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Full Length Article

Effect of Indigenous Mycorrhizal Fungi on the Productivity of Cotton (*Gossypium hirsutum*) Growing in the Far North Region of Cameroon

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Abstract

Cotton growing is faced with low yields as a result of soil degradation and disease. Although chemical fertilizers are the most widely used means of mitigating this degradation, they are not widely available, are very expensive and are harmful to the environment. This study was therefore conducted to assess the effect of arbuscular mycorrhizal fungi (AMF) endogenous to the Far North region of Cameroon on cotton (*Gossypium hirsutum* L.) productivity. On three sites cultivated during two cropping seasons and covering an area of 1932 m^2 each, an experiment was conducted using a split-plot design, with the main factor consisting of treatments with inoculum of the best-performing AMF originating from three localities (T1, T2 and T3); with a commercialized exogenous inoculum (T4) and two controls (T- and T+). The secondary factor consisted of three cotton varieties (IRMA Q302, IRMA L484 and IRMA L457). The results show that growth and development were significantly improved by treatments T1, T2 and T4, with an increase 2 to 3 times greater than T- in all cultivated varieties. Compared with negative control, the yield of inoculated plants increased from 703 ± 93 kg. ha^{-1} to 1127 ± 90 kg. ha^{-1} in IRMA L457, from 839 ± 71 kg. ha^{-1} to 1209 ± 58 kg. ha^{-1} in IRMA L484 and from 680 ± 15 kg. ha^{-1} to 1148 ± 100 kg. ha^{-1}, with 30 to 50% of yield gain. Although T+ was better for most of the parameters evaluated, no significant difference ($P > 0.05$) was detected compared with treatments T1, T2 and T4. Significant interactions were recorded between treatments and varieties for most of the parameters assessed. These results suggest that indigenous AMF can be considered as a preferential inoculation tool to ensure the re-establishment of the cotton plant in degraded soils, while considerably increasing its growth and yield in the same way as synthetic fertilizers.

Keywords: Cotton; Yield; Productivity; Indigenous mycorrhizal fungi

Introduction

The cotton sector is one of the most important in Cameroon's agriculture due to its contribution to the inflow of foreign currency for the state; as it represents a substantial source of income for many populations and for actors in the marketing chain, in both rural and urban areas (Kosma *et al.* 2017). It also contributes to food security in this part of the country, which is severely threatened by poverty and increasingly deteriorating climatic conditions (Mbetid-Bessane *et al.* 2006, Folefack *et al.* 2014). However, the degradation of soil fertility in the northern cotton zone of Cameroon is a real brake on agricultural production. Since 2007, the cotton industry in Cameroon has suffered a decline in area (-40%), production (-40%), yields (-28%) and export revenues (-35%) (Folefack 2010). To compensate for the drop in yields, the increased use of mineral fertilizers is the most widely adopted means of resolving soil deficiency in mineral elements (Olina *et al.* 2008). However, the use of mineral fertilizers is limited by their low availability and very high cost, and they are sometimes even unsuitable in the tropical context, contributing at the same time to increasing soil acidification, the repercussions of which are synonymous with poor mineral nutrition, a slowdown in biological activity and low availability of elements for plants (Olina *et al.* 2008; Ndonda 2018). Yet the mineral nutrition of cotton plants, particularly in terms of nitrogen, phosphorus and potassium, is a key factor in fiber production and quality (Reiter *et al.* 2008). It is in this context that the use of biofertilizers, such as arbuscular mycorrhizal fungi (AMF), seems essential to guide the fertilisation of Cameroonian farmland for

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sustainable agriculture (Megueni *et al.* 2011). The action of AMF in plants is manifested through mycorrhizae, which are symbioses between soil fungi and plant roots, enabling the latter to acquire a larger root absorption surface thanks to the proliferation of their hyphae (Plenchette 1982). These mycorrhizae thus increase the plant's acquisition of nutrients (Ngakou *et al.* 2007; Smith *et al.* 2010), improve its growth (Megueni *et al.* 2011; Abakar *et al.* 2019), combat certain pathogens or pests (Dalpe 2005) and increase its tolerance to metal toxicity and low soil pH (Hassan *et al.* 2011). Despite their importance, the agricultural use of mycorrhizal biotechnologies in Cameroon is very limited to cash crops, in particular cotton plant. Although several studies have been carried out to identify the species of mycorrhizal fungi present in cultivated soils in the different agro-ecological zones of Cameroon (Onguene *et al.* 2002; Ngonkeu *et al.* 2013; Mbogne *et al.* 2015; Begoude *et al.* 2016; Tchinmegni *et al.* 2016; Temegne *et al.* 2017; Tobolbai *et al.* 2018; Koulagna *et al.* 2020), the effect of these identified strains on crop productivity is still unknown. This study was therefore conducted to assess the effect of arbuscular mycorrhizal fungi endogenous to the Far North Region of Cameroon on cotton productivity. Specifically, the aim was (i) to evaluate the effect of mycorrhizal inoculation on the growth and production yield of three varieties of cotton grown in the Far North Region of Cameroon; (ii) to evaluate the level of root colonization of inoculated plants.

Materials and Methods

Description of experimental site

Experiments were conducted in the field during the 2019 and 2020 growing seasons, in localities such as Dogba, Hossom and Laf, all located in the Far North region of Cameroon and whose geographical coordinates are given in Table 1. The climate in this area is a dry Sudano-Sahelian climate, characterized by recurrent droughts and monomodal rainfall of variable duration and intensity over time (Ramza *et al.* 2020). During the experiment, which took place from June to November 2019 and 2020, an average of 811.6 to 932.6 mm of rain was recorded, with an average annual temperature of 28.3 to 32.4°C, for a relative humidity of 80% in the rainy season and falling to 30 to 40% in the dry season. The soils on the cultivated plots are sandy-loam, with an average predominance of sand (Table 2). These soils are acidic with a pH ranging from 4.5 to 5.26 and low in organic matter (0.38 to 0.72%). The quantities of assimilate and total phosphorus vary respectively from 9.65 to 12.12 $mg.kg^{-1}$ and 47.63 to 61.51 $mg.kg^{-1}$, for an average total nitrogen quantity of 0.04% (Table 2).

Plant material

The plant material used for this study consisted of uncoated seeds of *Gossypium hirsitum* L. (Malvaceae) of the varieties IRMA Q302, IRMA L484 and IRMA L457. These were supplied by the Agricultural Research Institute for Development (IRAD) of Maroua. They are characterized by their fairly short life cycle (120 days on average) and have been the main varieties popularized in this part of the country over the last two decades (Palaï 2012).

Fungal material

The fungal material used for this study consisted of an exogenous mixed fungal inoculum from the collection of the soil laboratory of the Biotechnology center at the University of Yaoundé I and three mixed inocula consisting of the best-performing endogenous fungal isolates from the Far North region of Cameroon from greenhouse production (Ramza *et al.* 2020). These consisted of a mixture of soil (clay, sand grains), root fragments from trap plants containing infectious spores and propagules of four species of the genus *Acaulospora*, *Glomus*, *Gigaspora* and *Scutellopspora* with a concentration of around 18 to 20 spores/g of substrate (Table 3).

Experimental design

The experimental design used in this work was a split plot, arranged in a completely randomized block. The primary factor was the mycorrhizal inocula treatments applied, the secondary factor was three different cotton varieties, the sites grown (Dogba, Laf and Hossom) and the cropping seasons (2019 and 2020) representing the replicates. For each of the three cultivated varieties (IRMA Q302, IRMA L484 and IRMA L457), 20 g of each inoculum was applied per plant according to the following treatments: T1 (mycorrhizal fungi from the Dogba locality), T2 (mycorrhizal fungi from the Zidim locality), T3 (mycorrhizal fungi from the Laf locality), T4 (commercialized mycorrhizal fungi), with control treatments represented by T- (no application) and T+ (4 g/plant of NPKSB chemical fertilizer of formula 22/10/15/5/1 at 15 days after sowing). The three plots were cultivated over an area of 1932 m^2 each (42 x 46 m). These cultivated areas were divided into 3 blocks and each block contained 3 experimental units (plots measuring 10 x 10 m each) containing 6 sub-plots of the same area: 8 m^2 (4 x 2 m). These received 30 plants each subjected to the same treatment, with a spacing of 80 x 40 cm.

Data sampling

As soon as the first rains fell in June 2019 and 2020, the plots were ploughed by animal traction. At sowing time, poquets was sown with 4 cotton seeds to a depth of 3 cm in order to facilitate the emergence of the seedlings. Mycorrhizal inoculation was carried out on the day of sowing by depositing 20 g of inoculum at the bottom of the tray before closing it after sowing. The plugs were removed

Table 1: Geographic coordinates of cultivated plots

Sites	Latitude	Longitude	Altitude (m)	Température (°C)	Relative humidity (%)	Rainfall (mm)
Dogba	10°31'57.65''N	14°36'15.84''E	402	29.14	71	883.1
Laf	10°46'18. 68 N	14°18'27.90''E	480	32.4	62	811.6
Hossom	10°11'49.17''N	14°97'46.79''E	545	28.3	80	932.6

Table 2: Chemical characteristics of cultivated soils

Soil parameters	pH	MO(%)	N(%)	P ass. (mg.kg^{-1})	P tot. (mg.kg^{-1})	C.E.C (méq.100 g^{-1})	K (méq.100 g^{-1})	Ca (méq.100 g^{-1})	Mg (méq.100 g^{-1})	Fe (méq.100 g^{-1})	Al (méq.100 g^{-1})
Dogba	4.5	0.38	0.042	9.65	47.63	12.27	0.43	8.84	2.11	25.60	17.45
Hossom	4.33	0.57	0.041	12.69	61.51	21.46	0.71	5.70	1.76	27.25	15.87
Laf	5.26	0.72	0.042	10.42	49.20	15.98	0.36	5.39	1.88	20.33	15.06

pH: Hydrogen potential; OM: Organic matter; N: Total nitrogen; P ass: Assimilate phosphorus; P tot: Total phosphorus; CEC: Cation exchange capacity; K: Potassium; Ca: Calcium; Mg: Magnesium; Fe: Iron; Al: Aluminium

Table 3: Characteristics of mycorrhizal Inocula

Inoculum	Fungal species	Sporulation (number/g)	Colonisation (%)
Mycorrhizal fungi from the Dogba locality (T1)	*Acaulospora sp.2* *Gigaspora margarita* *G. hoi* *Glomus intraradices*	19 ± 8	71.92 ± 2.91
Mycorrhizal fungi from the Zidim locality (T2)	*Acaulospora sp.2* *Gigaspora margarita* *G. hoi* *Glomus intraradices*	19 ± 4	77.32 ± 4.38
Mycorrhizal fungi from the Laf locality (T3)	*Acaulospora sp.1* *G. hoi* *G. manihotis* *S. gregaria*	18 ± 6	67.70 ± 3.26
Commercial exogenous mycorrhizal fungi (T4)	*Glomus hoï,* *Gigaspora margarita,* *Scutellospora dipurpurescens,* *Glomus intraradices*	20 ± 3	64 ± 12

15 days after sowing, leaving one plant per pot. Several parameters were assessed during the experiment. The height of the cotton plants was assessed from the height of the main stem measured from the cotyledonary nodes to the highest apex of the plant using a tape measure after 120 days of cultivation. After measuring the collar diameter of plants using an electronic caliper, 30 randomly selected plants per treatment were carefully removed from the soil at 98 days after sowing, then the dry weight of the above-ground part of each plant was obtained after oven drying at 80°C until a constant weight was obtained in order to determine the dry biomass of the plants. The extracted roots were washed under running water, then cleared with KOH (10%) and stained with Trypan Blue (0.05%) using the technique developed by Phillips and Hayman (1970). The frequency and intensity of mycorrhization were calculated using the method of Trouvelot *et al.* (1986), after mounting the stained root fragments between slide and coverslip and observing them under the microscope. As soon as the capsules had been fully opened, 30 plants were randomly selected from each treatment. From each of these plants, 3 capsules were harvested in the low, middle and high positions respectively, using the method described by Hau and Gobel (1987). The average capsular weight was then calculated for each treatment by dividing the total weight of seed cotton fibers harvested from the thirty (30) plants by the total number of bolls after 128 days of cultivation. Yield was calculated by dividing the fibers mass of the area cultivated per hectare by the total number of plants present per experimental unit and per variety. After dehulling the harvested fibers, 100 randomly selected seeds were weighed on a sensitive electronic balance in three replicates to determine the Seed Index.

Statistical analysis

Before analysis, the processed data were subjected to the Shapiro-Wilk and Levene tests to check for normality and homogeneity of variance. The standardized data were subjected to a two-factor analysis of variance (ANOVA) using STATIGRAPHICS Centurion 16.1 software. Where the analysis revealed significant differences, Duncan's test for separation of means was applied at the 5% threshold. The relationships between the different parameters were assessed by a multivariate approach based on principal component analysis (PCA) using XL Stat 2018 software.

Results

Plant height

For all varieties grown, the analysis of variance revealed a highly significant difference between the treatments applied (Table 4). The variation in the height of the plants cultivated after 120 days follows the sequence T+ > T1 > T2 > T3 = T4 > T- in the variety IRMA L457, T+ > T1 > T2 = T4 > T3 > T- in IRMA L484 and T+ > T1 = T2 > T3 > T4 > T- in IRMA Q302. The highest significant height plant was observed in T+ (101.14 ± 18.14 cm). On the other hand, no significant difference was recorded between T1 (84.92 ± 17.11 cm) and T2 (80.06 ± 13.56 cm) in the variety IRMA L457 and between T2 (75.54 ± 15.18 cm) and T4 (74.37 ± 15.84 cm) in IRMA L484, which represents the intermediate values. On the other hand, the smallest height

Table 4: Effect of treatments and variety on cotton plant height

Varieties	Treatments (mean ± standard error in cm)						*P*-value
	T-	T+	T1	T2	T3	T4	
IRMA L457	56.36±12.51 aB	93.2±13.46 eA	82.7±13.53 dA	75.73±12.21 cA	70.26±12.24 bA	77.85±11.24 bA	< 0.0001***
IRMA L484	51.24±16.15 aA	91.64±18.93 eA	82.86±16.34 dA	75.54±15.18 cA	69.43±13.08 bA	74.37±15.84 cA	< 0.0001***
IRMA Q302	51.08±15.11 aA	101.14±18.14 eB	84.92±17.11 dA	80.06±13.56 dB	69.87±16.71 bA	73.28±15.08 cA	< 0.0001***
Means	52.9±14.82	95.32±17.45	83.49±15.71	77.11±13.81	69.85±14.09	75.17±14.28	
P-value	0.0243*	0.0004**	0.5338^{ns}	0.0451*	0.9243^{ns}	0.0809^{ns}	

T1: mycorrhizal fungi from Dogba locality; T2: mycorrhizal fungi from Zidim locality; T3: mycorrhizal fungi from Laf locality; T4: commercialized mycorrhizal fungi; T-: negative control (no application) and T+: positive control (4 g/plant of NPKSB chemical fertilizer). Within a row for each variety, means followed by different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$). Within a column for each treatment, means followed by different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$). *: Significant; **: Very significant; ***: Highly significant; ns: not significant

Table **5:** Variance analysis of interaction between treatments and varieties on all parameters assessed

Source	Plant height	Collar diameters	Biomass	Average capsular weight	Cotton yield	Seed Index	Frequency of mycorrhization	Intensity of mycorrhization
A : Treatments	< 0.0001***	< 0.0001***	< 0.0001***	< 0.0001***	< 0.0001***	0.1273^{ns}	< 0.0001***	< 0.0001***
B : Varieties	0.0161*	< 0.0001***	< 0.0001***	< 0.0001***	0.0660 ^{ns}	0.3762^{ns}	0.0540^{ns}	0.1911^{ns}
Interactions (A x B)	0.0006**	< 0.0001***	0.0046**	0.0023**	0.8962^{ns}	0.9615^{ns}	0.8048^{ns}	0.5506^{ns}

*: Significant; **: Very significant; ***: Highly significant; ns: not significant

Table 6: Effect of treatments and variety on biomass of cotton plants.

Variétés	Treatments (mean ± standard error in g)						*P*-value
	T-	T+	T1	T2	T3	T4	
IRMA L457	34.03 ± 16.34 aA	68.36 ± 19.99 cdA	58.16 ± 18.21 cA	51.73 ± 24.64 bcA	41.80 ± 15.75 abA	57.33 ± 22.76 cA	< 0.0001***
IRMA L484	32.22 ± 13.99 aA	94.66 ± 28.50 dB	93.66 ± 37.14 dB	76.13 ± 25.52 cB	60.26±19.85 bB	64.23 ± 18.61 bB	< 0.0001***
IRMA Q302	31.63 ± 12.18 aA	74.80 ± 24.58 dA	66.42 ± 24.89 cdA	58.96 ± 23,25 bcA	51.30±21.33 bA	64.23 ± 25.78 cdB	< 0.0001***
Means	32.67 ± 14.15	79.27 ± 26.80	72.82 ± 31.48	62.27 ± 26.31	51.12 ± 20.37	66.45 ± 21.15	
P-value	0.8009^{ns}	0.0013**	< 0.0001***	< 0.0001***	0.0015**	0.0037**	

T1: mycorrhizal fungi from Dogba locality; T2: mycorrhizal fungi from Zidim locality; T3: mycorrhizal fungi from Laf locality; T4: commercialized mycorrhizal fungi; T-: negative control (no application) and T+: positive control (4 g/plant of NPKSB chemical fertilizer). Within a row for each variety, means followed by different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$). Within a column for each treatment, means followed by different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$). *: Significant; **: Very significant; ***: Highly significant; ns: not significant

was observed in T- and these differed significantly from all the other treatments (T1, T2, T3, T4 and T+). As regards the varietal effect, no significant difference was observed between the three varieties grown for treatments T1, T3 and T4. However, there was a significant difference between these varieties in treatments T+, T- and T2, with the variety IRMA Q302 having the largest height. Overall, the effect of the varieties grown was significant on plant height and that of the treatments was highly significant. This is why a highly significant interaction was recorded between treatments and varieties (Table 5).

Biomass

Analysis of variance reveals a highly significant difference between the treatments applied, for all varieties cultivated (Table 6). This difference is presented according to sequences such as T+ ≥ T1 = T4 ≥ T2 ≥ T3 ≥ T- in the variety IRMA L457, T+ = T1 > T2 > T3 = T4 > T- in IRMA L484 and T+ ≥ T1 = T4 ≥ T2 ≥ T3 > T- in IRMA Q302. The highest values are obtained by T1 with 93.66 ± 37.14 g in IRMA L484; 66.42 ± 24.89 g in IRMA Q302 and 58.16 ± 18.21 g in IRMA L457. On the other hand, the lowest values were observed in T3 with 41.8 ± 15.75 g; 60.26 ± 19.85 g and 51.3 ± 21.33 g in IRMA L457, IRMA L484 and IRMA Q302 respectively. The highest biomass was observed in the T+ treatment, but no significant difference was found between this treatment and T1 and T2 in IRMA L457 and IRMA Q302. The lowest biomass was observed in the negative control (T-), which differed significantly from all the other treatments, regardless of the variety grown. With the exception of T-, analysis of variance revealed a

Table 7: Effect of treatments and variety on collar diameters of cotton plants

Variétés	Treatments (mean ± standard error in cm)						P-value
	T-	T+	T1	T2	T3	T4	
IRMA L457	8.24 ± 1.8 aA	16.37 ± 2.75 dA	14.60 ± 3.03 cA	13.92 ± 2.78 cA	11.75 ± 2.43 bA	13.83 ± 2.71 cA	<0.0001***
IRMA L484	10.27±1.94 aB	17.51±3.36 eB	16.73 ± 3.05 eB	15.81 ± 2.96 dB	12.4 ± 2.36 bAB	14.58 ± 2.51 cAB	<0.0001***
IRMA Q302	9.82 ± 1.65 aB	15,54 ± 2.84 dA	15.26 ± 30.0 dA	14.41 ± 3.01 cA	13.22 ± 2.27 bB	15.04 ± 2.96 cdB	<0.0001***
Means	9.44 ± 1.99	16.47 ± 3.09	15.53 ± 3.16	14.71 ± 3.02	12.45 ± 2.42	14.48 ± 2.78	
P-value	< 0.0001***	< 0.0001***	< 0.0001***	< 0.0001***	< 0.0001***	< 0.0001***	

T1: mycorrhizal fungi from Dogba locality; T2: mycorrhizal fungi from Zidim locality; T3: mycorrhizal fungi from Laf locality; T4: commercialized mycorrhizal fungi; T-: negative control (no application) and T+: positive control (4 g/plant of NPKSB chemical fertilizer). Within a row for each variety, means followed by different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$). Within a column for each treatment, means followed by different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$). *: Significant; **: Very significant; ***: Highly significant; ns: not significant

significant difference between the three varieties grown compared with all the other treatments applied (T1, T2, T3, T4 and T+). The biomass of the variety IRMA L484 was significantly greater than that of the varieties IRMA L457 and IRMA Q302, where no significant difference was observed between them. Since the effect of the treatments and that of the varieties on the above-ground biomass of the plants were highly significant, a significant interaction was recorded between these factors (Table 5).

Collar diameter

Collar diameters of cotton plants varied significantly between treatments in each of the three varieties grown (Table 7). This variation is presented according to the sequences T+ > T1 = T2 = T4 > T3 > T- in the variety IRMA L457, T+ = T1 > T2 > T4 > T3 > T- in IRMA L484 and T+ = T1 ≥ T4 = T2 > T3 > T- in IRMA Q302. The diameter was significantly higher in T+ (15.54 ± 2.84 to 17.51 ± 3.36 cm) and T1 (14.41 ± 3.01 to 15.81 ± 2.96 cm), where no significant difference was recorded between them in the varieties IRMA L484 and IRMA Q302. On the other hand, it is significantly lower for T- in all varieties. Treatments T2, T3 and T4 showed intermediate values. With regard to the varietal effect, the analysis of variance reveals a significant difference between the varieties grown, whatever the treatment applied. The largest diameter was observed in IRMA L484 and no significant difference was observed between this variety and IRMA Q302 with treatments T3 and T4. IRMA L457 showed intermediate values. Given that the effect of the treatments and that of the varieties on the diameter at the crown of the plants were highly significant, a highly significant interaction was recorded between these factors (Table 5).

Average capsular weight

The analysis of variance indicates that there is a significant difference between the treatments applied regardless of the variety grown and this difference is presented according to sequences such as T1 ≥ T2 ≥ T+ > T4 > T3 = T- to IRMA L457 variety, T1 ≥ T+ = T4 ≥ T2 > T3 > T- to IRMA L484 and T1 = T+ = T4 > T2 > T3 = T- to IRMA Q302 (Fig. 1A). The average capsular weight of T1 was significantly higher in IRMA L457 (5.11 ± 0.74 g) and IRMA L484 (4.69 ± 0.85 g) than in the other treatments, but no significant difference was observed between this treatment and T+. Similarly, no significant difference was observed between T1 and T2, T4 and T+ in IRMA Q302. Treatment T- had the lowest weight of all the varieties grown, but no significant difference was observed between T- and T3 in IRMA L457 and IRMA Q302. Concerning the varietal effect, there was a significant difference between the average capsular weight of all the varieties grown with treatments T1 and T2, where IRMA L457 had the most significantly high value (Fig. 1B). On the other hand, no significant difference ($P > 0.05$) was observed between the three varieties grown with treatments T-, T+, T3 and T4. Since the effect of treatments and varieties on the above-ground biomass of plants was highly significant, a significant interaction was recorded between these factors (Table 5).

A: Effect of treatments on average capsular weight according to variety; B: Effect of varieties on average capsular weight according to treatment. T1: mycorrhizal fungi from Dogba locality; T2: mycorrhizal fungi from Zidim locality; T3: mycorrhizal fungi from Laf locality; T4: commercialized mycorrhizal fungi; T-: negative control (no application) and T+: positive control (4 g/plant of NPKSB chemical fertilizer). Within a variety, bands bearing different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$). Within a treatment, bands bearing different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$).

Cotton yield

The analysis of variance reveals a significant difference between the treatments applied, regardless of the variety grown (Table 8). In the IRMA L457 variety, the cotton yield varied according to the sequence T+ ≥ T1 ≥ T2 ≥ T4 ≥ T3 > T-, whereas in IRMA L484 and IRMA Q302 the yield

Table 8: Effect of treatments and variety on cotton yield

Variétés	Treatments (mean ± standard error in kg)						*P*-value
	T-	T+	T1	T2	T3	T4	
IRMA L457	703 ± 93 aA	1208 ± 14 dA	1127 ± 90 cdA	1063 ± 112 bcdA	957 ± 70 bA	1032 ± 63 bcA	< 0.0001***
IRMA L484	839 ± 71 aA	1268 ± 150 cA	1209 ± 58 cA	1161 ± 75 bcA	965 ± 62 bA	1146 ± 102 bcA	< 0.0001***
IRMA Q302	680 ± 15 aA	1240 ± 104 cA	1148 ± 100 cA	1067 ± 115 bcA	916 ± 29 bA	1044 ± 117 cA	< 0.0001***
Means	794 ± 60	1248 ± 89	1161 ± 83	1097 ± 101	936 ± 54	1074 ± 94	
P-value	0.0570^{ns}	0.7560^{ns}	0.5229^{ns}	0.5252^{ns}	0.1129^{ns}	0.2906^{ns}	

T1: mycorrhizal fungi from Dogba locality; T2: mycorrhizal fungi from Zidim locality; T3: mycorrhizal fungi from Laf locality; T4: commercialized mycorrhizal fungi; T-: negative control (no application) and T+: positive control (4 g/plant of NPKSB chemical fertilizer). Within a row for each variety, means followed by different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$). Within a column for each treatment, means followed by different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$). *: Significant; **: Very significant; ***: Highly significant; ns: not significant

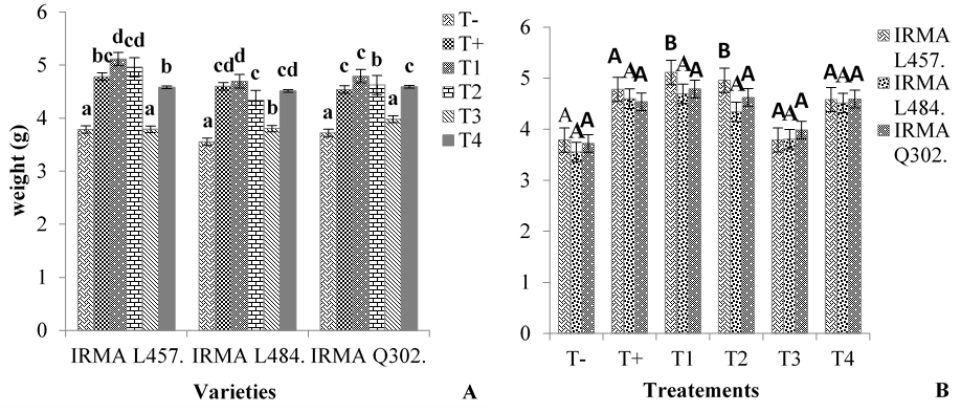

Fig. 1: Effect of treatments and variety on average capsular weight of cotton plant

varied according to the sequence T+ = T1 ≥ T2 = T4 ≥ T3 > T-. Despite the fact that the T+ treatment has the highest yield, particularly in the IRMA L457 variety where it is 1268 ± 150 kg/ha, there is no significant difference between this and T1 in IRMA L484 (1127 ± 90 kg/ha) and IRAM Q302 (1148 ± 100 kg/ha), as well as T4 in IRAM Q302 (1044 ± 117 kg/ha). T4 and T2 had intermediate values, with respective averages of 1097 ± 101 kg/ha and 1074 ± 94 kg/ha. On the other hand, the lowest yield was obtained with T- (negative control) for all the varieties grown, and it differed significantly from all the treatments applied. As for the varietal effect on yield, no significant variation was observed between the varieties grown, whatever the treatment. Given that the effect of the treatments applied on the gross seed cotton yield was highly significant, but that of the varieties was not significant, no significant interaction was recorded between these two factors according to the analysis of variance (Table 5).

Seed index

Although the responses varied from one treatment to another, the analysis of variance revealed no significant difference between the treatments applied, regardless of the variety grown (Table 9). However, the seed Index varied from 7.7 to 9.39 g, with the highest values obtained with T1 (9.39 ± 1.14 g) in the variety IRMA Q302 and with T+ (8.85 ± 0.69 g) in IRMA L457 and 8.48 ± 0.34 g in IRMA L484. On the other hand, the lowest values were all obtained with T- (7.69 ± 1.04 g) whatever the variety grown. However, no significant difference was detected between the varieties grown, regardless of the treatment applied (Table 9). These effects are therefore established, since the treatments applied had no significant effect on seed Index of cotton plant. However, there was no significant influence of varieties on seed Index. This is why the analysis of variance recorded no significant difference between these factors (Table 5).

Frequency of mycorrhization of roots

The analysis of variance indicates that there is a highly significant difference between the treatments applied regardless of the variety used (Fig. 2A). This difference follows the sequence T1 ≥ T2 = T4 ≥ T3 > T- > T+. The highest frequencies were obtained with the T1 treatment with 54 ± 5.44% in IRMA Q302, 53.65 ± 7.12% in IRMA L484 and 49.33 ± 6.35% in IRMA L457. However, no significant difference was detected between this treatment and treatments T2 (48.30 ± 7.71% on average) and T4 (48.64 ±

Table 9: Effect of treatments and variety on seed Index of cotton plant

Variétés	Treatments (mean ± standard error in g)						*P*-value
	T-	T+	T1	T2	T3	T4	
IRMA L457	7.7 ± 0.85	8.85 ± 0.69	8.71 ± 0.97	7.83 ± 0.87	7.76 ± 0.63	8.14 ± 1.43	0.5481^{ns}
IRMA L484	7.44 ± 0.68	8.48 ± 0.34	8.05 ± 0.79	8.36 ± 1.15	7.81 ± 0.64	8.42 ± 1.02	0.7602^{ns}
IRMA Q302	7.94 ± 1.04	8.60 ± 0.80	9.39 ± 1.14	8.66 ± 1.72	7.67 ± 0.40	8.90 ± 0.65	0.3768^{ns}
Means	7.69 ± 0.86	8.64 ± 0.80	8.71 ± 0.97	8.28 ± 1.24	7.75 ± 0.56	8.49 ± 1.03	
P-value	0.7953^{ns}	0.8802^{ns}	0.3207^{ns}	0.7433^{ns}	0.9551^{ns}	0.6979^{ns}	

T1: mycorrhizal fungi from Dogba locality; T2: mycorrhizal fungi from Zidim locality; T3: mycorrhizal fungi from Laf locality; T4: commercialized mycorrhizal fungi; T-: negative control (no application) and T+: positive control (4 g/plant of NPKSB chemical fertilizer). Within a row for each variety, means followed by different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$). Within a column for each treatment, means followed by different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$). *: Significant; **: Very significant; ***: Highly significant; ns: not significant

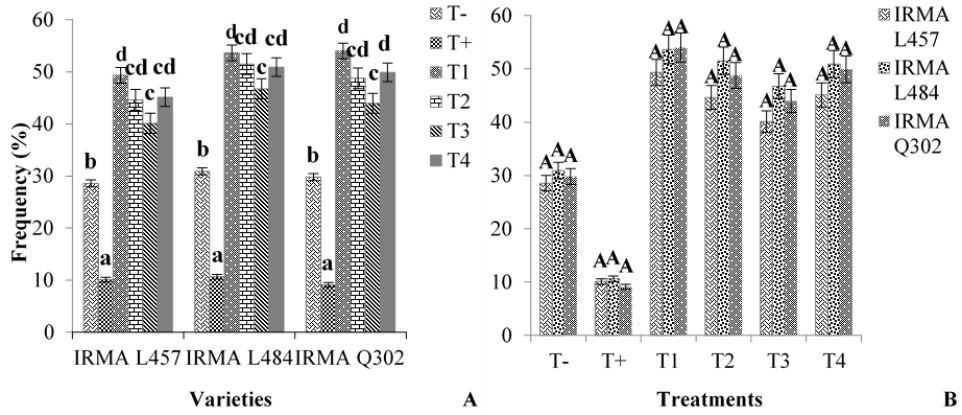

Fig. 2: Effect of treatments and variety on frequency of mycorrhization of roots of cotton plant

T1: mycorrhizal fungi from Dogba locality; T2: mycorrhizal fungi from Zidim locality; T3: mycorrhizal fungi from Laf locality; T4: commercialized mycorrhizal fungi; T-: negative control (no application) and T+: positive control (4 g/plant of NPKSB chemical fertilizer). Within a row for each variety, means followed by different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$). Within a column for each treatment, means followed by different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$)

5.80% on average) in all the varieties grown. The lowest frequency was obtained with T+ (9.93 ± 3.78% on average) in all varieties, and analysis of variance revealed a significant difference between this treatment and all the other treatments. With regard to the three varieties grown, no significant difference was observed between them or in any of the treatments applied (Fig. 2B). These results show that the treatments applied had a highly significant influence on the frequency of mycorrhisation of cotton roots. On the other hand, the varieties did not significantly influence the frequency of mycorrhization of the roots analyzed. Despite this influence, no significant interaction was identified between treatments applied and the varieties grown (Table 5).

Intensity of mycorrhization of roots

The analysis of variance reveals the existence of a significant difference between the treatments applied regardless of the variety grown and following sequences such as T1=T2=T4 >T3>T- >T+ in IRMA L457, T1 ≥T2=T4 ≥T3>T- >T+ in IRMA L484 and T1 >T2=T4 =T3>T- >T+ (Fig. 3A). In fact, the lowest mycorrhizal colonization intensity was observed with treatment T+ (1.90 ± 0.97% on average) in all the varieties grown and it differed significantly from all the other treatments (T1, T2, T3, T4 and T-). However, the highest values were obtained with T1 with 28.23 ± 6.23% in IRMA L457, 34.61 ± 6.98% in IRMA L484 and 32.81 ± 4.09% in IRMA Q302. Treatments T2, T3 and T4 had intermediate values, with respective mean intensities of 28.45 ± 7.71%, 23.60 ± 6.75% and 28.84 ± 5.18%. Furthermore, no significant difference was observed between this treatment and T2 and T4 (for the varieties IRMA L457 and IRMA L484). Concerning the varietal effect, no significant difference was detected between the three varieties studied for all the treatments applied (Fig. 3B). The treatments had a highly significant effect on the intensity of root colonization of the cotton plant. On the other hand, the cultivated varieties showed no significant effect on root colonization intensity. This is why the analysis of variance did not reveal any significant interaction between the treatments applied and the varieties used (Table 5).

Correlation between parameters

Fig. 4A and 4B show, respectively, the mapping of factors (treatments and varieties) and the correlation circle of the

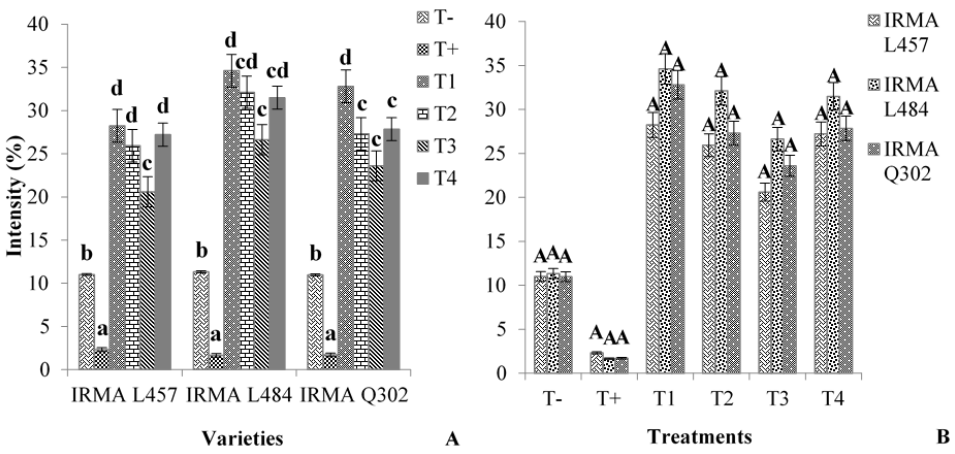

Fig. 3. Effect of treatments and variety on intensity of mycorrhization of roots of cotton plant
A: Effect of treatments on intensity of mycorrhization of roots according to variety; B: Effect of varieties on intensity of mycorrhization of roots according to treatment. T1: mycorrhizal fungi from Dogba locality; T2: mycorrhizal fungi from Zidim locality; T3: mycorrhizal fungi from Laf locality; T4: commercialized mycorrhizal fungi; T-: negative control (no application) and T+: positive control (4 g/plant of NPKSB chemical fertilizer). Within a variety, bands bearing different lowercase letters indicate that treatments are significantly different according to Duncan test ($P < 0.05$)

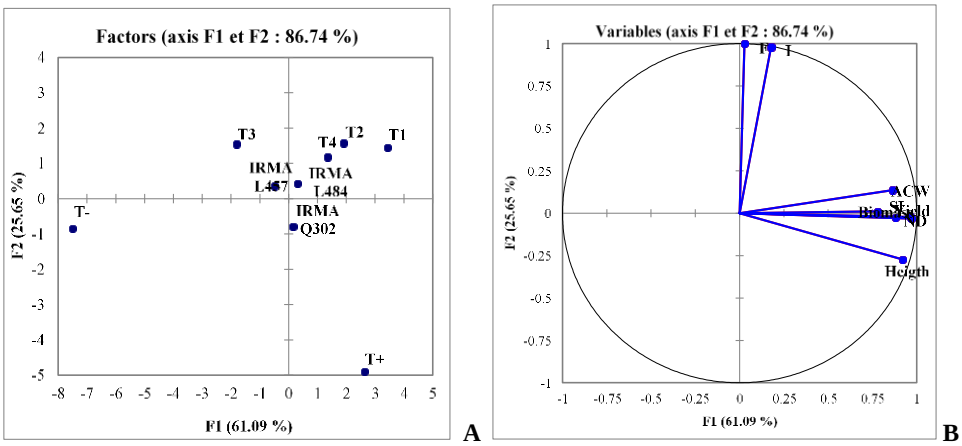

Fig. 4: Mapping of factors and the correlation circle of the variables studied on the F1 and F2 axis plane
A: mapping of factors (treatments and varieties); B: Correlation circle of the variables studied on the F1 and F2 axis plane. T1: mycorrhizal fungi from Dogba locality; T2: mycorrhizal fungi from Zidim locality; T3: mycorrhizal fungi from Laf locality; T4: commercialised mycorrhizal fungi; T-: negative control (no application) and T+: positive control (4 g/plant of NPKSB chemical fertiliser). ND: Collar diameter, ACW: Average capsular weight; SI: Seed Index; F: Frequency; I: Intensity

variables studied on the F1 and F2 axis plane, which express 86.74% of the results obtained. On this distribution of factors (Fig. 4A), we can see that treatments T1, T2 and T4, as well as the variety IRMA L484, are positively and strongly correlated with the F1 axis, which expresses 61.09% of the results. Treatment T3 and the variety IRMA L457 are strongly correlated with the F2 axis (25.65%). Fig. 4B, on the other hand, illustrates the correlation circle of the variables studied, showing that two major correlation groups stand out: the first, made up of average capsular weight, biomass, crown diameter, height, yield and seed index, are strongly correlated with each other and significantly linked to the F1 axis (61.09%). In contrast, the second group, consisting of mycorrhization frequency and intensity, were significantly correlated with each other and with the F2 axis (25.65%), but had almost no correlation with the variables in the second group.

These various comparisons are best appreciated in Table 10, which shows the contribution of each factor and variable to the representation of the axes. With regard to the factors studied, only treatments T1 (66.99%), T- (13.96%) and T+ (8.25%) show a strong contribution to the construction of the F1 axis. While the contribution of treatments T+ (70.59%), T1 (6.16%), T2 (7.23%) and T3 (7.06%) are significant on the F2 axis. Concerning the variables studied, height (17.31%), biomass (15.90%), collar diameter (19.13%), average capsular weight (15.26%), yield (19.31%) and seed index (12.41%) contributed significantly

Table 10: Contribution of factors and variable to the representation of axes

	Variables	F1	F2	F3	F4	F5	F6	F7
Treatments	T-	66.99	2.09	5.25	0.05	3.93	0.30	4.68
	T+	8.25	70.59	4.19	0.13	0.01	0.14	0.00
	T1	13.96	6.16	2.16	3.59	19.59	37.36	0.49
	T2	4.31	7.23	0.25	1.12	22.03	8.20	40.18
	T3	3.88	7.06	30.12	0.90	16.12	5.88	19.33
	T4	2.15	4.08	10.72	3.55	5.84	34.26	22.70
	IRMA L457	0.27	0.37	15.42	34.23	8.11	8.23	0.00
	IRMA L484	0.12	0.55	2.28	54.12	3.09	0.32	6.16
	IRMA Q302	0.03	1.83	29.57	2.26	21.23	5.27	6.44
variables	Height	17.31	3.62	0.01	4.59	43.75	19.39	9.88
	Biomass	15.90	0.03	26.81	8.70	22.04	25.15	0.74
	ND	19.13	0.02	5.12	0.07	1.85	39.08	34.70
	ACW	15.26	0.89	13.56	49.84	17.98	0.42	2.00
	Yield	19.31	0.04	3.44	0.26	11.16	13.81	51.47
	SI	12.41	0.00	50.48	36.33	0.37	0.25	0.05
	F	0.01	48.54	0.01	0.18	1.10	0.10	0.01
	I	0.64	46.81	0.56	0.01	1.73	1.76	1.13

T1: mycorrhizal fungi from Dogba locality; T2: mycorrhizal fungi from Zidim locality; T3: mycorrhizal fungi from Laf locality; T4: commercialized mycorrhizal fungi; T-: negative control (no application) and T+: positive control (4 g/plant of NPKSB chemical fertilizer). ND: Collar diameter, ACW: Average capsular weight; SI: Seed Index; F: Frequency; I: Intensity

Table 11: Pearson correlation matrix for different variables studied

Variables	Height	Biomass	ND	ACW	Yield	SI	F	I
Height	**1.00**							
Biomass	**0.78****	**1.00**						
ND	**0.87****	**0.91****	**1.00**					
ACW	**0.76****	**0.62***	**0.78****	**1.00**				
Yield	**0.91****	**0.89****	**0.96****	**0.77****	**1.00**			
SI	**0.67***	**0.52***	**0.66***	**0.72***	**0.68***	**1.00**		
F	-0.24^{ns}	0.01^{ns}	0.01^{ns}	0.14^{ns}	0.01^{ns}	0.03^{ns}	**1.00**	
I	-0.09^{ns}	0.15^{ns}	0.15^{ns}	0.26^{ns}	0.15^{ns}	0.12^{ns}	**0.98****	**1.00**

ND: Collar diameter, ACW: Average capsular weight; SI: Seed Index; F: Frequency; I: Intensity. Values in bold indicate a significant correlation. * significant at 5% level, * significant at 1% level, ^{ns}: not significant

to the construction of the F1 axis. On the other hand, only mycorrhization frequency (48.54%) and intensity (46.81%) are significantly linked to the F2 axis.

The Pearson correlation matrix (Table 11) shows the links between the different variables studied. Values close to 1 and shown in bold are significant ($P < 0.05$). Two main groups of variables were observed, the first of which includes all the growth and production parameters evaluated and shows a significant and positive correlation between them. However, the second group of variables, consisting of the frequency and intensity of root mycorrhisation of the plants, also showed a positive and significant correlation (r = 0.98). Furthermore, a non-significant but positive correlation was observed between these two groups of variables, with the exception of plant height, which was negatively correlated with root mycorrhisation frequency (-0.24) and intensity (-0.09).

Discussion

After 120 days of cultivation, endogenous mycorrhizal inoculation of Dogba (T1) and Zidim (T2) significantly increased plant height in all the cotton varieties grown (Table 4). In fact, whatever the variety considered, plant height was quite pronounced for inoculated plants compared with non-inoculated plants or negative controls (T-), with a highly significant difference. Although variations were observed, no significant effect ($P > 0.05$) of the varieties on this growth was recorded. Similar results were reported for cotton in the Far North region of Cameroon by Abakar *et al.* (2019) and for sesame in Senegal by Ndoye *et al.* (2016). These authors found that mycorrhized plants grew 1.5 to 3 times faster than control plants. In addition, no significant interaction was detected between the effect of treatments and that of varieties on the leaf growth of the cotton plants (Table 5). This suggests that the growth of the cotton plant does not depend essentially on the variety grown, but on its capacity to absorb the mineral elements present in the soil, and that this capacity could be boosted by the presence of AMF. In fact, it is well established that the primary role of AMF is to increase the uptake of elements that are not very mobile in the soil, such as phosphorus (P). Although the mechanism of action involved in this symbiotic association (fungus-host plant) is still very complex and varied, mycorrhiza is capable of developing physiological and biochemical mechanisms that improve the mobilization of soil nutrients, while improving soil quality through the acquisition of better physical, chemical and biological

properties (Plenchette 1982; Caravaca *et al.* 2002). According to Caravaca *et al.* (2002), the presence of mycorrhizae allows soluble phosphorus to be absorbed beyond the depletion zone and in sufficiently high quantities for the plant, even when this element is only present in very low concentrations in the soil.

The results also show a clear increase in above-ground biomass (Table 6), as well as in the diameter at the crown of the plants under the highly significant effect ($P > 0.001$) of the endogenous mycorrhizal inocula. Treatment T1 showed better performance, but no significant difference was observed between it and T2, as well as the marketed exogenous mycorrhizal inoculum (T4), with a significant increase in above-ground dry biomass ranging from 1.5 to 2.5 times greater than the negative control T-. Thus, through the establishment of mycorrhizae, AMF contribute to plant survival and growth through their beneficial role in hydromineral nutrition, resulting in an increase in the height and weight of mycorrhised plants compared with non-mycorrhized plants (Nwaga 2000, 2008; Ngakou *et al.* 2007; Megueni *et al.* 2011).These results are similar to those obtained by Tsané *et al.* (2005) for plantain vitro plants grown in Cameroon, and by Diouf *et al.* (2009) for two sesame varieties grown in Senegal. These authors obtained an increase in biomass ranging from 20 to 100% in inoculated plants compared with control plants.

Although chemical fertilisation (T+) remains more effective, inocula T1 and T2 performed very well in improving the collar diameter at the crown of the plants, with a significant increase of between 25 and 45% compared with the negative control (Table 7). This can be explained by the fact that the increase in root diameter and branching under the effect of mycorrhizae confers better uptake of mineral elements, thus leading to an increase in the diameter at the crown of the plant for good distribution of these elements to the aerial part of the plant. The transition from root to stem takes place in the crown region, so the continuity of conductive tissue is maintained there and can be increased by the activity of mycorrhizae. Given that the responses are specific to each variety, as in the case of IRMA L484, which has the largest diameters at the crown compared with the other two varieties, we can conclude that this increase also depends on the genotypic characteristics of the plants. These results partially corroborate those obtained by Tsané *et al.* (2005), who found that the crown diameter of mycorrhized plants was twice that of non-mycorrhized plants. However, the beneficial effect of AMF on cotton growth and development depends on the nature of the fungal isolates involved in the symbiotic mechanism, as highlighted by Barea (1991) and also on the type of plant. We found that the varieties IRMA Q302 and IRMA L484 showed one of the best growths with the endogenous isolates (T1) consisting of a cocktail of AMF originating from Dogba, whereas those originating from Zidim (T2) were more efficient for IRMA L457. This can be explained by the fact that AMF are obligate symbionts, their connections with a host plant are not specific, but their interactions are highly compatible both structurally and physiologically (Selosse *et al.* 2006). According to Roland *et al.* (2008a, b), plants and fungi differ in both composition and physiology, factors which have a direct influence on the symbiotic relationship. By comparing the responses of different plant species to the effect of different fungal strains, these authors demonstrated that there were variations between taxa and intra-specific variability within AMF species in their ability to promote plant growth. These results are similar to those obtained by Diop *et al.* (2003) in Solanum and by Leye *et al.* (2015) in sesame, both grown in Senegal and by Gao *et al.* (2007) in rice grown in China. These authors found that the improvement in plant growth varied according to both the variety grown and the composition of the mycorrhizal inoculum applied. In addition, Ngonkeu *et al.* (2013) also revealed that inoculation with a mixture of certain mycorrhizal strains (*Archaeospora* sp., *Gigaspora margarita* and *Acaulospora tuberculata*) resulted in a considerable improvement in Z. mays grown on acid soil compared with a mono-specific inoculation. This suggests that mixing strains from the same source gives even better results, while allowing sensitive varieties to tolerate acid soils. In addition, it was noted throughout the experiments that the treatment consisting of a mixture of fungal isolates from Laf (T3) performed least well. This suggests that the cotton plant may act differently on mycorrhizal dependency factors. This is why Estaùn *et al.* (2010) state that it is difficult to determine similarities and differences, as well as variations in the behavior of different plant species or cultivars with regard to mycorrhizal symbiosis.

In line with the results obtained on growth, the production yields of the three cotton varieties receiving treatments T1, T2 and T4 were significantly higher than those of the negative control plants (Table 8). Although chemical fertilisation (T+) was still better, no significant difference was observed between it and inocula T1, T2 and T4, which showed a significant yield gain of around 30 to 50% compared with the negative control (T-). Furthermore, no significant interaction was observed between the treatments applied and the varieties grown in terms of gross yield and seed index. Our results thus concur with those of Abakar *et al.* (2019), who obtained gains in cotton fiber and seed yield ranging respectively from 9.8 to 36.32% in some cotton varieties grown in the Far North of Cameroon. In addition, in several experiments based on mycorrhization of two Z. mays varieties grown on acid soil, Nwaga *et al.* (2013) found that inoculation of the acid-sensitive Z. mays varieties resulted in yield increases ranging from 6 to 59% compared to the control. As such, the remarkable effect of the performance of these endogenous fungal isolates on yield is probably due to some sort of adaptability of these to the different edaphic constraints to which they have been subjected, since their sampling sites are characterized by agricultural practices essentially based on chemical

fertilisation. In the same way, Verbruggen *et al.* (2013) assert that native AMF can be considered as a preferential inoculation tool to ensure the re-establishment of plants in degraded soils.

The influence of mycorrhizae on the processes described above can only be explained by morphological and structural changes in the roots of the plant involved in the symbiotic mechanism. In this study, microscopic analysis of cotton roots showed that they are fairly well mycorrhized and the addition of endogenous or exogenous AMF increased the frequency of symbiosis establishment from 29.78% in negative control plants to 52.33% in mycorrhized plants (Fig. 2). The native AMF showed better responses than the controls, which were mainly marked by the negative effect of chemical fertilizers (T+) on the presence of mycorrhizal structures in the cotton roots (9.93% on average). These results are thus in partial agreement with those reported by Ngonkeu (2009), who obtained a mycorrhization frequency ranging from 15.6 to 79% depending on the maize variety grown on acid soil and inoculated with endogenous strains from the central and southern regions of Cameroon. However, although AMF colonization parameters were greater in inoculated plants, this colonization was not identical in all varieties and for all inocula. In fact, the results obtained show that the IRMA Q302 variety seems to be more receptive to the establishment of mycorrhizal structures than the IRMA L484 and IRMA Q302 varieties. The highest mycorrhization parameters were obtained with a frequency of 54 ± 5.44% and a rate of 23.85 ± 4.11%. However, the highest mycorrhization intensity (34.61 ± 6.82%) was observed in the IRMA L484 variety (Fig. 3). No significant interaction was observed between the treatments applied and the varieties grown (Table 5). In terms of infection efficiency, T1 proved to be more infectious, but no significant difference was identified between it and T2 and T4. Therefore, the improvement in mycorrhizal colonization of inoculated cotton roots is only the result of the expression of AMF isolates present in the inocula applied, thus acting on the root uptake performance of the crop plants. Our results thus concur with those of Nwaga *et al*. (2013) who showed that root colonization of *Zea mays* grown on acid soil varies according to the variety grown, as well as the inoculum applied. Thus, on the two varieties tested, these authors found that inoculation increased the arbuscular rate from 28% with native AMFs to 60% with selected AMFs for one of the varieties and from 20% (native AMF) to 38% (selected AMF) for the other.

Furthermore, the results do not show any significant correlation between mycorrhization parameters and agronomic parameters (Fig.4 and Table 11). Indeed, the work of Diagne and Ingleby (2003) showed that high mycorrhizal root colonisation does not always result in improved plant growth. Similar results were also reported by Ndoye *et al.* (2016) during mycorrhizal inoculation of white fonio grown under semi-controlled conditions in Senegal. Although this relationship was not significant, a positive correlation was nevertheless observed between its parameters. This is why Gnamkoulamba *et al.* (2018) reported the existence of a significantly positive correlation between the various morphological growth parameters and the mycorrhization rate of rice grown in Togo. This suggests that mycorrhizal development may also be the expression of an interaction that varies greatly depending on the host plant and fungal strains, as highlighted by Lumini *et al.* (2011).

Conclusion

The use of inocula exogenous and endogenous to the region, in particular those from the localities of Dogba and Zidim, significantly improved the growth and development of the three varieties of cotton grown in the same way as chemical fertilizers, with an increase 2 to 3 times greater than that of non-inoculated plants. At the same time, production yields were also significantly improved in the inoculated plants, with an increase in yield of around 30 to 50% compared with non-inoculated plants. Of the three varieties grown, the effect of IRMA L484 and IRMA Q302 was the most significant on the parameters assessed, compared with IRMA L457. Although the varietal effect was not significant on the production parameters, several significant interactions were recorded between the varieties and the treatments applied to several other parameters. These results show that mycorrhization is an ecological reality that could be beneficial to both farmers and the environment. In the future, it would be advisable to assess the effect of indigenous AMF on production quality and on the phytosanitary protection of cotton plants.

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Author Contributions

Ismael Haman Ramza: Carrying out the experiment, collecting and verifying the analyzed data; prepared the draft of the manuscript and approved the final manuscript; Honore Issa Koulagna: Member of the Laboratory, experimental monitoring, collection of field data and approved the field data; Philippe Kosma: Design the research plan, and supervised this study; Clautilde Megueni: Design the research plan, supervised this study, and approved the final manuscript.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data presented in this study will be available on fair request to the corresponding authors.

Ethics Approval

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and that no ethical issues are involved.

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