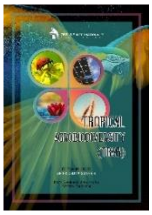
ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2716-7046 (Online)
CODEN: TARGCA

Tropical Agrobiodiversity (TRAB)

DOI: http://doi.org/10.26480/trab.01.2024.01.10



RESEARCH ARTICLE

SMART FARMING OF GERBERA PRODUCTION IN DIFFERENT SUBSTRATE CULTURE (SYSTEMS AND TYPES)

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ARTICLE DETAILS

Article History:

Received 20 December 2023
Revised 18 January 2024
Accepted 28 February 2024
Available online 01 March 2024

ABSTRACT

To maximize Gerbera production and avoid the different problems of soil, water shortage and climate change impacts, substrate culture performed an efficient technique for producing Gerbera flowers sustainability under greenhouse conditions. The investigation was conducted at the Central Laboratory for Agriculture Climate (CLAC), Agriculture Research Center, Egypt under greenhouse conditions during two cultivated winter seasons of 2020/2021 and 2021/2022. The smart system used for monitoring the micro-climate and environmental conditions for providing smart farming management system. The study investigating the effect and potentiality of different substrates peat moss : perlite (P:P 1:1 *v/v*) in different system (bags (40 and 30 L, pots (10 and 7.5 L) and container) compared to coco peat bags (CP) and rock wool bags (RW) with two densities (70 and 100) on Gerbera production. Micro-climate records (air temperature, and relative humidity) and environmental detections (substrate moisture, and EC and level of nutrient solution tanks) were sensing by different sensors to provide smart monitoring and alarm system for different substrate types and systems. The vegetative characteristics and yield parameters as well as bio chemical and chemical analysis were recorded. The revealed results indicated that peat moss : perlite substrate had the highest significant values of vegetative characteristics and yield parameters of Gerbera compared to other substrates. Also, increasing the substrate volume or density led to an increase in the vegetative characteristics and yield parameters of Gerbera. Container P: P followed by bags P: P followed by Pots P: P 10 gave the highest significant results of the vegetative characteristics, yield parameters and bio chemical and chemical analysis of gerbera while the lowest values recorded by bags RW followed by bags CP. The economic impact assessment promoted strongly the implement of Pots P: P 10 followed by Container P: P which presented the highest net profit of Gerbera production that matched the study recommendation.

KEYWORDS

Smart farming, substrate culture, bags, pots, container, peat moss, perlite, coco peat, smart monitoring, arduino mega, and sensors.

1. INTRODUCTION

Satisfying the food security needs or gaining the high profitable yield, this is the tricky question. Producing food or cut-flowers, the use of smart substrate culture system could help this clash. Producing cut flowers in different substrate systems and types under greenhouse conditions may play a role in achieving profitable yield.

The popularity of soilless culture systems under modern greenhouse get more achieved a steady increase last two decades regarding the climate change impacts, shortage of water, soils and the needs of sustainable agriculture and food security.

Substrate culture as one of the major soilless culture category has considerable changes in protected ornamental production as well as vegetables production while offer the opportunities to achieve: 1) a maximum-quantity and quality products, 2) uniform products, 3) high environmental control of greenhouse production, 4) mitigate the climate change impacts and extreme weather events, and 5) conserve natural resources (water, soil, energy, etc..) (Maloupa, 1993; Abul-Soud et al., 2020). The high initial investment cost, skilled labor and the required control technology create the disadventages of soilless culture.

Ornamental plants grown in substrate culture require optimum physical and chemical properties of substrate with adequate water retention and aeration while properate nutrient solution compostion that match the ornamental plants of nutrients requirments that ensures a continuous nutrient supply (Macz et al., 2001; Erstad and Gislerød, 1994). The physical and chemical properties of substrate should presented stability and salinity free during different stages of plant growth. The bio-stability of alternative substrates varies significantly, that had affects on the chemical properties of substrates, their management, and the growth of ornamental plants.

Gerbera is one of the most profitable ornamental crops grown under greenhouse for cut flowers (Vidalie 2007). Gerbera classified as moderately sensitive to salinity (Sonneveld et al. 1999). Gerbera grow best in EC range from 1.5 to 2.8 dS·m^{-1} in substrate culture systems. Inceasing the salinity above 2.8 dS·m^{-1} has a strong negative effect on the gerbera yield (María et al., 2018). To avoid the multi problems of gerbera production, it's recommended to apply substate culture.

The studied grow gerbera in different substrate types such as coconut fiber (coco peat), peat moss, rock wool, perlite, vermiculite, sand, expanded clay or different organic substrates, (compost cow, mushroom

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compost, spent date palm, zeolite, pumice, sand etc. with diferent mixtures and proporations (Iftkhar et al., 2012 , Khalaj, 2007, Khalaj et al., 2011 and Razieh et al., 2015). On the scale of sustainable concerns, peat moss become more exclusive use because its harvest is destroying endangered wetland ecosystems worldwide (Robertson, 1993). A majority of horticulture crops are produced in commercially available substrates. No need to mentioned that several substrate types are available with a large characteristics. Recommended the optimum substrate among the other is imperative to the plant productivity (Olympios, 1992).

Cultivation gerbera substrate culture is the most modern method of production, with very favorable results in terms of profitability, plant health and production quality. observed that the ideal substrates are essential for quality and production of gerbera cutflowers as these affect development and maintenance of plant rooting system and vegetative growth (Awang et al., 2009).

It has investigated the economic value of cultivating gerbera in soilless culture compared to soil cultivation under greenhouse condition (Grafiadellis et al., 2000). They found that soilless culture systems was more profitable compared to soil culture, particularly the plastic bag system using perlite media.

Monitoring of micro-climate and the environmental conditions integrated with internet of things (IOT) gave the oppturinty to mitigate the extreme weather events on the agriculture production and avoid the environmental risk. Sensors such as DHT 11 and DHT 22 have been used for measuring air temperature and relative humidity; LDR module and TSL 2561 for estimating light intensity; waterproof temperature for recording the water temperature; TDS and pH kit sensors for measuring EC and pH of solution respectively (Abul-Soud et al., 2021).

Most of researchers take in concer the substrate material types while substrate system had no the same attention. Also, employ smart management for greenhouse production to assisst the production management is very vital under the climate change impacts and extreme weather events. Thus, the study aimed to investigate the smart farming, sustainable and profitable substrate system and type in producing gerbera under greenhouse condition. Effect of substrate system and type on the growth and yield production of gerbera take in consider.

2. Materials and Methods

The experimental trial was carried out during two successive seasons (2020/2021 and 2021/2022) at Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center (ARC), Egypt. Gerbera plants were grown into different substrate culture systems and substrate types under smart monitoring and alarming system under greenhouse conditions.

2.1 Plant Material

Gerbera jamesonii cv. superba seedlings were transplanted in different substrate systems in the middle of December for both cultivated seasons 2020 and 2021. The final in-row plant distances were 30 cm in the row, 30 to 50 cm between the rows regard to the specific terms of different system and 70 cm in between the beds to create plant density 6.6 plant / m / system.

All other agriculture practices of Gerbera production (harvesting, IPM, weed control and etc.) regarding the standard recommendations for commercial growers under Egyptian condition were implemented.

2.2 Substrate Culture Systems

Rising slop beds (0.9 m width, 12.0 m length and 0. 2 m height) were established and surrounded by bricks to performed close different substrate systems and offer the stability frame for the different substrate systems, each bed was covered by black polyethyene sheet (400 micron) for recollecting drainage with a slope 1 %. Each bed had a seperated tank and submersible pump for pumped the nutrient solution.

2.3 Bags Substrate System

Horizontal polyethylene plastic (white outer and black inner side with 0.2 mm thickness) bags (0.25 x 1 m = 40 L volume = 13.33 L / plant) were filled with investigated substrate peat moss : perlite (1 :1 *v/v*), coco peat and rock wool with two density 70 and 100 g/m^2. Drainage hole at the bottom along the bags to allow recollecting the leaching nutrient solution. The bags arranged in two rows (12 bags/ row). Three Gerbera seedlings were cultivated in each bag.

2.4 Pots Substrate System

Vertical plastic pots included two volumes (7.5 L size 25 and 10 L size 30 / plant) were filled with standard substrate peat moss : perlite (1 :1 *v/v*). The pots arranged in two rows (40 pots/ row) to performed 80 pots / 80 plants / 2 rows / bed. Each pot was cultivated by one Gerbera seedling.

2.5 Container Substrate System

Containers system, container was created by using black polyethylene sheet (0.7 mm). The bed system (0.6 x 12 x 0.17 m) filled by about 1250 L (15.3 L of substrate /plant) of standard substrate peat moss : perlite (1 :1 *v/v*). Gerbera seedlings cultivated in two rows, in between the rows 30 cm. with the same plant density as the rest substrate systems. The establishment of different substrate systems presented in Image (1)

2.6 Substrate Types

Table (1) illustrated the physical and chemical properties of different substrate types that investigated in producing Gerbera as follows:

1. Peat moss: perlite (standard substrate) by mixing peat moss with perlite 1: 1 *v/v*.

2. Coco peat (bags ready to use 40 L volume 0.2 m width and 1 m length, imported product, Haraz Co.)

3. Rockwool (bags + block ready to use, 0.2 m width and 1 m length, local manufacture, Glass Rock Co., Egypt).

Table 1: The Physical And Chemical Properties Of Different Substrates.

	Physical				Chemical		
Substrate	B.D g/l	T.P.S %	W.H.C %	A.P %	E.C mmhos^{-1}	pH	O. M %
Peat: perlite	166.0	65.3	32.0	33.3	0.42	7.1	46.8
Coco Peat	75.7	85.9	80.1	5.8	1.13	6.5	94.5
Rockwool 70	70.5	90.0	75.6	14.4	0.06	6.6	0.0
Rockwool 100	99.5	82.0	76.2	6.8	0.08	6.6	0.0

Bags system peat moss: perlite Bags system rockwool Pots system peat moss: perlite

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Containers peat moss: perlite Bags system coco peat

Photo 1: The establishment of different substrate systems and their gerbera growth

2.7 The Fertigation System

Close fertigation system implemented for all substrate systems by using 200 L tank per each treatment. The fertigation program was applied via digital timer to manage the fertigation schedule during the day 4 to 6 times while during the night 2 to 4 times, each time varied from 5 to 10 minutes regarding the substrate moisture sensing via smart management system, growth stage and the climate conditions. The nutrient solution was pumped via submersible pump (110 watt) through drip irrigation system (30 cm between the drippers).

The composition of chemical nutrient solution was applied as illustrated in Table (2) (Abul-Soud et al., 2017;2021). The electrical conductivity (EC) of nutrient solution for all substrate systems and types was adjusted by using smart management system that use TDS sensor and for more accurate digital EC meter was used to the range level (900 – 1500 ppm). pH of nutrient solution of different treatments were adjusted in the range of 5.5 to 5.8 by using digital pH meter (Dragoș et al., 2020).

Table 2: The chemical composition of different sources of nutrient solutions.

Nutrient solution	Macronutrients (ppm)					Micronutrients (ppm)					
	N	P	K	Ca	Mg	Fe	Mn	Zn	B	Cu	Mo
Ch. N.S.	140	35	220	122	42	2.5	0.5	0.3	0.4	0.20	0.02

2.8 Smart Monitoring And Alarm System Material

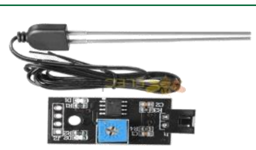
The smart monitoring and alarm system based on Arduino Mega 2560. Arduino Mega 2560 was programmed by using Arduino IDE 1.8.13 software . Different sensors and buzzers were wired for monitoring the micro-climate conditions (air temperature, relative humidity and light intensity) and environmental conditions (substrate moisture, EC and water level of nutrient solution) beside alarm buzzer as illustrated in Table (3).

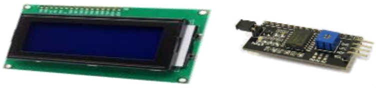
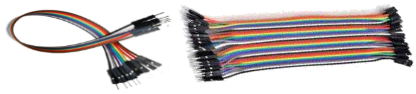
The Arduino sketch begins with identify the different sensors and buzzers. Sensing the required data of microcliamte conditions (air temperature (°C) and relative humidity (%)) each 30 minutes (1,800,000 mlSec) but adjusted later to sensing every 60 minutes (3,600,000 mlSec). Arduino Mega and all sensors were wired and constructed in plastic project box. DHT 22 sensor detected air temperature and relative humidity in float digit, the arduino sketch programmed to present a buzzer alarm in case of air temperature records 24 °C then modified under the operation conditions to 30 °C or more as well as 8 °C or less.

The substrates moisture of different substrate types and systems were tested by using mobile modified resistive soil moisture sensor. Mobile prob sensor used to have the ability to check the different substrates moisture types and systems easily and to avoid the interruptions among the different wires and sensors. Resistive soil moisture sensors were modified to observe innovation that performed with very low cost to be more efficient, durable, and accurate to access wide soil type and depth by replacing the unreliable BCP probe with electrical cable to select the required depth for soil moisture detection. EC of nutrient solution detected by mobile TDS kit sensor to check the EC of different nutrient solution tanks. Water level of different nutrient solution tanks were sensing via water-proof ultrasonic sensor. However, the water level is low, the buzzer will be On to presented buzzer alarm, otherwise the alarm is Off. Fig. (1) presented the software flow chart of Arduino sketch.

The all monitoring data will be displayed on LCD screen (multi-screen) as Fig. (1) demonstrated. The author designed the smart management system as monitoring and alarming system with no consideration for internet of things (IOT) that is not available in major farms under Egyptian condition.

Table 3: The different sensors and buzzers wired in smart monitoring and alarming system

Smart material	Job	Image
Arduino Mega 2560	Designed for complex electronic projects with more sketch memory and 54 digital input /output pins (of which 15 can be used as PWM outputs), 16 analog inputs connected to a pc with a USB cable	
DHT 22 sensor	Sensening air temperature (°C and °F) and relative humidity (%) 5 volt power sensor	
TDS sensor	Sensing Total Dissolved Solids (TDS) measure range from 0 to 1000 ppm. 5 volt power sensor (Need to calibration gradually). Use as mobil sensor	
Resistive Soil moisture sensor (modified)	Detecting substrate moisture (%) regarding to the opposite relation between electericity resistive and moisture content. 5 volt power sensor Use as mobil sensor	

Waterproof ultrasonic sensor	Water level sensing 5 volt power sensor Waterproof sensor Use as mobil sensor	
LCD - I2C (4*20)	Display the different sensors detections for monitoring 5 volt power screen	
Breadboard (830 pin holes)	a solderless construction base used for developing an electronic circuit and wiring for projects	
Buzzer	Create a buz voice for alarming. 5 volt power actuator	
Jumbers (male/male) (male/female)	Wiring the different sensors with Arduino, LCD, bread board and relay module	

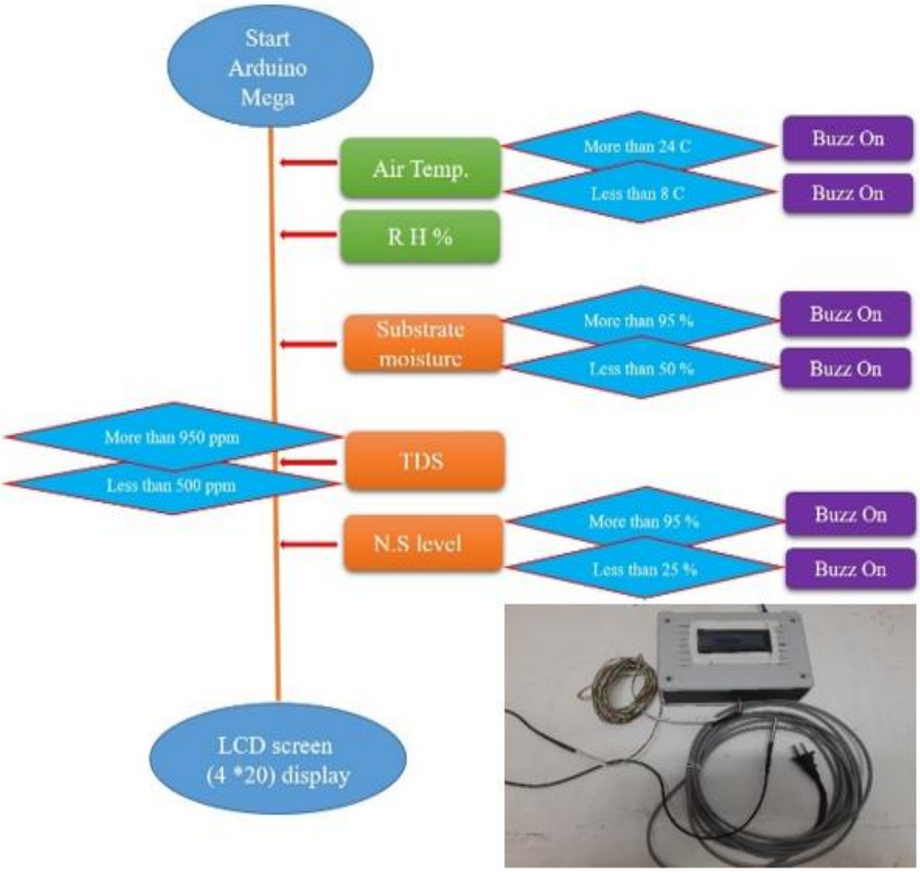


Figure 1: The flowchart of Arduino sketch

2.9 The Investigated Treatments

Three different substrate systems (bags, pots and container) with different substrate types and volumes (peat moss: perlite (1:*1v/v*), coco peat rock wool) were investigated under greenhouse conditions for producing gerbera cut flowers as follows:

I. Bags peat moss: perlite (1:1 *v/v*) 40 L volume = Bags P: P 40

II. Bags peat moss: perlite (1:1 *v/v*) 30 L volume = Bags P: P 30

III. Bags Rock wool with density 100 = Bags RW 100

IV. Bags Rock wool with density 70 = Bags RW 70

V. Bags coco peat 40 L volume = Bags CP 40

VI. Pots peat moss: perlite (1:1 *v/v*) 10 L volume = Pots P: P 10

VII. Pots peat moss: perlite (1:1 *v/v*) 7.5 L volume = Pots P: P 7.5

VIII. Container peat moss: perlite (1:1 *v/v*) = Cont. P: P

The experimental design was complete randomized blocks with 3 replicates. Each replicate had 24 gerbera plants.

3. The Measurements

3.1 The Physical And Chemical Properties Of Substrates

The physical and chemical properties of different substrates presented in **Table (1)**. Bulk density (*B.D*), total pore space (T.P.S), water hold capacity % (W.H.C) and air porosity % (A.P) were estimated regarding (Wilson, 1983; Raul, 1996). The pH of the potting mixtures were determined using a double distilled water suspension of each potting mixture in the ratio of 1:10 (w: v) that had been agitated mechanically for 2 h and filtered through Whatman no.1 filter paper (Inbar et al., 1993). The same solution was measured for electrical conductivity (EC mmhos^{-1}) with a conductance meter that had been standardized with 0.01 and 0.1M KCl.

3.2 The Vegetative Characteristics And Flower Parameters

The flower measurements bigan from the first flower till the season end while, the vegetative growth characteristics were measured at the end of

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flowering stage as follows:

Data were recorded on:

I. Plant height (cm)

II. Number of leaves/ plant (cm.) at the end of flowering stage.

III. Average leaf area (full expended leaf at the 4 and 5th leaf) (cm^2).

IV. Number of offsets per plant.

V. Number of days from planting to flowering (Days to flowering).

VI. Fresh and dry weights of flowers (gm).

VII. Number of cut flowers/ plant (flowers yield).

VIII. Stalk length (cm).

IX. Stalk diameter (cm) measured at the base of the stem by using digital diameter.

X. Flower head diameter (cm) by using digital diameter.

3.3 The Biochemical And Chemical Analysis

Chemical analysis of leaves at flowering stage was determined as follows:

- Determination of chlorophyll a and b as well as carotenoids content were determined in fresh leaves according to (Von Wettstein, 1957). Total chlorophyll (a+b) were mathematically calculated.
- Determination of total sugars: The leaves were dried, finely ground and total sugars were determined by using colorimetric method by (Smith et al., 1956).
- Mineral analysis (N, P, and K) of gerbera leaves were determined. Gerbera leaves plant samples (20 leaves/ plot) were dried at 70 ^{o}C in an air forced oven for 48 hours and then digested in H_2SO_4 according to the method described by (Allen, 1974). N, P and K contents were estimated in the acid digested solution. Total nitrogen was determined by micro Kjeldahl method according to the procedure described by (FAO. 1980). Phosphorus content was determined using spectrophotometer according to (Watanabe and Olsen, 1965). Potassium content was determined photo-metrically via flame photometer as described by (Dewis and Freitas, 1970).

3.4 The Economic Assessement Study

The economic impact assessment was calculated regarding standard greenhouse span area 540 m^2 (9 * 60 m). The investment cost take in consider the cost of each substrate type and system / Annual depreciation rate (3 years for substrates and 5 years for plastic) plus fertigation system (pumps, tanks, timers, and irrigation network) / Annual depreciation rate (5 years). The operation cost include the Gerbera seedlings, labor, nutrient solution, IPM and power use.

I. The standard greenhouse span 540 m^2 under the real operation condition = 1900 plant / span = 1900 * 5 = 9500 LE.

II. The cost of substrate differs regarding the used substrate type and system (all costs determined regarding the prices of 2021) as follows:

A. Peat moss: perlite 1:1 *v/v* = one L = 1 LE

B. Pot 7.5 L size 25 = 5 LE

C. Pot 10 L size 30 = 8 LE

D. Plastic polyethylene bag = 10 LE

E. Black polyethylene sheet (0.7 mm) = 1 m^2 / 30 LE

F. Coco peat bag (40 L) = 60 LE

G. Rockwool density 70 = 60 LE

H. Rockwool density 100 = 80 LE

3.5 The Statistical Analysis

Analysis of the data was done by computer, using SAS program for statistical analysis and the differences among means for all traits were tested for significance at 5 % level (Snedicor and Cochran, 1981).

4. RESULTS

4.1 The Effeciency Of Smart Monitoring And Alarming System

A smart system self-esteem for management all agriculture operations that assesses, determines and detects the different micro-climate and environmental conditions for improvement and provides individualized necessary feedback to greenhouse farmer. The smart system of monitoring and alarming system designed based on the ordinary small-scale farmer needs without automation or internet of things (IOT) to avoid the internet and communication absent conditions and to offer considerable alarming system.

4.2 The Monitoring Of Micro-Climate Conditions

The smart system provided an efficient impact for monitoring the air temperature (^{o}C) and relative humidity (%) as micro-climate conditions were presented in Fig. (2 and 3). Sensing temperature and relative humidity performed hourly along the cultivation season of Gerbera regarding the programming sketch. Maximum, average and minimum of both temperature and relative humidity recorded daily as Fig. (2 and 3) demonstrated.

Also, alarming system of micro-climate conditions operated in case of temperature more than 24 or less than 8 ^{o}C. The programming sketch modified to operate alarming system in case of temperature more than 30 ^{o}C starting from the first March in both cultivated seasons referring to the buzzing noise.

4.3 The Managemnet Of Environment Condition

Environmental conditions include substrate moisture, nutrient solution tank level and EC of nutrient solution. In case of The daily assistant for detecting the substrate moisture levels of different substrates and systems to modified the fertigation schedule to conserve the moisture level of different substrate in the range 70 to 90 %, The pumping schedule of nutrient solution of different substrate systems and types were adjusted to compensate the moisture depletion along the season of Gerbera. EC level of different treatments modified to be in range 600 – 950 ppm by sensing EC level every two days. Detecting the level of different nutrient solutions tanks via proofwater ultrasonic sensor assess in protecting the pumping system and avoid the irrigation shortage. The fixable design of mobile sensors illustrated a real support.

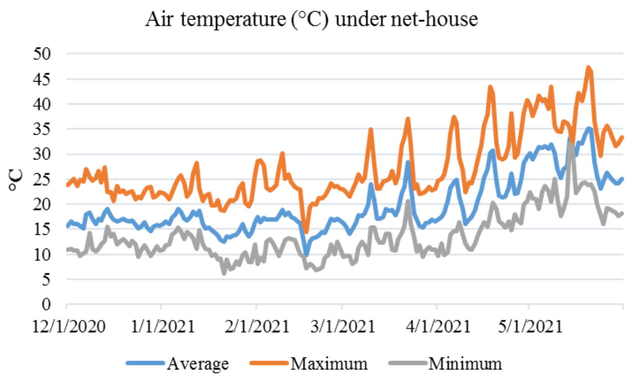

Figure 2: Air temperature (oC) during first season 2020 / 2021 under net house of gerbira

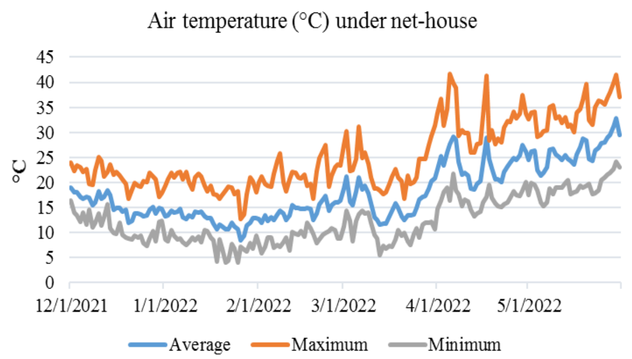

Figure 3: Air temperature (^{o}C) during second season 2021/2022 under net house of gerbira

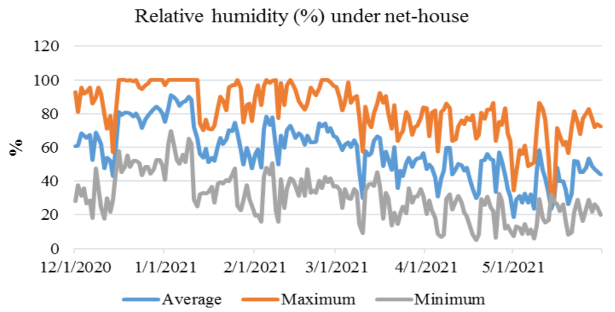

Figure 4: Relative humidity (%) during first season 2021 / 2022 under net house of gerbira

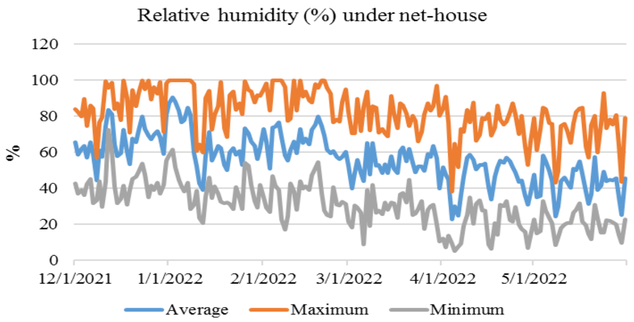

Figure 5: Relative humidity (%) during second season 2021/2022 under net house of gerbira

5. The Effect of Different Substrate Systems and Types on Gerbera Plant

5.1 The Vegetative Growth Characteristics Of Gerbera

Table (4) presented the effect of different substrates systems and types on *Gerbera* vegetative growth characteristics during the two cultivated seasons (2020 and 2021). The results thus obtained indicated that container peat moss : perlite treatment presented superior positive impact on vegetative growth characteristics of gerbera compared to the different substrate systems and types. Container peat moss : perlite treatment gave the highest significant values during the two cultivated seasons of plant height, No. of leaves/plant, and average leaf area (cm^2) followed by Cont. P:P treatment. The lowest measurements of vegetative growth characteristics of gerbera gave by both of bags RW 70 and bags CP 40.

More results could be extracted from Table (4) through investigated the impact of both substrae systems and types, Cont. P:P followed by bags P:P 40 followed by pots P:P 10 recorded the highest vegetative growth characteristics of gerbera. These results provide the positive effect of substrate system.

On the other hand, the impact of substrate type such as peat moss: perlite, rockwool and coco peat instead of different systems presented obvious impact while peat moss : perlite illustrated the highest results of vegetative growth characteristics of gerbera compared to other substrate types. The physical and chemical properties of different substrates play the main role in these impacts through offering the optimum growth conditions.

Table 4: Effect of different substrates systems and types on *Gerbera* vegetative characteristics during the cultivated seasons.

Treatments	Plant height (cm)		No. of leaves		Average leaf area (cm^2)	
	1st Season	2nd season	1st Season	2nd season	1st Season	2nd season
Bags P: P 40	24.1 A	22.8 AB	23.6 A	22.3 B	111.2 A	109.1 A
Bags P: P 30	22.7 AB	22.9 AB	22.1 B	20.0 C	102.5 AB	104.0 AB
Bags RW 100	21.4 B	21.4 B	19.6 BC	17.6 D	104.0 AB	94.3 B
Bags RW 70	20.8 B	20.6 B	18.0 C	16.6 D	97.1 B	81.7 C
Bags CP 40	21.3 B	22.1 B	17.5 C	19.6 C	96.6 B	104.6 AB
Pots P: P 10	23.3 A	24.8 A	22.7 AB	23.4 A	110.3 A	115.2 A
Pots P: P 7.5	22.6 A	22.5 B	19.5 BC	20.4 B	86.8 C	94.5 B
Cont. P: P	24.8 A	24.9 A	24.5 A	24.5 A	115.3 A	117.1 A

*Similar letters indicate non-significant difference at 0.05 levels.** Capital letters indicate the significant difference of different treatments at 0.05 levels. *** P: P40 (peat moss: perlite 40 L volume), P: P30 (peat moss: perlite 30 L volume), RW 100 (Rockwool density 100 g/m2), RW 70 (Rockwool density 70 g/m2), P: P10 (peat moss: perlite 10 L volume), P: P 7.5 (peat moss: perlite 7.5 L volume) and Cont. P: P (Containers system peat moss: perlite (1 :1 v/v)).

Consider Table (5) which presented the highest No. of offsets/plant, total sugar (%) and total chlorophyll content of gerbera leaves that recorded by Cont. P:P followed by Bags P:P 40 and Bags RW 100 while Bags P:P 30 and Bags RW 70 had the lowest values. The substrate volume of peat moss : perlite or substrate density of rockwool in bags system play a significant impact role on No. of offsets/plant, total sugar (%), and total chlorophyll content of gerbera leaves.

Table 5: Effect of different substrates systems and types on total suger and chlorophyll content of gerbera leaves during the two cultivated seasons.

Treatments	No. of offsets / plant		Total Sugar (%)		Total chlorophyll	
	1st Season	2nd season	1st Season	2nd season	1st Season	2nd season
Bags P: P 40	3.2 B	3.3 B	18.2 A	18.0 A	3.2 B	3.4 A
Bags P: P 30	3.1 B	3.0 B	15.0 B	16.2 B	2.7 C	3.0 B
Bags RW 100	2.6 C	2.8 C	18.0 A	17.4 A	3.3 B	3.3 A
Bags RW 70	2.3 D	2.5 D	13.5 C	14.0 C	2.7 C	2.8 C
Bags CP 40	3.3 A	3.5 A	16.0 B	17.3 A	2.9 C	3.2 B
Pots P: P 10	3.3 B	3.2 B	18.0 A	18.1 A	3.4 A	3.5 A
Pots P: P 7.5	2.7 C	2.9 C	16.5 B	17.0 B	2.9 C	3.2 B
Cont. P: P	3.6 A	3.7 A	18.5 A	18.6 A	3.7 A	3.7 A

*Similar letters indicate non-significant difference at 0.05 levels. ** Capital letters indicate the significant difference of different treatments at 0.05 levels. *** P: P40 (peat moss: perlite 40 L volume), P: P30 (peat moss: perlite 30 L volume), RW 100 (Rockwool density 100 g/m2), RW 70 (Rockwool density 70 g/m2), P: P10 (peat moss: perlite 10 L volume), P: P 7.5 (peat moss: perlite 7.5 L volume) and Cont. P: P (Containers system peat moss: perlite (1 :1 v/v)).

5.2 The Flowering Yield Parameters Of Gerbera

Concerning the effects of different substrate systems and types on the yield parameters (quantity and quality) of gerbera that illustrated in Table (6 and 7) as well as Fig. (2). Referring to Table (6), Cont. P:P treatment had the highest records of days to flowering (67.3 and 70) during the two cultivated seasons respectively that maybe explain the highest vegetative growth characteristics of gerbera plants that took the vegetative growth side more than flowering. Otherwise, Bags P:P 30 gave the lowest results of days to flowering (51.59 and 53.9).

In the context, similar results of flower fresh and dry weight (g) were achieved while Cont. P: P followed by Pots P:P 10 recorded the highest values while bags of both CP 40 and RW 70 gave the lowest records.

Table 6: Effect of different substrates systems and types on *Gerbera* yield parameters during the cultivated seasons.

Treatments	Days to flowering		Flower fresh weight (g)		Flower Dry weight (g)	
	1st Season	2nd season	1st Season	2nd season	1st Season	2nd season
Bags P: P 40	55.3 BC	58.1 C	9.1 A	9.1 A	1.54 A	1.56 A
Bags P: P 30	51.6 C	53.9 D	8.4 B	8.5 B	1.45 B	1.45 B
Bags RW 100	59.9 B	64.0 B	8.5 B	8.5 B	1.44 B	1.46 B
Bags RW 70	56.2 B	59.5 C	8.1 B	8.0 B	1.27 C	1.33 C
Bags CP 40	63.7 A	68.1 A	7.6 C	7.7 C	1.38 B	1.37 B
Pots P: P 10	52.3 C	54.8 CD	9.5 A	9.3 A	1.55 A	1.55 A
Pots P: P 7.5	55.6 BC	57.5 C	8.1 B	8.0 B	1.30 C	1.33 C
Cont. P: P	67.3 A	70.0 A	9.7 A	9.3 A	1.60 A	1.74 A

* Similar letters indicate non-significant difference at 0.05 levels. ** Capital letters indicate the significant difference of different treatments at 0.05 levels. *** P: P40 (peat moss: perlite 40 L volume), P: P30 (peat moss: perlite 30 L volume), RW 100 (Rockwool density 100 g/m2), RW 70 (Rockwool density 70 g/m2), P: P10 (peat moss: perlite 10 L volume), P: P 7.5 (peat moss: perlite 7.5 L volume) and Cont. P: P (Containers system peat moss: perlite (1 :1 v/v)).

The effect of different substrates systems and types on No. of flower / plant during the cultivated seasons illustrated in Fig. (6). The highest yield of Gerbera that presented in No. of flowers / plant, substrate system and type had a real significant impact that demonstrated Pots P: P 10 followed by Cont. P:P treatment presented the highest significant yield of Gerbera flower / plant during the both cultivated seasons. On the other hand, the lowest No. of flower / plant recorded by Bags RW 70 followed by Bags RW 100 treatments. The higher substrate volume whatever the system or density (Rock wool), the higher No. of Gerbera flower / plant occurred.

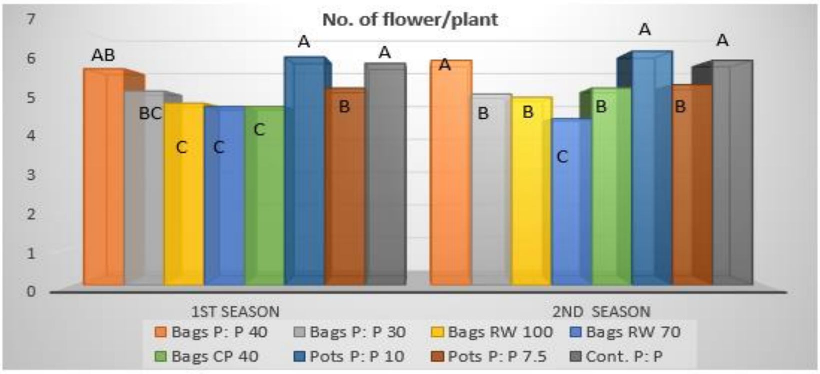

Figure 6: Effect of different substrates systems and types on No. of flower / plant during the cultivated seasons.

* Similar letters indicate non-significant difference at 0.05 levels. ** Capital letters indicate the significant difference of different treatments at 0.05 levels. *** P: P40 (peat moss: perlite 40 L volume), P: P30 (peat moss: perlite 30 L volume), RW 100 (Rockwool density 100 g/m2), RW 70 (Rockwool density 70 g/m2), P: P10 (peat moss: perlite 10 L volume), P: P 7.5 (peat moss: perlite 7.5 L volume) and Cont. P: P (Containers system peat moss: perlite (1 :1 v/v)).

The revealed results of Table (7) illustrate the effect of different substrates systems and types on Gerbera yield quality during the cultivated seasons. Bags P:P 40 followed by Cont. P: P gave the highest significant results of flower stalk length, flower stalk diameter and flower head diameter as a selected criteria of gerbera quality while the lowest values recorded by Bags RW 70 followed by Bags CP 40.

Table 7: Effect Of Different Substrates Systems And Types On *Gerbera* Yield Quality During The Cultivated Seasons.

Treatments	Flower stalk length (cm)		Flower stalk diameter (cm)		Flower head diameter (cm)	
	1st Season	2nd season	1st Season	2nd season	1st Season	2nd season
Bags P: P 40	36.6 A	36.8 A	0.32 A	0.34 A	7.91 A	8.25 A
Bags P: P 30	31.5 B	33.3 B	0.29 B	0.30 B	7.65 A	7.89 A
Bags RW 100	28.6 C	29.4 C	0.30 A	0.31 B	7.56 A	7.80 A
Bags RW 70	27.1 C	29.1 C	0.29 B	0.32 B	7.57 A	7.53 AB
Bags CP 40	30.1 B	31.6 B	0.28 B	0.33 AB	7.28 A	7.24 B
Pots P: P 10	33.8 AB	34.1 AB	0.30 A	0.31 B	7.92 A	7.90 A
Pots P: P 7.5	30.3 B	30.8 BC	0.28 B	0.27 C	7.46 A	7.45 AB
Cont. P: P	35.3 A	35.2 A	0.32 A	0.35 A	7.87 A	8.10 A

* Similar letters indicate non-significant difference at 0.05 levels. ** Capital letters indicate the significant difference of different treatments at 0.05 levels. *** P: P40 (peat moss: perlite 40 L volume), P: P30 (peat moss: perlite 30 L volume), RW 100 (Rockwool density 100 g/m2), RW 70

(Rockwool density 70 g/m2), P: P10 (peat moss: perlite 10 L volume), P: P 7.5 (peat moss: perlite 7.5 L volume) and Cont. P: P (Containers system peat moss: perlite (1 :1 v/v)).

5.3 The nutrient contents (N, P and K (%) of gerbera plants

As mentioned earlier, increasing the substrate volume or density had a significant increase on the vegetative growth characteristics and yield parameters as well as nutrient contents (N, P and K) of Gerbera plants. Peat moss: perlite substrate provided significant effect on the nutrient contents of Gerbera plants compared to the rest investigated substrates.

Container P: P followed by bags P: P followed by Pots P: P 10 demonstrated the highest significant values of nutrient contents (N, P and K) of Gerbera plants during the both studied seasons while the lowest results gave by Bags RW 70 followed by Bags CP 40 as Table (8) presented.

Table 8: Effect of different substrates systems and types on N, P and K contents (%) of *Gerbera* plants during the cultivated seasons.

Treatments	N (%)		P (%)		K (%)	
	1st Season	2nd season	1st Season	2nd season	1st Season	2nd season
Bags P: P 40	1.35 B	1.54 A	0.50 A	0.60 A	2.04 A	2.13
Bags P: P 30	1.20 BC	1.22 B	0.39C	0.41 CD	1.74 BC	1.83 B
Bags RW 100	0.90 C	1.07 C	0.39 C	0.38 D	1.89 B	1.95 B
Bags RW 70	0.80 C	1.09 BC	0.29 D	0.32 E	1.83 B	1.81 B
Bags CP 40	0.90 C	1.30 B	0.41 C	0.46 C	1.61 C	1.83 B
Pots P: P 10	1.32 B	1.53 A	0.48 B	0.52 B	1.93 AB	2.09 A
Pots P: P 7.5	1.25 B	1.37 B	0.47 B	0.46 C	1.75 BC	1.95 B
Cont. P: P	1.55 A	1.57 A	0.54 A	0.60 A	2.20 A	2.23 A

* Similar letters indicate non-significant difference at 0.05 levels. ** Capital letters indicate the significant difference of different treatments at 0.05 levels. *** P: P40 (peat moss: perlite 40 L volume), P: P30 (peat moss: perlite 30 L volume), RW 100 (rockwool density 100 g/m2), RW 70 (rockwool density 70 g/m2), P: P10 (peat moss: perlite 10 L volume), P: P 7.5 (peat moss: perlite 7.5 L volume) and Cont. P: P (Containers system peat moss: perlite (1 :1 v/v)).

5.4 The Economic Assessement Of Different Treatments On Gerbera Plants

Investment cost included the greenhouse rent and fertigation system (pumps, tanks, substrates, plastic, bags and pots) costs while seedlings, nutrient solution labor, IPM costs were included in operation cost as Table (9) that presented the economic impact of different substrate types and systems on Gerbera production. The highest investment cost illustrated by Bags RW 100 while Pots P: P 7.5 recorded the lowest value of investment cost. Operation cost of different treatments were constant. Total cost differed regarding the investiment cost value. Bags RW 100 had the highest total cost while the lowest total cost presented by pots P: P 7.5.

The yield of Gerbera per greenhouse span calculated based on the average Gerbera yield / plant * No. of plants / span. The price of Gerbera flower determined based on the average of commercial price along the season instead of the varied quality referring the Egyptian market condition. However, the gained results of Table (9) indicated that the real economic benefit of the current study, Pots P: P 10 treatment demonstrated the highest return followed by Cont. P: P. On the other hand Bags RW 100 followed by Bags RW 70 had the lowest net profit. In general, Peat moss: perlite instead of the used system had a positive economic effect on Gerbera production. Pots system Performed the economic suitable system for producing Gerbera under greenhouse.

Table 9: The economic impact of different substrate types and systems on gerbera production.

Soilless system & type	Average cost and profitable impact (LE / standard greenhouse span 540 m²)						
	Investment costs	Operation cost	Total cost	Av. yield (flower/ span)	Flower LE	Return LE	Net profit LE
Bags P: P 40	15167	22500	37667	11334	5	56668	19001
Bags P: P 30	13053	22500	35553	9899	5	49495	13942
Bags RW 100	21507	22500	44007	9500	5	47500	3493
Bags RW 70	17280	22500	39780	8864	5	44318	4538
Bags CP 40	17280	22500	39780	9652	5	48260	8480
Pots P: P 10	16000	22500	38500	11875	5	59375	20875
Pots P: P 7.5	12517	22500	35017	10213	5	51063	16046
Cont. P: P	14460	22500	36960	11476	5	57380	20420

* P: P40 (peat moss: perlite 40 L volume), P: P30 (peat moss: perlite 30 L volume), RW 100 (Rockwool density 100 g/m2), RW 70 (Rockwool density 70 g/m2), P: P10 (peat moss: perlite 10 L volume), P: P 7.5 (peat moss: perlite 7.5 L volume) and Cont. P: P (Containers system peat moss: perlite (1 :1 v/v)).

6. Discussion

Smart monitoring-alarming system presented a great assistance as a smart farming management for offering and accessing the real-time record data of micro-climate conditions (temperature and relative humidity) under the greenhouse as well as environmental conditions that led to manage smartly the fertigation, water, nutrient solution supply and conserve the pump operation and energy use. The monitoring maximum, average and minimum of both temperature and relative humidity daily regarding the hourly sensing of temperature and relative humidity plus alarming system of extreme weather events (mainly temperature in the current study) support significantly the controlled environmental agriculture (CEA). Moreover, the modification of pumping schedules for different substrate types and systems regarding the detection of substrate moisture as a result of developing the growth stage of Gerbera and climate conditions is playing a vital role in conserve the water and energy use effeciencies and avoiding any irrigation water stress on Gerbera plants.

On the other hand, the sensing of nutrient solution EC levels of different substrate types and systems performed a narrow range of EC. The investigation observed strongly the need to increase the range of sensing EC of nutrient solution more than 950 ppm that didn't match the actual fertigation program of Gerbera while the need to achieve to 1500 ppm during the flowering and production stage.

Producing Gerbera in substrate culture, the use of close substrate culture system drived the use of available standard substrates in Egyptian market. Increasing the volume of substrate in pots system from 7.5 to 10 L / plant or in bags system from 10 to 13.3 L / plant or up to 15.3 L / plant in container had a significant impact on Gerbera production and economic instead of the higher costs. The substrate volume could be lowerd until 25%, without yield reduction, if irrigation scheduling is adapted to the lower water buffer (Pardossi et al., 2011).

Adequate substrate type and volume offered the best growth conditions for root that led to enhance the vegetative growth and yield of gerbera. It's essential to strike a balance of the substrate volume, physical and chemical properties of substrate and its economic cost for Gerbera plants considering the used system of substrate, to develop of growth stage, climate, watering practices, and the specific requirements of Gerbera plants for proper growth and development. These facts agreed with (Ludwig et al., 2013; Gilmar and Betina, 2022).

Understanding the physical and chemical properties of substrates is crucial for successful gerbera production .Additionally, it's advisable to determine the physical and chemical properties of substrate and other growing conditions as needed to optimize their vegetative growth and yield productivity of Gerbera. As well as increasing the substrate rock wool density from 70 to 100 (kg/m^3) had a positive impact on the Gerbera production regarding better physical and chemical properties but not on the economic scale. Obviously, the peat moss: perlite 1 : 1 v/v provide superior effect on producing Gerbera instead of varied system. Peat moss : perlite presented the standard substrate that offer the best condition for vegetative growth and yield development compared the other substrate in the same system of bags. The results thus obtained are compatible with that reported the substrate 50% Perlite+ 50% peat gave the best that number of flowers, flower height, flower diameter, shoot diameter results (Dragoș et al., 2020). To mentioned that quality parameters of Gerbera flower were affected by choice of the substrate (Van Labeke and Dambre, 2008).

Container P: P followed by bags P: P followed by Pots P: P 10 gave the highest significant results of the Plant height (cm), No. of leaves, average leaf area (cm^2), No. of offsets / plant, total sugar (%), chlorophyll A, Chlorophyll B and total chlorophyll content of Gerbera leaves that could explain the results of yield parameters due to the strong vegetative growth of Gerbera in peat moss: perlite compared to the rest of substrate such as days to flowering, flower fresh and dry weight (g).

Logically under the positive effect of substrate peat moss : perlite, the highest yield parameters such as No. of flower / plant, flower stalk length, flower stalk diameter and flower head diameter recorded by the same substrate in the different systems (bags, pots and container). Concerning chemical analysis of Gerbera plants, similar results were obtained while the lowest values recorded by bags RW 70 followed by bags CP.

Coco peat had a suitable physical and chemical properties but the issue was in the high salinity of this substrate and the difficulty of leaching this salinity during the cultivation and season that appreared clearly on the Gerbera growth.

The physical and chemical properties of substrate had a significant impact on N, P and K (%) contents of Gerbira plants that demonstrated in peat moss: perlite due to the enhencement of root growth system and vegetative growth that agreed with (Ludwig et al., 2013; Abul-Soud et al., 2021).

Substrate culture of Gerbera based on increasing production and profit that drive the economic study of cultivation Gerbera under greenhouse (Maloupa et al., 1993). The economic impact assessment promote strongly the implement of Pots P: P 10 followed by Container P: P that presented the highest net profit of Gerbera production that match the study recommendtaion.

Conclusion

Although the study encourage the use of smart monitoring- alarming system as smart farming management, but the need for smart control also is urgent for matching the climate change impacts and to offer quick response for any emergency. Also, smart agriculture (monitoring and control) will increase not just the production and quality og Gerbera but also the water and power use efficiencies.

The study recommended strongly not just from the horticulture scale or production but with economic consideration the use of peat moss : perlite 1:1 v/v in pots system for achieving the yield net profit of gerbera.

Study also recommended taking in consider the coco peat salinity and the necessity of leaching before cultivation and repeat leaching every season in the begining and at the end.

In general, the use of different substrate types and systems in producing Gerbera were profitable economically under Egyptian greenhouse conditions. The most important factor in defining the substrate type or system should be based on profitability of production, not yield that could be the limited factors regarding the available conditions.

In summary, the choice of substrate and cultivation system significantly affects the growth, health, and overall productivity of Gerbera plants. Growers should implement the use of smart farming management for better management, control and production as well as select appropriate substrates and cultivation systems based on production and profitability for their Gerbera cultivation.

Competing interests

The authors declared that present study was performed in absence of any conflict or competing of interest.

References

Abul-Soud M, M. H. Mohammed, M. S. A. Emam, and Z. Y. Maharik. 2020. Sustainable Ecology Strawberry Production via Different Soilless Culture Techniques under Urban Conditions. Egypt. J. Hort., 47 (2): Pp. 205-218.

Abul-Soud M. A., M. S. A. Emam, and Sh. M. Mohammed. 2021(A). Smart hydroponic greenhouse (Sensing, monitoring and control) prototype based on Arduino and IoT. International Journal of Plant & Soil Science, 33(4): Pp. 63-77. 53.

Abul-Soud M. A., M. S. A. Emam, Z. Y. Maharik, M. H. Mohammed and A. M. H. Hawash. 2017. How to sustain ecology food production under urban condition. Zagazig J. Agric. Res., Vol. 44 No. (4): Pp. 1259-1276.

Allen, S. E., 1974. Chemical Analysis of Ecological Materials. Black-Well, Oxford,565.

Awang Y., Shaharom, A.S., Mohamad, R.B., and Selamat, A. 2009. Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of Celosia cristata. American Journal of Agricultural and Biological Sciences 4: Pp. 63–71.

Dewis, J., and Freitas, F., 1970. Physical and chemical methods of soil and water analysis food and Agric. Organization of the United Nations of Soils Bulletin No. (10): Pp. 275.

Dragoş Emanuel Draghici, Sorina Petra, Florin Toma, Ovidiu Ionuț Jerca. 2020. The influence of substrate type on growth and flowering of gerbera plants. Scientific Papers. Series B, Horticulture. Vol. LXIV, No. 1.

Erstad, J.L.F., and Gisleród, H.R., 1994. Water uptake of cuttings and stem pieces as affected by different anaerobic conditions in the rooting medium. ScientiaHortic., 58: Pp. 151-160.

FAO. Food and Agriculture Organization, 1980. Micro nutrients and the nutrient status of soils. FAO Soils Bulletin,;48: Pp. 242-250.

Gilmar Schafer and Betina Luíza Lerner. 2022. Physical and chemical characteristics and analysis of plant substrate. Ornamental Horticulture, 28, (2): Pp. 181-192.

Grafiadellis I, Mattas, K., Maloupa, E., Tzouramani, I., Galanopoulos, K., 2000. An Economic Analysis of Soilless Culture in Gerbera Production. HORTSCIENCE 35(2): Pp. 300–303.

Iftikhar Ahmad1, Tanveer Ahmad, Arfan Gulfam, Muhammad Saleem., 2012. Growth And Flowering Of Gerbera As Influenced By Various Horticultural Substrates Pak. J. Bot., 44: Pp. 291-299, Special Issue March 2012.

Inbar, Y., Hadar, Y., and Chen, Y., 1993. Recycling of cattle manure: The composting process and characterization of maturity. J. of Environ. Quality, 22: Pp. 857-863.

Khalaj M. A, M. Amiri and S.S. Sindhu. 2011.Study on the effect of different growing media and yield of Gerbera (GERBERA JAMESONII L). Journal of Ornamental plants, 1: 185-189.,

Khalaj, M., 2007. Gerbera cultivation guide. National Research Station of flowers and ornamental plants Publications, Bulletin No. 86, Pp. 394. Markazi, Iran.

Ludwig, F., Fernandes, D.M., Mota, P.R.D., Villas Boas, R.L., 2013. Electrical conductivity and pH of the substrate solution in gerbera cultivars under fertigation. Horticultura Brasileira 31: Pp. 356-360.

Macz, O., E.T. Paparozzi and W.W. Stroup. 2001. Effect of nitrogen and sulfur applications on pot chrysanthemum production and postharvest performance, Leaf nitrogen and sulfur concentrations. J. Plant Nutri., 24: Pp. 111-129.

Maloupa, E. I., Mitsios, P. F., Martinez, Bladenopoulou, S., 1993. Study of substrates used in Gerbera culture in plastic greenhouse, Acta Hort.(ISHS), 323:Pp. 139- 144.

María José Gómez Bellot, Giulia Carmassi2, Manuele Bartalucci2, María Jesús Sánchez-Blanco, Alberto Pardossi2., 2018. Evapotranspiration And Mineral Content Of Gerbera Under Combined Salinity And Excess Boron. Journal of Horticultural Research, 26(2): Pp. 61-69.

Olympios, C.M., 1992. Soilless media under protected cultivation rockwool, peat, perlite and other substrates. Acta Horticult., 323: Pp. 215-234.

Pardossi A, C. G, C. Diara, I. L, R. Maggini, D. Massa. 2011. .Fertigation and Substrate Management in Closed Soilless Culture. Dipartimento di Biologia delle Piante Agrarie, Università di Pisa, Pisa, Italy.

Raul, I. C., 1996. Measuring Physical Properties. Rutgers Cooperative Extension. New Jersey Agriculture Experiment Station, New Jersey University.

Razieh Nikpour, Ahmad Mohammadi Ghehsareh, and Jaber Fallahzade., 2015. Effects of Cultivation of Gerbera on some Physical and Chemical Properties of Different Growing Substrates. Research Journal of Soil Biology 7 (2): Pp. 64-71.

Robertson, R.A., 1993. Peat, horticulture and environment. Biodivers. Conserv.; 2: Pp. 541–547.

Smith, E.; M.A. Gilles; D.K. Hamilton and P.A. Gedees (1956). Colorimetric method for determination of sugars and related substances Anal. Chem., 28(1): 350.

Snedicor, G.W., Cochran, W.G., 1981. Statistical methods. 7th Iowa State Univ. Press, Iowa, USA,; Pp. 225-320 .

Sonneveld, C., Baas, R., Nijssen, H.M.C., de Hoog, J., 1999. Salt tolerance of flower crops grown in soilless cul ture. Journal of Plant Nutrition 22: Pp. 1033–1048.

Van Labeke, M.-C., and Dambre, P., 1998. Gerbera cultivation on coir with recirculation of the nutrient solution: a comparation with rockwool culture. Acta. Hort 458:Pp. 357-362.

Vidalie, H., 2007. Varietal richness and technology for gerbera. PHM – Revue Horticole 497: Pp. 33–41.

Von Wettstein, D., 1957. Chlorophyll letale and der sub-mikroskopishe formweschselder plastiden. Experimental Cell Research, 12, Pp. 427-506. doi: 10.1016/0014-4827(57)90165-9.

Watanabe, F.S., Olsen, S.R., 1965. Test of an ascorbic acid method for determining phosphorus in water and Na HCO3 extracts from soil. Soil Sci. Soc. Amer. Proc.29: Pp. 677-678.

Wilson, G.C.S., 1983. The physico-chemical and physical properties of horticultural substrate. Acta Hort., 150: Pp. 19-32.