Reprint **ISSN 1994-1978 (Web Version)**

Journal of Soil and Nature

(J. Soil Nature)

Volume: 10 **Issue: 1** **July 2023**

J. Soil Nature 10(1): 01-08 (July 2023)

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ISSN-1994-1978 (Online)
***J. Soil Nature* 10(1): 01-08 (July 2023)**

EFFECTS OF *Arbuscular mycorrhizal* FUNGUS (*AMF*) INNOCULATION AND WATER REGIMES ON CASHEW (*Anarcadium occidentale* L.) SEEDLINGS PERFORMANCE IN IBADAN, SOUTHWESTERN, NIGERIA

O.S.O. AKANBI[1]*, O.A. ONAWUMI[2], C.E. OGBEIDE[1], H. AMINU[1] AND S.O. ODEDELE[1]

[1]Soils and Plant Nutrition Section, Cocoa Research Institute of Nigeria, P.M.B. 5244, Ibadan, Oyo state, Nigeria.
[2]Soils & Tree Nutrition Department, Forestry Research Institute of Nigeria, Idi – Ishin, Ibadan, Oyo State, Nigeria.

Accepted for publication on 26 June 2023

ABSTRACT

Akanbi OSO, Onawumi OA, Ogbeide CE, Aminu H, Odedele SO (2023) Effects of *Arbuscular mycorrhizal* Fungus (AMF) inoculation and water regimes on cashew (*Anarcadium occidentale* L.) seedlings performance in Ibadan, Southwestern, Nigeria. *J. Soil Nature* 10(1), 01-08.

The cashew (*Anacardium occidentale* L.) is a tough herbaceous perennial plant that grows well in tropical America, Asia, and Africa where favorable climatic conditions promote economic development. In ecological settings where other woody crops cannot, it thrives. Despite the resilience of cashews against adverse weather conditions, the recent outcry and complaints from cashew farmers in growing communities in Nigeria indicate that large numbers of cashew seedlings are dying off especially in areas that are drier during the year. This is due to the on- going drought and high temperatures caused by global climate change. These indeed pose a lot of threats to the livelihood of farmers and the economy of the Nigerian country, so systematic research intervention is needed to develop an indigenous technology that is environmentally friendly, quickly accessible and most importantly affordable to poor farmers. Base on this backdrop, a screen house experiment was set up to evaluate the effect of *Arbuscular mycorrhizal* fungus (AMF) inoculation and water regimes on cashew (*Anarcadium occidentale* L.) seedlings establishment in Ibadan, South western, Nigeria. The experiment was a 3 × 3 × 2 factorial consisting of eighteen treatment combinations replicated three times thereby making a total number of 54 experimental units, laid out in a completely randomized design (CRD). The results showed that the cashew biotypes responded positively but differently to the varying water regimes and Arbuscular fungus inoculation treatments. The jumbo Cashew biotype (C_1), inoculated with Mycorrhizae (M_1) and treated with water at 80% field capacity (F_3), produced the highest number of leaves throughout the study periods. Cashew biotypes ($C_1F_1M_0$; $C_2F_1M_0$ and $C_3F_1M_0$) with the least water treatment (i.e., 40% field capacity) and without Mycorrhizae inoculation however, produced the lowest number of leaves per plant. Similarly, pots that were inoculated with Mycorrhizal in combination with water regime applied at 80% field capacity significantly ($p< 0.05$) enhanced plant height (cm); stem thickness; leaf area (cm^2) and number of branches produced by the cashew seedlings.

Key words: *Arbuschular mycorrhizal, cashew, climatic condition, drought, environmentally friendly, inoculation*

INTRODUCTION

The cashew (*Anacardium occidentale* L.) is a hardy, evergreen herbaceous perennial that grows in about 32 countries around the world, especially in tropical America, Asia, and Africa where climatic conditions favor economic growth (Pradeepkumar *et al*. 2008). Cashew is a strong and well-known for thriving in soils, particularly sandy ones that are typically unsuited for other fruit trees. (Department of Agriculture, South Africa (2018). Cashew nuts have huge foreign exchange earning potential and a source of industrial raw materials, and are expected to become Nigeria's largest economic forest crop. Cashew nuts are the largest monetary part of the cashew tree and provide exceptional alternative income to the country. Despite the many economic and dietary importance associated with cashew tree, its production in terms of nut yield and growth is threatened by drought, especially at the juvenile stage (i. e first and second years of growth) in the field (Dadzie *et al*. 2020). This is largely due to the effects of climate change, which has negatively impacted global agricultural productivity hence, the need for this study. However, with the current global climate change, drought has become a common complication that slows crop growth and reduces impacts on primary production in dry lowlands (Shukla *et al.* 2012; Trenberth *et al*. 2014; Mathur and Vyas, 2000). The cashew is a hardy evergreen tree plant that adapts to poor soils; receives little rainfall and thrives on all soil types except poor and acidic soils (IndiaAgroNet.com). Despite the resilience of cashews against adverse weather conditions, the recent outcry and complaints from cashew farmers in the growing communities in Nigeria indicate that large numbers of cashew seedlings are dying off especially in areas that are drier during the year. This is due to the on - going drought and high temperatures caused by global climate change. These indeed pose a lot of threats to the livelihood of farmers and the economy of the Nigerian country, so systematic research intervention is needed to develop an indigenous technology that is environmentally friendly, quickly accessible and most importantly affordable to poor farmers. Drought stunts growth and causes seedling death, allowing selection for plants with greater tolerance (Begum *et al.* 2019; Larekeng *et al.* 2019). Alterations at the biochemical, physiological and morphological levels enable plants to avoid or increase their tolerance to stress (Marschner and Dell, 1994; Mathur and Vyas, 2000). This modification can occur through the symbiosis of plant roots with *AMF*. *AMF* interactions are observed in about 80% of terrestrial plants (Miller and Jastrow, 2000). *AMF* hyphae reproduce and grow roots (Peng *et al*. 1993), which contribute to increased nutrient uptake.

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*Corresponding author & address: Akanbi Olorunfemi, E-mail: akanbioso2008@gmail.com
Akanbi Olorunfemi Sunday Ojo, Onawumi Olufisayo Adeyinka, Ogbeide Edugie Christerbeth, Habibu Aminu and Odedele Samson Oluseye

It invades cortical root cells and forms structures called arbuscules, which serve as mediators of metabolite exchange between the fungus and the host cytoplasm. Therefore, root colonization by AMF is directly associated with better nutrient and water uptake, increased chlorophyll content, photosynthesis, and increased transpiration rates (Rodríguez - Morelos *et al*. 2014; Morteza *et al*. 2023; Khan 2022; Rillig and Mummey, 2006), thereby improving plant resilience to drought conditions. This study however, aims to investigate the effects of *Arbuscular mycorrhizal* fungus inoculation and water regimes on Cashew seedlings performance in Ibadan. Likewise, the study will provide basic information for subsequent investigations on related topics, and ultimately, the results of the study will help improve the overall performance of cashew cultivation and cashew production in the growing eco-environment in the long run, thereby increasing the domestic Gross Product (GDP) of Nigeria as a country.

MATERIALS AND METHODS

Description of study area: The test was conducted in the Screen house at Cocoa Exploration Organization of Nigeria (C.R.I.N.) Central command, Onigambari, Kilometer 14, Ijebu – Ode Road, Adebayo, Idi Ayunre, Ibadan in Oluyole Local Government Area, Oyo state, Nigeria between December 2020 and April 2021 during the dry season. Ibadan is situated between scope 70˚10΄ N and longitude 30˚52΄ E. It lies at a height of around 122 meters over the ocean level and is found in the jungle zone of Nigeria.

Initial Soil sample collection: Preceding the setting of the investigation, soil tests were collected from one of the plots which have been fallowed for more than fifteen (15) years. Soil samples were collected with the aid of soil auger at 0 – 20 cm depth and were thoroughly mixed to form a composite sample.

Laboratory Analysis: Soil for routine laboratory investigation was air-dried, sieved to go through a 2 mm sieve and exposed to routine laboratory examination for both physical and chemical properties according to IITA (1982) analytical procedures.

Determination of particle size distribution: The particle size (Sand, Silt and Clay) distribution was determined by the hydrometer method as outlined by Gavlack *et al.* (2005). Soil samples were dispersed using 5% Calgon solution and the soil suspensions were stirred for 15 minutes with a multi - mix machine based on gravitational sedimentation as governed by Stooke's law. Hydrometer was used to measure the quantity of Sand, Silt and Clay and reported in percentages of total sample.

Determination of Soil pH (H_2O): The pH of the soil was determined using soil and distilled water suspension in ratio of 1:2.5: Soil: Water. After stirring for 30 minutes, the pH (H_2O) value was read using a glass electrode pH meter using Mclean, (1982) procedure. The samples were determined electronically on a direct reading of pH meter using electrode with a saturated potassium chloride calomel reference electrode. The pH was calibrated and standardized with buffer pH 4 and 7.

Determination of Organic Carbon (OC): Organic carbon (OC) was determined by wet dichromate oxidation method as described by Nelson and Sommers, (1982) and Organic matter was determined by multiplying organic carbon values by Van Bemmelen factor of 1.724 based on the assumption that soil organic matter was 58% carbon.

Determination of Total Nitrogen (N): Total nitrogen (N) was determined using a modified Kjedahl digestion procedure as described by Bremmer, (1996). Nitrogen in the soil was converted to ammonium sulphate by digesting the sample with concentrated sulphuric acid that was added. The ammonia liberated by distillation of the digest with the solution of hydroxide was collected by 5% boric acid mixed indicator solution and titrated with standard hydrochloric acid.

Determination of available Phosphorus (P): Available Phosphorus (P) was determined by BrayP-2 method and read from spectrophotometer as described by Nelson and Sommer, (1982).

Determination of exchangeable acidity: Exchangeable acidity was determined by soil extraction with 1N KCl and titration with 0.05N NaOH using phenolphthalein indicator as outlined by IITA (1982). The effective cation exchange capacity (ECEC) of the soil samples was determined by summation of exchangeable bases (Ca, Mg, K, Na) and the total exchangeable acidity. Percentage base saturation was calculated as the sum of exchangeable bases divided by ECEC expressed as percentage.

$$\%\ Base\ saturation = \frac{Ca + Mg + K + Na}{ECEC} \times \frac{100}{1}$$

Determination of micro – nutrients: Micro – nutrients – Cu, Fe, Zn and Mn were determined after extraction of the soil samples using Fonseca *et al.* (2010) extraction method.

Preparation of *Arbuscular mycorrhizal* fungus (AMF) inoculum: Mycorrhizal inoculum was multiplied using already available inoculum source. It consists of chopped root of the trapping plants, hyphae, spores and soil. Fifty grams of the inoculum was applied to ten litre sized pots and each filled with 10 kg sterile top soil and sown with 2-3 seeds of maize. After one week of growth, the plant was thinned to one per pot. Hoagland solution (half strength, low in phosphorus) was prepared to form additional source nutrient.

Table 1. The constituents of the Hoaglands solution

S/N	Constituents	g/litre
1	KNO_3	25.26
2	$MgSO_4.7H_2O$	24.60
3	NaFe EDTA	1.835
4	KH_2PO_4	0.348
5	H_3BO	0.62
6	$Na_2MoO_4.2H_2O$	0.50
7	$ZnSO_4.7H_2O$	0.29
8	$MnCL_2.4H_2O$	0.39
9	$CuSO_4.5H_2O$	0.12
10	$NiSO_4.6H_2O$	0.05

0.91 ml of HCL_3N was added per litre of the above constituents. In addition, 59 g of Ca $(NO_3)_2$ was dissolved separately to avoid precipitation of other ions in the mixture. Both solutions were further diluted ten times before using them to water the pots. The pots were well watered for three months and afterwards, subjected to drought stress to stimulate abundant spore production by the AM fungus. The top part of the plant was then cut off, the soil medium and the roots including the fungus hyphae and spores were stored until needed for inoculation, either in the screen house.

Determination of micro – nutrients: Micro – nutrients – Cu, Fe, Zn and Mn were determined after extraction of the soil samples using Fonseca *et al.* (2010) extraction method.

Statistical Analysis: All agronomic data collected in the course of the study were subjected to analysis of variance (ANOVA) and the means separated by Duncan's Multiple Range Tests (DMRT) at 5% level of significance.

RESULTS AND DISCUSSION

The results of the initial soil analysis indicated low organic carbon (OC) and other significant soil nutrient elements (N, P, and K). The soil pH value was 6.05 indicating that the soil was slightly acidic which was still within the pH range required for sustainable cashew production.

Number of Leaves per Plant

Table 2 shows the results of the effect of AMF inoculation and water regimes treatments at different field capacities on cashew leaf count. The results showed that the cashew biotypes responded positively but differently to the different treatments applied. The jumbo Cashew biotype (C_1), infected with Mycorrhizal fungus (M_1) and treated with water at 80% field capacity (F_3), produced the highest number of leaves throughout the study periods. This showed that Mycorrhizal inoculation and water application at 80% field capacity significantly ($p < 0.05$) enhanced the leaf production of Jumbo Cashew seedlings throughout the periods of growth relative to other Cashew biotypes without Mycorrhizal inoculation. However, Cashew biotypes ($C_1F_1M_0$; $C_2F_1M_0$ and $C_3F_1M_0$) with the least water treatment (i.e., 40% field capacity) and without Mycorrhizal treatment produced the lowest number of leaves per plant. Similar trend was observed among $C_1F_1M_1$; $C_1F_2M_1$ and $C_2F_3M_1$ at 2nd, 4th, 6th and 8th weeks after treatment application. Cashew seedlings without Mycorrhizal inoculation irrespective of biotypes produced significantly ($p < 0.05$) reduce the number of leaves per plant respectively.

Cashew Seedlings Plant height (cm)

Cashew biotypes inoculated with AMF at 80% field capacity significantly ($p < 0.05$) improved Cashew seedlings height (cm) throughout the periods of the experiment (Table 3). Similarly, pots that were inoculated with AMF in addition to 40% field capacity (F_1) recorded a significant ($p < 0.05$) increase in seedling height (cm) relative to those without AMF inoculation.

Effects of AMF and water regimes on Stem Girth (cm) of Cashew Seedlings

Table 4 assays the effects of AMF and water regimes on the stem girths (cm) of Cashew seedlings in the Screen house. The results showed that AMF inoculated Cashew biotype in combination with the highest water regime (80% field capacity) positively and significantly ($p < 0.05$) enhanced the thickness and stability of cashew stem compared to other biotypes without AMF infection from two weeks after treatment application (2WAP). Jumbo cashew biotype performed better relatives to other Cashew biotypes during the periods under review. The least stem girths (cm) values were recorded in pots treated with 40% field capacity and without Mycorrhizal infection ($C_1F_1M_0$).

Table 2. Effects of AMF and water regimes on the number of cashew leaves

Treatments	**2WAP**	**4WAP**	**6WAP**	**8WAP**	**10WAP**	**12WAP**	**14WAP**	**16WAP**
$C_1F_1M_0$	5.67^{d}	7.33^{d}	7.67^{e}	8.00^{d}	8.00^{f}	8.67^{e}	9.34^{e}	10.01^{b}
$C_1F_2M_0$	9.67^{bcd}	17.67^{abc}	17.33^{abcd}	18.33^{bc}	21.67^{bcde}	22.67^{bcd}	23.34^{bcd}	24.01^{bcd}
$C_1F_3M_0$	10.33^{bcd}	13.00^{bcd}	12.67^{cde}	12.67^{bcd}	13.00^{def}	14.33^{de}	15.00^{de}	15.67^{de}
$C_2F_1M_0$	9.00^{cd}	13.00^{bcd}	13.00^{bcde}	13.00^{bcd}	14.33^{def}	16.33^{cde}	17.00^{cde}	17.67^{cde}
$C_2F_2M_0$	10.00^{bcd}	13.33^{abcd}	14.00^{bcde}	12.33^{bcd}	16.33^{cdef}	20.00^{bcd}	20.67^{bcd}	21.34^{bcd}
$C_2F_3M_0$	9.00^{bcd}	10.67^{cd}	11.00^{de}	11.67^{cd}	11.00^{ef}	12.67^{de}	12.67^{de}	17.00^{de}
$C_3F_1M_0$	9.00^{cd}	11.33^{bcd}	11.00^{de}	11.33^{cd}	14.00^{def}	14.33^{de}	15.00^{de}	15.67^{de}
$C_3F_2M_0$	9.33^{bcd}	10.67cd	11.67^{cde}	13.33^{bcd}	15.00^{def}	15.33^{ed}	16.00^{ed}	16.67^{ed}
$C_3F_3M_0$	10.33^{bcd}	12.67^{bcd}	13.67^{bcde}	15.33^{bcd}	11.00^{def}	16.33^{cde}	17.00^{cde}	17.67^{cde}
$C_1F_1M_1$	14.67^{ab}	19.33^{ab}	21.00^{ab}	22.00^{ab}	30.67^{ab}	28.00^{ab}	29.67^{ab}	30.34^{ab}
$C_1F_2M_1$	14.67^{ab}	18.33^{abc}	19.00^{abcd}	21.33^{ab}	21.67^{bcde}	22.00^{bcd}	22.67^{bcd}	24.34^{bcd}
$C_1F_3M_1$	**17.67^{a}**	**20.67^{a}**	**23.67^{a}**	**29.00^{a}**	**33.67^{a}**	**35.00^{a}**	**35.67^{a}**	**36.33^{a}**
$C_2F_1M_1$	11.00^{bc}	12.00^{bcd}	12.67^{cde}	12.00^{bcd}	22.00^{bcde}	22.00^{bcd}	22.67^{bcd}	23.34^{bcd}
$C_2F_2M_1$	10.67^{bcd}	12.33^{bcd}	12.67^{cde}	17.67^{bc}	18.00^{cdef}	21.00^{bcd}	22.67^{bcd}	23.34^{bcd}
$C_2F_3M_1$	14.33^{abc}	18.00^{abc}	20.67^{abc}	20.00^{bc}	20.00^{bcde}	22.00^{bcd}	22.67^{bcd}	23.34^{bcd}
$C_3F_1M_1$	11.00^{bc}	11.67^{bcd}	14.67^{bcde}	15.33^{bcd}	30.00^{ab}	29.33^{ab}	30.02^{ab}	30.69^{ab}
$C_3F_2M_1$	10.00^{bcd}	11.33^{bcd}	12.67^{cde}	16.00^{bcd}	17.33^{cdef}	19.33^{bcde}	20.01^{bcde}	20.68^{bcde}
$C_3F_3M_1$	10.33^{cd}	11.67^{bcd}	14.67^{bcde}	16.00^{bcd}	19.33^{bcde}	20.67^{bcd}	21.34^{bcd}	22.10^{bcd}

Means that carried the same letter within each column are not significantly different from one another

Legend: C_1= Jumbo; C_2= Medium Cashew; C_3= Madras Cashew; F_1= 40% Field capacity; F_2 = 60% Field capacity; F_3 = 80% Field capacity; M_0 = Without Mycorrhizal; M_1=With Mycorrhizal.

Table 3. Effects of AMF and water regimes on the plant height of cashew seedlings

Treatments	**2WAP**	**4WAP**	**6WAP**	**8WAP**	**10WAP**	**12WAP**	**14WAP**	**16WAP**
$C_1F_1M_0$	5.67^{d}	7.65^{d}	7.33^{e}	7.33^{d}	9.93^{d}	9.97^{d}	11.22^{d}	12.47^{d}
$C_1F_2M_0$	14.00^{abc}	17.67^{abc}	17.33^{abcd}	18.33^{bc}	25.30^{bc}	26.73^{abc}	29.98^{abc}	29.23^{abc}
$C_1F_3M_0$	11.00^{bc}	18.33^{abc}	19.00^{abcd}	20.00^{bc}	29.47^{bc}	29.20^{abc}	30.45^{abc}	31.70^{abc}
$C_2F_1M_0$	11.00^{bc}	13.00^{bcd}	13.00^{bcde}	13.00^{bcd}	22.87^{c}	22.17^{bc}	23.42^{bc}	24.67^{bc}
$C_2F_2M_0$	11.00^{bc}	13.33^{abcd}	14.00^{bcde}	15.33^{bcd}	24.87^{bc}	25.97^{abc}	27.22^{abc}	28.47^{abc}
$C_2F_3M_0$	9.00^{cd}	11.67^{bcd}	14.67^{bcde}	15.33^{bcd}	26.83^{bc}	27.40^{abc}	28.65^{abc}	29.90^{abc}
$C_3F_1M_0$	9.00^{cd}	11.33^{bcd}	11.00^{cde}	11.33^{cd}	24.60^{bc}	25.90^{abc}	27.15^{abc}	28.40^{abc}
$C_3F_2M_0$	10.33^{bcd}	10.67^{cd}	11.67^{cde}	13.3^{bcd}	28.37^{bc}	26.40^{abc}	27.65^{abc}	28.90^{abc}
$C_3F_3M_0$	10.67^{bcd}	12.67^{bcd}	13.67^{cde}	19.33^{bc}	32.07^{ab}	27.40^{abc}	28.65^{abc}	29.00^{abc}
$C_1F_1M_1$	14.33^{ab}	13.00^{bcd}	12.67^{cde}	12.67^{bcd}	27.30^{bc}	33.30^{ab}	34.55^{ab}	35.80^{ab}
$C_1F_2M_1$	14.67^{ab}	15.67^{abcd}	22.00^{ab}	21.33^{ab}	27.87^{bc}	31.87^{abc}	33.12^{abc}	34.37^{abc}
$C_1F_3M_1$	**17.67^{a}**	**20.00^{a}**	**26.00^{a}**	**29.10^{abc}**	**36.67^{a}**	**37.67^{a}**	**38.92a**	**40.17^{a}**
$C_2F_1M_1$	10.33^{bcd}	19.00^{ab}	20.67^{abc}	22.00^{ab}	25.00^{bc}	24.53^{abc}	25.78^{abc}	30.38^{abc}
$C_2F_2M_1$	10.67^{bcd}	12.00^{bcd}	12.33^{cde}	12.67^{bcd}	28.70^{bc}	33.50^{ab}	34.75^{ab}	36.00^{ab}
$C_2F_3M_1$	9.67^{bcd}	12.33^{bcd}	13.67^{bcde}	17.00^{bc}	30.30^{bc}	33.35^{ab}	34.60^{ab}	35.85^{ab}
$C_3F_1M_1$	10.33^{bcd}	10.67cd	11.00^{de}	11.67^{cd}	25.90^{bc}	31.50^{abc}	32.75^{abc}	34.00^{abc}
$C_3F_2M_1$	9.00^{cd}	11.33^{bcd}	12.67^{cde}	16.00^{bcd}	26.83^{bc}	27.73^{abc}	28.98^{abc}	30.23^{abc}
$C_3F_3M_1$	9.00^{cd}	11.67^{bcd}	12.67^{bcde}	16.00^{bcd}	29.00^{bc}	29.87^{abc}	31.12^{bc}	32.37^{bc}

Means that carried the same letter within each column are not significantly different from one another

Table 4. Effects of *AMF* and water regimes on stem girth (cm) of cashew seedlings

Treatments	2WAP	4WAP	6WAP	8WAP	10WAP	12WAP	14WAP	16WAP
$C_1F_1M_0$	3.47^{d}	3.58^{b}	4.24^{c}	4.21^{d}	4.64^{b}	5.07^{b}	5.50^{b}	8.14^{b}
$C_1F_2M_0$	5.41^{bcd}	6.00^{ab}	6.26^{bc}	6.48^{abcd}	7.38^{b}	7.81^{b}	8.24^{b}	8.67^{b}
$C_1F_3M_0$	5.78^{bc}	5.99^{b}	7.07^{ab}	7.85^{abc}	9.08^{b}	9.51^{b}	9.94^{b}	10.37^{b}
$C_2F_1M_0$	4.75^{de}	6.03^{ab}	6.37^{bc}	6.31^{abcd}	7.38^{b}	7.81^{b}	8.24^{b}	8.67^{b}
$C_2F_2M_0$	5.98^{abc}	6.58^{ab}	7.12^{ab}	7.60^{abc}	8.03^{b}	8.46^{b}	8.89^{b}	9.32^{b}
$C_2F_3M_0$	5.47^{bc}	6.08^{ab}	6.76^{ab}	8.27^{ab}	9.00^{b}	8.43^{b}	9.86^{b}	10.29^{b}
$C_3F_1M_0$	5.20^{bcd}	5.32^{bc}	5.77^{bc}	6.21^{bcd}	6.94^{b}	7.37^{b}	7.80^{b}	8.23^{b}
$C_3F_2M_0$	4.31^{cde}	5.17^{bc}	6.34^{bc}	7.07^{abcd}	7.46^{b}	7.89^{b}	8.32^{b}	8.75^{b}
$C_3F_3M_0$	5.16^{cd}	5.49^{bc}	7.22^{ab}	7.10^{abcd}	7.82^{b}	8.25^{b}	8.68^{b}	9.11^{b}
$C_1F_1M_1$	5.11^{cd}	5.44^{bc}	5.94^{bc}	4.91^{cd}	6.68^{b}	7.50^{b}	8.66^{b}	9.82^{b}
$C_1F_2M_1$	5.24^{bcd}	5.93^{b}	6.26^{bc}	$6.62a^{bcd}$	7.81^{b}	8.24^{b}	8.67^{b}	9.10^{b}
$C_1F_3M_1$	6.41^{a}	6.69^{a}	9.10^{a}	9.98^{a}	10.38^{a}	10.81^{a}	11.24^{a}	11.64^{a}
$C_2F_1M_1$	5.31^{bc}	5.18^{bc}	6.34^{bc}	6.74^{abcd}	6.91^{b}	7.34^{b}	7.77^{b}	8.20^{b}
$C_2F_2M_1$	5.24^{bcd}	6.38^{ab}	6.47^{bc}	7.70^{abc}	8.10^{b}	8.53^{b}	8.96^{b}	9.39^{b}
$C_2F_3M_1$	6.09^{ab}	6.58^{ab}	7.64^{ab}	7.84^{abc}	9.42^{b}	9.85^{b}	10.28^{b}	10.71^{b}
$C_3F_1M_1$	5.57^{bc}	5.60^{bc}	5.64^{bc}	6.13^{bcd}	6.80^{b}	7.23^{b}	7.66^{b}	8.09^{b}
$C_3F_2M_1$	5.08^{bcde}	4.91^{c}	6.17^{bc}	$6{,}04^{bcd}$	6.68^{b}	7.11^{b}	7.54^{b}	7.97^{b}
$C_3F_3M_1$	4.73^{cd}	5.57^{bc}	6.45^{bc}	7.58^{abc}	8.61^{b}	9.04^{b}	9.47^{b}	9.90^{b}

Means that carried the same letter within the same column are not significantly different from one another

Legend: C_1= Jumbo; C_2= Medium Cashew; C_3= Madras Cashew; F_1= 40% Field capacity; F_2 = 60% Field capacity; F_3 = 80% Field capacity; M_0 = Without Mycorrhizal; M_1= With Mycorrhizal.

Effects of *AMF* and water regimes on the number of cashew branches per plant

There were no significant ($p < 0.05$) differences among the three cashew biotypes on their reactions to the applied treatments as far as the number of branches per plant in the first six weeks was concern after treatment imposition except Jumbo biotype watered at 80% field capacity that showed a consistent increase in the number of branches produced through the periods under study (Table 5). The increase was significantly different ($p < 0.05$) compared to other biotypes. The mean difference recorded for $C_2F_1M_0$, $C_2F_2M_0$, $C_2F_3M_0$, $C_3F_1M_0$, $C_3F_2M_0$, $C_3F_3M_0$, $C_3F_1M_1$ and $C_1F_1M_1$ respectively were not statistically different from one another at 2WAP but were significantly ($p < 0.05$) lower than the rest. Madras ($C_3F_2M_0$) without AMF inoculation at 60% field capacity did not produce braches at all; this may be due to genetic makeup of the biotype.

Table 5. Effects of AMF and water regimes on the number of cashew branches per plant

Treatments	2WAP	4WAP	6WAP	8WAP	10WAP	12WAP	14WAP	16WAP
$C_1F_1M_0$	2.00^{a}	1.33^{b}	1.00^{b}	1.67^{cd}	1.67^{cd}	1.87^{bcd}	1.99^{cd}	2.11^{cd}
$C_1F_2M_0$	2.50^{a}	2.00^{ab}	2.00^{b}	2.33^{bcd}	2.00^{bcd}	2.00^{bcd}	2.12^{c}	2.24^{c}
$C_1F_3M_0$	2.00^{a}	2.00^{ab}	3.33^{ab}	4.67^{a}	4.67^{ab}	5.00^{bcd}	5.12^{ab}	5.25^{ab}
$C_2F_1M_0$	2.00^{a}	0.33^{b}	0.67^{b}	0.67^{b}	1.00^{cd}	0.33^{cd}	0.45^{ef}	0.57^{ef}
$C_2F_2M_0$	1.00^{a}	0.67^{b}	0.33^{b}	0.67^{cd}	0.67^{cd}	1.67^{bcd}	1.79^{cd}	1.91^{cd}
$C_2F_3M_0$	0.00^{b}	0.00^{b}	0.67^{b}	2.00^{cd}	2.00^{bcd}	2.00^{bcd}	2.12^{c}	2.25^{c}
$C_3F_1M_0$	1.00^{a}	0.33^{b}	0.33^{b}	0.33^{cd}	0.67^{cd}	0.33^{cd}	0.45^{ef}	0.57^{ef}
$C_3F_2M_0$	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{d}	0.00^{d}	0.00^{d}	0.00^{f}	0.00^{f}
$C_3F_3M_0$	1.00^{a}	0.33^{b}	0.67^{b}	2.67^{bc}	3.00^{bc}	3.00^{ab}	3.12^{b}	3.25^{b}
$C_1F_1M_1$	2.00^{a}	0.67^{b}	0.67^{cd}	0.67^{d}	0.67^{cd}	0.67^{cd}	0.79^{e}	0.91^{e}
$C_1F_2M_1$	1.00^{a}	1.50^{b}	2.33^{ab}	2.33^{b}	2.67^{bcd}	3.00^{bc}	3.12^{b}	3.25^{b}
$C_1F_3M_1$	**3.33^{a}**	**3.33^{a}**	**4.33^{a}**	**4.00^{a}**	**5.67^{a}**	**5.67^{a}**	**5.79^{a}**	**5.91^{a}**
$C_2F_1M_1$	2.00^{a}	1.33^{b}	1.67^{b}	1.67^{cd}	1.67^{cd}	1.67^{cd}	1.79^{cd}	1.91^{cd}
$C_2F_2M_1$	1.00^{a}	0.33^{b}	0.33^{b}	0.33^{d}	0.33^{cd}	0.67^{cd}	0.79^{e}	0.91^{e}
$C_2F_3M_1$	1.00^{c}	1.00^{b}	1.00^{b}	1.00^{d}	1.00^{cd}	1.00^{bcd}	1.12^{d}	1.25^{d}
$C_3F_1M_1$	0.00^{b}	0.00^{b}	0.00^{b}	0.67^{d}	1.00^{cd}	1.00^{cd}	1.12^{d}	1.26^{d}
$C_3F_2M_1$	2.00^{a}	1.33^{b}	1.33^{b}	0.00^{d}	1.00^{cd}	1.00^{cd}	1.13^{d}	1.11^{d}
$C_3F_3M_1$	0.00^{b}	0.67^{b}	0.67^{b}	0.67^{d}	0.67^{cd}	0.67^{cd}	0.78^{e}	0.92^{e}

Means that carried the same letter within the same column are not significantly different from one another

Legend: C_1= Jumbo; C_2= Medium Cashew; C_3= Madras Cashew; F_1= 40% Field capacity; F_2= 60% Field capacity; F_3 = 80% Field capacity; M_0 = Without Mycorrhizal; M_1=With Mycorrhizal.

Effects of *AMF* and water regimes on the leaf area (cm^2) of Cashew

Table 6 shows the effects of *Mycorrhizal* and water regimes on leaf area (cm^2) of cashew in the screen house. Similar effects of the treatments were observed as found in the number of branches above. Jumbo cashew inoculated with *AMF* (M_1) at 80% field capacity produced more broader leaves per plant compared with other Cashew biotypes and levels of water regimes with or without *Mycorrhizal* from the second weeks after treatment imposition and afterwards. Although, $C_1F_3M_1$ produced many broader leaves than $C_1F_1M_1$, the differences were not significant at 5% probability level.

Table 6. Effects of AMF and water regimes on leaf area (cm^2) of cashew

Treatments	2WAP	4WAP	6WAP	8WAP	10WAP	12WAP	14WAP	16WAP
$C_1F_1M_0$	17.76^{f}	20.31^{e}	19.00^{c}	19.27^{b}	22.21^{c}	23.03^{g}	28.53^{g}	34.03^{g}
$C_1F_2M_0$	56.11^{cdef}	75.89^{bcd}	67.85^{bc}	77.76^{a}	73.03^{abc}	83.78^{cd}	89.28^{cd}	94.78^{b}
$C_1F_3M_0$	76.72^{abcd}	96.25^{abc}	120.34^{a}	77.35^{a}	108.41^{ab}	81.00^{cde}	86.5^{cde}	92.00^{bc}
$C_2F_1M_0$	44.03^{def}	64.60^{bcde}	68.75^{bc}	94.95^{a}	79.83^{ab}	73.49^{d}	78.99^{ab}	84.49^{c}
$C_2F_2M_0$	55.80^{cdef}	96.79^{abc}	99.44^{ab}	62.40^{ab}	66.68^{bc}	84.75^{c}	90.25^{bcde}	95.75^{b}
$C_2F_3M_0$	53.8^{cdef}	60.46^{bcde}	83.55^{b}	96.78^{a}	97.51^{ab}	91.34^{ab}	96.84^{bc}	102.34^{ab}
$C_3F_1M_0$	43.39^{cdef}	71.30^{bcd}	76.00^{b}	74.18^{a}	73.69^{ab}	40.74^{fg}	46.24^{efg}	51.74^{efg}
$C_3F_2M_0$	44.51^{def}	60.55^{bcde}	58.96^{bc}	54.94^{ab}	58.06^{bc}	61.69^{e}	67.19^{bcd}	72.69^{cd}
$C_3F_3M_0$	56.55^{bcdef}	65.4^{bcde}	75.49^{b}	85.91^{a}	87.42^{ab}	89.55^{bc}	95.05^{bcd}	100.55^{ab}
$C_1F_1M_1$	**100.30^{a}**	**109.54^{a}**	**144.01^{a}**	**149.00^{a}**	**119.33^{a}**	**105.03^{a}**	**108.4^{a}**	**118.60^{a}**
$C_1F_2M_1$	63.69^{bcde}	71.37^{bcd}	98.73^{ab}	82.01^{a}	68.06^{bc}	62.48^{e}	67.98^{ab}	73.48^{cd}
$C_1F_3M_1$	**102.96^{a}**	**111.90^{a}**	**149.22^{a}**	**152.87^{a}**	**123.99^{a}**	**106.63^{a}**	**111.13^{a}**	**120.63^{a}**
$C_2F_1M_1$	49.84^{bcdef}	74.36^{bcd}	76.61^{b}	64.42^{ab}	84.41^{ab}	80.88^{cde}	86.38^{cde}	91.88^{bc}
$C_2F_2M_1$	75.46^{abcd}	7.71^{bcd}	106.69^{ab}	88.72^{a}	98.70^{ab}	84.44^{c}	89.94^{bcde}	95.44^{b}
$C_2F_3M_1$	87.07^{ab}	107.29^{ab}	89.90^{ab}	90.39^{a}	99.70^{ab}	100.00^{ab}	102.50^{ab}	111.00^{ab}
$C_3F_1M_1$	51.17^{bcdef}	70.48^{bcd}	86.00^{b}	87.83^{a}	90.09^{ab}	46.88^{f}	52.38^{ef}	57.88^{ef}
$C_3F_2M_1$	34.35^{ef}	48.97^{cde}	62.99^{bc}	56.04^{ab}	60.50^{bc}	48.78^{f}	54.28^{ef}	59.78^{ef}
$C_3F_3M_1$	43.36^{def}	52.8^{cde}	70.80^{bc}	74.71^{a}	88.34^{ab}	93.53^{ab}	99.03^{abc}	104.53^{ab}

Means that carried the same letter within the same column are not significantly different from one another

The Soil used for the study was sandy clay loam, low in organic carbon (OC) and other significant soil nutrient elements (N, P, and K). The soil pH value was 6.05 indicating that the soil was slightly acidic but falls within the pH range required for sustainable cashew production. This result agreed with Owaiye (1989) who reported that cashew grows on soils with pH range between 3.0 and 6.5. In the present study, inoculation with AMF and water treatment with different treatment methods significantly increased the growth of cashew seedlings, regardless of biotype ($P < 0.05$). The effect of *AMF* inoculation and water regimes at different field volumes on cashew seedling productivity significantly increased ($p < 0.05$) the leaf area and number of leaves per plant in all study periods. These observations are consistent with the findings of Bolandnazar *et al.* (2007), Huey *et al.* (2020), Bastami *et al.* (2021) and Qiuxiao *et al*. (2022) who were of the opinions that *Mycorrhiza*l inoculation had a significant positive effect on the growth performance of crops and suggested a better boom rate of mycorrhizal-inoculated plants than managed flora because of multiplied photosynthetic activity. In addition, Assih *et al.* (2022) stated progress in the availability of mineral nutrients after *AMF* inoculation, resulting in an advanced increase in the fees of the inoculated vegetation under both drought stress and everyday watering conditions. However, they argued that MFA will be used to boost cashew nut growth and cause them to be more drought-tolerant by making greater nutrients available within the soil. Lu and Koide, (1994) stated that *mycorrhizal* contamination with the aid of Glomus etunicatum Becker and Gerd. And P modification (3 levels) on increase and replica of Abutilon improved total leaf place; however, character leaf size turned out to be more affected than leaf quantity. The Jumbo Cashew biotypes responses to *AMF* at low water stage (40% area capability) and those planted with *AMF* inoculation at 88% field capability have not been considerably different ($p < 0.05$) from each other, even though they definitely inspired all of the growth and agronomic parameters considered. That is an indication that infection with *AMF* encourages root effectiveness in water and vitamin absorption even at low moisture availability inside the soil. This observation is in agreement with Bengum *et al.* (2019) and Fulton (2011) findings that collaboration between *AMF* and host plant roots beneath drought conditions improves efficiency by increasing nutrient uptake, especially phosphate. Even though there were no large ($p < 0.05$) differences between most of the three cashew biotypes on their reactions to the carried-out treatments, the wide variety of branches consistent with the plant within the first six weeks changed into subjects after remedy imposition, except for Jumbo biotype, which was watered at 88% subject ability and showed regular growth inside the variety of branches produced through the intervals below. Taken together, shoot and root duration, number of branches in line with plant, dry weights, and leaf location, as well as chlorophyll content, were drastically advanced through the bio-fertilization treatments. Nevertheless, the combination remedy extensively resulted in maximum shoot length and root period observed through Mycorrhiza and Brady- rhizobium remedies in each growing season, respectively. However, the maximum range of branches in keeping with the plant changed as recorded with mycorrhiza treatment and observed by using the combination remedy at each growing season, respectively. Moreover, *AM* symbiosis has been shown to enhance plant overall performance beneath drought pressure and adjust plant-water family members in well-watered and drought-burdened situations (Bhardwaj *et al.* 2023).

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