

VARIETY-SPECIFIC RESPONSES OF MAIZE TO MYCORRHIZAL INOCULATION IN LOW-FERTILITY TROPICAL SOILS

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Abstract

Maize (*Zea mays* L.) productivity in tropical soils is often limited by acidity, low fertility, and nutrient deficiency. This study evaluated the effects of arbuscular mycorrhizal fungi (AMF) inoculation on the vegetative growth of three maize varieties namely: Sammaz-52, Oba-98, and Oba Super-2, which were cultivated in acidic sandy loam soils at the University of Port Harcourt, Nigeria. We used a completely randomized design with three AMF levels (0%, 5%, and 10%) and three replicates per treatment. Soils were sandy (sand 817–832 gkg⁻¹), moderately acidic (pH 4.70–5.30), with low to moderate organic carbon (4.78–13.56 gkg⁻¹), total nitrogen (0.98–1.75 gkg⁻¹), and available phosphorus (19.40–41.80 mgkg⁻¹). AMF inoculation significantly enhanced plant height, leaf area, and stem girth across the different cultivars. At 12 weeks after planting, the tallest plants were recorded in Oba Super 2 with 10 % AMF (382.33 cm² leaf area; 88–103 cm height), while Oba-98 and Sammaz-52 attained 84.0 and 91.7 cm, respectively, under the same treatment. The highest leaf area was observed in Oba Super-2 at 382.33 cm² (10% AMF), followed by Oba-98 (336.67 cm²) and Sammaz-52 (338.33 cm²). Stem girth responses were variety- and dose-dependent: Oba-98 performed best at 5 % AMF (5.33 cm), Oba Super-2 at 10 % AMF (5.13 cm), and Sammaz-52 showed limited response to higher inoculation (4.73–4.90 cm). Enhanced growth was attributed to improved nutrient uptake, particularly phosphorus and nitrogen, facilitated by mycorrhizal colonization, mitigating the constraints of acidic, low-fertility soils. The results highlight that varietal selection and optimized AMF application can significantly

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improve vegetative development, offering a sustainable strategy for maize production under tropical soil conditions.

Introduction

Maize (*Zea mays* L.) is one of the most widely cultivated cereal crops globally and constitutes a major staple food, livestock feed, and industrial raw material, particularly in sub-Saharan Africa. In Nigeria, maize significantly contributes to household food security and national agricultural output due to its wide adaptability and diverse uses. According to the Food and Agriculture Organization (FAO, 2019), maize remains a cornerstone crop in developing economies, where population growth continues to exert pressure on food production systems. Despite its importance, maize productivity in many tropical regions remains suboptimal, largely due to soil-related constraints. Tropical soils are often highly weathered, acidic, low in organic matter, and deficient in nitrogen and phosphorus. These conditions limit nutrient availability and reduce crop growth and yield potential (Veneman, 2012; Tiessen, 2015). Soil physical properties, including texture and structure, further influence water retention, aeration, and root development, whereas chemical properties, such as pH, organic carbon, exchangeable bases, and cation exchange capacity, determine nutrient dynamics and plant uptake efficiency.

Therefore, sustainable soil fertility management practices are essential for improving maize production under such conditions. The use of arbuscular mycorrhizal fungi (AMF) has gained considerable attention as an environmentally friendly and cost-effective approach. Arbuscular mycorrhizae form symbiotic associations with plant roots, enhancing nutrient acquisition, particularly phosphorus, nitrogen uptake, water absorption, and tolerance to soil acidity and nutrient stress (Johnson et al., 2017; Kapoor et al., 2021). In addition, mycorrhizal colonization improves soil structure and biological activity, thereby indirectly supporting plant growth.

Mycorrhiza application positively influences maize growth parameters such as plant height, leaf area, stem girth, and biomass accumulation (Elian et al., 2022; Ma et al., 2021). These growth attributes are closely linked to photosynthetic capacity and yield potential. However, the magnitude of mycorrhizal response is not uniform and often depends on soil conditions, application rate, and crop genotype. Varietal differences in root architecture and mycorrhizal compatibility can lead to differential growth responses under similar environmental conditions (Rasmussen et al., 2020).

Understanding the interaction between soil properties, mycorrhiza application levels, and maize varieties is critical for optimizing the benefits of mycorrhizal technology in maize-based production systems. This study aimed to characterize the physical and chemical properties of the experimental soils and evaluate the effects of varying mycorrhiza application rates on the growth performance of three maize varieties. The outcomes of this study are expected to provide empirical evidence to support the integration of mycorrhiza into sustainable maize production strategies under tropical soil conditions.

Materials and Methods

Experimental Site

The experiment was conducted at the University of Port Harcourt Teaching and Research Farm, Choba, Rivers State, Nigeria. It is located at latitude 4°45'N and longitude 6°59'E. The site lies within the humid tropical rainforest zone, characterized by high rainfall (2,000–2,500 mm annually) and temperatures ranging from 25°C to 32°C, which are favorable for maize cultivation.

Experimental Materials

The materials used in the study included the following:

- Maize seeds (*Zea mays* L.): Three hybrid varieties—Sammaz-52, Oba-98, and Oba Super-2—were obtained from the Rivers State Agricultural Development Program.

- AMF: *Glomus mosseae* spores, sourced from the United Kingdom.
- Soil: Sterilized sandy loam was collected from the experimental site. Sterilization eliminated indigenous microorganisms to ensure controlled inoculation with AMF.
- Planting equipment: Plastic buckets (7 L), watering cans, labels, and other necessary tools were used.
- Replication and treatments: Each maize variety was subjected to three AMF inoculation levels (0 %, 5 %, and 10%), with three replicates per treatment, resulting in 27 experimental units (buckets).

Experimental Design and Layout

The experiment was arranged in a CRD with three treatments:

- T1 (control): maize without AMF inoculation.
- T2: Maize inoculated with 5 % AMF.
- T3: Maize inoculated with 10 % AMF.

Each bucket contained one maize plant and was arranged on a flat platform in a screen house to ensure uniform light and temperature exposure.

Soil sampling and analysis

Pre-planting soil sampling: Soil was collected at depths of 0–15 cm at multiple points, bulked, air-dried, and sieved through a 2-mm mesh for laboratory analyses. The following parameters were determined using standard procedures: Soil pH: Measured in a 1:2.5 soil-to-water suspension using a pH meter (Soil Survey Staff, 2014). Total organic carbon (TOC): the Walkley–Black wet oxidation method (Nelson and Sommers, 1996). Total N: Micro-Kjeldahl digestion method (Bremner, 1996). Available phosphorus (P): Bray I extraction method (Olsen and Sommers, 1982). Exchangeable bases (Ca, Mg, K, Na): Determined by atomic absorption spectrophotometry (Ca and Mg) and flame photometry (K and Na) after extraction with 1 N ammonium acetate (Rayment and Lyons, 2011).

Post-harvest soil analysis was similarly conducted to assess changes in chemical properties after the experiment.

Planting Procedure

The buckets were filled with 10 kg of sterilized soil. AMF inoculum was incorporated into the soil for the treatment groups (5 % or 10 %), whereas no AMF was added to the control buckets. Two maize seeds were planted per bucket and were thinned to one vigorous seedling 7 days after planting. Plants were watered daily to maintain field capacity, and all cultural practices were uniformly applied. No additional fertilizer was used to ensure that the observed effects were solely due to AMF inoculation.

Data Collection

Growth parameters were measured at the following biweekly intervals:

- Plant height (cm): From the soil surface to the tip of the tallest leaf using the meter rule.
- Stem girth (cm): Measured 5 cm above the soil using a Vernier caliper.
- Number of leaves: Counted manually per plant.
- Leaf area (cm²): Calculated using the formula $\text{Leaf Area} = L \times W$ (Pandey & Singh, 2011), where L = leaf length and W = leaf width.

Data Analysis

Data were subjected to analysis of variance using SPSS version 25. Treatment means were compared using the least significant difference at 5 % probability ($p \leq 0.05$).

Experimental Timeline

The study was conducted over 12 weeks. Growth parameters were recorded biweekly, and yield and postharvest soil analyses were conducted at the end of the experiment.

Results

Physical characteristics of the soil at the experimental sites

Table 1: Physical characteristics of soil at the experimental sites

Varieties (test crops)	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)
Oba-98			
Control	817.00±2.00 ^d	89.00±1.00 ^a	94.00±1.00 ^b
5 %	832.00±2.00 ^a	74.00±1.00 ^d	94.00±1.00 ^b
10 %	827.00±1.00 ^b	79.00±1.00 ^c	94.00±1.00 ^b
Oba Super-2			
Control	822.00±1.00 ^c	79.00±1.00 ^c	99.00±1.00 ^a
5 %	822.00±1.00 ^c	79.00±1.00 ^c	99.00±1.00 ^a
10 %	822.00±1.00 ^c	84.00±1.00 ^b	94.00±1.00 ^b
Sammaz-52			
Control	822.00±1.00 ^c	84.00±1.00 ^b	94.00±1.00 ^b
5 %	822.00±1.00 ^c	84.00±1.00 ^b	94.00±1.00 ^b
10 %	827.00±1.00 ^b	79.00±1.00 ^c	94.00±1.00 ^b

Results are expressed as mean ± standard deviation (n = 3). Mean values with different letters (a-d) as superscripts Down the column are significantly ($p < 0.05$) different.

Table 1 shows the particle size distribution of the soils used for cultivating different maize varieties under varying levels of AMF application. Sand constituted the largest proportion of the soil in all treatments, with values ranging from 817.00 to 832.00 g kg^{-1} . This sand dominance indicates that the experimental soils are predominantly sandy in texture. Significant differences ($p < 0.05$) in the sand content were observed among the treatments. The highest sand fraction was recorded in Oba-98 at 5 % AMF application, whereas the lowest occurred in Oba-98 under the control treatment. However, these differences were relatively small, suggesting only minor variation in sand content across the experimental sites.

Silt content varied from 74.00 to 89.00 g kg^{-1} and differed significantly among treatments. The highest silt content was observed in Oba-98 under the control, whereas the lowest was recorded in Oba-98 at 5% AMF application. This variation reflects slight differences in the finer soil fractions among locations and treatments.

The clay content showed a narrow range of 94.00 to 99.00 g kg^{-1} . The highest clay values were observed in Oba Super-2 at both the control and 5 % AMF application levels, while most other treatments, including the 10 % AMF application, recorded similar lower clay contents. Although statistically significant, these differences were small and did not substantially alter the overall soil texture.

The soils across all treatments can be classified as sandy soils with low silt and clay fractions. The lack of a consistent trend in particle size distribution with increasing AMF application (from control to 5 % and 10 %) indicates that AMF treatments did not influence soil texture. Therefore, the observed differences in soil physical properties are likely inherent to the experimental sites rather than treatment-induced, providing a relatively uniform physical soil environment for evaluating crop and AMF effects.

Table 2: Soil chemical characteristics of the experimental sites

Varieties (test crop)	pH (H ₂ O)	P (mg/kg)	N (g/kg)	OC (g/kg)	OM (g/kg)	Ca (Cmol/kg)	Mg (Cmol/kg)	K (Cmol/kg)	Na (Cmol/kg)	EA (Cmol/kg)	ECEC (Cmol/kg)	BS (%)
Oba-98												
Control	5.00 ± 0.20 ^{bc}	28.30 ± 1.18 ^d	1.68 ± 0.06 ^a	13.5 ± 0.33 ^a	23.3 ± 0.11 ^a	5.60 ± 0.12 ^a	1.60 ± 0.05 ^b	0.12 ± 0.01 ^c	0.38 ± 0.03 ^a	2.56 ± 0.04 ^a	10.25 ± 0.02 ^a	75.11 ± 0.04 ^g
5%	5.30 ± 0.10 ^a	19.40 ± 0.16 ^g	1.40 ± 0.09 ^c	10.3 ± 0.08 ^c	17.8 ± 0.10 ^c	4.00 ± 0.20 ^c	1.20 ± 0.05 ^c	0.35 ± 0.02 ^b	0.34 ± 0.02 ^{bc}	2.32 ± 0.01 ^b	8.20 ± 0.02 ^c	71.76 ± 0.20 ^h
10%	5.20 ± 0.10 ^{ab}	22.30 ± 0.18 ^f	1.54 ± 0.09 ^b	11.9 ± 0.10 ^c	20.6 ± 0.21 ^c	4.40 ± 0.20 ^b	1.20 ± 0.05 ^c	0.39 ± 0.04 ^a	0.37 ± 0.02 ^{ab}	1.92 ± 0.01 ^c	8.28 ± 0.01 ^b	76.82 ± 0.58 ^f
Oba Super-98												
Control	5.00 ± 0.20 ^{bc}	31.70 ± 1.14 ^c	1.75 ± 0.06 ^a	13.1 ± 0.02 ^b	22.6 ± 0.23 ^b	4.00 ± 0.20 ^c	2.00 ± 0.05 ^a	0.41 ± 0.02 ^a	0.34 ± 0.02 ^{bc}	1.12 ± 0.01 ^g	7.86 ± 0.02 ^d	85.83 ± 0.38 ^a
5%	5.10 ± 0.00 ^{ab}	41.80 ± 0.60 ^a	1.40 ± 0.03 ^c	10.7 ± 0.04 ^d	18.5 ± 0.20 ^d	4.40 ± 0.20 ^b	0.80 ± 0.10 ^d	0.40 ± 0.02 ^a	0.33 ± 0.01 ^{cd}	1.60 ± 0.01 ^e	7.52 ± 0.01 ^e	78.81 ± 0.16 ^c
10%	5.20 ± 0.10 ^{ab}	25.20 ± 0.08 ^c	1.26 ± 0.03 ^d	8.77 ± 0.08 ^f	15.1 ± 0.05 ^f	4.40 ± 0.20 ^b	0.80 ± 0.10 ^d	0.35 ± 0.02 ^b	0.37 ± 0.02 ^{ab}	1.12 ± 0.01 ^g	7.03 ± 0.02 ^g	84.15 ± 0.03 ^b
Sammaz-52												
Control	4.70 ± 0.10 ^d	22.90 ± 0.31 ^f	1.68 ± 0.04 ^a	13.5 ± 0.32 ^a	23.3 ± 0.17 ^a	4.00 ± 0.20 ^c	1.20 ± 0.05 ^c	0.18 ± 0.01 ^d	0.27 ± 0.02 ^e	1.28 ± 0.01 ^f	6.92 ± 0.02 ^h	81.60 ± 0.39 ^d
5%	4.80 ± 0.10	37.70 ± 0.50 ^b	1.40 ± 0.02 ^c	10.7 ± 0.06 ^d	18.5 ± 0.20 ^d	2.80 ± 0.12 ^d	0.80 ± 0.10 ^d	0.42 ± 0.02 ^a	0.30 ± 0.01 ^{dc}	1.84 ± 0.01 ^d	6.16 ± 0.02 ⁱ	70.24 ± 0.03 ⁱ
10%	4.70 ± 0.10 ^d	37.70 ± 0.50 ^b	0.98 ± 0.03 ^c	4.78 ± 0.07 ^g	8.25 ± 0.03 ^g	4.40 ± 0.20 ^b	1.20 ± 0.05 ^c	0.22 ± 0.01 ^c	0.27 ± 0.02 ^e	1.28 ± 0.01 ^f	7.37 ± 0.02 ^f	82.67 ± 0.43 ^c

BS = Base Saturation, values are means ± SD (n = 3). Different superscripts within columns differ significantly (p < 0.05), ECEC = effective cation exchange capacity, EA = exchangeable acidity

Table 2 summarizes the chemical properties of soils cultivated with different maize varieties under varying AMF application rates (control, 5 %, and 10 %). The soil pH ranged from 4.70 to 5.30, indicating that all soils were moderately to strongly acidic. Significant (p < 0.05) differences in pH were observed among treatments, with slightly higher pH values recorded in Oba-98 treatments, particularly under 5 % and 10 % AMF application, while Sammaz-52 soils exhibited the most acidic conditions. This level of acidity is typical of many tropical soils and may influence the availability of nutrients, particularly phosphorus and base cations.

Available phosphorus (P) varied widely across treatments, ranging from 19.40 to 41.80 mg/kg. The highest P content was observed in Oba Super-2 under 5 % AMF application, while the lowest occurred in Oba-98 under 5 % AMF application. These significant differences suggest variability in inherent soil fertility and possible treatment effects, with generally moderate to high P levels across most sites.

The total nitrogen (N) content ranged from 0.98 to 1.75 g/kg. Higher N values were recorded in the control treatments of Oba-98, Oba Super-2, and Sammaz-52, whereas reductions were observed at higher AMF

application rates, particularly in Sammaz-52 under 10 % AMF application. This pattern indicates moderate nitrogen status, with significant differences among treatments reflecting variations in OM content and nutrient dynamics.

Soil organic carbon (OC) and organic matter (OM) followed similar trends, with OC ranging from 4.78 to 13.56 gkg⁻¹ and OM from 8.25 to 23.38 gkg⁻¹. The highest OC and OM values were generally observed in control treatments (Oba-98 control and Sammaz-52 control), while the lowest values occurred in Sammaz-52 under 10 % AMF application. These results indicate a decline in soil organic reserves with increasing AMF application levels in some varieties, which may have implications for soil structure, nutrient retention, and microbial activity. The exchangeable base cations (Ca, Mg, K, and Na) significantly differed among the treatments. Calcium was the dominant base cation, ranging from 2.80 to 5.60 col kg⁻¹, with the highest values recorded in Oba-98 under the control treatment. The Mg values ranged from 0.80 to 2.00 col kg⁻¹, with Oba Super-2 under the control exhibiting the highest Mg content. Potassium and sodium levels were relatively low across all treatments, typical of highly weathered soils, although significant variations were still evident.

Exchangeable acidity (EA) ranged from 1.12 to 2.56 col kg⁻¹, with higher values generally associated with lower pH soils, particularly Oba-98 under the control treatment. The effective cation exchange capacity (ECEC) varied from 6.16 to 10.25 col kg⁻¹, reflecting low to moderate nutrient-holding capacity consistent with sandy, acidic soils. The highest ECEC was recorded in Oba-98 under the control, while Sammaz-52 under 5 % AMF application exhibited the lowest value.

BS was relatively high across treatments, ranging from 70.24 % to 85.83 %. The highest BS was observed in Oba Super-2 under the control treatment, indicating a greater proportion of exchange sites occupied by basic cations, while the lowest BS was observed in Sammaz-52 under 5 % AMF application. Despite soil acidity, the generally high base saturation suggests a moderate fertility status and a reasonable supply of exchangeable base nutrients. The soils across all experimental sites were generally acidic with moderate nutrient status, low to moderate organic matter content, and relatively high base saturation. Significant differences among maize varieties and AMF application rates (control, 5 %, and 10 %, respectively) indicate variability in soil chemical properties, which may influence crop performance and nutrient uptake in subsequent growth and yield responses.

Table 3: Effect of mycorrhiza on plant height of three maize varieties (cm)

Treatment	2WAP	4WAP	6WAP	8WAP	10WAP	12WAP
Oba-98						
Control	24.67 ± 0.80 ^{ab}	27.00 ± 0.47 ^b	9.33 ± 0.21 ^e	32.00 ± 0.44 ^h	36.00 ± 0.35 ^g	67.33 ± 0.21 ^h
5 %	24.00 ± 0.76 ^{bc}	28.00 ± 0.65 ^{ab}	33.00 ± 0.32 ^a	39.67 ± 0.46 ^b	47.33 ± 0.21 ^b	84.00 ± 0.48 ^f
10 %	25.33 ± 0.71 ^a	27.67 ± 0.43 ^b	33.67 ± 0.55 ^a	42.33 ± 0.21 ^a	52.67 ± 0.55 ^a	83.33 ± 0.21 ^f
Oba Super-2						
Control	22.33 ± 0.21 ^d	24.67 ± 0.46 ^c	29.67 ± 0.55 ^d	34.33 ± 0.22 ^f	42.67 ± 0.53 ^d	103.00 ± 0.35 ^a
5 %	22.67 ± 0.55 ^d	25.67 ± 0.44 ^c	30.67 ± 0.57 ^c	33.33 ± 0.23 ^g	140.00 ± 0.35 ^f	99.67 ± 0.31 ^b
10 %	24.00 ± 0.49 ^{bc}	28.00 ± 0.77 ^{ab}	33.00 ± 0.05 ^a	36.00 ± 0.35 ^d	45.00 ± 0.73 ^c	88.00 ± 0.76 ^e
Sammaz-52						
Control	23.33 ± 0.09 ^{cd}	29.00 ± 0.66 ^a	33.33 ± 0.24 ^a	38.00 ± 0.35 ^c	42.67 ± 0.49 ^d	76.67 ± 0.46 ^g

5 %	21.33 ± 0.23 ^e	25.00 ± 0.31 ^e	29.33 ± 0.12 ^d	35.33 ± 0.21 ^e	42.33 ± 0.21 ^d	93.00 ± 0.32 ^e
10 %	25.00 ± 0.77 ^{ab}	28.00 ± 0.65 ^{ab}	32.00 ± 0.42 ^b	36.00 ± 0.38 ^d	41.00 ± 0.75 ^e	91.67 ± 0.40 ^d

C: Control, WAP: Weeks after planting values are mean ± SD, n = 3. Different superscripts within the columns differ significantly ($p < 0.05$).

Table 3: Effect of Mycorrhiza on Plant Height of Three Maize Varieties

Table 3 presents the effect of different mycorrhiza application levels (control, 5 %, and 10 %) on the plant height of three maize varieties measured from 2 to 12 weeks after planting (WAP). Plant height increased progressively with crop age across all varieties and sampling periods, reflecting normal vegetative growth patterns.

For Oba-98, plant height differed significantly ($p < 0.05$) among treatments at all growth stages. At early growth (2–4 WAP), differences among treatments were relatively small; however, from 6 WAP onward, mycorrhiza application markedly enhanced plant height compared with the control. Both 5 % and 10 % treatments produced significantly taller plants than the control at 6–12 WAP, with the 10 % treatment consistently recording the highest values, particularly at 8 and 10 WAP. By 12 WAP, mycorrhiza-treated plants attained greater heights than the control, indicating a strong positive response to inoculation.

Significant differences were also observed among treatments across growth stages in Oba Super-2. The control treatment produced the tallest plants at 12 WAP, although mycorrhiza-treated plants (5 % and 10 %, respectively) showed comparable and sometimes superior growth at intermediate stages (6–10 WAP). The 10 % mycorrhiza treatment notably enhanced plant height at 6 and 8 WAP compared with the control and 5 % treatment, suggesting that this variety responded more strongly to higher mycorrhiza levels during active vegetative growth.

For Sammaz-52, plant height varied significantly with mycorrhiza application at all sampling periods. At early stages (2–4 WAP), differences among treatments were modest, but mycorrhiza-treated plants generally outperformed the control from 6 WAP onward. The 10 % treatment consistently produced taller plants than the control at most growth stages, while the 5 % treatment also resulted in significant height increases, particularly at 12 WAP.

Generally, mycorrhiza application significantly enhanced maize plant height across varieties, with more pronounced effects observed from mid to late growth stages (6–12 WAP). The 10% mycorrhiza treatment produced the tallest plants, indicating a dose-dependent response. These results demonstrate that mycorrhizal inoculation improves vegetative growth in maize, although the magnitude of response varies among varieties, reflecting differences in varietal compatibility and responsiveness to mycorrhizal association.

Table 4: Effect of Mycorrhiza on Leaf Area of Three Varieties of Maize (cm²)

Treatment	2 WAP	4 WAP	6 WAP	8 WAP	10 WAP	12 WAP
Oba-98						
Control	64.67 ± 0.44 ^e	118.00 ± 0.57 ^f	159.33 ± 0.4 ^g	232.33 ± 0.37 ^f	258.67 ± 0.42 ^g	291.67 ± 0.55 ^g
5 %	67.33 ± 0.35 ^d	122.33 ± 0.42 ^e	168.33 ± 0.64 ^f	246.67 ± 0.42 ^e	282.33 ± 0.57 ^e	322.00 ± 0.50 ^e
10 %	69.00 ± 0.57 ^c	126.67 ± 0.67 ^d	176.00 ± 0.52 ^e	257.33 ± 0.46 ^d	295.67 ± 0.44 ^d	336.67 ± 0.58 ^d
Oba Super-2						
Control	70.33 ± 0.52 ^c	133.33 ± 0.35 ^c	180.33 ± 0.44 ^d	268.33 ± 0.35 ^c	312.33 ± 0.40 ^c	358.33 ± 0.42 ^c

5 %	72.00 ± 0.49b	136.67 ± 0.53b	185.67 ± 0.41c	274.00 ± 0.46b	326.00 ± 0.58b	370.00 ± 0.65b
10 %	74.33 ± 0.55a	139.33 ± 0.41a	190.67 ± 0.38b	281.33 ± 0.35a	335.33 ± 0.50a	382.33 ± 0.58a
Sammaz-52						
Control	63.33 ± 0.46f	120.67 ± 0.50f	161.00 ± 0.43g	234.67 ± 0.42f	263.33 ± 0.46f	302.67 ± 0.44f
5 %	65.00 ± 0.40e	124.00 ± 0.52e	169.33 ± 0.46f	248.33 ± 0.49e	284.33 ± 0.58e	324.33 ± 0.46e
10 %	66.67 ± 0.38d	127.00 ± 0.40d	175.33 ± 0.44e	258.33 ± 0.44d	296.67 ± 0.52d	338.33 ± 0.41d

Values are presented in mean ± SD, n = 3)...Different superscripts within columns differ significantly (p < 0.05).

Table 4: Effect of Mycorrhiza on Leaf Area of Three Maize Varieties

Table 4 shows the effect of mycorrhiza application on leaf area development of three maize varieties measured from 2 to 12 weeks after planting (WAP). Across all varieties and sampling periods, leaf area increased progressively with plant age, reflecting normal canopy expansion during vegetative growth.

For Oba-98, leaf area differed significantly (p < 0.05) among treatments at all growth stages. Mycorrhiza application resulted in a consistent and progressive increase in leaf area relative to that of the control. The 10% mycorrhiza treatment produced the largest leaf area at each sampling period, followed by the 5% treatment, whereas the control consistently recorded the lowest values. In this variety, this trend indicates a clear dose-dependent response of leaf area development to mycorrhiza inoculation.

In Oba Super-2, significantly higher leaf area values were observed compared with the other varieties across all treatments and growth stages. The leaf area increased with increasing mycorrhizal levels, with the 10 % treatment consistently recording the highest values from 2 to 12 WAP. The superiority of Oba Super-2 in leaf area development suggests a strong varietal responsiveness and effective symbiotic association with mycorrhiza, particularly at higher inoculation levels.

For Sammaz-52, the leaf area also increased significantly with mycorrhiza application across all sampling periods. Although the absolute values were generally lower than those of Oba Super 2, both 5 % and 10 % mycorrhiza treatments produced significantly larger leaf areas than the control, with the 10% treatment again being superior. This indicates that Sammaz-52 also benefited from mycorrhiza, although to a lesser extent than Oba Super-2.

Mycorrhiza application significantly enhanced leaf area development in all three maize varieties, with the 10 % inoculation level consistently producing the largest leaf area across growth stages. The enhanced leaf area under mycorrhiza treatment suggests improved nutrient uptake and photosynthetic capacity, which are critical for biomass accumulation and subsequent yield formation. Varietal differences in response highlight the importance of genotype–mycorrhiza compatibility in the optimization of maize growth.

Table 5: Effect of mycorrhiza on the stem girth of 3 varieties of maize

Treatments	2WAP	4WAP	6WAP	8WAP	10WAP	12WAP
Oba-98						
Control	2.77±0.08 ^b	3.67±0.29 ^a	3.97±0.01 ^a	4.17±0.04 ^{ab}	4.53±0.04 ^{abc}	4.80±0.04 ^{cd}
5 %	2.60±0.08 ^{bc}	3.47±0.21 ^{ab}	3.87±0.12 ^{ab}	4.07±0.04 ^b	4.60±0.08 ^{ab}	5.33±0.12 ^a
10 %	2.40±0.09 ^{cd}	3.33±0.09 ^{abc}	3.53±0.04 ^{cd}	3.57±0.08 ^d	4.43±0.19 ^{abc}	5.07±0.06 ^b

Oba Super-2						
Control	2.30±0.15 ^d	3.07±0.05 ^{cd}	3.43±0.22 ^{de}	4.23±0.11 ^a	4.67±0.29 ^a	5.37±0.08 ^a
5 %	2.34±0.08 ^d	2.93±0.04 ^{de}	3.27±0.15 ^{ef}	3.83±0.04 ^c	4.27±0.08 ^c	4.63±0.04 ^e
10 %	2.60±0.18 ^{bc}	3.30±0.18 ^{bc}	3.77±0.12 ^{ab}	4.07±0.04 ^b	4.47±0.05 ^{abc}	5.13±0.02 ^b
Sammaz-52						
Control	2.40±0.19 ^{cd}	3.40±0.28 ^{abc}	3.67±0.10 ^{bc}	4.13±0.03 ^{ab}	4.40±0.08 ^{bc}	5.07±0.02 ^b
5 %	3.03±0.01 ^a	3.47±0.22 ^{ab}	3.73±0.06 ^{bc}	4.17±0.04 ^{ab}	4.27±0.08 ^c	4.90±0.05 ^c
10 %	2.27±0.15 ^d	2.67±0.10 ^e	3.17±0.06 ^f	3.83±0.08 ^c	4.27±0.12 ^c	4.73±0.15 ^{de}

Results are expressed as mean, $\pm$ standard deviation ($n = 3$). Mean values with different letters (a-f) as superscripts down the column are significantly ($p < 0.05$) different.

Table 5: Effect of Mycorrhiza on Stem Girth of Three Maize Varieties

Table 5 presents the effect of different mycorrhiza application levels on the stem girth of three maize varieties measured from 2 to 12 weeks after planting (WAP). Across all varieties and treatments, stem girth increased progressively with plant age, indicating normal maize plant structural development.

For Oba-98, stem girth differed significantly ($p < 0.05$) among treatments at most growth stages. At early growth (2–4 WAP), the control plants generally recorded higher or comparable stem girth values relative to the mycorrhiza-treated plants. However, from 8 WAP onward, mycorrhiza application, particularly at 5 %, resulted in increased stem girth compared with the control and 10 % treatment. By 12 WAP, the 5% mycorrhiza treatment produced the largest stem girth, indicating that moderate mycorrhiza application was more effective for enhancing stem thickness in this variety.

Significant treatment effects were observed across sampling periods in Oba Super-2. The 10 % mycorrhiza treatment consistently enhanced stem girth compared with the control and 5 % treatment at most stages, particularly from 6 to 12 WAP. Although the control exhibited relatively high values at later stages, plants receiving 10 % mycorrhiza generally showed superior stem girth, suggesting a positive response to higher mycorrhiza levels in this variety.

For Sammaz-52, the stem girth responded variably to mycorrhiza application. At 2 WAP, the 5 % treatment recorded the highest stem girth, indicating an early stimulatory effect. However, the control and 5% treatments often produced comparable or higher values than the 10% treatment at later growth stages (6–12 WAP). The 10 % mycorrhiza treatment consistently resulted in the lowest stem girth values across several sampling periods, suggesting that excessive mycorrhiza application may not be optimal for stem development in this variety.

Mycorrhiza application significantly influenced stem girth development in maize, but the response was variety- and dose-dependent. While moderate application (5 %) enhanced the stem girth in Oba-98 and Sammaz-52, higher application (10 %) was more beneficial for Oba Super-2. These results indicate differential varietal compatibility with mycorrhiza and highlight the importance of optimizing application rates to improve the structural growth of maize.

Discussion

The results of this study demonstrated that maize growth was strongly influenced by soil chemical properties, maize variety, and mycorrhiza application. The soils at the experimental sites were predominantly sandy, with moderate silt and low clay content, consistent with typical tropical soils (Table 1). The low clay and moderate organic matter content contributed to the limited nutrient-holding capacity, as reflected in the measured effective cation exchange capacity (ECEC). Despite this, the base saturation values were relatively high, indicating that exchangeable bases such as Ca^{2+} , Mg^{2+} , and K^{+} were sufficiently available for plant uptake. Soil pH ranged from 4.70 to 5.30, indicating acidic conditions that can reduce the availability of some nutrients—particularly

phosphorus—and may exacerbate metal toxicity in marginal soils if unmanaged (Brady & Weil, 2016; Foth, 1990).

Total organic carbon (TOC) and nutrient analyses of the soil indicated moderate levels of organic matter and nitrogen, while available phosphorus was generally low. Such nutrient status is characteristic of highly weathered tropical soils and suggests that nutrient limitations—particularly for phosphorus and nitrogen—could constrain maize growth in untreated plots (Sanchez, 2019; Weil & Brady, 2017). Low clay content, coupled with acidic soil pH, likely reduces the soil's buffering capacity and cation retention, thereby limiting nutrient availability and increasing susceptibility to nutrient losses through leaching (Sanchez, 2019). These conditions underscore the importance of soil amendments or biological interventions, such as arbuscular mycorrhizal fungi inoculation, which enhance nutrient acquisition—especially phosphorus—and improve nutrient-use efficiency under low-fertility, acidic soil environments (Barea et al., 2011; Chen et al., 2018).

Mycorrhiza application significantly enhanced vegetative growth across all three maize varieties, as evidenced by increased plant height (Table 3), leaf area (Table 4), and stem girth (Table 5) compared with the control group. The improvement in growth parameters is strongly linked to the chemical properties of the soil. Mycorrhizal colonization facilitates greater access to phosphorus, nitrogen, and other essential nutrients in sandy, acidic soils that are otherwise poorly mobile. Mycorrhizal hyphae enhance nutrient uptake from low-fertility soils by extending the effective root surface area, mitigating the limitations posed by low organic matter and ECEC (Smith & Read, 2008; Hussain et al., 2022).

The treatment with 10% mycorrhiza generally produced the tallest plants and largest leaf areas, indicating a dose-dependent response, although varietal differences were evident. Oba Super 2 exhibited the greatest leaf area and overall vegetative vigor, suggesting higher compatibility and responsiveness to mycorrhizal inoculation, likely due to its root morphology and nutrient demand. These findings highlight the interplay between soil chemical properties and plant genotype in determining the efficiency of marginal soil nutrient uptake (Smith & Smith, 2011; Egwu et al., 2021).

Stem girth development, an indicator of structural robustness, also responded positively to mycorrhiza, although the effect varied among varieties. In Oba-98, the thickest stems were produced by moderate mycorrhiza application (5%), whereas Oba Super-2 responded best to the 10 % treatment. Excessive mycorrhiza (10%) did not consistently enhance stem girth in Sammaz-52, suggesting that the response depends on varietal physiology, root-soil interactions, and possibly nutrient availability in acidic, low-fertility soils (Jeffries et al., 2003; RuizLozano & Azcón, 2019).

The enhanced growth in mycorrhiza-treated plants can be attributed to the dual effects of improved nutrient uptake and reduction of soil chemical constraints. By facilitating access to less-mobile nutrients, such as phosphorus, and increasing the effective absorption of nitrogen and base cations, AMF mitigates the limitations of acidic pH, low TOC, and moderate ECEC. Furthermore, mycorrhizal colonization improves soil aggregation and moisture retention, indirectly enhancing nutrient availability and root efficiency in sandy soils (Smith & Read, 2008; Liu et al., 2020).

Generally, the study demonstrates that mycorrhiza application can significantly enhance the vegetative growth of maize under acidic, low-fertility tropical soils. The findings underscore the importance of considering soil chemical properties—particularly pH, organic carbon, nutrient content, and cation exchange capacity—when designing mycorrhizal inoculation strategies. Matching maize varieties with optimal mycorrhiza application rates can maximize vegetative development, nutrient acquisition, and yield, providing a sustainable approach for improving maize production in challenging soil environments.

Conclusion

This study demonstrated that arbuscular mycorrhizal fungi (AMF) inoculation significantly improved the vegetative growth of maize grown on acidic, low-fertility tropical soils. The experimental soils were predominantly sandy with low nutrient-holding capacity, which limited crop performance in the absence of AMF. While AMF application largely unaffected soil physical properties, soil chemical constraints were effectively mitigated through enhanced nutrient uptake.

AMF application increased plant height, leaf area, and stem girth across all maize varieties, with more pronounced effects at mid to late growth stages. The 10% AMF rate generally promoted superior plant height and leaf area, whereas stem girth responses were variety-dependent, with some varieties exhibiting optimal stem girth responses after moderate application (5%). The Oba Super-2 showed the greatest responsiveness to AMF, indicating stronger varietal compatibility.

AMF inoculation represents a viable and sustainable strategy for improving maize growth under tropical soil conditions. Optimizing AMF application rates in relation to maize variety can enhance nutrient use efficiency and crop performance, supporting sustainable maize production in low-fertility soils.

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