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Original Article

Conditioning of desert sandy soil and investigation of the ameliorative effects of poultry manure and bentonite treatment rate on plant growth

Condicionamento do solo arenoso do deserto e investigação dos efeitos melhoradores do esterco de aves e da taxa de tratamento com bentonita no crescimento das plantas

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Abstract

Soil is the base of any ecosystem since it conserves nutrients and water for plant roots including agriculture and plantations. In dry and semi-arid places across the world, including the UAE, sandy soils are common. Their fertility is extremely low, and production is hampered by a number of agronomic challenges. Soil conditioner sources like bentonite and chicken manure might be used to improve the poor sandy soil attributes and hence boost soil productivity. From November 2019 to March 2020, an experiment was conducted to investigate the growth rates of Bougainvillea following bentonite and chicken manure amendments to sandy soil taken from Lehbab, Dubai. Bougainvillea was evaluated for its plant height (cm), max length of primary branch (cm), the number of leaves per plant, number of secondary branches, shoot weight (g), root length (cm), root weight (g), root/shoot ratio, chlorophyll contents, and chlorophyll a* and b*. In this experiment, a complete randomized design (CRD) with five treatments was used (10 replications per treatment). According to the findings, bentonite and chicken manure additions considerably influence the productive properties of sandy soil, as indicated by Bougainvillea growth. Additionally, the research suggests that Bougainvillea may be efficiently planted with 10% bentonite and 15% chicken manure applied to sandy soil, resulting in the healthiest plants compared to other amendments.

Keywords: soil physiochemical properties, sandy soil conditioning, bentonite, poultry manure, plants, growth analysis.

Resumo

O solo é a base de qualquer ecossistema, incluindo agricultura e plantações, pois conserva nutrientes e água para as raízes das plantas. Em lugares secos e semiáridos em todo o mundo, incluindo os Emirados Árabes Unidos, os solos arenosos são comuns. Sua fertilidade é extremamente baixa e a produção é prejudicada por uma série de desafios agronômicos. Fontes de condicionador de solo, como bentonita e esterco de galinha, podem ser usadas para melhorar os atributos do solo arenoso pobre e, portanto, aumentar a produtividade do solo. De novembro de 2019 a março de 2020, foi realizado um experimento para investigar as taxas de crescimento de buganvílias após bentonita e esterco de galinha em solo arenoso retirado de Lehbab, Dubai. A buganvília foi avaliada quanto à altura da planta (cm), comprimento máximo do ramo primário (cm), número de folhas por planta, número de ramos secundários, peso da parte aérea (g), comprimento da raiz (cm), peso da raiz (g), razão raiz/parte aérea, teores de clorofila e clorofila a* e b*. Neste experimento foi utilizado o delineamento inteiramente casualizado (DIC) com cinco tratamentos (10 repetições por tratamento). De acordo com os resultados, as adições de bentonita e esterco de galinha influenciam consideravelmente as propriedades produtivas do solo arenoso, conforme indicado pelo crescimento de buganvílias. Além disso, a pesquisa sugere que a buganvília pode ser plantada com eficiência

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com 10% de bentonita e 15% de esterco de galinha aplicado em solo arenoso, resultando, assim, em plantas mais saudáveis em comparação com outras alterações.

Palavras-chave: propriedades físico-químicas do solo, condicionamento de solo arenoso, bentonita, esterco de frango, plantas, análise de crescimento.

1. Introduction

The soil, which stores nutrients and water for plant roots, is the cornerstone of any ecosystem, including urban gardening and plantations. The ability of soil to operate within ecosystems by sustaining plant productivity, protecting or enhancing air and water quality, and promoting environmental and human health is characterized as soil quality (Wander et al., 2002; Yang et al., 2022). Soil quality also affects plant development by altering the quality of nutrients acquired by plant roots. Chemical indicators in soil include salinity, pH, organic matter, cation exchange capacity, phosphorus concentrations, nutrient cycling, and concentrations of potentially polluting components (examples are heavy metals and radioactive substances, etc.) or the ingredients which are necessary for the development and growth of the plants. The chemical health of the soil influences soil-plant relationships (Adil et al., 2023; Adil et al., 2022), quality of water available, buffering capacity, accessibility of plants and soil organisms to water and nutrient content, contaminant movements, and a few physical properties of soil, for example, crust formation. Soil quality analyses have been offered as a management tool or support to assist gardeners and farmers in selecting specific management options as well as a measure of sustainability (Kourgialas et al., 2022; Gondal et al., 2021b; Gondal and Tayyiba, 2022; Jiang et al., 2022). They also advocated those approaches for assessing and defining soil quality be suited to specific goals, including sustainable agriculture, environmental quality, and the health of humans and animals.

Sandy soils can be found all throughout the world, including the UAE, in dry and semi-arid climates. It is commonly considered as soil with well-defined physical properties, such as loss structure or no structure, low water retention capability, high permeability, and high vulnerability to erosion, all of which have severe consequences for plantation and agriculture. Sandy soil has low cation exchange capacity (CEC), soil buffering capacity, and readily leached cations because it contains little clay and organic matter (Sohail et al., 2021; Gondal et al., 2022). On the other hand, clayey soils have a higher CEC as well as a higher nutrient and water retention capacity and if the clay soil is nutrient-rich, adding clay soil to sandy soil may boost nutrient availability. To ameliorate the sandy soil's fertility, measures to boost nutrients and water-holding capacity are required, including the addition of clay and organic matter. The presence of microorganism can also boost the productivity of the soil (Younas et al., 2022). A clay ameliorant also decreased N and P leaching in sandy soils from Penola in South Australia (Tahir and Marschner, 2017). The clay soil may be acquired from neighbouring locations or from any source and mixed with the sandy soil to improve its properties and productivity. It is evident that the importance of the organic matter in sandy soils follows water and is assumed to overcome weak physical features, notably hydro-physical properties, and stimulate aggregate formation. Organic amendments to sandy soil, such as compost, crop waste, and animal manure, improve its quality (Abdelrahman and Dawi, 2009; Gondal et al., 2022). This method is crucial in sandy dune soils, where poor features constitute a considerable impediment to plantation and agriculture. Organic components in organic additives can significantly increase water infiltration, soil aggregation, microbial activity, water-holding capacity, and structure, particularly in dry desert and semiarid soils, while also lowering soil compaction and erosion (Rezig et al., 2013).

Organic amendments can also improve the chemical properties of soil, such as organic carbon, cation exchange capacity, and soil pH. Poultry manure is an extraordinary fount of organic fertiliser when compared to other organic sources because it contains a high percentage of nitrogen, phosphorous, potassium, and other important minerals that are easily available for plant uptake (Gondal et al., 2021a). It ameliorates the physical qualities and needs of the soil, as well as nutrient absorption and crop and plant productivity. Poultry manure improves soil quality by increasing organic matter content, which stimulates the aggregate stability and structure, increases aeration, buffers soil reactivity, cation exchange capacity, capacity to retain water, and microbiological activities. Furthermore, organic content in the soil improves the total porosity of the soil, degree of aggregation, and hydraulic conductance of poor soil (Ojeniyi et al., 2013). Poultry manure can also ameliorate water penetration in soil by serving as an alternate for the soil's capacity to allow the flow of water in both horizontal and lateral gradients into and through the soil profile.

2. Significance of Work

According to United Nations forecasts, the globe's population will reach 9.7 billion by 2050. To fulfil the food requirements of the world's expanding population, soil fertility investigations using a scientific approach are crucial for evaluating the possibilities and limits of a given soil in terms of fitness for a certain application and assuring its long-term use to produce plants. The fertility and texture of desert soils are defined by their loose structure, higher sandy particle percentage, restricted biological impacts, and lower organic matter presence and nutrient content and cultivation on sandy desert soils is very challenging. However, after reclamation, soil fertility and texture can be significantly enhanced as a result of considerable changes in the soil formation process, notably increases in root carbon intake and biomass production as well as other organic matter influx. The primary goal of this study was to assess the beneficial impacts of bentonite and chicken manure treatment rates on plant growth in arid sandy soils. This research is primarily pertinent to ornamentals, but it will help the worldwide work on desert sandy soils for agricultural goals in order to fulfil rising food demands by producing crops on desert sandy soils.

3. Methodology

3.1. Study area description

The research area is located in the United Arab Emirates, Dubai Emirate. The experimental site was in Dubai, and the soil for the study was gathered from Lehbab district of Dubai Emirate. The Emirate's climate is arid, subtropical, and warm. Air temperatures vary between 35 degrees and 50 degrees Celsius in the middle of the day from May to October, and between 20 and 35 degrees Celsius in the winter months. The warmest temperatures on the ground in the interior of the desert during the summer can reach 70°C, while the coldest temperatures during the winter can plummet below 0°C. The Emirate's average annual rainfall is less than 100 millimeters, with most of it falling during the winter months. Monsoon rains pour on the east coast and in the mountain belt that forms the watershed between the Gulf of Oman and the Arabian Gulf during the summer months. The rainfall, on the other hand, is very irregular and fluctuates greatly from one year to the next and location to location. Windstorms and sandstorms are also prevalent across the Emirate of Dubai. Sand dunes dominate the scenery across much of the Emirate.

3.2. Soil sampling

For experimental purposes, six soil samples were gathered from three separate places inside Lehbab. Soil samples were collected from each place at two different intervals of depth (0–20 and 20–40 cm). Samples were collected by using a soil auger at each sampling location. After collection, all the samples were transported to the lab, air-dried, and sieved (2 mm) to be carefully analyzed for physiochemical characteristics. The fundamental physicochemical properties were investigated through the passage of a 2 mm sieve.

3.3. Physiochemical analysis of soil samples

Soil texture, pH, total nitrogen, sulphate, zinc (Zn), manganese (Mn), potassium (K), phosphorus (P), nickel (Ni), molybdenum (Mo), magnesium (Mg), electrical conductivity, copper (Cu), calcium (Ca), and boron (B) were determined in the laboratory.

The soil samples used to investigate the physiochemical characteristics were subsampled. Wet sieving according to Blaud et al. (2017) was used on one fraction of each sample to determine a uniform particle size distribution (PSD). Before the analyses, the other sections of the samples were air dried and put through a 2-mm screen to eliminate any extraneous impurities. The organic matter content of soil samples was determined using Blaud et al. (2017). Total metals were extracted from sieved soil samples using a version of EPA SW-846 Method 3050. The total elemental composition (Zn, Mn, K, Ni, Mo, Mg, Cu, and B) of the soil extracts was determined using an Inductively-Coupled Plasma Optical Emission Spectrometer (ICPE-9820, Plasma Atomic Emission Spectrometer) in accordance with EPA SW-846 Method. Total nitrogen content was determined using the Kjeldahl technique, while phosphorus (P) content was determined after Bray 1 extraction from 2 grammes of soil using the molybdenate reduction procedure as described in HACH Method. using the spectrometer system (Estefan et al., 2013). The electrical conductivity (EC) of the soil samples was assessed using a 1:10 water extraction followed by a conductivity meter probe (ECCONSEN9501D, ATC probe), and the pH of the soil samples was determined using.

The data showed that the percentage of clay and silt content of the soils was 1-2 percent for soil samples obtained from the Lehbab region. The sand content of the soil samples ranged from 98 to 99 percent, and the soil's electroconductivity varied between 0.141-0.144 mmhos/cm. Furthermore, the total nitrogen content ranged from 10.85 to 11.5 mg/kg. Micro and macro nutrients were also examined, and the findings for all physiochemical parameters are shown in Table 1.

3.4. Soil fertility improvement and plantation

The soil from Lehbab was obtained for experimental purposes after a thorough investigation of its physiochemical characteristics. Bentonite was acquired from a Sharjah-based vendor, and a commercial variety of poultry manure was purchased and applied to the soil to improve its properties. Table 2 shows the manufacturers' listed characteristics of bentonite while Table 3 shows the manufacturers' listed characteristics of poultry manure. The manure came in the shape of a powder and was simple to apply. To prepare the soil for subsequent organic amendments, bentonite was mixed at various percentage rates initially. The potting soil was made by combining varying quantities of Lehbab sandy soil with clayey soil from bentonite samples and poultry manure.

Round earthenware planter pots with a depth of 46 cm and a diameter of 31 cm were used in this study. To prepare the conditioned soil for filling the pots, the pots were first filled with oven-dried and cooled Lehbab sandy soil, which was then weighted. Later, the potting soil was produced by mixing 5% bentonite with 95% Lehbab Sandy Soil (treatment L95 before chicken manure addition) and 10% bentonite with 90% Lehbab Sandy Soil (treatment L90 before poultry manure addition). Later, the ratios of poultry manure were determined using already prepared Lehbab sandy soil and bentonite blends. The varying amounts of organic additions were manually and consistently mixed into the already prepared bentonite and sandy soil mixes to fill the pots. To prepare the amended soil for this investigation, chicken manure was added to both blended mixes in percentages of 10 (L95A and L90A) and 15 (L95B and L90B), respectively, whereas treatment L100 (control) corresponds to 100 percent Lehbab sandy soil with no addition of bentonite or poultry manure. Except for the treatment L100, an inorganic fertiliser (NPK 12-12-17) was subsequently supplied and blended into the soil medium

Table 1. Physiochemical properties of Lehbab Sandy Soil (desert soil).

Physiochemical Properties of Soil		Soil Sample / Depth (cm)					
		L1A	L1B	L2A	L2B	L3A	L3B
Element	Units	0-20	20-40	0-20	20-40	0-20	20-40
Sulphate	%	0.05	0.52	0.51	0.51	0.53	0.51
Organic Matter Content	%	0.09	0.085	0.11	0.093	0.13	0.09
Zinc	mg/kg	11.6	11.5	11.2	11.1	11.9	11.1
Total Nitrogen	mg/kg	11	10.9	11.2	10.85	11.5	11
Manganese	mg/kg	163	163	162.5	162	164	163.5
Potassium	mg/kg	920	930	925	922	926	918
Phosphorus	mg/kg	5.01	5.02	5	5.2	5.08	5.1
Nickel	mg/kg	81.9	82.3	80.3	79.6	76.8	82.3
Molybdenum	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Magnesium	mg/kg	12494	12500	12498	12495	12490	12488
Electrical Conductivity	mmhos/cm	0.141	0.142	0.141	0.143	0.143	0.144
Copper	mg/kg	5.91	5.92	4.88	4.95	5.95	5.98
Calcium	mg/kg	126327	126300	126301	126350	126338	126330
Boron	mg/kg	30.4	30.2	30.1	30.9	31.1	31.2
Clay/ Silt	%	2	1	2	2	1	2
Sand	%	98	99	98	98	99	98
pH	-	8.61	8.58	8.56	8.56	8.6	8.6

Table 2. Physiochemical properties of Bentonite used in this study.

Parameters	Specification
PH (5% Soln.)	8.5
Calcium as CaO, %	2.47
Silica as SiO2, %	53.31
Iron as Fe2O3,%	12.44
Magnesium as MgO,%	3.95
Calcium as CaO,%	1.85
Sodium as Na2O, %	1.89
Potassium as K2O,%	0.08

Table 3. Physiochemical properties of poultry manure used in this study.

Parameters	Specification
Organic Matter, %	74.07
pH	5.56
CN ratio	10.99
Sodium Chloride, %	1.15
Electrical Conductivity, mmhos/cm3	12.63
Phosphorus, %	1.5
Potassium, %	1.5
Fe, ppm	700
Zn, ppm	450
Mn, ppm	10
Cu, ppm	6.5
B, ppm	20

for each pot at a regulated rate of 20 grammes per pot. Following the preparation of these blends, the prepared soil medium was offered a 10% moisture addition. Before filling the pots, moisture was correctly and evenly mixed into the prepared media. Planting pots were then filled to the brim with these prepared soil combinations, leaving the top 1 cm unoccupied (L95A, L95B, L90A, and L90B). Pots were filled with the goal of providing an adequate substrate for root development and producing healthy plants. After filling the pots, they were left open and watered every day to avoid moisture loss and offer an ideal substrate for the improved soil to thrive. After one week, the plants were planted in the pots.

The moisture measurement technique was used before irrigation. Every day, between 9 a.m. and 11 a.m. in the morning and 5 p.m. to 6 p.m. in the afternoon, a moisture check reading was obtained. Irrigation was used anytime the moisture content in the soil fell below 6%. Since the weight of the conditioned soil was already known, a certain amount of water was supplied to the pots to achieve the 10% moisture by weight of the potting medium. The irrigation cycle was resumed if the soil moisture level dropped below 6%. Controlled drip irrigation was used in this study, and the required amount of water was given on two sides of each plant within the planting container. Moisture measurements were taken for each pot, and each pot was watered separately as needed. Irrigation was performed once a day before the plantation and as needed following the plantation. During this investigation, the proportions of sandy soil, bentonite, and chicken manure mentioned in Table 4 were mixed thoroughly to prepare the growing substrates for plants.

On November 12, 2019, rooted cuttings of a commercial kind of Bougainvillea were obtained from a nursery in Dubai, United Arab Emirates, and the plants (two months old) were transplanted into the pots. Rooted cuttings were carefully chosen for their uniform height and number of leaves.

3.5. Determination of plant attributes

The 10 best plants for each treatment were divided into roots, leaves, and stems at the end of this study (20 March 2020; 128 days after transplanting DAT) to perform plant growth analysis. Bougainvillea was evaluated for its plant height (cm), max length of primary branch (cm), the number of leaves per plant, number of secondary branches, shoot weight (g), root length (cm), root weight (g), root/shoot ratio, chlorophyll contents (SPAD value), and chlorophyll a* and b*.

The plant's height attributes were measured using a meter tap as the total distance between its top and the substrate's surface. The number of leaves on each under-examination plant was also counted. In addition to counting secondary branches, the distance between the main stem of the plant and the tip of the longest primary branch was measured and termed as max branch length.

The distance between the stem's base and the tip of the longest root, known as the maximum root length, was also measured. After soaking in water, roots jumbled inside soil aggregates of the growth media were carefully pushed through a mesh sieve (0.50 mm) to remove the roots trapped in the substances with the least amount of breakage and loss. The sieved potting medium materials were then disposed.

Plant tissues were dried at 70°C for 96 hours until they reached a consistent weight and then weighted using an electrical balance to calculate the appropriate dry biomass. The dried biomass of the shoots, determined in grammes per plant, was equal to the total of the stems and leaves. Dried root weight was also calculated using the same technique. The root/shoot ratio was determined by dividing the root's dry weight by the overall dry weight of the leaves and stem.

Table 4. Growing substrates with different proportions of bentonite and poultry manure.

Sample Identity	Lehbab Sandy Soil %	Bentonite %	Poultry Manure %
L100	100	0	0
L95A	95	5	10
L95B	95	5	15
L90A	90	10	10
L90B	90	10	15

A portable chlorophyll meter, SPAD-502, was used to measure the chlorophyll contents on enlarged leaves on March 20, 2020 (128 DAT) (Konica Minolta, Japan). The chlorophyll contents measurements were obtained at the center of the leaves, between the midrib and the leaf margin. For each replication, twenty leaves were picked at random and averaged to get a single chlorophyll contents value.

In this experiment, the Hunter Lab colour space coordinates a* and b* were adopted. The red-green axis (a*) offers chlorophyll a value with positive values for red and negative values for green. The yellow-blue axis (b*) offers chlorophyll b values with positive values for yellow and negative values for blue. While the value 0 is neutral in both cases a* and b*. These colour space parameters were measured using a Minolta CR-300 Chroma Meter (Minolta Camera Co. Ltd, Japan) near the top portion's midpoint of the studied leaf's surface. Before sampling the Bougainvillea leaf, the Minolta standard white plate was used to calibrate the Chroma Meter, and the measurement diameter of the aperture was 8 mm.

4. Statistical Analysis

The investigation in this experiment was administered using a complete randomized design (CRD) with five treatments (10 replications per treatment), and "Statistix 8.1®" software was used to pool and analyse the data. The one-way ANOVA was used to determine if there were significant variations in the parameters investigated across treatments.

5. Results

5.1. Bougainvillea plant attributes

The addition of bentonite and chicken manure to the growth substrates enhanced Bougainvillea plants' attributes, including plant height (cm), max length of primary branch (cm), the number of leaves per plant, number of secondary branches, shoot weight (g), root length (cm), root weight (g), root/shoot ratio, chlorophyll contents, and chlorophyll a* and b* (Table 5). The effect of the addition of bentonite and poultry manure on Bougainvillea attributes varied significantly among different applied concentrations. The highest values of plants were attributes obtained from the substrate L90B. The lowest values of plant attributes were obtained in the substrate L100, which was without poultry manure and bentonite treatment (control). Findings show that Bougainvillea may be effectively planted with 15% chicken manure, providing the healthiest plants (Table 5).

Aeqt45The data regarding plant height showed that the addition of bentonite and poultry manure significantly increased Bougainvillea plant height (60.5 cm) in treatment

Table 5. Bougainvillea plants attributes under different soil treatments. L100 substrate contains 100% Lehbab Sandy Soil without any addition of Bentonite and Poultry Manure. L95A substrate contains 95% Lehbab Sandy Soil, 5% Bentonite, and 10% Poultry Manure. L95B substrate contains 95% Lehbab Sandy Soil, 5% Bentonite, and 15% Poultry Manure. L90A substrate contains 90% Lehbab Sandy Soil, 10% Bentonite, and 10% Poultry Manure. L90B substrate contains 90% Lehbab Sandy Soil, 10% Bentonite, and 15% Poultry Manure. Statistical letters a, b, c, d, show significant difference between plants attributes grown on different substrates, while the ab, bc, cd etc. show there is no significant difference between plants attributes.

Plant attributes	Treatments				
	L100	L95A	L95B	L90A	L90B
Plant height, cm	33.41^{d}	42.58^{c}	42.97^{c}	45.93^{b}	55.87^{a}
Leaves/ plant	129.1^{c}	142.7^{c}	149.2^{c}	192.3^{b}	289.2^{a}
Root length, cm	21^{d}	23.05^{c}	23.68^{c}	25.3^{b}	28.53^{a}
Dry Shoot weight, g	22.27^{c}	25.99^{b}	26^{b}	26.64^{ab}	27.41^{a}
Dry Root weight, g	6.06^{d}	7.55^{c}	7.8^{bc}	8.36^{b}	9.61^{a}
Root/ Shoot	0.273^{c}	0.291^{bc}	0.300^{b}	0.314^{b}	0.351^{a}
Number of Secondary branches	4^{d}	5^{c}	6^{b}	6^{b}	8^{a}
Max length of branch, cm	18.2^{d}	19.32^{c}	18.99^{cd}	25.04^{b}	29.82^{a}
Chlorophyll contents	18.73^{d}	21.79^{c}	23.17^{bc}	24.44^{b}	27.91^{a}
Chlorophyll a*	-6.27^{d}	-7.15^{cd}	-7.92^{c}	-10.7^{b}	-22.35^{a}
Chlorophyll b*	19.85^{c}	16.04^{b}	15.48^{b}	15.83^{b}	14.2^{a}

L90B compared to other treatments. Additionally, there was also a significant increase in maximum branch length and root length under the 10 percent bentonite and 15 percent poultry manure application in treatment L90B. We found a maximum branch length of 31.2 cm and a maximum root length of 30.8 cm for the plants grown in the treatment L90B. However, the addition of bentonite and poultry manure also performed better with plant height, maximum branch length, and root length in treatment L90A, with a max plant height of 48.9 cm, a maximum branch length of 26.9 cm, and a root length of 26.3 cm. However, the control treatment showed the least plant attributes as compared to other studied treatments. Figure 1 designates the effects of different percentages of bentonite and poultry manure on Bougainvillea plants' height, maximum branch length, and root length.

The data regarding the number of secondary branches and number of leaves per plant showed that the addition of bentonite and poultry manure significantly increased Bougainvillea plant's number of secondary branches to a maximum of 8 branches per plant and the number of leaves per plant to 338 leaves per plant in treatment L90B compared to other treatments. Figure 2 designates the effects of different percentages of bentonite and poultry manure on the number of secondary branches per plant and number of leaves per plant for Bougainvillea grown in different substrates (Treatment L100, L95A, L95B, L90A, and L90B). However, the control treatment showed the least number of secondary branches and the number of leaves per plant as compared to other studied treatments.

The data regarding the dry shoot weight, dry root weight, and root/shoot ratio showed that the addition of bentonite and poultry manure significantly increased Bougainvillea plant's dry shoot weight to a maximum of 28.5 grammes, and dry root weight to a maximum of 11.2 grammes per plant, and a root/shoot ratio of 41 percent in treatment L90B compared to other treatments (Figure 3). However, the addition of bentonite and poultry manure also performed better with the dry shoot weight, dry root

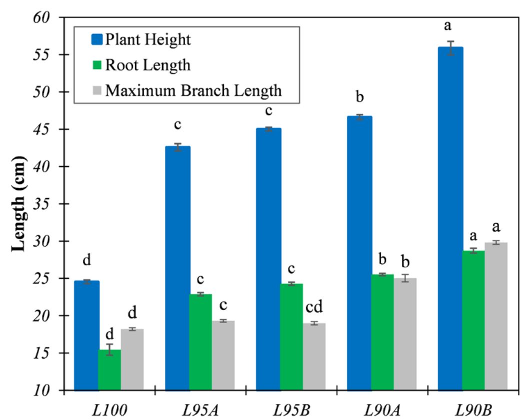

Figure 1. Comparison of Plant Height, Root Length, and Maximum Branch Length for Bougainvillea grown in different substrates (Treatment L100, L95A, L95B, L90A, and L90B. L100 substrate contains 100% Lehbab Sandy Soil without any addition of Bentonite and Poultry Manure. L95A substrate contains 95% Lehbab Sandy Soil, 5% Bentonite, and 10% Poultry Manure. L95B substrate contains 95% Lehbab Sandy Soil, 5% Bentonite, and 15% Poultry Manure. L90A substrate contains 90% Lehbab Sandy Soil, 10% Bentonite, and 10% Poultry Manure. L90B substrate contains 90% Lehbab Sandy Soil, 10% Bentonite, and 15% Poultry Manure. Statistical letters a, b, c, d, show significant difference between plants attributes grown on different substrates, while the ab, bc, cd etc. show there is no significant difference between plants attributes.

weight, and root/shoot ratio in treatment L90A, with a maximum dry shoot weight of 27 grammes, a maximum dry root weight of 9.1 grammes, and a root/shoot ratio of 33 percent. However, the control treatment showed the least weights of the dry shoot weight, dry root weight, as well as the least root/shoot ratio as compared to other studied treatments. Figure 3 designates the effects of different percentages of bentonite and poultry manure on the dry shoot weight, dry root weight, and root/shoot ratio for Bougainvillea plants grown in different substrates (Treatment L100, L95A, L95B, L90A, and L90B).

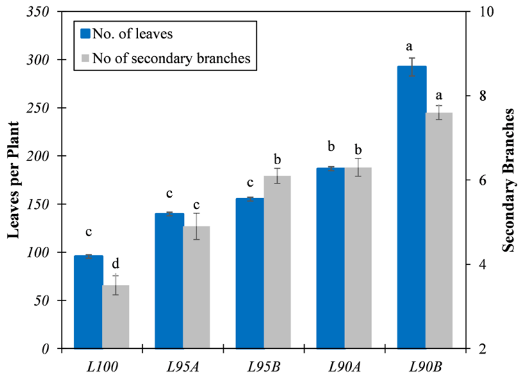

Figure 2. Comparison of Number of Secondary Branches per Plant and Number of Leaves per Plant for Bougainvillea grown in different substrates (Treatment L100, L95A, L95B, L90A, and L90B. L100 substrate contains 100% Lehbab Sandy Soil without any addition of Bentonite and Poultry Manure. L95A substrate contains 95% Lehbab Sandy Soil, 5% Bentonite, and 10% Poultry Manure. L95B substrate contains 95% Lehbab Sandy Soil, 5% Bentonite, and 15% Poultry Manure. L90A substrate contains 90% Lehbab Sandy Soil, 10% Bentonite, and 10% Poultry Manure. L90B substrate contains 90% Lehbab Sandy Soil, 10% Bentonite, and 15% Poultry Manure. Statistical letters a, b, c, d, show significant difference between plants attributes grown on different substrates, while the ab, bc, cd etc. show there is no significant difference between plants attributes.

Similar to plant agronomic development characteristics, the colour parameters of Bougainvillea plants' leaves, a* (Figure 4), were strongly impacted by the bentonite and poultry manure percentage used in the growing soil. Although not remarkable, there were treatment effects on the colour parameters b* as well. Figure 4 designates the effects of different percentages of bentonite and poultry manure on the Chlorophyll a*, Chlorophyll b*, and chlorophyll contents for Bougainvillea grown in different substrates (Treatment L100, L95A, L95B, L90A, and L90B). The plants cultivated in the medium with 100 percent Lehbab sandy soil had the least plant growth attributes of Bougainvillea.

5.2. Correlation among different attributes of Bougainvillea

Correlation analysis showed that there was a highly significant relationship among all the growth and physiological parameters of Bougainvillea. Figure 5 revealed a correlation matrix graphically by corrplot. A highly significant association was observed in the growth and physiological parameters of Bougainvillea with a very strong correlation with Poultry Manure and Bentonite addition to soil with all other measured attributes.

5.3. Principal component analysis (PCA)

The principal component analysis (PCA) showed the distribution of different treatments in the Bougainvillea plant in sandy soil and amended sandy soil with the addition

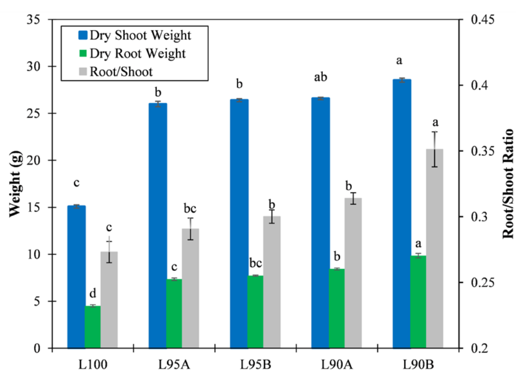

Figure 3. Comparison of Dry Shoot Weight, Dry Root Weight, and Root/Shoot ratio for Bougainvillea plants grown in different substrates (Treatment L100, L95A, L95B, L90A, and L90B. L100 substrate contains 100% Lehbab Sandy Soil without any addition of Bentonite and Poultry Manure. L95A substrate contains 95% Lehbab Sandy Soil, 5% Bentonite, and 10% Poultry Manure. L95B substrate contains 95% Lehbab Sandy Soil, 5% Bentonite, and 15% Poultry Manure. L90A substrate contains 90% Lehbab Sandy Soil, 10% Bentonite, and 10% Poultry Manure. L90B substrate contains 90% Lehbab Sandy Soil, 10% Bentonite, and 15% Poultry Manure. Statistical letters a, b, c, d, show significant difference between plants attributes grown on different substrates, while the ab, bc, cd etc. show there is no significant difference between plants attributes.

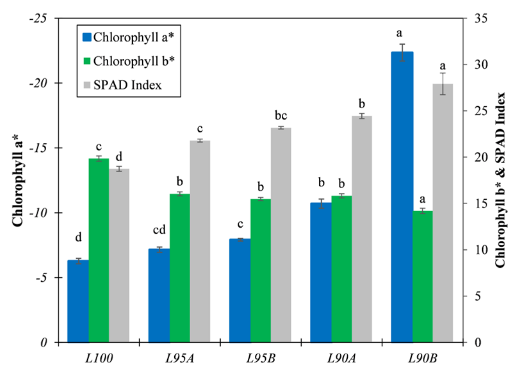

Figure 4. Comparison of Chlorophyll a*, Chlorophyll b*, and chlorophyll contents for Bougainvillea grown in different substrates (Treatment L100, L95A, L95B, L90A, and L90B. L100 substrate contains 100% Lehbab Sandy Soil without any addition of Bentonite and Poultry Manure. L95A substrate contains 95% Lehbab Sandy Soil, 5% Bentonite, and 10% Poultry Manure. L95B substrate contains 95% Lehbab Sandy Soil, 5% Bentonite, and 15% Poultry Manure. L90A substrate contains 90% Lehbab Sandy Soil, 10% Bentonite, and 10% Poultry Manure. L90B substrate contains 90% Lehbab Sandy Soil, 10% Bentonite, and 15% Poultry Manure. Statistical letters a, b, c, d, show significant difference between plants attributes grown on different substrates, while the ab, bc, cd etc. show there is no significant difference between plants attributes.

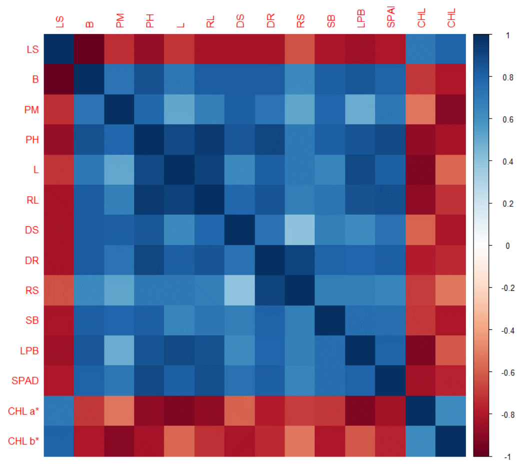

Figure 5. Corrplot (Correlation plot) represents correlation matrix among different attributes of Bougainvillea followed by treatments as (1) L100 (2) L95A (3) L95B (4) L90A (5) L90B. L100 substrate contains 100% Lehbab Sandy Soil without any addition of Bentonite and Poultry Manure. L95A substrate contains 95% Lehbab Sandy Soil, 5% Bentonite, and 10% Poultry Manure. L95B substrate contains 95% Lehbab Sandy Soil, 5% Bentonite, and 15% Poultry Manure. L90A substrate contains 90% Lehbab Sandy Soil, 10% Bentonite, and 10% Poultry Manure. L90B substrate contains 90% Lehbab Sandy Soil, 10% Bentonite, and 15% Poultry Manure. The dark blue color shows a high positive correlation while light blue and sky blue represent less association among measured parameters. The color legend on the right-hand side of corrplot shows the correlation coefficient and corresponding colors. The abbreviations are Lehbab Sandy Soil (LS) Poultry Manure (PM), Bentonite (B), Plant Height (PH), Number of Leaves (L), Root Length (RL), Dry Shoot Weight (DS), Dry Root Length (DR), Root to Shoot Ratio (RS), Number of Secondary Branches (SB), Max Branch Length (LPB), Chlorophyll contents (SPAD), Chlorophyll a* (CHL a), Chlorophyll b* (CHL b).

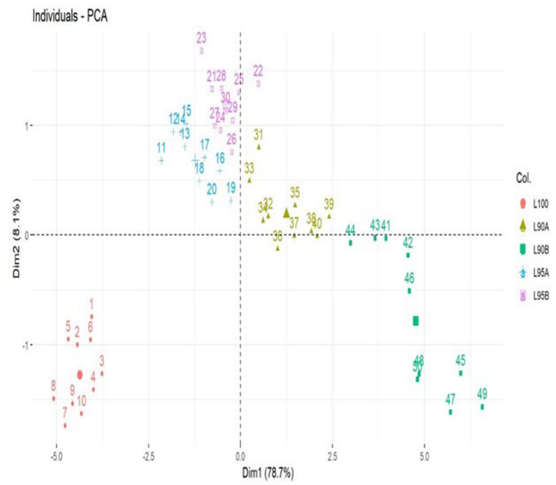

Figure 6. Principal component analysis (PCA) showing score plot plots of different attributes of Bougainvillea plants in sandy soil and amended sandy soil with the addition of different proportions of Bentonite and Poultry Manure. The figure represents the separation of treatments as (1) L100, (2) L95A (3) L95B (4) L90A (5) L90B. L100 substrate contains 100% Lehbab Sandy Soil without any addition of Bentonite and Poultry Manure. L95A substrate contains 95% Lehbab Sandy Soil, 5% Bentonite, and 10% Poultry Manure. L95B substrate contains 95% Lehbab Sandy Soil, 5% Bentonite, and 15% Poultry Manure. L90A substrate contains 90% Lehbab Sandy Soil, 10% Bentonite, and 10% Poultry Manure. L90B substrate contains 90% Lehbab Sandy Soil, 10% Bentonite, and 15% Poultry Manure.

of different proportions of Bentonite and Poultry Manure as presented in the score plot (Figure 6). Significant results were obtained from the score plot of PCA performed for two factors (Cumulative variance 86.8%), the first represents 78.7% of variation while 8.1% of the difference is explained by the second factor. Hence, there is great variation among all treatments in Bougainvillea plants. The loading plot (Figure 7) shows a better visualization of the relationship and variation among all studied parameters of Bougainvillea planted in sandy soil and amendments with the addition of different proportions of Bentonite and Poultry Manure.

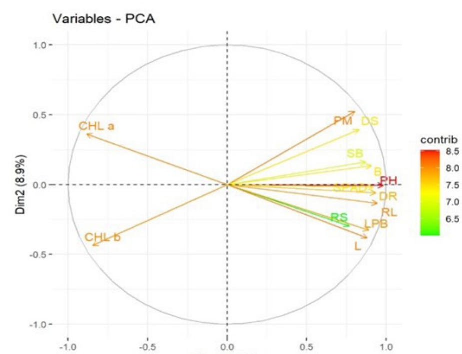

Figure 7. Principal component analysis (PCA) showing loading of each studied attribute (arrow) and arrow lengths approximate their variance whereas the angles between them represent their correlation. The abbreviations are Poultry Manure (PM), Bentonite (B), Plant Height (PH), Number of Leaves (L), Root Length (RL), Dry Shoot Weight (DS), Dry Root Length (DR), Root to Shoot Ratio (RS), Number of Secondary Branches (SB), Max Branch Length (LPB), Chlorophyll contents (SPAD), Chlorophyll a* (CHL a), Chlorophyll b* (CHL b).

6. Discussion

According to United Nations predictions, the world's population will reach 9.7 billion by 2050, posing a monumental task of producing enough food to feed that population. As a result, we must make rational decisions about new strategies to expand our food production capability in the future. Food production issues are and will remain challenging, particularly on sandy soils. Due to high bulk density, limited water-holding and nutrient retention capacity, and fast mineralization of soil organic matter, sustainable agriculture on sandy soils often faces significant challenges. Because of these factors, most sandy soils are unsuitable for large agricultural yields because they are physically and chemically unstable, have low fertility, and are deficient in mineral reserves.

Bentonite is a natural soil conditioner, and using it as such may be an effective way to address some of the modern agricultural issues associated with drought stress and soil deterioration in agricultural systems. Adding clay as a soil supplement to sandy soil will improve soil accessible water, organic carbon, and potassium, as well as boost crop emergence and yield (Hall et al., 2010; Mohamed Amanullah et al., 2010).

Organic additions, such as poultry manure, enhance soil characteristics by increasing organic matter content, which has a stimulating influence on structure and aggregate stability. When compared to other organic sources, poultry manure is an extraordinary source of organic fertiliser because it includes a high percentage of nitrogen, phosphorous, potassium, and other critical elements that are readily available for plant absorption (Xiang et al., 2022). It enhances soil physical properties and conditions, as well as nutrient absorption and crop yield (Arora et al., 2022).

Several studies (Ronchi et al., 2006) demonstrated the relatively small size of a plant's container restricted the root development. Scientists discovered that reducing a plant's root expansion impacts nutrient uptake and hence the plant's growth. Chlorophyll is a key photosynthetic pigment in plants, influencing photosynthetic capability and hence plant development [40]. Previous studies have shown that photosynthetic rates have a direct effect on plant growth. Furthermore, photosynthesis is the most significant source of energy for plant development and growth (Puangbut et al., 2017; Baker, 2008; Li et al., 2018).

The addition of bentonite and chicken manure to the growth substrates enhanced Bougainvillea plants agronomic and physiological attributes including plant height (cm), max length of primary branch (cm), the number of leaves per plant, chlorophyll contents and chlorophyll a* and b* (Table 5). The effect of the addition of bentonite and poultry manure on Bougainvillea agronomic and physiological attributes varied significantly among different applied concentrations. The highest values of plants agronomic attributes were obtained in the substrate L90B, while the lowest values of plant attributes were obtained in the substrate L100, which was without poultry manure and bentonite treatment (control). Similar to agronomic characteristics, the physiological parameters, chlorophyll a* (Figure 4), of Bougainvillea plants' leaves were strongly impacted by the bentonite and poultry manure percentage used in the growing soil. Although not remarkable, there were bentonite and poultry manure percentage effects on the chlorophyll b* as well (Figure 4). When compared to other treatments, growing the Bougainvillea plants in pots containing 10% bentonite and 15% chicken manure (L90B) boosted leaf greenness while decreasing yellowness. The chlorophyll contents increased linearly (Figure 5) as the bentonite and chicken manure percentage in the growth substrates rose, with the L100 treatment yielding the lowest results. Similarly, the L100 treatment had the lowest chlorophyll concentration, whereas L90B had the reverse tendency with healthiest grown plant.

The least plant development attributes of Bougainvillea grown in the medium that included 100 percent Lehbab sandy soil are quite probably connected to the soil's physicochemical properties, for example, lower water content and higher content of air, this usually equates to less water availability for plants and less water retention capacity in comparison to other studied growing mediums. The reduced biomass output and reduction in plant development characteristics seen in plants grown on 100 percent Lehbab sandy soil appear to be connected to the ability to sustain a lower degree of photosynthesis in comparison to other treatments. Photosynthesis rose with bentonite and chicken manure increments in soil treatments, which was accompanied by a rise in a* achlorophyllous pigments and an increase in the chlorophyll value. Furthermore, a lack of nutrient availability in growth substrates might explain the lower photosynthesis and growth associated with L100.

7. Conclusion

According to the results of the current experiment, the addition of bentonite and chicken manure enhanced the characteristics of sandy soil while also promoting the development and photosynthetic activity of potted bougainvillea. The results show that 15% chicken manure and 10% bentonite added to sandy soil may effectively plant bougainvillea and produce the best plants when compared to other researched amendments. The poor plant development features of the L100 treatment, which were later enhanced by the addition of bentonite and chicken manure, revealed that the examined sandy soil had a comparatively low fertility level. The results of the plant characteristics discovered throughout this investigation might be experiment-specific. These results will need to be supported by future research that conduct further experiments with a wide range of plant species and soil amendment approaches. The verification of the findings from this study's growth analysis of Bougainvillea could be seen as a crucial and important step in illuminating the intricate and complex sandy soil amelioration techniques used to improve the quality and growth of plants and undertaking the advantageous effects of bentonite and poultry manure amendments, resulting in more sustainable plants and crop production. Despite the fact that this research primarily pertains to ornamental plants, it will support efforts being made worldwide to cultivate crops on desert sandy soils in order to meet the world's growing food demand.

References

ABDELRAHMAN, M.A. and DAWI, B.E.S.I. (2009). Decomposition and nutrient release from various tree litters in a sandy soil of a semi-arid tropics. *Sudan Journal of Desert Research*, vol. 1, no. 1, pp. 36-55.

ADIL, M., BASHIR, S., BASHIR, S., ASLAM, Z., AHMAD, N., YOUNAS, T., ASGHAR, R.M.A., ALKAHTANI, J., DWININGSIH, Y. and ELSHIKH, M.S., 2022. Zinc oxide nanoparticles improved chlorophyll contents, physical parameters, and wheat yield under salt stress. *Frontiers in Plant Science*, vol. 13, p. 932861. http://dx.doi.org/10.3389/fpls.2022.932861. PMid:35991444.

ADIL, M., SHAH, A.N., KHAN, A.N., YOUNAS, T., MEHMOOD, M.S., MAHMOOD, A., ASGHAR, R.M.A. and JAVED, M.S., 2023. Amelioration of harmful effects of soil salinity on plants through silicon application: a review. *Pakistan Journal of Botany*, vol. 55, no. 1, pp. 1-10. http://dx.doi.org/10.30848/PJB2023-1(24).

ARORA, A., NANDAL, P., and CHAUDHARY, A. (2022). Critical evaluation of novel applications of aquatic weed Azolla as sustainable feedstock for deriving bioenergy and feed supplement. *Environmental Reviews*, vol. 30, no. 4, pp. 1-12. https://doi.org/10.1139/er-2022-0033.

BAKER, N.R., 2008. Chlorophyll fluorescence: a probe of photosynthesis in vivo. *Annual Review of Plant Biology*, vol. 59, pp. 89-113. http://dx.doi.org/101146/annurev.arplant59032607092759. PMID: 18444897.

BLAUD, A., MENON, M., VAN DER ZAAN, B., LAIR, G.J. and BANWART, S.A., 2017. Effects of dry and wet sieving of soil on identification and interpretation of microbial community composition. *Advances in Agronomy*, vol. 142, pp. 119-142. http://dx.doi.org/10.1016/bs.agron.2016.10.006.

ESTEFAN, G., SOMMER, R. and RYAN, J., 2013. *Methods of soil, plant, and water analysis: a manual for the West Asia and North Africa region*. 3rd ed. Beirut: International Center for Agricultural Research in the Dry Areas.

GONDAL, A.H. and TAYYIBA, L., 2022. Prospects of using nanotechnology in agricultural growth, environment and industrial food products. *Reviews in Agricultural Science*, vol. 10, pp. 68-81. http://dx.doi.org/10.7831/ras.10.0_68.

GONDAL, A.H., BHAT, R.A., GÓMEZ, R.L., ARECHE, F.O. and HUAMAN, J.T., 2022. Advances in plastic pollution prevention and their fragile effects on soil, water, and air continuums. *International Journal of Environmental Science and Technology*, pp. 1-16. http://dx.doi.org/10.1007/s13762-022-04607-9. Online.

GONDAL, A.H., TAMPUBOLON, K., TOOR, M.D. and ALI, M., 2021a. Pragmatic and fragile effects of wastewater on a soil-plant-air continuum and its remediation measures: a perspective. *Reviews in Agricultural Science*, vol. 9, no. 0, pp. 249-259. http://dx.doi.org/10.7831/ras.9.0_249.

GONDAL, A.H., ZAFAR, H., YOUSAF, H., FAROOQ, Q., IMRAN, B., CH, M.D.T. and SALEEM, S., 2021b. Impacts of tillage technologies on soil, plant, environment and its management: a short communication. *Indian Journal of Pure and Applied Biosciences*, vol. 9, no. 3, pp. 76-83. http://dx.doi.org/10.18782/2582-2845.8682.

HALL, D.J.M., JONES, H.R., CRABTREE, W.L. and DANIELS, T.L., 2010. Claying and deep ripping can increase crop yields and profits on water repellent sands with marginal fertility in southern Western Australia. *Soil Research (Collingwood, Vic.)*, vol. 48, no., 2, pp. 178-187. http://dx.doi.org/10.1071/SR09078.

JIANG, W., GONDAL, A.H., SHAHZAD, H., IQBAL, M., BUSTAMANTE, M.A.C., YAPIAS, R.J.M., MARCOS, R.N.D.L.C., ARECHE, F.O., VICTORIO, J.P.E., COTRINA CABELLO, G.G. and NIETO, D.D.C., 2022. Amelioration of Organic Carbon and Physical Health of Structurally Disturbed Soil through Microbe–Manure Amalgam. *Processes (Basel, Switzerland)*, vol. 10, no. 8, pp. 1506. http://dx.doi.org/10.3390/pr10081506.

KOURGIALAS, N.N., HLIAOUTAKIS, A., ARGYRIOU, A.V., MORIANOU, G., VOULGARAKIS, A.E., KOKINOU, E., DALIAKOPOULOS, I.N., KALDERIS, D., TZERAKIS, K., PSARRAS, G., PAPADOPOULOS, N., MANIOS, T., VAFIDIS, A. and SOUPIOS, P., 2022. A web-based GIS platform supporting innovative irrigation management techniques at farm-scale for the Mediterranean island of Crete. *The Science of the Total Environment*, vol. 842, pp. 156918. http://dx.doi.org/10.1016/j.scitotenv.2022.156918. PMid:35753465.

LI, Y., HE, N., HOU, J., XU, L., LIU, C., ZHANG, J., WANG, Q., ZHANG, X. and WU, X., 2018. Factors influencing leaf chlorophyll content in natural forests at the biome scale. *Frontiers in Ecology and Evolution*, vol. 6, pp. 64. http://dx.doi.org/10.3389/fevo.2018.00064.

MOHAMED AMANULLAH, M., SEKAR, S. and MUTHUKRISHNAN, P., 2010. Prospects and potential of poultry manure. *Asian Journal of Plant Sciences*, vol. 9, no. 4, pp. 172-182. http://dx.doi.org/10.3923/ajps.2010.172.182.

OJENIYI, S.O., AMUSAN, O.A., and ADEKIYA, A.O., 2013. Effect of poultry manure on soil physical properties, nutrient uptakeand yield of Cocoyam (Xanthosoma saggitifolium) in Southwest Nigeria. *American-Eurasian Journal of Agricultural & Environmental Sciences*, vol. 13, no. 1, pp. 121-125. http://dx.doi.org/10.5829/idosi.aejaes.2013.13.01.1861.

PUANGBUT, D., JOGLOY, S. and VORASOOT, N., 2017. Association of photosynthetic traits with water use efficiency and SPAD chlorophyll meter reading of Jerusalem artichoke under drought conditions. *Agricultural Water Management*, vol. 188, pp. 29-35. http://dx.doi.org/10.1016/j.agwat.2017.04.001.

REZIG, F.A.M., MUBARAK, A.R. and EHADI, E.A., 2013. Impact of organic residues and mineral fertilizer application on soil–crop system: II soil attributes. *Archives of Agronomy and Soil Science*, vol. 259, no., 9, pp. 1245-1261. http://dx.doi.org/10.1080/03650340.2012.709623.

RONCHI, C.P., DAMATTA, F.M., BATISTA, K.D., MORAES, G.A., LOUREIRO, M.E. and DUCATTI, C., 2006. Growth and photosynthetic down-regulation in Coffea arabica in response to restricted root volume. *Functional Plant Biology*, vol. 33, no. 11, pp. 1013-1023. http://dx.doi.org/10.1071/FP06147. PMid:32689312.

SOHAIL, S., GONDAL, A.H., FAROOQ, Q., TAYYABA, L., ZAINAB, D.E., AHMAD, I.A. and USAMA, M. 2021. Organic vegetable farming; a valuable way to ensure sustainability and profitability. In E. YILDIRIM and M. EKINCI, eds. *Vegetable crops - health benefits and cultivation*. London: IntechOpen.

TAHIR, S. and MARSCHNER, P., 2017. Clay addition to sandy soil reduces nutrient leaching: effect of clay concentration and ped size. *Communications in Soil Science and Plant Analysis*, vol. 48, no. 15, pp. 1813-1821. http://dx.doi.org/10.1080/00103624.2017.1395454.

WANDER, M., WALTER, G.L., NISSEN, T.M., BOLLERO, G.A., ANDREWS, S.S., and CAVANAUGH-GRANT, D.A., 2002. Soil quality: science and process. *Agronomy Journal*, vol. 94, no. 1, pp. 23-32. http://dx.doi.org/10.2134/AGRONJ2002.2300.

XIANG, L., HARINDINTWALI, J.D., WANG, F., REDMILE-GORDON, M., CHANG, S.X., FU, Y., HE, C., MUHOZA, B., BRAHUSHI, F., BOLAN, N., JIANG, X., OK, Y.S., RINKLEBE, J., SCHAEFFER, A., ZHU, Y.G., TIEDJE, J.M. and XING, B., 2022. Integrating biochar, bacteria, and plants for sustainable remediation of soils contaminated with organic pollutants. *Environmental Science & Technology*, vol. 56, no. 23, pp. 16546-16566. http://dx.doi.org/10.1021/acs.est.2c02976. PMid:36301703.

YANG, W., MIN, Z., YANG, M. and YAN, J., 2022. Exploration of the implementation of carbon neutralization in the field of natural resources under the background of sustainable development: an overview. *International Journal of Environmental Research and Public Health*, vol. 19, no. 21, pp. 14109. http://dx.doi.org/10.3390/ijerph192114109. PMid:36360986.

YOUNAS, T., UMER, M., HUSNAIN GONDAL, A., AZIZ, H., KHAN, M.S., JABBAR, A. and ORE ARECHE, F., 2022. A comprehensive review on impact of microorganisms on soil and plant. *Journal of Bioresource Management*, vol. 9, no. 2, pp. 12.