



Response of Jute Mallow (*Corchorus olitorius* L.) Grown in an Alfisol and Inceptisol to Different Organic Fertilizers and Mycorrhizal Inoculation in Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Authors FBM and OFO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OFO, DAA and RVO managed the analyses of the study. Authors CII and FTA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Background and Objective: The use of organic fertilizers in soil usually upsurge the infection rate of mycorrhizal in a plant, thereby increases the nutrients content, uptake and promotes the vegetative growth of the host plant. This experiment was conducted to assess the influence of different organic fertilizers and mycorrhizal inoculation on *Corchorus olitorius* growth and yield in an Alfisol and Inceptisol in Nigeria.

Materials and Methods: The experiment was set up at the screenhouse of the Department of Agronomy, Ibadan. 2 x 2 x 5 factorial experiment in a completely randomized design was conducted with two levels of soil (Alfisol and Inceptisol); two levels of mycorrhizal inoculation (with and without) and five levels of organic fertilizers (organic fertilizers; poultry manure, cattle manure, Moringa, Tithonia and control) in two-kilogram soil under three replications.

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Results: Soil supplemented with organic fertilizers significantly ($p < 0.05$) influenced the growth and yield of *Corchorus olitorius*. The height, leaf area and number of leaves of *Corchorus olitorius* in soil supplemented with organic fertilizers were significantly ($p < 0.05$) higher than control. Higher leaf area and number of leaves were obtained in *C. olitorius* influenced by mycorrhizal (+AM) than without mycorrhizal (-AM) under poultry manure application in Alfisol. Inceptisol without fertilizers and mycorrhizal inoculation was also high in the leaf area of *C. olitorius* compared to Alfisol corresponding treatment with about 31.1%. Number of leaves of *C. olitorius* without mycorrhizal (-AM) inoculation and Tithonia can be compared with mycorrhizal (+AM) inoculation and cattle manure at 7 weeks after transplanting in both soils. Plants height obtained was highest in *C. olitorius* grown in Alfisol without mycorrhizal and cattle manure with about 12.2% higher over Inceptisol. Shoots and roots observed under mycorrhizal inoculation were also significantly different from those observed without mycorrhizal inoculation in both soils under different fertilizers application.

Conclusion: Integration of different fertilizer types (organic fertilizers and mycorrhizal inoculation) can be efficiently used as a suitable nutrient management system due to positive responses observed in this investigation.

Keywords: Inoculation; organic fertilizers; mycorrhizal; growth; yield; alfisol; inceptisol.

1. INTRODUCTION

Difficulties encountered in vegetables production in Nigeria starts with the soil, a necessity for sustainable food production. Low soil quality could be attributed to erosion, fixation and leaching amongst others. Most Nigeria soils ranges from low to medium in productivity but with appropriate management, soil can be further improve. According to [1], crop output, profit and environmental sustenance has become a major concern as majority of humid and sub-humid tropical soils have "marginal fertility". Nonetheless, among the yield building factors, plant nutrition remain the foremost factor-controlling the yield of crops [2]. In Nigeria agro-ecological zones, most surface soils are coarsely-textured with very low organic matter and chemical fertility. Aggregates of these soils are weak; productivity is rapidly lost and retention for water and nutrients for sustainable production is void [3]. These features indicates that soils with exceptional fertility amendments and physiological conditions should consistently undergo proper management to accomplish improved food production through various agricultural intensification practices such as fertilization.

Fertilizer can be organic or inorganic, though the adoption of organic farming has been encouraged in previous years to maintain and increase the long-term fertility of soils, enhance biological cycles within the farming system, involving micro-organisms, soil flora and fauna, plants and animals [4,5]. Organic matter improves the soil structure, reduces soil erosion,

has a regulating effect on soil temperature and helps the soil to store more moisture, thus significantly improving soil fertility. For depletion of the organic matter content of fragile soils of the humid tropics caused by intensive tillage, hence additions of organic manures have been recommended [6]. In addition, the application of organic manure can increase the soil nutrient status as a result of slow release of nutrients to the soil [7,8]. According to [9], organic manure also supports the performance of crop and yield. The availability of nutrients to plant depends on the inherent and derived mechanisms to access these nutrients by plants through microbial activities.

Arbuscular mycorrhizal (AM) fungi have a major impact on the functioning and stability of any ecosystem. AM fungi directly enhance plant growth by providing efficient access via fungal hyphae for absorption of nutrients, especially P and delivery of these nutrients to the plants [10]. Network in the soil can be increase by AM which assimilates nutrients (N, P, K, and some micronutrients) and water, a proportion of which is transferred directly to the host plant [11]. Furthermore, they are but one element of soil biodiversity, which strongly influences soil health. In addition to being influenced by the presence of other soil biota, such as saprophytic fungi [12] the abundance and role of AM fungi are in turn influenced by soil treatments such as tillage and soil amendments [13,14]. While their complete range of impacts on agricultural and natural ecosystems is yet to be fully appreciated, their potential for beneficial effects in all types of ecosystems has been acknowledged [15].

However, dispersal and selective variables may influence the colonization and functioning of mycorrhizal as well as soil types in different ecological region [16].

Soil are grouped into 12 orders in soil taxonomy. The processes through which the soil is formed and their characteristics are used to describe the soil. Some of the examples of major soil orders includes Alfisol and Inceptisol. According to Soil Survey Staff, USDA [17,18], Alfisol has been the most intensive and extensively studied soil due to its availability. Along with Mollisols, Alfisols account for a major portion of soils that are used to grow crops in the world. They are found generally in climates favourable to crop production; in warm moist climates, they are used to grow many crops [19]. Most Alfisol accessible for crop productions are intensely weathered and naturally low in organic matter and nutrient status [20, 21] and as a results of this inherent fertility, it must be fertilized to obtain high yield [6,19]. However, Inceptisol are soils of early stages of formation with relatively new origin [19]. They are characterised by having only the weakest horizons or layers produced by soil forming factors. According to 'The Editors of Encyclopedia Britannica' [22], the geographical settings of Inceptisol are widely from river delta to upland forest to tundra environment and are usually arable with appropriate control of erosion or drainage.

Soils commonly are not similar in all its properties due to different factors, nearly all soils contain more than traces of both mineral and organic components in some horizons, but most soils are dominantly one or the other. Therefore, fertilizers are intended to supplement the already present nutrients in the soil. Application of organic fertilizer or bio-fertilizer has its benefits and limitations in the context of nutrient supply, crop growth and environmental quality. However, the benefits need to be integrated in order to derive optimum use of each type of fertilizer to accomplish a balanced nutritional management for crop growth. Hence, this study was taken using *Corchorus olitorius* (as test crop) to determine it response to organic fertilizer in two different Nigeria soils under mycorrhizal inoculation.

2. MATERIALS AND METHODS

2.1 Experimental Site and Soil Collection

An experiment to monitor the response of *Corchorus olitorius* to different organic fertilizers

and mycorrhizal inoculation planted in two soil types was set up at the screen house of the Department of Agronomy, University of Ibadan. The soil samples were collected from Parry road at two locations (07°27' 08.4 N and 03°50' 27.2 E), Inceptisol and (07°27' 05.4 N and 03°50' 27.2 E) Alfisol, University of Ibadan. The two soils were selected based on their varying amounts of nutrients and characteristics. Topsoil of 0 – 15 cm depth was used for the experiment. The soil was air-dried; grounded and sieved using 2 mm sieve to remove gravel and large plant roots. The soil samples were chemically analyzed for nutrient content. Processed soil was placed in 2 kg pots and incorporated with organic fertilizers and mycorrhizal (*Glomus clarum*). Seeds of *Corchorus olitorius* were sourced from National Horticultural Research Institute (NIHORT) Ibadan and raised in a germination basket for two weeks before transplanting into the pots.

2.2 Mycorrhizal Propagation and Inoculation

Mycorrhizal inoculum of *Glomus clarum* was obtained from Soil Microbial Laboratory University of Ibadan. The spores were propagated in sterilized sand with corn as a host. 10 grams of AMF inoculum was placed into 2 kg pots of sand. 3 seeds of corn were placed per pot on the inoculum. The seeds and the inoculum were then covered with sand. Watering was done before germination started till 2 weeks after germination, the seedlings were thinned leaving only one (1) seedling in the pot. 10 ml of Hoagland solution without P was applied to the seedling alternate with water for another one (1) month, after which was left for another one (1) month without watering. The corn was harvested with the sand and spores were counted by wet sieving technique. Approximately 10 g of *Glomus clarum* inoculant with 100 spores was placed into a hole at a sub-level of 5-10 cm of the pot.

2.3 Experimental Design and Treatments Application

The experimental design was a 2 x 2 x 5 factorial in a completely randomized design (CRD) with three (3) replication for this study. 20 treatments consisting of two (2) soil types (Alfisol and Inceptisol), two (2) mycorrhizal inoculation (with/without) and five treatments (cattle manure, poultry manure, *Tithonia*, *Moringa*, and control). Cattle manure, poultry manure, *Moringa* and *Tithonia* were obtained from Agro farm, Ibadan.

Organic fertilizers (treatments) were analyzed to determine the nutrients content. The nitrogen content was used to determine the quantity of fertilizer to apply to *Corchorus olitorius* at a rate of 20 t ha⁻¹ each. Treatments were incorporated into the soils, two weeks before transplanting. The following organic fertilizers and mycorrhizal were mixed with soils as follows: Alfisol T1 (+AM and no fertilizer), Alfisol T2 (+AM and *Tithonia*), Alfisol T3 (+AM and *Moringa*), Alfisol T4 (+AMF and poultry manure), Alfisol 5 (+AM and cattle), Alfisol T6 (-AM and no fertilizer), Alfisol T7 (-AM and *Tithonia*), Alfisol T8 (-AM and *Moringa*), Alfisol T9 (-AM and poultry manure), Alfisol 10 (-AM and cattle manure). Inceptisol T11 (+AM and no fertilizer), Inceptisol T12 (+AM and *Tithonia*), Inceptisol T13 (+AM and *Moringa*), Inceptisol T14 (+AM and poultry manure), Inceptisol T15 (+AM and cattle manure), Inceptisol T16 (-AM and no fertilizer), Inceptisol T17 (-AM and *Tithonia*), Inceptisol T18 (-AM and *Moringa*), Inceptisol T19 (-AM and poultry manure) and Inceptisol T20 (-AM and cattle manure).

2.4 Data Collection

The growth variables of *Corchorus olitorius* taken were; plant height (cm) using meter rule, number of leaves by counting, leaf area using meter rule (cm) and oven-dried weight of shoots and roots (g) using the sensitive scale. The plant samples were oven-dried at 65°C until a constant weight was obtained for dry matter yield.

2.5 Soil Analysis

The soil pH was determined with the pH meter (SM-3H Micro field England) using a glass electrode in 1:2 soil to water ratio. Organic carbon was estimated by the dichromate wet

oxidation method of Walkey and Black [23]. Nitrogen (N) by micro- Kjeldahl distillation method [24]. Available P using Mehlich (III) extracting solution [25], exchangeable bases (K, Mg, and Ca) were determined using a modified shaking method [26] where 1M of neutral normal ammonium acetate (NH₄OAc) was used as a reagent. Particle size analysis was done using the hydrometer method [27].

2.6 Statistical Analysis

Quantitative data were analyzed using the ANOVA procedure and means separated using the Duncan Multiple Range Test (DMRT) at a 5% probability [28].

3. RESULTS

3.1 Chemical Properties and Particle Size Distribution of Experimental Soil

The two soil order are different in texture, pH and in chemical composition. Alfisol was sandy loam, slightly acidic and low in nitrogen content. Inceptisol was sandy clay loam, moderately acidic and low in nitrogen content. Inceptisol showed higher nutrient content (K, Ca, Mg and Na) compared to Alfisol. Ca and Na in Inceptisol were more than two folds the corresponding value in the Alfisol (Table 1).

3.2 Nutrients Content of Organic Fertilizers

Moringa leaves had the highest total N compared to other organic fertilizers while the least N

Table 1. Characterization of soils used for the experiment

Parameters	Alfisol	Inceptisol
pH(Soil : H ₂ O)	6.20	5.40
Nitrogen (g/kg)	0.14	0.19
Avail. P (mg/kg)	2.14	2.25
Exchangeable cation (cmol /kg)		
K	0.18	0.18
Ca	3.10	7.33
Mg	1.55	1.93
Na	2.74	6.31
Organic Carbon (g/kg)	1.82	5.07
Particle size distribution (%)		
Sand	74.6	64.6
Silt	16.0	10.0
Clay	9.4	25.4
Textural class	SL	SCL

Sandy Clay Loam = SCL, Sandy Loam = SL

Table 2. Nutrients content of organic fertilizers

Element (%)	Poultry manure	Cattle manure	<i>Moringa</i>	<i>Tithonia</i>
N	1.15	0.54	1.60	0.79
Total P	1.15	8.45	0.30	7.94
K	1.80	0.95	2.23	3.92
Ca	9.70	1.06	1.05	3.00
Mg	0.44	0.86	0.15	0.01

Table 3. Influence of organic fertilizers and mycorrhizal inoculation on leaf area of *Corchorus olitorius*

Soil types		AM	OF	3WAT	5WAT	7WAT
Alfisol	T1	+	Control	10.17 ^{hi}	16.90 ^{ghij}	23.83 ^{efghi}
	T2	+	<i>Tithonia</i>	10.77 ^{gh}	17.33 ^{ghi}	22.07 ^{ghi}
	T3	+	<i>Moringa</i>	7.27 ^k	13.43 ^j	23.40 ^{fghi}
	T4	+	Poultry manure	21.07 ^a	26.43 ^{bc}	39.93 ^a
	T5	+	Cattle manure	17.30 ^{bcd}	30.60 ^a	33.77 ^{abc}
	T6	-	Control	8.23 ^{ij}	13.13 ^{ij}	17.70 ⁱ
	T7	-	<i>Tithonia</i>	19.47 ^{ab}	24.89 ^{bcd}	29.43 ^{cdef}
	T8	-	<i>Moringa</i>	8.73 ^{hij}	14.60 ^{hij}	25.10 ^{defgh}
	T9	-	Poultry manure	16.17 ^{cd}	22.73 ^{cde}	27.89 ^{cdefg}
	T10	-	Cattle manure	16.23 ^{cd}	21.77 ^{def}	30.80 ^{cde}
Inceptisol	T11	+	Control	15.72 ^{cde}	18.60 ^{efgh}	19.30 ^{hi}
	T12	+	<i>Tithonia</i>	13.57 ^{ef}	17.30 ^{ghi}	22.97 ^{fghi}
	T13	+	<i>Moringa</i>	12.94 ^{fg}	19.07 ^{efg}	23.83 ^{defghi}
	T14	+	Poultry manure	13.00 ^{fg}	19.13 ^{efg}	26.93 ^{cdefg}
	T15	+	Cattle manure	18.37 ^{abc}	25.00 ^{bcd}	38.20 ^{ab}
	T16	-	Control	17.63 ^{abc}	22.07 ^{def}	24.50 ^{defghi}
	T17	-	<i>Tithonia</i>	15.60 ^{de}	18.43 ^{fgh}	23.47 ^{fghi}
	T18	-	<i>Moringa</i>	18.00 ^{bcd}	24.75 ^{bcd}	31.43 ^{cd}
	T19	-	Poultry manure	16.31 ^{cd}	27.43 ^{ab}	32.53 ^{bc}
	T20	-	Cattle manure	18.07 ^{abc}	22.73 ^{cde}	26.84 ^{cdefg}
Interaction						
Soil types(ST)				**	*	Ns
Arbuscular Mycorrhizal (AM)				**	*	Ns
Organic fertilizers(OF)				**	**	**
O*ST				**	***	Ns
O*AM				**	**	**
ST*AM				*	***	Ns
O*ST*AM				**	***	**

Means followed by the same letters are not significantly different from each other at $p \leq 0.05$ according to DMRT, * = significant at $p \leq 0.05$; ** = Significant at $p \leq 0.01$; *** = Significant at $p \leq 0.001$; ns = not significant; WAT= weeks after transplanting, AM = arbuscular mycorrhizal; OF = organic fertilizers; ST= soil types

content was observed in cattle manure (Table 2). The total P of cattle manure and *Tithonia* were comparable but were more than twenty times that of poultry manure and *Moringa*. The least K content was also observed in cattle manure while the highest was in *Tithonia*. *Moringa* had the least Ca while poultry manure had the highest Ca content. Mg was highest in cattle manure with *Tithonia* recording the least.

3.3 Leaf Area

There was a significant difference in the leaf area of *C. olitorius* at three (3), five (5) and seven (7)

weeks after transplanting (WAT) with soil types, mycorrhizal inoculation and organic fertilizer treatments (Table 3). The highest leaf area was obtained in Alfisol with mycorrhizal and poultry manure at three (3) and seven (7) WAT while the least leaf area was obtained under Alfisol without mycorrhizal and organic fertilizers at five (5) and seven (7) WAT. Inceptisol without fertilizers and mycorrhizal inoculation was significantly higher in the leaf area of *C. olitorius* compared to Alfisol corresponding treatment at three (3) and seven (7) WAT. However, at seven (7) WAT, there was no significant difference in the leaf area of

Table 4. Influence of organic fertilizers with mycorrhizal inoculation in two soil types on number of leaves of *Corchorus olitorius*

Soil types		AM	OF	3WAT	5WAT	7WAT
Alfisol	T1	+	Control	14.00 ⁱ	25.00 ^{jl}	39.33 ^{lgh}
	T2	+	<i>Tithonia</i>	16.00 ^{hi}	27.33 ^{ghij}	37.33 ^{ghi}
	T3	+	<i>Moringa</i>	15.67 ^{hi}	26.67 ^{hij}	34.33 ^{hi}
	T4	+	Poultry manure	41.67 ^a	48.33 ^a	67.00 ^a
	T5	+	Cattle manure	33.00 ^{bcd}	44.00 ^{abc}	49.67 ^{bc}
	T6	-	Control	13.00 ⁱ	22.33 ^j	32.00 ⁱ
	T7	-	<i>Tithonia</i>	37.67 ^{ab}	47.33 ^a	56.33 ^a
	T8	-	<i>Moringa</i>	28.33 ^{def}	38.67 ^{bcdef}	45.33 ^{cde}
	T9	-	Poultry manure	30.33 ^{cde}	40.00 ^{abcdef}	46.33 ^{cd}
	T10	-	Cattle manure	22.00 ^{fgh}	37.00 ^{cdef}	49.33 ^{bc}
Inceptisol	T11	+	Control	21.33 ^{gh}	34.33 ^{defgh}	40.33 ^{efg}
	T12	+	<i>Tithonia</i>	23.00 ^{fg}	33.33 ^{efghi}	42.33 ^{defg}
	T13	+	<i>Moringa</i>	21.33 ^{gh}	32.00 ^{efghi}	39.33 ^{fgh}
	T14	+	Poultry manure	23.00 ^{fg}	31.00 ^{fghi}	40.33 ^{efg}
	T15	+	Cattle manure	29.67 ^{de}	33.67 ^{defghi}	56.33 ^a
	T16	-	Control	34.00 ^{bcd}	42.33 ^{abcd}	49.00 ^{bc}
	T17	-	<i>Tithonia</i>	25.33 ^{efg}	36.00 ^{cdefg}	44.67 ^{cdef}
	T18	-	<i>Moringa</i>	36.33 ^{abc}	46.33 ^{ab}	53.00 ^{ab}
	T19	-	Poultry manure	28.00 ^{def}	37.33 ^{cdef}	44.00 ^{cdef}
	T20	-	Cattle manure	33.67 ^{bcd}	35.33 ^{cdefgh}	58.33 ^a
Interaction						
Soil types(ST)				*	Ns	Ns
Arbuscular Mycorrhizal (AM)				***	**	***
Organic fertilizers(OF)				**	**	***
O*ST				***	**	***
O*AM				***	***	***
ST*AM				**	Ns	***
O*ST*AM				***	***	**

Means followed by the same letters are not significantly different from each other at $p \leq 0.05$ according to DMRT, * = significant at $p \leq 0.05$; ** = Significant at $p \leq 0.01$; *** = Significant at $p \leq 0.001$; ns = not significant; WAT= weeks after transplanting, AM = arbuscular mycorrhizal; OF = organic fertilizers; ST= soil types

C. olitorius in both soils (without amendment), although Inceptisol was 38.1% higher than Alfisol. Higher leaf area was obtained in *C. olitorius* influenced by mycorrhizal more than the plants without mycorrhizal at three (3), five (5) and seven (7) WAT under poultry manure in Alfisol. *C. olitorius* without mycorrhizal inoculation and *Moringa* was significantly different at three (3) WAT when compared with corresponding treatment with mycorrhizal inoculation in Inceptisol.

3.4 Number of Leaves

There was a significant difference in the number of leaves of *C. olitorius* at three (3), five (5) and seven (7) WAT under soil types, mycorrhizal and organic fertilizer treatments (Table 4). The number of leaves of *Corchorus olitorius* was at highest in Alfisol

with mycorrhizal and poultry manure amendment at three (3), five (5), and seven (7) WAT while the least number of leaves was observed in Alfisol without mycorrhizal and organic fertilizer. The number of leaves obtained in *Corchorus olitorius* under Alfisol and poultry manure with mycorrhizal inoculation was significantly higher when compared with Inceptisol of the same treatments at three (3), five (5) and seven (7) WAT. The number of leaves was significantly higher in Inceptisol than Alfisol without organic fertilizer and mycorrhizal inoculation (control) across the weeks. Mycorrhizal influenced a higher number of leaves in Alfisol with poultry than without mycorrhizal at three, five and seven WAT while Inceptisol had a significantly lower number of leaves when compared to Alfisol with poultry and mycorrhizal treatment at three (3), five (5) and seven (7) WAT.

Table 5. Influence of organic fertilizers, soil types and mycorrhizal inoculation on the plant height of *Corchorus olitorius*

Soil types		AM	OF	3WAT	5WAT	7WAT
Alfisol	T1	+	Control	7.43 ^h	15.67 ^{hij}	20.80 ^g
	T2	+	<i>Tithonia</i>	9.83 ^{efgh}	20.83 ^{ef}	28.27 ^{d^{efg}}
	T3	+	<i>Moringa</i>	6.73 ^h	13.37 ^{ij}	26.47 ^{efg}
	T4	+	Poultry manure	15.87 ^{ab}	29.43 ^a	50.33 ^{ab}
	T5	+	Cattle manure	17.07 ^a	29.47 ^a	33.30 ^{cde}
	T6	-	Control	7.47 ^h	11.13 ^j	18.20 ^g
	T7	-	<i>Tithonia</i>	8.47 ^{gh}	21.17 ^{def}	36.30 ^{cde}
	T8	-	<i>Moringa</i>	8.53 ^{gh}	16.50 ^{ghi}	27.87 ^{efg}
	T9	-	Poultry manure	14.33 ^{abc}	26.70 ^{abc}	42.50 ^{bc}
	T10	-	Cattle manure	13.27 ^{bcd}	26.70 ^{abc}	53.43 ^a
Inceptisol	T11	+	Control	9.00 ^{gh}	20.97 ^{ef}	27.43 ^{efg}
	T12	+	<i>Tithonia</i>	9.47 ^{fgh}	19.57 ^{efg}	26.73 ^{efg}
	T13	+	<i>Moringa</i>	8.23 ^{gh}	24.50 ^{abcde}	29.77 ^{def}
	T14	+	Poultry manure	11.23 ^{cdefg}	20.10 ^{efg}	30.00 ^{def}
	T15	+	Cattle manure	12.90 ^{bcde}	26.27 ^{abcd}	37.17 ^{cde}
	T16	-	Control	10.93 ^{defg}	24.20 ^{abcde}	37.83 ^{cde}
	T17	-	<i>Tithonia</i>	9.27 ^{gh}	22.07 ^{cde}	30.17 ^{def}
	T18	-	<i>Moringa</i>	12.03 ^{cdef}	28.17 ^{ab}	39.77 ^{cd}
	T19	-	Poultry manure	12.20 ^{cdef}	24.87 ^{abcde}	35.60 ^{cde}
	T20	-	Cattle manure	13.10 ^{bcd}	23.03 ^{bcde}	30.40 ^{def}
Interaction						
Soil types(ST)				ns	***	ns
Arbuscular Mycorrhizal (AM)				ns	Ns	**
Organic fertilizers (OF)				***	***	***
O*ST				***	***	***
O*AM				*	Ns	ns
ST*AM				*	*	ns
O*ST*AM				ns	***	***

Means followed by the same letters are not significantly different from each other at $p \leq 0.05$ according to DMRT,

* = significant at $p \leq 0.05$; ** = Significant at $p \leq 0.01$; *** = Significant at $p \leq 0.001$; ns = not significant; WAT= weeks after transplanting, AM = arbuscular mycorrhizal; OF = organic fertilizers; ST= soil types

3.5 Plant Height

C. olitorius showed a significant difference in the plant height under the two soils, mycorrhizal inoculation and organic fertilizer treatments at three, five and seven WAT (Table 5). Plant height obtained was highest in *C. olitorius* grown in Alfisol with mycorrhizal and cattle manure at three (3) and five (5) weeks after transplanting. However, the least plant height was obtained in Alfisol without mycorrhizal inoculation and organic fertilizer at five (5) and seven (7) weeks. Alfisol with cattle manure and mycorrhizal had significantly higher plant height at three (3) and five (5) WAT when compared with Alfisol and cattle manure without mycorrhizal but the later treatment had a significantly higher plant height at seven (7) WAT. The plant height of *C. olitorius* obtained was significantly higher in Alfisol under the application of cattle manure without mycorrhizal than in Inceptisol at three (3) WAT.

At five (5) WAT plant height was 12.2% higher in Alfisol over Inceptisol but at seven (7) WAT there was no significant difference in plant height. Moreover, Inceptisol showed 11.6% increase over Alfisol. *C. olitorius* had no significant difference in the plant height across the weeks in Alfisol without mycorrhizal and organic fertilizers when compared to mycorrhizal inoculated soil with corresponding treatments. Higher plant height was measured in Alfisol with mycorrhizal with no organic fertilizer at five (5) and seven (7) WAT with 40% and 14.3% increase respectively over Alfisol without mycorrhizal and organic fertilizer.

3.6 Shoot and Root Biomass (Dry Weight) of *Corchorus olitorius* as Influenced by Organic Fertilizers and Mycorrhizal

There was a significant difference in shoot and root biomass under mycorrhizal inoculation

Table 6. Shoot and root biomass (Dry weight) of *Corchorus olitorius* as influenced by organic fertilizers and mycorrhizal

Soil types		AM	OF	Shoot (g)	Root (g)
Alfisol	T1	+	Control	5.09 ^{bc}	1.71 ^c
	T2	+	<i>Tithonia</i>	8.77 ^{abc}	3.64 ^{abc}
	T3	+	<i>Moringa</i>	7.83 ^{abc}	3.41 ^{abc}
	T4	+	Poultry	7.69 ^{abc}	2.71 ^{abc}
	T5	+	Cattle	11.72 ^{ab}	4.89 ^a
	T6	-	Control	2.29 ^c	1.33 ^c
	T7	-	<i>Tithonia</i>	7.97 ^{abc}	1.97 ^c
	T8	-	<i>Moringa</i>	6.42 ^{bc}	2.53 ^{abc}
	T9	-	Poultry manure	9.27 ^{ab}	2.89 ^{abc}
	T10	-	Cattle manure	11.74 ^{ab}	4.67 ^{ab}
Inceptisol	T11	+	Control	5.68 ^{bc}	1.68 ^c
	T12	+	<i>Tithonia</i>	8.77 ^{abc}	1.70 ^c
	T13	+	<i>Moringa</i>	8.25 ^{abc}	3.21 ^{abc}
	T14	+	Poultry manure	8.31 ^{abc}	2.89 ^{abc}
	T15	+	Cattle manure	7.65 ^{abc}	2.73 ^{abc}
	T16	-	Control	7.14 ^{bc}	2.13 ^{bc}
	T17	-	<i>Tithonia</i>	8.44 ^{abc}	2.46 ^{abc}
	T18	-	<i>Moringa</i>	8.83 ^{abc}	2.89 ^{abc}
	T19	-	Poultry manure	13.85 ^a	4.94 ^a
	T20	-	Cattle manure	7.08 ^{bc}	2.59 ^{abc}
Interaction					
Soil types(ST)				Ns	Ns
Arbuscular	Mycorrhizal			*	*
(AM)					
Organic fertilizers(OF)				Ns	Ns
O*ST				Ns	Ns
O*AM				Ns	Ns
ST*AM				Ns	Ns
O*ST*AM				Ns	Ns

Means followed by the same letters are not significantly different from each other at $p \leq 0.05$ according to DMRT, * = significant at $p \leq 0.05$; ** = Significant at $p \leq 0.01$; *** = Significant at $p \leq 0.001$; ns = not significant; WAT= weeks after transplanting, AM = arbuscular mycorrhizal; OF = organic fertilizers; ST= soil types

(Table 6). Highest shoot and root biomass was observed in Inceptisol and poultry manure without mycorrhizal; Inceptisol with mycorrhizal and *Tithonia* had the least root biomass among the inoculated treatments and can be compared with the control. However, a double fold biomass was obtained when grown in the same soil without mycorrhizal and *Tithonia*. Under soil types and organic fertilizer application, no significant differences was recorded.

4. DISCUSSION

Nutrients are one of the primary factors that influences crop production especially in less fertile soil. The occurrence of high nutrient contents from added organic fertilizers under mycorrhizal inoculation influences nutrient uptake and improved growth of crops. In this study, assessment of *C. olitorius* under the application

of different organic fertilizers and mycorrhizal inoculation in two soil types (Alfisol and Inceptisol) was conducted. Our results demonstrated the efficiency of the various organic fertilizers added to soil on the growth of *C. olitorius*. Application of Poultry manure > Cattle manure > *Tithonia diversifolia* > *Moringa oleifera* > non-amendment in this order with and without mycorrhizal inoculation in both soils had clearly increased the leaf area and number of leaves of *C. olitorius*, thereby indicating the effectiveness of organic fertilizers and the contribution of soil organisms to the growth and nutrients uptake [29]. Several discussions have been done on positive effects of organic fertilization on mycorrhizal and was noted that when micro-organisms finds a suitable habitat for their growth, they tends to be very efficient in dissolving nutrients and making them available to plants [30]. Additionally [31], indicated that humic

substances produced as a result of organic fertilizer decomposition can adsorb free cations from soil solution, which may favour the fungi mycelia physiological functions for absorptions and transportation of nutrients.

The significant increase in all the growth parameters under the application of different organic fertilizers without mycorrhizal inoculation in both soils (Alfisol and Inceptisol) is an indicator that adequate fertilization of the soil is needed to maximize the yield of leafy vegetables through the use of organic fertilizer particularly poultry manure and cattle manure. This corroborate the result of [32], who presented that animal manure increased number of leaves, stem girth and leaf length of *C. olerius*. The highest values in the leaf area of *C. olerius* for mycorrhizal and without mycorrhizal inoculated soil was recorded under the application of poultry manure and cattle manure, this result can be ascribed to the release of nitrogen from this manure and corroborate the result presented by [33], who stated that positive response of *C. olerius* was observed when sole chicken manure was added to soil. Also, the decomposition of cattle manure enhanced the mineralization of nutrients in the soil. [34], presented that a viable alternative to chemical fertilizer is organic waste. Organic farming is relatively efficient in the management of soil for productivity and sustainable food security. The least performance of the plants in the non- amended pots (control) could be a reflection of soil nutrients deficit.

5. CONCLUSION

The application of organic fertilizers and mycorrhizal influenced the growth and yield of *Corchorus olerius* in Alfisol and Inceptisol. The soil types showed no effect on the yield of the crop. Mycorrhizal inoculation influenced the vegetative growth of the crop. Mycorrhizal inoculation showed significant effect on roots and shoots biomass. The sum of the shoots and roots biomass of *C. olerius* had this order of yield in Inceptisol; Poultry manure > Cattle manure > *Tithonia* > *Moringa* > Control. The sum of the shoots and roots biomass of *C. olerius* had this order of yield in Alfisol; Cattle manure> Poultry manure >> *Tithonia* > *Moringa* > Control. In general, plants supplemented with organic fertilizers and mycorrhizal had greater growth more than the other fertilization system (without mycorrhizal) in both soils. Hence, the use of arbuscular mycorrhizal can serve as a means of improving sustainable production as it increases

the efficiency of organic fertilizers to improve the growth and yield of *C. olerius*.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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