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Cultivar Differences in Plantain Growth Response to Mycorrhizal Inoculant and Effect on Incidence of Plant Parasitic Nematodes

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Abstract

An experiment was set up to investigate the relative mycorrhizal dependence of a Falsehorn and a French plantain cultivars at the Teaching and Research farm of the Federal University of Technology, Akure. The experiment was laid out in a completely randomized design, all suckers were pared prior to planting and treatment assigned as either inoculated with the mycorrhizal inoculant or not. At 182 days after planting (DAP), aerial and subterranean growth parameters were assessed on plants and soil chemical composition was also analysed. The results showed that mycorrhized plants of either cultivar had better below and above-ground growth. The results also established that Relative Mycorrhizal Dependency (RMD) is, to an extent, cultivar dependent with the French genotype exhibiting better dry matter response. Hence, the cultivation of the French plantain could better be enhanced by mycorrhizal fungi inoculation. The chemical analysis of the soil samples at the end of the study revealed that mycorrhizal fungi inoculation makes for efficient uptake and utilization of nutrients in the soil, most especially phosphorus. Meanwhile, further investigation of the abilities of mycorrhizal fungi to intervene nutrients mobilization processes in this ecosystem is required.

Keywords: mycorrhizal fungi, plant parasitic nematodes, plantain genotypes, root health, vegetative growth

1. Introduction

Sustainable plantain production is dependent upon yield stability of the genotype. The key objective in avoiding yield decline and/or sustenance of stable yield is to promote vigorous growth, and/or to eliminate those factors causing poor growth and development (Baiyeri, 1996). Such non-genetic factors that could influence growth and development, especially as they relate to banana and plantain production in the sub-Saharan Africa include: Cropping system, soil and soil fertility, moisture, light and temperature and cultural practice such as mulching.

The most important chemical properties of banana and plantain soils pertain to organic matter, phosphorus (P), potassium (K) , calcium (Ca), magnesium (Mg), pH and the cation exchange capacity (Stover and Simmonds, 1987). According to these authors, the important aspects of soil chemistry are to maintain adequate levels by fertilization of Nitrogen (N) and K and the correct balance between the cations (K, Ca, and Mg). As a result of rapid growth pattern of banana and plantain, they have high nutritional demand. Nitrogen is a key element in banana nutrition and a close correlation exists between the dry matter accumulation and leaf N level (Robinson 1996; Baiyeri, 1996). In the tropics, N is required the whole year round but excessive rain and leaching can cause severe losses. Also, banana and plantain crops have high K demand and large quantities of these elements are removed from the soil. Soil K deficiency will severely reduce yield via reduction in fruit number and size (Robinson, 1996). For optimum crop performance soil pH (water) should be between 5.8 and 6.5.

Like many plants, bananas are dependent on some vesicular arbuscular mycorrhizal (VAM) fungi which improve greatly their nutrition, especially under poor fertility conditions (Strullu, 1991.; Declerck et *al.*, 1995). Furthermore, mycorrhiza may play a role in the control of root pathogens, including nematodes (Umesh *et al.*, 1988; Pinochet *et al.*, 1996; Jaizme-Vega *et al.*, 1997). The way mycorrhizal fungi interact with root pathogens is not known, but they are supposed to increase the plant tolerance by improving nutrition, and they also may interact physically (site occupation) and/or have a suppressive effect on nematode reproduction due to alteration of root / shoot ratio as a result of enhanced root biomass (Hurt *et al.*, 2001). The absorptive areas of the roots are increased due to mycorrhiza colonization for the better absorption of nutrients from soil (Subba Rao, 1993). These effects are clearly important and will have a major influence on plant functions (Hooker *et al.*, 1998). The study aimed at investigating the contribution of mycorrhizal fungi to comparative plantain genotypic growth and mineral nutrient.

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2. Materials and Methods

2.1 Site Description, Planting Materials and Treatment application

The experiment was carried out at the Crop Section of the Teaching and Research Farm of the Federal University of Technology, Akure. Suckers of plantain (*Musa* spp AAB-subgroup) cultivars Agbagba, a Falsehorn and Obino l'Ewai, a French were acquired from the commercial farm of Federal College of Agriculture, Akure. The cultivars were the ones commonly cultivated by farmers in the ecological zone. Also, bags of mycorrhizal innoculant with sand as carrier, bagged by the Ondo-State Accelerated Poverty Alleviation Authority (APAA) for the use of local farmers, were acquired for the experiment. The inoculant was expected to contain the *Glomus* species but was not verified.

Treatment comprised of two factors, each with two levels: the first factor being plantain cultivars (Falsehorn (H), and 'French' (F) and the second factor mycorrhizal fungi (with mycorrhiza (M), and without Mycorrhizal (MN). There were a total of four (4) treatment combinations. All suckers were cleared by removing the roots and paring (i.e. peeling the rhizomes). Treatments were arranged in a completely randomized design of four rows, with five plants per row. Each treatment was randomized five times. All the four treatments were randomized through the balloting process. The experimental field was 15m x 15m. A total of 20 plants were spaced at 3m between rows and 2m within rows. Eighteen border plants were planted around the field area.

Pared suckers were planted directly into 30cm x 30cm x 30cm planting holes in the field. A 1.25kg of mycorrhizal innoculant infected soil was poured around the base of each of the suckers receiving mycorrhizal treatment at 2 weeks after planting (WAP). Prior to planting, the field had been ploughed and harrowed. Slashing was done to keep weeds low before the field was ploughed. After planting, the field was again slashed at 4 and 12 weeks after planting (WAP).

2.2 Data Collection

Random soil samples were collected from the field prior to planting for physical and chemical analyses and for nematode extraction to respectively ascertain the fertility status and identify species of plant parasitic nematodes present in the soil and their levels. Pre-planting data on parameters like pseudostem girth, number of root bases, and types of lesions, corm circumference before and after paring, sucker weight before and after paring, dead and functional roots, number of eyes (buds) and sucker length, were collected from all the suckers to be used in the experiment. Establishment count was taken at two and four weeks after planting respectively.

Following establishment, aerial growth data were collected on each plant at four weeks intervals. Parameters taken into consideration include plant height, pseudostem girth at soil level, length and width of the youngest leaf opened, number of suckers, numbers of green and dead leaves and leaf emission.

At 182 DAP, aerial growth parameters were assessed and thereafter, all plants were carefully uprooted and the following data were taken on each of the suckers: total plant fresh weight, fresh weight of corm, fresh weight of pseudostem, fresh weight of leaves, number of functional roots, number of dead roots (expressed in percentages) and number of eyes or buds.

Root and rhizome damage were assessed as percent necrotic root tissues, small and large root base lesions. Nematodes were extracted from both roots (5g) and soil samples taken from the base of each mat.

The pseudostems and leaves of each mat were separated and dried at 75^0c in an oven until relatively constant dry weights were recorded for each. These were recorded as the dry weight of pseudostem and leaves.

2.3 Data Analysis

The nematode population densities were log (x+1) transformed (Gomez and Gomez, 1984), damage parameters in percentages and scores were arcsine (x/100) and (x +0.5) transformed, respectively, while counted data were square root transformed prior to using the generals linear model in SPSS. Where statistical differences were observed, means were separated using the Duncan Multiple Range Test at 5% significance level.

3. Results

3.1 Summary of plant establishment

Table 1 shows the pre-planting parameters of the planting materials used for the experiment, giving the details based on each cultivar.

Table 1. Pre-planting parameters of suckers

Parameter	Falsehorn cvr. Agbagba			French cvr. Obino l'Ewai		
	Min	**Max**	**Mean**	**Min**	**Max**	**Mean**
Sucker fresh weight (Kg) B/P	0.7	2.15	1.43	1	2.5	1.75
Sucker fresh weight (Kg) A/P	0.65	2	1.33	0.8	2.3	1.55
Pseudostem girth (cm)	22	34	17.05	12	40	26
Rhizome inner length (cm)	1	6	3.5	5	13	9
Rhizome outer length (cm)	6	16	11	12	23	17.5
Rhizome circumference (cm) B/P	30	48	39	27	44	35.5
Rhizome circumference (cm) A/P	26	45	35	21	38	29.5
Total number of roots	11	55	33	0	29	14.5
Number of dead roots	0	3	1.5	0	2	1
Number of root bases on rhizome	15	60	37.5	26	49	37.5
Number of large lesions on root bases	0	3	1.5	0	2	1
Number of small lesions on root bases	0	6	3	0	6	3
Number of lateral buds/eyes	0	4	2	0	4	2

3.2 Effects of treatments on the establishment of suckers at 28 days after planting (DAP)

The establishment count taken at 28 days after planting (DAP) showed that all the Falsehorn suckers, either mycorrhized or not mycorrhized, had emerged and established while only 60% and 80% of the mycorrhized and non-mycorrhized French genotype had emerged and established respectively (Table 2). Of the mycorrhized Falsehorn cultivar, 80% emerged from the top position while only 20% emerged from the side position. Also, of the not mycorrhized suckers of the falsehorn cultivars 60% emerged from the top position while 40% emerged from the side. Meanwhile, from the French genotype, 66.67% and 33.33% of the emerged mycorrhized suckers did so from the top and side positions respectively. Of the not mycorrhized suckers of the French genotype, 75% and 25% of the emerged suckers did so from the top and side positions respectively (Table 2).

Table 2. Establishment count at 28 days after planting (DAP)

MH = Mycorrhized Falsehorn
MF = Mycorrhized French
MNH = Not Mycorrhized Falsehorn
MNF = Not Mycorrhized French
N = sample size WAP = weeks after planting

Treatment	**Emergence Position**		**Plant Emergence 2 WAP (%)**	**Plant Established 4 WAP (%)**
	Top (%)	**Side (%)**		
MH	80	20	100	80
MF	40	20	60	60
MNH	60	40	100	80
MNF	60	20	80	60
N	20	20	20	20

3.3 Pre-plant soil physico-chemical properties

Laboratory analysis classified soil as sandy-clay-loam with 36%, 13.6% and 50.4% sand, clay and silt respectively. The percentage of organic matter was 8.2% while Nitrogen was 1.2%; thus giving a C: N ratio of 0.25. The soil has low cation exchange capacity (CEC) of 2.61 and was also slightly acidic with pH of 5.70 (Table 3).

Table 3. Physico-chemical properties of the soil before planting.

Soil Properties	Values	Standard deviation
Sand (%)	36	0.74
Clay (%)	50.4	0.66
Silt (%)	13.6	0.55
Nitrogen (%)	1.2	0.35
Organic Carbon (%)	4.9	0.12
C/N	1:04	n/a
Organic Matter (%)	8.2	0.46
Calcium (cmol/kg)	3.66	0.16
Magnesium (cmol/kg)	1.04	0.08
Potassium (ppm)	0.3	0.03
Phosphorous (cmol/kg)	1.4	0.07
pH	5.7	0.28
CEC	2.61	0.01
Sample size	5	Not applicable

3.4 Effect of mycorrhization on chemical properties of the soil

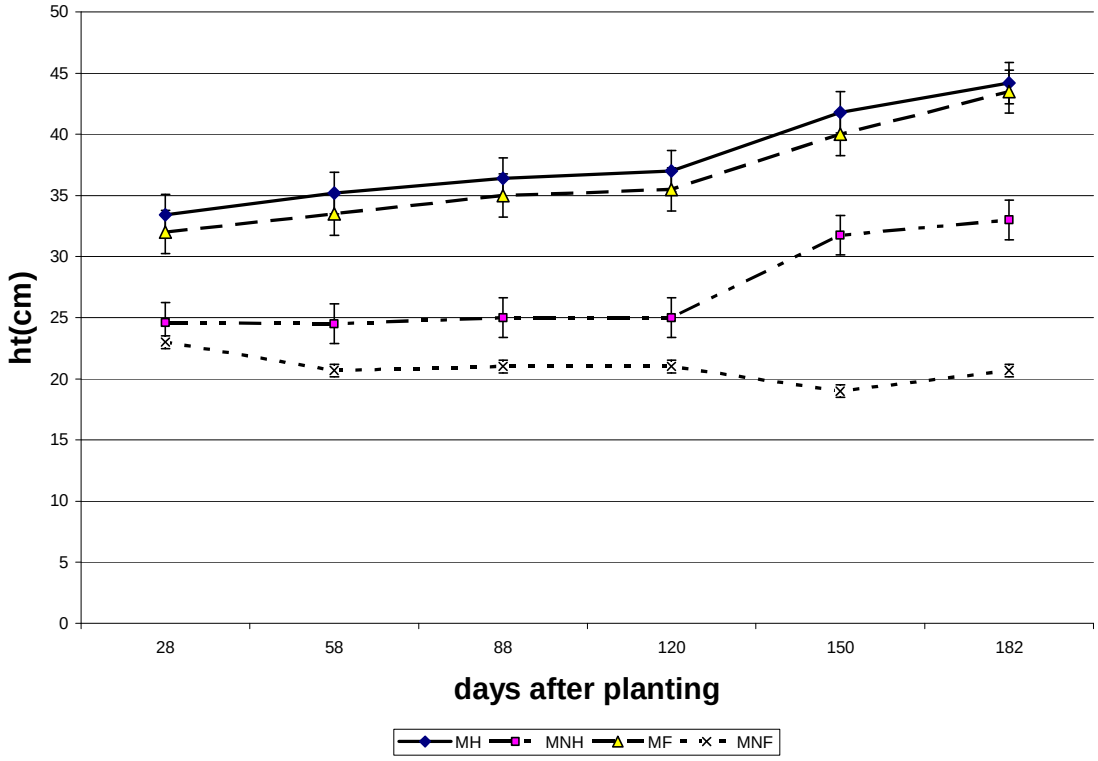
Irrespective of *Musa* genotypes, mycorrhizal association increased the soil pH of the mycorrhizosphere to 6.05 but not significantly (Table 4). Mycorrhization increased the organic matter and Magnesium levels of the soil while depressing potassium and phosphorus levels significantly.

Table 4: Chemical properties of soil at six (6) months after planting

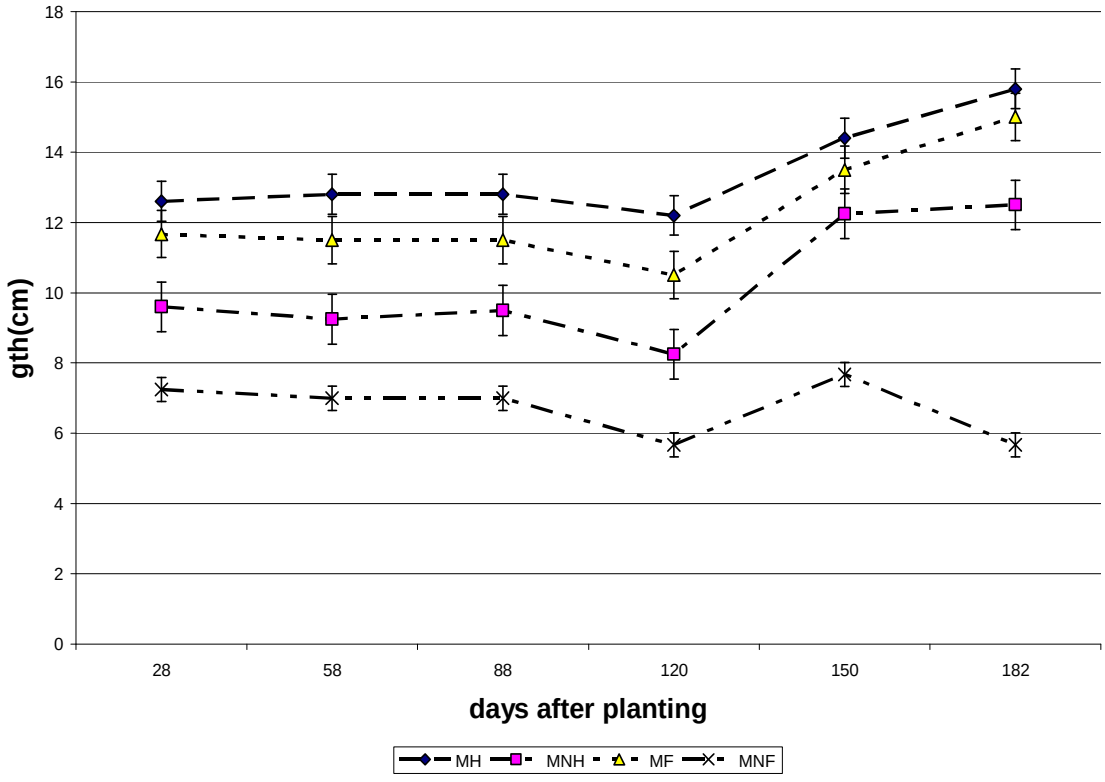
Treatments	Nitrogen (%)	Organic matter (%)	Potassium (ppm)	Phosphorus (cmol/kg)	Magnesium (cmol/kg)	Calcium (cmol/kg)	pH
Mycorrhized falsehorn	1.02a	9.93a	0.16b	0.91b	2.14a	3.32a	6.05a
Mycorrhized French	1.02a	9.93a	0.16b	0.91b	2.14a	3.32a	6.05a
Not Mycorrhized falsehorn	1.28a	8.6b	0.23a	1.46a	0.97b	3.44a	5.85a
Not Mycorrhized French	1.28a	8.6b	0.23a	1.46a	0.97b	3.44a	5.85a
Sample size	3	3	3	3	3	3	3

3.4 Vegetative plant growth response of plantain genotypes to mycorrhization

All the aerial growth parameters exhibited significant associations with mycorrhization at one time or the other during the sampling dates. Plant growth was better in the mycorrhized plants, either of the Falsehorn or French genotypes, compared with the non-mycorrhized plants. Mycorrhized plants were taller (Figure 1A) and thicker (Figure 1B). The mycorrhized Falsehorn (MH) plants had the best height and girth, followed by the mycorrhized French (MF) plants. The not mycorrhized French plants (MNF) were the least performer both in height and girth.



A



B

Figure 1. Effect of mycorrhization on the height of the established suckers. A = Pseudostem height, gth = pseudostem circumference; MH: Mycorrhized Falsehorn; MF: Mycorrhized French; MNH: Not Mycorrhized Falsehorn; MNF: Not Mycorrhized French. Error bars are displayed on the curves.

The number of functional green leaves generally increased from the first sampling date (Figure 2), dropped at 120 days after planting (DAP) and picked up again at 150 DAP. However, while other treatments increased in number of functional green leaves over time, the number of green leaves on the mycorrhized Falsehorn cultivar

dropped to a mean of 4 leaves per plant. The treatments did not have any significant effect on non-functional leaves on the first, second and third sampling dates (Figure 3) until 120DAP and at subsequent sampling dates afterwards.

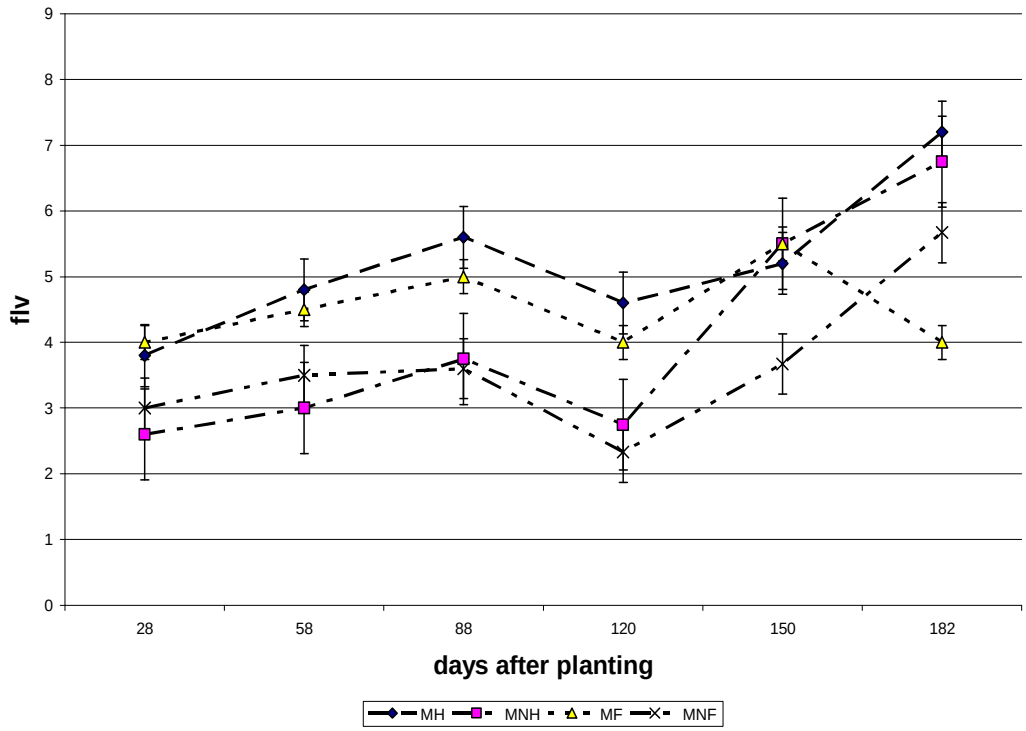


Figure 2. Effect of mycorrhization on the number of functional leaves of established suckers. Flv = functional leaves; MH = Mycorrhized Falsehorn; MF = Mycorrhized French; MNH = Not Mycorrhized Falsehorn; MNF = Not Mycorrhized French. Error bars are displayed on all the curves.

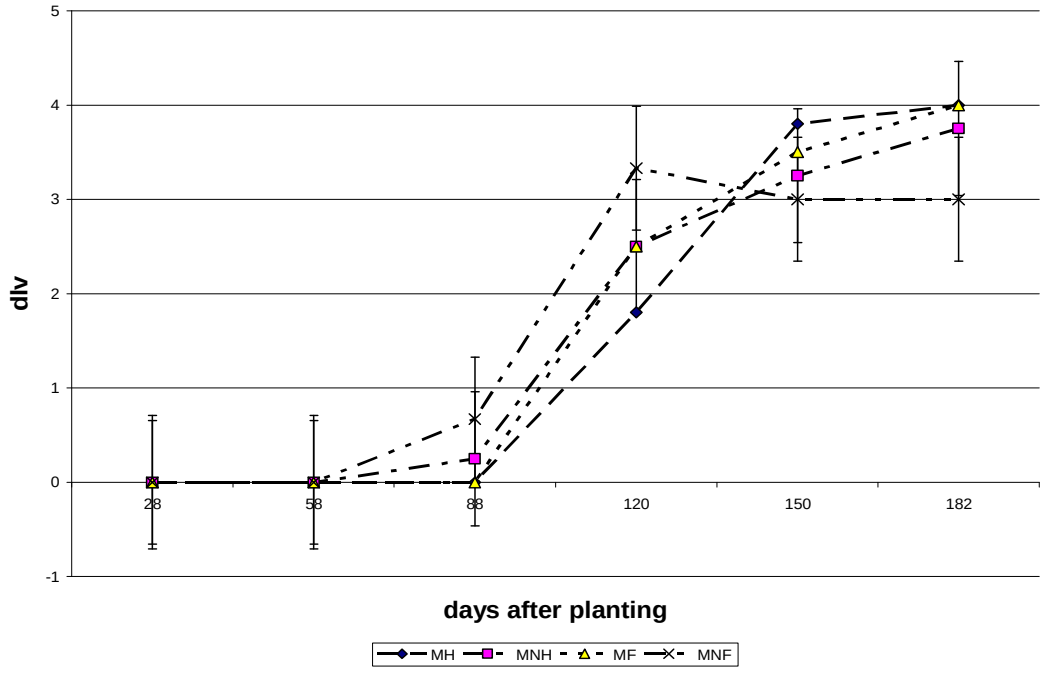


Figure 3. Effect of mycorrhization on the number of dead leaves on established suckers. Dlv = dead/non-functional leaves; MH = Mycorrhized Falsehorn; MF =: Mycorrhized French; MNH = Not Mycorrhized Falsehorn; MNF = Not Mycorrhized French. Error bars are displayed on all the curves.

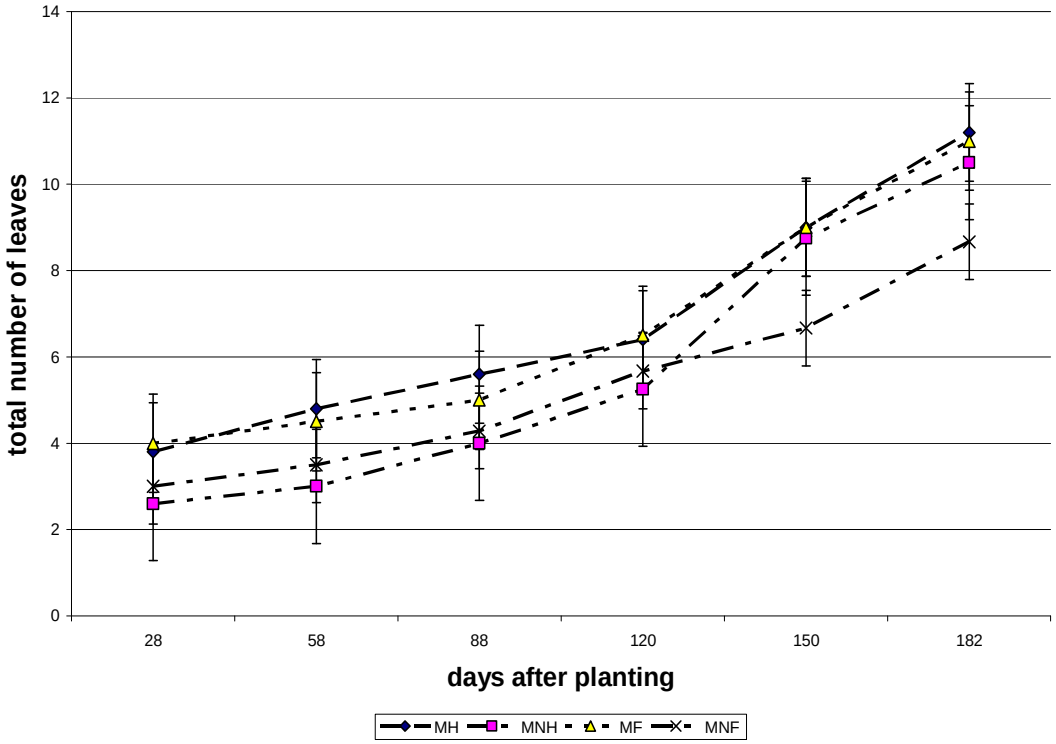


Figure 4. Effect of mycorrhization on the total number of leaves on established suckers. MH = Mycorrhized Falsehorn; MF = Mycorrhized French; MNH = Not Mycorrhized Falsehorn; MNF = Not Mycorrhized French. Error bars are displayed on all the curves.

Meanwhile, the total number of leaves did not conspicuously differ for most of the sampling dates (Figure 4) but for the 150 and 182 DAP. However, the mycorrhized plants (MH and MF) still showed a better trend.
The active leaf area of the youngest leaves dropped from the first sampling dates and did so conspicuously at 120DAP (Figure 5) except for the MNF but picked up again at 150 DAP and 180DAP.

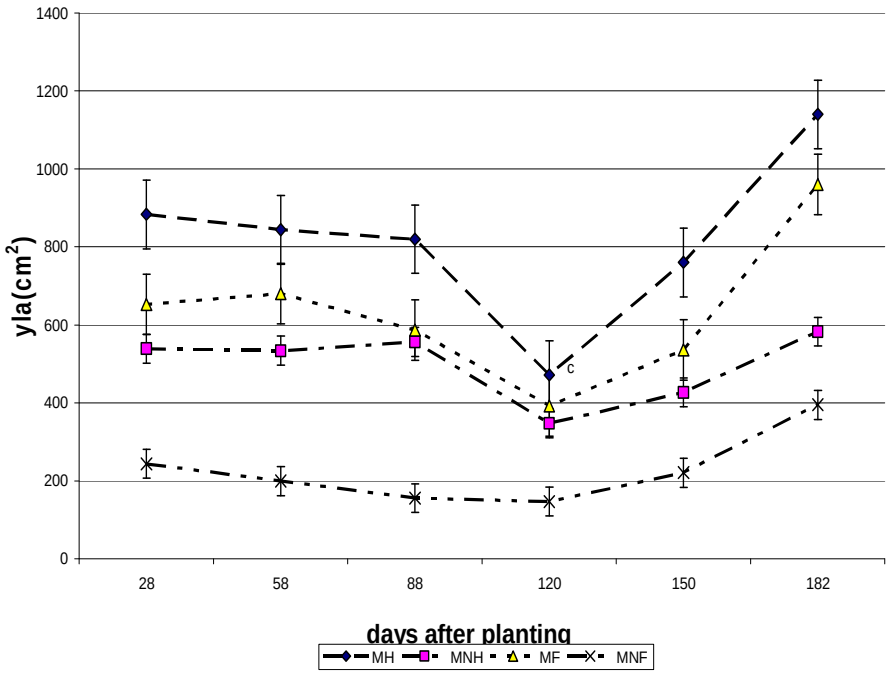


Figure 5. Effect of mycorrhization on the leaf area of the youngest leaf produced by the established suckers. yla(cm^2) = active area of the youngest leaves; MH= Mycorrhized Falsehorn; MF = Mycorrhized French; MNH = Not Mycorrhized Falsehorn; MNF = Not Mycorrhized French. Error bars are displayed on all the curves.

3.5 Relative mycorrhizal dependency (RMD) of Falsehorn (cv. Agbagba) and French (Obino l'Ewai) genotypes

When mycorrhized, there was no significant difference in the fresh pseudostem weight (FPW), dry pseudostem weight (DPW), fresh leaf weight (FLW) and dry leaf weight (DLW) respectively (p=0.05) between the falsehorn and French genotypes considered in this study. However, there was significant difference in the pseudostem fresh and dry weights respectively where there was no mycorrhizal fungi association, but no differences were observed in the dry and fresh leaf weights when mycorrhizal fungi were applied (Table 5). Moreover, there were significant differences in the fresh and dry root weights of falsehorn and French genotypes either when mycorrhized or not. Meanwhile, the range of values for all these parameters between the mycorrhized and not mycorrhized plants was higher for the French genotype than for the falsehorn cultivar used in this study. Therefore, taking into consideration the pseudostems' and leaves' weights, both fresh and dry, mycorrhized falsehorn had an average of 62.67% relative mycorrhizal dependency (RMD) while mycorrhized French had 63.74% RMD (Table 5).

Table 5. Effect of mycorrhization on shoot weight, root weight and mycorrhizal dependency of Falsehorn and French plantain

FPW = fresh pseudostem weight; DPW = dry pseudostem weight; FLW: fresh leaf weight; DLW: dry leaf weight; FRW = fresh root weight; DRW = dry weight of 25% of fresh root weight; RMD: relative mycorrhizal dependency; *na* = not applicable.

Treatments	**FPW (g)**	**DPW (g)**	**FLW (g)**	**DLW (g)**	**FRW (g)**	**DRW (25%) (g)**	**RMD (%)**
With Mycorrhizal fungi							
Falsehorn	300a	142a	110.0a	56a	140a	1.71a	62.76a
French	225ab	115ab	125.0a	45a	100b	0.79bc	63.74a
Without Mycorrhizal fungi							
Falsehorn	165b	67.5b	92.5b	25b	105b	1.16b	*na*
French	70c	20c	56.7b	16.7b	30c	0.26c	*na*

4. Discussion

The results of the study showed that Falsehorn plantain cultivar Agbagba and French plantain cultivar Obino l'Ewai responded positively to mycorrhizal fungi inoculation. The mycorrhized plants of either cultivar had better below and above-ground growth. They had taller and thicker pseudostems than their uninnoculated counterparts. They also had more functional (green) leaves with larger active area. More lateral and feeder roots were also produced on the inoculated plants than their uninnoculated counterparts. This is indicative of the stimulating effect on overall plant development by mycorrhizae as it was evident that both shoot and root development benefited from the presence of mycorrhizal fungi. From these observation therefore, it could be concluded that the presence of mycorrhizal fungi created a larger root network for the inoculated plants which would have facilitated better uptake of nutrients and water thus enhancing better vegetative growth.

This conclusion corroborated the findings of Blomme (2000), who stated that the root development in *Musa* is related to shoot development especially in early vegetative growth phase. More so from visual observations and other growth assessment made, the French plantain employed in this study responded in higher degree to mycorrhizal inoculation than the False horn plantain used. This conclusion was reached as the differences between inoculated and the uninnoculated plantain plants of the two genotypes seem to be wider for French. This ascertained the fact that Relative Mycorrhizal Dependency (RMD) is, to an extent, genotype dependent (Declerck *et al*., 1995).

Despite having higher percentage of organic matter (OM), the mycorrhizosphere of the plants revealed lower nitrogen (N), potassium (K), phosphorus (P) and calcium (Ca) but higher magnesium (Mg) and pH values. A logical explanation for these would be rapid depletion of the nutrient with lower values and accumulation of the ones with higher values as a result of obvious reduction in uptake from the mycorrhizosphere, as there was no

external source of fertilization while the experiment lasted. Already, the beneficial effect of mychorrhizal fungi symbiosis with plant roots on plant growth has been attributed to improved uptake of nutrients, especially phosphorus (Smith *et al*., 1992) as well as making the nutrients more available from their occlusion and simplifying their hitherto complex forms.

However the result seems to implicate Calcium. Increased uptake of nitrogen is known to enhance the import of P and K, whereas increased uptake of K is known to reduce import of Ca and Mg. A reduction in uptake of a nutrient would result into build-up of the excess in the soil while increased uptake is expected to result in lower value of the available amount of the specific nutrient in the soil. This condition was satisfied by Mg having higher value in the mycorrhizosphere compared to the non-mycorrhized control. But the lower value of Ca in the mycorrhizosphere, indicating that it was taken up more, belied this antagonistic relationship between K and Ca. Meanwhile, this study was not the only case where this antagonism between K and Ca did not hold as Pinochet *et al.* (1997) recorded a reduction in available Ca and some other micro-elements on inoculated media in the presence of increased uptake of K.

The chemical analysis of the soil samples taken from the mats of the plants also revealed that mycorrhizal fungi inoculation impacted well on the soil, thus confirming the earlier observation that mycorrhizal fungi inoculation makes for efficient uptake and utilization of nutrients in the soil, most especially phosphorus. Meanwhile, further investigation of the abilities of mycorrhizal fungi to intervene nutrients mobilization processes in this ecosystem is required.

In conclusion, mycorrhizal inoculation enhanced field establishment of planted suckers of the two plantain genotypes tested in this study. The results further showed that mycorrhizal dependence in plantain development is to a considerable extent genotype-dependent, being more pronounced on the French plantain type. Thus it is suggestive that the cultivation of the French plantain could better enhanced by mycorrhizal fungi inoculation. The effect of this treatment on resulting yield needs to however be investigated before a definite conclusion could be reached.

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