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Potentials of Arbuscular Mycorrhiza Fungus in Tolerating Drought in Maize (*Zea mays* L.)

Odunayo Joseph Olawuyi[1], Adegboyega Christopher Odebode[1], Busayo Joshua Babalola[1], Ezekiel Taiwo Afolayan[2], Chidinma Pauline Onu[3]

[1]Department of Botany, University of Ibadan, Ibadan, Nigeria
[2]Biology Department, Federal College of Education Abeokuta, Abeokuta, Nigeria
[3]Department of Biosciences and Biotechnology, Babcock University, Ilisan-Remo, Lagos, Nigeria
Email: oj.olawuyi@ui.edu.ng

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Abstract

Maize is one of the most important cereal crops widely grown for food, feed, and fodder/forage throughout the world in a range of agroecological environments. Drought stress continues to haunt the maize farmers across south western part of Nigeria, thereby leading to low quantity of this essential staple food in the market. Efforts have been made to enhance the growths and yields in maize by investigating the influence of Arbuscular mycorrhizal fungus (*Gigaspora gigantea*) on the tolerance of maize to drought stress. The experiment was conducted in the teaching and research farm of Babcock University, Ilishan-Remo, Nigeria. The experiment was laid out in a complete randomized design with four replicates. Data were collected on eight morphological drought related characters. The objective of this research work was to evaluate the morpho-agronomic responses and potential of *Gigaspora gigantea* colonization in maize drought tolerance, and also to select parents in maize breeding for improved yield related components. The combined analysis of variance showed significant ($P < 0.05$) treatment effect on majority of the traits evaluated. The treatments of Arbuscular Mycorrhiza Fungus (AMF) produced significant higher growth related traits suggesting that AMF treated plants had higher potential in influencing the tolerance to drought. Accession 3 was considered best for most of the traits studied and can be selected as parents in maize breeding for yield related components.

Keywords

Maize; *Gigaspora gigantea*; Drought Stress; Tolerance; Growth; Yields

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1. Introduction

Maize (*Zea mays* L.) also known as corn is an important monocotyledonous plant of the family Poaceae. It is the most widely grown grain crop in the world as a direct staple food for millions of individuals and, through indirect consumption as a feed crop, is an essential component of global food security [1]-[3]. Maize becomes stressed by drought at the reproductive period, however, the development and adoption of drought-tolerant varieties are seen as a long-term solution to many of the problems plaguing drought-prone maize production regions around the globe [2]. The change in global climate is now generally considered to be underway [4] and is expected to result in a long-term trend towards higher temperatures and an increased incidence of drought in specific regions. There is significant amount of yield losses due to water stress in both temperate and tropical environments [5]. Since water availability is variable across fields and farmers typically grow only one hybrid in a particular field, a moderate amount of drought tolerance is necessary in all maize hybrids [6]; the use of drought-tolerant cultivars may be the only economical option for many small-scale farmers [7]. The utilization of Arbuscular mycorrhizal fungi can enhance yield stability by improving drought tolerance which can be a major solution to stabilizing global maize production. Maize agronomic responses to drought stress have been detailed in multiple review and research articles [8]-[12].

G. gigantea plays an important ecological role and symbiotic relationship with the root of higher plants by contributing significantly to plant nutrition and promoting growth in the cultivation of agricultural crop species, such as hardwood tree seedlings, corn (*Zea mays*), carrot (*Daucus carota*), grape (*Vitis vinifera*) and soybean (*Glycine max*) [13]-[15] and has been shown to increase the productivity of a variety of agronomic crops including maize [16]. Horticultural plants can utilize AMF to increase their growth and yield responses in drought stress condition to well-watered conditions due to mobility of nutrient that is limited under drought conditions [17] [18]. In case of soybean, *Gigaspora gigantea* can be used in combination with *Bradyrhizobium japonicum*, a nitrogen fixing bacterium, to promote plant growth [19]. The colonization of some cuttings of yew (*Taxus x media var. densiformis*) plant inoculated with *G. gigantea* has been reported of higher levels of chlorophyll [20], [21]. However, in maize, the most widely recognized contribution of AM fungi to host-plant nutrition involves their ability to extract Phosphorus from outside the Phosphorus depleted regions near the plant roots [22]-[27] and non-AM-host weed suppression [28]. Yet the positive effects of AM fungi on host-plant growth and development are not only noticeable in low soil fertility conditions [29], [30] but also in drought environments [17] [20], improved soil structure may also trigger plant growth and development [31]. The potential of *G. gigantea* in integrated striga management has also been reported in maize but the information on influence on drought tolerance and growth of maize is limited [32]. Although, drought can strike at any time, the plants are most prone to damage due to limited water. Some of the drought-tolerance related traits include plant height, number of leaves, stem girth. It has however been studied recently that AM fungi has positive influence on the performance of these traits. Therefore, this study aimed at investigating the influence of *G. gigantea* on drought tolerance and growth of maize accessions.

2. Materials and Methods

The experiment was conducted at the teaching and research farm of the Department of Agriculture, Babcock University teaching and research farm Ilishan Remo Ogun State, South western Nigeria which is situated at the altitude (6˚ 52″ 00 N and 3˚ 43″ 00 E) from January to March, 2012. Maize accessions were obtained from four different market locations in Ogun State, Nigeria (**Table 1**). The Arbuscular mycorrhizae species collected from Soil Biology Unit of the Department of Botany, University of Ibadan, Ibadan, Nigeria was a soil inoculum obtained from extracted spores using a wet-sieving technique according to the procedure described by Sieverding and Schenck (1989). The experiment was laid out in a complete randomized design and replicated four times. The treatments were; T1 = Maize + AMF only; T2 = Maize + AMF + Water only and T3 = Maize only which served as contro l.50 Spores of AMF (*G. gigantea*) in mixtures soil and root fragments were inoculated in 8 kg plastic pots filled with sterile depleted soil according to the procedure described by [33] Each treatment consists of 3 rows of 60cm per accession, with spacing of 30 cm between rows. The treatments were applied four weeks after planting to assess the tolerance and susceptibility levels of drought in the accessions. Weed control was carried out through manual weeding. The data collected on morphological drought-related traits of maize using descriptive sampling at 4 and 6 weeks after planting were; plant height, stem length, leaf length, leaf width, number of leaves, number of node, node per length of plant, stem girth. The data obtained were subjected to analysis of variance using [34]. Significant difference between treatment means were separated using Duncan Multiple Range Test at P < 0.05.

3. Result and Discussions

The analysis of variance shows that the height of maize plant in day after treatment (DAT) for AMF only and AMF + Water treated plants were significantly different(P < 0.05) from control which had the least value of 64.20 cm (**Table 2**). This implies that maize accession from Ilishan has the potential to resist drought, while untreated plant (Control) could not. On third DAT, there were significant differences in accessions from Ikene, Iperu and Ilara for plant height, while treated plant with AMF only in accession from Ilishan-Remo was significantly different from other treatments. Also maize treated with AMF + water in Ikene and Ilara accessions were higher and significantly different from other treatments and control, while AMF only in Ilishan—Remo and Iperu accessions were significantly different from Maize treated with AMF + Water and control. This conforms to the observation of [28]. The number of leaves per plant for Ilishan-Remo accession were not significantly different from maize treated plants after the 3DAT and 5DAT as well as plant treated after 9DAT for Ikene accession, while significant effect of the treatments were observed for other accessions except Ikenne (**Table 2**).

Table 1. Accessions and their sources.

ACCESSIONS	SOURCES
Accession 1	Ilishan-Remo
Accession 2	Ikenne
Accession 3	Iperu
Accession 4	Ilara

Table 2. Growth response of maize accessions in treatment combinations of *G. gigantea* at different days.

		Plant height (cm)					Number of leaves					Leaf length (cm)				
		1DAT	3DAT	5DAT	7DAT	9DAT	1DAT	3DAT	5DAT	7DAT	9DAT	1DAT	3DAT	5DAT	7DAT	9DAT
A1	T1	74.20a	78.85a	81.25a	86.80a	88.20a	4.50ab	5.00a	5.00a	4.00b	4.00b	28.10b	51.65b	56.25b	59.50b	55.00b
	T2	71.20ab	69.50b	76.10ab	71.20b	74.40b	5.00a	5.00a	5.00a	6.50a	6.50a	44.80a	54.45a	59.40a	68.30a	68.30a
	T3	64.20b	69.25b	71.90b	61.60c	61.60c	5.50a	5.50a	5.50a	3.50b	3.50b	22.00c	50.75b	53.30b	45.30c	45.30c
A2	T1	71.90b	78.50b	80.15b	88.35b	94.70a	5.50c	5.00ab	5.00ab	5.00c	4.00a	49.50c	48.65c	59.90b	59.35c	59.35c
	T2	90.35a	93.75a	97.20a	112.30a	122.80a	7.00a	7.00a	7.00a	7.00a	7.00a	66.30a	64.90a	68.40a	86.10a	86.10a
	T3	61.45c	63.00c	68.95c	79.35b	79.35a	6.00ab	5.50ab	5.50ab	6.00b	5.50a	50.65b	52.00b	55.20c	62.95b	62.95b
A3	T1	97.40a	103.50a	107.45a	109.95a	111.95a	8.50a	8.00a	8.00a	4.50b	4.00b	73.70a	77.95a	81.00a	79.75a	79.75a
	T2	93.60ab	99.95b	106.00a	110.05a	112.05a	8.00ab	6.50b	6.50b	7.00a	6.00a	67.35b	73.75b	79.25b	75.85b	75.85b
	T3	78.65c	81.00c	83.75b	77.00b	77.10b	7.00b	5.00c	5.00c	4.50b	4.00b	59.30c	58.10c	61.25c	56.90c	56.90c
A4	T1	66.50a	73.75b	76.05ab	89.00b	89.00b	6.50ab	6.50ab	6.50ab	6.50ab	6.50ab	58.45a	54.30b	62.35b	68.50b	68.50b
	T2	67.60a	82.75a	87.40a	103.50a	103.50a	7.00a	7.50a	7.50a	8.00a	8.00a	56.35ab	59.90a	66.10a	76.25a	76.25a
	T3	65.35ab	71.25c	75.70c	70.75c	70.75c	6.00b	6.00b	6.00b	5.50b	5.50b	52.50b	50.40c	50.90c	52.50c	52.50a

1DAT = 1st day after treatment
3DAT = 3rd day after treatment
5DAT = 5th day after treatment
7DAT = 7th day after treatment
9DAT = 9th day after treatment

T1 = Maize + AMF only
T2 = Maize + AMF + Water
T3 = Maize only

Accession 1 = A1
Accession 2 = A2
Accession 3 = A3
Accession 4 = A4

Mean with the same value in the column are not significantly different P < 0.05.

Plants treated with AMF + water was significantly higher than other treatments and control in Ilishan-Remo, Ikenne and Iperu accession. On the other hand, the varietal influence favored the performance of plants treated with AMF only at the initial stage after treatments for production of leaves. Also, there were significant different in leaf length for all the treated maize accessions (**Table 2**). Similar observation was reported by [35]. Again, the result from **Table 3** shows that the leaf width of maize plant in 2DAT for AMF + Water treated plants were significantly different from controls which had the least value of 2.80 cm.

On the third DAT, there were no significant differences ($P > 0.05$) in leaf width from all the treatments from Ikenne, while treated plant with AMF + Water only in Ilishan-Remo was significantly different ($p < 0.05$) from other treatments of other accessions. At 4DAT, the control plants were not significantly different in all the locations, but at 5DAT, plants treated with AMF only were significantly different from control with the least value of 3.40 cm in Ikene (**Table 3**). For number of node at 1DAT, there were significant differences for all the treatment in Ilishan Remo and Iperu accessions, while significant differences were not observed in all the treatments in Ikenne and at 2DAT for all the treatments in Ilishan-Remo.

At 3DAT, the number of nodes had the least value of 2.00 cm for control plant in Ilara accession, while plant treated with AMF only was significantly different from other treatment including control in Iperu for all the days after treatment. At 5DAT, the node per length of 6.00 cm in AMF + Water treated plant was significantly different from other treatment in which with 3.95 cm was the least for all the accessions (**Table 3**). The result of the growth response of maize to AMF treatment at different days is shown in **Table 4**. At 1DAT, the stem height of AMF treated plant was significantly different from untreated plants while plants treated with AMF only and AMF + Water at 2DAT, 3DAT, 4DAT and 5 DAT were significantly different from untreated plant. The stem girth at 1DAT in AMF + Water only was significantly different from untreated plants but at 4DAT, there were no significance differences in all the treatments for Ilishan-Remo accession (**Table 4**). This agrees with the findings of [36].

Figure 1 shows the effect of AMF + Water on drought tolerance of maize, **Figure 2** also shows the maize plant treated with AMF only, while the effect of water on maize is shown in **Figure 3**.

4. Conclusion

The results showed that maize accession treated with AMF produced significant higher growth related traits suggesting that AMF treated plants had high potential in influencing the tolerance to drought. The use of AM fungus can be recommended for farmers since most agricultural crops can perform better and more productive

Table 3. Effect of AMF treatments on leaf width, number of node and node per length at different days.

		Leaf width (cm)					Number of node					Node per length				
	Treatment	1DAT	2DAT	3DAT	4DAT	5DAT	1DAT	2DAT	3DAT	4DA T	5DAT	1DAT	2DAT	3DAT	4DAT	5DAT
A1	T1	2.75a	2.95ab	3.20b	3.80b	4.80a	2.00b	3.00a	4.00a	3.00b	4.00b	2.95a	3.75a	4.75a	5.30a	5.00b
	T2	2.95a	3.55a	3.95a	4.55a	4.55ab	3.00a	3.00a	3.80ab	4.50a	5.00a	2.95a	3.75a	4.75a	5.30a	6.00a
	T3	2.75a	2.80b	3.05c	3.75b	3.95c	2.50ab	3.00a	3.50ab	2.50b	3.00c	1.95a	2.80b	3.05b	3.75b	3.95c
A2	T1	2.90b	3.80b	4.05a	4.50a	4.60a	3.00a	3.00b	3.00b	3.50b	4.50a	7.85b	8.75b	9.25a	9.25a	10.33a
	T2	3.50a	4.10a	4.25a	4.70a	4.70a	3.50a	3.50a	3.80a	4.00a	4.10ab	8.10a	9.50a	9.55a	9.55a	10.50a
	T3	3.55a	4.05a	4.15a	3.55b	3.40b	3.00a	2.00c	2.50c	3.00c	3.00b	7.50c	8.50b	8.65b	8.65b	8.75b
A3	T1	4.20a	4.65a	4.85a	6.15a	6.60a	4.00ab	4.50a	4.50a	5.00a	5.00a	7.95b	7.45b	7.60b	7.75b	8.45b
	T2	3.95ab	4.30a	4.75a	5.95ab	6.20ab	4.50a	3.00b	3.00b	3.50b	3.50b	8.80a	8.50a	8.50a	9.10a	9.50c
	T3	3.70b	4.15b	4.35ab	3.85b	3.90b	3.50b	2.00c	2.00c	3.00c	3.00c	7.40c	6.65c	6.95c	7.25c	7.00c
A4	T1	3.05a	4.30a	4.45a	4.85a	5.10a	3.00b	3.00ab	3.00ab	3.0ab	3.00ab	8.00a	8.55a	8.60a	8.25b	8.25b
	T2	3.55a	3.85ab	3.95b	4.70ab	4.95ab	4.00a	3.50a	3.50a	4.00a	4.00a	6.45b	8.25b	8.25b	9.50a	9.50a
	T3	3.20a	3.40b	3.85b	3.90b	4.15b	3.00b	2.00c	2.00b	2.00b	2.00b	6.00c	7.00c	7.00c	7.75c	7.25c

Table 4. Growth response of maize to AMF treatments at different days.

treatment		Stem height (cm)					Stem girth (cm)				
		1DAT	2DAT	3DAT	4DAT	5DAT	1DAT	2DAT	3DAT	4DAT	5DAT
A1	T1	23.45a	22.60b	21.85b	26.20b	26.20b	3.00c	3.50b	3.60b	3.80a	4.15ab
	T2	16.45b	25.05a	26.60a	28.50a	28.50a	4.25a	4.30a	4.50a	4.70a	4.90a
	T3	16.10b	17.60c	18.60c	16.30c	16.30c	3.95b	4.60a	4.00a	4.05a	4.65a
A2	T1	21.25b	26.50b	24.95b	20.00b	22.00b	3.00b	3.75b	3.85c	4.00c	4.00c
	T2	24.05a	28.74a	28.80a	26.50a	26.50a	4.60a	4.90a	5.10a	5.40a	5.90a
	T3	11.95c	14.35c	19.05c	15.75c	15.75c	4.10ab	4.15ab	4.55b	4.85b	5.15b
A3	T1	23.70a	25.55b	26.45b	30.20b	31.20b	6.50a	6.75a	6.75a	7.10a	7.40a
	T2	26.25b	26.20a	26.75a	34.20a	34.50a	6.10a	6.65a	6.75a	6.85a	6.95b
	T3	15.35c	22.90c	22.50c	20.20c	20.20c	5.95b	5.95b	6.15b	6.10b	6.10c
A4	T1	18.05a	29.45a	28.70a	20.50b	20.50b	4.10b	4.20b	4.25b	4.30b	5.20b
	T2	11.25c	22.85b	23.30c	27.25a	27.25a	4.85a	5.45a	5.45a	5.95a	6.05a
	T3	12.85b	20.85c	24.80b	18.07c	18.20c	4.10b	4.00b	4.00b	4.10b	4.10c

DAT = day after treatment, Accession = A, Mean with the same value in the column are not significantly different P < 0.05.

Figure 1. AMF + Water only (T2).

Figure 2. AMF only (T1).

Figure 3. Water only (T3).

when well colonized by AM fungus, especially in the cultivation of Maize. The farmers should be encouraged to use AMF as it is environmentally friendly in preventing water pollution and reducing soil toxicity, and required no specialized skill for its application and there is no need of frequent application.

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