FORESTRY IDEAS, 2021, vol. 27, No 2 (62): 483–495

EFFECTS OF MYCORRHIZAE INOCULATION AND WATER REGIME ON THE GROWTH OF *CASSIA FISTULA* L. SEEDLINGS

Abiodun Oladipo[1,4], Ademola Adebayo[2,4], Olakunle Ogunyemi[3,4], Adegboyega Aduradola[4], and Fu Fang-Fang[1*]

[1]Co-Innovation Center for Sustainable Forestry in Southern China, College of Forestry, Nanjing Forestry University, 210037 Nanjing, Jiangsu, China. E-mails: oladipoabiodun@njfu.edu.cn; fffu@njfu.edu.cn[*]

[2]Department of Forest and Conservation Sciences, Faculty of Forestry, University of British Columbia, V6T1Z4 B.C, Vancouver, Canada. E-mail: aadebayo@alumni.ubc.ca

[3]Department of Social and Environmental Forestry, University of Ibadan, 900001 Ibadan, Oyo State, Nigeria. E-mail: olakunle4impact@yahoo.com

[4]Department of Forestry and Wildlife Management, Federal University of Agriculture, Abeokuta, Ogun state, Nigeria. E-mail: amaduradola@yahoo.com

Received: 12 August 2021 Accepted: 30 November 2021

Abstract

We examined the effects of two mycorrhizae fungi (endomycorrhiza and ectomycorrhiza) and varying moisture supply on certain growth parameters of *Cassia fistula* L. seedlings. The seedlings were inoculated with endomycorrhiza and ectomycorrhiza, compared with no mycorrhiza, and watered every day, every other day and once a week for a period of 12 weeks. The results revealed that mycorrhiza contributed significantly to relative water content while moisture supply also significantly influenced shoot height, collar diameter, leaf number, fresh weight of leaves, turgid weight of leaves, fresh weight of shoots, and fresh weight of roots. However, interaction of mycorrhiza and moisture supply had no significant effect on seedling growth of *C. fistula* but endomycorrhiza at watering every other day had the best growth performance.

Key words: drought, ectomycorrhiza, endomycorrhiza, fungi, moisture supply, seedlings performance.

Introduction

Forests, being an important aspect of land ecosystem have been negatively affected (Keenan et al. 2015) mostly by anthropogenic factors (Kelley et al. 2015, Mohamed Ait El et al. 2019). The loss of natural forests has triggered the establishment and expansion of man-made forest (Warman 2014). The degradation of forest ecosystem has led to complex changes with negative consequences economically, culturally (Caputo et al. 2017, Qiao et al. 2019) and environmentally. Man-made forests are therefore suitable choice not just to meet up with the increasing demand of wood and wood products, but also to reduce the destructive harvesting of natural forests, protect forest soil and water resources as well as enhancing biodiversity and restoration of degraded soil (FAO 2010, Li et al. 2020). The hazardous effects of chemical fertilizers on human and environment (Chandini et al. 2019) have necessitated the need to holistically consider biological and environmentally friendly approaches that could possibly improve the optimum growth and development of plants generally.

A mycorrhizal association with plant is a symbiotic relationship between a fungus and the root of a plant, that is primarily responsible for nutrient transfer (Brundrett 2004). Mycorrhiza fungi are essential representative of the plant microbiome that support its access to soil nutrients and water uptake (van der Heijden et al. 2015). Thus, the use of Mycorrhiza (fungi) to enhance the optimum performance of plants is arguably one approach which cannot be jettisoned. Predominantly, endomycorrhizal also known as arbuscular mycorrhizal (AM) and ectomycorrhizal (EM) fungi are functional types which exhibit symbiotic association with the roots of most terrestrial plants (Tedersoo 2017).

Endomycorrhizal are found in about ninety percent of plant families encompassing grasses, forbs, and some woody plants (Zhu et al. 2010) . It has been reported that inoculation of *Cupressus atlantica* Gaussen with endomycorrhiza alleviated the impact of drought stress by improving water and nutrient uptake (Zarik et al. 2016). AM fungi which are soil-borne and capable of significantly improving plant nutrient uptake could as well enhance plant resistance against several abiotic stress factors (Sun et al. 2018). AM inoculation can contribute to water availability and water transport after colonization in plants (Bitterlich et al. 2018).

Ectomycorrhizal fungi known to be associated with woody plant species (Roy-Bolduc et al. 2015) are significant components of temperate forests (Toju et al. 2014). Some few plant families that are involved in ectomycorrhizal association include Betulaceae, Dipterocarpaceae, Fagaceae and Pinaceae (Futai et al. 2008). Ectomycorrhizal fungi have also been reported to reduce root pathogens (Liang et al. 2020) and shields the host trees from attack (Futai et al. 2008), thereby preventing diseases and death.

Tree growth is generally affected by low water availability and/or drought which are consequences of climate change (Meineke and Frank 2018). It has been reviewed many times that moisture stress tolerance of various plant mainly depend on their ability to access and efficiently use soil water (Richards et al. 2010) but this also depends on type of tree species and cultivar, time and duration of water availability, and forest conditions (Munns et al. 2010, Richards et al. 2010, Isah et al. 2012). Thus, it is essential to evaluate the inclusive water stress tolerance mechanism of plant species (Lisar et al. 2012, Shamim et al. 2014) for optimum performance.

Cassia fistula Linn. (Caesalpiniaceae) is commonly known as the Golden Shower or popularly called ‘Indian Laburnum’ because of its beautiful bunches of yellow flowers (Danish et al. 2011). It is a deciduous tree with greenish-gray bark and cylindrical pods containing black seeds. The pulp is dark brown, sticky, sweet and mucilaginous, with odour characteristic (Gupta et al. 2005, Gupta 2010). The plant is native to India, the Amazon and Sri Lanka; it has also been discovered in various countries including Mexico, Mauritius, South Africa, East Africa, West Indies, China (Kumar et al. 2006, Chauhan Neelam et al. 2011). It is a medicinal plant (Orwa et al. 2009, Ali 2014) with the potential to treat infected wound (Siddhuraju et al. 2002, Nirmala et al. 2008), skin diseases (Singh et al. 2013) health benefits (Rahmani 2015) and other uses.

We therefore proposed to investigate the performances of two mycorrhizal (endomycorrhizal and ectomycorrhizal) fungi, moisture supply, and interaction between mycorrhiza inoculation and moisture supply to determine the best treatment of mycorrhizal fungi as well as the most appropriate water regime suitable for the growth of *Cassia fistula* seedlings.

Materials and Methods

Experimental site

The experiment was carried out at the forest nursery unit of the Department of Forestry and Wildlife Management, Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria. The latitude is within 7° and 7°58’ N and longitude is within 3°20’ and 3°37’ E. The land is gently sloping due to its undulating landscape which permits for easy surface run-off. This area has notably an annual rainfall of 1200 mm with peak in June and July, average monthly temperature of about 35 °C and relative humidity of 82.54 %.

Seedling preparation and mycorrhizae inoculation

The pods (matured) of *C. fistula* were collected from matured and healthy trees in FUNAAB. The matured pods were further processed for seed extraction and treatment; they were then raised on germination bed. Seeds were fully germinated in about 14 days. A total of 54 seedlings of similar height and size were selected from the germination bed and transplanted to polythene pot after three weeks.

Endomycorrhiza soil used was procured from the College of Plant Science and Crop Production, FUNAAB, while ectomycorrhiza soil was collected from the roots rhizosphere of matured and healthy *Pinus caribaea* Mor. tree. Top soil from the forest nursery with close proximity to matured *C. fistula* in FUNAAB was also excavated and used as planting medium to imitate natural soil environment for seedlings growth. Before filling the polythene pots, the soil was sieved to remove debris and soil lumps.

The fungal (endomycorrhiza and ectomycorrhiza) inoculum which contained mixtures of soil and root fragments at 20 g respectively was added to 600 g soil used and properly mixed together before filling the pots. Top soil of the same quantity was used for the control (no mycorrhiza). Water was added to the filled polythene pots and allowed to drain before transplanting. Seedlings of *C. fistula* were then transplanted from germination bed to pots which had been perforated at the base to allow for drainage of excess water and prevent water logging.

Experimental design and treatments

The experiment was conducted with a three-factorial design under randomized block condition. The factors were endomycorrhiza, ectomycorrhiza and moisture supply; where, endomycorrhiza (M_1), ectomycorrhizal (M_2) and no mycorrhiza (M_3), and water supply (watering daily (W_1), watering 1st and 4th day of the week 2/7 (W_2) and watering once a week 1/7 (W_3)). The experiment was designed with 6 replicates. Thus, a total of nine treatments were used for this study and were represented as M_1W_1, M_1W_2, M_1W_3, M_2W_1, M_2W_2, M_2W_3, M_3W_1, M_3W_2, and M_3W_3. For each replicate of the experiment at one seedling per pot, 18 seedlings were allocated for each sources of mycorrhizae (M_1, M_2, M_3) used while 6 seedlings were allocated to each watering regime (W_1, W_2, and W_3). At the commencement of the 2nd week of transplanting, seedlings under each treatment were subjected to varying watering regime.

Data collection

The measurements of both the morphological and the physiological parameters during growth were taken fortnightly. The morphological parameters examined include: seedling height (cm) which was determined using a measuring tape, leaf number, leaf area (cm^2), collar diameter (mm) which was determined using a digital caliper, fresh and dry weight, and turgid weight (g) which was determined using a weighing scale. The physiological parameters measured were the relative water content (%) and turgidity.

Fresh weight

After 12 weeks the seedlings of each treatment were harvested from the pot and were separated into leaf, stem, and root. Root and shoot length was measured and fresh weights of each component were recorded.

Dry matter

Dry weights of each component (leave, root and shoot) were obtained after being oven-dried for 24 h at 600 °C.

Relative turgidity

To determine the relative turgidity, the fresh leaf was soaked in water in a petri-dish overnight and was weighed. The plant turgidity (*PT*) was calculated by formula (1):

$$PT = (S_{wt} - F_{wt}) / F_{wt} \cdot 100, \qquad (1)$$

where: S_{wt} is weight of plant (soaked in water); F_{wt} is fresh weight.

Relative water content

To determine the relative water content (*RWC*) of the species the formula (2) was employed.

$$RWC = (F_{wt} - D_{wt}) / (T_{wt} - D_{wt}) \cdot 100, \qquad (2)$$

where: F_{wt} is fresh weight; D_{wt} is dry weight; T_{wt} is turgidity weight.

Statistical analysis

All the data collected were analysed by two-way analysis of variance (ANOVA) on the general linear model of SAS Software (SAS institute, inc. 1999) and significant means were separated by Duncan's multiple range test.

Results

Seedlings response to mycorrhizae

To establish the performance of *C. fistula* seedling after inoculation with endomycorrhiza and ectomycorrhiza, morphological and physiological parameters listed above were examined. M_1 resulted to increased mean value of shoot height, leaf area, fresh weight of stems, and fresh weight of roots, and dry weight of roots by 11.93 cm (Fig. 1.1), 26.49 cm^2 (Fig. 1.4), 0.34 g (Fig. 1.7), 0.82 g (Fig. 1.7), and 0.39 g (Fig. 1.8) respectively. Furthermore, seedlings with M_2 had the highest mean value for collar diameter – 1.75 mm (Fig. 1.2) and relative water content (29.44 %). However, leaf numbers, turgid weight of

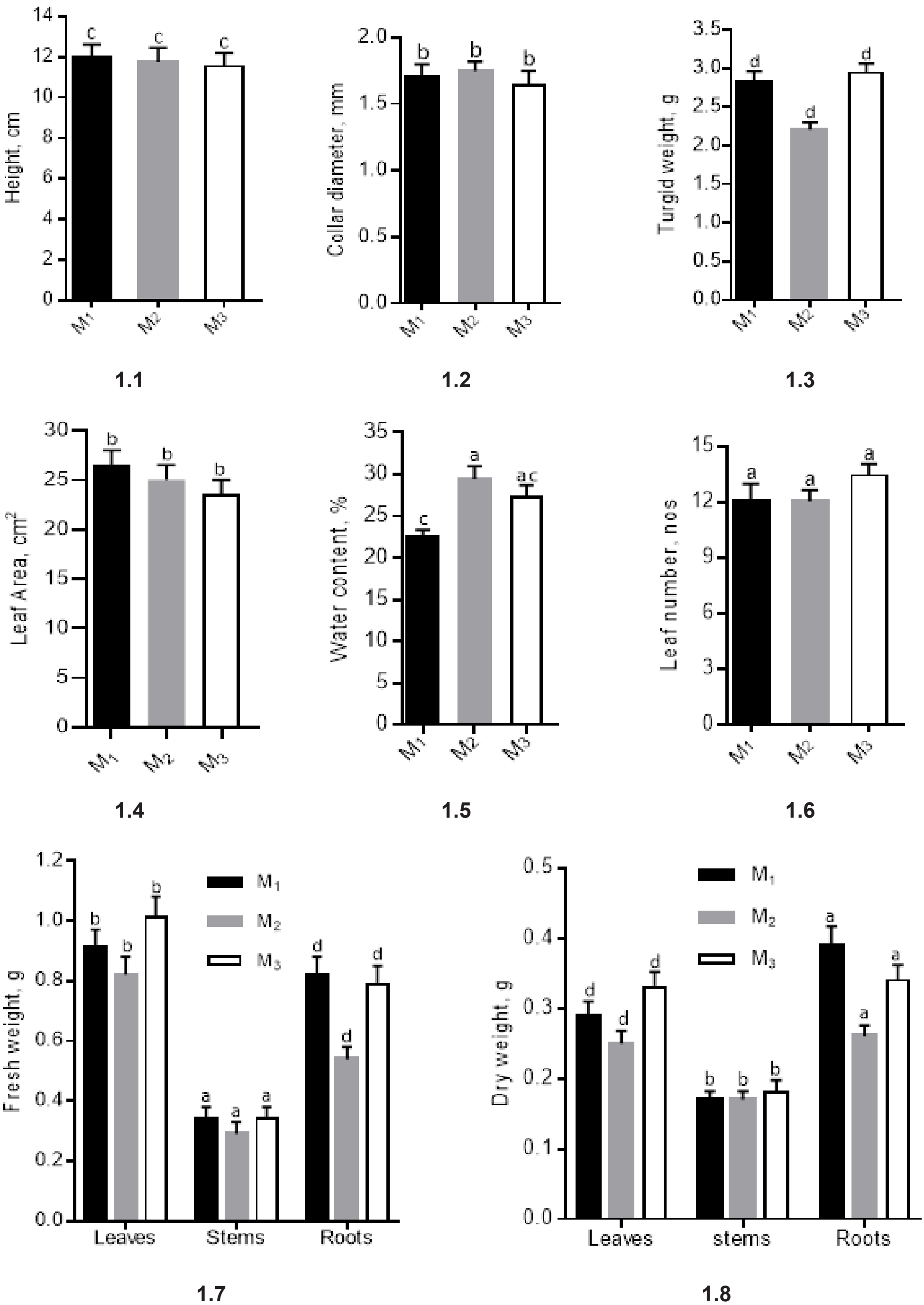

Fig. 1. Effect of mycorrhiza inoculation.

Note: Different letters indicate significant difference between treatments (p<0.05).

leaves, dry weight of leaves, fresh weight of stems and leaves, and dry weight of stems had highest mean value by 13.44 (Fig. 1.6), 1.01 g (Fig. 1.3), 2.94 g, 0.33 g, 0.34 g, and 0.21 g respectively in M_3. More so, the result showed that seedlings inoculated with M_2 were significantly different (p<0.05) for relative water content having the highest mean value of 29.44 % (Fig. 1.5) while those inoculated with M_1 and M_3 were not significantly different from each other with mean value of 22.43 % and 27.30 % respectively. Analysis of variance showed that mycorrhiza had significant effect (p<0.05) on relative water content only (Table 1).

Table 1. Analysis of variance (ANOVA).

Parameters	Mycorrhiza		Water		Mycorrhiza × water	
	F	***P***	***F***	***P***	***F***	***P***
Shoot height	0.150	0.860	3.410	0.050*	1.400	0.260
Collar diameter	1.620	0.220	3.350	0.050*	1.180	0.340
Leaf area	0.650	0.530	0.100	0.900	0.950	0.450
Leaf number	1.550	0.230	8.320	0.002*	1.350	0.270
Fresh weight of leaves	0.550	0.580	7.740	0.002*	1.640	0.190
Turgid weight of leaves	1.080	0.350	7.480	0.003*	0.970	0.440
Dry weight of leaves	0.460	0.640	1.980	0.150	0.640	0.640
Fresh weight of shoots	0.380	0.690	9.380	0.001*	1.010	0.420
Dry weight of shoots	0.640	0.540	2.170	0.130	0.640	0.640
Fresh weight of roots	2.420	0.120	7.500	0.003*	2.340	0.080
Dry weight of roots	2.010	0.150	2.830	0.080	1.190	0.340
Relative water contents	3.810	0.030*	0.820	0.450	1.460	0.240

Note: * Indicate significant difference of treatments (p<0.05).

Seedlings response to moisture supply

To underscore the effect of various water regimes on the growth performance of *C. fistula* seedlings, morphological and physiological parameters listed above were measured. The result revealed that W_1 seedlings had the highest mean value of 1.77 mm (Fig. 1.1) for collar diameter only. However, W_2 seedlings had the highest mean values of 12.46 cm (Fig. 2.1), 25.61 cm^2 (Fig. 2.4), 13.69 nos (Fig. 2.3), 1.30 g (Fig. 2.7), 3.76 g (Fig. 2.6), 0.36 g (Fig. 2.8), 0.46 g (Fig. 2.7), 0.22 g (Fig. 2.8), 0.94 (Fig. 2.7), 0.38 g (Fig. 2.8), and 28.10 % (Fig. 2.5) for shoot height, leaf area, leaf number, fresh weight of leaves, turgid weight of leaves, dry weight of leaves, fresh weight of stems, dry weight of stems, fresh weight of roots, dry weight of roots, and relative water content respectively. The results further revealed that seedlings watered daily were significantly different (p<0.05) for collar diameter (Fig. 2.2) with the highest mean value of 1.77 mm. In addition, seedlings watered every other day were also significantly different (p<0.05) with the highest mean value of 12.46 cm, 13.69 cm^2, 3.76 g, 1.30 g, 0.46 g, and 0.94 g for shoot height, leaf number, turgid weight of leaves, fresh weight of leaves, stems and roots respectively. Furthermore, W_3 seedlings had no highest mean value for the growth parameters but had the lowest mean value of 1.67 mm, 24.47 cm^2, and 24.77 % for collar diameter, leaf area, and relative water content respectively. Analysis of variance

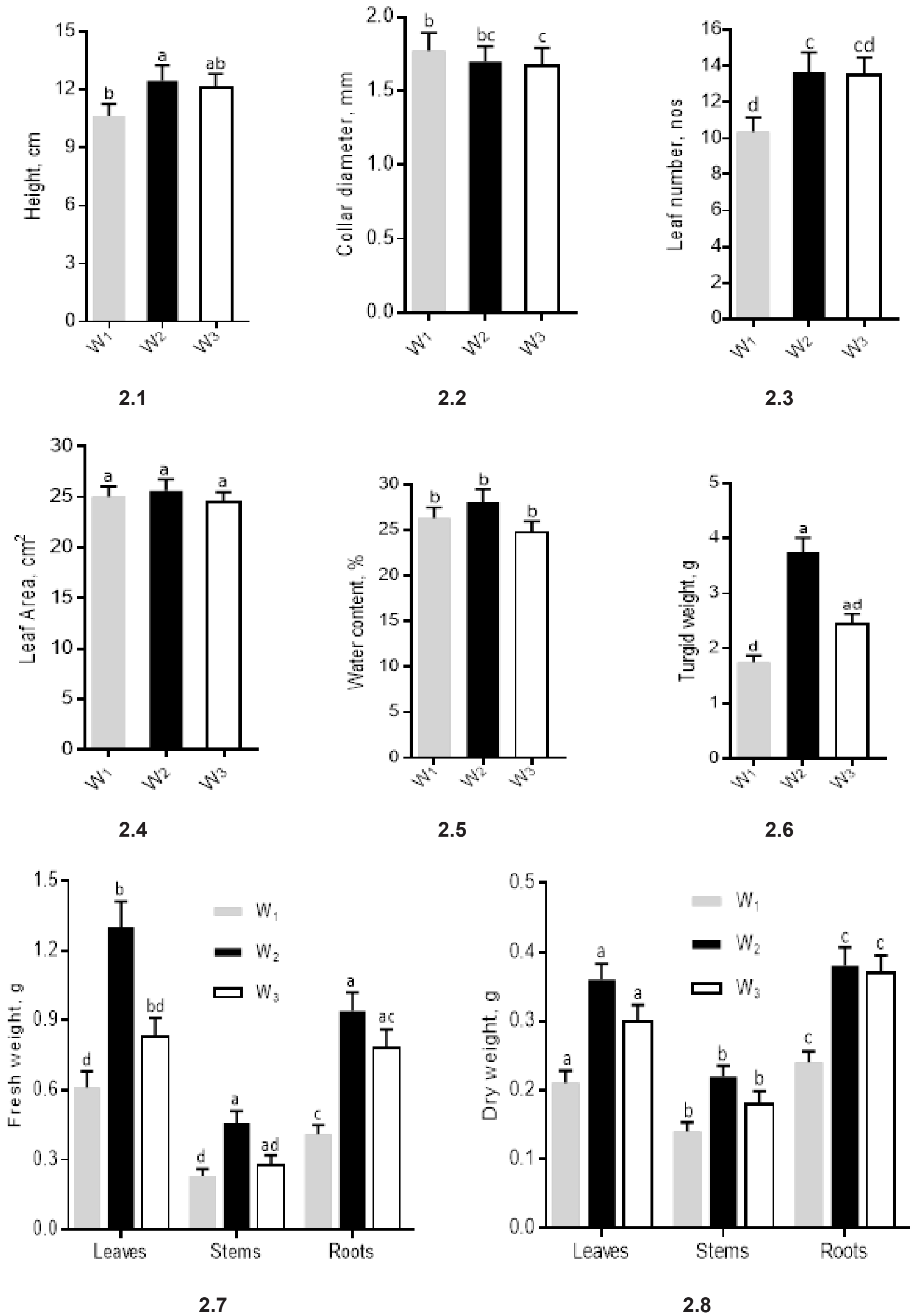

Fig. 2. Effect of varying moisture.

Note: Different letters indicate significant difference between treatments (p<0.05).

showed that moisture supply had significant effect ($p<0.05$) on shoot height, collar diameter, fresh weight of leaves, turgid weight of leaves, fresh weight of shoots, and fresh weight of roots (Table 1).

Interactive effect of mycorrhizae and moisture supply

To verify the interactive effect, the same physiological and morphological parameters as above were examined. Considering the effect of endomycorrhiza with varying moisture supply, the result revealed that seedlings inoculated with endomycorrhiza and watered once a week (M_1W_3) had no highest mean value for all the parameters measured. However, seedlings inoculated with endomycorrhiza and watered every other day (M_1W_2) had the highest mean value for most of the parameters measured, which include shoot height (13.98 cm), collar diameter (1.80 mm), leaf area (29.68 cm^2), leaf number (14.63), fresh weight of leaves (1.62 g) turgid weight of leaves (4.47 g), dry weight of leaves (0.44 g), fresh weight of stems (0.57 g), dry weight of stems (0.26 g), fresh weight of roots (1.39 g), dry weight of roots (0.53 g) and relative water content (29.11 %) (Table 2). In addition, seedlings inoculated with endomycorrhiza and watered every day (M_1W_1) had no highest mean value for all parameters measured. Results from the effect of ectomycorrhiza with varying moisture supply showed that seedlings treated with ectomycorrhiza and watered once a week (M_2W_3) had the highest mean value for shoot height (12.64 cm), leaf area (27.63 cm^2), leaf number (13.04), dry weight of leaves (0.33 g), fresh weight of roots (0.70 g). More so, seedlings inoculated with ectomycorrhiza and watered every other day (M_2W_2) had the highest mean value for fresh weight of leaves (1.03 g), turgid weight of leaves (3.00 g), fresh weight of stems (0.41 g), dry weight of stems (0.20 g), dry weight of roots (0.31 g) while seedlings inoculated with ectomycorrhiza and watered every day (M_2W_1) had the highest mean value for collar diameter (1.83 mm) and relative water content (29.65 %) only. Furthermore, seedlings treated in the absence of mycorrhiza but watered once a week (M_3W_3) had the highest mean value for shoot height

Table 2. Interactive effect of mycorrhiza and moisture supply.

Treatments		SH, cm	CD, mm	LA, cm^2	LN	FWL, g	TWL g	DWL, g	FWS, g	DWS, g	FWR, g	DWR, g	RWC, %
M_1	W_3	11.23^{d}	1.58	24.45^{t}	12.50^{i}	0.55^{u}	2.03^{k}	0.21^{n}	0.26^{z}	0.13^{b}	0.67^{j}	0.43^{h}	17.61^{l}
	W_2	13.98^{d}	1.80^{v}	29.68^{t}	14.63^{i}	1.62^{u}	4.47^{k}	0.44^{n}	0.57^{z}	0.26^{b}	1.39^{j}	0.53^{h}	29.11^{l}
	W_1	10.58^{d}	1.71^{v}	25.34^{t}	09.13^{i}	0.56^{u}	1.95^{k}	0.22^{n}	0.19^{z}	0.11^{b}	0.39^{j}	0.21^{h}	20.58^{l}
M_2	W_3	12.64^{d}	1.71^{v}	27.63^{t}	13.04^{i}	0.77^{u}	1.91^{k}	0.33^{n}	0.28^{z}	0.18^{b}	0.70^{j}	0.28^{h}	29.20^{l}
	W_2	11.92^{d}	1.71^{v}	23.82^{t}	11.88^{i}	1.03^{u}	3.00^{k}	0.26^{n}	0.41^{z}	0.20^{b}	0.56^{j}	0.31^{h}	29.50^{l}
	W_1	10.69^{d}	1.83^{v}	23.58^{t}	11.17^{i}	0.67^{u}	1.74^{k}	0.16^{n}	0.20^{z}	0.13^{b}	0.35^{j}	0.20^{h}	29.65^{l}
M_3	W_3	12.38^{d}	1.56^{v}	21.34^{t}	14.92^{i}	1.16^{u}	3.40^{k}	0.38^{n}	0.30^{z}	0.24^{b}	0.98^{j}	0.40^{h}	27.54^{l}
	W_2	11.49^{d}	1.59^{v}	23.32^{t}	14.58^{i}	1.26^{u}	3.82^{k}	0.40^{n}	0.42^{z}	0.21^{b}	0.88^{j}	0.31^{h}	25.69^{l}
	W_1	10.71^{d}	1.78^{v}	26.21^{t}	10.83^{i}	0.61^{u}	1.60^{k}	0.22^{n}	0.30^{z}	0.17^{b}	0.51^{j}	0.32^{h}	28.66^{l}

Note: Mean values with similar letters indicate no significant differences between treatments ($p>0.05$). SH – shoot height, CD – collar diameter, LA – leaf area, LN – leaf number, FWL – fresh weight of leaves, TWL – turgid weight leaves, DWL – dry weight leaves, FWS – fresh weight of shoot, DWS – dry weight of shoot, FWR – fresh weight of root, DWR – dry weight root, RWC – relative water content.

(12.38 cm), leaf number (14.92), dry weight of stems (0.24 g), fresh weight of roots (0.98 g), and dry weight of roots (0.40 g) while seedlings that were not inoculated with mycorrhiza but were watered every other day (M_3W_2) had highest mean value for fresh weight of leaves (1.26 g) turgid weight of leaves (3.82 g), and dry weigh of leaves (0.40 g). Nevertheless, seedlings that were not inoculated with mycorrhiza but were watered every day (M_3W_1) had the highest mean value for collar diameter (1.78 mm), leaf area (26.21 cm^2), relative water content (28.66 %).

Discussion

Most trees in the field are exposed to challenging environmental conditions which affect their survival. Drought which is a prevalent and dominant abiotic stress factor that many tree species are subjected to, has led to poor forest health and ultimately death of tree species in the long term. Mycorrhizae are important soil microorganisms present in terrestrial ecosystems that, through establishing a symbiotic relationship with most terrestrial plants, contribute to the growth and development of plant species.

In this study, it was observed that mycorrhiza inoculation contributed positively to the growth of *C. fistula* seedlings. In M_3, the plants exhibited an increase in leaf number, fresh weight of leaves, dry weight of leaves, dry weight of shoots, and turgid weight of leaves. Inoculation with M_1 was responsible for improved shoot height, leaf area, fresh weight of root and dry weight of root, whereas M_2 contributed to higher collar diameter and relative water content (Fig. 1). However, the result showed that there was a level of significance ($p<0.05$) only on the relative water content of seedlings inoculated with mycorrhizae (Table 1) where ectomycorrhiza had the highest mean value. In a similar research to examine the potential of endomycorrhiza in improving drought tolerance of *C. atlantica*, it was observed that plants inoculated with mycorrhiza maintained higher relative water content when compared with non-inoculated plants (Zarik et al. 2016). The variation in the response of different mycorrhizal fungi could be traced to the plant species in which they interact with to maintain a symbiotic relationship (Ortas and Ustuner 2014); hence it can be said that *C. fistula* is selective in its association with mycorrhiza and ectomycorrhiza significantly contributed to relative water content (Shi et al. 2017) since all the plants were cultivated under the same soil and climatic conditions. In new soil environments, endomycorrhizal fungi within a short time begins to establish itself to improve soil quality/fertility especially soil with poor nutrient conditions. Hence, endomycorrhizal fungi support plant through the provision of water, nutrient, and also help plants to acclimatize to new soil environment. When drought stress is reduced in the presence of endomycorrhizal fungi, plants experience improved growth rate (Huey et al. 2020, Rydlová and Püschel 2020) enhancing physiological and morphological parameters.

Subsequently, response to varying water regime was observed. Considering the three watering regimes examined, seedlings reaction to water stress and general growth response clearly showed that daily watering contributed to increase in collar diameter only, suggesting that daily watering is not the best for this tree species. Also seedlings watered once a week had no highest mean value for all parameters examined. Seedling watered every other day had the highest mean values for all the parameters except for collar diameter. Furthermore, the result showed significant effect ($p<0.05$) on shoot height, collar diameter, turgid weight of leaves, fresh weight of leaves, turgid weight of leaves, fresh weight of shoots, and fresh weight of roots (Table 1) of the seedlings. Plant response to water availability varies from plant to plant and different plant parts adaptation to water stress condition differs (Gbadamosi 2014). Our findings showed that watering every other day improved about 92 % of all the parameters stressing the fact supported by Sconiers et al. (2020) that plants subjected to moderate water stress were more developed compared to severely stressed plants.

The interactive effect of mycorrhizae and varying moisture supplies showed no significant effect on the parameters of *C. fistula* seedlings. When inoculated with endomycorrhiza, seedlings watered every other day (M_1W_2) exhibited improvement on shoot height, leaf area, fresh weight of leaves, turgid weight of leaves, dry weight of leaves, fresh weight of shoot, dry weight of shoot, fresh weight of roots, and dry weight of roots (Table 2); this interaction contributed to 75 % of the overall parameters, nevertheless there was no significant different ($p>0.05$) for all these parameters. More so, the interactive effect of ectomycorrhiza and daily watering (M_2W_1) only contributed to improved collar diameter and relative water content of the seedlings while seedlings watered once a week without mycorrhiza inoculation (M_3W_3) benefited only leaf numbers.

Conclusions

To the best of our knowledge, this is the first test on *Cassia fistula* to examine the effect of mycorrhiza inoculation and water regimes. Our study reveals that mycorrhiza inoculation at various watering regime can stimulate and enhance the growth of *C. fistula* seedlings. Considering the effect of mycorrhiza, endomycorrhiza (M_1) generally contributed to shoot height, leaf area, fresh weight of stems, and fresh weight of roots, and dry weight of roots while ectomycorrhiza (M_2) generally contributed to collar diameter and relative water content, however, only relative water content was significantly influence statistically by ectomycorrhiza. Furthermore, there are differences in the rate at which seedlings of *C. fistula* responded to endomycorrhiza (M_1), ectomycorrhiza (M_2) and no mycorrhiza (M_3) at watering daily (W_1), watering every other day (W_2) and once a week (W_3). Watering every other day mostly develop growth parameters such as shoot height, leaf area, leaf number, turgid weight of leaves, fresh weight of leaves, dry weight of leaves, fresh weight of shoot, dry weight of shoot, fresh weight of root, dry weight of root and relative water content. Seedlings with no mycorrhiza at watering every other day recorded best performance for fresh weight of leaves, turgid weight of leaves, dry weight of leaves and fresh weight of shoot. Ectomycorrhiza at watering every other day recorded best performance for fresh weight of leaves, turgid weight of leaves, fresh weight of shoot, dry weight of shoot and dry weight of root while watering every day for ectomycorrhiza enhanced collar diameter. However, endomycorrhiza at watering every other day (Table 2) recorded best performance for all the parameters. Therefore endomycorrhiza could enhance uptake of water and nutrient in plants, reducing environmental (drought) stresses and improve the overall growth condition of plants (Chanda et al. 2014). Hence, application of endomycorrhiza at watering every other day is very effective for the growth and development of *C. fistula* seedlings so as to produce healthy and fast growing planting stocks and could be employed under extreme drought condition to prevent death of seedlings due to harsh environment. However, the mechanism by which endomycorrhiza contribute to the overall development of potted plants such as *C. fistula* should be well studied because the resultant effect of this symbiotic association varies among different plant species.

Acknowledgement

We acknowledge the support of Dr. Mrs. Yisau and staffs of Forest Nursery Unit of the Department of Forestry and Wildlife Management, Federal University of Agriculture Abeokuta.

References

Ali M.A. 2014. *Cassia fistula* Linn: A Review of Phytochemical and Pharmacological Studies. International Journal of Pharmaceutical Sciences and Research 5: 2125–2130. DOI: 10.13040/Ijpsr.0975-8232.5(6).2125-30

Bitterlich M., Sandmann M., Graefe J. 2018. Arbuscular Mycorrhiza Alleviates Restrictions to Substrate Water Flow and Delays Transpiration Limitation to Stronger Drought in Tomato. Frontiers in Plant Science 16(9): 154. DOI: 10.3389/Fpls.2018.00154

Brundrett M. 2004. Diversity and Classification of Mycorrhizal Associations. Biological Reviews 79(3): 473–495. DOI: 10.1017/S1464793103006316

Caputo J., Beier C.M., Fakhraei H. 2017. Impacts of Acidification and Potential Recovery on the Expected Value of Recreational Fisheries in Adirondack Lakes (USA). Environmental Science and Technology 51(1): 742–750. DOI: 10.1021/Acs.Est.6b05274

Chanda D., Sharma G.D., Jha D. 2014. The Potential Use of Arbuscular Mycorrhiza in the Cultivation of Medicinal Plants in Barak Valley, Assam: A Review. Current World Environment 9: 544–551. DOI: 10.12944/Cwe.9.2.40

Chandini, Kumar R., Kumar R., Prakash O. 2019. The Impact of Chemical Fertilizers on our Environment and Ecosystem. In: Research Trends in Environmental Sciences Edition, 2nd Chapter 5: 569–586.

Danish M., Singh P., Mishra G., Srivastava S., Jha K.K., Khosa R.L. 2011. *Cassia fistula* Linn. (Amulthus) – an Important Medicinal Plant: A Review of its Traditional Uses, Phytochemistry and Pharmacological Properties. Journal of Natural Product and Plant Resources 1: 101–118.

FAO 2010. Global Forest Resources Assessment (0048-9697). Main Report. Food and Agriculture Organization of the United Nations.

Futai K., Taniguchi T., Kataoka R. 2008. Ectomycorrhizae and their Importance in Forest Ecosystems. In: Siddiqui Z.A., Akhtar M.S., Futai K. (Eds). Mycorrhizae: Sustainable Agriculture and Forestry. Dordrecht, Springer Netherlands: 241–285.

Gbadamosi A. 2014. Effect of Watering Regimes and Water Quantity on the Early Seedling Growth of Picralimanitida (Stapf). Sustainable Agriculture Research 3, 35. DOI: 10.5539/Sar.V3n2p35

Gupta A.K., Tandon N., Sharma M. 2005. Quality Standards of Indian Medicinal Plants. Indian Council of Medical Research 2: 47–53.

Gupta R. 2010. Medicinal and Aromatic Plants. CBS Publishers and Distributors 234, 499.

Huey C.J., Gopinath S.C.B., Uda M.N.A., Zulhaimi H.I., Jaafar M.N., Kasim F.H., Yaakub A.R.W. 2020. Mycorrhiza: a Natural Resource Assists Plant Growth under Varied Soil Conditions. 3 Biotech 10(5), 204. 9 p. DOI: 10.1007/S13205-020-02188-3

Isah A.D., Bello A.G., Maishanu H.M., Abdullahi S. 2012. Research Article Effect of Watering Regime on the Early Growth of *Acacia senegal* (Linn) Willd. Provenances. International Journal of Plant, Animal and Environmental Sciences 3(2): 52–56.

Keenan R., Reams G., Achard F., De Freitas J., Grainger A., Lindquist E. 2015. Dynamics of Global Forest Area: Results from the FAO Global Forest Resources Assessment 2015. Forest Ecology and Management 352: 9–20.

Kelley C.P., Mohtadi S., Cane M.A., Seager R., Kushnir Y. 2015. Climate Change in the Fertile Crescent and Implications of the Recent Syrian Drought. Proceedings of the National Academy of Sciences 112(11): 3241–3246. DOI: 10.1073/Pnas.1421533112

Kumar V.P., Chauhan N.S., Padh H., Rajani M. 2006. Search for Antibacterial and Antifungal Agents from Selected Indian Medicinal Plants. Journal of Ethnopharmacology 107(2): 182–188. DOI: 10.1016/J.Jep.2006.03.013

Li C., Barclay H., Roitberg B., Lalonde R. 2020. Forest Productivity Enhancement and Compensatory Growth: A Review and Synthesis. Frontiers in Plant Science 11, 575211. DOI: 10.3389/fpls.2020.575211

Liang M., Johnson D., Burslem D.F.R.P., Yu S., Fang M., Taylor J.D., Taylor A.F.S., Helgason T., Liu X. 2020. Soil Fungal Networks Maintain Local Dominance of Ectomycorrhizal Trees. Nature Communications 11(1), 2636. DOI: 10.1038/S41467-020-16507-Y

Lisar S.Y.S., Motafakkerazad R., Hossain M.M., Rahman I.M.M. 2012. Water Stress in Plants: Causes, Effects and Responses. In: Ismail M.M., Rahman Hiroshi Hasegawa (Eds). Water Stress. Chapter 1. InTech, Rijeka, Croatia. 13 p. DOI: 10.5772/39363

Meineke E.K., Frank S.D. 2018. Water Availability Drives Urban Tree Growth Responses to Herbivory and Warming. Journal of Applied Ecology 55(4): 1701–1713. DOI:10.1111/1365-2664.13130

Mohamed Ait El M., Raja Ben L., Mohamed A., Abderrahim B., Abdessamad F., Said W., Abdelilah M. 2019. Climate Change and its Impacts on Oases Ecosystem in Morocco. In: Ahmed K. (Ed.) Climate Change and its Impact on Ecosystem Services and Biodiversity in Arid and Semi-Arid Zones. Hershey, Pa, USA: Igi Global: 217–245.

Munns R., James R.A., Sirault X.R.R., Furbank R.T., Jones H.G. 2010. New Phenotyping Methods for Screening Wheat and Barley for Beneficial Responses to Water Deficit. Journal of Experimental Botany 61(13): 3499–3507. DOI: 10.1093/Jxb/Erq199

Neelam C., Ranjan B., Komal S., Nootan C. 2011. Antimicrobial Activity of *Cassia fistula* Linn. Legumes. International Research Journal of Pharmacy 2(10): 100–102.

Nirmala A., Eliza J., Rajalakshmi M., Priya E., Daisy P. 2008. Effect of Hexane Extract of Cassia Fistula Barks on Blood Glucose and Lipid Profile in Streptozotocin Diabetic Rats. International Journal of Pharmacology 4(4): 292–296.

Ortas I., Ustuner O. 2014. Determination of Different Growth Media and Various Mycorrhizae Species on Citrus Growth and Nutrient Uptake. Scientia Horticulturae 166: 84–90. DOI: Https://Doi.Org/10.1016/J.Scienta.2013.12.014

Orwa C., Mutua A., Kindt R., Jamnadass R., Simons A.J. 2009. Agroforestree Database: A Tree Reference and Selection Guide, Version 4.0. World Agroforestry Centre, Kenya.

Qiao X., Gu Y., Zou C., Xu D., Wang L., Ye X., Yang Y., Huang X. 2019. Temporal Variation and Spatial Scale Dependency of the Trade-Offs and Synergies Among Multiple Ecosystem Services in the Taihu Lake Basin of China. Science of the Total Environment 651: 218–229. DOI: Https://Doi.Org/10.1016/J.Scitotenv.2018.09.135

Rahmani A.H. 2015. *Cassia fistula* Linn: Potential Candidate in the Health Management. Pharmacognosy Research 7(3): 217–224.

Richards R.A., Rebetzke G.J., Watt M., Condon A.G., Spielmeyer W., Dolferus R. 2010. Breeding for Improved Water Productivity in Temperate Cereals: Phenotyping, Quantitative Trait Loci, Markers and the Selection Environment. Functional Plant Biology 37(2): 85–97. DOI: Https://Doi.Org/10.1071/Fp09219

Roy-Bolduc A., Laliberté E., Hijri M. 2015. High Richness of Ectomycorrhizal Fungi and Low Host Specificity in a Coastal Sand Dune Ecosystem Revealed by Network Analysis. Ecology and Evolution 6(1): 349–362. DOI: 10.1002/Ece3.1881

Rydlová J., Püschel D. 2020. Arbuscular Mycorrhiza, but not Hydrogel, Alleviates Drought Stress of Ornamental Plants in Peat-Based Substrate. Applied Soil Ecology 146, 103394. DOI: Https://Doi.Org/10.1016/J.Apsoil.2019.103394

Sconiers W., Rowland D., Eubanks M. 2020. Pulsed Drought: The Effects of Varying Water Stress on Plant Physiology and Predicting Herbivore Response. Crop Science 60: 2543–2561. DOI: 10.1002/Csc2.20235

Shamim F., Farooq K., Waheed A. 2014. Effect of Different Water Regimes on Biometric Traits of Some Tolerant and Sensitive Tomato Genotypes. Journal of Animal and Plant Sciences 24(4): 1178–1182.

Shi L., Wang J., Liu B., Nara K., Lian C., Shen Z., Xia Y., Chen Y. 2017. Ectomycorrhizal Fungi Reduce the Light Compensation Point and Promote Carbon Fixation of *Pinus thunbergii* Seedlings to Adapt to Shade Environments. Mycorrhiza 27(8): 823–830.

Siddhuraju P., Mohan P.S., Becker K. 2002. Studies on the Antioxidant Activity of Indian Laburnum (*Cassia fistula* L.): A Preliminary Assessment of Crude Extracts from Stem Bark, Leaves, Flowers and Fruit Pulp. Food Chemistry 79(1): 61–67. DOI: Https://Doi.Org/10.1016/S0308-8146(02)00179-6

Singh S., Singh S.K., Yadav A. 2013. A Review on Cassia Species: Pharmacological, Traditional and Medicinal Aspects in Various Countries. American Journal of Phytomedicine and Clinical Therapeutics 1(3): 291–312.

Sun Z., Song J., Xin X.A., Xie X., Zhao B. 2018. Arbuscular Mycorrhizal Fungal 14-3-3 Proteins are Involved in Arbuscule Formation and Responses to Abiotic Stresses During AM Symbiosis. Frontier in Microbiology 9: 91–91. DOI: 10.3389/Fmicb.2018.00091

Tedersoo L. 2017. Global Biogeography and Invasions of Ectomycorrhizal Plants: Past, Present and Future. In: Tedersoo L. (Ed.). Biogeography of Mycorrhizal Symbiosis. Cham, Springer International Publishing: 469–531.

Toju H., Sato H., Tanabe A.S. 2014. Diversity And Spatial Structure of Belowground Plant-Fungal Symbiosis in a Mixed Subtropical Forest of Ectomycorrhizal and Arbuscular Mycorrhizal Plants. Plos One 9(1), E86566. DOI: 10.1371/Journal.Pone.0086566

van der Heijden M.G., Martin F.M., Selosse M.A., Sanders I.R. 2015. Mycorrhizal Ecology and Evolution: The Past, the Present, and the Future. New Phytology 205(4): 1406–1423. DOI: 10.1111/Nph.13288

Warman R.D. 2014. Global Wood Production from Natural Forests has Peaked. Biodiversity and Conservation 23(5): 1063–1078. DOI: 10.1007/S10531-014-0633-6

Zarik L., Meddich A., Hijri M., Hafidi M., Ouhammou A., Ouahmane L., Duponnois R., Boumezzough A. 2016. Use of Arbuscular Mycorrhizal Fungi to Improve the Drought Tolerance of *Cupressus atlantica* G. Comptes Rendus Biologies 339(5): 185–196. DOI: Https://Doi.Org/10.1016/J.Crvi.2016.04.009

Zhu X.C., Song F.B., Liu T.D., Liu S.Q. 2010. Arbuscular Mycorrhizae Reducing Water Loss in Maize Plants Under Low Temperature Stress. Plant Signaling and Behavior 5(5): 591–593. DOI: 10.4161/Psb.11498