

BEYOND BLOOMS: HARNESSING UNDEREXPLORED PLANT EXTRACTS TO ENHANCE YIELD, QUALITY, AND LONGEVITY OF ORNAMENTAL PLANTS

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ABSTRACT

Plant extracts are increasingly recognized as sustainable alternatives that can improve the yield and quality of ornamental plants while reducing reliance on synthetic inputs. These extracts are rich in bioactive compounds, amino acids, phytohormones, and minerals that can influence various physiological and biochemical processes within plants. This review synthesizes current knowledge on the use of plant extracts in ornamental horticulture, from seed germination and seedling emergence to vegetative growth, flowering, and postharvest maintenance. Reports indicate that such extracts can stimulate germination, improve photosynthetic efficiency, and promote balanced growth, thereby enhancing yield traits. Moreover, plant extracts improve chemical quality, including essential oil content and antioxidant capacity, and extend the postharvest life of cut flowers and potted plants. Underlying mechanisms include hormonal regulation, stress tolerance, nutrient uptake, and improved assimilation. Although promising, the effectiveness of plant extract depends on factors such as plant species, extract composition, concentration, and timing of application. This review addresses the need for standardized production methods, optimized application protocols, and deeper investigation into molecular-level mechanisms to fully harness the potential of plant extracts in ornamental plant cultivation.

Key words: bioactive compounds, germination, growth stimulation, postharvest quality, protection, resistance

INTRODUCTION

Ornamental plants are an economically fundamental part of horticultural production. Ornamental production includes cut flowers, foliage plants, potted plants, garden and nursery plants, trees, and shrubs for indoor and outdoor use (Long et al. 2018). Ornamental plants are cultivated mostly for their aesthetic and cultural value, and are used for perfumes, medicines, and culinary purposes (Altman et al. 2022).

Global production of ornamental plants was valued at USD 40.25 billion in 2022 and is projected to reach USD 45.07 billion by 2029 (Mekapogu et al. 2023; Bhattacharjee et al. 2024). More specifically,

the ornamental plant industry is a major contributor to the economic activity of the Indonesian agricultural sector. In 2019, it accounted for approximately 1.47% of gross domestic product (GDP) and is growing steadily, becoming a profitable agricultural sector (Tiasmalomo et al. 2021; Mubarak et al. 2023).

In recent years, the ornamental plant industry has faced significant challenges in improving quality and production efficiency. In addition, there is growing interest in developing sustainable alternatives that reduce the need for chemical fertilizers and pesticides. The use of plant extracts has proven to be a promising and environmentally friendly innovation that can meet this challenge (Godlewska et al. 2021).

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Plant extracts are a combination of several chemical compounds that act synergistically (Gonçalves et al. 2025). It is considered a good source of phytohormones (gibberellins and cytokinin), macronutrients (K, Ca, N, Mg, and P), micronutrients (Zn, Cu, Mn, and Fe), vitamins (B1, B2, B6, and C), essential and nonessential amino acids, saccharides (mannose, glucose, and cellulose), among others (Kursa et al. 2024). It also provides osmoprotectants and antioxidants, such as salicylic acid, ascorbic acid, glutathione, α -tocopherol, soluble sugars, and proline (Feng et al. 2025). Accordingly, the extract regulates many physiological processes in plants from germination to fructification, affecting photosynthesis activity, mineral nutrition, primary and secondary metabolism, signaling-related processes, and oxidative metabolism (Ritota et al. 2025).

Plant extracts can be prepared from various plant parts, including leaves, stems, roots, seeds, flowers, and bark (Ahmad et al. 2022). These extracts are inexpensive, widely available, and environmentally benign (Shahbaz et al. 2022). Due to possessing a high content of various bioactive compounds, nutrients, and phytohormones, plant extracts have been shown to enhance germination, growth, flowering, yield, and quality in many ornamental plants, including *Helianthus annuus* (Iqbal et al. 2020), *Rosa damascena* (Ali et al. 2022), *Gladiolus grandiflorus* (Zulfiqar et al. 2020), and more. In addition, previous studies have demonstrated that plant extracts can induce stress tolerance and extend the shelf life of ornamental plants – an important consideration for the industry (Hassan et al. 2020; Buthelezi et al. 2024).

The effectiveness of plant extracts and their precise mechanisms of action in ornamentals are not yet fully understood. Most available studies focus on various categories of growth enhancers in horticultural crops in general (Drobek et al. 2019; Parađiković et al. 2019). Therefore, this review aims to highlight the potential of plant extracts for improving germination, growth, yield, quality, and postharvest performance of ornamentals, as well as to outline their possible modes of action. Importantly, to the best of our knowledge, there is currently no comprehensive review focusing solely on the use of plant extracts in ornamentals.

This work therefore fills an important gap by consolidating existing evidence and providing a focused synthesis of the topic. To provide a concise visual overview of this review, Figure 1 summarizes the range of topics discussed. Starting with the general uses and mechanisms of plant extracts, continuing through their effects on germination, growth, flowering, and quality parameters, and concluding with their role in improving postharvest quality of ornamentals.

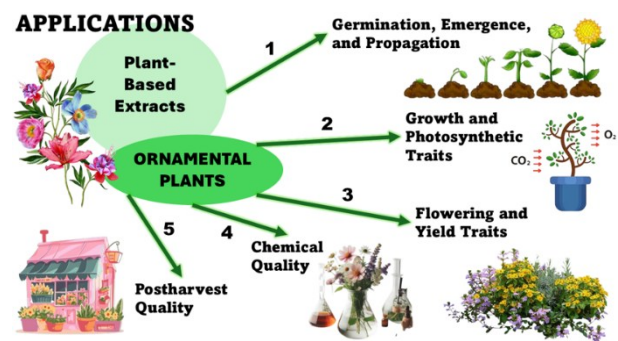


Figure 1. Effects of plant extracts on ornamental plants: (1) germination, emergence, and propagation; (2) growth and photosynthetic traits; (3) flowering and yield; (4) chemical quality; and (5) postharvest quality

APPLICATIONS AND GENERAL MECHANISMS

Plant extracts are produced using wild or plantation plants homogenized in solvents (Suteu et al. 2020). Water is undoubtedly the primary solvent in biomass extraction, as it is environmentally friendly, inexpensive, and nontoxic to humans (Godlewska et al. 2021). In certain cases, organic solvents such as ethanol have been used (Adnan et al. 2020; Ei et al. 2024; Gomes et al. 2025).

The application method of plant extracts plays a crucial role in their use and plant responses. They can be used as a seed soak before planting, as a foliar spray, or applied to the soil or growing medium (Pacyga et al. 2024). However, foliar spraying is the predominant application method. It can involve immediate interaction with plant tissues, as foliar absorption occurs almost immediately (Ali et al. 2021).

Plant extracts influence plants by interacting with plant signaling systems or hormonal activity, thereby enhancing biomass production and metabolite synthesis (Priolo et al. 2024). They have been reported to trigger metabolic cascades that

counteract abiotic stress damage, restoring plant performance (Di Sario et al. 2025). These processes often involve hormone mobilization and the upregulation of stress-induced genes that express specific peptides, bioactive compounds, and enzymes (Goñi et al. 2018; Admane et al. 2023). For example, ElSayed et al. (2022) reported that treating seeds with a 0.5% *Cupressus macrocarpa* leaf extract improved growth and salinity tolerance by upregulating the expression of antioxidant-related genes (*CuZnSOD2*, *CAT1*, *APX*, *GR*, *DHAR*, and *PrxQ*). They also found that this extract outperformed salicylic acid in stimulating growth and salinity tolerance. Similarly, Admane et al. (2023) linked the application of *Moringa oleifera* leaf extract (MLE) – via root immersion and foliar spraying – to increased levels of phenolic compounds and enhanced resistance to pathogenic fungi. In ornamental plants, Ahmad et al. (2019) demonstrated that applying MLE to *Freesia hybrida* – through corm soaking or preharvest foliar spraying – increased chlorophyll content, leaf number, stem length and diameter, flower count, and vase life. This improvement was associated with the presence of zeatin in the MLE – a cytokinin known to promote cell division and elongation (Sadak et al. 2024).

Beyond their influence on hormone mobilization and gene regulation, the beneficial effects of plant extracts are also attributed to the nutrients and growth factors they contain. For instance, Zulfiqar et al. (2020) associated increased biomass yield with improved soil nutrient availability following the application of MLE. This preparation contains gibberellins, indole-3-acetic acid (IAA), and abscisic acid (ABA), as well as macronutrients (N, P, K, Mg, Ca) and micronutrients (B, Cu, Zn, Fe). Likewise, El-Hefny and Hussien (2025) found that spraying *Lavandula latifolia* with *Malva parviflora* extract combined with humic acid increased essential oil content by up to 107% (from 0.30% to 0.62%) and improved other vegetative parameters. According to Ali et al. (2022), the application of *Zingiber officinale* rhizome extract also enhanced plant growth, quality, and essential oil content of *Rosa damascena*.

The authors attributed these enhancements to nutrients elements present in the extract, such as phosphorus, which is important for root promotion and development. It can improve the plant's nutrient and water absorption capabilities.

EFFECT OF PLANT EXTRACTS ON GERMINATION, SEEDLING EMERGENCE, AND PROPAGATION OF ORNAMENTAL PLANTS

Germination and emergence are distinct yet sequential stages that are critical to the success of crop production (Yuniati et al. 2023). Germination is a complex process that begins with water imbibition by the seed, followed by the rupture of the seed coat and the emergence of the radicle (Sembada & Lenggono 2024). Emergence and the establishment of uniform seedlings represent the most vulnerable phase in the crop life cycle and determine the final yield (Hafiz et al. 2025; Sembada et al. 2025). Studies have reported that the use of plant extracts for seed treatment can accelerate germination and break seed dormancy in several ornamental plant species. The findings summarized in Table 1 highlight the potential of various plant extracts to improve the germination, emergence, and propagation in ornamental plants. These early-stage enhancements provide a solid foundation for subsequent vegetative development and physiological performance, as discussed in detail in the following section.

Promising results were obtained by using MLE to soak both seeds and corms. For example, priming *Helianthus annuus* seeds with this extract significantly increased the emergence index, confirming its growth-promoting potential (Iqbal et al. 2020). Research demonstrated that soaking *Freesia hybrida* corms in a 5% MLE for 24 h resulted in sprouting in 5.1 days, compared with 8.1 days for the control (Ahmad et al. 2019). Similarly, for the *Gladiolus grandiflorus* soaking corms in MLE reduced the time to sprouting by about 25% compared to the control (Zulfiqar et al. 2020). These effects were attributed to the presence of endogenous cytokinins in MLE (zeatin, dihydrozeatin, and isopentyladenine), which are essential for biological processes such as cell elongation and division. Cytokinins also counteract ABA-induced inhibition during germination, thereby removing dormancy-associated inhibitors present in the seeds (Sabir et al. 2025).

In *Calendula officinalis*, Ahmed et al. (2023) reported a lower incidence of damping-off disease, at both the pre- and postemergence stages, following seed soaking and foliar spraying with extracts from *Cymbopogon citratus*, *Lantana camara*, and *Zingiber officinale*. Damping-off is a fungal disease causing seed and root rot, potentially killing germinating seeds and young seedlings in nurseries (Poveda et al. 2024). Plant extracts are rich in bioactive compounds with potential antimicrobial properties that can increase fungal mortality, inhibit fungal growth, or stimulate plant defense mechanisms (Draz et al. 2019). Furthermore, sunflower seeds soaked in an aqueous extract of *Curcuma longa* rhizome showed higher germination rates and improved seedling growth compared to the untreated control (Alsahli et al. 2018). This study also showed the ability of this extract to reduce the incidence of root rot caused by *Fusarium* species.

Vegetative propagation via cuttings is another important horticultural technique that enables the rapid and cost-effective production of large numbers of plants from mother plants (Kettenhuber et al. 2019). Plant extracts serve as a tool for optimizing the propagation efficiency of ornamental plant cuttings (Kisvarga et al. 2022). For example, the use of *Salix* spp. bark extract as a propagation solution in an aeroponic system shortened the time of root branching in *Chrysanthemum* spp. and *Lavandula* × *hybrid* cuttings. This is likely because salicylic acid, the main component of the extract,

enhances the activity of rooting-related hormones, such as IAA (Wise et al. 2020). Similarly, immersing *Justicia spicigera* cuttings in *Aloe vera* and *Clitoria ternatea* leaf extract increased both root weight and volume (Salazar-Arias et al. 2025). Promising results were also obtained by dipping *Breynia disticha* cuttings in *Aloe vera* extract, which improved root and shoot growth (El-Banna et al. 2023). The authors attributed these results to the sugars and nutrients (K, Ca, Mg, Zn) in the *Aloe vera* extract, which are taken up by the cutting stem, promoting faster root development.

EFFECT OF PLANT EXTRACTS ON THE GROWTH AND PHOTOSYNTHETIC TRAITS OF ORNAMENTAL PLANTS

Vegetative growth is a vital process encompassing the initiation and expansion of roots, shoots, leaves, branches, and tillers. Although several ornamental plants are cultivated primarily for their flowers, the vegetative stage is crucial for ensuring adequate plant growth. Proper vegetative development is essential for producing high-quality flowers and spikes, thereby increasing the economic value of ornamental plants (Satari et al. 2022). The studies summarized in Table 2 provide clear evidence that various plant extracts can enhance vegetative growth and photosynthetic performance in ornamental plants through a range of mechanisms, including nutrient enrichment, hormonal stimulation, and increased stress tolerance.

Table 1. Plant extracts and germination, emergence, and propagation of ornamental plants

Ornamental plant	Extract	Method	Response	Reference
<i>Breynia disticha</i>	<i>Aloe vera</i>	Dipping solution (75%, 100%)	Improved root and shoot length and fresh and dry root weight	El-Banna et al. 2023
<i>Calendula officinalis</i>	<i>Cymbopogon citratus</i> , <i>Lantana camara</i> , <i>Zingiber officinale</i>	Seed soaking (40%) + foliar spraying (20%)	Reduced damping-off incidence at the pre- and postemergence stages	Ahmed et al. 2023
<i>Chrysanthemum</i> spp.	<i>Salix</i> spp. bark	Propagation solution (1.06 µL per 1 L) in aeroponic system	Reduced time to root branching	Wise et al. 2020
<i>Freesia hybrida</i>	<i>Moringa oleifera</i> leaves	Corm soaking (1%, 2%, 5%, and 10%)	Reduced time to 50% sprouting	Ahmad et al. 2019
<i>Gladiolus grandiflorus</i>	<i>Moringa oleifera</i> leaves	Corm soaking (5%)	Reduced time to 50% germination	Zulfikar et al. 2020
<i>Helianthus annuus</i>	<i>Moringa oleifera</i> leaves	Seed priming in petri dish (25%)	Reduced time to emergence and mean emergence time, increased emergence index	Iqbal et al. 2020
<i>Helianthus annuus</i>	<i>Curcuma longa</i> rhizomes	Seed soaking (100 g of dried turmeric per 1 L of distilled water)	Increased germination percentage, seedling height, fresh and dry weight, and the leaf number	Alsahli et al. 2018
<i>Justicia spicigera</i>	<i>Aloe vera</i> and <i>Clitoria ternatea</i> leaves	Immersing cuttings (5% and 10%)	Increased root weight and volume	Salazar-Arias et al. 2025
<i>Lavandula</i> × <i>hybrid</i>	<i>Salix</i> spp. bark	Propagation solution (1.06 µL per 1 L) in aeroponic system	Reduced time to adventitious root formation and branching	Wise et al. 2020

Table 2. Plant extracts and growth and photosynthetic traits of ornamental plants

Ornamental plant	Extract	Method	Response	Reference
<i>Antirrhinum majus</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (10%, 20%, and 30%)	Enhanced leaf number, internode length, stem diameter, and plant height	Jan et al. 2022
<i>Calendula officinalis</i>	<i>Cymbopogon citratus</i> , <i>Lantana camara</i> , and <i>Zingiber officinale</i>	Seed soaking (40%) + foliar spraying (20%)	Improved plant height, leaf number, number of branches per plant, and chlorophyll content	Ahmed et al. 2023
<i>Carthamus tinctorius</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (3% and 20%)	Enhanced chlorophyll a, chlorophyll b, total chlorophyll, Fv/Fm, shoot length and fresh weight	Hafeez et al. 2022
<i>Chrysanthemum</i> spp.	<i>Toona sinensis</i> leaves	Foliar spraying (0.15% and 0.25%)	Increased plant height	Rahardjo et al. 2020
<i>Cyclamen persicum</i>	<i>Conyza canadensis</i> roots	Soil application	Increased total biomass, leaf number, and SPAD index	Batista et al. 2024
<i>Dahlia pinnata</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (10 g per 1 L)	Enhanced plant height, number of branches per plant, number of leaves per branch, and shoot dry weight per plant	Swedan et al. 2023
<i>Freesia hybrida</i>	<i>Moringa oleifera</i> leaves	Corm soaking (5%), foliar spraying (2% and 3%)	Increased plant height, number of leaves per plant, stem length, stem diameter, leaf area, and chlorophyll content	Ahmad et al. 2019
<i>Gardenia jasminoides</i>	<i>Thymus vulgaris</i> and <i>Majorana hortensis</i>	Foliar spraying (1.25% and 2.5%)	Improved plant height, branch number, leaf number, leaf area, and stem diameter	Shahin et al. 2020
<i>Gladiolus communis</i>	<i>Hibiscus sabdariffa</i>	Foliar spraying (10 g per 1 L)	Improved plant height, leaf number, and chlorophyll content	Al-Asadi et al. 2023
<i>Gladiolus grandiflorus</i>	<i>Moringa oleifera</i> leaves	Corm soaking (5%)	Increased plant height, leaf number, leaf area, leaf greenness, and photosynthesis rate	Zulfikar et al. 2020
<i>Helianthus annuus</i>	<i>Moringa oleifera</i> leaves and seeds	Foliar spraying (25% and 50%)	Increased fresh shoot weight, shoot dry weight, and root dry weight	Iqbal et al. 2020
<i>Helianthus annuus</i>	<i>Sorghum bicolor</i>	Seed priming (1.5% and 2%)	Improved plant height, leaf number, shoot dry weight, and root dry weight	Farooq et al. 2018
<i>Iris tingitana</i>	<i>Allium sativum</i> cloves	Irrigation (250 and 500 mL per 1 L)	Increased plant height, leaf number, chlorophyll content, and carotenoid content	Atwa et al. 2023
<i>Pelargonium graveolens</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (1 : 30, 1 : 20 and 1 : 10)	Increased plant height, number of branches per plant, leaf area, total chlorophyll content, and total carotenoids	Ali et al. 2018
<i>Pelargonium graveolens</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (0.9%)	Enhanced plant height, stem diameter, branch number, fresh weight of aerial part, root length, and root fresh weight	Elsayed et al. 2023
<i>Petunia hybrida</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (50 g of moringa powder in 200 mL of distilled water)	Increased the leaf number, leaf area, and stomatal conductance	Toscano et al. 2023
<i>Rosa damascena</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (1 : 30)	Improved plant height, number of branches per plant, and total chlorophyll content under salinity stress	Hassan et al. 2021
<i>Rosa damascena</i>	<i>Zingiber officinale</i> rhizomes	Foliar spraying (5, 10, and 15 g per 1 L)	Increased plant height and the branch number	Ali et al. 2022
<i>Schefflera arboricola</i>	<i>Allium sativum</i> cloves	Foliar spraying and soil drenching	Increased plant height, leaf number, fresh and dry leaf weight, and leaf area	Hanafy et al. 2012
<i>Silybum marianum</i>	<i>Moringa oleifera</i> leaves	Irrigation at seedling stage (3%)	Increased shoot and root length, leaf area, and fresh shoot and root weight	Zahra et al. 2022
<i>Silybum marianum</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (5 and 10 g per 1 L)	Enhanced plant height, number of leaves and branches, root weight, and dry weight and of aerial part under nonsaline conditions	Yap et al. 2021
<i>Spathiphyllum wallisii</i>	<i>Vitis vinifera</i> seeds	Foliar spraying and soil drenching (0.25%)	Increased average number of offsets and leaves per plant	Manda et al. 2014
<i>Sutherlandia frutescens</i>	<i>Moringa oleifera</i> seeds	Foliar spraying (2%)	Increased plant height, stem diameter, leaf area index, branch number, shoot dry weight, root dry weight, and total carotenoids	Buthelezi et al. 2022
<i>Sutherlandia frutescens</i>	<i>Moringa oleifera</i> seeds	Foliar spraying (4%)	Improved plant height, branch number, and total carotenoid concentration under heat stress	Buthelezi et al. 2024
<i>Tagetes erecta</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (1% and 2%)	Improved plant height, stem diameter, leaf number, root length, and root fresh weight	Nofal et al. 2021
<i>Tagetes erecta</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (3%)	Enhanced plant height, number of main branches, root length, and fresh and dry root weight	Rashed et al. 2025

Numerous trials have established the effectiveness of MLE as a growth stimulator for ornamental plants. For instance, an increase in the number of leaves was observed in *Dahlia pinnata* following the MLE application (Swedan et al. 2023). Similarly, *Pelargonium graveolens* plants subjected to foliar MLE treatment exhibited a significant increase in leaf area (Ali et al. 2018). MLE at a concentration of 0.9% also notably enhanced stem diameter and the number of branches in *Pelargonium graveolens* (Elsayed et al. 2023). Under nonstress conditions, the MLE application to *Silybum marianum* (both Gujranwala and Quetta ecotypes) resulted in higher fresh shoot and root weights compared to untreated plants (Zahra et al. 2022). *Silybum marianum* treated with MLE under nonsaline conditions also showed outstanding growth performance (Yap et al. 2021). When *Rosa damascena* was exposed to salinity stress, the MLE application enhanced plant height and the number of branches (Hassan et al. 2021). In *Antirrhinum majus*, foliar spraying with various MLE concentrations resulted in an increased number of leaves and stem diameter (Jan et al. 2022). *Tagetes erecta* also responded positively to MLE. An increase in root length and root fresh weight was observed, proportional to the increase in extract concentration (Nofal et al. 2021). Similarly, Rashed et al. (2025) reported improved growth performance in *Tagetes erecta* after foliar spraying with MLE.

The fascinating results obtained from MLE treatment may stem from the presence of numerous constituents, such as zeatin, vitamins, carbohydrates, macro- and microelements, and antioxidants, that activate physiological processes in plants (Alkuwayti et al. 2020). Ahmad et al. (2019) found that MLE enhanced *Freesia hybrida* growth, attributing this effect to the role of zeatin in promoting photosynthetic activity. Similarly, Zulficar et al. (2020) reported higher photosynthetic rates in *Gladiolus grandiflorus* treated with MLE. Under nonstress conditions, foliar MLE application gave excellent results on stomatal conductance of *Petunia hybrida* (Toscano et al. 2023). In *Carthamus tinctorius*, MLE significantly increased chlorophyll content and fluorescence (Fv/Fm) (Hafeez et al. 2022). This was likely due to the content of magnesium and iron, elements that regulate chlorophyll production by facilitating the conversion of protoporphyrin into chlorophyllide (Farooq & Koul 2020).

In addition to MLE, other plant extracts also show promising results. *Moringa oleifera* seed extract (MSE) effectively improved plant height, stem diameter, and leaf area index in *Sutherlandia frutescens* under full irrigation (Buthelezi et al. 2022), while under heat stress conditions, it contributed to an increase in the number of branches and carotenoid content (Buthelezi et al. 2024). The application of *Toona sinensis* leaf extract enhanced plant height in *Chrysanthemum* spp. (Rahardjo et al. 2020). This effect was associated with the suppression of leaf-mining pathogens, improving the leaf area for photosynthesis and supporting plant growth.

In *Cyclamen persicum* seedlings, soil application of *Conyza canadensis* root extract increased the number of leaves and SPAD index (Batista et al. 2024). Ali et al. (2022) applied *Zingiber officinale* rhizome extract to the leaves of *Rosa damascena*. At a concentration of 15 mg·L⁻¹, both plant height and the number of branches were higher than in untreated plants. Shahin et al. (2020) and Ahmed et al. (2023) tested various plant extracts, including *Zingiber officinale*, *Thymus vulgaris*, and *Majorana hortensis*. They reported that these extracts enhanced branching and stem diameter in *Gardenia jasminoides*. *Sorghum bicolor* water extract, used for seed priming, increased the number of leaves, height, and biomass of *Helianthus annuus* (Farooq et al. 2018). In *Spathiphyllum wallisii*, *Vitis vinifera* seed extract also remarkably increased the number of leaves per plant (Manda et al. 2014). As previously reported, supplementation with *Hibiscus sabdariffa* leaf extract at a concentration of 10 g·L⁻¹ affected the vegetative growth of *Gladiolus communis* (Al-Asadi et al. 2023). The presence of potassium and magnesium in the extract may explain its growth-promoting effect, which are essential for enzymatic processes and chlorophyll biosynthesis, respectively.

The potential to improve agronomic performance through the use of *Allium sativum* was also studied. *Iris tingitana* plants treated with *Allium sativum* extract showed significant improvements in plant height, leaf number, and chlorophyll content (Atwa et al. 2023). Its application also showed encouraging results for *Schefflera arboricola*, with higher leaf area and biomass (Hanafy et al. 2012). *Allium sativum* contains many essential components, including minerals (P, K, Ca, Zn, Na, Mn, and Fe), vitamins, sugars, alkaloids, and flavonoids, that promote accelerated plant growth by stimulating levels of soluble sugars and photosynthetic pigments (Hayat et al. 2018).

EFFECT OF PLANT EXTRACTS ON FLOWERING AND YIELD TRAITS OF ORNAMENTAL PLANTS

Plant extracts have attracted significant attention for their ability to promote flowering and enhance

the yield of ornamental plants. The use of various plant extracts (Table 3) has been demonstrated to improve flowering and enhance the overall ornamental value, often by influencing flower initiation, size, color intensity, and longevity through hormonal regulation and metabolic enhancement.

Table 3. Plant extracts and flowering and yield parameters of ornamental plants

Ornamental plant	Extract	Application method	Response	Reference
<i>Antirrhinum majus</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (10, 20, and 30%)	Increased floret number, spike length, and flowering duration	Jan et al. 2022
<i>Calendula officinalis</i>	<i>Cymbopogon citratus</i> , <i>Lantana camara</i> , and <i>Zingiber officinale</i>	Seed soaking (40%) combined with foliar spraying (20%)	Improved inflorescence diameter, fresh weight, and dry weight of inflorescences	Ahmed et al. 2023
<i>Chrysanthemum</i> spp.	<i>Toona sinensis</i> leaf extract and <i>Chrysanthemum pyrethrum</i> petal extract	Foliar spraying (0.25%)	Improved marketable flower number	Rahardjo et al. 2020
<i>Dahlia pinnata</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (10 g per 1 L)	Increased flower number per plant, flower diameter, earlier flowering, stalk length and diameter, fresh stalk weight, and fresh and dry flower weight	Swedan et al. 2023
<i>Dianthus caryophyllus</i>	<i>Glycyrrhiza</i> spp. roots	Foliar spraying (30 g per 1 L)	Increased number of flowers and decreased number of deformed flowers	Al-Ma'athedi et al. 2018
<i>Freesia hybrida</i>	<i>Moringa oleifera</i> leaves	Corm soaking (2% and 5%) and foliar spraying (3%)	Increased number of flowers per stem, flower diameter, and inflorescence quality	Ahmad et al. 2019
<i>Gardenia jasminoides</i>	<i>Thymus vulgaris</i> and <i>Majorana hortensis</i>	Foliar spraying (1.25% and 2.5%)	Increased petal number per flower, flower diameter, and fresh flower weight	Shahin et al. 2020
<i>Gladiolus communis</i>	<i>Hibiscus sabdariffa</i>	Foliar spraying (10 g per 1 L)	Improved floret number	Al-Asadi et al. 2023
<i>Gladiolus grandiflorus</i>	<i>Moringa oleifera</i> leaves	Corm soaking (5%)	Increased spike length and floret number per spike	Zulfiqar et al. 2020
<i>Gladiolus grandiflorus</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (1 : 30 at 3-leaf, 5-leaf, and floral bud stages)	Improved spike length and diameter, floret number, and closed bud diameter	Younis et al. 2018
<i>Helianthus annuus</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (50%)	Increased achene count per plant, 1000-achene weight, and flower diameter	Iqbal et al. 2020
<i>Narcissus</i>	<i>Musa</i> spp. peel	Soil application (10 g)	Increased flower number and flower holder length	Altaee 2019
<i>Pelargonium graveolens</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (10 g per 1 L)	Increased fresh plant weight per hectare and oil yield	Gadallah et al. 2020
<i>Pelargonium graveolens</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (0.9%)	Increased fresh herb yield	Elsayed et al. 2023
<i>Rosa damascena</i>	<i>Zingiber officinale</i> rhizomes	Foliar spraying (5, 10, and 15 mg per 1 L)	Increased flower count per hill, flower yield per hill, and flower yield per hectare	Ali et al. 2022
<i>Silybum marianum</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (5 and 10 g per 1 L)	Increased capitula number	Yap et al. 2021
<i>Spathiphyllum wallisii</i>	<i>Vitis vinifera</i> seeds	Foliar spraying and soil drenching (0.25%)	Increased inflorescence number per plant and average spathe length	Manda et al. 2014
<i>Tagetes erecta</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (1% and 2%)	Enhanced flower diameter and fresh and dry flower weight	Nofal et al. 2021
<i>Tagetes erecta</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (3%)	Enhanced flower number, diameter, and yield	Rashed et al. 2025

Swedan et al. (2023) reported a beneficial effect of foliar-applied MLE on the flowering traits of *Dahlia pinnata*, including earlier flowering, increased stalk length and diameter, and improved overall floral quality. Similarly, Ahmad et al. (2019) observed that soaking *Freesia hybrida* corms in MLE resulted in the highest flower number and largest diameter. The authors attributed these improvements to the presence of zeatin, K, and Ca in the MLE, which enhance photosynthetic rate and thereby improve flowering performance. Consistent with earlier reports, soaking *Gladiolus grandiflorus* corms in MLE significantly improved spike length and floret number per spike (Zulfiqar et al. 2020).

Foliar application of 50% MLE to *Helianthus annuus* increased the number of achenes per plant, the 1000-achene weight, and the flower diameter (Iqbal et al. 2020). Similar beneficial effects were observed in *Antirrhinum majus*, expressed as a greater floret number and spike length (Jan et al. 2022). Younis et al. (2018) also reported that MLE improved flowering traits in *Gladiolus grandiflorus*, including spike length and diameter and floret count. In *Pelargonium graveolens*, a foliar-applied MLE enhanced both fresh plant weight and oil yield (Gadallah et al. 2020). In MLE-treated *Silybum marianum* plants, the number of capitula was also higher over two consecutive growing seasons (Yap et al. 2021). Boosted yields were also recorded for *Pelargonium graveolens* (Elsayed et al. 2023) and *Tagetes erecta* (Nofal et al. 2021; Rashed et al. 2025).

Other plant-derived extracts have also exhibited positive results. Ali et al. (2022) found that the foliar application of *Zingiber officinale* extract to *Rosa damascena* significantly increased the flower number and the overall yield compared to the control. Ahmed et al. (2023) reported that *Calendula officinalis* plants treated with extracts from *Cymbopogon citratus*, *Lantana camara*, and *Zingiber officinale* produced significantly more inflorescences with greater fresh and dry weights. As noted by Moussa et al. (2024), *Zingiber officinale* extract contains phenolics, flavonoids, lipids, ascorbic acid, and nutrients (P, K, Ca, Zn, Fe, Mg, and Mn) that are incorporated into plant metabolism and stimulate the synthesis of structural compounds, thereby promoting yield.

Al-Ma'athedi et al. (2018) assessed the influence of *Glycyrrhiza* spp. root extract on *Dianthus caryophyllus*. They noticed that the use of 30 g·L⁻¹ of the extract significantly increased the number of flowers and reduced the number of deformed flowers, possibly by elevating endogenous gibberellin levels and stimulating overall vegetative and floral development. According to Atteya et al. (2022), gibberellins present in the plant extract can boost sink demand by enhancing carbon assimilation, promoting fruit cell elongation, and improving the phloem unloading. They also concluded that this hormone can activate sugar-metabolizing enzymes to meet the high energy demands of reproductive growth.

Vitis vinifera seed extract was also effective in increasing inflorescence number per plant and the spathe length in *Spathiphyllum wallisii* (Manda et al. 2014). Foliar spraying with *Toona sinensis* leaf extract and *Chrysanthemum pyrethrum* petal extract resulted in an outstanding increment in marketable flower number of *Chrysanthemum* spp. (Rahardjo et al. 2020). Furthermore, *Gladiolus communis* treated with *Hibiscus sabdariffa* extract elicited a significant improvement in floret number (Al-Asadi et al. 2023). In *Gardenia jasminoides*, foliar spraying with *Thymus vulgaris* and *Majorana hortensis* extract slightly increased petal number and flower diameter (Shahin et al. 2020). Additionally, soil application of *Musa* spp. peel extract had a beneficial effect on the flower number and flower holder length in *Narcissus* sp. (Altaee 2019), likely due to the high K content, which plays a crucial role during the flowering phase.

PLANT EXTRACTS AFFECT THE CHEMICAL QUALITY OF ORNAMENTAL PLANTS

Ornamental plants contain a wealth of bioactive compounds and nutrients, making them an important resource across various industries. Many species also produce essential oils that can be extracted from different parts of the plant. These essential oils are highly regarded for their applications in aromatherapy, cosmetology, and medicine. Table 4 presents the influence of plant extracts on the chemical quality parameters of ornamental plants, highlighting their role in improving traits such as the content of antioxidant compounds and the overall phytochemical composition.

Table 4. Plant extracts and chemical quality parameters of ornamental plants

Ornamental plant	Extract	Method	Response	Reference
<i>Alternanthera dentata</i> , <i>Gynura aurantiaca</i> , and <i>Tradescantia pallida purpurea</i>	<i>Aloe vera</i> and <i>Glycyrrhiza glabra</i>	Foliar spraying (3%, 6%, and 9%)	Increased concentration of anthocyanins and carbohydrates	Eissa and El-Hadidy 2021
<i>Oenothera biennis</i>	<i>Juglans regia</i> leaves and <i>Quercus castaneifolia</i> fruits	Foliar spraying (25%)	Increased oil percentage and free fatty acid content	Ghezel et al. 2022
<i>Pelargonium graveolens</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (1 : 30, 1 : 20, and 1 : 10)	Increased content of volatile oils (citronellol, geraniol, citronellyl formate, geranyl formate, 10-epi- γ -eudesmol, 6,9-guaiadiene, linalool, β -caryophyllene, germacrene D, geranyl tiglate), total phenolics, and antioxidant activity	Ali et al. 2018
<i>Pelargonium graveolens</i>	<i>Moringa oleifera</i> leaves	Foliar spraying (0.9%)	Enhanced content of total sugars, total phenols, total flavonoids, and essential oil compounds (citronellol and (–)- β -bourbonene)	Elsayed et al. 2023
<i>Rosa damascena</i>	<i>Zingiber officinale</i> rhizomes	Foliar spraying (5, 10, and 15 g per 1 L)	Increased content of volatile oils (citronellol, geraniol, nerol, linalool, and nonadecane)	Ali et al. 2022

Among plant extracts, MLE has shown a beneficial effect on the content of essential oils and bioactive constituents of ornamental plants. For instance, MLE increased several volatile oil constituents in *Pelargonium graveolens* leaves, including citronellol, geraniol, citronellyl formate, geranyl formate, 10-epi- γ -eudesmol, and others (Ali et al. 2018). Moreover, Elsayed et al. (2023) reported that applying MLE to *Pelargonium graveolens* increased the content of total sugars, phenols, flavonoids, and volatile oil constituents in the shoots. This may be due to the fact that moringa leaves are rich in Ca and K, elements that play a key role in enzyme activation, osmoregulation, and photosynthesis, thereby enhancing the nutraceutical properties of the plants.

Other plant extracts also contribute to improving chemical quality. The percentage content of oil and fatty acids in *Oenothera biennis* treated with *Juglans regia* leaf extract and *Quercus castaneifolia* fruit extract was notably higher than in the control, indicating their potential for medicinal purposes (Ghezel et al. 2022). In *Rosa damascena*, the application of moderate-to-high concentrations of *Zingiber officinale* extract significantly increased the proportions of several volatile oil components – geraniol, citronellol, linalool, nerol, and nonadecane

(Ali et al. 2022). In *Alternanthera dentata*, *Gynura aurantiaca*, and *Tradescantia pallida purpurea*, foliar spraying with *Aloe vera* and *Glycyrrhiza glabra* extract successfully enhanced anthocyanin and carbohydrate content (Eissa & El-Hadidy 2021). These results were attributed to nutrients within the extracts being adsorbed by the leaves, subsequently improve plant growth and chemical composition.

EFFECT OF PLANT EXTRACTS ON THE POSTHARVEST QUALITY OF ORNAMENTAL PLANTS

Plant extracts play a vital role in enhancing the postharvest quality of ornamental plants. It is widely reported that their use prolongs shelf life, maintain visual and structural quality, and reduces postharvest spoilage (Shahbaz et al. 2022). Thanks to their antimicrobial and antioxidant properties, these extracts offer a promising natural alternative for extending the vase life of cut flowers and other ornamental plant materials. The beneficial effects of various plant extracts on the postharvest quality of ornamental plants are summarized in Table 5, which illustrates their diverse mechanisms of action, including antimicrobial activity, antioxidant enhancement, and improved water relations.

Table 5. Plant extracts and postharvest quality parameters of cut ornamental plants

Ornamental plant	Extract	Method	Response	Reference
<i>Anthurium andraeanum</i>	<i>Stevia rebaudiana</i> leaves	Pulsing solution (0.1 and 0.2 mg per 1 L) combined with sucrose (20 g per 1 L)	Extended vase life and dry matter, reduced microbial count	Amin 2017
<i>Dianthus caryophyllus</i>	<i>Psidium guajava</i> and <i>Piper betle</i> leaves	Vase solution (2 mL per 1 L) in combination with Sprite	Extended vase life, flower diameter opening, water uptake rate, and antibacterial and antifungal activity	Rahman et al. 2012
<i>Dianthus caryophyllus</i>	<i>Mentha spicata</i> and <i>Salix nigra</i> leaves	Pulsing treatments (25, 50 and 100 mg per 1 L)	Extended vase life, relative fresh weight, relative flower diameter, catalase and peroxidase enzymes, reduced bacterial count	Dehestani-Ardakani et al. 2022
<i>Freesia hybrida</i>	<i>Moringa oleifera</i> leaves	Corm soaking (5%), Foliar spraying (3%)	Extended vase life	Ahmad et al. 2019
<i>Gerbera jamesonii</i>	<i>Camellia sinensis</i> and <i>Cinnamomum</i> spp.	Vase solution (3 g per 1 L)	Extended vase life and relative fresh weight, reduced number of colony-forming units	Jamja et al. 2024
<i>Gladiolus grandiflorus</i>	<i>Moringa oleifera</i> leaves	Holding solutions (3% and 4%)	Extended vase life, open floret number, relative fresh weight, total phenol content, CAT and POX activity, reduced bacterial count, and MDA and H ₂ O ₂ content	Hassan and Fetouh 2019
<i>Gladiolus grandiflorus</i>	<i>Calotropis procera</i> leaves	Holding solution (2% and 4%)	Extended vase life, open floret number, and antioxidant enzyme activity (CAT, POX, SOD), reduced closed floret number and bacterial count	Akhtar et al. 2021
<i>Gypsophila paniculata</i>	<i>Thymus vulgaris</i>	Holding solution (25%)	Enhanced vase life	Khenizy et al. 2014
<i>Mokara red orchid</i>	<i>Jatropha curcas</i> , <i>Andrographis paniculata</i> , and <i>Psidium guajava</i> leaves	Vase solution (10 and 15 mg per 1 L)	Enhanced vase life	Rahman et al. 2014
<i>Rosa hybrida</i>	<i>Moringa oleifera</i> leaves and seeds	Pulsing solution (1 : 40, 1 : 30, 1 : 20, and 1 : 10)	Extended vase life, phenol content, and radical scavenging capacity, reduced bacterial count and MDA accumulation, maintained relative water content, inhibited H ₂ O ₂ production	Hassan et al. 2020

MLE is one of the most important plant extracts due to its strong antimicrobial activity and beneficial effect on the postharvest quality of various agricultural products. For instance, the longest vase life in *Freesia hybrida* was obtained by corm soaking (5%) and foliar spraying (3%) with MLE (Ahmad et al. 2019). In cut *Gladiolus grandiflorus*, the use of MLE as a holding solution significantly reduced bacterial counts, an effect attributed to the antimicrobial properties of this extract (Hassan & Fetouh 2019). Similarly, cut *Rosa hybrida* treated with MLE or MSE as pulsing solutions showed higher relative water content (RWC) and prolonged vase life (Hassan et al. 2020).

The longevity of cut flowers depends largely on biochemical and physiological processes associated with senescence. Oxidative stress is a major factor contributing to flower senescence and reduced postharvest quality (Hassan & Fetouh 2019).

According to Hasanuzzaman et al. (2020), oxidative stress triggers the production of reactive oxygen species (ROS), which can damage nucleic acids, pigments, proteins, and lipids, ultimately leading to cell death. Pulse treatments with leaf extracts from *Mentha spicata* and *Salix nigra* remarkably reduced oxidative stress by enhancing the activity of antioxidant enzymes such as peroxidase and catalase, thereby extending vase life in *Dianthus caryophyllus* (Dehestani-Ardakani et al. 2022).

Other plant extracts have also demonstrated significant postharvest benefits. The use of leaf extracts from *Psidium guajava* and *Piper betle* in vase solutions extended vase life, flower opening, improved water uptake rate and antimicrobial activity in cut *Dianthus caryophyllus* (Rahman et al. 2012). In cut *Anthurium andraeanum*, *Stevia rebaudiana* water extract inhibited bacterial growth in the vase solution and increased the dry matter and vase life (Amin 2017).

Similarly, 3% extracts of *Camellia sinensis* and *Cinnamomum* spp. extended the vase life and maintained relative higher fresh weight in *Gerbera jamesonii*, while reducing bacterial colony-forming unit (CFU) counts (Jamja et al. 2024). In *Gladiolus grandiflorus*, a greater open floret number and higher antioxidant enzyme activity were recorded following the treatment with *Calotropis procera* leaf extract compared to the control and other natural extracts (Akhtar et al. 2021). A similar trend was observed in *Gypsophila paniculata* treated with *Thymus vulgaris* extract (25%) as a holding solution, resulting in extended vase life (Khenizy et al. 2014). Moreover, the vase life of cut *Mokara* red orchid was extended by the separate application of leaf extracts from *Jatropha curcas*, *Andrographis paniculata*, and *Psidium guajava* (Rahman et al. 2014).

CONCLUSIONS

Plant extracts offer a promising, eco-friendly alternative to synthetic chemicals for enhancing the growth, physiological performance, and market quality of ornamental plants. Evidence from various studies indicates that they can positively influence germination, seedling emergence, and propagation efficiency, which is critical for large-scale production. They also play an important role in stimulating vegetative growth, leaf area development, photosynthetic efficiency, and nutrient assimilation, thereby contributing to greater more vigor and enhanced ornamental value. Furthermore, plant extracts have been shown to enhance flowering traits such as spike length, flower diameter, and the number of inflorescences, ultimately improving the aesthetic and commercial appeal of ornamental crops. Their ability to improve chemical quality parameters, including pigment content and levels of antioxidants and aroma compounds, further supports their potential to increase the market competitiveness of ornamental products. Postharvest applications of plant extracts have also demonstrated effectiveness in delaying senescence, maintaining freshness, and extending vase life, thereby reducing postharvest losses.

Despite these promising findings, there are gaps in the existing literature that need to be addressed. Many studies focus on a limited number of ornamental plant species, while the diversity of plant extracts and their modes of action remain underexplored. Variations in extract preparation methods, application rates, and treatment timings also complicates the development of standardized protocols. Moreover, although most research emphasizes physiological and morphological responses, detailed studies of mechanisms at the biochemical and molecular level are still lacking.

Future research should prioritize: (i) identifying the bioactive compounds responsible for specific plant responses, (ii) standardizing extraction and application procedures to ensure consistent outcomes, and (iii) extending investigations to a wider range of ornamental plant species under both controlled and field conditions. Collaboration among researchers, the industry, and policymakers will be essential to translate laboratory findings into cost-effective, scalable, and sustainable solutions for the ornamental plant sector. Through such efforts, plant extracts can become a key driver of sustainable ornamental horticulture, helping to reduce chemical use, improve environmental health, and enhance product quality.

Author contribution statement

NY – A – Research concept and design, B – Collection and/or assembly of data, C – Data analysis and interpretation, D – Writing the article, E – Critical revision of the article, F – Final approval of the article

YT – B – Collection and/or assembly of data, C – Data analysis and interpretation, D – Writing the article, F – Final approval of the article

AS – A – Research concept and design, D – Writing the article, E – Critical revision of the article, F – Final approval of the article

Conflict of interest

The authors report there are no competing interests to declare.

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