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Germination and Seedling Characteristics of *Moringa Oleifera* (Lam.) from Different Sites in Egypt.

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ABSTRACT

The aim of this paper is to study the effect of seed source and soil type on growing *Moringa oleifera* in Egypt. Germination percentage varied highly significantly among the seeds collected from the five studied sites (Sheikh Zuweid Station, Qanatir Horticulture Research Institute, Ain Shams University - Faculty of Science Botanic Garden, Orman Botanic Garden and Aswan Botanic Garden). The seeds of Sheikh Zuweid recorded the highest germination percentage (98.7%). Seedlings were grown in five soil mixtures and growth parameters were measured weekly (The experiment lasted for 4 weeks). Seedling height was more significantly affected by the type of soil mixture than the no. of leaflets. Also, the seed source affected significantly on the measurements of the previous two parameters and highly significantly on root length, no. of root branches and dry weight. The seedlings grown from Sheikh Zuweid seeds had the maximum values of growth parameters. Seedlings grown in sandy soil recorded the maximum values of seedling height (29.0 cm), root length (8.0 cm), no. of root branches (17.3 branch root^{-1}) and dry weight (0.16 g seedling^{-1}). The results revealed that *M. oleifera* seedlings can be easily grown in many soil types, but it prefers sandy well drained type.

Keywords: Imbibition, Seed coat, Height, Leaflets number, Root, Dry weight.

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INTRODUCTION

M. oleifera is the best known and most widely cultivated species of Moringaceae [2]. It is a fast-growing tree reaching up to 10 or 12 m in height with a spreading open crown of drooping fragile branches, feathery foliage of tripinnate leaves, and thick, corky, and whitish bark [3]. This tree is native to the sub-Himalayan region of northwest India and Pakistan, from where it was introduced into several warm countries in the Tropics [4,5].

This tree is evergreen in tropical, while deciduous in sub-tropical climates [6]. *M. oleifera* does well even in arid, sandy conditions, grows to four meters, and bears fruit within the first year of growth [7]. It can tolerate a wide range of soil and rainfall conditions and grow under wide ecological ranges [8,9]. This tree grows in a wide variety of soil types, but it prefers well-drained sandy or loamy soils that are slightly alkaline and can tolerate a soil pH of 5 - 9. Also, *M. oleifera* tolerates clay soils, but cannot tolerate water logging and poor drainage [8,10].

M. oleifera is an important food commodity which has had enormous attention as the natural nutrition of the tropics. Tree different parts (i.e., leaves, fruits, flowers and immature pods) are used as a highly nutritive vegetable in many countries [11]. Many developing poor countries have been benefited from *M. oleifera* as a multipurpose tree. The economic value and uses of this tree have attracted the attention of researchers, development workers and farmers [8]. This search aims at studying the factors affecting the success of cultivation of *M. oleifera* crop in Egypt. Germination percentage for *M. oleifera* seeds collected from different sites in Egypt will be evaluated. In order to obtain seedlings with the highest quality, the effect of soil type on seedling growth parameters through growing seedlings in 5 soil mixtures will be illustrated.

MATERIALS AND METHODS

Seeds needed for germination test were collected from five sites as mentioned in Table 1. Seeds were collected from *M. oleifera* trees representing each site to determine seed weight (3 replicate × 100 seed for each site). The germination experiment was performed during October 2009 in Faculty of Science - Benha University (30° 28' 53.4'' N, 31° 12' 20.8'' E). Germination was monitored daily for 4 weeks (recorded as the time of emergence of the radical). Germination percentage (daily and overall) was determined using to the following equation:

$$\text{Germination percentage} = \frac{\text{No. of germinated seeds}}{\text{Total No. of seeds in germination box}} \times 100$$

Table 1: Features of the 5 studied botanic sites in Egypt.

Site	Governorate	Latitude (N)	Longitude (E)	Average Temperature (°C)[R]	Climate [R]
1-Sheikh Zuweid Station	North Sinai	31º 14' 10"	34º 06' 53"	12.7 - 26.1	Desert
2-Qanatir Horticulture Research Institute	Qalubeiya	30º 10' 56.0"	31º 07' 50.7"	13.0 - 27.5	Desert
3-Botanic Garden of Faculty of Science - Ain Shams University	Cairo	30º 04' 38.7"	31º 16' 56.3"	13.1 - 27.5	Hot desert
4-Orman Botanic Garden	Giza	30º 01' 49.1"	31º 12' 47.1"	13.0 - 27.5	Hot desert
5-Aswan Botanic Garden	Aswan	24º 05' 33.8"	32º 53' 07.4"	16.9 - 34.4	Hot desert

R: According to en.climate-data.org [1].

In order to evaluate what kind of soil mixture should be used to obtain seedlings of higher quality, *M. oleifera* seedlings were grown in five soil mixtures. Seedlings for this purpose were grown from seeds collected from the previously mentioned study sites during October 2010. Sandy soil was gotten from Dahshour, Giza (29º 47' 23.5" N, 31º 12' 46.5" E) and clay soil was brought from a land close to the River Nile in Kafr Shokre, Qalubeya (30º 33' 33.0" N, 31º 14' 47.7" E). Both soils were air dried and passed through a 2 mm sieve. Both types of soil were mixed together in five mixtures (weight : weight) as follows: Sand (1 sand : 0 clay); Clay (1 clay : 0 sand), CS (1 sand : 1clay); SCC (1 sand : 2 clay); CSS (1 clay : 2 sand). Physical and chemical analyses were performed according to Allen, et al. [12] to estimate the properties of the five prepared soil mixtures.

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Seeds were germinated and planted in well drained pots (capacity of 1 kg) containing the five soil mixtures (three replicates for each site in each soil mixture were assayed), placed in shaded room (35 - 37 °C) and irrigated with tap water (200 ml in each pot) every 48 h. Seedling height (cm) and number of leaflets for each seedling (leaflet seedling^{-1}) were measured weekly. By the end of the experiment, seedlings were carefully unearthed, washed, drained, and then root length (cm) and number of root branches (branch root^{-1}) were measured for all seedlings. Dry weight (g) of the whole seedling was measured after drying at 70 °C for two days.

The results were subjected to Analysis Of Variance (ANOVA) according to IBM SPSS Statistics 20.0 software. Duncan multiple range test for the means was used to detect the significant differences between the means of the studied properties. Correlation analysis was used to test the relations between seedling growth parameters and properties of prepared soil mixtures. These analyses were according to IBM SPSS Statistics 20.0 software.

RESULTS

Seed weight varied highly significantly among the five sources. Sheikh Zuweid seeds had the maximum weight (273.4 mg seed^{-1}) (Table 2). The germination behavior of *M. oleifera* indicated that the seeds had no dormancy and the germination was hypogeal. Germination percentage varied highly significantly from day 6 to 13 (F Value = 67.2***) as well as between studied sites. On the sixth day, seeds from all sites started to germinate, and the maximum daily percentage of germination occurred (Table 3).

Table 2: Means and Standard deviations (SD) of the weight of *Moringa oleifera* seeds collected from five sites in Egypt.

Seed weight (mg)	Seed source					F Value
	SZ	QA	SA	OR	AS	
Mean	273.4^{c}	139.4^{b}	134.5^{b}	106.3^{a}	111.6^{a}	123.7***
SD	0.1	0.0	0.1	0.0	0.1	

Note: SZ: Sheikh Zuweid Station, QA: Qanatir Horticulture Research Institute, SA: Ain Shams University - Faculty of Science Botanic Garden, OR: Orman Botanic Garden, AS: Aswan Botanic Garden.

Means with the same letters are not significantly different (P ≤ 0.05) as evaluated by One - Way ANOVA

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*****: Significant at P ≤ 0.001.**

Table 3: Mean (M) and standard deviation (SD) of daily germination percentage of *Moringa oleifera* seeds collected from five studied sites in Egypt.

Day	Seed source										Overall	
	SZ		QA		SA		OR		AS			
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
6	93.0	3.0	86.0	4.0	75.7	7.0	17.0	1.7	55.7	15.0	65.5^{c}	9.0
7	3.6	2.5	1.3	1.5	6.3	5.7	8.7	7.5	6.7	5.9	5.3^{b}	5.1
8	0.6	1.2	4.3	4.0	9.3	2.5	2.7	2.3	16.7	3.5	6.7^{b}	6.4
9	0.6	1.2	1.7	1.2	2.7	4.6	6.7	5.5	9.6	8.7		0.3
10	0.6	1.2	1.7	1.5	0.3	0.6	6.0	3.6	6.6	3.0	3.1^{ab}	3.4
11	0.0	0.0	1.3	2.3	0.0	0.0	2.0	1.0	1.0	1.0	0.9^{a}	1.3
12	0.0	0.0	1.3	1.5	0.0	0.0	1.3	0.6	0.7	0.6	0.7^{a}	0.9
13	0.0	0.0	0.0	0.0	0.3	0.6	1.0	1.7	0.0	0.0	0.3^{a}	0.8
Total (%)	98.7^{b}	1.5	97.7^{b}	0.6	95.7^{b}	4.0	45.3^{a}	4.2	97.0^{b}	4.4	86.9	21.7

Note: SZ: Sheikh Zuweid Station, QA: Qanatir Horticulture Research Institute, SA: Botanic Garden of Faculty of Science - Ain Shams University, OR: Orman Botanic Garden, AS: Aswan Botanic Garden.

Means with the same letters in the lowermost row and the highlighted column are not significantly different (P ≤ 0.05) as evaluated by One - Way ANOVA.

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Physico-chemical analyses of the five soil mixtures, used in this experiment, indicated that the type of soil mixture affected highly significantly on soil properties (Table 4). The seedling height was more significantly affected by the type of soil mixture than the no. of leaflets (Table 5). The increase rate of seedling height was rapid from week 1 to 3 then slowed down in the last week, while the increase rate of leaflets number was slow from week 1 to 2, then increased rapidly until the fourth week. By the end of 4th week, the values of seedling height varied significantly between soil mixtures; the maximum value was attained in sand soil (29.0 cm), while the minimum was in clay soil (22.3). Also, the minimum leaflet number was for seedlings grown in clay soil. Whereas, there were insignificant variations in leaflet number of those grown in sand, CSS, SC and SCC soil mixtures (Table 5). Also, the seed source affected significantly on the measurements of seedling height and leaflet number. The seedlings grown from Sheikh Zuweid seeds achieved the maximum height (28.4 cm) and leaflet number (40.3 leaflet seedling^{-1}) when compared with the seedlings grown from seeds of the other studied sites (Table 6).

Table 4: Mean (M) and Standard deviation (SD) of the physico-chemical properties of the five prepared soil mixtures used to study seedling growth.

Property		Soil mixture										F Value
		S		C		SC		SCC		CSS		
		M	SD	M	SD	M	SD	M	SD	M	SD	
Sand	(%)	90.5^{e}	0.2	30.3^{a}	2.0	58.8^{c}	3.1	45.2^{b}	2.1	69.3^{d}	0.3	17.2***
Silt		9.5^{a}	0.2	15.2^{b}	0.3	15.3^{b}	3.1	24.5^{c}	2.2	11.3^{a}	1.2	440.6***
Clay		0.0^{a}	0.0	55.0^{e}	1.5	25.8^{c}	1.2	30.3^{d}	0.3	19.2^{b}	1.2	114.6***
OM		0.4^{a}	0.2	7.6^{e}	0.9	4.2^{c}	0.2	5.5^{d}	0.1	3.1^{b}	0.1	1186.9***
pH		7.5^{a}	0.2	7.9^{ab}	0.1	8.1^{c}	0.0	8.0^{ab}	0.1	7.9^{b}	0.1	32.3***
EC (m S cm^{-1})		0.5^{a}	0.0	0.8^{e}	0.0	0.4^{c}	0.0	0.5^{d}	0.0	0.3^{b}	0.0	443.1***

Note: S: (1 sand: 0 clay), C: (1 clay: 0 sand), SC: (1 sand: 1 clay), SCC: (1 sand: 2 clay), CSS: (1 clay: 2 sand), OM: organic matter, EC: Electrical conductivity.

Means with the same letters in the same row are not significantly different (P ≤ 0.05) as evaluated by One - Way ANOVA.

*****: Significant at 0.001 probability level.**

Table 5: Mean (M) and standard deviation (SD) of growth variables of *Moringa oleifera* seedlings in five soil mixtures.

Week	Soil mixture										F Value
	S		C		SC		SCC		CSS		
	M	SD	M	SD	M	SD	M	SD	M	SD	
	Seedling height (cm)										
1	8.4^{b}	0.6	6.2^{a}	0.9	8.1^{b}	0.9	6.7^{a}	1.1	9.0^{c}	0.8	31.8***
2	17.0^{cd}	1.7	12.6^{a}	1.4	16.4^{c}	1.6	14.6^{b}	2.2	17.8^{e}	2.0	25.6***
3	25.0^{d}	1.2	18.3^{a}	1.7	24.1^{bc}	1.6	23.2^{b}	1.8	23.7^{b}	1.9	49.3***
4	29.0^{d}	1.9	22.3^{a}	2.0	27.2^{c}	1.8	26.6^{bc}	2.0	25.9^{b}	2.3	49.0***
	No. of leaflets (leaflet seedling^{-1})										
1	12.1^{a}	3.0	10.7^{a}	1.9	11.9^{a}	3.1	11.7^{a}	3.2	11.5^{a}	2.3	1.0^{ns}
2	14.1^{b}	4.3	11.7^{a}	2.5	12.7^{ab}	2.7	11.8^{a}	3.3	12.9^{ab}	4.1	2.6*
3	25.8^{a}	5.5	22.7^{a}	4.3	26.1^{a}	6.0	25.6^{a}	5.5	26.1^{a}	4.7	1.4^{ns}
4	32.5^{b}	5.4	29.7^{a}	2.6	32.9^{b}	4.5	32.9^{b}	7.1	32.6^{b}	5.8	3.7*

Note: S: (1 sand : 0 clay); C; (1 clay : 0 sand); SC: (1 sand : 1 clay); SCC: (1 sand : 2 clay); CSS; (1 clay : 2 sand).
Means with the same letters in the same row are not significantly different (P ≤ 0.05) as evaluated b Univariate ANOVA.

ns: Not significant
***: Significant at P ≤ 0.05.**
*****: Significant at P ≤ 0.001.**

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Table 6: Mean (M) and Standard deviation (SD) of weekly changes of growth variables of *Moringa oleifera* seedlings grown from seeds collected from different sources in five soil mixtures.

Week	Seed source										F Value
	SZ		QA		SA		OR		AS		
	M	SD	M	SD	M	SD	M	SD	M	SD	
	Seedling height (cm)										
1	8.3^{b}	1.2	7.8^{ab}	1.3	7.3^{a}	1.5	7.3^{a}	1.5	7.6^{a}	1.3	3.5^{*}
2	16.5^{c}	2.9	15.0^{ab}	2.4	16.1^{bc}	2.8	14.8^{a}	2.0	16.0^{abc}	2.7	3.2^{*}
3	28.2^{b}	2.4	22.6^{a}	3.2	22.9^{a}	3.6	22.6^{a}	2.1	22.0^{a}	2.8	4.9^{**}
4	28.4^{c}	2.6	26.3^{b}	2.8	25.6^{b}	3.3	26.2^{b}	2.1	24.4^{a}	2.7	17.5^{***}
	No. of leaflets (leaflet seedling^{-1})										
1	14.9^{c}	3.1	11.8^{b}	2.2	10.7^{ab}	2.1	10.0^{a}	1.1	10.5^{ab}	1.4	15.8^{***}
2	17.3^{b}	4.4	11.5^{a}	1.4	12.1^{a}	1.5	11.4^{a}	2.8	11.0^{a}	1.7	19.7^{***}
3	31.0^{b}	4.7	25.7^{a}	6.0	23.6^{a}	3.3	22.6^{a}	4.6	25.0^{a}	5.1	4.5^{**}
4	40.3^{b}	5.9	30.4^{a}	2.7	30.9^{a}	2.2	29.2^{a}	2.5	29.7^{a}	1.8	41.5^{***}

Note: SZ: Sheikh Zuweid Station, QA: Qanatir Horticulture Research Institute, SA: Ain Shams University - Faculty of Science Botanic Garden, OR: Orman Botanic Garden, AS: Aswan Botanic Garden.

Means with the same letters in the same row are not significantly different (P ≤ 0.05) as evaluated by Univariate ANOVA.

***: Significant at P ≤ 0.05.**
****: Significant at P ≤ 0.01.**
*****: Significant at P ≤ 0.001.**

The type of soil mixture affected highly significantly on the no. of root branches, significantly on the measurements of root length and non-significantly on seedling dry weight (Table 7). The seedlings grown in sand soil attained the maximum values of root length (8.0 cm), root branches (17.3 branch root^{-1}) and dry weight (0.16 g). On the other hand, seed source affected highly significantly on the previously mentioned three parameters (Table 8). The maximum values of root length (9.6 cm), no. of root branches (15.9 branch root^{-1}) and dry weight (0.20 g) were for the seedlings grown from Sheikh Zuweid seeds. The analysis of correlation between soil variables and seedling growth parameters indicated a significant positive correlation between the sand and all the growth parameters (Table 9).

Table 7: Mean (M) and standard deviation (SD) of growth variables of *Moringa oleifera* seedlings at the end of the experiment (fourth week) in five soil mixtures.

Growth variable	Soil mixture										F Value
	S		C		SC		SCC		CSS		
	M	SD	M	SD	M	SD	M	SD	M	SD	
	Root										
Length (cm)	0.8^{b}	2.8	6.2^{a}	1.4	7.6^{ab}	2.9	6.2^{a}	0.6	7.7^{b}	2.8	3.4^{*}
No. of branches	17.3^{b}	4.4	13.3^{a}	3.3	14.9^{a}	4.5	14.1^{a}	3.7	15.3^{ab}	5.3	3.9^{**}
	Seedling weight (g seedling^{-1})										
Dry	0.16^{b}	0.06	0.14^{a}	0.04	0.14^{ab}	0.03	0.14^{ab}	0.05	0.15^{ab}	0.04	2.0^{ns}

Note: S: (1 sand : 0 clay); C: (1 clay : 0 sand); SC: (1 sand : 1 clay); SCC: (1 sand : 2 clay); CSS: (1 clay : 2 sand).
Means with the same letters in the same row are not significantly different (P ≤ 0.05) as evaluated by Univariate ANOVA.

ns: Not significant.
***: Significant at P ≤ 0.05**
****: Significant at P ≤ 0.001.**

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Table 8: Mean (M) and Standard deviation (SD) of growth variables of *Moringa oleifera* seedlings grown from seeds collected from different sources in five soil mixtures at the end of the experiment.

Growth variable	Seed source										F Value
	SZ		QA		SA		OR		AS		
	M	SD	M	SD	M	SD	M	SD	M	SD	
	Root										
Length (cm)	9.6^{b}	3.7	6.7^{a}	1.2	7.1^{a}	1.3	6.1^{a}	1.4	6.1^{a}	1.3	9.6***
No. of branches	15.9^{b}	5.3	15.7^{b}	2.8	16.7^{b}	3.2	15.3^{b}	5.1	11.3^{a}	3.2	7.6***
	Seedling weight (g seedling^{-1})										
Dry	0.20^{c}	0.05	0.14^{b}	0.03	0.15^{b}	0.07	0.12^{a}	0.02	0.12^{a}	0.02	18.0***

Note: SZ: Sheikh Zuweid Station, QA: Qanatir Horticulture Research Institute, SA: Ain Shams University - Faculty of Science Botanic Garden, OR: Orman Botanic Garden, AS: Aswan Botanic Garden.

Means with the same letters in the same row are not significantly different (P ≤ 0.05) as evaluated by Univariate ANOVA.

*****: Significant at P ≤ 0.001.**

Table 9: Matrix of simple linear correlation coefficient between seedling growth parameters and soil properties.

	Variable	Seedling				
		Height	No. of Leaflets	Root Length	No. of root branches	Dry Weight
	pH	-0.34	-0.29	-0.35	-0.63*	-0.64**
Soil	Electrical conductivity (%)	-0.88**	-0.63*	-0.73**	-0.79**	-0.62*
	Organic matter (%)	-0.88**	-0.63*	-0.70**	-0.81**	-0.59*
	Clay (%)	-0.93**	-0.68**	-0.69**	-0.78**	-0.61*
	Silt (%)	-0.32	-0.22	-0.66**	-0.43	-0.54*
	Sand (%)	0.88**	0.63*	0.78**	0.78**	0.66**

***: P ≤ 0.05 and **: P ≤ 0.01**

DISCUSSION

Variation of seed weight between studied sites may be related to soil properties (nutrients and drainage) and cultivation practices. The average germination percentage of *M. oleifera* seeds in the present study (86.9%) was lower than that of 100% [13] and 99.5% [14], but were higher than 80% [15]. There is a difference between germination percentages of *M. oleifera* seeds from Egypt and other countries. This result was supported by the study of Kokou, et al. [16] which indicated that seed source (country) has a great effect on germination percentage of *M. oleifera* seeds.

Absence of dormancy in *M. oleifera* seeds may be due to their permeable seed coat which readily imbibes water [17]. The maximum germination percentage of Sheikh Zuweid seeds may be due to their highest weight, which agrees with the finding of Bezerra, et al. [18]. Germination beginning on 6th day, after sowing, is comparable with the results recorded by Kokou, et al. [16] and Ganatra, et al. [19], but later than the 3 days recorded by Medina, et al. [13]. This may be due to variation in germination conditions among these studies. The reaction of seeds after imbibition affects germination which occurs when the seed moisture contents equilibrated with the relative humidity (RH) in their surrounding environment. This case was interpreted by the search of Moravec, et al. [17] which studied the moisture equilibrium of *M. oleifera* seeds at different temperatures and humidity levels. The seed moisture contents equilibrated with the humidity in their respective chambers within the six-day of incubation period (RH = 97%). Imbibition may be controlled by seed coat permeability, and also by seed constituents [20]. *M. oleifera* seeds have high oil content which is estimated to range between 25 and 50% [21,22]. If much of the interior seed volume consists of hydrophobic

molecules (lipid contents), like *M. oleifera* seeds, there will be fewer hydrophilic surfaces to which water will easily bind [17].

The highest values of growth variables of the seedlings grown from Sheikh Zuweid seeds may be due to seed properties (e.g., seed weight); which had the maximum weight (273.4 mg seed^{-1}). This result agrees with the finding of Bezerra, et al. [18] which indicated that heavy seeds yielded more vigorous seedlings. Rapid increase rate of height may be due to having a deep root system, which makes better use of nutrients and available water in the soil [13]. The seedling height is an important feature because it is an index of the success of seedling establishment. Seedling that will grow rapidly could have ability to browsing [23]. After 4 weeks of growth, shoots were almost nearly 4 times longer on average than the root. The same pattern was observed for *M. peregrina* seedlings in Egypt [24] and other tree species growing in arid or semiarid areas, such as *Acacia senegal* in Sudan [25] and *Acacia tortilis* in Kenya [26]. The minimum leaflet number of seedlings grown in clay soil agrees with the study of Swiader, et al. [27] which indicated that the best soil for growing vegetables is one that is well-drained.

Root length is of critical importance during early growth stage, because a deeper primary root system provides access to more stable water source in short time than available shallow root system [28]. *M. oleifera* was reported to grow on nearly rocky soil [29,30], which can be explained by the ability of this plant to develop deep tuberous rootstock [31] which can access deep water supplies. The insignificant variation in dry weight of seedlings grown in the different soil mixtures indicated the suitability of all of these mixtures for growth of *M. oleifera* seedlings. This result agrees with the finding of Asante, et al. [32] which indicated that dry weight varied insignificantly at 4 weeks after germination for *M. oleifera* seedlings grown in three soil amendments (compost, poultry manure and rice husk). The rapid development of *M. oleifera* is a peculiarity of this species [7]. Toral [33] assessed the field establishment of 67 trees species and observed that *M. oleifera* exceeded the setting speed of the rest. The recorded results may be related to the favorable environmental conditions during the test, seed quality and the wide adaptability of this plant to many soil types. The behavior found in all measured variables indicates the feasibility of growing *M. oleifera* seedlings in the prepared soil mixtures (sand, clay, SC, SCC, CSS), which could be an excellent encouraging character of this tree.

CONCLUSIONS

This search indicated that *M. oleifera* seeds collected from most studied sites in Egypt had good germination percentage, provided good storage conditions, especially the seeds of Sheikh Zuweid. In addition, the seedlings can be easily grown in many soil types, especially the sandy soil. All these are considered attractive features which encourage the easy cultivation of *M. oleifera* crop in Egypt, especially in desert reclaimed lands.

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