*Original Research Article*

Evaluation of the impact of control methods based on local products against the *Striga hermonthica* (Del.) Benth. on millet [*Pennisetum glaucum* (L.) R. Br.] in a rural environment in the north Côte d’Ivoire

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Abstract

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| **Objectives :** To assess the impact of local product-based control methods against *Striga hermonthica* infestation*.****Study desi*gn :** a randomized complete block design was set up with four replications and five treatments (T0=control, T1=compost, T2=millet seeds coated with *Parkia biglobosa* powder, T3=millet seeds coated with *Parkia biglobosa* powder combined with compost and T4= peanut+millet combination.**Location and duration of studies :** the study was carried out in Tiaplé, in the sub-prefecture of Diawala, during the years 2022 and 2023.**Methodology :** Observations and measurements focused on the emergence time and morphological development of *Striga hermonthica* plants, the degree of infestation of millet plants and their yield.**Results :** In year 1, T2 treatment delayed the emergence of *Striga hermonthica* plants compared with the control (T0 = 53.00 jas and T2 = 56.75 jas) and reduced the infestation rate of millet plants (T0 = 44.52% and T2 = 28.03%). In year 2, the same results were obtained with treatments T2 and T4 for *Striga hermonthica* plant emergence (T0 = 51.75 jas ; T2 = 56.25 jas and T4 = 57.25 jas) and millet plant infestation rate (T0 = 64.80% ; T2 = 62.30% and T4 = 64.00%). The best yields were obtained in year 1 with treatment T3 (T0 = 378.94 kg/ha and T3 = 683.53 kg/ha) and in year 2 with treatment T4 (T0 = 446.07 kg/ha and T4 = 938.86 kg/ha). **Conclusion :** *Parkia biglobosa*powder and legumes, taken together or separately, could provide a solution for controlling *Striga hermonthica* in millet. |

*Keywords: Compost, Côte d'Ivoire, millet, Parkia biglobosa, control strategies, Striga hermonthica*

1. INTRODUCTION

 Traditional cereals are the staple food of human populations in Africa [1]. Unlike other cereals, millet (*Pennisetum glaucum*) is an annual plant that is better able to adapt to extreme conditions [2]. It seems to be more resistant to drought, which is why it is so important for local populations in areas where climatic conditions do not allow for the cultivation of cereals sorghum, maize and rice to develop normally [3]. Millet has impressive nutritional values, with its high carbohydrate and protein content [4]. It is an energetic, nutritious food, particularly recommended for children and the elderly [5].

 In Côte d'Ivoire, millet occupies over 65% of the sown area [6]. Annual millet production is estimated at 67,000 tonnes per year [7], against a requirement of 120,000 tonnes [8]. It ranks third among the cereals produced and consumed in the country, after rice and maize [9]. Two varieties of millet are grown in the north of the country. The traditional variety, which has a longer development cycle than the early variety, is the most widely grown. It is grown alone or in association with other crops, depending on the dietary habits of the producers, who are the Malinkés of the north-west, the Senoufos of the centre-north and the Koulango and Lobi of the north-east. From a cultural, economic and social point of view, millet (*Pennisetum glaucum*) occupies an important place among the populations of northern Côte d'Ivoire. It is a staple food at all ceremonies, especially funerals. [10].

 Despite the advantages of these practices, millet yields remain very low, at around 500 kg/ha in farming areas [9]. In the context of our study, the low yields are essentially explained by phyto-parasitic problems, accentuated by climatic and environmental problems. These biotic and abiotic constraints hamper the development of cereal crops. Among these constraints, we can cite the proliferation of parasitic weeds such as Striga species, which constitute the major biotic constraint to cereal production [11]. Of all Striga species, *Striga hermonthica,* (Del.) Benth. is the most dreaded weed, parasitizing many cereal crops [12] and causing major crop losses of up to 100% of grain yield [13]. A number of local control methods have been identified [14] as curative for controlling *Striga hermonthica* parasitism in Burkina Faso. These include manual uprooting and weeding, the application of organic manure to fields, and the burial of *Parkia biglobosa* pods [15], seed treatment with *Parkia biglobosa* pod powder before sowing [16], spreading shea kernel residues, crop rotation and fallowing. In addition, the efficacy of using *Parkia biglobosa* pulp powder has been demonstrated in Mali [17] in millet cultivation, without an in-depth study to understand the mechanism.

Despite numerous studies on the biology and control methods of *Striga hermonthica*, the eradication of this parasitic plant is proving difficult due to the complexity of the biological interaction between it and its host. However, the extent of damage caused by Striga spp. depends on ecological conditions, cropping systems and practices, and growers' level of ecological and agronomic knowledge. It is therefore important to take farmers' knowledge into account. Taking their knowledge into account is crucial and should not be relegated to second place, as emphasized by Brush [18]. This will help to develop control methods against *Striga hermonthica* infestation in millet-based cropping systems. Hence the interest of this study, the general aim of which is to assess the impact of control methods based on local products such as compost and pulp *Parkia biglobosa* powder, in a farming environment, against the infestation of this parasite on millet plants.

2. materials and methods

**2.1 study site**

 The study was carried out in the village of Tiaplé (latitude : 10°4'48'‘ ; longitude : 5°23'53'‘ ; altitude : 338 m), in a farmers' field located in the Sous-préfecture of Diawala, in the Tchôlôgô Region, over two successive years. This locality is located in the north of Côte d'Ivoire (Figure 1) and is one of the regions most infested by *Striga hermonthica* species [19]. The field was chosen on the basis of a previous cereal crop and the abundant presence of *Striga hermonthica* observed the year before the experiment was set up. Rainfall in the study area was recorded during the experiment, using a direct-reading rain gauge.

**Figure 1 : Map of the study area**

**2.2 Plant material**

 The plant material was a traditional variety of millet (*Pennisetum glaucum*) locally called

" sagnon" grown in the study area and susceptible to *Striga hermonthica*. It has a yield of 2.5 t/ha, when rainfall conditions are good, and a cycle length of between 120 and 140 days [20].

**2.3 Experimental setup**

 The experiment was conducted in a completely randomized block design with four replicates and a factor of five (5) treatments over the two years. Each block consisted of 5 elementary plots. The elementary plots were spaced 2 m apart, with a distance of 2 m separating the blocks. The dimensions of the elementary plots were 5 m by 5 m, i.e. a surface area of 25 m². They were made up of 6 ridges separated by 0.75 m, each containing 10 stacks of millet. The distance between bunches on the row was 0.5 m. Each elementary plot was randomly assigned a treatment. Treatments were applied to the plots as follows :

- T0 : control ;

- T1 : “Bokashi” powder to control Striga ;

- T2 : *Parkia biglobosa* pulp powder to control Striga;

- T3 : T1 +T2 to control Striga ; and

T4 : legume association with millet (*Pennisetum glaucum*) to control Striga. For the second year of experimentation, the millet (*Pennisetum glaucum)* was sown on the peanut rows, while the peanut was sown on the millet rows.

**2.4 Measurements and observations**

Measurements and observations focused on the vegetative development of *Striga hermonthica* plants, the degree of infestation of millet plants by *Striga hermonthica* and millet production.

- Vegetative development of *Striga hermonthica* plants

Vegetative development of *Striga hermonthica* plants was monitored by measuring emergence time, morphology (height and branching) and dry biomass of Striga plants.

* Emergence time

The emergence time of *Striga hermonthica* plants corresponds to the time elapsed between sowing and the date of appearance of the first *Striga hermonthica* plant in an elementary plot, expressed in days after sowing (das).

* Morphology of *Striga hermonthica* plants

The morphology of *Striga hermonthica* plants was monitored in terms of height and branching at flowering. Measurements were taken on 10 randomly selected plants per plot at flowering.

* Dry biomass of a *Striga hermonthica* plant

The dry biomass of a *Striga hermonthica* plant was determined from 10 plants taken from each elementary plot at harvest. The plants were harvested, dried and weighed on a precision balance until a constant dry weight was obtained.

- The degree of infestation of millet plants by *Striga hermonthica*

The number of *Striga hermonthica* plants was counted at flowering per elementary plot. This number was used to calculate the density of Striga plants/m² per plot, using the following ratio:

$$Striga plant density/m² =\frac{number of Striga plants}{25}$$

To determine the rate of infestation of millet plants by *Striga hermonthica*, the number of millet plants infested by *Striga hermonthica* was counted at flowering per elementary plot. A millet plant is considered infested when a *Striga hermonthica* plant emerges at its foot. The calculation was based on the following ratio :

$$Infestation rate (\%) =\left.\left(\frac{number of infested millet pockets}{total number of pockets of millet}\right.\right)x100$$

- millet production

 Measurements of millet production were taken at harvest in a yield square (3.75 m²), comprising ten bunches located on the inner rows of each elementary plot. Measurements were taken on ear length (cm) and diameter (mm), dry weight of grains per ear (g) and dry weight of grains (g)/yield square. Yield (kg/ha) was calculated as the ratio of the dry weight of grains in the yield square to the area of the yield square.

2.5 Physico-chemical analysis of soil samples from the experimental site, compost and cowpea powder

soil samples were analyzed using standard methods of mckeague, 1978, at the plant and soil laboratory (LAVESO) of the Yamoussoukro university college ((Côte d’Ivoire).

chemical analyses were carried out according to AOAC, 2010 : official methods of analysis of association of official analytical chemists.

For soil samples, the following elements were analyzed from 100 g of sample : pH water, pH Kcl, organic C (%), organic M (%), total N (%), P (mg/kg), available K (mg/kg), assimilable phosphorus, sand (%), clay (%), silt (%) and electrical conductivity (µs/cm). Soil analyses were carried out in the first year before the experiment was set up and in the second year after the experiment was completed.

For compost, the following elements were analyzed for both experiments, based on 100 g of sample : organic matter (%), total carbon (%), total nitrogen (%), total phosphorus (P2O5) (%), total potassium (K2O) (%) and pH.

In the case of cowpea powder, the following elements were analyzed for the samples used over the two years of experimentation, starting from 5 g of sample : phenolic compounds (polyphenols, flavonoids and tannins) and mineral salts (calcium, phosphorus, magnesium, potassium, sodium, manganese, zinc, copper, iron, iodine and selenium).

**2.6 Statistical analysis**

 Statistical analysis of the data collected was carried out using R software version 4.3.1. The one-factor analysis of variance (ANOVA) test was used to compare means. In the event of a significant difference, Fischer's LSD test at the 5% threshold was used to separate means into homogeneous groups.

**3. RESULTS**

**3.1 Results of physico-chemical analyses of soil samples, compost and cowpea powder**

**3.1.1 Results of soil sample analysis at the experimental site**

 Table 1 presents the results of soil sample analysis carried out prior to the implementation of the experiment in year 1. These results showed that the site soil is sandy (coarse : 59.47% and fine sand: 30.10%) with low clay (2.17%) and silt (fine silt 1.83% and coarse silt 6.43%) contents. It was low in organic matter (0.05%), organic carbon (0.09%) and nitrogen (0.04%). On the other hand, it had high levels of assimilable phosphorus (26.67 ppm) and available potassium (46.45 g/kg). Electrical conductivity was 0.21 µS/cm, and the water's hydrogen potential (pH water) was 5.33.

 The results of the analysis of soil samples taken after the experiment in year 2 are shown in Table 2. They showed almost identical water pH values for the different treatments. Average electrical conductivity was higher in treatments T1 (0.85 µS) and T3 (0.83 µS) than in the other treatments (T0 : 0.52 µS ; T2 : 0.53 µS ; T4 : 0.65 µS). Average organic carbon content was higher in treatment T4 (0.75%) than in the other treatments (T0 : 0.46% ; T1 : 0.53% ; T2 : 0.54% ; T3 0.47%). Assimilable phosphorus content was higher in treatments T3 (35 ppm) and T4 (28 ppm) than in the other treatments. other treatments (T0 and T2: 19 ppm; T1: 18 ppm). The average content of cation exchange capacity was higher for treatments T2 (4.78 cmol+/kg), T3 (3.56 cmol+/kg) and T4 (2.10 cmol+/kg). After experimentation, the site soil showed low levels of sodium ions, potassium ions and nitrogen for all treatments. However, magnesium and calcium ion concentrations were higher for the various treatments.

**3.1.2 Results of analysis of “Bokashi” compost samples**

 Table 3 shows the results of compost analysis for years 1 and 2. Observation of the analysis results shows that the compost used in year 2 was richer in mineral elements than that used in year 1. In fact, its contents were higher respectively in magnesium (0.38% m.s. and 0.32% m.s.), carbon (7.3 and 3.21% m.s.), total nitrogen (0.9% m.s. and 0.9% m.s.) and phosphorus (0.9% m.s. and 0.9% m.s.). s and 0.32% m.s), carbon (7.3 and 3.21% m.s), total nitrogen (2.6 and 0.7% m.s), calcium (1.14 and 0.83% m.s), phosphorus (0.26 and 0.20% m.s) and organic matter (12.56 and 5.52% m.s) respectively. On the other hand, total potassium (0.93 and 0.71% m.s) and C/N ratio (4.59 and 2.80) were higher in year 1 than in year 2.

**3.1.3 Results of *Parkia biglobosa* powder sample analysis**

 The results of the *Parkia biglobosa* powder analysis show that the powder used in year 2 was richer in phenolic compounds and mineral salts than that used in year 1. Indeed, the néré powder used in year 2 had higher content values than that used in year 1, in compounds such as polyphenols (350.34 and 317.34 mg/100g) and tannins (86.89 and 68.16 mg/100 g). On the other hand, flavonoid content was higher in year 1 than in year 2 (13.77 and 11.95 mg/100g) (table 4).

 The results of the analysis of the mineral salts contained in the *Parkia biglobosa* powder are shown in Table 5. These results showed a higher magnesium and sodium content respectively in year 1 compared with year 2 (62.27 and 58.15; 3.99 and 3.21). The respective mineral salts such as calcium (88.03 and 87.12 mg/100g), phosphorus (93.08 and 91.76 mg/100g), potassium (105.66 and 103.01mg/100g), manganese (0.68 and 0.61mg/100g), zinc (0.14 and 0.11 mg/100g), copper (0.05 and 0, 03 mg/100g), iron (0.43 and 0.36 mg/100g), iodine (0.02 and 0.016 µg/100g) and selenium (0.01 and 0.007 mg/100g) showed higher levels in the *Parkia biglobosa* powder used in year 2 than in that used in year 1.

**3.2 Rainfall recorded in the study area**

 During the first year of experimentation, a total rainfall of 647 mm was recorded. Millet plants received 567 mm during the vegetative phase, compared with 80 mm during the reproductive phase. For the second year, a total of 678 mm was recorded, with 636 mm during the vegetative phase and 42 mm during the reproductive phase (Table 6).

**Table 1 : Results of soil sample analysis from year 1**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Clay (%) | Fine silt (%) | Coarse silt (%) | Fine sand (%) | Coarse sand (%) | PhH 2 O | pHKcl | EC (µS) | Available phosphorus (ppm) | MO (%) | C (%) | N (%) | K (g/kg) |
| 2.17 | 1.83 | 6.43 | 30.10 | 59.47 | 5.33 | 4.43 | 0.21 | 26.67 | 0.05 | 0.09 | 0.04 | 46.45 |

*ph H2O: hydrogen potential of water; ph Kcl : hydrogen potential of potassium chloride; C-organic: organic carbon; M-organic: organic matter; C/N: carbon/nitrogen, N: total nitrogen; K available: available potassium; available phosphorus; CE: electrical conductivity; MO: organic matter (= C x 1.72).*

**Table 2 : Results of soil sample analysis from year 2**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatments | PhH 2 O | pHKCL | EC (µS) | C (%) | N (%) | P. assi (ppm) | CEC (cmol +/kg) | Ca 2+ (cmol +/kg) | Mg 2+ (cmol +/kg) | K + (cmol +/kg) | Na + (cmol+ kg) |
| T0 | 5.80 | 4.82 | 0.52 | 0.46 | 0.03 | 19 | 1.94 | 0.84 | 0.40 | 0.14 | 0.06 |
| T1 | 5.88 | 5.08 | **0.85** | 0.53 | 0.05 | 18 | 1.80 | 1.05 | 0.50 | 0.06 | 0.07 |
| T2 | 5.78 | 4.95 | 0.53 | 0.54 | 0.05 | 19 | **4.78** | 0.89 | 0.43 | 0.05 | 0.06 |
| T3 | 5.78 | 4.92 | **0.83** | 0.47 | 0.05 | **35** | **3.56** | 0.95 | 0.46 | 0.09 | 0.06 |
| T4 | 5.55 | 4.78 | 0.65 | **0.75** | 0.06 | **28** | 2.10 | 0.83 | 0.40 | 0.09 | 0.05 |

*ph H2O: hydrogen potential of water; ph Kcl : hydrogen potential of potassium chloride; EC: electrical conductivity; C-organic: organic carbon; N: total nitrogen; p. assi : assimilable phosphorus; CEC: cation exchange capacity; Ca: calcium; Mg: magnesium; K: potassium; Na: sodium.*

**Table 3 : Results of the analysis of compost samples Bokashi**

|  |  |  |
| --- | --- | --- |
| Mineral elements | Year 1 | Year 2 |
| Mg (% m.s) | 0.32 | 0.38 |
| Carbon (% m.s) | 3.21 | 7.3 |
|  Total nitrogen (% m.s) | 0.7 | 2.6 |
| Calcium (% m.s) | 0.83 |  1.14 |
| Potassium total (% m.s) | 0.93 |  0.71 |
| Phosphorus (% m.s) | 0.20 |  0.26 |
|  Organic matter (% m.s) | 5.52 |  12.56 |
| C/N | 4.59 |  2.80 |

**Table 4 : Results of the analysis of the *Parkia biglobosa* powder**

|  |  |  |
| --- | --- | --- |
| Mineral elements |  Year 1 |  Year 2 |
| Value | Standard deviation |  Value | Standard deviation |
| Polyphenols (mg/100g) | 317.34 | 1.35 | 350.35 |  0.80 |
| Tannins (mg/100g) | 68.16 | 0.88 | 86.89 |  1.11 |
| Flavonoids (mg/100g) | 13.77 | 0.33 | 11.95 |  0.07 |
| Total carbohydrates (%) | 72.94 | 0.16 | 74.49 |  0.20 |

**Table 5 : Results of the analysis of mineral salts contained in *Parkia biglobosa* powder**

|  |  |  |
| --- | --- | --- |
| Mineral salts | Year 1 | Year 2 |
| Calcium (mg/100g) | 86.21 | 88.03 |
| Phosphorus (mg/100g) | 90.45 | 93.08 |
| Magnesium (mg/100g) | 66.39 | 58.15 |
| Potassium (mg/100g) | 100.36 | 105.66 |
| Sodium (mg/100g) | 4.77 | 3.21 |
| Manganese (mg/100g) | 0.55 | 0.68 |
| Zinc (mg/100g) | 0.09 | 0.14 |
| Copper (mg/100g) | 0.02 | 0.05 |
| Iron (mg/100g) | 0.29 | 0.43 |
| Iodine (µg /100g) | 0.012 | 0.02 |
| Selenium (mg/100g) | 0.004 | 0.01 |

**Table 6 : Rainfall recorded in the study area**

|  |  |  |
| --- | --- | --- |
| Phenological phases  | Rainfall amounts (mm) year 1 | Rainfall amounts (mm) year 2 |
| Vegetative | 567 | 636 |
| Reproductive | 80 | 42 |
| Cycle | 647 | 678 |

**3.3 Influence of treatments on vegetative development of *Striga hermonthica* plants**

**3.3.1 Effect of treatments on emergence time of *Striga hermonthica* plants**

 The results of the analysis show significant differences between the different treatments studied (P<0.05) for the 2 years (Table 7). For both year 1 and year 2, treatment T1 (45.25 jas ; 44 jas) shortened the emergence time of *Striga hermonthica* plants compared with the control treatment (53 jas ; 51.75 jas). On the other hand, Treatment T2 (56.75 jas ; 56.25 jas) delayed the emergence of *Striga hermonthica* plants compared with the control treatment. In year 2, treatment T4 (57.25 jas) also delayed the emergence of *Striga hermonthica* plants. Moreover, there was no difference between the same treatment from one year to the next.

**3.3.2 Effect of treatments on morphological development of *Striga hermonthica* plants**

 Table 8 shows the results of monitoring the morphological development of *Striga hermonthica* plants in years 1 and 2. Statistical analysis showed a significant difference (P<0.05) between the plant heights of the different treatments in year 1. Treatment T2 had the lowest mean plant height (44.02 cm), while T0 had the highest mean height (48.20 cm). However, there were no significant differences in the number of branches between treatments. In year 2, no significant differences were observed between treatments for any variable. From one year to the next, treatments T0 (T01 : 48.20; T02 : 55.57), T1 (T11 : 46.65; T12 : 57.22), T2 (T21 : 44.02; T22 : 54.45), and T4 (T41 : 47.45; T42 : 55.37), showed significant differences in Striga plant height. Treatment T3 (T31 : 47.26; T32 : 57.30) showed a highly significant difference. However, for the number of branches, no difference was observed for the same treatment from one year to the next.

**3.3.3 Effect of treatments on dry biomass per *Striga hermonthica* plant**

The results of the statistical analysis showed no significant differences between treatments for Striga plant dry biomass values in year 1. In year 2, the results of the statistical analysis showed significant differences (P<0.05) between treatments. Striga plants in treatments T2 and T3 had the highest dry biomass values, with mean values of 2.71 g and 2.77 g respectively. In contrast, T4 had the lowest dry biomass value at 1.23 g (Table 9). In both years, non-significant differences were observed for the same treatment.

**Table 7 : Emergence time of seedlings *Striga* *hermonthica***

|  |  |  |  |
| --- | --- | --- | --- |
| Treatments |  Year 1 Year 2 | P-value year 1 and year 2 | P-value significance |
| Emergence(jas) | Emergence(jas) |
| T0 | 53.00 ab | 51.75 c | 0.8263 | ns |
| T1 | 45.25 b | **44. 00 d** | **0.6343** | **ns** |
| T2 | **56.75 a** | **56.25 a** | **0.8376** | **ns** |
| T3 | 56.00 ab | 55.00 b | 0.8182 | ns |
| T4 | 53.00 ab | **57. 25 a** | **0.189** | **ns** |

*For a given variable and effect, means assigned the same letter are not significantly different at the 5% level. The number of stars indicates the significance of the difference between the values at the 5% level. NS : Non-significant differences, \*: Significant differences, \*\*: Very significant differences; \*\*\*: Highly significant; P-value: Probability*

**Table 8 : Morphological development of *Striga hermonthica* plants**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Settings | Treatments | Year 1 | Year 2 | P-value year 1 and year 2 | P-value significance |
|  | T0 | 48.20 a | 55.57 a | 0.0341 | \* |
| Height (cm) | T1 | 46.65 ab | 57.22 a | 0.0152 | \* |
| **T2** | **44.02 b** | 54.45 a | 0.0487 | \* |
|  | T3 | 47.26 ab | 57.30 a | 0.0079 |  \*\* |
|  | T4 | 47.45 ab | 55.37 a | 0.0108 |  \* |
|  | T0 | 9.81 a | 11.45 a |  0.11 |  ns |
|  | T1 | 10.20 a | 11.97 a | 0.2232 |  ns |
| Ramification | T2 | 10.04 a | 12.80 a |  0.1915 |  ns |
|  | T3 | 9.65 a | 11.90 a |  0.3153 |  ns |
|  | T4 | 10.45 a | 10.57 a | 0.9507 |  ns |

*For a given variable and effect, means assigned the same letter are not significantly different at the 5% level. The number of stars indicates the significance of the difference between the values at the 5% level. NS : Non-significant differences, \*: Significant differences, \*\*: Very significant differences ; \*\*\*: Highly significant; P-value: Probability*

**Table 9 : Dry biomass per *Striga* *hermonthica* plant**

|  |  |  |  |
| --- | --- | --- | --- |
| Treatments |  Year 1 Year 2 | P-value year 1 and year 2 | P-value significance |
| Dry biomass (g) | Dry biomass (g) |
| T0 | 1.22 a | 1.70 ab | 0.2408 | ns |
| T1 | 1.36 a | 1.53 ab | 0.6487 | ns |
| T2 | 2.46 a | **2.71 a** | 0.6857 | **ns** |
| T3 | 2.55 a | **2.77 a** | 0.8198 | **ns** |
| T4 | 1.96 a | 1.23 b | 0.7635 | ns |

*For a given variable and effect, means assigned the same letter are not significantly different at the 5% level. The number of stars indicates the significance of the difference between the values at the 5% level. NS : Non-significant differences, \*: Significant differences, \*\*: Very significant differences; \*\*\*: Highly significant; P-value: Probability*

**3.4 Influence of treatments on the degree of infestation of millet plants by *Striga hermonthica***

**3.4.1 Effect of treatments on the density of Striga plants/m² at flowering**

 Significant differences (P<0.05) were observed between the different treatments for the density of Striga plants/m² for the 2 years. In year 1, treatment T2 reduced Striga plant density/m² with a lower mean value (7.21) than treatment T0 (9.20 plants) (Table 10). In year 2, Striga density/m² increased with treatment T1 (28.50 plants) compared with the control (11.36 plants). Conversely, treatments T2 and T4 reduced the density of Striga plants/m², with averages of 6.68 and 3.71 plants respectively, compared with 11.36 plants for treatment T0 (Table 10). Furthermore, treatments T0 and T2 showed no significant difference from one year to the next. On the other hand, treatments T1 (T11 : 7.98; T12 : 28.50) and T3 (T31 : 7.70; T32 : 18.41) showed significant differences from year 1 to year 2. For T4 (T41 : 7, 96 ; T42 : 3, 71), a highly significant difference was observed.

**3.4.2 Effect of treatments on the rate of infestation of millet plants by *Striga hermonthica* at flowering**

 The results of the statistical analysis showed significant differences (P<0.05) between treatments in year 1 and year 2 (Table 11). In Year 1, treatments T1, T2 and T3, with values of 35.00%, 28.03% and 28.91% respectively, significantly reduced the infestation rate of millet plants compared with the control, which had a value of 44.52%. On the other hand, treatment T4, with a value of 62.19%, showed a significant increase in the infestation rate compared with the control (44.52%). In Year 2, treatments T2 and T4 (62.30% and 64.00% respectively) reduced the infestation rate of millet plants compared with the control (64.80%). Conversely, treatment T1 (89.80%) led to an increase in the infestation rate of millet plants compared with the control control (44.52%). Similarly, it showed a highly significant difference in infestation rate from one year to the next (T11 : 35, 00 ; T12 : 89, 80). Treatment T2 (T21 : 28, 03 ; T22 : 62, 30) showed different infestation rate values from year 1 to year 2. Treatment T3 (T31 : 28, 91 ; T32 : 81, 40) showed a highly significant difference in infestation rate from one year to the next. Conversely, treatments T0 and T4 showed no difference from year 1 to year 2.

**Table 10 : Density of Striga plants /m2 at flowering**

|  |  |  |  |
| --- | --- | --- | --- |
| Treatments |  Year 1 Year 2 | P-value year 1 and year 2 | P-value significance |
| Striga plant density / m2 | Striga plant density / m2 |
| T0 | 9.20 a | 11.36 bc | 0.5817 | ns |
| T1 | 7.98 b | 28.50 a | 0.0226 | \* |
| T2 | **7.21 c** |  **6.68 c** |  0.6198 |  **ns** |
| T3 | 7.70 b | 18.41 ab | 0.0250 | \* |
| T4 | 7.96 b |  **3.71 c** | 0.0012 |  \*\* |

*For a given variable and effect, means assigned the same letter are not significantly different at the 5% threshold. The number of stars indicates the significance of the difference between the values at the 5% threshold. NS : Non-significant differences, \*: Significant differences, \*\*: Very significant differences; \*\*\*: Highly significant; P-value: Probability*

**Table 11 : *Striga hermonthica*** **infestation rate of millet plants *in* bloom**

|  |  |  |  |
| --- | --- | --- | --- |
| Treatments |  Year 1 Year 2 | P-value year 1 and year 2 | P-value significance |
| Infestation rate (%) | Infestation rate (%) |
| T0 | 44.52 ab | 64.80 bc |  0.283 |  ns |
| T1 | **35.00 b** | 89.80 a |  0.0002 |  \*\*\* |
| T2 | **28.03 b** | **62.30 c** |  0.0162 | \* |
| T3 | **28.91 b** | 81.40 ab |  0.0035 |  \*\* |
| T4 | 62.19 a | **64.00 c** |  0.9401 |  **ns** |

*For a given variable and effect, means assigned the same letter are not significantly different at the 5% threshold. The number of stars indicates the significance of the difference between the values at the 5% threshold. NS : Non-significant differences, \*: Significant differences, \*\*: Very significant differences; \*\*\*: Highly significant; P-value: Probability*

**3.5 Influence of treatments on millet production**

**3.5.1 Treatment effects on yield components**

 The results of the statistical analysis showed differences between the different treatments in Year 1 and Year 2 (Table 12). In Year 1, cobs were longer in treatments T3 and T4 (22.51 cm and 22.21 cm) than in the control (20.32 cm). In Year 2, treatment T3 obtained the longest cobs (29.85 cm) compared with the control (26.46 cm), and treatment T1 obtained the shortest cobs (23.50 cm) compared with the control. From one year to the next, highly significant differences were observed with the respective treatments T0 (T01 : 20, 32 ; T02 : 26, 46), T2 (T21 : 21, 16 ; T22 : 27, 04) and T4 (T41 : 22, 21 ; T42 : 26, 65). A significant difference was observed with T3 (T31 : 22, 51 ; T3-2 : 29, 85). On the other hand, no difference was observed with treatment T1.

 With regard to cob diameter, in Year 1, treatments T1, T3 and T4 respectively obtained the largest cobs (22.21, 22.99 and 22.46 mm). In Year 2, the highest value was obtained with treatment T4 (23.58 mm) and the lowest value was obtained with treatment T1 (17.88 mm) compared with the control (21.32mm). From year 1 to 2, no significant differences were observed between treatments.

 In Year 1, treatments T1 and T3 (17.50 g and 17.44 g) respectively achieved the highest dry weight of grain per ear compared with the control (12.20 g). In Year 2, treatment T1 (5.44 g) obtained the lowest value and treatment T4 (24.29 g) the highest value compared with the control (11.74 g). Furthermore, no significant differences were observed from one year to the next for all treatments except T1 (T11 : 17.50; T12 : 5.44).

The results of the statistical analysis of grain dry weight/yield square showed no difference between treatments in year 1. However, the best grain dry weight/yield square value was obtained with treatment T3 (256.34 g) compared with the other treatments (T0 : 142.10; T1 : 235.76; T2 : 197.70 and T4 : 231.23 g). In year 2, treatment T1 (64.41 g) obtained the lowest value and treatment T4 (352.07 g) the highest value of grain dry weight/square of yield compared with the control (167.27 g). No significant year-to-year differences were observed for all treatments except T1 (T11 : 235.76; T12 : 64.41).

**3.5.2 Effects of treatments on yield**

The results of the statistical analysis showed no significant difference between treatments in Year 1. However, treatment T3 with a value of 683.53 kg/ha achieved the highest yield compared with the other treatments (T0 : 378.94; T1 : 628.70; T2 : 527.20 and T4 : 616.61 kg/ha). In Year 2, treatment T1 achieved a lower yield than the control (T1 : 171.76 kg/ha and T0 : 446.04 kg/ha). Treatment T4, on the other hand, produced the highest yield (938.86 kg/ha) compared with the control, which achieved a value of 446.07 kg/ha (Table 13). Furthermore, no significant difference was observed from year 1 to year 2 for all treatments except treatment T1 (T11 : 628.70; T12 : 171.76), which showed different yield values.

**Table 12 : Components of performance**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Settings | Treatments | Year 1 | Year 2 |  P-value year 1 and year 2 |  Significance P-value |
|  | T0 | 20.32 b |  26.46 b 0.0083 |  \*\* |
|  | T1 | 21.36 ab |  23.50 c 0.3231 |  ns |
| Spike length (cm) | T2 | 21.16 ab |  27.04 b |  0.0039 |  \*\* |
|  | T3 | **22.51 a** |  **29.85 a** |  0.0115 |  \* |
|  | T4 | **22,21 a** |  26,65 b |  0.0058 | \*\* |
|  | T0 | 20,35 b |  21,32 bc |  0,5908 | ns |
|  | T1 | **22,21 a** |  17,88 d |  0.0972 | ns |
| Ear diameter (mm) | T2 | 20,92 b |  20,94 c |  0,987 | ns |
|  | T3 | **22,99 a** |  23,14 ab |  0,9272 | ns |
|  | T4 | **22,46 a** |  **23,58 a** |  0,4577 | **ns** |
|  | T0 | 12,20 b |  11,74 b |  0,9311 | ns |
|  | T1 | **17,50 a** |  5,44 c |  0,0235 | \* |
| Dry weight of grains on an ear (g) | T2 | 14,80 ab | 14,00 b |  0,8081 | ns |
|  | T3 | **17,44 a** |  15,53 b |  0,8286 | ns |
|  | T4 | 16,14 ab |  **24,29 a** |  0,2941 | **ns** |
|  | T0 | 142,10 a |  167,27 bc |  0,685 | ns |
|  | T1 | 235,76 a |  64,41 c |  0,0331 | \* |
| Dry weight of grains/squareyield (g) | T2 | 197,70 a |  207,13 b |  0,8674 | ns |
|  | T3 | 256,34 a |  250,56 ab |  0,9683 | ns |
|  | T4 | 231,23 a |  **352,07 a** |  0,3578 | **ns** |

*For a given variable and effect, means assigned the same letter are not significantly different at the 5% level. The number of stars indicates the significance of the difference between the values at the 5% level. NS : Non-significant differences, \*: Significant differences, \*\*: Very significant differences; \*\*\*: Highly significant; P-value: Probability*

**Table 13 : Yield (kg/ha)**

|  |  |  |  |
| --- | --- | --- | --- |
| Treatments | Year 1 Year 2 | P-value year 1 and year 2 | P-value significance |
| Yield (Kg/ha) | Yield(Kg/ha) |
| T0 | 378.94 a | 446.07bc | 0.685 | ns |
| T1 | 628.70 a | **171.76 c** | 0.0331 |  \* |
| T2 | 527.20 a | 552.35 b | 0.8674 | ns |
| T3 | 683.53 a | 668,17 ab | 0.9683 | ns |
| T4 | 616.61 a | **938.86 a** | 0.3578 | **ns** |

*For a given variable and effect, means assigned the same letter are not significantly different at the 5% level. The number of stars indicates the significance of the difference between the values at the 5% level. NS : Non-significant differences, \*: Significant differences, \*\*: Very significant differences; \*\*\*: Highly significant; P-value: Probability*

4. Discussion

The late appearance of *Striga hermonthica* seedlings for seeds coated with néré powder could be explained by the fact that the roots of the millet plants did not release stimulants likely to induce germination of *Striga hermonthica* seeds present in the soil. This corroborates that of [21], who states that germination of *Striga hermonthica* seeds only occurs when the host roots secrete a substance called strigol in the vicinity (4 mm) of the *Striga hermonthica* seeds. As for the delay in emergence observed in year 2 in the plots of millet seedlings associated with groundnuts, this was the result of two factors : the suicidal germination caused by the groundnut seedlings, and nitrogen fixation by the roots of the groundnut seedlings during the first year of experimentation. This result is in line with that of [22], who showed that legumes used as false hosts or trap plants cause suicidal germination of *Striga asiatica*.

 With regard to the vegetative development of *Striga hermonthica* plants, in year 1 the plants from millet seedlings coated with *Parkia biglobosa* powder were smaller than the control millet plants. This result could be linked to the late emergence date of these *Striga hermonthica* plants. For dry biomass of *Striga hermonthica* plants in year 1, no difference was observed between treatments. However, in year 2, *Striga hermonthica* plants emerging from millet plants with seeds coated with *Parkia biglobosa* powder, and from millet plants with seeds coated with *Parkia biglobosa* powder and compost, showed the highest dry biomass values. Dry biomass production is generally linked to the assimilation of carbon contained in carbonaceous substrates or carbohydrates, which in the case of *Striga hermonthica* comes from the host plant [23]. In fact, these millet seedlings benefited from the high levels of mineral salts contained in *Parkia biglobosa* powder to ensure their growth and development. The carbohydrates synthesized by these plants would have been taken up by the *Striga hermonthica* plants to ensure their growth. On the other hand, *Striga hermonthica* was less abundant in millet plants grown in association with groundnuts. This could be explained by the low density of *Striga hermonthica* plants in these plots.

The reduction in the infestation rate of millet plants grown from millet seeds coated with *Parkia biglobosa* powder could be explained by the fact that the chemical composition of *Parkia biglobosa* powder contains substances that inhibit the germination, growth and development of *Striga hermonthica* grains. In fact, the results of physicochemical analysis of *Parkia biglobosa* powder have shown the presence of polyphenols, flavonoids and tannins in its composition, which are alkaloids and glycosides. These elements are thought to be responsible for the low number of *Striga hermonthica* plants in the plots, as well as for the low infestation rate observed. Our results corroborate those of [24], who assert that the reduction in Striga hermonthica population density following the application of medium and high doses of P. biglobosa pod powder results from several factors. These include the presence of tannins or polyphenols, glycosides and saponosides in the chemical composition of *Parkia biglobosa* pod powder, which are said to be highly toxic and affect the germination and growth of *Striga hermonthica* plants. In fact, coating wet millet seeds with *Parkia biglobosa* powder would have favoured a direct supply of polyphenols, flavonoids and tannins around the germinating seed, thus inhibiting the secretion of root exudates and consequently the germination of Striga seeds present in this zone. This nutrient supply then prevented the development of *Striga hermonthica* plants [26]. The reduction in the infestation rate of millet plants in association with groundnuts is thought to be due to the fact that the groundnut stover left on the plots from the previous trial enriched the soil with organic matter. Indeed, the results of physico-chemical soil analysis at the end of the second year of experimentation showed that the soil in plots sown with millet in association with groundnuts had the highest organic carbon content compared with the other treatments. This result is in line with that of [28], who showed that the number of *Striga hermonthica* plants decreases as the doses of organic matter increase, particularly in cropping systems combining cereals and legumes. The high level of infestation in the control treatment is the result of the soil's lack of mineral elements. According to [26], *Striga hermonthica* develops preferentially in poor, structurally degraded soils with a sandy surface horizon, low clay content (2-5%) and very low organic matter content (below 0.7%), such as degraded ferruginous soils. The results of the physico-chemical analysis of the soil at the test site showed that it is sandy (89.57%), with a low clay (2.17%) and silt (8.26%) content. It is also low in organic matter (0.05%), organic carbon (0.09%) and nitrogen (0.04%). These results show that the soil on the experimental site is highly conducive to the development of *Striga hermonthica*.

 With regard to yield components, in year 1, the best results were achieved in terms of ear length, ear diameter and dry weight of grains per ear for plants sown with coated seeds on compost and for plants sown only on compost. These results could be explained by the richness of *Parkia biglobosa* powder and compost in mineral elements responsible for the good growth of millet plants. Indeed, the *Parkia biglobosa* powder used in the experiment contains high levels of phosphorus and potassium, which promote good plant development, particularly of roots and flowers [29]. Similarly, the compost used showed an availability of mineral elements. Indeed, [29], in their study, demonstrated the ability of mineral and organic fertilizers to improve the growth, fruiting and yield of millet. According to [30] and [31], when mineral fertilizers are combined with organic amendments, the risk of soil acidification is reduced and productive, sustainable production systems can be achieved. In both experiments, coated seedlings sown on compost and millet seedlings sown in association with groundnuts obtained the longest spikes. In the second experiment, the largest ears and large-calibre grains were obtained. obtained from millet plants sown in association with groundnuts. The peanut stover from the previous trial left on the plots improved their fertility by promoting phosphorus acquisition by the millet plants. This increased the yield parameter values for this experiment.

 In terms of yield, the best yield obtained in year 1 was due to the rapid and easy availability of the mineral elements in the *Parkia biglobosa* powder, combined with the availability of those in the compost, which act as a mineral fertilizer [32]. In fact, these plants would have benefited from the mineral salts present in the *Parkia biglobosa* powder and those released by the compost. As for the better yield obtained in year 2, this can be explained by the enrichment of the soil in phosphorus by the groundnut during the first experiment. Indeed, the results of the physico-chemical analysis of the soil at the end of the experiment showed a high phosphorus content for this treatment as well as for the plots of coated seeds sown on the plots amended with compost. The low yields obtained from seedlings sown on plots fertilized with compost were due to the very high density of *Striga hermonthica* plants. Add to this the early cessation of rains, which led to poor development of millet ears and grains. Indeed, [33] and [34] have shown that in millet, even if fertilization can have a positive effect, its success remains limited in cases of water deficit. Thus, amended plots suffer more than others from water stress in the event of early cessation of rainfall [35]. In general, yields obtained during the study were low, below one tonne per hectare for all treatments. These results could be explained by the impact of *Striga hermonthica* plants on millet plants, coupled with the low amounts of rainwater received by the latter during the reproductive phases. According to [36], millet plants need a maximum of 6.5 mm per day during the heading stage, in order to achieve a significant final grain yield. The amount of rainfall received would not have ensured good ear formation and grain filling, through the transfer of assimilates to the millet grains.

**5. Conclusion**

 A study carried out as part of the management of millet seedling infestation [*Pennisetum* *glaucum* (L.) R. Br.] by *Striga hermonthica* (Del.) Benth. highlighted the impact of using *Parkia biglobosa* powder, compost and legumes on the infestation of this pest in millet crops. Coating millet seeds with *Parkia biglobosa* powder delayed the emergence of *Striga hermonthica* plants in years 1 and 2. This was also observed in year 2, with the combination of millet and groundnuts. The degree of infestation of millet plants by *Striga hermonthica* was low in years 1 and 2 for millet plants grown from seeds coated with *Parkia biglobosa* powder. In the second year of experimentation, the millet-arachid combination also produced a low infestation rate. In terms of yield, millet seeds coated with *Parkia biglobosa* powder in combination with compost proved more effective in year 1, with a yield around twice that of the control. In year 2, the millet-arachid combination produced the highest yield. The early cessation of rains, at the end of the crop cycle, had a negative impact on yields during this work. These results may serve as a basis for the development of a sustainable control method using *Parkia biglobosa* powder alone or in combination with compost and the millet-arachid association to combat *Striga hermonthica* infestation.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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