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Decoupling between Arbuscular Mycorrhizal Fungal Root Colonization and Early Rice Growth Responses in a Low-Phosphorus Sahelian Substrate: A Greenhouse Proof-of-Concept Study

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Abstract

Rice cultivation in Sahelian countries requires fertility-management strategies that improve early crop growth while reducing reliance on mineral fertilizers alone. Arbuscular mycorrhizal fungi (AMF) can contribute to plant nutrition under phosphorus-deficient conditions, but plant responses depend on the fertility context in which root colonization occurs. This greenhouse proof-of-concept study evaluated whether a mixed native AMF inoculum, applied alone or in combination with compost or reduced NPK/urea fertilization, was associated with differences in AMF root colonization and early vegetative performance in rice (*Oryza sativa* L., cv. FKR64). Six treatments were compared in a completely randomized design with nine replicates: 100% AMF, 100% compost, AMF + 100% compost, AMF + 50% compost, AMF + 50% NPK/urea, and an uninoculated, unfertilized control. Plant height, tiller number, aboveground dry biomass, root dry biomass, and mycorrhizal frequency and intensity were measured over a 56-day period. Treatment profiles were analyzed using principal component analysis and hierarchical clustering. Inoculated treatments generally showed greater root colonization than the control. The highest colonization frequency and intensity were observed in the AMF + 50% NPK/urea treatment, but its mean growth responses were comparatively low. Significant pairwise growth differences depended on the variable and comparator. Treatments containing compost generally exhibited the most favorable early growth profiles. The AMF + 50% compost combination produced the

tallest plants at 56 days, whereas the 100% compost and AMF + 100% compost treatments showed more favorable biomass or tillering responses, depending on the variable considered. This study should be interpreted as a greenhouse proof-of-concept that identifies promising treatment contrasts for future field validation rather than as a direct agronomic recommendation. Field validation, compost characterization, explicit nutrient-balance assessment, and direct measurements of nutrient uptake are required before AMF-compost strategies can be recommended for rice production.

Keywords

Arbuscular Mycorrhizal Fungi, Native Inoculum, Compost, Rice Early Growth, Root Colonization

1. Introduction

Rice (*Oryza sativa* L.) remains central to food security in many Sahelian countries, yet its production is constrained by rainfall variability, limited access to inputs, and low fertility in many cultivated soils. Across the Sudano-Sahelian zone of West Africa, low soil organic matter, nutrient depletion and phosphorus limitation are widely recognized constraints to sustainable cereal production and soil fertility restoration [1] [2]. Recent work on phosphate-enriched composts in Burkina Faso also highlights the importance of organic amendments, phosphorus availability and microbial processes for improving nutrient cycling in low-fertility soils [3]. The substrate used in the present study was sandy, very low in organic matter and low in available phosphorus, conditions that can limit early rice growth and reduce the efficiency of conventional fertility inputs. These constraints justify evaluating integrated fertility-management options that combine organic amendments, mineral fertilization and biological processes, while recognizing that their effectiveness depends on the local soil and management context.

Arbuscular mycorrhizal fungi (AMF) are root-associated symbionts that can contribute to plant nutrient acquisition, particularly for relatively immobile nutrients such as phosphorus, by producing extraradical hyphae that explore soil beyond the root depletion zone. In rice, AMF symbiosis has received renewed attention as a potential component of more sustainable nutrient-management strategies, although rice genotypes differ in their capacity to establish and benefit from AMF associations [4]. Under phosphorus-deficient aerobic rice conditions, AMF colonization has been linked to phosphorus utilization, plant growth, soil enzyme activity and microbial biomass when these variables are directly measured [5]. However, AMF benefits are context-dependent rather than automatic: they vary with host genotype, soil fertility, water regime, resident microbial communities and inoculum compatibility. For this reason, root colonization should be interpreted alongside plant growth and biomass responses rather than used as the sole evidence of agronomic benefit.

Compost amendment represents another potential approach to improving crop growth in nutrient-poor sandy substrates. By adding organic matter, supplying nutrients and improving nutrient retention, compost can modify the rhizosphere environment in ways that may also influence AMF establishment and plant response. Evidence from compost-amended cropping systems indicates that compost can increase root AMF colonization, extraradical hyphal density and AMF sporulation, although these effects depend on plant species, growth stage and soil context [6]. Reviews of AMF-microbe interactions in the rice mycorrhizosphere further emphasize that AMF can interact with bacterial and fungal communities involved in nutrient cycling, but the direction and magnitude of these interactions depend strongly on soil conditions and crop management [7]. Similarly, broader evidence on AMF, phosphate-solubilizing bacteria and silicon indicates that microbial strategies may support phosphorus availability and plant P uptake in P-deficient systems, but such effects require direct functional measurements to be demonstrated [8]. Accordingly, in the present experiment, mechanisms such as phosphorus mobilization, improved nutrient uptake or enhanced microbial activity are treated as plausible interpretations rather than measured outcomes, because compost chemistry, soil nutrient dynamics, microbial activity and plant nutrient uptake were not assessed.

Despite growing interest in AMF-based strategies for rice, an important gap remains in understanding when root colonization is associated with measurable plant growth benefits in low-fertility tropical substrates. Previous studies have shown that AMF colonization and phosphorus-related responses in rice are influenced by genotype, phosphorus status and associated microbial processes [4] [5] [7]. However, much of the available evidence either examines AMF inoculation independently of organic amendment, focuses on phosphorus-related mechanisms under controlled nutrient conditions, or does not explicitly connect root colonization with early plant performance under Sahelian soil constraints. This gap is particularly relevant for sandy, low-organic-matter and low-available-phosphorus rice substrates, where strong AMF colonization may not translate into agronomic benefit unless the surrounding fertility context supports measurable growth responses. In this greenhouse proof-of-concept study, we tested the hypothesis that AMF inoculation would be more consistently associated with positive vegetative responses when combined with compost than when applied alone or with reduced mineral fertilization. We compared inoculation alone, compost alone, AMF-compost combinations, AMF with reduced NPK/urea fertilization and an uninoculated unfertilized control in rice cultivar FKR64. Mycorrhizal colonization, plant height, tiller production, aboveground biomass, root biomass and multivariate treatment profiles were assessed to identify treatment contrasts most closely associated with both root colonization and early growth responses. Because nutrient uptake, compost chemistry, grain yield and field performance were not evaluated, the study was interpreted as a greenhouse proof-of-concept for future field validation rather than as a direct agronomic recommendation.

2. Materials and Methods

2.1. Biological Materials

2.1.1. AMF Inoculum Origin and Characterization

The fungal material was a mixed native arbuscular mycorrhizal fungal (AMF) inoculum obtained from the collection of the Forest Microbiology Laboratory of the Institute of Environment and Agricultural Research (INERA), Ouagadougou, Burkina Faso. The term "native" refers to the geographic origin of the propagules, which were derived from Burkina Faso rhizosphere samples. The inoculum contained 686 spores per 10 g and was mainly affiliated, on the basis of morpho-anatomical identification, with the genera *Gigaspora* sp., *Glomus* sp., *Scutellospora* sp., *Entrophospora* sp. and *Racocetra* sp. Because the inoculum was characterized morphologically at the genus level, the species composition, relative abundance of each taxon, infective propagule density and functional viability were not quantified separately.

2.1.2. Trap Culture and Inoculum Composition

The AMF propagules were initially obtained from soil samples collected in three rhizospheres in Burkina Faso associated with *Oryza sativa* L., *Vigna unguiculata* and *Sclerocarya birrea*. They were multiplied under semi-controlled greenhouse conditions using maize (*Zea mays* L.) as a highly mycotrophic trap plant for three months. The resulting inoculum consisted of colonized root fragments, spores and rhizospheric substrate. No sterilized inoculum control or microbial filtrate control was included; therefore, the experiment cannot separate the effects of living AMF propagules from possible effects of the inoculum carrier substrate or associated microorganisms.

AMF spores were identified at the genus level based on morpho-anatomical characteristics after the spores were mounted in polyvinyl alcohol-lacto-glycerol (PVLG) supplemented with Melzer's reagent, following Koske and Tessier [9] and Morton [10]. Identification was based on microscopic observation of diagnostic traits and comparison with reference specimens from the INVAM collection. Molecular identification was not performed, and the taxonomic resolution of the inoculum should therefore be considered limited to the genus level.

2.1.3. Plant Material

The plant material was rice (*Oryza sativa* L.), cultivar FKR64, a variety widely cultivated in Burkina Faso and reported to have an average yield potential of approximately 7 $t \cdot ha^{-1}$ [11]. Seeds were supplied by INERA and were sown without chemical pretreatment in order to avoid interference with the early establishment of mycorrhizal symbiosis.

2.2. Experimental Conditions

2.2.1. Growth Substrate

The experiment was conducted using a local substrate that was sieved and homogenized before the pots were filled. The substrate was not sterilized, thereby allow-

ing the experiment to retain part of the native microbial background. Its main physicochemical characteristics were: clay, 3.92%; total silt, 5.88%; total sand, 90.2%; total organic matter, 0.331%; total carbon, 0.192%; total nitrogen, 0.016%; C/N ratio, 12; total phosphorus, 172.52 ppm; available phosphorus, 1.74 ppm; and pH(H_2O) 6.44, measured at a soil-to-water ratio of 1:2.5 (m/v). These values indicate a sandy substrate with very low organic matter and low available phosphorus, conditions suitable for testing AMF responses under nutrient limitation.

2.2.2. Greenhouse Conditions

Plants were grown under greenhouse conditions with temperatures ranging from 22˚C to 35˚C and relative humidity of 60% - 70%. Permanent flooding was initiated from the third week after sowing. A water layer of approximately 2 - 3 cm above the substrate surface was then maintained and adjusted according to plant water requirements throughout the experimental period.

2.2.3. Experimental Design and Treatment Application

The experiment was conducted under semi-controlled greenhouse conditions using a completely randomized design. The experimental unit was the pot (5 L), and each treatment was replicated nine times, resulting in 54 pots in total. Pots were randomly assigned to treatments to limit positional effects within the greenhouse.

The treatment structure was designed to compare contrasting fertility-management options rather than to estimate independent main effects or formal interactions among AMF inoculation, compost amendment and mineral fertilization. Therefore, the treatment effects reported in this study should be interpreted as treatment contrasts. The untreated control (T0) was neither inoculated nor fertilized and was used as the baseline response of rice grown in the low-fertility substrate. The treatments were defined as follows:

- 100% AMF: mycorrhizal inoculation alone;
- 100% compost: organic fertilization alone (4 t·ha^{-1});
- AMF + 100% compost: mycorrhizal inoculation + standard compost dose (4 t·ha^{-1});
- AMF + 50% compost: mycorrhizal inoculation + half compost dose (2 t·ha^{-1});
- AMF + 50% NPK/urea: mycorrhizal inoculation + half mineral fertilization dose (NPK 200 kg·ha^{-1} and urea 150 kg·ha^{-1});
- Control (T0): uninoculated and unfertilized plants.

Mycorrhizal inoculation was performed at sowing by applying 30 g of inoculum per pot, corresponding to 10 g per planting hole. The inoculum was placed in direct contact with the seeds to promote early root-fungus contact and facilitate the establishment of symbiosis.

Mineral and organic fertilization followed equivalent field rates commonly recommended for rice: 200 kg·ha^{-1} NPK, 150 kg·ha^{-1} urea and 4 t·ha^{-1} compost.

Pot-equivalent doses of compost, NPK and urea were calculated for pots with a volume of 5 L and a surface area of 314 cm^2, based on the following formula:

Thus, the 100% fertilizer treatments received 12.56 g of compost per pot. The

50% fertilizer treatments received half of the corresponding recommended dose, that is, 0.314 g of NPK, 0.235 g of urea and 6.28 g of compost. These field rates were converted to pot-equivalent doses according to the surface area represented by each pot.

Compost was applied in a single dose at the time of sowing. NPK fertilizer with the composition (23-10-5 + 2% MgO + 3% S + 0.3% Zn) was applied in a single dose two weeks after inoculation.

One-third of the urea dose was applied two weeks after inoculation; the remaining two-thirds were scheduled for the panicle-initiation stage but were not applied because the experiment ended at 56 days after sowing.

Accordingly, the AMF + 50% NPK/urea treatment refers to the planned reduced mineral-fertilization regime. Because final sampling occurred before panicle initiation, the treatment response reflects the NPK dose and first urea split actually applied during the 56-day vegetative period, rather than the full planned urea program.

Compost chemical composition was not determined in the present experiment. This limitation should be considered when interpreting treatment effects because compost nutrient content, organic carbon concentration, maturity, C/N ratio, salinity and pH can strongly influence both plant growth and AMF-associated responses. Consequently, the observed responses cannot be attributed to specific compost-derived nutrient inputs or physicochemical properties. No soluble phosphorus was applied outside the defined fertilization treatments in order to avoid artificially altering the expression of AMF-associated responses.

2.2.4. Growth Measurements and AMF Colonization Assessment

The measured response variables were plant height (cm), tiller number per plant, aboveground dry biomass without panicles (g plant^{-1}), root dry biomass (g plant^{-1}), and mycorrhizal colonization parameters. These variables were used as indicators of early vegetative performance and AMF establishment. They should not be interpreted as direct indicators of grain yield, nutrient uptake or nutrient-use efficiency, because these variables were not measured in the present greenhouse experiment.

Plant height was measured at four stages during vegetative growth: T1, T2, T3 and T4, corresponding to 14, 28, 42 and 56 days after sowing, respectively. Tiller number was recorded during growth and at final harvest. Final harvest measurements, coded as Trec, were taken at 56 days after sowing and included final tiller number, aboveground dry biomass and root dry biomass.

Because the experiment ended at the vegetative stage, grain yield and yield components were not assessed. Consequently, treatment responses are discussed in terms of early growth, tillering, biomass accumulation and AMF colonization rather than final rice productivity.

At harvest, shoots and roots were separated. Aboveground biomass was measured without panicles, and root biomass was determined separately. Plant material was oven-dried at 70˚C for 120 h until constant weight, and dry biomass val-

ues were expressed in grams per plant.

Mycorrhizal root colonization was assessed at harvest. Fine roots (approximately 10 g per sample) were initially stained according to the method described by Phillips and Hayman [12]. The roots were first decolorized with 10% potassium hydroxide (KOH) at 90˚C in a water bath for 30 minutes. The decolorized roots were then stained with Trypan blue at 90˚C for 30 minutes. After staining, they were lightly rinsed with tap water to remove excess dye. For each sample, 10 slides, each containing 10 randomly selected root fragments approximately 1 cm long, were prepared and examined under a light microscope at 200× magnification. The presence of hyphae, vesicles and/or arbuscules in the roots allowed the plant to be classified as mycorrhizal (**Figure 1**). After fungal structures were identified, the frequency (F%) and intensity (I%) of mycorrhization of root fragments were estimated according to the method of Trouvelot et al. [13], using a scale consisting of six classes ranging from zero (0) to five (5) (**Figure 2**).

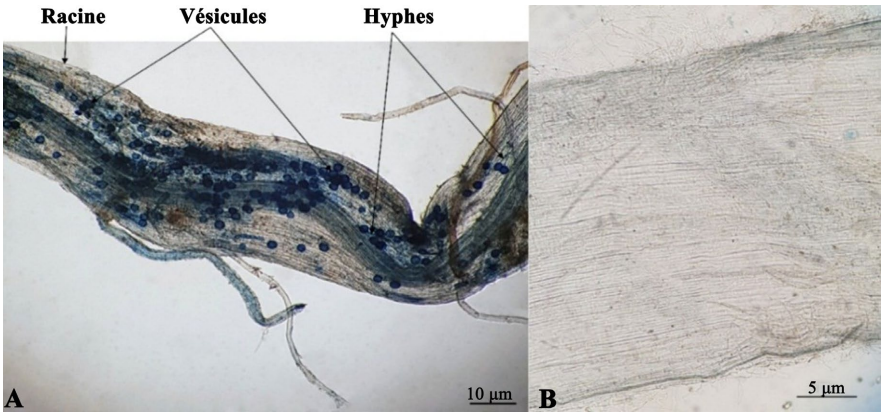


Figure 1. Mycorrhizal and non-mycorrhizal rice roots observed after staining. (A) Mycorrhizal rice root; (B) Non-mycorrhizal rice root.

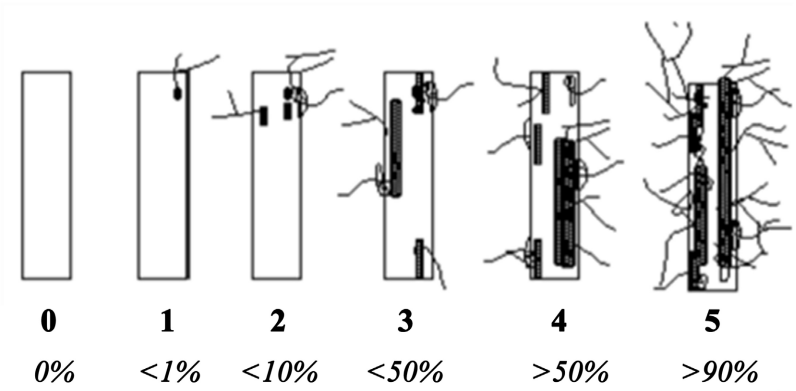


Figure 2. Rating scale for AMF root colonization, from 0 to 5.

Mycorrhizal colonization frequency (F%):

$$F\% = \frac{\text{Number of mycorrhizal fragments}}{\text{Total number of fragments observed}} \times 100$$

Mycorrhizal colonization intensity (I%):

$$I\% = \frac{95n5 + 70n4 + 30n3 + 5n2 + n1}{\text{Total number of fragments observed}}$$

2.3. Statistical Analysis

All statistical analyses were performed in R version 4.6.1 on a 64-bit Windows 11 platform. The analysis workflow included data screening, assumption checking, treatment comparisons for univariate response variables, generalized modeling for count data and exploratory multivariate analyses to summarize treatment profiles. The main analyses used standard R functions and complementary packages for data handling, modeling and visualization, including *dplyr*, *tidyr*, *ggplot2*, *MASS*, *lme4*, *nlme*, *boot*, *tibble*, *purrr*, *scales* and *RColorBrewer*. The pot was considered the experimental unit for all treatment comparisons.

For continuous variables measured at a single final harvest date, residual normality was assessed with the Shapiro-Wilk test and homogeneity of variance with Levene's test. These tests were complemented by inspection of residual patterns because the number of replicates per treatment was limited. When the assumptions of normality and homoscedasticity were reasonably satisfied, treatment effects were analyzed using one-way analysis of variance (ANOVA), followed by Tukey's honestly significant difference test at $\alpha = 0.05$. When variance heterogeneity persisted after logarithmic transformation, Welch's ANOVA was applied, followed by Games-Howell post-hoc comparisons. When parametric assumptions were not met, the Kruskal-Wallis test was used, followed by Dunn-type post-hoc comparisons with Bonferroni correction. The statistical test used for each variable is indicated in the corresponding table notes.

Plant height and tiller number were recorded repeatedly on the same experimental units during the vegetative period. Therefore, temporal patterns were interpreted with caution. In the present analysis, plant height was evaluated for treatment, time and treatment × time effects, and treatment comparisons were performed within each measurement date. Tiller number was analyzed as count data using generalized linear models. Overdispersion was assessed by comparing residual deviance with residual degrees of freedom. When no substantial overdispersion was detected, a Poisson GLM with a log link was used; when overdispersion was detected, a negative binomial GLM with a log link was fitted using the *MASS* package. Pairwise comparisons among treatments were performed using adjusted multiple comparisons, with Sidak correction when estimated marginal means were used.

Colonization frequency and colonization intensity were analyzed as percentage variables. Because raw colonization counts were not available for the present analysis, colonization frequency and intensity were analyzed using procedures appropriate for the reported percentage data. When parametric assumptions were not met, Kruskal-Wallis tests followed by Dunn-type post-hoc comparisons with Bonferroni correction were applied.

Principal component analysis (PCA) was performed on centered and scaled agronomic and mycorrhizal variables using the *prcomp()* function from the *stats* package so that variables measured on different scales contributed comparably to the ordination. Hierarchical agglomerative clustering was then performed on PCA scores using Euclidean distance and Ward's minimum-variance method with the *hclust()* function using *method* = "*ward.D2*". These multivariate analyses were used as exploratory tools to describe treatment profiles and should not be interpreted as confirmatory tests of treatment effects, causality or functional nutrient transfer.

All multiple-comparison procedures were selected according to the distributional properties of each response variable and the assumptions met by the fitted model. Statistical significance was assessed at $\alpha = 0.05$. Where available, approximate 95% confidence intervals were reported descriptively to support interpretation of selected treatment contrasts, together with p-values and post-hoc grouping letters.

2.4. Data Interpretation and Reporting Approach

Because the experiment compared predefined fertility-management treatments rather than a complete factorial combination of AMF inoculation, compost rate and mineral fertilization, the results were interpreted as treatment contrasts. Therefore, differences among treatments were not used to infer independent main effects or formal interaction effects. In particular, because the design did not include a 50% compost treatment without AMF, the response of AMF + 50% compost cannot be attributed specifically to AMF, compost dose reduction, or their interaction. Similarly, the absence of a 50% NPK/urea treatment without AMF limits interpretation of the AMF + 50% NPK/urea response.

Mycorrhizal colonization frequency and intensity were interpreted as indicators of AMF establishment in roots, not as direct evidence of functional nutrient transfer. Accordingly, the biological significance of high colonization was assessed in conjunction with plant height, tiller production and biomass responses. Because plant nutrient uptake, soil nutrient dynamics, microbial biomass, enzyme activity and photosynthesis were not measured, mechanisms related to phosphorus mobilization, nitrogen acquisition, microbial stimulation or nutrient-use efficiency were discussed as plausible explanations rather than demonstrated processes.

The principal component analysis and hierarchical clustering were used to summarize the multivariate structure of the measured responses and to describe treatment profiles. These analyses were treated as exploratory tools and were not used as confirmatory tests of treatment superiority, biological causality or identification of an optimal treatment. Throughout the results and discussion, the terms "promising" or "favorable" refer to observed early vegetative and mycorrhizal response profiles under greenhouse conditions and should not be interpreted as field-level recommendations.

3. Results and Discussion

3.1. Treatment Effects on AMF Colonization and Early Rice Growth

3.1.1. Effect of Organic and Mineral Fertilization on AMF Colonization of Rice Roots

Table 1 summarizes AMF colonization frequency and intensity in rice roots across the six fertility-management treatments. As specified in the "Data interpretation and reporting approach" section, the treatment structure was not factorial; therefore, the colonization responses are interpreted as contrasts among management options rather than as separate effects of AMF inoculation, compost amendment, mineral fertilization or their interactions.

Colonization frequency differed significantly among treatments ($p < 0.05$). The highest mean frequencies were observed in AMF + 50% NPK/urea (86.66%), 100% AMF (81.11%), AMF + 50% compost (77.78%) and AMF + 100% compost (72.22%). These treatments shared the same statistical group in Table 1, indicating that their colonization frequencies were not significantly different from one another. Because only the NPK dose and first urea split were applied before final sampling in the AMF + 50% NPK/urea treatment, this treatment should be interpreted as the reduced mineral-fertilization schedule actually applied during the 56-day vegetative period. The lowest frequency was recorded in the uninoculated and unfertilized control (T0; 21.11%).

Colonization intensity followed a broadly similar trend but showed greater contrasts among treatments. The highest mean intensity was recorded under AMF + 50% NPK/urea (55.22%), followed by 100% AMF (51.00%), AMF + 50% compost (46.56%) and AMF + 100% compost (25.13%). The 100% compost treatment showed lower colonization intensity (10.27%), whereas T0 had the weakest intensity (1.44%). These values indicate that inoculated treatments generally supported stronger development of mycorrhizal structures than the uninoculated control, although the magnitude differed among fertility contexts.

The presence of measurable colonization in both the 100% compost treatment and the uninoculated control indicates that the non-sterilized substrate, compost or resident microbial background may have contained indigenous AMF propagules. This observation is biologically important because it means that treatment differences should be interpreted as differences in colonization level rather than as a strict contrast between colonized and non-colonized roots. However, this interpretation remains cautious because the experiment did not include sterilized-substrate, sterilized-inoculum or microbial-filtrate controls.

The colonization results also show that higher AMF establishment did not necessarily correspond to stronger early rice growth. In particular, AMF + 50% NPK/urea produced the highest mean colonization frequency and intensity but showed weak vegetative responses under the reduced mineral-fertilization schedule actually applied before final sampling. Conversely, compost-containing treatments showed more favorable growth responses despite lower or intermediate colonization intensity. These treatment-level patterns suggest a descriptive sepa-

ration between colonization and plant performance under the tested conditions; however, a formal colonization-growth relationship would require correlation or regression analyses based on individual pot-level data.

Table 1. Frequency and intensity of AMF colonization in rice roots according to inoculation and fertilization treatments.

Treatments	Frequency (%)	Intensity (%)
100% AMF	81.11 ± 7.82[a]	51.00 ± 7.96[a]
AMF + 50% compost	77.78 ± 24.83[a]	46.56 ± 31.08[ab]
AMF + 50% NPK/urea	86.66 ± 18.03[a]	55.22 ± 32.48[a]
AMF + 100% compost	72.22 ± 6.66[a]	25.13 ± 11.11[ab]
100% compost	54.44 ± 26.03[ab]	10.27 ± 6.04[bc]
T0	21.11 ± 9.27[b]	1.44 ± 1.48[c]
p-value	<0.05	<0.05

Values are means ± SE (n = 9). Values sharing at least one letter within a column are not significantly different at $\alpha = 0.05$ according to Dunn's post-hoc test.

3.1.2. Effects of Treatments on Rice Plant Height and Tillering

Table 2 and Table 3 summarize treatment contrasts for rice plant height and tiller production over time. These variables provide complementary indicators of early vegetative performance: plant height reflects shoot elongation, whereas tiller number reflects the development of lateral shoots. Because the treatment structure was not factorial, the results are interpreted as comparisons among the tested fertility-management options rather than as independent effects of AMF inoculation, compost amendment or mineral fertilization.

For plant height, the analysis considered the effects of time, treatment and their interaction. Plant height increased significantly during the experiment ($p < 0.01$), indicating active vegetative growth across treatments. The overall treatment effect was marginal ($p = 0.06$), whereas the treatment × time interaction was significant ($p = 0.01$), suggesting that differences among treatment trajectories became more apparent as plants developed.

At the first two measurement dates, plant height did not differ significantly among treatments, with p-values greater than 0.90 and 0.59, respectively. Significant differences were detected from the third measurement date onward ($p < 0.05$ at T3 and T4), indicating that treatment-associated differences in shoot elongation emerged mainly during the later part of the vegetative period.

At 56 days after sowing, the highest mean plant height was recorded in AMF + 50% compost (50.67 cm), followed by 100% compost (46.48 cm) and AMF + 100% compost (46.21 cm). These three treatments belonged to the same statistical group in Table 2 and did not differ significantly from one another. They also shared a grouping letter with T0 (ab), so their higher mean final heights did not indicate significant differences from the control. AMF + 50% NPK/urea showed the lowest final plant height (28.08 cm) under the mineral-fertilization schedule actually ap-

plied before final sampling. Thus, the observed pattern indicates stronger shoot elongation in compost-containing treatments than in the reduced mineral-fertilization treatment during the 56-day vegetative period, but it does not isolate the specific contribution of AMF within the AMF + 50% compost treatment.

Table 2. Effect of treatments on rice plant height over time.

Treatments	Plant height at T1 (cm)	Plant height at T2 (cm)	Plant height at T3 (cm)	Plant height at T4 (cm)
100% AMF	18.53 ± 0.30^{a}	24.34 ± 0.71^{a}	33.67 ± 2.18^{b}	42.23 ± 1.79^{b}
AMF + 50% compost	17.21 ± 0.90^{a}	23.93 ± 1.90^{a}	40.41 ± 4.26^{a}	50.67 ± 5.73^{a}
AMF + 50% NPK/urea	15.16 ± 0.63^{a}	16.34 ± 0.96^{a}	25.91 ± 4.20^{c}	28.08 ± 9.05^{c}
AMF + 100% compost	16.18 ± 0.41^{a}	20.19 ± 0.76^{a}	25.18 ± 1.48^{c}	46.21 ± 3.01^{a}
100% compost	13.46 ± 0.43^{a}	21.59 ± 2.15^{a}	35.02 ± 4.58^{b}	46.48 ± 8.99^{a}
T0	18.09 ± 0.40^{a}	21.82 ± 0.65^{a}	31.20 ± 1.68^{ab}	39.06 ± 2.81^{ab}
p-value	>0.90	>0.59	<0.05	<0.05

Values are means ± SE (n = 9). Values sharing at least one letter within a column are not significantly different at $\alpha = 0.05$ according to Tukey's post-hoc test. T1, T2, T3 and T4 indicate measurements taken at 14, 28, 42 and 56 days after sowing, respectively. Approximate 95% confidence intervals for plant height are provided in **Supplementary** Table S1.

Table 3. Effect of treatments on tiller production in rice plants over time.

Treatments	Tiller number at T1	Tiller number at T2	Tiller number at harvest
100% AMF	1.00 ± 0.00^{b}	1.11 ± 0.33^{c}	2.11 ± 0.92^{ab}
AMF + 50% compost	1.77 ± 0.66^{a}	2.33 ± 1.00^{b}	2.77 ± 1.30^{b}
AMF + 50% NPK/urea	1.00 ± 0.00^{b}	0.89 ± 0.92^{c}	1.66 ± 1.50^{ab}
100% compost	1.66 ± 1.00^{a}	2.56 ± 1.87^{a}	3.33 ± 2.12^{a}
AMF + 100% compost	1.00 ± 0.00^{b}	1.89 ± 0.92^{ab}	4.00 ± 1.65^{a}
T0	1.00 ± 0.00^{b}	1.00 ± 0.00^{c}	1.00 ± 0.00^{c}
p-value	<0.05	<0.05	<0.05

Values are means ± SE (n = 9). Values sharing at least one letter within a column are not significantly different at $\alpha = 0.05$ according to Sidak-adjusted pairwise comparisons of estimated marginal means from generalized linear models. T1 and T2 indicate measurements taken at 14 and 28 days after sowing, respectively; Trec indicates the final harvest measurement at 56 days after sowing.

Tiller number differed significantly among treatments at all measurement dates ($p < 0.05$; Table 3). Compost-containing treatments generally had higher mean tiller numbers than the control and AMF + 50% NPK/urea, but significant pairwise differences depended on the measurement date. At harvest, all compost-containing treatments differed significantly from T0, whereas none differed significantly from AMF + 50% NPK/urea, with which they shared at least one grouping

letter. The design does not allow the contribution of AMF to be isolated at the 50% compost level.

At T1, AMF + 50% compost and 100% compost recorded 1.77 and 1.66 tillers per plant, respectively, compared with 1.00 tiller per plant in the control. At harvest, the highest mean tiller numbers were observed under AMF + 100% compost (4.00 tillers), 100% compost (3.33 tillers) and AMF + 50% compost (2.77 tillers), whereas the control remained at 1.00 tiller. According to the post-hoc grouping in Table 3, AMF + 100% compost and 100% compost were assigned the letter a at harvest and differed significantly from AMF + 50% compost (b) and T0 (c). However, they did not differ significantly from 100% AMF or AMF + 50% NPK/urea, both classified as ab. Thus, the highest mean tiller numbers did not indicate significant superiority over every other treatment.

Overall, compost-containing treatments showed favorable mean height and tillering profiles, but pairwise statistical differences varied with the response variable and measurement date. At T4, these treatments were significantly taller than 100% AMF and AMF + 50% NPK/urea, but not T0. At harvest, their tiller numbers were significantly higher than those of T0, but not those of 100% AMF or AMF + 50% NPK/urea. AMF + 50% compost had the highest mean final height, whereas AMF + 100% compost and 100% compost had the highest mean final tiller numbers. However, because the design did not include 50% compost without AMF or 50% NPK/urea without AMF, and because only the first urea split was applied before harvest, the results should not be interpreted as evidence of a formal AMF × compost interaction or as proof that AMF specifically improved the response to the reduced compost dose.

3.1.3. Effects of Treatments on Rice Dry Biomass

Table 4 summarizes treatment contrasts for aboveground dry biomass without panicles and root dry biomass at harvest. These variables provide complementary indicators of early biomass accumulation: aboveground biomass reflects shoot growth, whereas root biomass reflects belowground development. Because the experiment ended at the vegetative stage, these biomass variables should not be interpreted as direct indicators of grain yield or final rice productivity.

Aboveground dry biomass differed significantly among treatments ($p < 0.01$), with mean values ranging from 0.64 g in the uninoculated and unfertilized control (T0) to 4.56 g in the 100% compost treatment. This indicates that the tested fertility-management options were associated with contrasting shoot biomass accumulation under greenhouse conditions.

The highest mean aboveground biomass values were observed in the 100% compost, AMF + 50% compost and AMF + 100% compost treatments, with 4.56 g, 3.58 g and 3.16 g, respectively. These three treatments shared the same statistical group in Table 4 and therefore should not be interpreted as clearly different from one another. The 100% AMF and AMF + 50% NPK/urea treatments produced lower mean values of 2.81 g and 1.22 g, respectively, while the control showed the lowest value. The response of AMF + 50% NPK/urea reflects the NPK dose and

first urea split applied before final sampling, not the full planned urea program. According to the grouping letters in Table 4, all compost-containing treatments had significantly higher aboveground biomass than 100% AMF and T0. However, none differed significantly from AMF + 50% NPK/urea (ab), which shared a grouping letter with both the compost-containing treatments (a) and 100% AMF (b). The lower mean biomass under the reduced mineral-fertilization schedule therefore does not establish a significant difference from the compost-containing treatments. The design also does not isolate the contribution of AMF at the 50% compost level.

Root dry biomass also differed significantly among treatments ($p < 0.05$). The highest mean root biomass values were recorded under AMF + 100% compost (8.01 g) and 100% compost (7.46 g), followed by AMF + 50% compost (5.77 g). According to the post-hoc grouping in Table 4, AMF + 100% compost and 100% compost belonged to the highest statistical group, whereas the control showed the lowest root biomass (1.98 g). AMF + 100% compost and 100% compost (a) had significantly higher root biomass than 100% AMF and AMF + 50% NPK/urea (bc), AMF + 50% compost (b), and T0 (c). AMF + 50% compost differed significantly from T0, but not from 100% AMF or AMF + 50% NPK/urea, with which it shared the letter b. The two treatments classified as bc did not differ significantly from T0. The response of AMF + 50% NPK/urea should be interpreted in relation to the reduced mineral-fertilization schedule actually applied before final sampling. However, because compost chemistry, plant nutrient uptake and root nutrient concentrations were not measured, the observed biomass differences cannot be directly attributed to improved nutrient acquisition or nutrient-use efficiency.

Table 4. Effect of treatments on aboveground and root dry biomass of rice plants.

Treatments	Aboveground dry biomass (g)	95% CI aboveground biomass (g)	Root dry biomass (g)	95% CI root biomass (g)
100% AMF	2.81 ± 0.38^{b}	1.93 - 3.69	2.53 ± 0.23^{bc}	2.00 - 3.06
AMF + 50% compost	3.58 ± 2.36^{a}	0.00 - 9.02	5.77 ± 2.29^{b}	0.49 - 11.05
AMF + 50% NPK/urea	1.22 ± 1.22^{ab}	0.00 - 4.03	2.58 ± 1.66^{bc}	0.00 - 6.41
100% compost	4.56 ± 3.57^{a}	0.00 - 12.79	7.46 ± 0.96^{a}	5.25 - 9.67
AMF + 100% compost	3.16 ± 1.74^{a}	0.00 - 7.17	8.01 ± 2.05^{a}	3.28 - 12.74
T0	0.64 ± 0.30^{c}	0.00 - 1.33	1.98 ± 0.42^{c}	1.01 - 2.95
p-value	<0.01	—	<0.05	—

Aboveground biomass was measured without panicles. Values are means ± SE (n = 9). Approximate 95% confidence intervals were calculated as mean ± 2.306 × SE using $t_{0.975,8}$. Because biomass values cannot be negative, intervals with negative lower bounds were truncated at 0. For aboveground dry biomass, values sharing at least one letter within a column are not significantly different at $\alpha = 0.05$ according to the Games-Howell test. For root dry biomass, values sharing at least one letter within a column are not significantly different at $\alpha = 0.05$ according to Tukey's post-hoc test. Confidence intervals are approximate and should be interpreted as descriptive intervals derived from the reported standard errors.

3.2. Multivariate Structure of Agronomic and Mycorrhizal Responses

Principal component analysis (PCA) was used as an exploratory ordination to summarize the joint variation in growth, biomass and mycorrhizal colonization variables across treatments (Figure 3). The first two principal components explained 67.7% of the total variance, with PC1 and PC2 accounting for 46.8% and 20.9%, respectively. This indicates that the two-dimensional ordination captured a substantial proportion of the observed multivariate structure, but the PCA should be interpreted descriptively rather than as a confirmatory test of treatment effects.

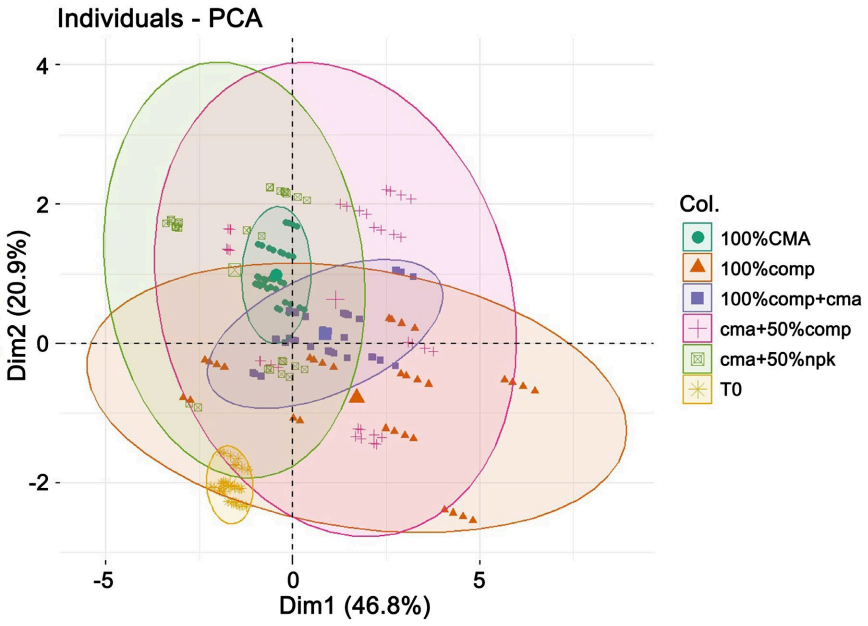


Figure 3. Exploratory principal component analysis of agronomic and mycorrhizal response variables. The ordination summarizes variation among treatments but should not be interpreted as a confirmatory test of treatment superiority or causality.

PC1 was mainly associated with vegetative performance variables, including plant height, aboveground biomass, root biomass and tiller number. Higher PC1 scores therefore reflected stronger overall early growth and biomass accumulation among the measured variables.

PC2 was primarily related to mycorrhizal colonization variables, particularly colonization frequency and colonization intensity. Higher PC2 scores therefore reflected greater AMF root establishment, but not necessarily greater functional nutrient transfer or stronger plant growth.

The ordination separated compost-containing treatments with stronger growth responses, including 100% compost, AMF + 50% compost and AMF + 100% compost, from treatments with weaker vegetative performance, particularly T0 and AMF + 50% NPK/urea. The latter represents the reduced mineral-fertilization schedule actually applied before final sampling, because the second urea split was

not applied. Along the colonization-related dimension, treatments with higher AMF colonization, including 100% AMF, AMF + 50% compost, AMF + 100% compost and AMF + 50% NPK/urea, were separated from treatments with lower colonization, such as T0 and 100% compost. This pattern supports a descriptive separation between growth-related and colonization-related responses, but it does not provide direct evidence of causality, nutrient transfer or identification of an optimal treatment.

Hierarchical agglomerative clustering based on PCA scores and Ward's method was used as a complementary exploratory summary of treatment profiles (Table 5). AMF + 50% compost and AMF + 100% compost grouped together because they combined relatively favorable growth responses with high AMF colonization. The 100% compost treatment was characterized by favorable growth responses but comparatively lower colonization, whereas 100% AMF showed high colonization with more moderate growth responses. AMF + 50% NPK/urea, interpreted as the reduced mineral-fertilization schedule actually applied before final sampling, combined high colonization with weak growth, and T0 showed the weakest overall response profile. These clusters should be interpreted as descriptive groupings of measured variables rather than as statistically validated treatment classes.

Table 5. Exploratory hierarchical agglomerative clustering groups based on PCA scores using Ward's method.

Treatments	Cluster	PCA profile	Interpretation
AMF + 50% compost	Cluster 1	PC1+/PC2+	Favorable growth and high colonization profile
AMF + 100% compost	Cluster 1	PC1+/PC2+	Favorable growth and high colonization profile
100% compost	Cluster 2	PC1+/PC2−	Favorable growth and lower colonization profile
100% AMF	Cluster 3	PC1−/PC2+	Moderate growth and high colonization profile
AMF + 50% NPK/urea	Cluster 4	PC1−/PC2+	Weak growth and high colonization profile
T0	Cluster 5	PC1−/PC2−	Lowest measured response profile

4. Discussion

This study shows that AMF root colonization and early rice growth responded differently to the tested fertility-management treatments. The main descriptive finding is the partial uncoupling between mycorrhizal establishment and vegetative performance across treatment means: high colonization confirmed that fungal structures were established in roots, but it did not necessarily coincide with greater plant height, tillering or biomass. This distinction is central for interpreting AMF inoculation because plant response depends not only on colonization, but also on host genotype, soil fertility and the balance between fungal carbon

demand and nutrient-related benefits [14] [15]. Because nutrient uptake was not measured, any contribution of AMF to plant nutrition must be interpreted indirectly and cautiously.

The relatively high colonization observed in inoculated treatments indicates compatibility between rice cultivar FKR64 and the mixed native AMF inoculum in the sandy, low-phosphorus substrate used in this greenhouse experiment. This is consistent with evidence that rice can establish AMF symbiosis and that the outcome of this association varies with genotype and phosphorus status [4] [5]. Therefore, the response observed for FKR64 should not be generalized to other rice cultivars without comparative testing. The low available phosphorus content of the substrate may also have favored mycorrhizal establishment, and molecular work in rice has shown that phosphate-starvation-response networks contribute to the regulation of mycorrhizal symbiosis [16]. However, this regulatory mechanism was not directly tested here.

The weak growth response of AMF + 50% NPK/urea despite its high colonization illustrates why colonization should not be treated as a proxy for functional benefit. Meta-analytical evidence shows that increased AMF abundance or colonization does not always translate into greater plant biomass, particularly when soil phosphorus availability, indigenous inoculum potential or host responsiveness constrain the net benefit of the symbiosis [17]. This pattern is also consistent with the mutualism-parasitism continuum of mycorrhizal associations, in which the outcome depends on whether nutritional benefits offset the carbon cost of maintaining the fungal symbiont [18] [19]. In the absence of direct nutrient-uptake or carbon-allocation measurements, this remains a plausible biological interpretation rather than a demonstrated mechanism.

Compost-containing treatments showed the most consistent early growth and biomass responses among the management options tested. This pattern is consistent with evidence that organic amendments can modify the rhizosphere environment and influence AMF-related traits, including hyphal growth and sporulation, although these responses are strongly context-dependent [6]. In the present study, compost-containing treatments generally had higher mean biomass, but significant differences depended on the variable and comparator. For aboveground biomass, none differed significantly from AMF + 50% NPK/urea. For root biomass, 100% compost and AMF + 100% compost differed significantly from that treatment and from AMF alone, whereas AMF + 50% compost did not. The available data do not establish the mechanisms underlying this pattern. Compost chemical composition was not determined in the present experiment; therefore, its nutrient content, C/N ratio, maturity, salinity, pH and phosphorus availability cannot be used to explain the observed growth responses. The observed responses should therefore be interpreted as treatment-associated growth patterns rather than direct evidence of nutrient mobilization or microbial stimulation.

The AMF + compost combinations showed some of the more favorable response profiles, but they should be interpreted with caution as predefined treat-

ment contrasts. AMF + 50% compost had the greatest mean final plant height, whereas AMF + 100% compost showed higher mean root biomass and final tillering. This suggests that compost-containing treatments differed in the balance between shoot elongation and belowground development. However, because the experiment did not include a 50% compost treatment without AMF, the response of AMF + 50% compost cannot be attributed specifically to AMF, compost dose reduction, or their interaction. Therefore, these results should not be presented as evidence of a formal AMF × compost interaction, synergy, or compost-use efficiency improvement by AMF.

The AMF + 50% NPK/urea treatment provides a useful counterexample to the assumption that higher colonization necessarily improves plant performance, but it must be interpreted in relation to the fertilization schedule actually applied before final sampling. This treatment had the highest mean colonization frequency and intensity but comparatively low mean growth responses. Its final height was significantly lower than that of the compost-containing treatments. However, its final tiller number and aboveground biomass did not differ significantly from theirs, and its root biomass differed significantly only from 100% compost and AMF + 100% compost, not AMF + 50% compost. Because only the NPK dose and first urea split were applied during the 56-day vegetative period, the response does not represent the full planned reduced NPK/urea program through panicle initiation. The reduced mineral-fertilization schedule actually applied may have been insufficient or nutritionally unbalanced, nutrient retention may have been limited in the sandy low-organic-matter substrate, or the carbon demand of maintaining colonization may not have been offset by nutritional benefits. These hypotheses are consistent with the broader view that nutrient availability can shift AMF associations along a continuum from beneficial to less beneficial outcomes [18] [19]. They remain hypotheses because plant nutrient uptake, soil mineral nitrogen, available phosphorus after fertilization and host carbon allocation were not measured.

From an integrated fertility-management perspective, these results support evaluating AMF inoculation as a complementary biological input rather than as a stand-alone substitute for organic or mineral fertilization. The observed treatment profiles are consistent with the view that mycorrhizal outcomes depend on plant genotype, soil fertility, organic amendments and resident microbial communities [7] [8]. However, because microbial community composition, enzyme activity, soil nutrient dynamics and plant nutrient uptake were not directly assessed, these processes should be treated as plausible explanatory pathways requiring further testing rather than as demonstrated drivers of the observed responses.

This interpretation is consistent with broader literature describing AMF-based biofertilization as a component of sustainable crop-management strategies, although the agronomic performance of such approaches remains strongly dependent on crop species, soil fertility, inoculum quality and field validation [20] [21].

Previous work on microbial inoculation and soil fertility management in West

African cropping systems further supports the need to evaluate inoculant performance under local soil and management conditions [22].

The results are useful for designing future rice fertility trials in nutrient-poor Sahelian substrates. AMF + 50% compost showed a favorable early-growth profile for shoot elongation, whereas AMF + 100% compost and 100% compost showed more favorable responses for root biomass or tillering. Nevertheless, AMF + 50% compost cannot yet be considered superior to 100% compost or AMF + 100% compost across all response variables and should be viewed as a candidate treatment for further dose-response testing. Similarly, the weak performance of AMF + 50% NPK/urea should be interpreted as the response to the reduced mineral-fertilization schedule actually applied before final sampling, not as the response to the full reduced NPK/urea program originally planned. This interpretation should be verified using a corresponding 50% NPK/urea treatment without AMF and a fertilization schedule extending to the reproductive phase.

Overall, the study provides a greenhouse proof-of-concept showing that the relationship between AMF colonization and early rice performance is context-dependent. Its main contribution is not the identification of an optimal fertilizer strategy, a demonstrated AMF × compost interaction, or a field-ready recommendation, but the observation that high AMF colonization alone was not associated with the strongest vegetative performance, whereas compost-containing treatment contrasts showed more favorable early growth profiles. This interpretation agrees with studies emphasizing that mycorrhizal responsiveness depends on host identity, phosphorus limitation, soil fertility, indigenous microbial context and experimental environment [14] [15] [17], as well as with rice-focused studies showing that phosphorus status, genotype and rhizosphere processes can regulate whether AMF colonization is associated with plant performance [4] [5] [7] [16]. Future work should use factorial treatment structures, chemically characterized compost, explicit nutrient balances, nutrient-uptake measurements and field validation before AMF-compost strategies are recommended for rice production.

5. Study Limitations

This study should be interpreted as a greenhouse proof-of-concept rather than as a field-validated agronomic recommendation. The semi-controlled conditions allowed early rice responses to contrasting fertility-management treatments to be compared, but they did not reproduce field variability in temperature, rainfall, soil moisture, redox status, pest pressure or microbial community dynamics. In addition, the experiment ended at the vegetative stage and did not measure grain yield or yield components. Therefore, plant height, tillering and biomass should be interpreted as indicators of early vegetative performance rather than final rice productivity.

The treatment structure also limits causal interpretation. Because the experiment was not a complete factorial design, it can compare treatment profiles but cannot isolate independent effects of AMF inoculation, compost amendment or

mineral fertilization. The absence of 50% compost without AMF, 50% NPK/urea without AMF, a complete mineral-fertilizer reference without AMF and a sterilized-inoculum control prevents formal testing of AMF × compost or AMF × mineral-fertilizer interactions. This limitation is particularly important when interpreting the apparent promise of AMF + 50% compost and the weak response of AMF + 50% NPK/urea. In addition, in the AMF + 50% NPK/urea treatment, only the NPK dose and first urea split were applied before final sampling; therefore, this treatment reflects the reduced mineral-fertilization schedule applied during the 56-day vegetative period rather than the full planned NPK/urea program through panicle initiation.

Mechanistic interpretation is further constrained by the absence of direct functional measurements. Compost chemical composition was not determined in the present experiment, and the AMF inoculum was a mixed native consortium characterized morphologically at the genus level without infective propagule density, functional viability or molecular confirmation. Plant nutrient uptake, tissue nutrient concentrations, soil nutrient dynamics, microbial activity, photosynthesis and mycorrhizal dependency were not measured. Consequently, mechanisms such as phosphorus mobilization, nitrogen acquisition, microbial stimulation or nutrient-use efficiency should be discussed as plausible explanations rather than demonstrated processes.

Finally, the statistical and multivariate results should be interpreted with appropriate caution. Height and tiller number were measured repeatedly on the same pots, colonization variables were analyzed as percentages, and PCA and hierarchical clustering were used as exploratory summaries rather than confirmatory tests. If individual longitudinal and colonization-count data are available, future analyses should consider mixed-effects models, binomial or beta-regression approaches, effect sizes and 95% confidence intervals. Future work should test the AMF-compost approach across multiple rice cultivars, compost sources, soil types and field environments before practical recommendations are made.

6. Conclusions

This greenhouse proof-of-concept study shows that AMF root colonization in rice can be successfully established without necessarily translating into stronger early vegetative performance. The mixed native AMF inoculum colonized roots of rice cultivar FKR64 in the sandy, low-phosphorus substrate used in this experiment, especially in inoculated treatments. However, plant height, tillering and biomass responses were not proportional to colonization frequency or intensity, indicating that mycorrhizal establishment and early plant performance represented partly distinct response dimensions under greenhouse conditions.

Compost-containing treatments showed favorable mean early-growth profiles among the management options tested, although significant pairwise differences varied with the response variable. AMF + 50% compost was associated with the greatest mean final plant height, whereas AMF + 100% compost and 100% com-

post showed more favorable responses for root biomass or final tillering. In contrast, AMF + 50% NPK/urea combined high mean mycorrhizal colonization with comparatively low mean growth responses under the reduced mineral-fertilization schedule actually applied before final sampling. Its final height was significantly lower than that of the compost-containing treatments, but its final tiller number and aboveground biomass did not differ significantly from theirs. These treatment contrasts suggest that the fertility context influenced whether AMF colonization coincided with measurable plant performance, but they do not demonstrate a formal AMF × compost interaction, synergy, optimal treatment, or nutrient-transfer mechanism.

The study should therefore be interpreted as a greenhouse proof-of-concept identifying promising treatment contrasts for future field validation. The apparent promise of AMF + 50% compost remains provisional because the experiment did not include a 50% compost treatment without AMF; consequently, its response cannot be attributed specifically to AMF, compost dose reduction, or their interaction. The response of AMF + 50% NPK/urea should also be interpreted cautiously because only the NPK dose and first urea split were applied during the 56-day vegetative period, not the full planned reduced mineral-fertilization program. The experiment also did not measure nutrient uptake, did not characterize compost chemistry and did not evaluate grain yield or field performance. Future research should combine factorial treatment structures, chemically characterized compost, explicit quantification of nutrient inputs from NPK and urea, nutrient-uptake measurements, molecular or functional characterization of the inoculum, multi-site field validation and dose-response testing before AMF-compost strategies are recommended for rice production in Sahelian systems.

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Author Contributions

Conceptualization, H.H. and M.D.; methodology, T.M.A., H.H. and M.D.; investigation, T.M.A.; formal analysis, T.M.A. and H.H.; writing—original draft preparation, T.M.A.; writing—review and editing, H.H., A.A.B.Y.Z. and M.D.; supervision, H.H. and M.D. All authors have read and approved the final manuscript.

Conflicts of Interest

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

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Supplementary

Table S1. Approximate 95% confidence intervals for rice plant height across treatments and measurement dates.

Treatments	T1	T2	T3	T4
100% AMF	17.84 - 19.22	22.70 - 25.98	28.64 - 38.70	38.10 - 46.36
AMF + 50% compost	15.13 - 19.29	19.55 - 28.31	30.59 - 50.23	37.45 - 63.89
AMF + 50% NPK/urea	13.71 - 16.61	14.13 - 18.55	16.23 - 35.59	7.21 - 48.95
AMF + 100% compost	15.23 - 17.13	18.44 - 21.94	21.77 - 28.59	39.27 - 53.15
100% compost	12.47 - 14.45	16.63 - 26.55	24.46 - 45.58	25.75 - 67.21
T0	17.17 - 19.01	20.32 - 23.32	27.33 - 35.07	32.58 - 45.54

Note: Confidence intervals are expressed in cm and were calculated as mean ± 2.306 × SE using $t_{0.975,8}$. T1, T2, T3 and T4 indicate measurements taken at 14, 28, 42 and 56 days after sowing, respectively.