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Studies on Cucumber Production Using Substrate Culture under North Sinai Conditions

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ABSTRACT

A wide range of soilless cultivation techniques have been developed and introduced for intensive cropping systems and for boosting the crop yield of many vegetables, mainly in greenhouses. Adoption of some local natural by-products to be utilized as a substrate growing medium to overcome soil-related problems appeared to be a promising project. Therefore, greenhouse experiments were conducted at the Baloza Experimental Station of the Desert Research Center (DRC), North Sinai Governorate, Egypt, during the two consecutive winter growing seasons of 2016–2017 and 2017–2018. These experiments aimed to investigate the effects of seven growing substrate culture treatments of separated or mixed sand obtained from sand dunes and date palm tree residues (Karenna) on plant vegetative growth, flowering, fruit yield and quality traits, and fruit nutritional values of cucumber plants (*Cucumis sativus* L.) Filial-1 hybrid 1101. Crop evapotranspiration reference (ETc) and water use efficiency (WUE), as well as treatment feasibility, were also studied. The experiment was set up in a complete randomized block design with three replicates. The obtained results strongly indicated that growing substrate media containing 25% sand (S) from sand dunes mixed with 75% grinded Karenna (Kg) of date palm (1 S + 3 Kg) significantly recorded the superiority of all studied characters of plant vegetative growth, number of flowers, fruit set, yield and its components, as well as fruit N, P and K contents, compared with other growing substrate medium treatments. On the contrary, the worst values of all studied parameters were achieved when sand was used alone (100% S) as a growing media. Furthermore, the highest water use efficiency and net income values were also attained by the 1 S + 3 Kg media treatment relative to the other growing substrate medium treatments.

Keywords: *Cucumis sativus* L., date palm tree residues, growing substrate medium, vegetative growth, yield and quality traits, WUE and Feasibility study.

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the most important vegetable crops grown under protected cultivation in Egypt. It is grown for local consumption as well as exportation. Successful cucumber cultivation requires sterilization of the soil to protect growing plants from soil-borne pathogens. Several fungi, such as *Fusarium oxysporum*, *Rhizoctonia solani*, *Pythium ultimum, Phytophthora* sp. and *Botrytis* sp., cause plant wilt, root rot and damping-off diseases which may result in changes in the plant transpiration rate and cellular water potential status within the plants that lead to plant wilt (Wang et al., 2012) and also occur a plant growth inhibition and a significant plant yield quantity and quality reduction. They are recognized as unlimited survival pathogens in the soil, making them one of the most difficult agents to control (El-Mohamedy et al., 2017; Aljawasim et al., 2020). In addition to fungus diseases, nematode parasites cause root-knot disease, which is one of the limiting factors for cucumber production under protected cultivation, particularly during spring and summer cultivation. Controlling disease management is very expensive and causes negative impacts on the environment as well as human health. Cucumber plants were also unable to grow and reproduce well in infertile, salt-affected, poorly structured, or polluted soils, particularly in the newly reclaimed desert areas. As a result, it is necessary to provide or develop an alternative promising, cost-effective, easily applied, safe and eco-friendly agronomic practice to boost sustainable agricultural production of vegetable crops in disease and nematode epidemic areas, poor soil quality and on-house roof cultivation, as well as ensuring consumer health and maximizing producer return profit.

The protected cultivation of cucumber in different soilless culture systems (substrate culture or hydroponic) under optimal operating microclimate conditions has become a promising alternative for sustainable production as a result of shifting climate change scenarios as well as soil-related problems (Singh et al., 2018). In addition, soilless culture techniques, as intensive cropping systems, lead to not only maximizing crop yield per square meter of land but also per cubic meter of water, thus increasing water use efficiency under the water scarcity crisis (Singer et al., 2015). Soilless culture is a technique for growing a crop without soil in nutrient solutions or in growing substrate media where plant roots can grow and absorb water and nutrients (Wilson et al., 2001; Savvas et al., 2013). A good growing substrate media should offer adequate support to the plant, serve as a reservoir for water and nutrients, permit oxygen diffusion to the roots and also allow gaseous exchange between the roots and the outside atmosphere (Abad et al., 2002). There is a better relationship between growth substrate media of organic origin and the susceptibility to pests and disease than conventional soil mixes (Akanbi et al., 2002).

Agricultural residues or the by-products generated through productive of farming system, are a good source of income when managed properly. There are approximately an estimated amount of over 1.16 million tons of residues that are discarded annually produced from almost 15.0 million date palm trees (Economic Affairs Sector, Ministry of Agriculture and Land Reclamation, 2021). Date palm tree residue most commonly generated includes leaves, fronds, spadix stems, and stem barks. They are obtained seasonally by the pruning of date palm trees which is an essentially agricultural practice and discarded with no value. Therefore, from economical and environmental points of view, the utilization of date palm residues is a promising project (Almi et al., 2015). Date palm tree residues are used in a variety of profitable industries (Al-Oqla et al., 2014). On the other hand, in some remote areas that are far from industry sites or when they are grown in small quantities, they become an obstacle because they may cause pollution and create a fertile ecological environment for the spread of insects and may represent a major environmental problem that hinders agricultural development when they are not disposed of in a safe manner (FAO, 2017). Recycling date palm tree residues in soilless culture as a good growing substrate component is a type of safe disposal and utilization. In this respect, date palm residues are rich in lignin (32%), as reported by Mirmehdi et al. (2014), making them hard against microbial decomposition, which guarantees considerable stability and a long life span when used as a growing substrate media (Basirat, 2011; Dhen et al., 2018). However, it may need to solve the problem of the air-water ratio relationship when used as a component of a growing substrate by being mixed with fine materials (Rahman et al., 2017).

According to a comparative study conducted by Rostami Zeinab et al. (2014) date palm growing media with 0–5 mm particular size had the highest growth and yield of strawberry, which was not significantly different from traditional growing media of coco peat-perlite cultivation substrate. In addition, they found that the date palm growing media increased water availability for the strawberry plants. The date palm growing media has a higher water-holding capability than coconut-fiber media. Aydi et al. (2023) reported that date-palm waste-based media positively enhanced the growth, fruit yield and quality of greenhouse melons relative to soil-based culture. They also added that date palm waste-based media could be a cheaper alternative compared to coconut fiber medium used in soilless cultivation systems. Furthermore, Heidari et al. (2021) found that 20% perlite + 80% grinded palm trunk resulted in the highest values of plant height, number of leaves/plant, leaf surface area and bulb depletion rate (%) of lily plants when compared to other growing substrate medium containing low levels of grinded palm trunk and high levels of perlite or coco peat. Dhen et al. (2018) reported that date palm waste peat is an appropriate growing substrate media for nursery production, with physical and chemical properties comparable to commercial peat and that the best substitution percentage for better seedling growth ranged from 25 to 50%.

The present study aimed to obtain a safe and economic growing substrate mixture from local agricultural residues that protect plants from adverse soil conditions, whether they are pathogenic, harsh conditions, or of an unsuitable chemical composition. Also, it enhances the plant growth and production and preserves irrigation water and nutrients as well. Thus, the effect of using separated or mixed sand obtained from sand dunes and/or date palm tree residues (grinded Karenna) as a growing substrate medium on vegetative growth, flowering, fruit yield and quality as well as chemical composition of cucumber plants Filial-1 hybrid 1101 was investigated under North Sinai conditions. Crop evapotranspiration reference (ETc), water use efficiency (WUE), and treatment feasibility were also studied.

MATERIALS AND METHODS

Two experiments were conducted under greenhouse conditions at the Baloza Experimental Station, Desert Research Center (DRC), North Sinai Governorate, Egypt (Latitude 31º 01′ 42.07″N; Longitude 32º 35′ 27.89″E) to study the production of cucumber plants using substrate culture technique and closed trickle irrigation systems during two successive winter growing seasons of 2016–2017 and 2017–2018. Aiming to investigate the effect of separated or mixed sand obtained from sand dunes and/or date palm tree residues (grinded Karenna) as a growing substrate medium on vegetative growth parameters, flowering, fruit yield and quality traits as well as the chemical compositions of cucumber plants (*Cucumis sativus* L.) Filial-1 hybrid 1101. Also, hydrological (ETc and WUE) and economic feasibility studies were performed.

Experimental treatments

The experiment consisted of seven growing substrate medium treatments, as follows:

1. Sand alone media, 100% sand of sand dunes (S).
2. Karenna raw (Ka) without grinding alone media, 100% Ka.
3. 1 (S) + 1 (Karenna grinding, Kg) media (v : v).
4. 1 (S) + 2 (Kg) media.
5. 1 (S) + 3 (Kg) media.
6. 2 (S) + 1 (Kg) media.
7. 3 (S) + 1 (Kg) media.

Karenna was prepared through the maceration of date palm tree residues and then divided by a special machine to be like hair in shape with a particular size of 0.5 : 1 mm and a length around 20–30 cm, with a bulk density of 0.58 g/cm^3 and a water holding capacity (WHC) of 211% (Atiyeh et al., 2001; Raviv and Lieth, 2008). Finally, a portion of the prepared Karenna was grinded into small pieces of 0.5 : 1 cm in length to be used as a growing substrate media component.

The sand used in this study to prepare the growing substrate medium was obtained from sand dunes near the study area, its texture parameters were 0.2–0.4 mm diameter, 2.65 g/cm^3 specific density, 0.16 m^3 m^{-3} field capacity, 0.052 m^3 m^{-3} permanent wilting point and 0.069 m^3 m^{-3} available water capacity estimated according to the method mentioned by Saxton and Rawls (2006).

Nutrient solution and irrigation

A black polyethylene film of 1 mm thickness was used to make a cylindrical bag with 0.3 m diameter and 17.5 m length with a volume of 1.24 m^3 and filled with the suggested seven growing substrate medium. Each bag had a small slot in the end of one side for drainage of nutrient solution with a slope of 1% toward the drainage point (catchment tank).

A submersible pump (0.4 HP and 40 W) was used to pump the nutrient solution through the polyethylene pipe (16 mm) to the black polyethylene cylindrical bags. The nutrient solution was adjusted to be pumped into the black polyethylene cylindrical bags for 5 minutes twice a day using a digital timer. Then the pumping time and pumping numbers were gradually increased over time, according to the cucumber's phenological stage, until they reached 15 minutes for three times a day at the end of the experiment. The drainage nutrient solution was returned to a 200 liter plastic tank (reservoir) by gravity and re-pumped through the irrigation system into cylinder bags again. The nutrient solution was prepared as described by El-Behairy (1994). The electrical conductivity (EC) and the pH of the nutrient solution were maintained within a range of 2–2.5 dS/m and 5.5–6.5, respectively, during the whole period of the experiment. The volume of nutrient solution was adjusted twice a week by adding a measured amount of irrigation water up to the labeled mark in the nutrient tank (150 liters) of each treatment.

Chemical analyses of irrigation water and chemical properties of the growing substrate

Table 1. Analyses of chemical properties of irrigation water and different growing substrate medium used (average of both seasons)

Media	pH	EC dS m^{-2}	Bulk density g/cm^3	WHC %	Saturation soluble extract							
					Soluble anions [mmol L^{-1}]				Soluble cations [mmol L^{-1}]			
					SO_4^{--}	Cl^-	HCO_3^-	CO_3^{--}	K^+	Na^+	Mg^{++}	Ca^{++}
Irrigation water	8.01	2.65	0.00	0.00	5.00	14.75	5.90	0.00	0.44	13.50	3.60	8.05
Sand	8.11	5.45	2.65	16	1.40	0.62	0.88	0.00	0.20	0.61	1.02	1.31
Karenna	5.93	3.35	0.24	217	12.02	15.77	3.01	0.00	9.80	3.24	12.87	8.01
1 S + 1 Kg	7.02	4.46	1.48	138	7.09	7.65	2.21	0.00	5.11	1.89	7.86	5.11
1 S + 2 Kg	6.85	4.27	1.12	181	8.98	9.08	2.68	0.00	6.64	2.65	9.73	6.38
1 S + 3 Kg	6.44	4.08	0.69	201	10.31	10.97	2.91	0.00	7.58	3.02	10.44	7.18
2 S + 1 Kg	7.21	4.92	2.06	78	6.02	6.48	1.84	0.00	3.89	1.34	5.08	3.24
3 S + 1 Kg	7.68	5.11	2.21	51	4.58	5.14	1.35	0.00	2.64	0.98	4.00	2.81

medium were estimated according to the methods described by Jackson (1962) and Richards (1954), respectively, as shown in Table 1.

Experimental design

A double-span plastic greenhouse of 17.4 m wide, 60 m long and 3.5 m height was used. The experiment consisted of twenty one pairs of bags, each pair of bags was placed side by side to represent a treatment and was randomly arranged with a 1 m interval among experimental treatments. The experiment treatments were arranged in a randomized complete block design (RCBD), with three replicates. Cucumber seedlings were transplanted at the two true-leaf stage into bags with 50 cm distance between holes on November 1st in both experimental seasons of 2016–2017 and 2017–2018. During the growing season, the cucumber plants were irrigated with a limited and calculated amount of water based on crop reference evapotranspiration (ETc).

Data recorded

Vegetative growth characteristics

After 45 and 75 days from transplanting date, six cucumber plants from each experimental treatment were randomly taken for vegetative plant growth measurements: number of leaves per plant, leaf area (cm^2) was determined using a leaf area meter, using the fifth leaf from the top of plant (fully expanded leaf), fresh and dry weight of shoot per plant (g) and dry matter (%) were estimated according to AOAC (1990). Also, the absolute growth rate (AGR) was calculated using the following formula:

$$AGR\ (\text{g/day}) = \frac{W_2 - W_1}{T_2 - T_1} \quad (1)$$

where: W_1 – plant dry weight in the first sample;
W_2 – plant dry weight in the second sample;
T_1 – first sample time;
T_2 – second sample time.

Flowering

Five cucumber plants in each experimental treatment were randomly selected and labeled to record the number of elapsed days from the transplanting date to the appearance of the first flower (flowering period) and also count the number of total flowers per plant to calculate the fruit setting ratio.

Fruit yield and its components

At a horticultural maturity stage when the cucumber fruit was about 15 cm long, the average fruit number per plant and average fresh and dry fruit weight were determined, TSS (%) was also measured using a hand-held refractometer, Atago-No. 1 (AOAC, 1990), and the average total fruit yield per plant and per plot were calculated. Moreover, marketable and un-marketable fruit yield in addition to net income were assessed.

Chemical parameters

In the upper fifth leaf, chlorophyll reading was measured using the Minolta SPAD reading-502 leaf chlorophyll meter. Fruit mineral contents were determined using the wet ash procedure for the dry powdered of fruit samples according to Johnson and Ulrich (1959). Total nitrogen, phosphorus and potassium were determined according to the methods of Peach and Tracey (1955), Frie et al. (1964) and Brown and Lilliland (1964) using Kieldahl method, spectrophotometer method and flame photometer method for N, P and K, respectively.

Reference evapotranspiration of crop (ETc)

Daily irrigation water quantities were carried out with a specific amount of water during plant life. The Hargreaves model (Hargreaves et al., 1985) was used for calculating reference evapotranspiration (ETo) inside a greenhouse which was given by the following equation:

$$ET_o = \frac{1}{\lambda}(0.0023)(T_{mean} + 17.8) \cdot \cdot (T_{max} - T_{min})^{0.5} R_a \tag{2}$$

where: ET_o – reference evapotranspiration (mm day^{-1});
λ – latent heat of vaporization (MJ kg^{-1});
R_a – extra-terrestrial solar radiation (MJ m^{-2} day^{-1});
T_{max} – maximum daily air temperature (°C);
T_{min} – minimum daily air temperature (°C);
T_{mean} – mean daily air temperature (°C).

The input energy required to change the state from liquid to vapor at a constant temperature is called the latent heat of vaporization. The latent heat of vaporization (λ) of water is 2256 KJ kg^{-1}. Extraterrestrial solar radiation (R_a) was calculated according to Duffie and Beckman (1993), and converted from W m^{-2} to MJ m^{-2} day^{-1}.

The plant growth cycle is divided into three phenological stages, the first stage is the initial stage which was started from transplanting to 35 days later. The second stage was the mid-season stage, started 35 to 50 days after transplanting, while the third stage was the end-season stage, took 40 days after the end of the second stage. Reference evapotranspiration (ETo) data inside greenhouse and crop coefficients (Kc) during different growth stages, were used to calculate reference evapotranspiration of crop (ETc) based on crop coefficients of 0.5, 1.0 and 0.6 for first, second and third growth stages, respectively, as described in FAO (1998). The metrological data (monthly average) for the experimental site outside and inside the greenhouse during the experiment period in both seasons were obtained from the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC) and presented in Table 2. The experimental area has a Mediterranean climate, with a hot, dry summer and a relatively cool winter.

Water use efficiency (WUE)

It is an indicator for the efficiency of the crop yield (main and secondary crop yield) attributed to the amount of consumed water:

$$WUE = \frac{P}{V} \tag{3}$$

where: P – productivity of crop yield (kg plot^{-1});
V – amount of water consumed (m^3) during growth season.

Statistical analysis

The data of the two experimental seasons of 2016–2017 and 2017–2018 were collected,

Table 2. Meteorological data of the experimental site outside and inside the greenhouse during both seasons of 2016–2017 and 2017–2018

Season	Year	Month	Maximum temp °C		Minimum temp °C		Mean temp °C		ETo mm/day
			Out	In	Out	In	Out	In	Out
1st Season	2016	November	29.0	33.6	14.2	16.6	21.6	25.1	1.90
		December	24.1	29.1	10.1	15.3	17.1	22.2	1.32
	2017	January	20.4	25.9	8.2	10.9	14.3	18.4	1.27
		February	17.5	23.2	11.9	14.8	14.7	19.0	1.64
		March	22.8	28.3	12.2	18.5	17.5	23.4	2.45
2nd Season		November	27.6	33.1	15.4	20.3	21.5	26.7	1.85
		December	20.5	26.3	10.1	14.7	15.3	20.5	1.25
	2018	January	18.2	23.5	9.4	13.9	13.8	18.7	1.34
		February	21.9	27.2	10.7	16.8	16.3	22.0	1.86
		March	22.6	28.6	13.2	18.2	17.9	23.4	2.54

tabulated and evaluated for normality and homogeneity within and between replications and years, and were considered random effects in the mathematical model, then subjected to a combined analysis of the variance as described by McIntosh (1983). The statistical analysis of variance of the data was carried out using Two-way ANOVA of the Microcomputer Statistical Package (MSTAT-C software) Program for the Design, Management, and Analysis of Agronomic Research Experiments (Russell, 1991). Duncan's multiple range test (DMRT) was employed to compare the significant differences among means at $P \leq 0.05$ level of probability according to the procedures reported by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Vegetative growth parameters

Combined data presented in Tables 3 and 4 showed that all growing substrate medium treatments had a significant positive effect on all measured parameters of vegetative growth including; number of leaves per plant, plant fresh and dry weight, dry matter percentage and the average leaf area at both sampling dates, 45 and 75 days after transplanting date, as well as absolute growth rate and leaf chlorophyll content (SPAD readings) compared to growing substrate media of sand (S) and Karenna (Ka) alone. It is obvious that the values of all vegetative growth parameters were gradually increased as the percentage component of date palm grinded Karenna (Kg) in the growing medium increased. Data also showed that the media treatment with a low level of sand (S) mixed with a high level of grinded Karenna (Kg) of date palm (1 S + 3 Kg) led to recording the highest values of all vegetative growth parameters when compared with other growing medium treatments, while the lowest values were achieved when sand (S) was used alone as a growing media. The obtained results were in conformity with the findings of Grimstand (1990); Koodzeij and Kostecka (1994); Asano (1994) on cucumber. Also, Ghehsareh et al. (2012) reported that the higher yield biomass, plant height, root weight and leaf area index (LAI) of cucumber plants were achieved when date palm wastes were used as a growing substrate media compared to the conventional soil system. In addition, results also agreed with those reported by Kumari et al. (2018) who stated that media composed of garden soil + vermicompost + coco peat resulted in the highest values of cucumber vegetative growth parameters compared with media containing only garden soil.

The superiority of vegetative growth parameters of cucumber plants grown in (1 S + 3 kg) media could be attributed to the media's ability to conserve irrigation water and nutrient solution, which in turn reflected on the availability of nutrients in the root zone, resulting in increased cell size, cell elongation, cell division, more healthy and vigorous plants, and more metabolite accumulation as a result of increased nutrient uptake and photosynthesis capacity (Heidari et al., 2021). Furthermore, such growing media provide a balanced air-water ratio, which positively improves the growth of plants (Rahman et al., 2017).

Table 3. The effect of sand and/or date palm Karenna as growing substrate medium on vegetative growth parameters of cucumber plants at two sampling dates after 45 and 75 days from transplanting date (combined analysis of both seasons)

Parameters treatments	No. of leaves/plant		Plant fresh weight (g)		Plant dry weight (g)		Dry matter(%)	
	1st sample*	2nd sample*	1st sample	2nd sample	1st sample	2nd sample	1st sample	2nd sample
Sand (*S*)	24.4 bc	36.7 b	398.0 g	599.0 d	52.6 g	73.8 g	13.2 bc	12.3 e
Karenna (*Ka*)	24.2 c	37.5 b	425.7 f	658.7 c	56.1 f	86.3 f	13.2 bc	13.1 c
1 S +1 Kg	26.5 a	42.6 a	471.1 c	757.1 ba	62.7 c	100.8 c	13.3 b	13.3 b
1 S + 2 Kg	27.0 a	42.7 a	493.4 b	780.4 a	65.8 b	102.4 b	13.3 b	13.1 c
1 S + 3 Kg	27.3 a	42.9 a	501.3 a	789.0 a	69.4 a	110.4 a	13.8 a	14.0 a
2 S + 1 Kg	26.4 ab	41.8 a	461.2 d	729.2 b	59.8 d	91.2 d	13.0 cd	12.5 d
3 S + 1 Kg	26.1 abc	41.3 a	444.1 e	703.1 b	57.2 e	87.2 e	12.9 d	12.4 de

Note: S – sand, Ka – Karenna without grinding, Kg – Grinding Karenna, S* – sample, 1st after 45 and 2nd after 75 days from transplanting date. Means followed by the same letter in the same column are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

Flowering

Concerning the effects of different growing medium treatments on the first flower appearance, number of flowers/plant and the percentage of fruit set, combined data in Table 4 showed that increasing the grinding date palm residues (Kg) level in the growing media up to 75% significantly increased the number of flowers per plant consequently fruit set percentage compared with sand media alone (S). On the other hand, the higher level of sand (3 S) mixed with a lower level of grinded Karenna (1 Kg) of date palm (3 S + 1 Kg), Karenna alone (Ka) or sand alone (S) in the growing medium decreased the aforementioned parameters. Regarding the number of elapsed days to the appearance of first cucumber flower, it was 5.6 days earlier with the treatment of sand alone media (S) than the treatment of sand plus Karenna (1 S + 3 Kg) which was the last treatment to produce flowers (the highest number of elapsed days to the appearance of the first flower). The obtained results matched those mentioned by Kumari et al. (2018) on cucumber. The used sand, which is composed of sand dunes, often does not have organic matter or any substances able to absorb nutrients or hold irrigation water. Plants grown in such soil or under other stressful conditions usually try to conserve their species by speeding up their metabolic processes to complete their life cycle in a short time (Soubeih et al., 2018).

Fruit yield and its components

Data presented in Table 5 showed the mean values of the combined analysis of the studied fruit yield and its component parameters, i.e., number of fruits per plant, average of fruit fresh and dry weight, average of fruit yield per plant and per plot, total soluble solids (TSS) in addition to marketable and un-marketable fruit yield. It is evident that different growing substrate medium treatments significantly affected all studied fruit yield parameters. Cucumber plants grown in a growing substrate media containing 25% sand mixed with 75% date palm grinded Karenna (1 S + 3 Kg) significantly recorded the highest values of all studied parameters of fruit yield as well as the lowest values of un-marketable fruit yield. In contrast, cucumber plants grown in growing media containing 100% sand (S) or 100% Karenna (Ka) alone produced the highest un-marketable fruit yield compared to those cucumber plants grown in other growing medium treatments. The percentage of increments were found to be 49.5, 18.9, 9.2 and 9.5% for the number of fruits per plant, fruit fresh weight, fruit dry weight and total soluble solids, respectively, when cucumber plants grown in media containing 25% sand mixed with 75% date palm grinding Karenna (1 S + 3 Kg) compared with sand alone media (S). In the same regard, the increments expressed as percentages were found to be 77.42, 77.3, 125.81 and 20.01% for fruit yield per plant, per plot, marketable fruit yield per plot and marketable fruit yield of total fruit yield, respectively, with growing media containing a lower sand level mixed with a higher date palm grinding Karenna level (1 S + 3 Kg) treatment relative to growing media containing 100% sand (S).

The obtained results are in good accordance with Ghehsareh et al. (2012) who reported that TSS and fruit yield of cucumber plants were significantly increased when date-palm wastes were

Table 4. The effect of sand and/or date palm Karenna as growing substrate medium on vegetative growth, leaf chlorophyll reading and flowering parameters of cucumber plants (combined analysis of both seasons)

Parameters treatments	Leaf area (cm^2)		AGR (g/day)	Chlorophyll reading (SPAD)	First flower appearance (day)	No. flowers/ plant	Fruit setting (%)
	1st Sample*	2nd Sample*					
Sand (S)	112.5 e	135.1 e	0.71 f	42.9 e	28.3 d	34.9 d	30.7 c
Karenna (Ka)	115.6 d	142.9 d	1.00 e	43.5 de	31.2 cb	36.2 c	31.1 c
1 S +1 Kg	128.5 c	179.6 b	1.27 b	45.9 c	31.9 b	37.2 bc	32.1 bc
1 S + 2 Kg	131.0 b	182.1 b	1.22 c	47.9 b	33.0 a	38.0 ab	34.8 b
1 S + 3 Kg	134.2 a	189.3 a	1.37 a	49.5 a	33.9 a	38.6 a	41.4 a
2 S + 1 Kg	127.1 c	172.0 c	1.05 d	44.8 cd	31.1 cb	36.5 c	32.9 bc
3 S + 1 Kg	127.2 c	170.4 c	1.00 e	44.2 de	30.4 c	36.5 c	31.7 cb

Note: S – sand, Ka – Karenna without grinding, Kg – grinding Karenna, S* – sample, 1st after 45 and 2nd after 75 days from transplanting date. Means followed by the same letter in the same column are not significantly different at P≤0.05 according to Duncan's multiple range test.

Table 5. The effect of sand and/or date palm Karenna as growing substrate medium on cucumber fruit yield and its components as well as marketable and un-marketable fruit yield (combined analysis of both seasons)

Parameters treatments	No. of fruits/ plant	Average of fruit weight (g)		Average of fruit yield (kg)		TSS (%)	Marketable fruit yield		Un-marketable fruit yield		
		Fresh	Dry	Plant	Plot		Plot (kg)	% of total fruit yield	No. of fruit/ plant	Weight of fruit/plant (g)	Weight of fruit/plot (kg)
Sand (S)	10.7 d	87.0 f	8.7 g	0.93 e	65.2 e	4.93 c	48.20 e	74.1 d	1.66 a	144.7 a	16.96 a
Karenna (Ka)	11.3 cd	88.1 f	9.0 f	0.99 de	69.5 de	5.20 ab	55.57 de	79.78 cd	1.50 ab	131.9 a	13.93 b
1 S +1 Kg	11.9 c	94.2 c	9.8 c	1.13 c	78.7 c	5.29 ab	65.98 c	83.72 bc	1.37 ab	129.3 a	12.73 b
1 S + 2 Kg	13.2 b	98.7 b	10.5 b	1.31 b	91.2 b	5.37 a	81.29 b	89.11 ab	1.19 bc	117.8 ab	9.92 c
1 S + 3 Kg	16.0 a	103.4 a	11.2 a	1.65 a	115.6 a	5.40 a	108.84 a	94.13 a	0.97 c	100.2 b	6.79 d
2 S + 1 Kg	12.0 c	92.6 d	9.5 d	1.11 c	77.8 c	5.24 ab	64.22 cd	82.58 bc	1.44 ab	133.6 a	13.55 b
3 S + 1 Kg	11.6 cd	90.9 e	9.3 e	1.05 cd	73.9 cd	5.13 b	60.08 cd	81.49 bcd	1.46 ab	133.1 a	13.77 b

Note: S – sand, Ka – Karenna without grinding, Kg – grinding Karenna. Means followed by the same letter in the same column are not significantly different at P≤0.05 according to Duncan's multiple range test.

used as growing media compared to the conventional soil system. The same trend was obtained by Dhen et al. (2018); Soubeih et al. (2018); Heidari et al. (2021); Aydi et al. (2023).

Many researchers reported that cucumber cultivation in substrate culture systems have been increased significantly over the last couple of decades (Gul et al., 1999; Lorenzo et al., 1999; Al-Mulla et al., 2008; Janapriya et al., 2010; Zhang et al., 2012; Mazahreh et al., 2015) than conventional soil cultivation due to the occurrence of soil-borne diseases. Hickman and Klonsky (1993) reported that a yield of 33.0 kg m^{-2} could be attained from cucumber cultivated in bag culture inside a greenhouse. Furthermore, Gul et al. (1999) reported that there were no significant differences in plant growth, yield or fruit quality between cucumber plants grown in vertical or horizontal bags containing perlite as a growing media in open and closed systems.

The main target of plant production could be summarized in two items, the first is a marketable fruit yield with high quantity and quality, and the second is net crop income (gained profit). The optimum fruit yield was logically produced by cucumber plants when grown in a media containing an equal ratio of sand and Karenna (1 S + 1 Kg). Thus it is considered as a reference for the other treatments, Figure 1 showed that marketable fruit yield was increased by 5.39 and 10.40% over the optimum logic yield when cucumber plants were grown in a media containing 33.3% sand mixed with 66.7% date palm grinding Karenna (1 S + 2 Kg) and media containing 25.0% sand mixed with 75.0% date palm grinding Karenna (1 S + 3 Kg), respectively. On the other hand, the marketable fruit yield was negatively affected by the growing medium having a higher level of sand or date palm Karenna alone, the decrements were 9.62, 3.94, 2.23 and 1.14% when cucumber plants

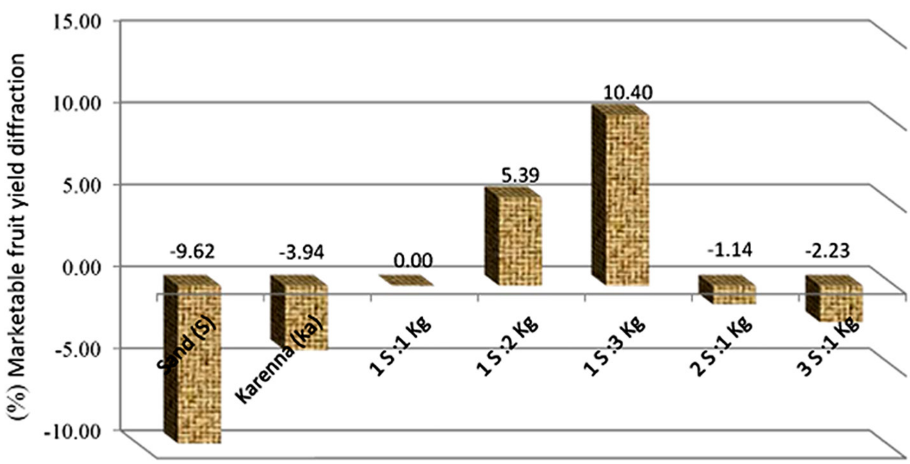

Figure 1. Marketable fruit yield diffraction (%) as negatively affected with growing medium treatments, Kg – grinding Karenna, Ka – Karenna without grinding, S – sand

were grown in 100% sand (S), 100% Ka, 3 S + 1 Kg and 2 S + 1 Kg medium, respectively. Overall, it is suggested that using sand at a rate of 25% mixed with date palm grinding Karenna at 75% (1 S + 3 Kg) media could provide a useful tool to improve the fruit yield and quality of cucumber plants in different soilless substrate cultural systems.

Fruit nutrient contents

According to the findings in Figure 2, the mineral contents of N, P, and K in cucumber fruit were significantly affected by the different growing medium treatments. Cucumber fruits produced from the treatment of 1 S + 3 Kg had the highest contents of macronutrients, nitrogen, phosphorus and potassium, while those fruits produced from the sand alone media (S) treatment had the lowest contents. Lorenzo et al. (1999); Kumari et al. (2018) on cucumber and Heidari et al. (2021) on Lily cut flowers reported similar results. They mentioned that increasing date palm waste levels in the growing media significantly increased N, P and K contents in grown plants. These results may be due to that medium contained date palm wastes have the ability to conserve the nutrient solution and water in root zone distribution which in turn results in greater nutrient absorption by the plant roots (Hickman and Klonsky, 1993; Gul et al., 1999; Ghehsareh et al., 2012).

It is of interest to clarify that Vital et al. (2002) indicated that nutrient absorption is usually proportional to the concentration of nutrients in the solution near the roots and is heavily influenced by environmental factors such as salinity, oxygen, temperature, pH of the nutrient solution, light intensity, photoperiod, and air humidity. Also, they added that the nutrient uptake depends only on plant demand as determined by environmental conditions.

Reference evapotranspiration of crop (ETc)

Data illustrated in Table 6 showed the calculated reference evapotranspiration (ETo) under greenhouse conditions during both experimental seasons, which can be used to find the values of ETc for cucumber plants during different growth stages. Furthermore, the data presented in Table 7 demonstrated that the growing medium treatments significantly affected the actual quantity of irrigation and drainage water that is applied during the three phenological plant growth stages (initial-season, mid-season and end-season stages). The superior drainage water quantity was attributed to the sand alone media (100% S). During the three plant growth stages, the amount of drainage water reached 12.66, 10.68 and 29.69% of the supplied irrigation water through the initial, mid and end growth stages, respectively, or equal to 742.6 m^3/hectare during the growing season. This amount of soil solution is being carried to underground water by gravity with soluble nutrients, resulting in significant water and agrochemical resource losses as well as underground water contamination. Such a

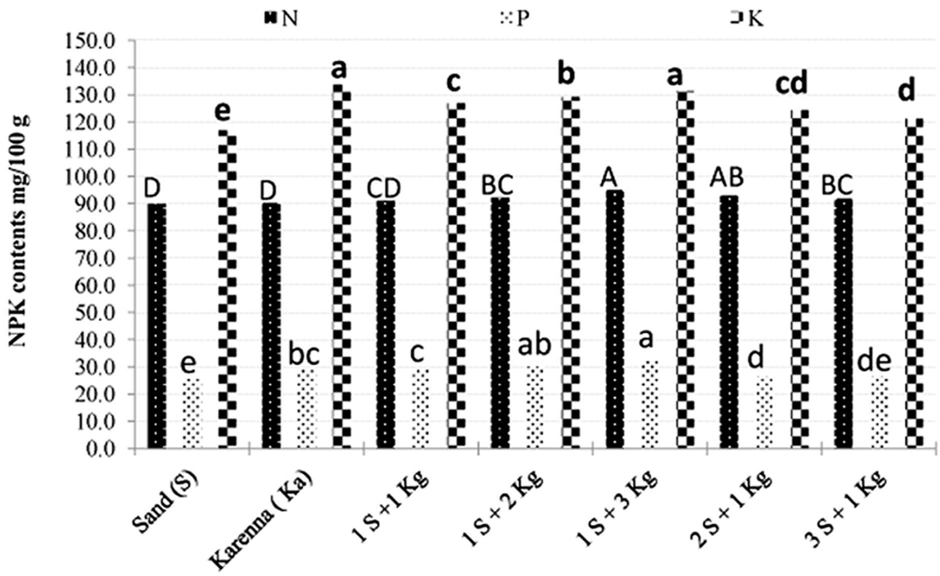

Figure 2. Effect of medium substrates on fruit NPK contents, Kg – grinding Karenna, Ka – Karenna without grinding, S – sand

lost amount of water could be recycled by using a closed soilless culture system. On the other hand, the highest actual water quantity was consumed in the growing media which contained 1 S + 3 Kg. The water consumed by cucumber plants when grown in 1 S + 3 Kg growing media treatment was equal to 97.04, 97.01 and 81.37% of the water supplied through the three plant growth stages, or equal to 4579.12 m^3/hectare (4.81 m^3 $plot^{-1}$) during both growing seasons.

Water use efficiency (WUE)

Water use efficiency can be defined as the ratio of CO_2 assimilation into the photosynthetic biochemistry machinery (A) to water lost via transpiration through the stomata (T). A and T are regulated by a stomatal conductance (gs) to water and CO_2 and the respective concentration gradients in water vapour and CO_2 between the inside and outside of the leaf (Bacon, 2004). This definition illustrated a simple aspect of the biological water use efficiency account. The efficiency of photosynthetic assimilation in the plant has a direct relationship with crop yield. Water use efficiency could be expressed in two ways: as kg of economic fruit yield per unit of consumed water (m^3) or as amount of consumed water (m^3) per kg of economic fruit yield; both are important. Whatever, the data presented in Table 7 demonstrated a significant effect on irrigation water use efficiency, with the highest efficiency (24.04 kg/m^3) obtained with a growing media containing 1 S + 3 Kg, and the lowest with a sand alone (100% S) media (14.94 kg/m^3) for cucumber plants grown under greenhouse conditions. Previous work was conducted under Egyptian conditions, studied the beneficial relationship between actual evapotranspiration (m^3 ha^{-1}/season) and applied irrigation water (m^3 ha^{-1}/season), which could be used as an indicator of water use efficiency (Seidhom and Evon, 2006).

Economic evaluation (feasibility study)

The agricultural occupation is mainly an economic process, so the net profit per each input pound is important for getting the highest rate of revenue, for that reason, a last important point of the current study may come to mind as a question, how much do the treatments cost and what is the net profit of such treatments?

Data in Table 8 showed the fixed input and variable cost (LE per season, LE = Egyptian

Table 6. Reference evapotranspiration (ETo) mm/day inside the greenhouse during both experimental seasons of 2016–2017 and 2017–2018

Seasons	1st season					2nd season				
Year	2016		2017					2018		
Month	November	December	January	February	March	November	December	January	February	March
ETo Mm/day	4.92	4.78	4.83	4.71	5.18	5.82	4.24	4.48	5.02	5.24

Table 7. The effect of sand and/or date palm Karenna as growing substrate medium on reference evapotranspiration of crop (ETc) during the three plant growth phenological stages and water use efficiency of cucumber plants (combined analysis of both seasons)

Parameters treatments	ETc during initial-season stage L $plot^{-1}$ ETc = ETo x $K_{c\ ini\ (0.5)}$			ETc during mid-season stage L $plot^{-1}$ ETc = ETo x $K_{c\ mid\ (1.0)}$			ETc during end-season stage L $plot^{-1}$ ETc = ETo x $K_{c\ end\ (0.6)}$			Quantity of irrigation water consumed during season (m^3 $plot^{-1}$)	Water use efficiency (kg/m^3)
	Water quantity	Drainage water	Actual quantity	Water quantity	Drainage water	Actual quantity	Water quantity	Drainage water	Actual quantity		
Sand (*S*)	810.3	102.6 a	707.8 g	3215.3	343.5 a	2871.7 f	1111.3	329.9 b	781.4 d	4.36 g	14.94 d
Karenna (*Ka*)	810.3	95.1b	715.2 f	3215.3	303.4 b	2911.9 e	1111.3	344.7 a	766.7 e	4.39 f	15.82 cd
1 S + 1 Kg	810.3	74.1 e	736.2 c	3215.3	237.9 d	2977.4 c	1111.3	219.1 e	892.2 a	4.61 c	17.09 c
1 S + 2 Kg	810.3	58.0 f	752.4 b	3215.3	167.1 e	3048.2 b	1111.3	245.5 d	865.9 b	4.67 b	19.55 b
1 S + 3 Kg	810.3	24.0 g	786.3 a	3215.3	96.1 f	3119.2 a	1111.3	207.0 e	904.3 a	4.81 a	24.04 a
2 S + 1 Kg	810.3	83.1 d	727.2 d	3215.3	271.1 c	2944.1 d	1111.3	251.0 d	860.3 b	4.53 d	17.16 c
3 S + 1 Kg	810.3	86.9 c	723.4 e	3215.3	275.5 c	2939.7 d	1111.3	287.6 c	824.1 c	4.49 e	16.46 cd

Note: S – sand, Ka – Karenna without grinding, Kg – grinding Karenna. Means followed by the same letter in the same column are not significantly different at P ≤ 0.05 according to Duncan's multiple range test.

pound, 1 USD = 30.63 LE), as well as the fruit yield prices output during both growing seasons. In addition, data shown in Table 9 showed the quantity and the cost of irrigation water consumed (m^3 $plot^{-1}$), variable, fixed and total cost (LE $plot^{-1}$) during both experimental seasons.

Table 8. Average of input fixed and variable cost (LE* season/greenhouse) and the production prices output during the winter seasons of 2017 and 2018

Items	Unit	Counts	Life span $year^{-1}$	Unit cost LE	Total LE	Cost LE $season^{-1}$
Input Fixed cost $plot^{-1}$						
Greenhouse:						
1. Iron skeleton	unit	30	15	450.0	13500.0	450.0
2. Concrete foundation	unit	60	15	150.0	9000.0	300.00
3. Polyethylene (200 µ)	Kg	125.0	5	28.5	3562.5	356.25
4. Irrigation net	unit	5	5	600.0	3000.0	300.0
5. Water tanker	1	1	15	2000.0	2000.0	66.67
Total					31062.5	1472.92
Bags preparation:						
1. Polyethylene (1 mm)	Kg	580.0	10	28.5	16530.0	826.5
2. Manufacturing	unit	42	10	50.0	2100.0	105.0
3. Packing	unit	42	10	30.0	1260.0	63.0
Total						994.5
Organic fertilizer	m^3	1	1	700.0	700.0	350.0
Chemical fertilizers						
1. Ammonium nitrate	unit	1		300.0	300.0	300.0
2. Calcium superphosphate	unit	1		75.0	75.0	75.0
3. Potassium sulphate	unit	1		350.0	350.0	350.0
4. Magnesium sulphate	unit	1		120.0	120.0	120.0
5. Micronutrients	unit	1		250.0	250.0	250.0
Seedlings	Salver	8		600.0	4800.0	4800.0
Labour cost						
Pesticides	Person	40		60.0	2400.0	2400.0
Fungicides	L	1		120.0	120.0	120.0
	kg	1		150.0	150.0	150.0
Total						8615.0
Variable cost						
Karenna preparing	Ton	10	10	150.0	1500.0	75.0
Water cost	m^3	270.0		0.5	135.0	135.0
Total						210.0
Total cost season/greenhouse					11292.42	
Output						
Marketing				Unit Price		
Marketable yield	Kg			6.0 LE		
Unmarketable yield	Kg			2.5 LE		

Note: LE* – Egyptian pound (1 USD = 30.63 LE).

Table 9. Gross input (LE*/plot) of cucumber cultivation in sand and/or date palm Karenna growing substrate medium

Variables Treatments	Irrigation water		Variable cost (LE)	Fixed cost (LE)	Total cost (LE)
	Quantity (m^3 $plot^{-1}$)	Cost (LE)			
Sand (S)	4.36 g	2.18 b	1.1 g	263.87	267.2 b
Karenna (Ka)	4.39 f	2.20 b	7.2 a		273.3 a
1 S +1 Kg	4.61 c	2.31 ab	3.6 d		269.8 ab
1 S + 2 Kg	4.67 b	2.34 ab	4.8 c		271.0 ab
1 S + 3 Kg	4.81 a	2.41 a	5.4 b		271.7 ab
2 S + 1 Kg	4.53 d	2.27 ab	2.4 e		268.5 ab
3 S + 1 Kg	4.49 e	2.25 ab	1.8 f		267.9 ab

Note: S – sand, Ka – Karenna without grinding, Kg – grinding Karenn, LE* – Egyptian pound (1 USD = 30.63 LE). Means followed by the same letter in the same column are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test..

Table 10. Total output and net income (LE*/plot) of cucumber cultivation in sand and/or date palm Karenna growing substrate medium

Variables treatments	Fruit yield income (LE plot^{-1})			Net income (LE plot^{-1})
	Marketable	Un-marketable	Total income	
Sand (S)	289.23 e	42.39 a	331.62 f	65.57 f
Karenna (Ka)	333.44 d	34.83 b	368.27 e	95.00 e
1 S +1 Kg	395.88 c	31.83 b	427.72 c	157.94 c
1 S + 2 Kg	487.75 b	24.80 c	512.54 b	241.53 b
1 S + 3 Kg	653.04 a	16.97 d	670.01 a	398.33 a
2 S + 1 Kg	385.31 c	33.86 b	419.17 cd	150.63 c
3 S + 1 Kg	360.51 cd	34.42 b	394.93 de	127.01 d

Note: S – sand, Ka – Karenna without grinding, Kg – grinding Karenna, LE* – Egyptian pound (1 USD = 30.63 LE). Means followed by the same letter in the same column are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

Data obtained revealed that the highest significant water quantity and cost of irrigation water consumed were attributed to that media treatment, which contained one portion of sand and three portions of date palm grinded Karenna (1 S + 3 Kg). However, the 100% date palm Karenna media treatment significantly increased variable and total costs. Whatever, marketable fruit yield, unmarketable fruit yield, total fruit yield incomes and net income (LE plot^{-1}) are shown in Table 10. The obtained results also revealed that a higher significant difference was observed among growing medium treatments, the 1 S + 3 Kg treatment had the highest marketable yield, total yield incomes and net income (LE plot^{-1}) while the sand alone media (100% S) treatment had the highest un-marketable yield income.

CONCLUSIONS

The ultimate goal of novel and innovative agricultural practices to achieve sustainable agricultural development is the highest usefulness of plant production, including both primary and secondary products. Date palm tree residues mixed with sand from sand dunes could be used as an economical local growing substrate media for soilless culture even in a greenhouse, above a roof-house, or in unsuitable soil for cultivation due to soil-related problems. The current study concluded that the best mixing ratio between sand and grinding date palm Karenna was found to be 25% sand and 75% grinding Karenna (1 S + 3 Kg). Such date-palm residue-based growing media significantly recorded the highest values of all studied characters of plant vegetative growth, number of flowers, fruit set, yield and its components, as well as fruit N, P and K contents of cucumber plants relative to other growing substrate medium treatments. Furthermore, such a medium has better physical and chemical properties, mainly the ability to regularly distribute irrigation water and nutrients in the root zone, as well as maintain a suitable air-water ratio, which is reflected positively on the growth and production of grown plants. More studies are still needed to reach alternative, optimal local agricultural residue-based media component ratios for better growth of vegetable crops in soilless culture systems.

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