66</td>
<td>0.6</td>
<td>5.6</td>
<td>30.1</td>
<td>56</td>
<td>1.4</td>
<td>2.4</td>
<td>139</td>
<td>10.4</td>
<td>4.19</td>
</tr>
</tbody>
</table>

$^1$OM: organic matter.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>Mean square</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPH cm</td>
<td>5</td>
<td>8.746**</td>
</tr>
<tr>
<td>SFW</td>
<td>30</td>
<td>0.043</td>
</tr>
<tr>
<td>SDW</td>
<td></td>
<td>1.112**</td>
</tr>
<tr>
<td>RFW$^2$</td>
<td></td>
<td>1.112**</td>
</tr>
<tr>
<td>RDW$^1$</td>
<td></td>
<td>1.357**</td>
</tr>
<tr>
<td>TDW$^1$</td>
<td></td>
<td>1.329**</td>
</tr>
<tr>
<td>TPW</td>
<td></td>
<td>26.26</td>
</tr>
</tbody>
</table>

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).

**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 \textit{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 \textit{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 \textit{S. herbacea} revealed better results, when compared to those of Chanda et al. (2020), in which fertilizer doses and plant density per m\(^{2}\) were evaluated using the \textit{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 \textit{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.](image-url)
**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).

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