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***Article***

**Factors affecting ornamental plant growth and quality for export preparation: A review**

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**ABSTRACT:**

**Ornamental plants are an ideal way to create attractive and restful settings while improving our sense of well-being, whether inside facilities or in private or public gardens. In order to gain the confidence of global markets, it is necessary to identify the needs of these markets and the quality specifications required in the products exported to them, which were defined by the European Economic Community (EEC) in its laws issued in this regard, and these are the same standards that are used as basic items for quality in many The main international markets, especially the Aalsmeer market in the Netherlands. To reach these specifications, many environmental factors must be met for the production of ornamental leafy plants, potted plants, and cut flower plants, the most important of which are temperature, light, ventilation, relative humidity, and others. In addition to agricultural operations during growth, the most important are irrigation, fertilization, breeding, pruning, and spraying with nutrients and growth regulators and resistance to diseases and pests. In addition, great attention is paid to the appropriate stage of picking, care for the rotation and cultivation of leafy plants, and the appropriate stage of flower picking to obtain the highest quality, which can be graded and packaged according to the export specifications required in international markets.**

**Key words: ornamental plants, quality, environmental, fertilization, export, international markets.**

**1. Introduction**

**INTRODUCTION**

Ornamental plants and cut flowers are considered as nontraditional horticultural crops with outstanding economic returns, where production is available throughout the year, which allows Egypt to occupie a privileged position on the global map (**Mohamed and Moawad, 2016**). Approximately 45 thousand tons of flowers, picking, ornamental plants, and palms were exported, with a value of 52 million dollars, from September 2018 to the end of May 2019 (**EAEC, 2019**). Ornamental plants

are grown for decoration, rather than as raw materials or food. They are most often intentionally planted for esthetic appeal. However, ornamental plants also serve some less obvious uses such as fragrance, cleaning the air, and attracting wildlife (**Mahoney, 2021**). Ornamentals encompass a wide array of plants and are classified into several groups: lawn or turf grasses, ornamental grasses, cut flowers, potted and indoor plants, trees and shrubs, and bordering and bedding plants.

Growing media play a significant role in plant support, serve as a source of water and essential plant nutrients, and permit the diffusion of oxygen to the roots. The materials of growing media consist of clay soil and sand as fully, or replaced it partially by one or more from various materials such as peat moss, perlite, vermiculite, leaf mold, farm yard manure, municipal sewage sludge, and vermicompost, which alter the physical and chemical properties of the growing mixtures and influence plant growth, root system, and nutritional status of the plant (Habib, 2012). Generally, planting media and nutritional requirements are one of the major factors that affect vegetative growth, flowering behavior, and quality (**Abd El Gayed and Attia, 2018**).

In addition, composted materials are used widely in some areas of the world; for example, composted bark is the principal constituent of growing media in many countries (**Carlile, 2008**). Many composted materials have been studied for their potential as constituents of growing media, including bark, wood fibers manufactured timber by-products and green composted materials, and their use in media is currently increasingglobally.

Fertilization is also one of the most important cultural practices that affect the growth and chemical composition of foliage plants. The fertilizer source, rate, and method of application are major factors influencing the growth and quality of indoor plants. In this connection, **Schwemmer (1985)** stated that the addition of slow-release N (300-600 mg/plant) improved the growth and quality of pothos plants. Saleh (2000) also reported that soil drench of urea (1 g/l) or kristalon 19-19-19 (2 g/l) increased plant height, stem diameter, and leaf measurements of *Ficus benjamina*.

Numerous researchers have discussed the problem of diminishing water resources and their impact on agriculture. **Valdez-Aguilar *et al*. (2009)** stated that the scarcity of water for landscape irrigation is a major concern in arid and semiarid regions because of competition with the urban population. Competing claims from urban, agricultural, environmental, and industrial groups leave less water for landscape maintenance. **Lucia (2009)** remarked that knowledge of plant performance under reduced irrigation can drastically reduce the amount of applied container irrigation water, but there is still a lack of information about growth and physiological behavior relative to potted ornamentals grown under limited water availability.

Growth-regulating substances, plant hormones, or simply phytohormones are compounds produced naturally by plants that participate in the control of plant growth. They are versatile chemical regulators of plant growth (**Rademacher, 2015**). Plant growth regulators consist of a large group of naturally occurring or synthetically produced organic chemicals and are considered as a helping tool in the modern ornamental production system. Their exogenous application helps improve the different economically important and market desirable characteristics of ornamental plants. The use of plant growth regulators is being practiced by commercial ornamental plant growers as a part of cultural practice (**Sajjad *et al*., 2017**).

Light strongly affects plant growth and development. Light, as an energy source, affects photosynthesis and related parameters. Light quality is one of the main factors of light signaling and affects numerous processes from seed germination, leaf formation, and flower development (**Demotes-Mainard *et al*., 2016** and **Zheng and Van Labeke, 2017**). The effect of high relative humidity and/or high temperatures has mainly focused on indoor plants instead of landscape cultivars. from an ecological point of view, different plants have different adaptation strategies with respect to water use efficiency, assimilation rate, and other morphological and physiological traits (**Xie *et al*., 2019**).

The main objectives of this review were to determine the influence of medium type, fertilization and irrigation, plant growth regulators, and environmental factors on the growth and quality of ornamental plants.

**A Review:**

**Role of growing media:**

Successful greenhouse and nursery production of container-grown plants is largely dependent on the chemical and physical properties of the growing media (**Mahmood, 2005**). Numerous studies have been conducted over the last 5 decades that have attempted to identify what makes a successful container substrate based on physical and chemical properties(**Gabriel *et al*., 2009**). Moreover, **Popescu and Popescu (2015)** found that using growing media with 60% biolan peat, 30% acid peat, and 10% perlite (BP60-AP30-P10) significantly increased photosynthesis and respiration rate and chlorophyll pigments in leaves as well as number of leaves per plant, leaf area, number of flowers per plant, and leaf area/flowers ratio of both petunia and ornamental tobacco. In the flowering stage, the highest photosynthesis rates (8.612 μmol CO2 m-2 s-1) as well as leaf area (1.766 dm2) of petunias were obtained on growing media with 60% bioban peat, 30% acid peat, and 10% perlite (BP60-AP30-P10). Flowering responses to growing conditions vary greatly among plants, and the largest number of ornamental tobacco flowers (22 flowers plant-1) was registered as an effect of BP60–AP30–P10 media.

There are numerous efforts to optimize the inputs of growing media in individual or mixture types in ornamental production, as presented in Table 1, such as improving plant growth and quality.

**Table 1. Influence of growing media on ornamental plant growth and quality**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No.** | **Media type** | **Ornamental plant** | **Response** | **Reference** |
| 1 | Sawdust, cocopeat, compost | Gerbera, carnation, rose | Increased plant growth | Sachin *et al*., 2020 |
| 2 | river sand: Coir dust: compost: Cow dung (1:1:1:1) | *Petunia hybrida* | Enhanced flowering and increased chemical constituents | Madurangani *et al*., 2020 |
| 3 | peat moss: perlite (1: 1 v/v) | Saintpaulia (*Saintpaulia ionantha* Wendi) | Improved flowering characters | Aslanpour *et al*., 2019 |
| 4 | Peat + sand (2: 1 v/v) | Cocks Comb  (*Celosia argentea*) | Enhanced growth, and increased chlorophyll content and total carbohydrate as well as leaf, N, P and K % | Abd El Gayed and Attia, 2018 |
| 5 | Soil: coco-peat (1:1) | *Anchomanes difformis* | Improved growth characters | Rivai *et al*., 2017 |
| 6 | Rice husk and cowdung (2: 1 v/v) | *Hippeastrum hybridum* | Enhanced growth and flowering | Jamil *et al*., 2016 |
| 7 | Peat moss or  Rice straw or clay | Gardenia (*Gardenia jasminoides*) | Improved growth and flowering traits | Abdul-Hafeez *et al*., 2015 |
| 8 | coconut compost + soil loam; 1:1 | zinnia *(Zinnia elegans)* | Improved plant growth and increasing flower quality | Sardoei *et al*., 2014 |
| 9 | river sand+silt+leaf mold (1:1:1) | *Antirrhinum majus* L. cv. ‘Orchid Rocket Mixed’ | Improved plant growth and development parameters | Naz *et al*., 2013 |
| 10 | Peat moss | Schefflera (*Brassaia actinophylla*) | Enhanced growth and increased N, P, K, Zn and Fe in leaves | El-Sayed and El-Shal 2008 |
| 11 | peat moss: perlite (1: 1 v/v) | *Euphorbia pulcherrima* &  *Codiaeum variegatum* & *Ficus benjamina* | Increased growth and root characters as well as enhanced foliage fresh weight | Papafotiou *et al.*, 2001 |

***The features of growing media:***

1- It acts as a store for nutrients.

2- Reserving irrigation water for plant use.

3- Availability of oxygen in the appropriate amount for the use of roots.

4- Providing the appropriate medium for rooting and planting.

***Conditions to be satisfied in a good growing media:***

1- High ability to retain moisture.

2- Lightweight, well-ventilated, with a suitable pH.

3- It has the ability to retain nutrients.

4- It should be completely homogeneous with easy mixing of its components.

5-Stable and does not change chemically when sterilized with steam or disinfectants.

**Role of fertilization and irrigation:**

**Abou-Dahab (1996)** stated that, spraying schefflera (*Brassaia arboricola* cv. "Gold Capelia") plants with some commercial fertilizers as foliar application (All-Grow, Irral, Kristalon and Sangral). He demonstrated that all commercial fertilizers improved plant height, leaf area as well as number of leaves per plant and fresh weight of leaves. Also, the best fertilizers in this connection were Sangral and All-Grow compared to the other ones under study.

There are many beneficial influences of inorganic and organic as well as biological fertilizers on soil and ornamental plants such as:

1. Enhancing the availability of nutrients.

2. Improving soil buffering and water holding capacity.

3. Releasing plant growth-stimulating hormones.

4. Promote the uptake of numerous macro and micronutrients.

5. Enhance biomass production in ornamental plants.

6. Stimulating microflora population in the rhizosphere.

7. Provides sites for the microflora to use various bacterial secreting enzymes.

8. Reducing the damage caused by pathogen/pest.

9. Improving tolerance to abiotic stress.

There are many studies to optimize the inputs of fertilization type (inorganic, organic and biological fertilizers) in individual or mixture rate in ornamental production as presented in Table 2 like improving plant growth, flowering, chemical constituents and quality.

**Table 2. Influence of fertilization on ornamental plants growth and quality**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No.** | **Fertilizer type** | **Ornamental plant** | **Response** | **Reference** |
| 1 | NPK fertilizers | *Eleutherine bulbosa* | Increased vegetative growth | Wiendi *et al*., 2021 |
| 2 | Farm Yard Manure | *Aglaonema* cv. Silver Queen and *Dieffenbachia* cv, Tropic Snow | Enhanced growth and increased color grades | Pradhan *et al*., 2020 |
| 3 | *Arbuscular mycorrhiza* | *Gazania rigens, Pelargonium peltatum*  *and P. zonale* | Raised growth and flowering | Rydlová, and Püschel, 2020 |
| 4 | NPK as complete fertilizers | Orchid Plant (*Dendrobium sylvanum*) | Improved growth and flowering | Hariyanto *et al*., 2019 |
| 5 | Nitrogen fertilization | *Dracaena sanderiana* | Increased vegetative growth | Srikrishnah *et al*., 2018 |
| 6 | NPK  and manure rates | *Amarnthus tricolar* and *Amarnthus cruentus* | Improved growth and landscape use | Kariithi, 2018 |
| 7 | Bio and inorganic fertilizers | Heliconia (*Heliconia psittacorum* ) | Improved vegetative growth | Linares-Gabriel *et al*., 2017 |
| 8 | Nitrogen fertilization | Potted *Costus*  *productus* | Increased flowering and mineral nutrition | Merida *et al*., 2017 |
| 9 | NPK fertilizers | *Panax notoginseng* | Enhanced growth and root system | Xia *et al*., 2016 |
| 10 | Seaweed  extract | *Calendula officinalis*,  *Tagetes erecta* and *Begonia*  *sempervirens* | Raised growth and flowering | Ragab, 2016 |
| 11 | Mycorrhizal fungi | Taif Rose (*Rosa damascena trigintipetala*) | Enhanced growth and essential oil | Bahobail *et al*., 2014 |
| 12 | Farm Yard Manure | Floral Shower (*Antirrhinum majus* L*.*) | Increased plant growth and improved flowering parameters | Mehmood *et al*., 2013 |
| 13 | NPK fertilization | *Ficus benjamina* and *Ficus hawaii* | Recorded higher values of N, P and K (%) and total chlorophyll content | Sharaf El-Din *et al*., 2012 |
| 14 | NPK fertilization | *Lilium longiflorum* | Enhanced growth and flowering | Treder, 2008 |

Moreover, **Iersel *et al*. (2010)** reported that more efficient irrigation practices are needed in ornamental plant production to reduce the amount of water used for production as well as fertilizers runoff. **Álvarez *et al*. (2013)** declared that the irrigation water requirements and sensitivity to water deficits of ornamental plants is of great interest to horticultural producers for planning irrigation strategies.

There are various efforts to optimize the inputs of irrigation methods and quantity in ornamental production as listed in Table 3 like enhancing plant growth and quality.

**Table 3. Influence of irrigation treatments on ornamental plants growth and quality**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No.** | **Irrigation treatments** | **Ornamental plant** | **Response** | **Reference** |
| 1 | 100 % field capacity | *Chrysanthemum* var. marigold | Enhanced plant growth | Vijayakumar *et al*., 2020 |
| 2 | 75 and 100% of field capacity | *Impatiens* × *novae-guinea* | Increased accumulated dry matter production and plant height | Chantoiseaua *et al*., 2018 |
| 3 | 70% water field capacity | *Bougainvillea* spp., | Improved growth and flowering | Cirillo *et al.*, 2014 |
| 4 | 75% water field capacity | *Pelargonium* × *hortorum* | Increased plant growth | Álvarez *et al.*, 2013 |
| 5 | With deficit irrigation | *Euphorbia* × *lomi* hybrids | produced more flowering stems | Fascella *et al.*, 2011 |
| 6 | the highest irrigation level (1 l/pot) | *Hibiscus rosa-sinensis* | increased number of branches and weights /plant | Garas, 2011 |
| 7 | 1.00 and 1.25 crop-pan coefficients | *Dianthus caryophyllus cv. 'Turbo'* | Gave the longest stems | Kazaz *et al.*, 2010 |
| 8 | 50% of evapo-transpiration (ET) | *Eremophila glabra* and *E. nivea* | Enhanced plant growth | Lucia, 2009 |
| 9 | 100% watering regime | *Petunia hybrida* cv. Hurrah White | Improved growth and flowering | Blanusa and Cameron, 2009 |
| 10 | 80% of soil water content | *Impatiens walleriana* | Enhanced growth and flowering | Chylinski *et al.*,2007 |
| 11 | 80% field capacity | *Dahlia pinnata* | Raised plant height | El-Shakhs *et al.,* 2002 |

**Role of growth regulators:**

In this regard, **Sardoei (2014)** showed that the highest rate of plant height with 76.5, 52.5 and 36.25 cm belonged to 200 mg l-1 GA3+200 mg l-1 BA, respectively between three indoor plants *Ficus benjamina, Schefflera arboricola* and *Dizigotheeca elegantissima*. The highest rate of number of leaves/plant with 133.25, 22.75 and 41.5 belonged to 200 mg l-1 GA3+100 mg l-1 BA and 200 mg l-1 GA3+200 mg l-1 BA for three plants, respectively*.* The highest value of *Ficus benjamina, Schefflera arboricola* and *Dizigotheeca elegantissima* of sum pigments in level of 100 mg l-1 GA3+200 mg l-1 BA and 200 mg l-1 GA3+200 mg l-1 BA with average of 19.59, 21.65 and 21.88 g.ml-1.

There are many studies to optimize the inputs of plant growth regulators in individual or mixture rate in ornamental production as presented in Table 4 like improving plant growth, flowering, chemical constituents and their quality.

**Table 4. Influence of plant growth regulators on ornamental plants growth and quality**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No.** | **Plant growth regulator** | **Ornamental plant** | **Response** | **Reference** |
| 1 | Thiourea and salicylic acid | Rose (*Rosa hybirda*) | Increased growth, flowering and chlorophyll content | Zahid *et al*., 2021 |
| 2 | PD–Toprex SC | *Chrysanthemum indicum* | Inhibited growth and flower size | Kentelky, *et al*., 2021 |
| 3 | Salicylic acid | *Tagetes sp* | Raised growth and flowering values | Basit *et al*., 2018 |
| 4 | Paclobutrazol | Potted rose | Reduced growth and increased flower longevity | Carvalho-Zanão *et al*., 2018 |
| 5 | Trinexapac-ethyl and paclobutrazol | Heliconia ‘Red Opal | Reduced plant growth | De Castro *et al*., 2016 |
| 6 | Paclobutrazol | *Dianthus barbatus × chinensis* | Inhibited growth and flower size | Lenzi *et al*., 2015 |
| 7 | Paclobutrazol | Salvia (*Salvia officinalis*) | Enhanced flower traits | Carey *et al* ., 2013 |
| 8 | isopentil adenin, Zeatin and Thidiazuron | Sutsuki Azalea  (*Rhododendron indicum*) | Increased shoot length and number | Rahimi *et al*., 2013 |
| 9 | GA3 and BA | *Aloe Barbadensis* | Enhanced growth and number of offset | Sardoei *et al*., 2013 |
| 10 | GA3 | Lemon cypress  (*Cupressus macrocarpa*) | Improved growth traits and chemical constituents | El-Keltawi *et al*. , 2012 |
| 11 | Paclobutrazol | Easter Lily | Decreased plant height | Currey and Lopez, 2010 |
| 12 | 6-benzyladenine | Petunia (*Petunia hybrida*) | Increased lateral branches | Carey *et al* ., 2007 |
| 13 | Gibberellic acid | [*Ornithogalum umbellatum*](https://en.wikipedia.org/wiki/Ornithogalum_umbellatum) | Promoted vegetative and flower growth | Wang and Walter, 2006 |
| 14 | GA3 and Paclobutrazol | Black iris (*Iris nigricans* Dinsm.) | Affected plant growth and flowering | Al-Khassawneh *et al*. , 2006 |
| 15 | Paclobutrazol and ethephon | *Reichardia tingitana* | Enhanced growth and flowering | Bañón *et al*. , 2003 |

**Role of environmental factors:**

There are numerous efforts to optimize the inputs of environmental factors in ornamental production as presented in Table 5 like improving plant growth and quality.

**Table 5. Influence of environmental factors on ornamental plants growth and quality**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No.** | **Environmental factor** | **Ornamental plant** | **Response** | **Reference** |
| 1 | Red and ultra violet light | Gerbera (*Gerbera jamisonii*) | Enhanced growth and flowering traits | Kamath, 2021 |
| 2 | 25/18°C (day/night) and relative humidity at 70% | Garden roses (*Rosa hybrida*) | Improved growth and increased total chlorophyll as well as net photosynthesis rate | Xie *et al*., 2019 |
| 3 | LED light at 1204 μmol. m-2 S-1 | Coleus (*Plectranthus scutellarioides* L.) | Increased growth parameters and chlorophyll content | Hussain *et al*., 2018 |
| 4 | 25°C air temperature, 80% relative humidity | Petunia (*Petunia hybrida*) | Decreased growth and flowering values | Hoang and Kim, 2018 |
| 5 | Without shade  or at 25 °C | Red firespike *(Odontonema strictum)* | Recorded the highest growth characters | Rezazadeh *et al*., 2018 |
| 6 | 100 μmol m−2 s−1 for 16 h using 75% red with 25% blue (RB) light | *Cordyline australis*  *, Ficus benjamina and Sinningia speciosa* | Gave greater growth | Zheng and Van Labeke, 2017 |
| 7 | High tem­perature (21°C) | *Coprosma* | Increased leaves number and total plant weight | Hong and Suh, 2012 |
| 8 | Red LED at 650 nm, and far-red LED at 720 nm. | *Withania Somnifera* | Improved photosynthesis and chlorophyll content | Lee *et al*., 2007 |
| 9 | Relative humidity at 50% | *Hydrangea macrophylla* | Decreased plant growth | [Codarin](https://www.researchgate.net/profile/Sandrine-Codarin) *et al*., 2006 |
| 10 | Fluorescent and blue LEDs light | Chrysanthemum | Enhanced stem elongation and branches number | Kim *et al*., 2004 |

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**تحسين نمو وجودة بعض نباتات الزينة لرفع القيمة التصديرية: استعراض مرجعي**

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تعتبر نباتات الزينة إحدى الوسائل المثالية الجذابة والمريحة مع تحسين إحساسنا بالرفاهية سواء داخل المنشآت أو بالحدائق الخاصة أو العامة. لكي نحظي بكسب ثقة الأسواق العالمية, فإنه لابد من التعرف علي احتياجات هذه الأسواق ومواصفات الجودة المطلوبة في المنتجات المصدرة إليها، والتي حددها الإتحاد الاقتصادي الأوربي في قوانينه الصادرة بهذا الخصوص، وهي نفس المقاييس التي تستخدم كبنود أساسية للجودة في العديد من الأسواق العالمية الرئيسية، وعلي رأسها سوق السميير في هولندا. للوصول لتلك المواصفات هناك العديد من العوامل البيئية التي يجب توافرها لإنتاج نباتات الزينة الورقية ونباتات أزهار القطف وأهمها درجة الحرارة والضوء والتهوية والرطوبة النسبية وغيرها. بالإضافة إلى العمليات الزراعية أثناء النمو وأهمها الري والتسميد والتربية والتقليم والرش ببعض المغذيات ومنظمات النمو ومقاومة الأمراض والآفات. كذلك، الإهتمام الشديد بمرحلة القطف المناسبة والعناية بتدوير وزراعة النباتات الورقية ومرحلة قطف الأزهار المناسبة للحصول على أعلى جودة والتي يمكن من تدريجها وتعبئتها طبقا للمواصفات التصديرية المطلوبة بالأسواق العالمية.

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