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THE EARLY GROWTH OF *ABELMOSCHUS ESCULENTUS* L. (OKRA) USING ARID SANDY SOIL AMENDED WITH POWDERED DATE-PALM KARAB WASTE

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Abstract

There are major challenges that impede agriculture in various parts of Saudi Arabia, and these include low soil fertility, water scarcity, and a huge amount of date palm waste. One approach to overcoming the first two hurdles is the use of moisture-retaining soil amendments, and date palm waste can be used as the required material. These amendments aim at enhancing the poor water-holding capacity of sandy soils, while at the same time, utilizing the gigantic mass of annually produced Karab that becomes landfill, either directly or after cindering. Therefore, this study investigated the potential use of Karab obtained from two widely cultivated date palm cultivars, Khalas and Khunaizi, as a moisture-retaining soil amendment for the early growth of okra, and the results were successful.

Key words: Khunaizi (KZ), Khalas (KS), Karab date palm, sandy soil amendments, okra, Saudi Arabia

Introduction

Saudi Arabia (SA) is a major date producer in the world, generating 836,983 tons of dates annually (Pariona, 2017). However, beyond the fruit, this huge date palm (*Phoenix dactylifera*) tree production results in the generation of about 345 million tons of plant material per year, including more than 15,000 tons of date palm leaves and trunks (Hussain *et al.,* 2014; Ghori *et al.,* 2017). In addition to the biomass dilemma, sandy soils' low fertility and water scarcity constitute major challenges that hinder agriculture in various parts of SA (Kim and Beek, 2018; Waqas *et al.,* 2018). One approach to overcoming these hurdles is the use of moisture-retaining soil amendments and the cultivation of arid soil (sandy soil) that is favorable for increasing food production to meet the expected rise in global food demand, which is mainly anticipated due to population growth (El-Kader, 2010).

Soil amendments can be classified into organic such as biochar, compost, woody chips, and sawdust, peat moss (organic matter harvested from bogs) (Pandey *et al.,* 2016). And inorganic mainly used in commercial and horticulture practices as growth media such as vermiculite (heated mica, a common soil mineral, to 1,800 degrees Fahrenheit), perlite (volcanic minerals), peat moss, and superabsorbent polymers (SAP) (Ghehsareh *et al.,* 2011). SAPs synthetic polymers are widely used as enhancer for the soil water retention for dry land due to their excellent properties of retaining significant amounts of water through hydrogen bonding with water molecules and improve land WUE (Verma & Singh, 2018; Liao *et al.,* 2016; Yan & Shi, 2013). They are mainly made from synthetic polymers or natural (biodegradable) materials such as polysaccharides and clay minerals (Verma & Singh, 2018). Although they absorb water generally more than traditional absorbent amendments but they have disadvantages including their negative environmental effects and the gradual decrease in soil water content that increased in the early period of soil amended with artificial SAPs (Liao *et al.,* 2016).

Therefore, the replacement of artificial SAPs by alternatives including organic soil amendments such as natural polymer-based SAPs (i.e. polysaccharides and clay minerals), biochar, cocopeat (coconut husk), date-

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palm peat (crushed date palm wastes) become necessary (Pandey *et al.*, 2016; Ghehsareh *et al.*, 2011). These alternatives are sustainable, low cost, friendly biodegradable products having environmental and efficiency advantages over nonbiodegradable products. And many studies report their advantages on improving soil characteristics such as organic matter content, nutrient availability, CEC, and WHC (Verma & Singh, 2018; Parvathy *et al.*, 2014). Such amendments aim to enhance the poor water-holding capacity (WHC) of sandy soils, which is a critical physical parameter that determines the required amount and frequency of irrigation water for a given soil (Jun *et al.*, 2016). Currently, various moisture-retaining soil amendments are commercially available and widely used; yet, the quest for more sustainable, economical, efficient, and locally produced amendments continues **(**Ghehsareh *et al.*, 2011; Acharya and Kumar, 2018). A potential Saudi resource for producing such desired soil amendments is date palm trunk, termed “Karab” in Arabic. The gigantic mass of Karab produced annually is destined to become landfill, either directly or after cindering (AlHumid *et al.*, 2019).

No studies have been done on the utilization and characterization of a material derived from date palm trunks and utilized as soil amendment to improve sandy soil quality, mainly its WHC. Therefore, this study investigated the potential use of Khunaizi (KZ) and Khalas (KS) Karab for use as a moisture-retaining soil amendment. The potential efficiency was measured by comparing the early growth of okra (*Abelmoschus esculentus*) using powdered Karab mixed with sandy soil at different ratios for okra grown using neat sandy soil, neat powdered Karab, and neat multi-soil. Okra was selected for the current study because it is of economic significance as a vegetable crop in tropical and semi-tropical countries such as KSA, and Nigeria among many other countries. It is known to have high tolerance to heat and drought (Adigun *et al.*, 2018; Singh, 2018). And the early growth of okra was selected due to that germination stage (1) show mechanical resistance during this stage; (2) is good indicative of consequent seeds; (3) in addition to seedling development it is the developer steps for okra growth and development; (4) a reliable test to investigate the seedling quality using the developed DPT (Sarma & Gogoi, 2015; Khajeh-Hosseini *et al.*, 2009). The results revealed that Karab used as organic amendment offers a potential large-scale utilization for the waste. This use of Karab would conserve precious irrigation water, enhance crop yields, and abate an enormous amount of greenhouse gas emissions generated from landfill and incineration, which are widely used as agricultural waste treatments.

Materials and Methods

Experimental Details and Treatments

Experimental material: The experiment was performed in the Department of Biology, University of Putra, Serdang, Malaysia in August–November 2018. Date palm tree trunk waste of two major date palm (*Phoenix dactylifera* L.) cultivars, KZ and KS, was obtained from a farm in Dammam, a city located in the eastern region of SA Fig. 1. Medium-sized sandy soil samples (93.6% sand, 4.4% clay, 1.7% silt) were collected from Fodah, a village that is also located in the eastern region of SA. The village is classified by the Saudi Ministry of Agriculture as a barren land area. Furthermore, two controls were used in the current study-multipurpose growing soil produced by the Zaid Al-Hussain & Brothers Group (2014), with NPK (nitrogen, phosphorus, and potassium) values of 192-219-384, and sheep manure known as Growell organic sheep fertilizer (2017) by LKH Industries & Trading. Two seeds were sown at a depth of 2 cm per replication in a plastic pot (54cm × 51cm × 40cm) for each of the study treatments, and the treatment pots were punctured at the base to ensure proper aeration and drainage. Four mixtures of KZ and KS Karab and sandy soil were prepared, and the mixtures were amended with 10% w/w sheep manure throughout their growth periods.

Treatments: Sandy soil samples were collected at a depth of 0-20 cm using a specially fabricated auger of 20 cm in length. The collected samples were manually cleaned of stones and other plant or animal remnant debris. Further cleaning was performed by sieving the soil samples through a 2-mm sieve. Then, the samples were air dried and some chemical and physical properties were determined (Table 1). All the received KZ and KS Karab samples were washed with water to remove sand. Following this, the samples were air dried before proceeding with crushing according to the method by Wills and Napier (2005). They were initially crushed using a laboratory-scale Fritsch jaw crusher by Retsch, Germany (Fig. 2a) using four different opening seizes (10, 8, 6, 4, and 2), which produced small quantities of large, round particles along with huge amounts of long fibers. Since none of these products were sought, the samples underwent further crushing using a roll crusher by BBC Brown Boveri Incorporated., USA (Fig. 2b). This crusher consisted of two internally rotating rolls, with the gap between the rolls determining the particle size of the product. Still, the obtained particles were not as fine as desired, which was attributed to the high elasticity and moisture content of the particles. Therefore; the particles were dried in an oven for 8 hours at 70°C, after which the samples were further ground in a ball mill grinder by BICO, USA (Fig. 2c). The desired fineness was obtained, and the resulting KZ and KS Karab powdered samples used in this study had size distributions of 750 µm and 880 µm. Four mixtures (25, 50, 75 and 100) w/w % of Karab and sandy soil were prepared, and all the treatments were arranged in a randomized complete block design with three replications. These mixtures were used for the early growth of okra, and the growth was evaluated using the following growth parameters: plant height; leaf numbers at weeks 5, 6 and 7; root length; and leaf surface area.

Agricultural Water Use and Water holding capacity

The application of distilled water was done according to the pot capacity, as stated by Kirkham (2015), who found that the field capacity identified by Kurunç et al. (2010) is applicable only to field conditions where an underlying soil leads to water seeping deeply into the soil by capillarity as a result of surface tension. The pot capacity (PC) weight for each pot was calculated by the addition of water for a pot and covering the pot top to avoid evaporation. Water drainage took place until it was complete, and then the weight of the pot was considered the pot capacity. The amount of water application was estimated by calculating the difference between the pot capacity value and weight of the pot prior to each irrigation application. In the current study treatment, the pots were punctured at the base for ensuring the proper drainage and movement of water downwards. After the water was discharged and the soil was settled, the water holding capacity was measured, so water will not have evaporated, nor will evaporated water have affected the measurement. WHC which simply defined as the amount of water that a given soil can retain against gravity and can be used by plant use was used to compare the study treatments ability to remain (hold) water (Acharya et al., 2014). WHC is calculated based on the weight of the water held in the sample versus the dry weight of the sample using the following formula (Brischke & Wegener, 2019):

$$WHC = \frac{m_{soil,saturated} - m_{soil,0}}{m_{soil,0}} \times 100(\%)$$

where:

WHC = water holding capacity in %;

$m_{soil,saturated}$ = soil mass at saturation;

$W_{soil,0}$ = the dry soil mass in g.

Germination Test for Seed Evaluation

The germination and seedling stages, known as "the pioneer steps for crop growth, development and yield" (Sarma and Gogoi, 2015), were used as parameters for okra growth in all the study treatments. A period of germination (20 days) was set to allow the seeds to germinate. Seed germination was assessed using the germination percentage, defined as "the percentage of seeds that are alive from a seed population which produces a normal seedling" (Muhl *et al.*, 2011). On completion of the germination study, germination was calculated in the form of the germination percentage (GP) according to the following formula from Kandil *et al.*, (2012):

GP (%) = (Number of germinated seeds / Total number of seeds sown) × 100.

Evaluation of Agronomical Variables

Okra seeds are generally sown at depths of 5–6 cm. Collection of data started 4 days after sowing the okra seeds, and the number of leaves was counted and monitored for each plant during the study. Plant height (in cm) was monitored and assessed following Zaiton *et al.*, (2008) by measuring 1 cm above the soil level to the tip of the leaves using a meter rule. On completion of the experiment (2 months), the length of the roots per unit area and root density (number of roots per unit area) were measured. Root samples were taken, and their lengths were measured with a ruler after carefully removing soil and clumps from them. The leaf surface area (LSA) was calculated according to the following formula from Zaiton (2006): LSA = 0.70 (LW) – 1.06, where L is the leaf length and W is the leaf width.

Statistical Analysis

The data were analyzed using SPSS version 22, which was employed for performing one-way analysis of variance (ANOVA) and the standardized range of Duncan comparison tests at the level of 5% with a probability of $p \leq 0.05$.

Results

Water holding capacity and Germination Test for Seed Evaluation

The amendment of trunks to sandy soil for the four application rates (25, 50, 75, 100 % w/w) of each of KZ and KS had significant impact on the increase of the total amount of irrigated water used for about 20-30% per pot compared to control sandy soil samples and comparable to the commercial multi soil media (279 ml) (Tables 3 and 4). Seeds of all study treatments of KZ, KS, and multi soil germinate successfully accept those for sandy soil treatment fail to germinate. The highest germination percentages were 83% for trunk rates of 25% and 50% and 100% for the trunk rates of 75% and 100%.

Plant Height and Root Length

Okra was successfully grown using all the study treatments as growth media, including the four application rates each of KZ and KS and multi-soil, except the sandy soil treatment, which did not show any okra growth although it received 10% sheep manure as a source of organic fertilizer as the other treatments did. The plant height and root length for all the study treatments are presented in Table 4.

Leaf Number and Leaf Surface Area of Okra

The leaf number and LSA for all the study treatments are presented in Table 5.

Discussion

Water holding capacity (WHC) was measured for all soil treatments used for the early growth of *A. esculentus*. The four application rates each of KZ and

Fig. 1: Khunaizi (a) and Khalas (b) Karab collected from eastern region of Saudi Arabia; ground Khunaizi (c) and Khalas (d) obtained using a multistage mill.

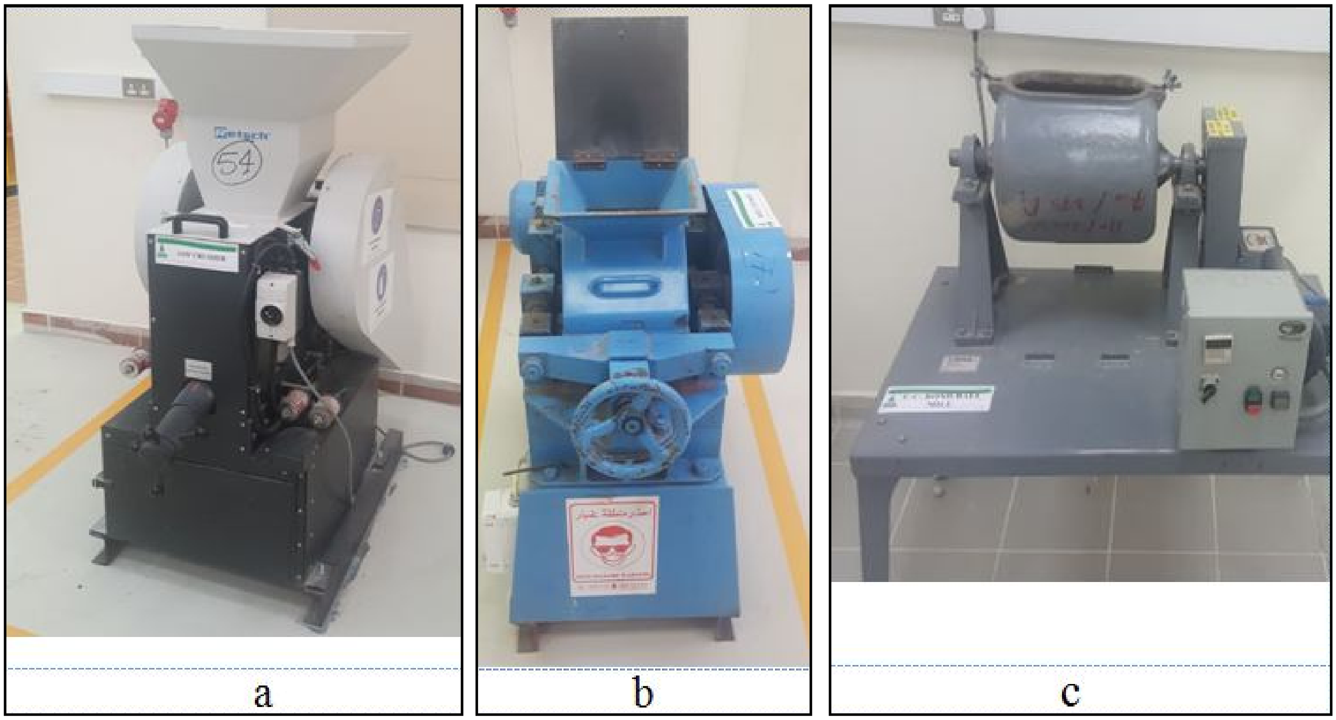

Fig. 2: Multistage mill used for grinding Khunaizi and Khalas Karab: (a) laboratory Fritsch primary jaw crusher, (b) laboratory secondary roll crusher, and (c) ball mill.

KS and multi-soil result on high WHC values and higher amount of irrigated water used compared to low WHC values (2.4-4.4%) for sandy soil samples with 45% of volume of irrigated water used (Table 3). This agreed with numerous other studies which reported the increase of the WHC of sandy soils due to the application of soil amendments such as biochar (Basso *et al.*, 2013; Khalifa and Yousef, 2015). The four application rates of each of KZ and KS, and multi-soil used as growth medium for the early growth of okra led to absolute increases of 3.6-10% on WHC compared to control sandy soil samples. This was higher than the percentage of WHC enhancement of 5.5% that was reported by Mangrich *et al.*, (2015) due to the application of 5% w/w of biochar from palm oil bunch applied to sandy soil. The volume of irrigated water was used by Khunaizi, Khalas DPT, sandy soil and multi soil is shown in Table 3. Although superabsorbent polymers (SAP) absorb water significantly more than KZ and KS amendments but they have disadvantages, they are non-biodegradable products causing serious and long-term environmental impact, having low water absorption capacity below the surface layer of sandy soil and under high electrolyte concentrations, and cause gradual decrease in soil water content that increased in the early period of soil amended with artificial SAPs (Liao *et al.*, 2016; Zhuang *et al.*, 2013). As an example of SAP disadvantages, a study conducted by Liao et al. (2016) finds that SAP added to soil although improve its water retaining capacity (2.7- 26.5 %) in the early days of the experiment, but soil water content gradually decreased in the

Table 1: Physical and chemical properties of the studied soil, Khunaizi, and Khalas DPT Before applying the treatments.

General chemical properties	Khunaizi DPT	Khalas DPT	Sandy soil
Texture (% w/w)	----	----	medium sized sand (3.6 clay, 2 silt, 94.4 sand)
Distribution size (µm)	880	750	----
Microbial count CFU/g			
Bacteria	$2.8x10^4 \pm 0.03^c$	$1.6x10^4 \pm 0.03^a$	$2.0x10^4 \pm 0.06^b$
Yeast	$6.1x10^3 \pm 0.1^b$	$1.8x10^3 \pm 0.^{a/b}$	10.0 ± 0.00^a
Mold	$18.7x10^2 \pm 0.7^b$	$4.6x10^2 \pm 0.2^a$	10.0 ± 0.00^a
CEC (cmol/kg)	18.85 ± 1.61^c	15.67 ± 0.87^b	2.00 ± 0.06^a
pH	5.6 ± 0.02^b	5.0 ± 0.02^a	$7+6.9 \pm 0^d$
Moisture (%)	7.48 ± 0.20^b	9.75 ± 0.01^c	0.37 ± 0.03^a
Proximate analysis (%)			
Volatiles	59.80 ± 0.57^b	58.63 ± 0.10^b	5.02 ± 0.27^a
Fixed carbon	17.82 ± 0.92^b	20.49 ± 0.09^c	0.97 ± 0.08^a
Ash	15.10 ± 0.03^b	11.02 ± 0.04^a	93.65 ± 0.33^c
Available NPK (%)			
N	$0.24 \pm .0.01^b$	$0.41 \pm .01^c$	0.01 ± 0^a
P	0.01 ± 0^a	0.02 ± 0^a	8.09 ± 0.02^c
K	0.51 ± 0.01^b	$0.79 \pm .03^c$	0.03±0d

Table 2: Water holding capacity of Khunaizi, Khalas DPT, sandy soil, and multi soil used for the early growth of *Abelmoschus esculentus*.

Treatment (w/w%)		WHC (%) Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
KZ	25	4.7±0.1[a/b]	5.7±0.1[a/b]	7.2±0.2[b/c]	8.9±1.1[a/b]	11.0±1[a/b]	8.4±1.0[x]	8.6±1.1[b/c/d]
KS	25	6.4±0.5[b/c/d]	5.5±0.0[a/b]	6.1±0.4[a/b]	9.0±0.3[a/b]	11.4±0.6[a/b]	6.4±0.3[a/b]	7.5±0.3[b/c]
KZ	50	7.4±1.2[b/c/d]	6.6±0.2[b]	8.3±0.5[b/c/d]	11.3±1.1[b/c]	15.4±0.6[b/c/d]	8.2±0.2[b/c]	8.9±0.7[b/c/d]
KS	50	6.1±0.6[b/c]	5.9±0.5[a/b]	8.0±0.4[b/c]	12.8±0.4[b/c]	16.8±1.3[c/d]	8.0±0.7[b/c]	6.5±0.1[a/b]
KZ	75	9.7±0.8[d]	6.9±0.5[b]	7.0±0.8[a/b/c]	9.4±2.6[a/b]	17.3±0.4[d]	8.8±0.5[b/c]	13.1±1.3[e]
KS	75	8.1±0.3[b/c/d]	6.0±0.5[b]	8.3±0.8[b/c/d]	12.4±0.8[b/c]	17.0±1.5[c/d]	8.0±0.5[b/c]	10.8±0.6[c/d/e]
KZ	100	9.9±0.9[d]	7.0±0.9[b]	8.9±0.4[c/d]	16.0±0.8[x]	17.7±1.9[d]	9.4±0.8[c]	12.1±1.4[d/e]
KS	100	8.4±1.1[c/d]	6.8±0.9[b]	8.0±0.8[b/c/d]	13.5±1.1[c]	11.7±0.6[a/b/c]	9.3±0.1[c]	9.4±0.9[b/c/d/e]
Multi soil	100	14.7±0.0[e]	6.9±0.1[b]	10.6±0.5[d]	16.0±1.4[c]	15.8±1.3[b/c/d]	8.3±0.3[b/c]	11.9±0.0[d/e]
Sandy soil	100	2.4±0.1[a]	3.6±0.1[a]	4.4±0.3[a]	4.8±0.7[a]	7.4±0.3[a]	4.4±0.3[a]	3.1±0.1[a]

Values are mean and SE of three replicates. Means in the same column for each treatment with different superscript letters indicating significant difference at $p<0.05$ according to DMRT.

Table 3: Total amount of irrigated water used by Khunaizi, Khalas DPT, sandy soil, and multi soil used for the early growth of *Abelmoschus esculentus.*

Treatment (w/w%)		Volume of irrigated water used(ml)	Percentage of irrigated water used(%)
KZ	25	300.3±7.4[c]	74.6±1.8[c]
KS	25	311.3±6.1[c/d]	77.3±1.5[c/d]
KZ	50	306.0±1.5[c/d]	76±0.4[c/d]
KS	50	319.3±2.0[d/e]	79.2±0.5[d/e]
KZ	75	329.0±3.1[e]	81.6±0.8[e]
KS	75	333.7±4.5[e]	82.8±1.1[e]
KZ	100	312.0±1.5[c/d]	77.4±0.4[c/d]
KS	100	284.3±4.3[b]	70.6±1.1[b]
Multi soil	100	279.0±10.0[b]	69.2±2.5[b]
Sandy soil	100	198.7±2.9[a]	49.3±0.7[a]

Values are mean and SE of three replicates. Means in the same column for each treatment with different superscript letters indicating significant difference at $p<0.05$ according to DMRT.

Table 4: Plant Height and Root Length of Okra Using All Study Treatments.

Treatment (w/w %)		Plant height (cm) Week 3	Week 5	Week 7	Root length
Khunaizi	25	5.1±1.2[a]	8.0±2.6[a]	10.2±2.2[b]	5.8±0.3[a]
	50	6.0±1.0[a]	9.7±0.9[a]	10.8±0.9[b]	7.3±0.2[abc]
	75	6.5±0.4[a]	8.8±0.5[a]	9.8±0.7[ab]	7.9±0.5[bcd]
	100	5.8±0.6[a]	8.4±1.2[a]	8.6±1.3[ab]	9.0±0.4[cd]
Khalas	25	4.9±1.1[a]	7.3±1.0[a]	8.3±0.9[ab]	9.3±0.3[cd]
	50	7.1±0.7[a]	9.5±1.0[a]	10.5±1.7[b]	9.5±0.4[d]
	75	5.8±0.5[a]	8.7±0.8[a]	9.5±0.9[ab]	8.0±0.6[bcd]
	100	4.8±0.8[a]	5.8±0.3[a]	5.8±0.3[a]	6.3±0.3[ab]
Multi soil	100	11.5±0.5[b]	14.7±0.7[b]	15±0.8[c]	7.7±0.7[abcd]

Values are the mean and SE of three replicates. Means in the same column for each treatment with different superscript letters are significantly different at $p > 0.05$ according to DMRT.

later period from 76.6% at 0 days to 1.2% at 120 days. The amendment of trunks to sandy soil for the four application rates (25, 50, 75, 100% w/w) of each of KZ and KS had significant impact on the increase of the total amount of irrigated water used for about 20-30% per pot compared to control sandy soil samples. And volume of irrigated water used by KZ and KS DPT at different application rates was 284-333 ml which were significantly higher than the sandy control (198.7 ml) that drain water quickly with less available water for plant use and comparable to the commercial multi soil media (279ml) (Table 3). This agreed with Ghehsareh *et al.*, (2011a, b) who found that coco peat, composted date-palm, and date palm peat have similar properties with the commercial perlite media and resulted in similar qualitative and quantitative indices in tomato fruit. The high WHC of KZ and KS may be explained by their natural fiber properties, elemental composition, and morphological structure. The main properties of the natural fibers of date palm trunk, as well as other palm plants like oil palm and coconut, are low density, less harshness, and high hydroxyl groups (OH) content, causing the high moisture absorption (hydrophilic character) (Mochane *et al.*, 2019). Their water absorption capability is due to the fibers' cellulose content (lignocellulosic fibers); their chemical composition also includes hemicellulose and lignin (Ghori *et al.*, 2017).

Significant growth rate of okra was achieved by using the four application rates of each of KZ and KS for some parameters (root length, seed germination and WHC). Whereas sandy soil treatment did not show any okra growth although it received as all other study treatments of 10% of sheep manure as source of organic fertilizer. And this agrees with other findings such as Basso *et al.,* (2013) who found that sandy soil amended with biochar improves the plant's available water and WHC and also agrees with Ouattara *et al.,* (2006) who reported that organic matter amendment enhanced FC and soil water content at wilting point. The significantly higher field capacity and AWC for KZ and KS indicate their ability of the enhancement of sandy soil WHC that is strongly related to their particle size that can hold water molecules more tightly than fine particles of coarse sand (diameters between 0.5 mm and 1 mm). Therefore, big sand particles lead to easier passage or transmission of water through the profile (Olorunfemi *et al.,* 2016). This concurs with earlier studies by G³¹b *et al.,* (2018) and Ismail and Ozawa (2007) who reported that the amendment of sandy soil with biomass material with high WHC such as compost and clay-rich subsoil results in enhancement of soil WHC.

The seed germination result showed evidence of strong positive linear correlations between the increase of the rates of both trunks and the germination percentage, with all the rates of KZ and KS resulting in high germination percentages. The plant height and root length results indicated that KZ and KS at the rates of 25, 50 and 75% w/w showed similar effects on okra height during the first month after planting. A month after planting, significant variation in plant height was observed; the rate of 100% w/w showed the lowest plant height, whereas 25% and 50 % of KZ and KS showed the highest. Okra root length is affected by soil pH, and most okra cultivars have an ideal pH level of between 6.0 and 6.8, at which the maximum nutrient uptake by roots occurs (Chittora and Singh, 2016). Therefore, the root results showed that they slightly increased with the increased KZ application rate with sandy soil due to the decreased pH value. However, this was not obviously seen with KS, which showed similar root length at all application rates except 100% w/w, at which it showed the shortest root length. Root density (number of roots per unit area) was found to be obviously higher for multi-soil compared with all the other study treatments, although the root length was comparable to the lengths of all the other study treatments, especially the rates of 50% and 75% of KZ. This may be explained by the high NPK contents of multi-soil (1.07, 0.06, 0.55%) compared with KZ (0.24, 0.01, 0.5%) and KS (0.41, 0.02, 0.79%), although all the study samples were amended with 10% sheep manure. Multi-soil treatment showed the highest LSA in weeks 3, 5, and 7 over all the other study treatments. However, there was no significant difference in the LSA between the different application rates of each of KZ and KS or in the number of leaves of okra between all the study treatments (*t*-test, $p = 0.05$). A significant difference may occur in the advanced stage of okra growth, and this finding shows that using Karab results in similar okra growth rates for some parameters compared with the positive control (multi-soil). However, the slow growth rate of okra that was observed during the early stages has also been reported by researchers like Adigun *et al*., (2018).

Table 5: Leaf Surface Area and Leaf Number of *Abelmoschus esculentus* Grown Using Developed DPT, Sand, and Multi-Soil and Amended with 10% Sheep Manure.

Treatment (w/w %)		Leaf Surface Area			Leaf Number		
		Week 3	Week 5	Week 7	Week 3	Week 5	Week 7
Khunaizi	25	1.8±1.8 [a]	3.9±2.9 [a]	6.9±1.2 [b]	1.3±1.3 [a]	3.3±0.3 [a]	4±0.6 [bc]
	50	1.9±1.0 [a]	4.1±0.5 [a]	5.3±0.5 [a]	4±0 [b]	4±0.6 [a]	3±0 [abc]
	75	3.0±0.4 [a]	3.6±0.7 [a]	5.3±0.3 [a]	3.3±0.3 [a/b]	4±0 [a]	3.7±0.3 [abc]
	100	4.0±0.7 [b]	6.0±1.0 [b]	6.7±1.1 [a]	4±0 [b]	3.7±0.6 [a]	2.7±0.6 [ab]
Khalas	25	3.0±0.9 [a]	4.0±0.8 [a]	5.5±0.9 [a]	3.7±0.9 [a/b]	2.7±0.6 [a]	2.7±0.9 [ab]
	50	2.7±0.5 [a]	3.5±0.7 [a]	4.1±0.5 [a]	3.3±0.7 [a/b]	3.7±0.9 [a]	3±0.6 [abc]
	75	2.3±0.5 [a]	4.0±0.3 [a]	5.4±0.4 [a]	4±0 [b]	4±0 [a]	4.7±0.3 [c]
	100	3.2±0.7 [a]	4.0±0.3 [a]	5.2±0.1 [a]	1.50±1.5 [a/b]	3±1 [a]	2±0 [a]
Multi-Soil	100	8.5±0.5 [b]	11.1±2.6 [b]	11±1.4 [b]	3.7±0.3 [a/b]	2.7±0.6 [a]	3±0.6 [abc]

Values are mean and standard error of three replicates. Means in the same column for each treatment with different superscript letters are significantly different at p>0.05 according to DMRT.

Conclusion

In conclusion, obtaining suitable size of KZ and KS DPT (around 880 µm) (semi powder form) during this study was difficult and different trials were carried out to achieve this for homogeny mixing them with sandy soil at four application rates (25, 50, 75, 100% w/w) to prepare four homogenous mixtures of each trunk. Finally, small laboratory scale multistage crushing was used. This study showed that sandy soil treatment did not show any okra growth and this agrees with other research findings indicating the unsuitability of sandy soil for plant growth and agricultural applications. Whereas KZ and KS Karab types were used successfully as moisture-retaining soil amendments for the early growth of okra due to their superior water retention capabilities. However, some of the growth parameters used to investigate the okra growth for all the study treatments were higher for multi-soil compared with Karab; this mainly related to the former's higher

NPK contents. Therefore, it is recommended to amend Karab with higher than 10% organic fertilizer. The use of Karab resulted in the following benefits: conserving valuable irrigation water, which may be an excellent solution for the limitation on water resources available for agriculture, especially in arid regions like SA; boosting crop yields; avoiding an enormous amount of greenhouse gas emissions generated from landfill and incineration, which are widely used as agricultural waste treatments; and utilizing the abundant date biomass for the production of renewable organic amendments for addressing sandy soil's low productivity.

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