Evaluation of the Performance of Direct Seeding Maize Under a Plant Cover of *Stylosanthes guianensis* Under the Conditions of the Imbo Plain (Burundi)

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**Abstract**

*Stylosanthes guianensis* (Stylo) is a fast-growing legume with great potential for improving soil fertility. It improves soil structure, limits or eliminates tillage as far as possible, and increases yields of subsequent crops by decomposing accumulated organic matter while maintaining a protective vegetation cover on the surface. The aim of this study was to assess the productivity of maize grown as a pure crop and as a direct-seeded crop in a *S. guianensis* cover crop, as well as the residual effect of mineral fertilisers in the maize/Stylo combination grown under the conditions of the Imbo plain. The results show that the system based on the maize/stylo combination with the application of mineral fertiliser is better, with an average of 3.1 ± 0.09 T/ha of grain, while the system based on maize alone comes last, with an average of 2.4 ± 0.2 T/ha. All the Stylo-based treatments had a higher yield than the overall average of 2.7 T/ha. The average yield obtained in adjacent plots without mulch was lower than the average production under mulch. These results show that *S. guianensis* provides the nutrients required for the development of the crop grown with it through symbiotic fixation and straw decomposition, which improves the soil nutrient content provided by this legume. In addition, it significantly improves
yields of subsequent crops, and growing these two plants together does not reduce maize yields.

**Keywords:** *Stylosanthes guianensis*, Maize, Direct seeding, Cover plant, Imbo plain

1. Introduction

Direct seeding mulch-based cropping systems (DMCS) were introduced in the tropics with the potential to restore soil fertility, increase soil productivity and improve the performance of subsequent crops [1]. In direct seeding under plant cover (DMC) cropping systems, the role of cover crops is to produce a biomass designed to protect the soil on a permanent basis and to prevent nutrients from leaching out of the reach of the roots of cultivated plants by moving them permanently upwards to the upper soil horizon [2, 3]. They enable the gradual release of nutrients via the decomposition of accumulated organic matter and maintain a protective vegetation cover on the surface [4, 5]. Cover crops have the potential to improve agricultural production while limiting the degradation of cultivated areas [5, 6].

Although the use of slow-decomposing cover crops is recommended in no-till cropping systems, the emphasis is on fast-growing legumes because of their potential to increase fertility through nitrogen fixation [3, 7, 8]. Cover crop mulch is strategically located at the soil-atmosphere interface and acts as both a soil protector and a soil amendment [3]. Cover crop mulch protects the soil from erosion, reduces runoff, increases infiltration of soil water and maintains favourable conditions for biological activity [1, 9]. Decomposition and mineralisation of the mulch ensure the regular release of nutrients that can be used by cultivated plants [10]. In this way, it conserves soil, improves soil structure and increases yields of subsequent crops [6]. Overall, the use of cover crop mulch can generate significant yields for subsequent crops if it can be maintained at a satisfactory level [8, 11].

In these systems, cover crops such as *Stylosanthes guianensis* are only established in the first year, and the following year crops of interest such as maize are sown directly into the cover crop. This practice is one of the three major components of conservation agriculture, the fundamental principles of which are essentially: i) maintaining permanent soil cover, ii) establishing optimal crop associations and rotations and iii) limiting tillage to a minimum and, if possible, eliminating it [4]. However, in the absence of any evaluation, the same fertiliser recommendations for conventional systems would be applied by default to these under-cover cropping systems [12]. Mulch retention levels are determined by vegetative biomass production and subsequent loss [6]. The minimum quantity of mulch recommended for effective direct seeding under green cover in northern Cameroon, for example, is 7.5 T/ha [12]. In cover crop systems, the influence of the previous crop includes the residual effects of fertilisers and those resulting from the presence of mulch [1].
According to research carried out in Madagascar and Cameroon, the maize-S. guianensis combination as a cover crop in DMC is particularly interesting in a rotation, as it requires little work and can be grown even without mineral fertiliser [5,13].

Maize (Zea mays L.) is one of the most widely grown crops in the Imbo plain, where it is often grown in rotation in the various cropping systems, which are generally practised without fallowing or adding manure. In most cases, maize is preferred by farmers because it matures after four or five months and is a staple food during the hunger gap. It is widely grown as a cereal for its starchy grains and is also considered the second most important cereal after rice in terms of volume of production and surface area [14,15].

The aim of this study was to evaluate the performance of no-till maize cultivation in a S. guianensis cover crop in rotation with cassava, and to assess the mulch produced by S. guianensis.

For our work, we set ourselves the following two specific objectives:
- To study the performance of the maize variety ECAVEL1 sown under a permanent cover of S. guianensis;
- To assess the economic profitability of growing maize under conservation agriculture compared with conventional farming.

2. Materials and methods

2.1. Study environment

The trial was conducted at the Mugerero experimental site belonging to the Institut des Sciences Agronomiques du Burundi (ISABU), where S. guianensis was planted and used as a cover crop. The installation of this cover plant on the experimental site had been the subject of previous research.

Climatic data collected from the IGEBU for the months of October 2016 to March 2017 show that the average monthly rainfall, maximum temperatures, minimum temperatures, minimum humidity and maximum humidity are 131.26 mm; 33.01 °C; 17.03 °C; 99.83% and 52.33% respectively [16]. These climatic conditions are conducive to the development of maize crops [17].

2.2 Data collection

2.2.1. Experimental set-up

The experimental design used (Figure 1) was a randomised complete block design with four replications. Each block consisted of seven treatments: T1: maize/stylo variety 1 (Ma/stylo variety 1), T2: maize/stylo variety 2 (Ma/stylo variety 2), T3: maize/stylo variety 1 + fertilizer (Ma/stylo variety 1+E), T4: pure maize (Ma), T5: maize/stylo variety 1* with installation of the S. guianensis variety as a pure crop in the 1st year of establishment (Ma/stylo 1*), T6: maize/stylo 2* variety intercropping with the S. guianensis variety as a pure crop in the 1st year of establishment (Ma/stylo 2*). The surface area of an experimental unit was 200 m²,
i.e. (20 m x 10 m). The entire set-up was 86 m long and 60 m wide. Consecutive blocks were separated by an alleyway 2 m wide. The cropping systems were installed in rotation with cassava in the same plots.

**Figure 1: Plan of the experimental set-up**

2.2.2. Sowing maize

During site preparation, two main activities were carried out: (i) pruning of *Stylosanthes* on the experimental site and (ii) ploughing of the plots intended for pure maize cultivation (1 plot per block). Maize sowing began 40 days after the *S. guianensis* had been pruned and spread. The maize variety was sown in all the plots at the 75 cm x 50 cm spacing recommended by ISABU [17].
2.2.3. Application of fertilisers
The mineral fertiliser used corresponded to the ISABU recommendations for the study area. It was based on the NPK formula (40-60-30), which is equivalent to 130 kg DAP/ha, 50 kg KCl/ha, 37 kg urea/ha [17]. The application of the fertiliser dose took into account the need to compensate for losses associated with nutrient exports. The choice to apply the usual dose of the standard formula is justified by the fact that during this period of maize sowing, soil analyses were not yet available to be able to compare a fertiliser dose corresponding to crop exports and soil characteristics. The addition of mineral N fertiliser to legumes is based on the hypothesis that legumes influence the use of nitrogen from different soil sources and fertilisers [13]. Based on the results of research carried out by ISABU [17] on maize cultivation at the Mugerero site, we applied the DAP + KCl mixture during sowing. Half of the urea was applied after the second week, with the remainder applied after the third week.

2.2.4. Harvesting and determination of parameters for maize and Stylosanthes guianensis cultivation
The maize produced per plot was harvested and weighed, with yield parameters measured, from 25 to 29 February 2017, i.e. 113 days after sowing.

The parameters assessed for the maize crop were: L.P: Pole emergence (%); H.T: Stalk height (cm); D: Diameter at the crown (cm); P.T: Stalk weight (g); N.P: Number of plants; N.E: Number of ears per plant; P.E: Ear weight (g); N. R: Number of rows of seeds per spike; P.M.G: Weight of 1000 seeds (g); T.E: Total number of spikes harvested per plot; P.T.E.R : Total weight of spikes harvested per plot (kg); R.D.T : Grain yield per ha (T/ha). Grain yield measurements were homogenised taking into account the 12% moisture content using a moisture meter.

For Stylosanthes guianensis the parameters evaluated were: N.R : Number of branches; LTP : Length of main stem (cm), B.F.H : Weight of fresh biomass per ha (Kg/ha), B.S.H : Weight of dry biomass per ha (kg/ha), M. S : Dry matter content (%), P.G : Seed weight (kg/ha), B.R.F : Fresh root biomass per ha (kg/ha), M.S.R : Root dry matter content (%), B.R.S : Dry root biomass per ha (kg/ha).

2.2.5. Data processing
The data collected were subjected to analysis of variance (ANOVA) using "Windostat version 8.5" software to highlight any significant differences between the values of the treatments tested. The ANOVA was completed by the Tukey test at the 5% threshold to identify groups of homogeneous means. Before applying these tests, the normality of the data was checked using the Shapiro-Wilk normality test [18].
3. Results

3.1 Results for maize

The results of the ANOVA on the maize parameters studied (Table 1) showed that the cropping system had no significant effect on the following parameters: crop emergence (%), stalk height (cm), collar diameter (cm), stalk weight (g), number of plants, ear weight (g), number of ears per plant, number of seed rows per ear, total number of ears harvested per plot (p>0.05). On the other hand, it had a highly significant effect on the weight of 1000 seeds (g), the total weight of ears harvested per plot (kg) and grain yield per ha (t/ha) (p<0.001). The comparison of the means of the parameters assessed is presented in Table 2. Mean values in the column followed by the same letter are not significantly different at the 5% threshold.

3.2. Results for Stylosanthes guianensis

The results of the ANOVA on the parameters studied for *Stylosanthes guianensis* (Table 3) showed that the cropping system had no significant effect on the parameters: number of branches, length of main stem (cm), dry matter content (%), fresh root biomass per ha (kg/ha), root dry matter content (%) and dry root biomass per ha (kg/ha) (p>0.05). However, it had a highly significant effect on the weight of fresh biomass per ha (kg/ha) (p= 0.003) and weight of dry biomass per ha (kg/ha) (p= 0.002). The comparison of the means of the parameters assessed is presented in Table 4. Mean values in the column followed by the same letter are not significantly different at the 5% threshold.

4. Discussion of the results

For maize, the ANOVA results showed that the cropping system had a highly significant effect on the weight of 1000 seeds (g), the total weight of cobs harvested per plot (kg) and grain yield per ha (t/ha).

4.1. Thousand kernel weight (TKW)

A comparison of averages for thousand kernel weight (MGW) showed that the maize/stylo system with or without mineral fertiliser application was the best, with values above the overall average of 254.9 g (Table 2). The maize-only system had a low average of 247.3 g, which is close to the values put forward by ISABU [17], according to which the thousand kernel weight of the ECAVEL1 maize variety is between 250 and 300 g. This shows that the maize/stylo combination treatments have significant effects thanks to the influence of the mineral fertiliser added by *Stylosanthes guianensis* [5,19]. It is reported that in legume-based cover cropping systems, the influence of the following crop benefits from the effects of the nitrogen fixed by the legume and those resulting from the presence of mulch [1]. This rotation system has been reported by other authors [5], with rice and maize crops in Brazil and Madagascar benefiting from this crop background in terms of nitrogen and other nutrients.
Table 1: ANOVA results for maize parameters (NS = Not significant; THS = Very highly significant)

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>ddf</th>
<th>Medium squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
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<td>27.55</td>
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<tr>
<td>System</td>
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<tr>
<td>Error</td>
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<td>32.69</td>
</tr>
<tr>
<td>Test F</td>
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<td>0.52</td>
</tr>
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</table>

Table 2: Comparison of means for the variables studied for maize

<table>
<thead>
<tr>
<th>SYSTEMS</th>
<th>Studied parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize+ stylo 1 (T1)</td>
<td>90.2±4.6</td>
</tr>
<tr>
<td>Maize+ stylo 2 (T2)</td>
<td>84.2±5.5</td>
</tr>
<tr>
<td>Maize+stylo1+E (T3)</td>
<td>83.3±3.4</td>
</tr>
<tr>
<td>Maize seul (T4)</td>
<td>87.9±10.0</td>
</tr>
<tr>
<td>Maize/stylo1*(T5)</td>
<td>90.3±5.2</td>
</tr>
<tr>
<td>Maize/stylo2*(T6)</td>
<td>84.1±6.3</td>
</tr>
<tr>
<td>Overall average</td>
<td>86.69</td>
</tr>
<tr>
<td>C.V (%)</td>
<td>7.8</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>57.3</td>
</tr>
</tbody>
</table>
Table 4: ANOVA results for *S. guianensis* parameters (NS = not significant; HS = highly significant)

<table>
<thead>
<tr>
<th>Source of Variation</th>
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</thead>
<tbody>
<tr>
<td>Block</td>
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<td>16.586</td>
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<tr>
<td>Systems</td>
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<td>2.086</td>
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<tr>
<td>Error</td>
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<tr>
<td>Test F</td>
<td></td>
<td>0.817</td>
</tr>
<tr>
<td>C.V (%)</td>
<td></td>
<td>3.05</td>
</tr>
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</table>

Table 5: Comparison of the means of the variables studied for *S. guianensis*

<table>
<thead>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize/stylo 1 (T1)</td>
<td>23.85±2.87</td>
<td>182.1±23.4</td>
<td>30.39±0.31</td>
<td>293.43±13.43</td>
<td>28735±1208</td>
<td>8731±350</td>
<td>22902±4031</td>
<td>14.88±2.32</td>
<td>3337±117.2</td>
</tr>
<tr>
<td>Maize/stylo 2 (T2)</td>
<td>24.05±3.19</td>
<td>192.7±34.1</td>
<td>30.84±0.14</td>
<td>265.93±15.10</td>
<td>26240±1720</td>
<td>8091±538</td>
<td>22856±4013</td>
<td>14.09±1.79</td>
<td>3168±251</td>
</tr>
<tr>
<td>Maize/stylo1+E (T3)</td>
<td>22.61±1.48</td>
<td>211.18±15.06</td>
<td>31.22±0.52</td>
<td>294.6±21.8</td>
<td>28047±1861</td>
<td>8750±464</td>
<td>19616±1420</td>
<td>16.07±1.20</td>
<td>3145±203</td>
</tr>
<tr>
<td>Maize/stylo1*(T5)</td>
<td>24.18±2.80</td>
<td>187.9±27.9</td>
<td>30.78±0.42</td>
<td>296.03±13.01</td>
<td>28720±1247</td>
<td>8837±358</td>
<td>21939±3018</td>
<td>14.93±1.12</td>
<td>3249±220</td>
</tr>
<tr>
<td>Maize/stylo2*(T6)</td>
<td>24.46±2.81</td>
<td>193.8±27.9</td>
<td>30.64±0.36</td>
<td>269.03±19.97</td>
<td>26331±1721</td>
<td>8068±529</td>
<td>22809±4007</td>
<td>14.21±1.73</td>
<td>3196±341</td>
</tr>
<tr>
<td>Overall average</td>
<td>23.69</td>
<td>195.34</td>
<td>30.84</td>
<td>288.95</td>
<td>28140.50</td>
<td>8677.50</td>
<td>22511.67</td>
<td>14.73</td>
<td>3270.67</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.72</td>
<td>10.70</td>
<td>0.31</td>
<td>18.40</td>
<td>1702.85</td>
<td>561.79</td>
<td>1732.51</td>
<td>0.75</td>
<td>143.88</td>
</tr>
<tr>
<td>CV (%)</td>
<td>3.05</td>
<td>5.48</td>
<td>1.02</td>
<td>6.37</td>
<td>6.05</td>
<td>6.47</td>
<td>7.70</td>
<td>5.12</td>
<td>4.40</td>
</tr>
</tbody>
</table>
4.2. Total weight of cobs harvested per plot
In terms of the total weight of cobs harvested per plot, the maize/pen combination with mineral fertiliser ranked first with an average of $107.2 \pm 2.2$ kg, while the maize-only system came last with an average of $59.8 \pm 7.2$ kg. The stylo-based treatments had an average of $92.56$ kg, which is higher than the overall average of $87.64$ kg of cobs per plot. This could be explained by the soil fertility-enhancing effect of *S. guianensis*, which increases the number of ears per plant [13,20].

4.3 Residual effect of *S. guianensis* on maize production
In terms of total yield per ha, the maize/stylo system with mineral fertiliser application was the best, with an average of $3.1 \pm 0.09$ T/ha. On the other hand, the maize-only system came last with an average of $2.4 \pm 0.2$ T/ha. All the stylo-based treatments that occupy an intermediate position between the two aforementioned treatments show yields higher than the overall average of $2.7$ T/ha. These results are similar to those found by ISABU [17] with the application of the recommended formula, which is a combination of 15 to 20 t/ha of farmyard manure and mineral fertilisers with the formula 40-60-30 NPK, i.e. a mixture per hectare of 37 kg urea +130 kg DAP +50 kg KCl. This shows that the use of *S. guianensis* can be a valid replacement for the organic fertilisation provided by ISABU for maize. And this would be possible because maize makes good use of organic fertilisers, given that its vegetation period corresponds to the mineralisation period (if water is not limiting) [17]. The addition of mineral fertiliser to the maize/Stylo combination increases yield [13]. The yield obtained in adjacent plots without mulch was on average lower than the average production under mulch. The higher maize yield under legume residues compared with without confirms the significant residual effect of *S. guianensis* [13]. Higher cereal yields were found in plots preceded by *S. guianensis* in Nigeria and Cameroon [8,21].

The effect of *S. guianensis* on subsequent maize production can be attributed to the significant residual effects due to the nutrients released by the decomposition and mineralisation of its mulch. Pen mulching increases the nutritive value and quantity of subsequent crop residues as well as soil fertility more rapidly than natural fallow [13,20].

This can also be justified by the advantage of the *S. guianensis* root system in recycling nutrients to the soil surface, which influence the main growth and yield processes of plants in association [5]. These results are similar to those found by other authors [22] in Cameroon with the evaluation of *S. guianensis* cover on the performance of the subsequent maize crop.

4.4 Evolution and persistence of mulch
In terms of dry biomass per ha, the system with the maize/Stylo + Fertiliser combination was the best, with an average of $8750\pm464$ kg/ha. On the other hand, the system involving the maize/Stylo 2 combination with the installation of stylo 2 as a pure crop in the first year came last with an average of $8068\pm529$ kg/ha. The overall
average for biomass production was 8677.50 kg/ha (Table 4), which shows that S. guianensis species are capable of producing high biomass without fertiliser on acid and highly degraded soils (5 to 10 T.ha-1 of dry matter), and up to 20 T.ha-1 on rich soils [5].

It has been confirmed that once S. guianensis has become established in a plot, its canopy can easily be reconstituted by natural resowing of the seeds produced before the stems are cut back to ground level at the end of the long dry season. This enables the desired permanent plant cover to be established [22].

The main condition to be met in tropical zones is whether the cover crop can rapidly produce the mulch needed to cover the soil during the growing season and provide the mulch needed to cover the soil during the dry season [8,21].

However, the quantity of mulch produced during the first phase of cover crop establishment represents the minimum level of mulch required by other authors in Madagascar [5] and Cameroon [12]. Thus, the mulch produced persists satisfactorily for a single growing season, making it possible to plant a cropping system with S. guianensis as a cover crop if the need for permanent soil cover is to be met [21,22].

5. Conclusion

The aim of this study was to evaluate the performance of direct seeding maize cultivation under a cover crop of Stylosanthes guianensis in the conditions of the Imbo plain. The results obtained show that for maize grain production, systems based on the maize/Stylo association come first (3.1±0.09 T/ha), followed by systems based on maize alone (2.4±0.2 T/ha). Stylosanthes guianensis thus provides the nutrients required for the development of the associated crop through symbiotic fixation and straw decomposition. This improves the yield of subsequent crops, and growing these two plants together does not reduce maize yields.

Given the quantities of biomass produced by the S. guianensis species, the variability in biomass yields is not significant between the systems tested. However, it was possible to produce up to 8750±464 kg/ha of dry biomass weight in the case of the maize/Stylo association, which shows that these quantities of biomass are sufficient, in line with those recommended in tropical zones, to ensure favourable soil cover and finally to establish a vegetation sub-cover for the following crop.
References


Evaluation of the performance of direct seeding maize under a plant cover of ...


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