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The Ecological Significance of Ornamental Plants in Enhancing Air and Soil Quality and Promoting Drought Resilience

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ABSTRACT
It was hard to select and apply an appropriate criterion for assisting the selection of the ornamental plant (O.P.) species in certain cases - species that are not the priority for environmental impacts (air and soil quality, drought resistance), which were the primary focus of this study. Despite the increasing attention focused on the ecological benefits of ornamental plants, few studies have evaluated the synergistic effects of ornamental plants (O.Ps.) on air pollution (A.P.) tolerance, heavy metal (H.M.) accumulation, and drought tolerance. 9 ornamental plants grown in the campus of Anbar, Iraq, were sampled. Biochemical parameters like relative water contents (R.W.C.), ascorbic acid content (A.A.C.), leaf extract pH, and aggregate chlorophyll concentration (A.C.C.) were analyzed to calculate values for the Air Pollution Tolerance Index (A.P.T.I.). To evaluate the potential of these plants for phytoremediation of H.M.-contaminated soils, plants were cultivated in plastic pots with two types of soil. Plant species and soils were initially and finally analyzed to determine the 5 H.Ms. concentrations through the atomic absorption spectrometer. In addition, these plants were subjected to four water regimes to assess their drought response and tolerance, with nine plant samples per treatment. After one month, different morphological indices were noted for each species with different treatments of water supply. Of the species studied, 8.7 (*Dieffenbachia sp.*), 8.4 (*Chlorophytum comosum*), and 7.4 (*Epipremnum aureum*) presented the highest A.P.T.I. values, differing significantly among species ($p < 0.001$). Moreover, the contents of H.Ms. in both soils were reduced during the plant growth, especially for Cd and Zn. For all species, the irrigation treatments (from 100 to 25% water) had a strong effect on the morphological indices. It is suggested that O.Ps. cannot only reduce the environmental hazards through A.P. reduction and heavy metal-contaminated soil remediation, but also fight against water deficit stress. Furthermore, the use of O.Ps. can contribute to dealing with environmental problems that are related to sustainability, and it is promising, efficient, and ecological.

الأهمية البيئية لنباتات الزينة في تحسين جودة الهواء والتربة وتعزيز القدرة على مقاومة الجفاف

زياد محمد عبد الرزاق ، لؤي صبحي ثابت ، هبة ارحيم الفهداوي ، اثير هاشم عبد المجيد ، اثير محمد اسماعيل الجنابي
قسم البستنة وهندسة الحدائق ، كلية الزراعة ، جامعة الأنبار ، العراق

الخلاصة
كان من الصعب اختيار وتطبيق معيار مناسب للمساعدة في اختيار أنواع نباتات الزينة (.O.P) في حالات معينة وخاصةً الأنواع التي ليست ذات أولوية للتأثيرات البيئية (جودة الهواء والتربة، ومقاومة الجفاف)، والتي كانت المحور الأساسي لهذه الدراسة. على الرغم من الاهتمام المتزايد الذي يركز على الفوائد البيئية لنباتات الزينة، إلا أن دراسات قليلة قامت بتقييم التأثيرات التآزرية لنباتات الزينة (.O.Ps) على تحمل تلوث الهواء (.A.P)، وتراكم المعادن الثقيلة (.H.M)، وتحمل الجفاف. تم أخذ عينات من 9 نباتات زينة مزروعة في حرم جامعة الأنبار بالعراق. تم تحليل المؤشرات الحيوية الكيميائية مثل محتوى الماء النسبي (.R.W.C)، ومحتوى حمض الأسكوربيك (.A.A.C)، ودرجة حموضة مستخلص الأوراق، وتركيز الكلوروفيل الكلي (.A.C.C) لحساب قيم مؤشر تحمل تلوث الهواء (.A.P.T.I). لتقييم إمكانات هذه النباتات في المعالجة النباتية للتربة الملوثة بـ .H.M، زرعت النباتات في أواني بلاستيكية مع نوعين من التربة. تم تحليل أنواع النباتات والتربة في بداية ونهاية التجربة لتحديد تركيزات 5 .H.Ms من خلال مطياف الامتصاص الذري. فضلاً عن ذلك، خضعت هذه النباتات لأربعة أنظمة مائية لتقييم استجابتها للجفاف وتحملها، مع تسع عينات نباتية لكل معاملة. بعد شهر واحد، لوحظت مؤشرات مورفولوجية مختلفة لكل نوع مع معاملات الري المختلفة. من بين الأنواع المدروسة، أظهرت *Dieffenbachia sp.* (8.7) و *Chlorophytum comosum*(8.4) و *Epipremnum aureum* (7.4) أعلى قيم .A.P.T.I، حيث اختلفت بشكل كبير بين الأنواع ($p < 0.001$). فضلاً عن ذلك، انخفض محتوى .H.Ms في كلتا التربتين أثناء نمو النبات، وخاصة بالنسبة للكادميوم والزنك. بالنسبة لجميع الأنواع كان لمعاملات الري (من 25% إلى 100٪ ماء) تأثير قوي على المؤشرات المورفولوجية. يُقترح أن .O.Ps لا يمكنها فقط تقليل المخاطر البيئية من خلال تقليل .A.P ومعالجة التربة الملوثة بالمعادن الثقيلة، ولكن أيضاً في مقاومة إجهاد نقص المياه. فضلاً عن ذلك إن إستخدام المنتجات التشغيلية يمكن أن يساهم في التعامل مع المشاكل البيئية المرتبطة بالاستدامة، وهو أمر واعد وفعال وصديق للبيئة.
الكلمات المفتاحية: الاستدامة ، نباتات الزينة ، تلوث الهواء ، إصلاح التربة ، الجفاف

INTRODUCTION

The unparalleled development of urbanization and population, especially in developing countries including Iraq, has shifted the focus towards A.P. and the environment. These areas are subject to serious A.P. due to various pollutants, such as industrial emissions (heavy gases), vehicular exhaust, dust, etc. Additionally, pollution levels are aggravated by human activities like haphazard burning and improper disposal of wastes (Abdulrazzaq *et al*., 2024a; Molnár *et al*., 2020 & Ahmad *et al*., 2019). Such pollution badly threatens the urban environment, the ecosystem, and human health. Studies have that O.Ps. may mitigate A.P. through the uptake of the fine particles by their roots (Kumar *et al*.,2023). This procedure will reduce the amount of pollutants by as much as a third. These plants are also good absorbing and purging toxic elements from the air in enclosed spaces (Jumaa *et al*., 2021; Teiri *et al*., 2018 & Setälä *et al*., 2013). As such, they help to improve indoor air quality. The leaves of many O.Ps. are also large, leading to a high surface area for the removal of various airborne pollutants (Ahmad *et al*., 2019).

Soil pollution is a critical global concern that jeopardizes environmental sustainability. The soil has been one of the Pollution by man's activities, which includes technological processes of mining and metallurgic processes led to deposition of heavy metals (H.Ms.) in the soils (Okunlola *et al*., 2021 & Nakbanpote *et al*., 2016). H.Ms. are regarded as some of the most toxic contaminants in soil, since both possible crop health and human health is at risk due to disturbed ecological balance (Khan *et al*.,2021). The lack of water resources under climate change has become a key challenge for global sustainable development (Zhao et al., 2024 & Elansary & Salem, 2015). Water constraint

intensifies drought stress, adversely impacting attractive plants and hindering the development of sustainable landscape.

Those that underwent a long time of selection, such as ornamental plants (O.Ps.) that are widely integrated into human environments, even show a wide divergence (Monder *et al*., 2024). In terms of horticulture, these plants are valued for aesthetics and leisure (Monder *et al*., 2024 & Katoch *et al*., 2024). The predominant species in colleges and public spaces include *Verbena, Spathiphyllum, Epipremnum, Chlorophytum, Asparagus* and *Dieffenbachia*. These plants are usually used as potted plant production, cut flowers or planted directly as ornamental plants (Amulu *et al*., 2023; Platis *et al*., 2023 & Kapoor *et al*., 2017). In an urban situation, life quality is improved by providing decorative passages or terraces that are exposed to intensive sunlight. They bring more benefits to urban green spaces as well (Katoch *et al*.,2024). Population living in cities will reach 68% by 2050 (Paiva *et al*.,2024). This is indicative of the increasing urgency for varied green infrastructure, where O.Ps. are anticipated to make a greater contribution to urban environmental quality. Because of their effects on thermal modulation, noise attenuation, A.P., and psychological well-being. These functions are increasingly important in urbanized, high-density areas filled with concrete buildings. Ornamental plants should be further studied for the potential environmental services they provide such as improvement of air quality, soil quality, drought tolerance and contribution to aesthetics, and because of their ecological importance and contribution to biodiversity.

Air purification and air quality improvement are important for urban sustainable development (Saxena *et al*.,2021). It can be achieved by decor with appropriate ornamental plants. There are A.P.-tolerant (high to very high) and A.P.-sensitive species there (Avilala *et al*.,2024). Various levels of sensitivity and/or tolerance to A.P. have been observed among ornamental plant species (Rai *et al*.,2013 & Molnár *et al*.,2020). This variation is in position to many of the biochemical parameters like R.W.C., pH, A.A.C. and A.C.C. These biochemical traits have proved their utility as tools to classify and study responses of plants to the A.P. They are also capable of identifying anti pollinate and sensitive species through Air Pollution Tolerance Index (A.P.T.I.). A.P.T.I. as a sustainability analysis tool is discussed (Molnár *et al*.,2020 & Saxena *et al*.,2021). These O.Ps. have been successfully employed by landscape architecture experts for urban environment election based on the A.P.T.I. A.P.T.I. indicates the plant's ability to tolerate A.P. such that high A.P.T.I. shows tolerant species, and low A.P.T.I. refers to a sensitive species (Ahmad *et al*.,2019 & Saxena *et al*.,2021).

For the sake of environmental sustainability, O.Ps. were used in phytoremediation to obtain toxic removal and H.M. desorption from the contaminated soil (Liu *et al*.,2018 & Okunlola *et al*.,2021). These plants, having specific morphological characteristics, proved to be effective in decreasing soil pollutants. They are also cheap and environmentally friendly, so the efficient Fenton oxidation process has been considered as a kind of green technology (Mandal *et al*.,2023).

Beyond this water-saving capacity for landscapes due to their drought tolerance and low water requirement, O.Ps. help to you sustain water too (Leotta *et al*.,2023 & Abdulrazzaq *et al*.,2024b). Ornamental plants can respond to drought due to their morphological and physiological adaptations for surviving water stress (Toscano *et al*.,2014). Ornamental species differ in drought tolerance, and some are more resistant to

drought while others are sensitive (Zhao *et al*., 2024).These adaptation processes also influence the ornamental and visual aesthetics of Ornamental Plants (O.Ps.). Therefore, there is a need to search for drought-resistant ornamental species to improve landscape quality and support urban green sustainability. Therefore, it is important to screen out drought-resistant ornamental species in order to improve landscape quality and to develop green sustainability in urban areas. In addition, O.P. species were selected in this study for their proven multifunctional characteristics, abundant accessibility, and typical use in modern landscaping.

Though many studies have dealt with the functions of single O.P. in air purifying, soil remediating or drought tolerance, few have examined three O.F.P. dimensions of the same species in a comprehensive way together. In general, these functional traits have been studied in an isolated way (e.g., as response to soil or air pollutants, as adjustment to water deficiency, or only as an decorative worth), overlooking the potential synergistic functions that certain species may offer. To fill this research gap, this experiment is the first to systematically evaluate and estimate the comprehensive potential of nine O.P. species to tolerate A.P., accumulate H.Ms. to restore soil, and survive drought stress. Using a multi-assessment approach, the work contributes to a comprehensive picture of how O.ps. can foster urban sustainability. It also provides a new method of choosing multifunctional species for use in green infrastructure planning. This extends approaches for building environmentally sustained urban fabric (a domain that has been neglected in past work). Because of the potential for O.Ps. to improve air quality and reduce environmental pollution, specifying species that have the greatest ecological value is one of key tasks on promoting sustainable landscapes. This investigation is taken a step further of testing the potential of ornamental plants for environmental clean-up. It assesses their potential for air pollution load mitigation and remediation capabilities to remove H.Ms., including lead (Pb), cadmium (Cd), zinc (Zn), nickel (Ni) and copper (Cu) from H.M. contaminated soils. Furthermore, the evaluation of drought resistance is necessary to both achieve sustainable landscaping and support long lasting urban greening projects. As such, continued study is needed to discover and rank ornamental species that provide aesthetic value and multiple ecosystem services.

MATERIALS AND METHODS

The Experimental Design and Plants Samples

The present study was carried out throughout the 2023-2024 season at the Campus of the University of Anbar in AL-Anbar/Ramadi, Iraq. Nine types of Ornamental Plants (O.Ps.) were chosen (Table 1) cultivated on campus and along the street, specifically those exposed to external air pollution and emissions. The selection of Ornamental Plant species was grounded in established functional features identified in prior research. Specific species were selected for their established ability to cleanse A.Ps., while others exhibited both air filtration and drought resistance. Moreover, some species have been documented to exhibit the capability to repair contaminated soils via heavy metal absorption. Several selected species were chosen for their abundant presence in local ecosystems and to evaluate their capacity to mitigate environmental pollution and enhance urban sustainability. The plants were cared for according to their needs with the proper fertilization and irrigation, and were subsequently monitored for six months. The investigation was conducted throughout the spring and summer months from March to

August. A.P. levels linked to several O.P. species were evaluated during spring, a time of enhanced vegetative development and physiologic activity in these species. This time of year was chosen because from July to September, moderate temperatures, low relative humidity, and high sun radiation promote healthy plant growth and enhance their ability to absorb contaminants. Mature leaves were gathered each September (at 8:00AM) from several sites of each species (Figure1), wrapped in sterile bags with sample codes stamped, and transported to the laboratory for analysis within three hours of collection.

Table1: This study encompasses ornamental plants

No.	General	Name of attractive plants Taxonomic Nomenclature with Authoritative Attribution	Familial and generic
1	Aibika	*Abelmoschus manihot* L. *Medik.*	Malvaceae (*Abelmoschus*)
2	Asparagus glass	*Asparagus densiflorus (Kunth) Jessop*	Asparagaceae (*Asparagus*)
3	Common ivy	*Hedera helix* L.	Araliaceae (*Hedera*)
4	Dumbcane	*Dieffenbachia sp.*	Araceae (*Dieffenbachia*)
5	Garden verbena	*Verbena hybrida Groenl*	Verbenaceae (*Verbena*)
6	Golden pothos	*Epipremnum aureum (Linden & André) G.S.Bunting*	Araceae (*Epipremnum*)
7	Impatiens	*Impatiens walleriana Hook.f.*	Balsaminaceae (*Impatiens*)
8	Spider plant	*Chlorophytum comosum (Thunb.) Jacques*	Asparagaceae (*Chlorophytum*)
9	Peace Lily	*Spathiphyllum wallisii Regel*	Araceae (*Spathiphyllum*)

Figure 1: Displays nine ornamental plant species utilized in the study to examine their effects on air and soil quality restoration and drought resistance.

Analysis of indicators Biological and chemical

The A.P.T.I. values were established through evaluation. The Biological and Chemical Indicators of the plant samples, including the pH of the leaf extract, were assessed. Utilising a pH metre (MP120/Mettler Toledo, European Union) to measure the relative water content (R.W.C.) of the leaf as per Agbaire and Esiefarienrhe (2009), assessing A.A.C. (Ascorbic Acid Content) via spectrophotometry following the methodology of Campos *et al*. (2009), and determining A.C.C. (aggregate chlorophyll content) in accordance with Wellburn (1994). The A.P.T.I. values were calculated using the approach outlined by Singh & Rao (1983), as follows:

$$\text{A. P. T. I.} = \frac{\text{A}(\text{T} + \text{P}) + \text{R}}{10}$$

Where: A = ascorbic acid ($mg.g^{-1}$), T = total chlorophyll ($mg.g^{-1}$), P = pH of the leaf extract, and R = relative water content (R.W.C.) of the leaves (%). The reaction of plants to air contaminants was categorised according to A.P.T.I. values; tolerant if A.P.T.I. values were >24, moderately tolerant if A.P.T.I. values were ranged from>20-24, intermediate if A.P.T.Is. were >15-19, and sensitive if A.P.T.I. values were <14 (Singh *et al*.,1991).

Plant and soil heavy metal analysis

To test the potential of the nine sample species to remediate H.M.-contaminated soil, the sample species were sown in pots with a diameter of 15cm. Each pot was filled with 2kg of two types of soil, up to eighteen pots. Nine were filled with agricultural soil, whereas nine included landfill and effluent material. The pots were conveyed to the screen house, and sample seedlings were procured from the gardens. The plants were transplanted into these containers and irrigated on a daily basis with subsequent monitoring and maintenance. All seedlings were placed one per pot in order to determine accurate uptake of H.Ms. To ensure three biological replicates were obtained per species and soil type, Twenty-seven pots were utilized for the agricultural soil and twenty-seven for the dumpsite and effluent dirt. All plants were cultivated under identical conditions in an irrigated setting with consistent daily care throughout the duration of the experiment. The seedlings were grown in the spring season to obtain favorable environmental conditions for efficient phytoremediation. This interval sustains enhanced microbial rhizospheric activity and the enhancement of a vigorous root system, which are essential for efficient uptake and accumulation of soil contaminants by O.P. species. The soil was harvested for teacher analysis two months after the seeding of the species. At 60 days after planting, plants were uprooted and taken out of the pots. The leaves, stems (shoots), and roots were meticulously taken from the plants and thoroughly washed using water. The botanical materials were washed with deionized water, subsequently drained, and desiccated in an oven at 60°C for 24hrs. The dehydrated plant materials were quantified and pulverised by a centrifugal mill. The specimens were sieved post-grinding to produce a consistent ultrafine powder. A 500mg dry weight sample was measured to the nearest milligram and placed into a digestive vessel. A mixed acid solution of nitric acid (25%) & hydrochloric acid (75%). (by volume) was subsequently introduced into the test sample. The digestive process was carried out for Fist pellet samples were made and digested with 9ml of H_2O_2 (30%) and 3ml HNO_3 in Microwave Digestion unit Model LI-MW6 at a temperature of 130°C for 2hrs to achieve complete soluble after digesting

organic matter to bring it into solution prior to H.M. analysis. The solution obtained was made up to 25 ml with D.W. and stored at 4°C till the metal determination. The amounts of heavy metals (Lead, Cadmium, Zinc, Nickel and Copper) in the plants were quantified using atomic absorption spectroscopy (A.A.S.) Model - ICE 3300F. The study was conducted throughout a wavelength range of 200 - 900 nm, in accordance with the instrument's operational criteria for element-specific detection. A soil sample was collected, desiccated, pulverised, and sorted to determine the presence of heavy metals. The soil samples underwent digestion utilising the same methodology applied to the botanical specimens. The amounts of metals in plants and soil were evaluated against the allowed limits set by the World Health Organisation (1996) as a standard for the prospective application of plants in soil remediation. (Table2 & Figure2).

Table2: Displays the allowed concentration metrics of heavy metals in plants and soil as established by the World Health Organization (World Health Organization,1996).

H.Ms.	Acceptable concentration levels of heavy metals in plants (mg.kg^{-1})	Acceptable concentration levels of heavy metals in soil (mg.kg^{-1})
Pb	2.00	85.0
Cd	0.02	0.8
Zn	0.60	50.0
Ni	10.00	35.0
Cu	10.00	36.0

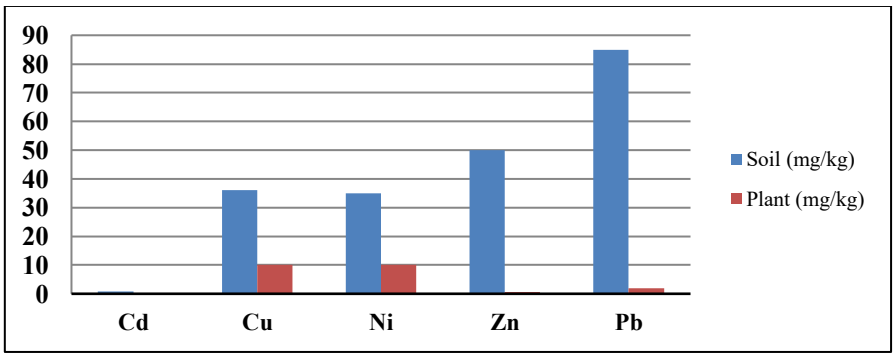

Figure2: Acceptable thresholds for heavy metals in plants and soil as established by the World Health Organization

Following observations, the initial concentrations of the five heavy metals in the shoots and roots of nine plant were recorded (Table3). The preliminary quantities of heavy metals in soil is presented in Table4. To assess the drought tolerance and resistance of nine plant species, Each seedling was cultivated in four pots of varying diameters and capacities, filled with farm soil. Various pot dimensions and volumes were utilised to replicate differing degrees of drought stress while ensuring uniform soil-water dynamics. Control (C) was grown in pots measuring 10×10cm with a capacity of 400 to 500mL. The pots for the moderate drought (M.D.) measured 8 × 8cm (200 to 300mL), those for the severe drought (S.D.) measured 6 × 6cm (100 to 150mL), and the very severe drought (E.S.D.) utilised 5 × 5cm pots (60 to 80mL). This stratified pot sizing sought to provide consistent

soil volume capable of keeping equivalent moisture levels across all drought treatments, so averting excessive saturation or quick dehydration. The method guaranteed that each O.P. species was consistently exposed to authentic conditions to assess the plants' responsiveness and resilience to drought. The aggregate quantity of pots was 36.The pots were kept in a semi-natural habitat, namely outdoors under shade netting, to simulate natural circumstances and protect them from excessive radiation. The mean daytime and night time temperatures were about 28 and 19°C during the experimental period, respectively Natural daylight is diffused through the shade net that was designed to allow P.A.R. of approximately 450 $\mu molm^{-2}s^{-1}$. The relative humidity is around 40%. Growth and tracking time was 4/1/2024 through 5/30/2024.

Table 3: The early concentrations of the five heavy metals in shoots the and roots of nine O.Ps.

Ornamental plants (OPs)	**Concentration levels of heavy metals in plant tissues (mg.kg^{-1})**									
	Pb		**Cd**		**Zn**		**Ni**		**Cu**	
	Shoot	**Root**	**Shoot**	**Root**	**Shoot**	**Root**	**Shoot**	**Root**	**Shoot**	**Root**
Abelmoschus manihot	0.019	0.037	0.014	0.022	0.218	0.429	0.063	0.095	0.341	0.652
Asparagus densiflorus	0.015	0.026	0.020	0.021	0.415	0.861	0.029	0.091	0.175	0.352
Hedera helix	0.043	0.061	0.013	0.018	0.246	0.513	0.052	0.096	0.417	0.824
Dieffenbachia sp.	0.034	0.052	0.010	0.021	0.425	0.746	0.041	0.14	0.282	0.613
Verbena hybrida	0.017	0.039	0.010	0.016	0.247	0.431	0.029	0.076	0.412	0.714
Epipremnum aureum	0.029	0.047	0.012	0.023	0.417	0.814	0.059	0.085	0.271	0.452
Impatiens walleriana	0.014	0.032	0.010	0.020	0.611	0.416	0.037	0.084	0.196	0.413
Chlorophytum comosum	0.019	0.035	0.016	0.024	0.391	0.615	0.024	0.086	0.361	0.542
Spathiphyllum wallisii	0.013	0.028	0.010	0.020	0.375	0.603	0.041	0.069	0.260	0.314

Table 4: The initial concentrations of the five heavy metals in two soil types

Soil types						
	Agricultural soil	**Initial concentration levels of heavy metals in soil (mg.kg^{-1})**				
		Pb	Cd	Zn	Ni	Cu
		0.129	0.068	27.310	0.526	0.731
	Dumpsite and effluent soil	**Initial concentration levels of heavy metals in soil (mg.kg^{-1})**				
		Pb	Cd	Zn	Ni	Cu
		0.326	0.346	36.470	1.279	2.352

Plant species were planted two months before the plants treatment at 4 different irrigation levels every two days. Four water quantity treatments were as follows: control (C, 150 ml), moderate drought (M.D., 75%, 100ml) severe drought (S.D., 50%, 50ml) and extremely severe drought (E.S.D., 25%, 25ml). Nine plant samples were pooled within each group. Soil moisture content was determined by soil water content (%) or field capacity (F.C.) as follows: Water at F.C. (mL or g)=Weight at F.C.−Dry Pot Weight. For the control treatment with a 10 × 10cm pot, the weight of the dry soil and was 400g, increasing to 550g after saturation and upon allowing for drainage over 24h. The water retained between these two weights was (150g recovery/loss among treatments significantly differed from all other observed values at alpha=0.05) equivalent to litters corresponding to the percentage of field capacity or its maximum content held in

retentive capacity after gravitational drainage. Soil moisture levels for drought treatments were correspondingly changed based on this value: M.D. at 75% F.C., S.D. at 50% F.C., and E.S.D. at 25% F.C. Following a 30-day treatment period, morphological indices such as leaf count (L.C.), leaf area (L.A.), plant dry weight (D.W.), and dry weight of both roots and shoots were assessed for O.Ps. across each treatment group. The aggregate leaf area (L.A.) was quantified by Digital picture analysis. The irrigation methods are depicted with greater clarity and precision in Figure3.

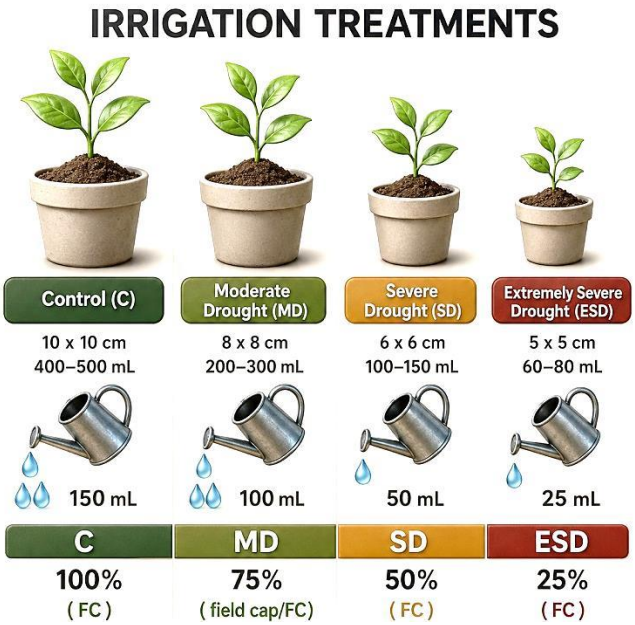

Figure3: Schematic illustration illustrating irrigation interventions for drought stress in O.Ps.

Statistical analysis

An analysis of variance (ANOVA) to assess variations in biochemical parameters, A.P.T.I., and morphological indices values. Variations in parameter values were assessed using L.S.D. (Least Significant Difference) at a significance threshold of p=0.05 by S.P.S.S. (Version23).

RESULT AND DISCUSSION

The findings revealed that *Asparagus densiflorus*, *Epipremnum aureum*, *Dieffenbachia sp*., and *Chlorophytum comosum* demonstrated the greatest A.A.C. among the examined species (Table 5). A.C.C. varied among species, with *Asparagus densiflorus*, *Epipremnum aureum*, *Abelmoschus manihot*, and *Chlorophytum comosum* exhibiting the highest A.C.C. values (2.85-1.33 mg/g for all species). Regarding R.W.C., *Dieffenbachia sp*., *Epipremnum aureum*, and *Impatiens walleriana* had the greatest values at 82.6 %, 67 %, and 60.0 %, respectively. The findings indicated that the O.Ps. species on the university campus with the highest A.P.T.I. values were *Dieffenbachia sp*. (8.7), *Epipremnum aureum* (7.4), and *Impatiens walleriana* (6.3), as illustrated in Table 5. This signifies that these species absorbed a greater quantity of air contaminants compared to the other species. *Verbena hybrid* and *Hedera helix* exhibited the lowest A.P.T.I. values of 5.3 and 5.5, respectively, categorizing them as the least effective air pollution absorbers. As indicated by the findings in Table 5, all plant species exhibited sensitivity according to the A.P.T.I. categorization (Singh et al., 1991). The statistical examination of the A.P.T.I. values revealed substantial differences ($p<0.001$) among the O.Ps.

Table5: Indicators of Biological Chemical and A.P.T.I. evaluated for nine kinds of ornamental plants cultivated on the University of Anbar Campus

Ornamental plants	R.W.C. (%)	pH	A.C.C. ($mg.g^{-1}$)	A.A.C. ($mg.g^{-1}$)	A.P.T.I.
Abelmoschus manihot	56.3	6.3	2.56	0.39	6.0
Asparagus densiflorus	51.3	7.0	2.85	1.54	6.7
Hedera helix	51.2	7.5	1.79	0.44	5.5
Dieffenbachia sp.	82.6	5.4	1.33	0.58	8.7
Verbena hybrida	49.5	7.0	1.67	0.42	5.3
Epipremnum aureum	67.0	6.4	2.80	0.75	7.4
Impatiens walleriana	60.0	6.2	1.85	0.35	6.3
Chlorophytum comosum	79.3	7.3	2.34	0.53	8.4
Spathiphyllum wallisii	58.5	7.0	2.15	0.35	6.2
p-value	< 0.001 ***	0.001 **	< 0.001 ***	0.0134 **	< 0.001 ***

Assessment of the initial and ultimate concentrations of heavy metals in plants and two soil types

Variations in H.Ms. concentrations among plant and soil types prior to and subsequent to cultivation

Table 3 indicates that the initial concentrations of heavy metals in the shoots and roots of all species were within permissible limits (Table2), with the exception of zinc concentrations in the roots of *Asparagus densiflorus*, *Dieffenbachia sp*., and *Epipremnum aureum*, which slightly exceeded the permissible threshold of 0.60.

Tables (6 & 4) display the results of the initial and final concentrations of heavy metals in soils. The concentration of all heavy metals in the agricultural soil diminished following the cultivation of *Asparagus densiflorus*, *Chlorophytum comosum*, *Dieffenbachia sp*., and *Epipremnum aureum*. Conversely, the other species demonstrated inconsistent impacts. *Abelmoschus manihot* was associated with diminished concentrations of Ni and Cu, but *Impatiens walleriana* had the highest residual concentrations of Cu and Pb in the soil. *Hedera helix* promoted the reduction of both Ni and Pb concentrations. *Spathiphyllum wallisii* was associated with an increase in Pb concentrations while demonstrating a decrease in Cd levels. Conversely, both *Abelmoschus manihot* and *Verbena hybrida* exhibited increased concentrations of Cd and Zn in the soil post-planting. The cultivation of species in landfill and effluent soil exhibited a notable decrease in metal concentrations for nine species relative to initial values, especially for cadmium and zinc.

Table6: The maximum concentration of five heavy metals in two soil types planted with nine O.Ps.

Soil of types	Ornamental plants	Final concentration values of heavy metals in soil ($mg.kg^{-1}$)				
		Pb	Cd	Zn	Ni	Cu
Agricultural soil	*Abelmoschus manihot*	0.130	0.071	30.012	0.398	0.493
	Asparagus densiflorus	0.084	0.041	27.057	0.319	0.541
	Hedera helix	0.095	0.052	25.915	0.436	0.921
	Dieffenbachia sp.	0.074	0.047	24.937	0.216	0.601
	Verbena hybrid	0.087	0.073	28.053	0.067	0.931
	Epipremnum aureum	0.097	0.051	26.013	0.501	0.653
	Impatiens walleriana	0.112	0.059	23.246	0.120	1.031
	Chlorophytum comosum	0.101	0.039	26.311	0.476	0.671
	Spathiphyllum wallisii	0.134	0.056	27.021	0.196	0.811
Dumpsite and effluent soil	*Abelmoschus manihot*	0.280	0.301	32.833	0.901	1.863
	Asparagus densiflorus	0.051	0.027	29.701	0.692	1.511
	Hedera helix	0.148	0.093	29.121	0.624	0.893
	Dieffenbachia sp.	0.106	0.136	30.085	0.513	0.913
	Verbena hybrid	0.263	0.312	31.852	0.957	1.746
	Epipremnum aureum	0.217	0.110	28.811	0.841	1.062
	Impatiens walleriana	0.195	0.289	33.650	0.872	1.914
	Chlorophytum comosum	0.094	0.058	26.914	0.439	1.421
	Spathiphyllum wallisii	0.087	0.081	27.092	0.739	1.791

Table7 illustrates the concentration of five metals in the shoots and roots of nine plant species (P.Os.) subsequent to their cultivation in two soil types. The analysis of agricultural soil, dumpsite, and effluent soil indicated an elevation in the concentrations of Pb, Ni and Cu, and for all organisms, remaining within permitted limits. However, the concentrations of Cd and Zn exceeded the acceptable limits of 0.02 and 0.60, respectively, particularly in *Asparagus densiflorus*, *Chlorophytum comosum*, *Dieffenbachia sp*., and *Epipremnum aureum*, as illustrated in Table7.

Table 7: The ultimate concentration of the five heavy metals in various areas of ornamental plant species across two soil types

Soil of types	O.Ps.	Metallic element concentration in plant tissues (mg.kg^{-1})									
		Pb		Cd1		Zn1		Ni		Cu	
		Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots
Agricultural soil	*Abelmoschus manihot*	0.026	0.058	0.022	0.028	0.546	2.014	0.058	0.097	0.502	0.873
	Asparagus densiflorus	0.027	0.045	0.034	0.053	1.112	3.058	0.042	0.093	0.391	0.562
	Hedera helix	0.051	0.087	0.029	0.036	0.586	2.065	0.072	0.176	0.507	0.962
	Dieffenbachia sp.	0.041	0.072	0.021	0.045	0.925	3.086	0.107	0.246	0.362	0.811
	Verbena hybrid	0.019	0.051	0.021	0.025	0.573	2.007	0.036	0.089	0.513	0.911
	Epipremnum aureum	0.033	0.053	0.022	0.034	1.302	3.011	0.062	0.093	0.351	0.631
	Impatiens walleriana	0.027	0.053	0.023	0.027	0.511	2.011	0.042	0.092	0.213	0.603
	Chlorophytum comosum	0.023	0.055	0.026	0.035	0.713	2.035	0.038	0.089	0.301	0.612
	Spathiphyllum wallisii	0.024	0.048	0.024	0.036	0.940	2.083	0.051	0.083	0.322	0.515
Dumpsite and effluent soil	*Abelmoschus manihot*	0.034	0.063	0.025	0.031	0.634	2.063	0.061	0.117	0.570	0.913
	Asparagus densiflorus	0.032	0.049	0.035	0.062	1.810	3.254	0.052	0.107	0.385	0.711
	Hedera helix	0.061	0.095	0.027	0.038	0.716	3.005	0.097	0.256	0.583	0.982
	Dieffenbachia sp.	0.051	0.085	0.022	0.048	1.025	3.581	0.125	0.345	0.512	0.913
	Verbena hybrid	0.026	0.069	0.020	0.029	0.585	2.039	0.038	0.092	0.610	0.981
	Epipremnum aureum	0.041	0.073	0.024	0.041	1.361	3.891	0.085	0.128	0.435	0.851
	Impatiens walleriana	0.031	0.070	0.022	0.029	0.586	2.048	0.054	0.096	0.315	0.733
	Chlorophytum comosum	0.030	0.067	0.028	0.057	0.913	2.185	0.049	0.098	0.321	0.681
	Spathiphyllum wallisii	0.027	0.059	0.026	0.036	1.020	3.023	0.062	0.095	0.362	0.615

Impact of dryness on morphological indices of nine O.Ps.

Varied species responses to drought stress resulting from reduced irrigation levels

Table8 illustrates that the irrigation treatment, with levels decreasing from 25 % - 100 %, substantially impacted all morphological indicators among the nine species. The C treatment demonstrated the most superior morphological indications in every species., signifying robust growth under optimal irrigation circumstances. Conversely, the E.S.D. treatment resulted in the most significant reductions in these indicators, indicating the impact of drought and extreme stress on the growth of O.P. species. Results demonstrate that plant disturbance by drought was observed in a species-specific manner, as it is with reduced irrigation. The observation results showed that the two growth indices of *Asparagus densiflorus*, *Chlorophytum comosum* and *Spathiphyllum wallisii* withered significantly under drought compared to watering condition. In particular, the total leaf number was significantly reduced from control (654.1) to E.S.D. (187.3) in *Asparagus densiflorus*, from 467.8 - 119.3 in *Chlorophytum comosum* and from 859.1 -

340.1 in *Spathiphyllum wallisii*. The total dry weight of the plant likewise diminished compared to the control group. (325.2g) to E.S.D. (98.5g), from 239.3g to 57.1g, and from 428.3g to 161.4g, respectively. These values imply sensitivity to drought stress is high in these species. In contrast, under C and M.D. treatments the morphological parameters of *Epipremnum aureum* were found to be consistent (Table 1). But a significant reduction was observed in S.D. and E.S.D. treatments. The reduced shoot dry weight was particularly significant, which ranged from 214.5g (C) to 39.4g (E.S.D.), suggesting that *Epipremnum aureum* is moderately drought sensitive, but highly sensitive to severe drought stress. Manioc resulted in a significantly reduced and all morphological parameters tested but not proportionately, as total plant dry-weight was about 74% lower compared with control. *Impatiens walleriana*, as well, improved in all the growth indices was decreased e.g. for root dry weight and rosette dry weight data from 89.5g (C) to 18.4g (E.S.D.). These data indicate high predisposition of both O.P. species to drought stress and may be considered as some of the most sensitive to drought in terms O.Ps. studied.

Additionally, *Dieffenbachia sp*. maintained stable leaf count and leaf area across varying drought levels of M.D.-E.S.D. Even if total plant dry weight decreased from control (58.3) to E.S.D. (42.1g), the decrease was less pronounced than in other species compared here-Table 8, indicating that *L. ariensis* has relatively high D.T.S. The drought tolerance of *Hedera helix* was moderate, but only the growth index declined slightly under both S.D. and E.S.D. treatments. Finally, the data also indicated that in *Verbena hybrida* there was little variability of growth indices between C and M.D. treatments involving its resistance to maintain relatively high growth performance under moderate drought stress. The observed reduction in growth under S.D. and E.S.D. conditions indicates that although the species exhibits drought tolerance under M.D., it becomes progressively more vulnerable as drought intensity increases.

Table 8: Displays the analytical outcomes of the morphological indices for nine ornamental plant species subjected to varying irrigation treatment intervals C, M.D., S.D., and E.S.D., aimed at assessing the impact of drought on these species.

O.Ps.	Irrigation treatment frequency	leaf number (leaf plant^{-1})	leaf area (cm^2 plant^{-1})	plant dry weight (g plant^{-1})	Shoot dry weight (g plant^{-1})	Root dry weight (g plant^{-1})
Abelmoschus manihot	C	487.2 a	3011.6 a	246.1 a	113.1 a	063.4 a
	M.D.	337.1 b	2839.4 b	168.5 b	091.3 b	048.2 b
	S.D.	261.5 c	1947.8 c	129.8 c	088.8 b	045.5 b
	E.S.D.	123.1 d	1165.2 d	063.1 d	052.7 c	027.1 c
Asparagus densiflorus	C	654.1 a	3119.2 a	325.2 a	215.4 a	098.7 a
	M.D.	507.3 b	2616.5 b	230.1 b	127.6 b	067.3 b
	S.D.	315.9 c	2030.1 c	166.4 c	104.9 c	056.5 c
	E.S.D.	187.3 d	1357.4 d	098.5 d	087.3 d	054.6 c
Hedera helix	C	769.2 a	3706.3 a	382.3 a	239.1 a	125.1 a
	M.D.	629.8 b	3284.6 b	313.3 b	147.7 b	081.3 b
	S.D.	356.7 c	2683.3 c	178.9 c	089.5 c	044.3 c
	E.S.D.	352.3 c	2680.1 c	174.5 c	083.7 c	042.6 c
Dieffenbachia sp.	C	112.3 a	1612.4 a	058.3 a	137.6 a	071.6 a
	M.D.	085.4 b	1143.1 b	43.1 b	123.1 b	069.5 a
	S.D.	088.6 b	1141.3 b	45.2 b	118.9 b	055.4 b
	E.S.D.	084.2 b	1140.7 b	42.1 b	084.7 c	045.2 c
Verbena hybrida	C	710.5 a	3613.9 a	357.3 a	235.1 a	110.3 a
	M.D.	705.2 a	3608.1 a	350.8 a	228.2 a	108.5 a
	S.D.	396.7 b	2322.9 b	193.5 b	093.7 b	047.2 b
	E.S.D.	238.1 c	1614.6 c	120.1 c	051.1 c	023.6 c
Epipremnum aureum	C	589.5 a	3186.2 a	293.1 a	214.5 a	105.4 a
	M.D.	581.3 a	3181.4 a	289.5 a	185.3 b	088.5 b
	S.D.	229.4 b	2018.1 b	114.6 b	082.3 c	046.2 c
	E.S.D.	226.1 b	2014.3 b	113.4 b	039.4 d	023.6 d
Impatiens walleriana	C	627.4 a	3493.3 a	315.4 a	186.5 a	089.5 a
	M.D.	558.1 b	2902.5 b	284.5 b	115.4 b	068.3 b
	S.D.	376.5 c	2182.3 c	183.9 c	087.3 c	049.1 c
	E.S.D.	198.7 d	1752.4 d	98.6 d	037.9 d	018.4 d

O.Ps.	Irrigation treatment frequency	leaf number (leaf plant^{-1})	leaf area (cm^2 plant^{-1})	plant dry weight (g plant^{-1})	Shoot dry weight (g plant^{-1})	Root dry weight (g plant^{-1})
Chlorophytum comosum	C	467.8 a	2911.5 a	239.3 a	111.5 a	078.2 a
	M.D.	317.1 b	2189.6 b	235.3 a	097.3 b	059.1 b
	S.D.	275.5 c	1917.4 c	159.9 b	085.6 b	039.8 c
	E.S.D.	119.3 d	1297.6 d	057.1 c	068.5 c	036.5 c
Spathiphyllum wallisii	C	859.1 a	3513.7 a	428.3 a	103.6 a	058.1 a
	M.D.	597.5 b	2812.3 b	291.5 b	087.2 b	040.6 b
	S.D.	336.4 c	2210.6 c	163.2 c	069.5 c	037.5 c
	E.S.D.	340.1 c	2207.2 c	161.4 c	067.4 c	035.6 c

Control (C), Moderate Drought (M.D.), Severe Drought (S.D.), Extremely Severe Drought (E.S.D.); distinct letters accompanying values denote significant variations in morphological indicators ($0.01 \leq p < 5\%$) among irrigation treatment intervals for each species.

The quality of the air is an essential element of the system of creation itself which affects the life and vitality of man, animal, and plant. Variations in air quality are correlated with the concentration of contaminants in the atmosphere (Ahmad *et al*.,2019). There are two ways that ornamental plants help in managing with air quality. Sensitive species are bioindicative as they respond to the level of pollutions, whereas tolerant species assimilate contaminants and purify the air (Mulay, 2020 & Kazemi *et al*., 2020). *Asparagus densiflorus*, *Epipremnum aureum*, *Dieffenbachia sp.,* and *Chlorophytum comosum* showed increased A.A.C. and enhanced protective responses. The higher contents of ascorbic acid play a role in stabilizing chloroplasts. They also mitigate the oxidative damage by A.Ps., particularly at environmental stress (Chauhan *et al*.,2022). A.C.C. is known as an important parameter for the evaluation of the photosynthesis of O.ps. It has been widely applied to study the effects of A.Ps. on plant leaves (Jin *et al*.,2012 & Ninave *et al*.,2001). The high level of A.C.C. in general for *Asparagus densiflorus*, *Epipremnum aureum*, *Abelmoschus manihot* and *Chlorophytum comosum* indicates they were overall the most successful at resisting A.P. stress. The results obtained herein are in accordance with work of Shrivastava (2024) who noted highest A.C.C. value in *Epipremnum aureum* and *Chlorophytum comosum*. However, this is in contradiction to Chauhan *et al*. (2022) *Epipremnum aureum* presented the lowest A.C.C. of all studied species. These results suggested that *Dieffenbachia sp*., *Epipremnum aureum*, and *Chlorophytum comosum* may be able to maintain a balance of their physiological activity under the influence of environmental stress such as A.Ps. (Ogunkunle *et al*., 2015 & Sharma *et al*., 2013). These findings are consistent with the report of Shrivastava (2024) showing that these three species were in fact ranked 1,2 and 3 in terms of R.W.C. among all the O.Ps. used. In this study, we found that the potential of *Dieffenbachia sp*., *Chlorophytum comosum* and *Epipremnum aureum* species in air cleaner quality was higher than other plant species planted in campus. This is consistent with the findings of various other studies which have reported high A.P.T.I. values for *Dieffenbachia sp*., *Epipremnum aureum* and *Chlorophytum comosum* (Chauhan *et al*.,2022; Chauhan *et al*.,2022 & Shrivastava,2024). This greater uptake capacity might be due to their broader or thicker leaves compared to the narrow (or cylindrical) ones, or thinner ones, that apparently have higher A.P.T.I. values (Singh *et al*.,2024). Furthermore, the non-detection of A.P.T.I. among other species can be related to the combination of morphological and physiological characters that make O.P. similar to other O.P. species. These comprise high levels of R.W.C., A.C.C. and A.A.C., favorable leaf pH and wax coated leaf surface as well as effectiveness in adoptive mechanism to the environmental stress. Nevertheless, all of the ornamental species studied had A.P.T.I. values of <14, suggesting that these trees are sensitive to air pollution. However, this could be due to the presence of these species on the campus, a place with low air pollution load. This sensitivity is in line with the a low concentration of pollutants generally present in campuses, as reported by Ahmad *et al*. (2019). On the other hand, due to the difference in the values of biochemical attributes, much of the variability of A.P.T.I. values among the nine species was noticed. These biochemical changes reflect the physiological reaction of plants to A.Ps., since pollutants can interrupt metabolic processes in plant tissues (Banerjee *et al*.,2022).

The results of this work are important to clarify the ornamental plants that can be planted for the beautification of high pollution-impacted urban and industrial areas. A.P.T.l. values can be used to classify species according to their ability to absorb pollutants. These species are important for the purification of the

air in polluted areas. It has already been emphasized in the preceding studies regarding the selection of the ornamental plants for remediation of A.P. in these conditions (Achakzai *et al*.,2017 & Singh *et al*.,2024). These results reveal that some O.Ps. can be positive solutions in urban sustainability and environmental recovery. Soil H.M. accumulation is a serious environmental issue. Soil pollution, soil deteriorating quality, crop damage and freshwaters groundwater and surface waters contaminated by layer are a serious threat to human health (Liu *et al*., 2018 & Motuzova *et al*., 2014). In the current study, examination of the possibility to let them absorb H.Ms. from the soil as a way of heavy metals pollution control by ornamental plants has been conducted. It was found that *Asparagus densiflorus*, *Chlorophytum comosum*, *Dieffenbachia sp*., and *Epipremnum aureum* largely reduced the mean values of H.Ms. in the agricultural soils (Cd and Zn were most in decrease at lower initial concentration even). These findings emphasize the purifying capacity of these plants. They are environmentally significant in the sense that potential toxic metals can be arrested (that lingers on soil for years, Mandal *et al*.,2023). Meanwhile, the reduction of soil H.M. content by these O.P. species was less than the maximum heavy metals tolerable levels recommended by several international regulatory authorities, such as Food and Agriculture Organization, World Health Organization report and United States Environmental Protection Agency (E.P.A.) (United States E.P.A.,1996; Food and Agriculture Organization & World Health Organization,2011 & Alloway,2013). Thus, the H.M. concentrations post-remediation meet safety levels for environment and agriculture. This helps to re-use these soils for agriculture, home gardens and land reclamation. This is particularly interesting for landscaping at university campuses or in urban environments with light to moderate contamination (Yan *et al*., 2020 & Ali *et al*., 2013 & Rascio & Navari-Izzo,2011). Moreover, all nine ornamental plant species studied had the potential to reduce heavy metal contents in the contaminated soil (dumpsite soil and effluent soil). Also, various other azalea and associated species for the same purpose have been reported in certain earlier studies. They have also been demonstrated to possess the capacity to accumulate H.Ms. from contaminated soils (Wang *et al*.,2012; Kumari *et al*.,2015 & Jelusic & Lestan 2015). Many of the H.Ms. in our soils were at relatively safe limits. But the concentrations of Cd and Zn were over the standard limit. This enhanced metal uptake may have been facilitated by the superior water, light, and nutrient absorption abilities of O.Ps., which in turn increase their suitability for phytoremediation (Liu *et al*.,2006).

After 60 days in two soil types, metal accumulation was higher for *Asparagus densiflorus*, *Chlorophytum comosum*, *Dieffenbachia sp.*, and *Epipremnum aureum* when comparing Cd and Zn in the roots and shoots of the plants. The above strains, which had great biomass, caused remarkable metal uptake. Heavy metal uptake significantly increases with greater biomass (Xiao *et al*.,2015). These findings reveal the possibility of using these decorative plants as agents for phytoremediation. They present a real, efficient, sustainable, and aesthetically good way to reduce H.M. levels in soils. There are various resistance and adaptation morphological responses that ornamental plants acclimatize to avoid drought, these including morphological, retardation and reduce of biomass (Zhao *et al*.,2024). Among these structures, the morphological adaptations are more relevant in the context of the survival of these plants under water stress. They allow the decorative features of the plants to be kept – that is good for landscape function and sustainability. The nine ornamental plants were affected differently by drought in the present study. One common response was a reduction in morphological characteristics in response to reduced water supply. According to their reactions to drought in physiologically and morphologically, the ornamental plant species used herein can be generally categorized into two types: drought-sensitive and drought-tolerant. Drought susceptibilities, including highly and moderately susceptible, varied among the species *Asparagus densiflorus*, *Chlorophytum comosum*, *Spathiphyllum wallisii*, *Epipremnum aureum*, *Abelmoschus manihot*, and *Impatiens walleriana*. These results are consistent with prior studies suggesting that drought stress in these species provokes a cascade of physiological changes. These comprise: modified phospholipid composition, fatty acid unsaturation, reduced carbohydrate levels, budding inhibition and wilting, stunting, and early leaf drop. These reactions are considered to be drought response adaptations, thereby validating the susceptibility of these species toward water deficit (Namaki *et al*.,2022; Wu *et al*.,2022 & Zhao *et al*.,2024). *Dieffenbachia sp.*; *Hedera helix* and *Verbena hybrida* were described as species resilient to drought, with best tolerance and adaptability to drought stress compared to the others. These species had relatively stable morphological performances under S.D. and E.S.D., as they exhibited

very small decreases in traits like L, L.A., G.R., and L.A.R. These results are similar to the findings of previous studies where leaf number, leaf area, and a decreased slow-growing phenomenon respond to the reduction in irrigation level (Zhao *et al*., 2024; Yu *et al*., 2023 & Xi *et al*., 2021). Therefore, these drought-tolerant plants might be ideal for cultivation in urban areas, deserts, and lands suffering from the inefficient irrigation systems. In comparison, the more drought-susceptible species were typically better adapted to habitats that keep water and soil moisture continuously active (Hammer & van der Maesen,2025). We observed large differences among species in total plant dry weight, shoot dry weight, and root dry weight at C and M.D. irrigation applications. This finding is in agreement with that of earlier researchers who indicated that non-irrigation decreases the weight of the plant, roots, and shoots. The range of this decrease is very variable among O.P. (Cirillo *et al*.,2014; Toscano *et al*.,2014 & Elansary and Salem, 2015). Nevertheless, *Hedera helix* & *Dieffenbachia sp.,* the total plant, roots and shoots dry weights did not significantly differ between the S.D. treatment and the E.S.D. treatment. This stability reflects the morphological adaptation of these species to be effective with limited water availability. These findings demonstrated the potential of these species as novel flora for arid regions.. Resistance to hydric stress and aesthetic value add principles of green sustainability and beautification in arid areas. This information is useful selecting ornamental plants that have both resistance and ornament function. This is consistent with the enhanced sustainability of urban and rural green space under water-limited conditions. The soil used in this study was collected from specific ecological conditions, low A.P. levels (compared to industrial areas), and unique properties of the soil at Anbar University, Iraq which is considered to have a dry climate with climatic changes and fluctuations. These may not be the conditions in other localities. Although these specific environmental and climatic conditions may prevent direct extrapolation of our results, they are still useful more generally. This study, which identifies ornamental species with relatively strong morphological and physiological responses to drought stress, as well as potential tolerance mechanisms against airborne and soil pollution (in particular for regions affected by similar problems), is one such example. Notably, such species may have inherent or genetically based adaptations for culture in arid, semi-arid and even industrial landscapes.

CONCLUSION

Most of the top rated ornamental plant species that had significant ecological importance, especially in improving air and soil quality was determined in the present study. The species *Asparagus densiflorus*, *Chlorophytum comosum*, *Dieffenbachia sp.*, and *Epipremnum aureum* proved to be efficient samplers of air and soil pollutants; this make them appropriate for employing in industrial sites, humanly crowded urban areas as well as public spaces close to roads. Furthermore, the results confirm the potential of these O.P. species as suitable candidates for phytoremediation and their realistic use in strategies to enhance air and soil quality. The post-plant concentrations of H.Ms. in remediated soils were lowered to the levels below which is considered safe for agricultural purpose, urban planting or scenic restoration according to internationally accepted environmental safety criteria. As a result, this study illustrates the potential to use O.Ps. for sustainable nature-based soil remediation in urban areas with low or moderate pollution. Furthermore, The O.P. species analyzed in the present study showed difference responses at tolerance level to drought stress and may be grouped according to their drought tolerance levels. *Asparagus densiflorus*, *Chlorophytum comosum*, *Spathiphyllum wallisii*, *Epipremnum aureum* and *Abelmoschus manihot* and *Impatiens walleriana* were classified as drought-sensitive due to the level of susceptibility to water stress that ranged between humility depending on species (Figur between species 4). On the other hand, *Dieffenbachia sp.,* & *Hedera helix,* & *Verbena hybrida* exhibited high drought tolerance in maintaining growth and physiological vigor under water deficit. These species, which proved to be tolerant species, have introduced adaptive characters which allow them to survive in dry conditions, so that they would be good candidates to grow in areas suffering from water shortage, the lack of irrigation facilities, and irregularity in watering timing. The results of this study help to elucidate mechanisms of drought resistance in O.Ps., which will aid in the intelligent choice of species for sustainable landscaping services, particularly in drought-challenged urban/suburban areas. Crucially, the incorporation of select O.P. species into green infrastructure design has the potential to be significantly more important for urban ecological resilience. Species like *Hedera helix*, *Verbena hybrida*, and *Dieffenbachia sp.*, have been reported to be tolerant to drought and prone to pollutant adsorption, and hence, are quite relevant for lining/ cladding feature vertical gardens, green rooftops, and roadside vegetation. Their resilience to environmental shocks and the ecological and aesthetic services they provide make them important in the establishment of multi-functional green areas. By selecting species which are sensitive to the environmental condition but at the

same time offer remedial action and stress tolerance, urban planners can improve sustainability and performance of green infrastructures. It can be concluded from this study that these O.P. species could have potential in contributing to greening of the environment and add aesthetic beauty to the landscapes through their quality growing. According to these findings, a more extensive list of O.P. species should be addressed by future studies in order to have a more detailed picture both on their EC effects and the sustainability of their products. This will contribute to determine which species are more likely to be the most effective in terms of improving the environmental quality and human well-being.

A number of limitations to this study should be acknowledged, notwithstanding the findings presented. First, there are only nine species of O.P. selected which makes the generalization of the results questionable. Using a wider variety of frames would also improve the accuracy and completeness of inferences regarding how O.Ps. might help to support environmental sustainability. Furthermore, the biochemical parameters used as determination of A.P.T.I. values reflected only some of the physiological effects due to A.P. Therefore, combining these indicators with other leaf surface microstructural characteristics on natural populations of A.P.-tolerant ornamental species may provide more detailed information about how the mechanisms behind A.P. tolerance. Another limitation of the present studies is that the time period over which soil-based H.M. uptake, drought and irrigations were applied was relatively short. Numerous O.P.s may necessitate extended durations to demonstrate quantifiable reactions to persistent environmental stresses, such as the progressive deposition of heavy metals or prolonged drought impacts. Consequently, future investigations should implement prolonged experimental durations to comprehensively capture plant responses and more accurately evaluate their ecological and environmental impacts.

CONFLICT OF INTEREST

The authors declare no conflicts of interest associated with this manuscript.

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