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Evaluation of the Effect of Rice Straw-Based Compost on Rice Brown Spot Caused by *Bipolaris oryzae* in Strict Rainfed Rice Cultivation

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Abstract

In order to contribute to the improvement of rice production in Côte d'Ivoire, through sustainable management of the diseases that reduce its production, the effect of rice straw-based compost was evaluated on rice brown spot. Five doses of this compost, namely 0, 2.5, 5, 7.5, and 10 t. ha^{-1}, were studied in a completely randomized Fisher block design with three replications. A total of 15 plots of 12 m^2 were delimited. The traditional *Gbéklélé* variety of rainfed rice was sown in aligned stacks 0.2 m apart. Rice brown spot severity was scored using the IRRI standard rating scale at a frequency of 15 days from tillering to maturity. The number of tillers (total and fertile), height on 25 plants, yield and paddy yield gain per treatment were determined. The results showed that the addition of rice straw compost had an impact on disease expression. The compost dose of 7.5 t. ha^{-1} reduced rice brown spot pressure, with a severity index of 3.89 and a yield of 2.18 t. ha^{-1}. This study shows that the application of 7.5 t. ha^{-1} of rice straw-based compost effectively reduced rice brown spot pressure in rice, with a 74% gain in paddy yield.

Keywords

Rice Straw-Based Compost, *Bipolaris oryzae*, Rice Brown Spot, Paddy Yield

1. Introduction

Rice (*Oryza sativa* L.) is the most widely consumed foodstuff in Côte d'Ivoire, but is insufficiently produced. At the root of this low productivity are pests, of which *Bipolaris oryzae*, responsible for rice brown spot, is the most damaging in rice cultivation. Like other serious fungal diseases of rice, rice brown spot induces production losses of varying magnitude and forces rice growers to incur high production costs when applying control methods [1] [2]. Rice brown spot causes paddy yield losses of up to 90% in Côte d'Ivoire, where it has become a major concern in rice cultivation over the past twenty years [3]-[6]. This disease is referred to as the "poor farmer's disease" because it manifests itself intensely under conditions of soil mineral imbalance and poor water supply to rice [7]-[9]. Thus, the fertilization control option could help reduce the epidemic pressure of helminthosporiosis. The aim of the study is to evaluate the effect of rice straw-based compost fertilization on helminthosporiosis pressure in rice cultivation. The accessibility of rice straw-based compost formulation materials in areas with high rice production justifies this choice, which in addition to complying with environmental standards provides a sustainable solution to soil fertility.

2. Materials and Methods

The trial was carried out under strict rainfed conditions on a 300 m^2 plot with geographical coordinates (N 07˚36'20.8"; W 007˚39'46.1"), located at Gbombélo in the Biankouma department, around 650 km from Abidjan, in the mountainous west of Côte d'Ivoire. This locality has been endemic for rice brown spot in recent decades. The plant material used is a traditional rice brown spot-susceptible rice cultivar called Gbékélé, widely grown in the study area. Rice straw-based compost applied as fertilizer was produced according to the method of Zadi *et al.* (2021). The rice straw-based compost applied as fertilizer was produced using the method of Zadi and colleagues [10]. The chemical composition of this compost is shown in **Table 1**.

The trial was conducted using a three-repetition Fisher block design, with the "dose of rice straw-based compost" as the study factor in 5 modalities (D0 = 0 t. ha^{-1}; D1 = 2.5 t. ha^{-1}; D2 = 5 t. ha^{-1}; D3 = 7.5 t. ha^{-1}; D4 = 10 t. ha^{-1}). The individual plots covered an area of 12 m^2 (4 m × 3 m). The trial comprised a total of 15 elementary plots and covered 300 m^2.

Table 1. Average chemical element content of rice straw-based compost.

Chemical element	C (%)	N (%)	P ppm)	Ca (%m.s)	Mg (%m.s)	K (%m.s)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Na (ppm)
Content	20.77	1.82	0.90	3.385	0.353	1.120	1.270	7.850	5.700	5.800	9.060

Conduct of the Trial

The trial was set up after land clearing and light tillage, during the rainfed rice sowing season, *i.e.*, June-July. Once the trial plots had been laid out, the rice straw-based compost was applied according to 05 doses specified in the experimental design, during the second ploughing. One week after compost application, rice was sown in aligned bunches, 20 cm apart. To maintain the plots, two manual weeding operations were carried out. The first was carried out 20 days after sowing (DAS), at the early tillering stage. The second weeding took place at the maximum tillering stage at 45 DAS. Net protection was installed at the heading. Leaf severity of rice brown spot was scored using the IRRI [11] standard assessment scale. This rating was made at a frequency of 15 days from tillering (20 DAS) to technological maturity of the panicles. In addition, agronomic parameters (number of tillers, plant height at technological maturity, paddy weights harvested in the elementary plot, after drying and winnowing and paddy yield), were noted.

Harvesting was carried out at technological maturity (paddy at 18% moisture content).

The data collected were analyzed using XLSTAT software version 2024. An analysis of variance (ANOVA) was performed for all the agronomic parameters measured. When a significant difference was found at the 5% threshold, Tukey's post-ANOVA test was used for multiple comparisons of means. For helminthosporiosis severity, Friedman's non-parametric test of severity scores was used.

3. Results

3.1. Effect of Rice Straw-Based Compost on the Severity of Rice Brown Spot

In the experimental plot, the level of helminthosporiosis pressure varied from one treatment to another. It was particularly intense on the control plots (with no compost added), with higher severity scores (**Figure 1**, **Table 2**).

Statistical analysis of the rice brown spot severity index revealed a significant difference ($p = 0.003$) between treatments. The highest severity index (6.40) was obtained in the control treatment without compost, compared with lower indices of 3.9 and 4.38 recorded in the plots that received doses of 7.5 t. ha^{-1} and 5 t. ha^{-1} of compost respectively. Treatments D1 (2.5 t. ha^{-1}) and D4 (10 t. ha^{-1}) showed intermediate severity indices (**Table 2**).

3.2. Effect of Rice Straw-Based Compost on Average Number of Tillers (Total Tillers and Fertile Tillers)

Statistical analysis of the number of total tillers emitted per plant revealed a significant difference ($p = 0.003$) between treatments. The highest number of tillers (8.26 tillers) was obtained on the plot received the D4 compost dose (10 t. ha^{-1}). This number was halved (4.76 tillers) on the control plots (D0: 0 t. ha^{-1}). For plots received compost doses D1 (2.5 t. ha^{-1}), D2 (5 t. ha^{-1}) and D3 (7.5 t. ha^{-1}), the average number of tillers obtained was 5.35, 6.65 and 7.26 respectively.

In terms of the number of fertile tillers, a significant difference ($p = 0.022$) was observed between treatments. Indeed, the lowest average number of fertile tillers (3.59 tillers) was obtained on the control plots (D0: 0 t. ha^{-1}). On plots treated with D3 compost (7.5 t. ha^{-1}), the average number of fertile tillers doubled (6.73). Plots received D1 (2.5 t. ha^{-1}), D2 (5 t. ha^{-1}) and D4 (10 t. ha^{-1}) had fertile tillers of 4.82, 5.52 and 6.63 respectively (**Table 3**).

(a) Plot received the compost **(b)** Control plot (no compost added)

Figure 1. Difference in the intensity of helminthosporiosis symptoms between plots fertilised and those not fertilised with rice straw-based compost.

Table 2. Average leaf severity indices of rice brown spot according to the dose of rice straw-based compost.

Compost dose	Severity grades
D0	6.40
D1	5.78
D2	4.38
D3	3.89
D4	5.25
Overall mean	5.14
Probability (P)	0.023
Chi-square (χ^2)	11.32
Effect	S

Values with the same letters in the column are not significantly different at the 5% threshold. S: Significant; D0 : without compost inputed; D1: compost inputed at the dose of 2.5 t. ha^{-1}; D2: compost inputed at the dose of 5 t. ha^{-1}; D3: compost inputed at the dose of 7.5 t. ha^{-1}; D4: compost inputed at the dose of 10 t. ha^{-1}.

Table 3. Average number of total tillers and fertile tillers according to the dose of rice straw-based compost.

Compost dose	**Total tile**	**Fertile tile**
D0	4.76 **c**	3.59 **b**
D1	5.35 **bc**	4.82 **ab**
D2	6.54 **abc**	5.52 **ab**
D3	7.26 **ab**	6.73 **a**
D4	8.26 **a**	6.11 **ab**
Overall mean	6.433	5.36
Probability (P)	0.003	0.022

Continued

Effect	S	S
Standard deviation	1.50	1.39

Values with the same letters in the column are not significantly different at the 5% threshold. S: Significant; D0: without compost inputed; D1: compost inputed at the dose of 2.5 t. ha^{-1}; D2: compost inputed at the dose of 5 t. ha^{-1}; D3: compost inputed at the dose of 7.5 t. ha^{-1}; D4: compost inputed at the dose of 10 t. ha^{-1}.

3.3. Effect of Rice Straw-Based Compost on Plant Height

A significant difference (p = 0.019) was observed between the average heights of rice plants according to treatments. The highest heights (113.25 cm) were obtained with compost at dose D3 (7.5 t. ha^{-1}), while an average height of 100.23 cm was recorded on plots that received no compost (control) (Table 4).

Table 4. Average height of rice plants according to the dose of rice straw-based compost.

Compost dose	Average height
D0	100.23 **b**
D1	103.97 **ab**
D2	111.48 **ab**
D3	113.25 **a**
D4	109.85 **ab**
Overall mean	106.957
Probability (P)	0.019
Effect	S
Standard deviation	4.89

Values with the same letters in the column are not significantly different at the 5% threshold. S: Significant; D0: without compost inputed; D1: compost inputed at the dose of 2.5 t. ha^{-1}; D2: compost inputed at the dose of 5 t. ha^{-1}; D3: compost inputed at the dose of 7.5 t. ha^{-1}; D4: compost inputed at the dose of 10 t. ha^{-1}.

3.4. Effect of Rice Straw-Based Compost on Rice Paddy Yields

Statistical analysis revealed a significant difference (p = 0.006) between treatments. Without compost application (control plots), paddy yield was very low (0.70 t. ha^{-1}). With increasing doses of compost, paddy yield increased progressively. For compost doses of 7.5 t. ha^{-1} or higher (10 t. ha^{-1}), paddy yield tripled (2.18 t. ha^{-1} paddy) or more (2.71 t. ha^{-1} paddy). Compost yield gains varied from 43.85% to 75.09%, depending on the compost dose (Table 5).

Table 5. Average paddy rice yields according to the dose of compost made from rice straw-base.

Compost dose	Yield in t. ha^{-1}	Yield gain (%)
D0	0.702 **c**	-

Continued

D1	1.25 **bc**	43.85
D2	1.79 **abc**	60.78
D3	2.18 **ab**	67.80
D4	2.71 **a**	74.09
Overall mean	1.727	-
Probability (P)	0.006	-
Effect	S	-
Standard deviation	0.845	-

Values with the same letters in the column are not significantly different at the 5% threshold. S: Significant; D0: without compost inputed; D1: compost inputed at the dose of 2.5 t. ha^{-1}; D2: compost inputed at the dose of 5 t. ha^{-1}; D3: compost inputed at the dose of 7.5 t. ha^{-1}; D4: compost inputed at the dose of 10 t. ha^{-1}.

3.5. Correlation between Compost Dose, Rice Brown Spot Pressure and Rice Paddy Yield

Table 5 shows the relationship between different doses of rice straw-based compost on rice brown spot pressure and rice paddy yield. Observation of this table shows a low level of pathogen pressure (severity index of 3.89 and 4.38) on plots received compost doses of 7.5 t. ha^{-1} and 5 t. ha^{-1} respectively. On these plots, paddy yields were relatively high (2.18 t. ha^{-1} and 1.79 t. ha^{-1} respectively). Conversely, disease pressure was particularly high (severity index 6.40) on plots receiving no compost. The lowest paddy yields (0.70 t. ha^{-1}) were also recorded here. The highest yields were recorded on plots received the highest compost dose. However, pathogen pressure was noticeably high on these plots (Table 6).

Table 6. Paddy yield in paddy in t. ha^{-1} as a function of compost dose and rice brown spot pressure.

Compost dose	Yield in t. ha^{-1}	Severity of helminthosporiosis
D0	0.702 **c**	6.40 **a**
D1	1.25 **bc**	5.78 **ab**
D2	1.79 **abc**	4.38 **b**
D3	2.18 **ab**	3.89 **b**
D4	2.71 **a**	5.25 **ab**

Values with the same letters in the column are not significantly different at the 5% threshold. S: Significant; D0: without compost inputed; D1: compost inputed at the dose of 2.5 t. ha^{-1}; D2: compost inputed at the dose of 5 t. ha^{-1}; D3: compost inputed at the dose of 7.5 t. ha^{-1}; D4: compost inputed at the dose of 10 t. ha^{-1}.

4. Discussion

This study was carried out during the region's rainfed rice-growing season, from June to October, when rainfall is regular. During this period, variations in temperature and humidity were very minimal. The results obtained are not affected by significant variations in environmental factors. On the trial site, leaf symptoms of rice brown spot were observed on all plots at varying levels of pressure. This noted presence of the pathogen indicates that the environmental conditions of this experiment were favorable to the manifestation of the disease. The results showed that rice brown spot pressure was very high on the control plots that had received no compost, compared with those that had been amended. The strong expression of leaf symptoms of rice brown spot in plots that did not receive compost testifies to the susceptibility of the plant material chosen for this study. Climatic conditions would therefore be conducive to the development of *Bipolaris oryzae* mycelium, which remained on plant debris before sowing, to form a primary focus of the disease [12].

The variability of rice brown spot pressure on the experimental site suggests that compost application modifies the pathogen's behavior towards its host, depending on the dose of fertilizer applied to the soil. In fact, a reduction in rice brown spot pressure was observed as the compost dose gradually increased. This regression in rice brown spot leaf pressure observed on the amended plots could be explained by the vigour of the plants following absorption of the minerals contained in the compost. In fact, Fageria and colleagues [13] have shown that the adequate supply of mineral elements to cultivated plants reduces the aggressiveness of fungal diseases. These results were corroborated by those of Balgude and Gaikwad [14], who were able to limit the aggressiveness of rice helminthosporiosis using rice straw ash. In addition to their role in plant growth and physiology, nutrients also influence metabolic processes such as disease resistance [15].

Indeed, several authors have shown that adequate plant nutrition would be advantageous in maintaining the level of their disease resistance [16] [17]. This suggests that in this study, plots with a low level of pathogen pressure would have received an adequate dose, enabling the rice plants growing on these plots to develop resistance to the pathogen. This resistance would be due to the action of the mineral elements contained in the rice straw-based compost. The latter potentially boosted plant immunity by directly activating the enzymes involved in the synthesis of defense metabolites, or indirectly, by modifying microbial activity, the composition of root exudates and the pH of the rhizosphere [18]. Conversely, deficiencies of major mineral elements such as nitrogen, phosphorus and potassium favor attacks by the rice brown spot pathogen [19].

The agronomic parameters (number of total tillers emitted, number of fertile tillers and plant height) know a remarkable increase when rice straw-based compost was added at increasing doses, compared with the control (no compost added). This result shows that rice straw-based compost improves soil fertility. Compost activates soil micro-organisms and fauna. Their activities improve the textural and mineralogical quality of the soil [20] [21]. The action of compost in restoring soil fertility has been demonstrated by several researchers [20] [22] [23]. According to these authors, organic fertilizers contribute to the retention and supply of water and mineral elements to plants. Indeed, the organic matter contained in compost loosens the soil, making it friable and porous, thus improving aeration and the circulation of soil water. These conditions contribute to good vegetative crop growth [24]. This could explain the agronomic performance recorded in plots that received the necessary doses of compost.

At the end of the paddy yield, the use of compost had a significant impact on results compared with the control. Indeed, increasing the dose of compost improved the paddy yield of the local rice variety used. Yield gains ranging from 43.85% to 74.09% were obtained depending on the compost dose applied. There was a correlation between compost dose and paddy yield. Increasing doses of compost improve paddy yield. This could justify the increasing yield gains recorded on the amended plots. In addition, the greatest yield gain (over 74%) was obtained when compost was added at a dose of 10 t. ha^{-1}. These results corroborate those of Zadi and colleagues [25], who showed that a dose of 10 t. ha^{-1} of rice straw-based compost would be optimal for rainfed rice cultivation.

However, in terms of health, increasing compost doses had mixed effects on pathogen expression. A regression of the disease's foliar pressure was observed with the progressive increase in compost dose. However, above the dose of 7.5 t. ha^{-1}, a resurgence in leaf pressure was observed. This suggests that there is a fertilization threshold beyond which the plant becomes susceptible to infection [26].

There is therefore a correlation between adequate fertilization, pathogen expression and paddy yield. Compost doses ranging from 0 t. ha^{-1} to 5 t. ha^{-1} were unable to provide the plant with sufficient quantities of the mineral elements involved in the plant defense system to counteract *Bipolaris oryzae* pressure. Soil nutritional status therefore has a positive or negative impact on the health of the plants grown in it. Plants in a nutritional deficit would be less productive and more vulnerable to pests [27]. This would explain the low yields recorded on these plots. When the plant's needs for water and mineral elements are met, it sets up a defense mechanism against bio-aggressors. Their impacts are reduced, and yield can only increase. This would explain the low level of rice brown spot pressure recorded on plots amended at doses ranging from 5 t. ha^{-1} to 7.51 t. ha^{-1}. Compost made from rice straw-based contains chemical elements [21] that play a direct or indirect role in the plant defence system. The impact of mineral elements such as Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Silicon (Si), Sulfur (S), Zinc (Zn) and Magnesium (Mg) as amplifiers of plant disease resistance and on their ability to effectively reduce the frequency and pressure of fungal infections has been demonstrated by several researchers [28] [29]. It is generally accepted that a balanced diet strengthens the plant's defense system. It limits diseases and infections, leading to healthy plants [30]. However, excessive nutrient supply makes the plant susceptible to infection [26]. This is demonstrated by the increase in pressure recorded on plots amended at a dose of 10 t. ha^{-1}. The high yield observed with a dose of 10 t. ha^{-1}, despite the resurgence of rice brown spot leaf symptoms, indicates that the level of pressure exerted by the disease was not sufficient to adversely affect rice paddy yield.

The results of this study demonstrate the ability of the minerals contained in rice straw-based compost to manage rice brown spot.

5. Conclusion

The specific objective of this study was to evaluate the effect of rice straw-based compost on rice brown spot pressure in order to determine the dose that would reduce rice brown spot pressure while increasing paddy yield. The study carried out in a strict rainfed environment in the Biankouma department highlighted the regulating effect of rice straw compost on rice brown spot pressure in rice. Thus, the dose of 7.5 t. ha^{-1} would provide the best protection for the rice crop against rice brown spot in rainfed rice cultivation, providing a yield gain of over 67%. Although no cost-benefit analysis has been carried out, the 7.5 t. ha^{-1} dose is considered more economical in terms of compost production costs than the 10 t. ha^{-1} dose, which would require more resources. It could be recommended as part of the sustainable fight against *Bipolaris Oryzae*, the fungus responsible for rice brown spot of rice in Côte d'Ivoire.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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