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EFFICACY OF A BIOSTIMULANT- A MYCORRHIZAL INOCULANT ON RICE YIELD

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ABSTRACT

The challenge in food security is important for rice in west Africa. As well, this study on the use of mycorrhizal inoculants in rice field, is a contribution to improving rice yields by biological fertilization. Incidence of intake of a mycorrhizal inoculant is compared to mineral fertilization, through growth and development parameters of upland rice, on ferralsol in West part of Côte d'Ivoire. Experimental design is a Fisher Block with six replications. In order to assess the efficiency of these two fertilization methods, an unfertilized treatment was integrated in the experimen. The symbiotic association (mycorrhizal-rice) has contributed to improve tillering (147.5 tillers/m²) and yield (1.62 tha^{-1}) in reference to unfertilized control (126.2 tillers/m² and 1.44 tha^{-1}). Yields are better as mycorrhizae are combined with mineral fertilizers for a gain of 64% in terms of paddy yields. In short, mycorrhization appears to be a powerful biological tool for optimizing sustainable soil management and rice yields.

Keywords: Mycorrhizal inoculants; Biofertilization, Rice, Yield.

1. INTRODUCTION

In Côte d'Ivoire, as in most African countries, the challenge of food security is enormous for rice. Rice production, in Côte d'Ivoire, estimated to 1,399,407 tonnes of milled rice, is 80 % provided by rainfed rice (ONDR, 2016). However, various constraints limit productivity of rainfed rice. The most important are climatic disturbances and the major problem of soil fertility declining (Sanchez et al., 2003, Koné et al., 2004b, Amani et al., 2017). Average yield of rainfed rice is

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estimated at less than 1.5 tha^{-1} (Bahan et al., 2012, Konan, 2016). As a result, Côte d'Ivoire continues to rely on imports, to fill its production gap, by around 40 % today (ONDR, 2016).

To cope with climatic hazards, drought-tolerant and early-cycle varieties have been selected and disseminated (Doumbia et al., 2005). In addition, favorable planting dates for rainfed rice are proposed, based on climate forecast models (Amani et al., 2017). The decline in soil fertility is a consequence of overexploitation of land (Becker and Johnson, 2001), linked to demographic pressure and expansion of industrial plantations (coffee, cocoa, rubber, palm oil). To cope with this, fertilization remains one of the ways to increase yields (FAO, 2001). The mineral fertilization, however, faces problems of adoption because of high cost of mineral fertilizers and their often negative impact on environment (Gala et al., 2007, Konaté et al., 2012). As for organic fertilizers, biodegradable (compost, manure, poultry manure) that have been proposed, their adoption remains hypothetical for practical and commercial reasons (CNRA, 2016). Thus, reflections on rice fertilization are worth pursuing, especially in current context of biological agriculture and preservation of environment.

Among telluric components particularly involved in biological processes governing functioning of main biogeochemical cycles and, consequently, soil fertility, are mycorrhizal fungi (Barea and Jeffries 1995, Rioux 2001, Dechamplain and Gonelin 2002, Cardoso and Kuyper 2006). These ubiquitous microorganisms evolve in symbiotic association with various host plants and optimize development of plant by the stimulation of mineral nutrition and a better tolerance or resistance of plant to biotic and abiotic stress (Azcon-Aguilar and Barea, 1996; Berthelin et al., 2004. Duponnois et al., 2007). In recent years, industrial production of mycorrhizal inoculants, in Côte d'Ivoire, offers new prospects for fertilization of strategic crops such as rice.

This study, conducted in Côte d'Ivoire, aimed to assess effectiveness of a mycorrhizal inoculant on yield of upland rainfed rice.

2. MATERIAL AND METHODS

2.1. Experimental site

The study was conducted at CNRA research station in Man, in semi-mountainous region of western Côte d'Ivoire. The rainfall regime is monomodal. Rains start in March and end in October, followed by a dry season from November to February. In 2014, an annual rainfall of 1721.9 mm was recorded at Man research station. The experimental design was installed under strict rain conditions. Previous crop was a natural fallow of 3 years, dominated by *Panicum maximum* species. The soil is slightly humic, with sand-clay textures on the surface (0-20 cm) and sandy-clay-sand in depth (20-60 cm). It has good internal drainage. However, soil has a

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compact horizon with coarse elements (> 50 p.c.) between 20 cm and 60 cm deep. These coarse elements consist essentially of ferromagnesian nodules and quartz gravels.

2.2. Plant material

The rainfed rice variety IDSA85 was used for the test. IDSA85 is an improved rice popular in Côte d'Ivoire, for grain size (fine and long) and taste. The duration of its seed-to-maturity cycle is 120 days with an estimated average yield of 1.8 tha^{-1} (MINAGRI, 2015).

2.3. Fertilizers

Two types of fertilizer were used. These are two mineral fertilizers and a biostimulant. The mineral fertilizers are those usually used in rice cultivation in Côte d'Ivoire, namely: pearled urea (46% N) and NPK 12-24-18. The biostimulant is an active ingredient - a mycorrhizal fungus "AGTIV", produced by the agro-industrial group, Premier Tech Agriculture. It is packaged in bag of 200 g with a concentration of 3200 spores / g.

2.4. Experimental design

The experimental design is a Fisher block with six (06) repetitions or blocks. Factor studied is method of fertilization, with four (04) modalities, as following:

- T1: No fertilizer (control)
- T2: 200 kg/ha NPK 12-24-18 basal application + 100 kg/ha Urea
- T3: Mycorrhizae
- T4: 200 kg/ha NPK 12-24-18 basal application + 100 kg/ha Urea and Mycorrhizae

2.5. Conduct of the test

Soil preparation consisted of clearing followed by shallow tillage. On the eve of sowing, NPK 12-24-18 fertilizer was brought to soil at rate of 200 kg ha^{-1}. In addition, 25 g of mycorrhizal inoculant was used to coat 1250 g of seed of IDSA85 variety, as dose of 800 g ha^{-1}. Seeding was carried out in rows aligned with a spacing of 0.20 m between hills and between lines. Fifteen days after sowing, in wet soil, it was left one plant per hill. Urea (46%N) was applied at a dose of 100 kg ha^{-1} in a fractional manner, namely: 50 kg/ha at the beginning of tillering and 50 kg/ha at panicle initiation. Maintenance (hand weeding, insecticide treatment) was assured until rice was harvested at 18% grain moisture.

2.6. Data collection and statistical analysis

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Data collection focused on seed-to-maturity cycle of rice, number of mature rice tillers, height of the main tiller of mature rice, severity of rice blight at 45 days and at 70 days after emergence according to Standard Assessment System (SES), dry weight of aboveground biomass of rice, dry weight of rice root biomass, weight of paddy after drying and winnowing (grain yield) and weight of 1000 grains of paddy.

These variables were analyzed statistically with GenStat Discovery software edition 4. Comparison of averages was made by Newman-Keuls test at 5% probability level.

3. RESULTS

3.1. Effect of fertilization methods on rice growth and development

Table 1: Parameters of growth and development of rice for the modes of fertilization tested.

Treatment	variables			
	Cycle duration (day)	**Height at maturity (cm)**	**Root biomass (g/plant)**	**Aerial biomass (tha^{-1})**
Control	124**a**	110,8**c**	1,83**d**	0,96**d**
NPK + Urea	118**b**	135,8**b**	2,69**b**	1,63**b**
Mycorrhizae	123**a**	114,4**c**	2,06**c**	1,12**c**
NPK+Urea et Mycorrhizae	116**b**	150,0**a**	3,00**a**	2,01**a**
Probability (%)	0,021	0,001	0,006	0,001

The numbers of the same column with the same letter are not significantly different according to the Newman-Keuls test at the probability level of 5 p.c.

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3.1.1. Duration of the rice cycle

The results on the duration of the seed-to-maturity cycle of rice (Table 1) indicate that there are significant differences between the treatments. The duration is not modified with the application of the biofertilizer, compared to the control. But, the application of mineral fertilizers on the plots shortened the rice cycle by at least 5 days (119 days) with reference to the control plot (124 days).

3.1.2. Growth in height of rice

Statistical analyzes results show significant differences for rice height at mature (Table 1). But the height does not change significantly with the addition of mycorrhizae compared to the control. The rice reached an average size of 114 cm with the mycorrhizae against an average size of 110.8 cm for the control treatment. NPK and urea, on the other hand, allowed rice to reach a height of 135.8 cm at maturity. This growth in height is more important with the combination biostimulant - mineral fertilizer (150 cm).

3.1.3. Rice root biomass

The informations in Table 1 shows there are significant differences between fertilization methods about rice root biomass. The biostimulant allowed significant root development compared to the control. But it has been shown to be less effective than mineral fertilizers. The performance of mineral fertilizers was 2.69 g/plant against 2.06 g/plant for mycorrhizae. In addition, rice root development was more boosted by combining biological and mineral fertilization for an average value of 3 g/plant (Table 1).

3.1.4. Rice aerial biomass

Rice aerial biomass are significantly different depends on treatments (Table 1). The average aboveground biomass produced on the control plots was 0.96 tha^{-1}. This average is lower than that obtained with mycorrhizal inoculants (1.12 tha^{-1}), which itself is below the biomass produced on plots fertilized with NPK and urea (1.63 tha^{-1}). The combination of two fertilization modes, allows to obtain the optimal average (2.01 tha^{-1}).

3.2. Effect of fertilization methods on rice yield components

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Table 2: Components of paddy yield for the fertilization methods tested.

Traitement	variables				
	Tillers/m²	Panicles/m²	Grains/panicle	Full grains (%)	Weight of 1000 grains (g)
Control	126,2**d**	107,9**d**	100,4**d**	92,0	33,0
NPK + Urea	190,0**b**	147,1**b**	136,4**b**	91,2	33,8
Mycorrhizae	147,5**c**	130,0**c**	115,7**c**	91,4	33,5
NPK+Urea et Mycorrhizae	210,8**a**	195,0**a**	151,7**a**	91,8	33,8
Probability (%)	< 0,001	< 0,001	0,001	0,936	0,856

The numbers of the same column with the same letter are not significantly different according to the Newman-Keuls test at the probability level of 5 p.c.

3.2.1. Rice tillering

Analysis of rice tillering data reveals significant differences between the treatments tested (Table 2). It is noted, a positive effect of the biostimulant relative to the control. In fact, tillering rose from 126.2 tillers/m² on average for the control to 147.5 tillers/m² with the addition of mycorrhizae. However, this average is less than that obtained with NPK and Urea (190.0 tillers/m²). The NPK + Urea and mycorrhizae association gives an average of 210.8 tillers/m². So the mineral fertilizer – biostimulant combination optimize rice tillering.

3.2.2. Number of panicles

In the analysis of Table 2, the number of rice panicules per m² shows the same trends as the number of tillers. The fertilization modes are significantly different for this variable, according to the Newman-Keuls test at 5% probability level. The average values are 107.9 panicles/m², 130 panicles/m², 147.1 panicles/m² and 195 panicles/m² respectively for the control, the plot with mycorrhizae, the plot with NPK + Urea, and the plot combining the two modes of fertilization.

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3.2.3. Number of grains per panicle

The number of grains per panicle varied according to the fertilization method (Table 2). It is growing with the addition of mycorrhizae, mineral fertilizers and more with the combination of both fertilization modes. The average obtained with the combination is 151.7 grains/panicle against 100.4 grains/panicle for the control.

3.2.4. Percentage of full grains per panicle

According to the results reported in Table 2, the percentage of full seeds per panicle does not vary statistically according to the fertilization method tested. The average of the test was 91.63%.

3.2.5. Weight of 1000 grains

The data on the weight of 1000 grains of paddy (Table 2), indicate that the averages obtained with the fertilization modes tested are not significantly different ($p = 0.856 > 0.05$). Namely, neither the application of mineral fertilizers nor mycorrhizas affected the weight of the paddy grain. The overall mean revealed for this variable is 0.033 g.

3.2.6. Effect of fertilization methods on paddy yield

The results of the analysis of variance revealed a significant difference between the average yields obtained with the four modes of fertilization tested. This reflects an impact of the fertilization method on paddy production. The application of mycorrhizae yielded an average yield of 1.62 tha^{-1}, giving a yield gain of 12.5% compared to the control (1.44 tha^{-1}). But, the best yields are obtained with mineral fertilizers and mycorhizes combination, 2.36 tha^{-1}; which represents a yield gain of 11.8% compared to the conventional fertilizer NPK + Urea (2.11 tha^{-1}) and 63.9% compared to the control. The difference between biological fertilization and mineral fertilization is 23% in favor of mineral fertilization (Figure 1).

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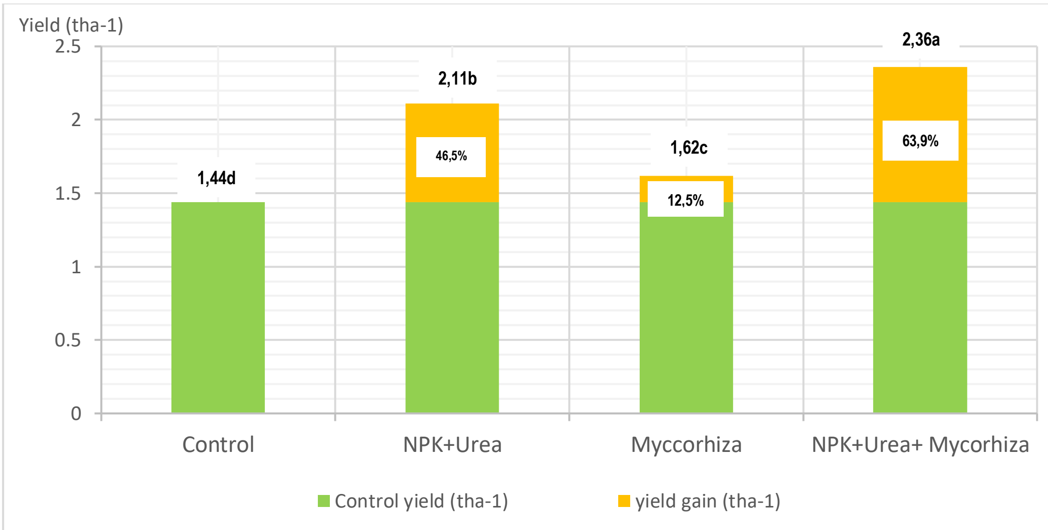

The numbers with the same letter are not significantly different according to the Newman-Keuls test at the probability level of 5 p.c.

Figure 1: Paddy yield according the fertilization mode

4. DISCUSSION

In the face of the risks of environmental pollution by agricultural activities, there is increasing concern for organic farming (FAO, 2014). Direct or stimulation biofertilisation is therefore one of the options that can accommodate the major challenges of sustainable development. Since 2013, the industrial production of mycorrhizal inoculants in Côte d'Ivoire has been offering new opportunities for the biological fertilization of strategic crops such as rice (CNRA, 2016).

The purpose of the test was to assess the incidence of mycorrhizal activity on some parameters of a Ferralsol and on rice growth and yield. The mycorrhizal ingredient used in the study was validated on field crops such as wheat and potato in Canada, the United States and France (Premier Tech, 2013).

The mycorrhizal fungus involved, *Glomus intraradices*, is characterized by a particular type of mycorrhizal: endomycorrhizae (Rioux, 2001). According to some authors, endomycorrhizae or internal mycorrhizae was the first mycorrhizal symbiosis with plants (Selosse and Le Tacon 1999, Albino and Andrade 2006). It allowed plants to come out of the water about 400 million years ago. This type of mycorrhiza occurs mainly in cultivated plants and some trees including small undergrowth plants (Lerat, 2001).

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At the agronomic level, mycorrhizal intake had no effect on the duration of the rice-sowing cycle. However, the addition of mineral fertilizers alone, in combination with mycorrhizae, reduced the rice cycle by 6 to 8 days. The nutrients immediately available with the input of mineral fertilizers contribute without delay to the nutrition of the rice plant. As for the mycorrhizal patch, a latency period is necessary for the development of the fungus hyphae network, in order to increase the plant's capacity to feed itself. Egerton-Warburton and Allen (2001) indicated that this network of hyphae would take one to two weeks, depending on the species of fungi and the growing environment.

Regarding the growth of rice, an optimal height of 150 cm was reached with the combination of biofertilizer and mineral fertilizers. The same trends were observed with the biomasses produced namely: root biomass (3 g/plant) and aboveground biomass (2.1 tha^{-1}). The simple effect of mycorrhizae on these variables was almost always less than the performance achieved with mineral fertilizers. However, the mycorrhization has a significant beneficial effect vis-à-vis the unfertilized control. This beneficial effect of the mycorrhizae on the rice growth parameters, would be to put in the active hyphae developed by the fungus. These filaments, by their mass, have an influence on root weight and by their activity have contributed to the nutrition of the rice plant (Garbaye, 2000, Gobat et al., 2003, Douds et al., 2005).

Regarding the components of paddy yield, the fertilization methods tested did not affect grain filling and the weight of 1000 grains. On the other hand, for the most important variables such as tillering, the number of panicles produced and the number of spikelets per panicle, significant differences between treatments were noted. The tillering capacity of rice has been significantly improved with, in increasing order: mycorrhizae (147.7 tillers/m²), mineral fertilizers (190 tillers/m²) and mycorhizes-mineral fertilizer combination (210 tillers/m²). This trend was also observed for the number of panicles and the number of grains per panicle.

Like its main components, the paddy yield is determined by the fertilization method (Lacharme, 2001). With reference to the unfertilized control, the contribution of mycorrhizae yielded 12.5% yield, or more than half a tonne of paddy per hectare (0.67 tha-1). In addition, in the presence of mineral fertilizers (NPK and Urea), mycorrhizas have optimized paddy production, with gains of about 64 %, or nearly one tonne of paddy per hectare (0.92 tha^{-1}). The combination of biological fertilization and mineral fertilization has doubled the number of tillers and the number of panicles compared to the control. It has also increased the number of grains per panicle by about 50 %.

Namely that the addition of mushrooms improves the efficiency of chemical fertilizers. As a result, the amounts of chemical fertilizer added could be reduced in the presence of mycorrhizae.

These fertilizers are indeed harmful to soil biodiversity and in this case to plant diversity (Dechamplain and Gonelin, 2002). In addition, this reduction will contribute to lowering the costs related to the enrichment of rice-enriched soils for better paddy yields.

In sum, the study showed the possibility of achieving a rice-mycorrhizal mushroom symbiosis. This symbiosis allows better access to soil nutrients, especially phosphorus for which tropical soils have a proven deficit. The paddy yield gains obtained in the presence of mycorrhizae testify to this activity. In addition, mycorrhizal symbiosis did not favor the development of rice leafminer disease, unlike mineral fertilizers. Thus, these mushrooms are an excellent alternative to chemicals.

5. CONCLUSION

The purpose of the study was to assess the effectiveness of a mycorrhizal ingredient on rice yield under strict rain conditions. It was conducted with to contributing to the biological fertilization of rice, for food security for the Ivorian and even African populations.

The results obtained showed a beneficial effect of mycorrhizae for rice cultivation, at the level of plant growth and development. Yield gains of 12.5% and 64% were obtained, respectively, with the addition of mycorrhizae and their combination with mineral fertilizers. It is therefore not excluded, in the presence of mycorrhizal fungi, to provide fertilizers (organic or mineral) since the soil is not an inexhaustible resource of nutrients.

In view of these conclusions, it seems appropriate to identify the optimal dose mycorrhizal inoculant - mineral fertilizers for shelf rice and extend the study to lowland ecology and other rice growing areas of Côte d'Ivoire.

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