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REVIEW ARTICLE

Exploring the potential of lisianthus (*Eustoma grandiflorum*) in India: Challenges, opportunities and future prospects in floriculture

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Abstract

Lisianthus (*Eustoma grandiflorum*), commonly known as Prairie Gentian or Texas Bluebell, is among the top ten popular cut flowers globally. The plant originates from the grasslands of North America. Lisianthus is admired for its wide colour range, long vase life and suitability for cut flowers and potted plants. However, despite its global popularity, lisianthus cultivation poses several challenges, including light and temperature sensitivities, susceptibility to rosetting, nutrition management issues, seed propagation difficulties and postharvest handling concerns. Pests and diseases also present serious threats to flower production and protection. Effective management strategies involve using light spectra for improved germination, maintaining balanced nutrient levels and implementing pest and disease control measures. Emerging technologies, such as genetic improvements for disease resistance and heat tolerance and protected cultivation methods like soilless culture and greenhouse automation, contribute to better flower growth, yield and quality. Therefore, successful lisianthus cultivation requires innovation in breeding technology, production methods and postharvest treatments to enhance its potential in the floriculture industry. Efficient marketing and optimal harvesting practices are essential for extending postharvest longevity and maintaining flower quality. Understanding these characteristics, this review is crucial for improving the sustainability and profitability of lisianthus (*Eustoma grandiflorum*) cultivation worldwide.

Keywords: *Eustoma grandiflorum*; future strategies; lisianthus; marketing; production challenges

Introduction

Texas Bluebell or Prairie Gentian, scientifically called lisianthus (*Eustoma grandiflorum*), is a stunning and calming emerging cut flower worldwide. Eu (beautiful, good, well) and stoma (mouth) are the Greek words from which *Eustoma* is named. Lisianthus belongs to the Gentianaceae family, which originates in the warm regions of the southern United States, Mexico, the Caribbean and Northern South America (1). Lisianthus is an annual or biennial plant with moderate tolerance to cold (2). The growth and quality of this crop vary depending on the variety and they thrive mostly at pH 6.3 to 6.7 (3). They can tolerate the ideal temperature ranges from 15 to 25 °C (4). These plants are propagated by conventional methods, *viz*., generative by seeds and vegetative by cuttings (5).

The vase life varies from 5 to 28 days (6). Yields single or double blooms, grown as cut flowers and is valued for its longevity and potential (7). Among the global market, it is recognized as one of the top ten cut flowers in the world (5). The production rate of cut flowers for this crop will increase in the coming years and commercial cultivars will be produced extensively in Japan (2). Hence, there is a growing demand for cut flowers on the global market because they are seen as luxurious goods with high social values that improve people's quality of life (8). Marketing flowers is a profitable industry on the global market due to the growing usage of decorative and flowering plants (8, 9). There is massive demand in India and the cultivated area is progressively increasing (10, 11). Considering its longer stem, prolonged vase life and variety of flower colours, it ought to be in high demand in Bangladesh and the Himalayan region (India) (12, 13). It has enormous potential and is cultivated as an ornamental potted plant and a cut flower (14). However, they exhibit significant genetic variation in growth rate, leaf form, flower colour, inflorescence morphology, ethylene sensitivity and blooming cycle (15). Hence, growing it has a wide range of potential as well as difficulties in cultivation. Optimizing their chances of success by addressing matters like breeding, production methods and market prospects. Lisianthus also has demand in floriculture and suggests a series of essays that may help in resolving difficulties. This review addressed the challenges in lisianthus production and future strategies for improving flower crops growth, yield and vase life.

Challenges of lisianthus Production in India

Environmental risk

Temperature sensitivity: Temperature is a significant agro-meteorological factor that directly affects the phenology of lisianthus species. It also regulates the photosynthetic rate, subsequently affecting growth and development (16, 17). As each species has a base temperature that varies according to the genotype of the plant and the season of growth, its determination is expensive (18). Lisianthus prefers temperatures between 15 and 25 °C, although some cultivars can tolerate higher temperatures (19).

Light requirements: Light is essential for plant growth, development and regeneration (20). Light-emitting diodes (LEDs) with appropriate light spectra are crucial for horticulture crops. LEDs regulate fundamental plant functions by producing a customized light spectrum that may be adapted to plant photoreceptors (21). Plants absorb wavelength of light that ranges from 300 to 800 nm. The light spectrum has an impact on the morphology of seedlings as well as the physiological behaviour and development of plants (22). It is challenging to handle in-field plantings due to the small seed size (19000 seeds per gram) (23). Lisianthus frequently indicates a slow germination rate under unfavourable light requirement conditions, as low as zero percent germination (24). Studies were conducted on four lisianthus cultivars to examine how different LED light spectrums (Red LED (620 nm to 720 nm), White LED (390 nm to 700 nm) and Blue LED (400 nm to 525 nm) affected the cultivars' emergence, growth and development. Red LED light dramatically increased seedling height, survival rates and germination speed, while Arena Type I Light Pink (V3) had the best growth and survival parameters. More leaves and roots were observed in white LEDs, offering crucial new information about sustainable lisianthus seedling production (25) (Fig. 1)

Nutrient constraints: Plant nutrients are essential for crop growth and development. The availability of the right amounts of macronutrients and micronutrients plays a significant role in plant growth and flower harvests. These elements are naturally present in the soil, but due to intense farming practices, increased salinity and changes in soil pH, plants may not always get the required amount of nutrients (26). Lisianthus belongs to the category of floriculture crops that require a lot of fertilizer at the plug stage and are grown as cut flowers or ornamental flowering pot plants (27). The physiological condition is believed to be caused by calcium deficiency and is characterized by the abortion of the apical meristem and young flower buds. And high amounts of nitrogen (N) (250–300 g m^{-3}) have a direct impact on chlorophyll content and photosynthetic rate (28).

Propagation constraints: The primary method of lisianthus propagation is by seeds. However, its delayed germination and growth make seed propagation of lisianthus complex and challenging. Its seeds are tiny and several environmental elements such as temperature, light and moisture content affect the seed germination (29). Due to their heterozygous nature, several features vary greatly when propagated by seeds. For seeds to germinate, a temperature of 20 to 25 °C must be maintained constantly (30). Vegetative propagation via rooted cuttings and micro-propagation are substitute techniques for the growth of this plant (31, 32).

Pest and disease incidence: Due to plant sensitivity, planting density and other conditions that promote the growth and development of pathogens, which decrease productivity and the production of flowers, control of pests and diseases globally has always been required (33). Fungus gnats (*Basidia* spp.) have been identified as a prominent

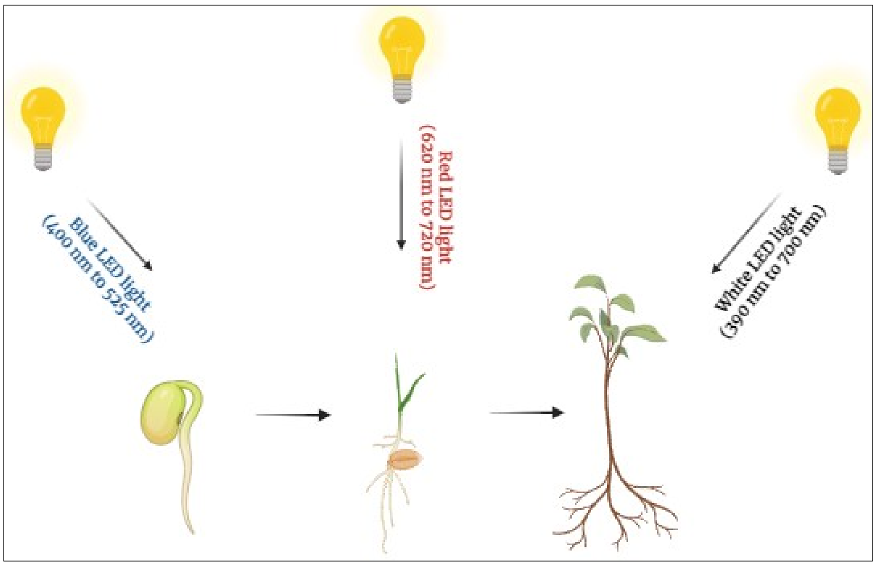

Fig. 1. Different LED lights on the emergence, growth and development of lisianthus.

pest of lisianthus, although they cause a nuisance than a pest and cause infestation to many crops. They consume young seedlings, roots and leaves. It attracts fungus gnats. They usually prefer lisianthus in greenhouse conditions (27). Other pests like aphids, thrips, whiteflies, red spider mites and leaf miners seriously damage this crop. They also serve as the viruses' vectors (34-38). The typical symptoms of viruses include mottling, chlorosis, deformation, yellowing of the leaves and poor flowering (39, 40). A lethal disease of lisianthus is fusarium crown and stem rot, which often results in mortality rates as high as 70 %, Gray Mold (*Botrytis blight)*, powdery mildew, Pythium root rot, Fusarium wilt and Impatiens necrotic spot virus or INSV (46) are some of the most often causal diseases in lisianthus (33, 41-46).

Physiological disorder

Rosetting

Rosettes are plants with a cluster of leaves on the stem with short internodes. Rosettes are usually formed in young plants when exposed to higher temperatures. The circumstances can affect a variety susceptible to rosetting during seed production. Rosetted plants will start to grow, although the quality of the stems is frequently reduced. Additionally, rosettes are inappropriate for commercial production because they take longer to flower. Researchers are creating technologies to reverse heat-induced rosetting and use the knowledge learned about the effect of low temperatures on seed development to enjoy cut blooms year-round (4, 47).

Postharvest complications

Most cut flowers, including lisianthus, do not have longer vase life (48, 49) and differ according to cultivars (50). As the process of postharvest senescence takes place after cutting, cut flowers have a shorter vase life. Often, morphological (sepals, petals, androecium, gynoecium, stem and leaves), physiological and biochemical degradation precedes flower senescence (51). Researchers have identified it as a significant drawback in cut flower marketing and sales (52). Artificial pollination in lisianthus accelerates flower senescence more quickly due to a climacteric increase in the ethylene produced from the pistil. They were sensitive to ethylene. Ethylene is a phytohormone that causes leaf drop and flower senescence. Ethylene formation in flowers increases during flower ageing and most ethylene is produced in the pistil (53). It has been extensively shown that ethylene increases respiration rate, leading to an oxidative burst caused by excess free radicals and relative oxygen species generation. Hence, ethylene is the primary factor influencing harvested perishable products' quality and postharvest life, including cut flowers (54, 55) (Table 1).

Opportunity of lisianthus in Flower Market

Marketing of specialty cut flower (Lisianthus)

The global market for cut flowers is worth $5.7 billion. The Netherlands accounted for 54 % of exports in 2005. The other top exporters are Colombia (16 %), Ecuador (6 %) and Kenya (6 %). The central import countries for cut flower exports are EU countries. The most popular country is Germany (18 %), followed by the UK (17 %)and the USA (16 %) (56). In recent years, countries like Equator, Kenya and Colombia, with favourable environmental conditions and fewer labour charges, have become cut flowers' leading producers and exporters. The productivity of flowers is increasing in traditional production centres, yet the amount of land needed for production is either stable or reducing (57). Data on horticultural items, such as flowers and ornamental plants, provided by USDA (United States Department of Agriculture) and Eurostat give facts on market dynamics and production trends, covering a variety of industry factors from 2006 to 2019 (58). Many SCF (Specialty Cut Flowers) and native Australian acacia species are becoming more popular in the US market; some species are even viable for commercial cultivation. Profitability of Specialty Cut Flowers may make between $25,000 and $35,000 annually for every hectare of land. Certain SCF crops, such as *Antirrhinum majus, Zinnia elegans, Scabiosa atropurpurea, Cosmos bipinnatu* and *Eustoma grandiflorum,* have proven profitable for growers at different income levels (59). Recently, the cut flower industry production has increased from traditional cut flowers (TCF) to speciality cut flowers (SCF). SCFs are expected to offer more environmentally friendly processes and attain larger production volumes and market shares worldwide. Specialty cut flowers (SCFs) are more beneficial due to their low phytochemical content, low CO_2 footprint and sustainable production techniques (60).

Table 1. Lisianthus challenges

Cultivars	Treatments / methods	Result	References
DBL Echo Blue, Robella 2 Pink, Excalibur White, Excalibur 2 Blue Picotee, DBL Echo Champagne and Arena III Red.	The lowest variability (LV) and Development ratio (DR) to measure base temperature	The base temperature for LV is between 13.9 and 15.0°C and for DR is 14 to 15 °C.	(82)
Yodel White, Heidi Pink, Blue Lisa, GCREC-Blue	Photoperiod (12 hr and 18 hr) and Temperature (26 °C and 12 °C) to evaluate resetting occurrence.	Less rosetting occurs at short days (12hr) - Low temperatures (12 °C).	(47)
Echo double Yellow, Echo Double Champagne, Echo Double White, Echo Double Lavender, Echo Double Pink Picotee, Echo Double Blue Echo Double Pink	Indole-3-butyric acid (IBA: 250 & 500 ppm) and naphthalene acetic acid (NAA: 250 & 500 ppm) On rooted cuttings	IBA with 250 ppm shows better results on vegetative propagation an alternative to seed propagation.	(10)
Mariachi Blue	Sucrose, Ascorbic acid, NaOCl, 8-HQC and their combinations	Sucrose @ 2.5 % + Salicylic acid at 200 mg L_{-1} + NaOCl 50 ppm resulted in better flower quality and vase life.	(83)

India ranks 18th in global floriculture trade with a 0.6 % share and its domestic flower market is growing rapidly at 15-25 % annually. Key flower-producing states include Karnataka, Tamil Nadu and Maharashtra. Major export destinations are the USA, UK and European countries, with Egypt receiving over 63 % of India's cut flower exports. Demand peaks during festivals, weddings and Valentine's Day, but limited cold storage and supply chain infrastructure often lead to shortages and price hikes. Roses, gerberas, chrysanthemums, lisianthus and marigolds dominate production, especially in southern India under protected cultivation. Despite strong domestic growth, India's export potential remains underutilized (61).

Lisianthus contributes to the variety of cut flower options available in the market (Fig. 2), along with other popular varieties like ranunculus, dahlias and zinnias (62). Understanding the factors that affect postharvest longevity, such as harvest timing and carbohydrate status, is critical to ensure flower quality and commercial viability of lisianthus flowers (63). Overall, flower farmers have the chance to satisfy the market's demand for high-quality blooms by marketing lisianthus cut flowers. Farmers may improve the sustainability and profitability of their cut flower businesses by adopting efficient harvesting techniques, succession planting schemes and production maximization. Regions such as Asia, Latin America and Eastern Europe will experience a rise in demand due to improved wealth and prosperity of cut flowers (64).

Future strategies for improving growth, yield and vase life.

Genetic improvement

Breeders have recently identified a wide range of hybrids and cultivars with superior qualities such as heat tolerance, diverse flower shapes and sizes, disease resistance, lack of rosetting and larger blooms with various colours (61). Flavonoids are the primary plant pigments responsible for the colour of many flowers, fruits and vegetables. Flavonoids are also involved in pollen fertility and protection against UV light damage and they support various other plant processes (65-67). Several genetically modified lisianthus lines with modified flavonoid biosynthesis have been produced successfully (68, 69). In recent studies, adding chalcone synthase (CHS) cDNA as a component of an antisense RNA construct changed the degree and pattern of pigmentation in purple -flowered lisianthus cultivars. Chalcones are the precursor utilized in the biosynthesis of all flavonoids, which include coloured anthocyanins and CHS catalyzes their reaction (70). The creation of genetic linkage maps and QTL (Quantitative Trait Locus) is identified using SSR markers on lisianthus (71). There are also lisianthus cultivars that do not require vernalization for bolting and flowering. Genetic transformation has been used to enhance fragrance in scentless varieties of lisianthus flowers by adding key enzymes like kinetin and Naphthalene Acetic Acid (5). Many researchers have improved propagation techniques like micropropagation to improve their propagation as it will reduce the mortality rate of plants (23, 72, 73) (Fig. 3).

Improved cultivation practices

Cultural operations

Irrigation systems: Lisianthus plant requires moderate water for growth. They need consistent moisture but should not be waterlogged, as this leads to root rot and fungal diseases. Drip irrigation is the most effective method, providing water directly to the root zone while minimizing moisture on the foliage. Irrigate the plants when the top 1-2 cm of soil is dry, but avoid overwatering (74). Water the plants with 0.5 to 2 inches of water each week (or about ¼ to 1 gallon per square foot), depending on the temperature, the growth stage of the plants and the type of soil you have. Lisianthus prefers a humid environment but does not tolerate stagnant water around the roots (75).

Fertilizer schedule: Lisianthus flowers have great potential for export and earning foreign income. It's essential to manage fertilizers properly to grow them under sustainable production. Nitrogen helps the plant grow and flowers to open, phosphorus supports the development of buds and blooms and potassium improves overall plant health and flower quality (76). Maintain a high amount of nitrogen at the initial stages of planting. Lisianthus appears to prefer low levels of this nutrient (45 mg N per pot each week) as well as low levels of calcium (75 mg L_{-1} Ca) for optimal growth (28). Considering a planting density of 64 m^{-2} plants, the total demand (in gr m^{-2}) of lisianthus was 16.27 of N, 4.05 of P, 8.14 of K, 2.58 of Ca and 3.12 of Mg (77).

Fig. 2. Lisianthus (*Eustoma grandiflorum*): Plants displayed for sale in an Indian market.

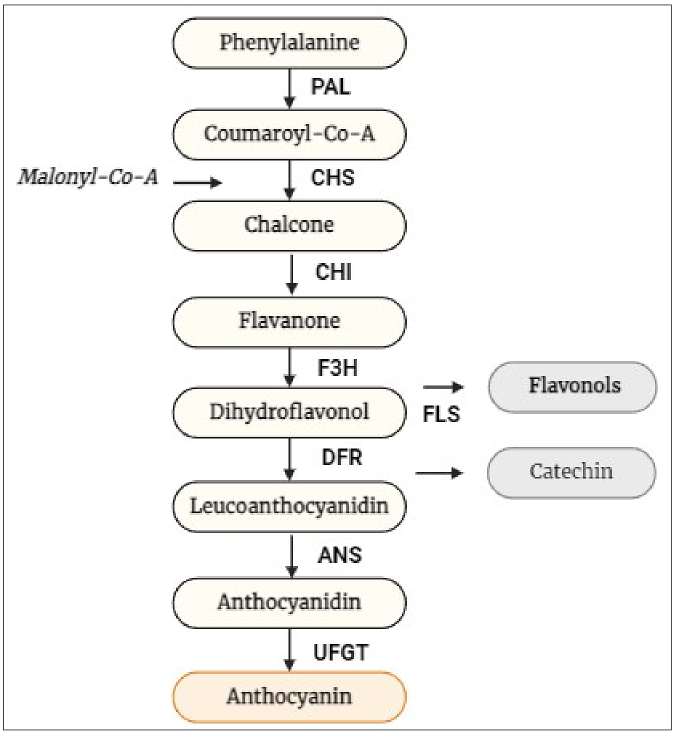

Fig. 3. The flowchart represents a possible simplified process for anthocyanin biosynthesis. Enzymes: Phenylalanine ammonia-lyase (PAL), Chalcone synthase (CHS), Chalcone isomerase (CHI), Flavanone-3-hydroxylase (F3H), Dihydroflavonol-4-reductase (DFR), Anthocyanidin synthase (ANS), Anthocyanidin synthase (ANS), UDP glucose flavonoid-3-O-glucosyltransferase (UFGT) and Flavonol synthase (FLS).

Pest & disease control: Lisianthus are susceptible to common pest like Fungus gnats (*Basidia spp*.,), aphid, thrips, whiteflies, red spider mites and leaf miners. And common diseases include Gray Mold (Botrytis blight), powdery mildew, Pythium root rot, Fusarium wilt and Impatiens necrotic spot virus or INSV and their control measures (Table 2).

Harvesting Stage

Harvest lisianthus during the cooler parts of the day, ideally when two or more florets per stem have opened-starting with the base florets fully open and the middle ones partially open (Fig. 4). Florist-grade stems should be at least 12 inches long, preferably between 16-30 inches. Cut stems should be immediately placed in water to prevent wilting. After harvest, remove leaves from the lower half of the stem, recut stem ends and place them in clean water containing floral preservative. Stems should be stored upright at 40 °F (4 °C) to minimize curvature and maintain quality. Cool storage is effective for up to 4 days; prolonged storage reduces quality. With proper handling, including fresh stem cuts, preservatives and regular water changes, vase life can extend to 14 days or more (61).

Protected cultivation.

Innovations in greenhouse technology conducted by controlling the growing environment of crop plants. Crops have been protected from pests, disease and unfavourable weather conditions in the external environment. This creates a suitable environment that helps crop growth and development (78). Greenhouse automation is one of the modern intensive agriculture cultivations. It recycles data, makes use of available resources and also maintains greenhouse productivity (79). Cultivation of lisianthus under soilless culture (perlite and coconut coir dust) enhances the growth and development of plants (80).

Fig. 4. Lisianthus (*Eustoma grandiflorum*) cultivars at harvesting stage.

Table 2. List of major pests and diseases of lisianthus with their control measures

Common name	Scientific name	Control measures	Reference
Major Pest			
Fungus gnats	*Bradysia spp.*	Field sanitation. Biological controls such as *Steinernema feltiae* (beneficial nematodes) and predatory mites (*Stratiolaelaps scimitus*) - manage larvae naturally. Biopesticides (e.g., *Beauveria bassiana*) - 1-2 g/L or 1 mL/L (as soil drench or foliar spray). Yellow sticky traps - 1 trap per 10-20 m^2 (replace weekly).	(87)
Aphids	*Myzus persicae, Aphis gossypii*	Maintain field hygiene. Monitor using yellow sticky traps. Introduce natural enemies like *Aphidius colemani*, *Chrysoperla carnea* (green lacewing), or ladybird beetles. Spray insecticides like Imidacloprid 17.8 % SL – 0.3–0.5 mL/L, Thiamethoxam 25 % WG – 0.25 g/L	(34)
Thrips	*Frankliniella occidentalis, Thrips tabaci*	Use blue sticky traps. Introduce predatory mites (*Amblyseius swirskii*, *Orius insidiosus*). Spray insecticides like Spinosad 45 % SC – 0.3 mL/L, Fipronil 5 % SC – 1.5 mL/L	(35)
Whiteflies	*Bemisia tabaci*	Install yellow sticky traps. Release Encarsia formosa, a parasitic wasp for biological control. Spray insecticides like Buprofezin 25 % SC – 1.25 mL/L, Spiromesifen 22.9 % SC – 1 mL/L	(36)
Red Spider Mites	*Bemisia tabaci*	Introduce predatory mites (*Phytoseiulus persimilis*). Spray insecticides like Abamectin 1.9 % EC – 0.5 mL/L, Fenpyroximate 5 % EC – 0.5–1 mL/L	(37)
Leaf Miners	*Liriomyza trifolii*	Remove and destroy affected leaves. Release parasitoids like *Diglyphus isaea* for biological control. Use reflective mulches to deter adult flies. Spray insecticides like Abamectin 1.9 % EC – 0.5 mL/L as foliar spray, Spinosad 45 % SC – 0.3 mL/L	(38)
Major disease			
Gray Mold (Botrytis blight)	*Botrytis cinerea*	Maintain low humidity (<85 %) and ensure good air circulation. Remove and destroy infected plant material promptly. Avoid overhead watering; water at the base in the morning. Apply fungicides like Iprodione 50 % WP – 1–1.5 g/L water, Chlorothalonil 75 % WP – 2 g/L water.	(33)
Powdery Mildew	*Erysiphe cichoracearum*	Improve airflow and light penetration through proper spacing and pruning. Use resistant cultivars where available. Apply fungicides such as Sulfur 80 % WP – 2–3 g/L, Myclobutanil 10 % WP - 0.5 g/L	(43)
Pythium Root Rot	*Pythium spp.*	Use well-drained, sterile growing media. Avoid overwatering; ensure adequate drainage in pots and trays. Mefenoxam 22.5 % SC (Subdue Maxx) – 1 mL/L as soil drench, Etridiazole – 1.5 mL/L	(44)
Fusarium Wilt	*Fusarium oxysporum f. sp. eustomae*	Use disease-free planting material. Avoid soil reuse; solarize or sterilize soil before use. Apply biological control agents like *Trichoderma harzianum*. Fungicides such as Thiophanate-methyl 70 % WP – 1 g/L, Carbendazim 50 % WP – 1 g/L (early stage)	(45)

Aeroponic techniques have also been used to understand crop nutrition, root growth and gas concentrations in the root zone (81). Apart from, greenhouse cultivation now its gaining importance under polytunnel condition in India (Fig. 5). As lisianthus is one of the emerging cut flowers in the world, cultivating cut flowers in protected conditions enhances the quality of the crop for domestic and export purposes and needs further research in protected cultivation to improve flower production and productivity.

Postharvest treatments

Numerous technologies were identified to prolong the postharvest life of the cut flowers and potted flowering plants. Various vase solutions are being used to enhance the vase life of flower crops. Sucrose, sodium tripolyphosphate and aluminium sulphate are the main solutions used in the cut flower industry (52). However, exogenous hydrogen-rich water (HRW) increases the vase life and quality of lisianthus flowers by preserving redox homeostasis. Redox equilibrium is prevented by the vase period decreases in endogenous hydrogen gas (H_2) concentrations. DCPIP (2,6-dichlorophenolindophenol) accelerates aging but the addition of HRW stops it. By lowering lipid peroxidation and increasing antioxidant enzyme activity, H_2 treatment reversed the effects of DCPIP and increased the level of soluble protein, total chlorophyll and proline. Thus, endogenous H2 contributes to vase life extension by maintaining redox equilibrium (82). Lisianthus flowers by adding 2 mg L^{-1} pectin-derived oligosaccharides to vase solutions containing 4 % sucrose increasing the floral diameter by 20 % and bud opening by 12 % compared to the negative control (water only). In addition, this treatment enhances the vase life by changing the amount of antioxidant compounds and flower colour. The postharvest quality of lisianthus was improved by the combined effect of sucrose and oligosaccharides, which was found to be superior to individual treatments. Research can be done to enhance the vase life of lisianthus flowers for the betterment of quality (83). Combining 60 g L^{-1} sucrose with 160 mg L^{-1} citric acid results in a long vase life (31 days). The highest relative water content (82.37 %) and the most significant percentage of opened flower buds were achieved with 60 g L^{-1} sucrose and 160 mg L^{-1} aluminium sulphate. These treatments significantly enhance the postharvest quality of Lisianthus cut flowers (84).

Conclusion

In conclusion, lisianthus (Eustoma grandiflorum) holds immense potential as a premium cut flower due to its attractive flower colours, long vase life and international market demand. However, its cultivation is affected by challenges such as temperature sensitivity, light requirements, small seed size and ethylene sensitivity. Advances in protected cultivation, nutrient management, vegetative propagation and genetic improvements for heat tolerance and disease resistance are key to overcoming these issues. Future research and innovation in production methods and postharvest treatments will be critical for maximizing the crop's productivity and sustainability, meeting the growing global demand for premium cut flowers.

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Authors' contributions

VR conceptualized the review article and designed the methodology for the literature search. CR guided the review work by formulating the review concept and approving the final manuscript. AB critically reviewed and edited the manuscript for intellectual content. RM helped in editing, summarizing and revising the manuscript. SS helped in editing, summarizing and revising the manuscript.

Fig. 5. Cultivation of Lisianthus under polytunnel condition at H&FRS, Kodaikanal (Upper Pulney Hill) zone of TamilNadu.

Compliance with ethical standards

Conflict of interest: The Authors do not have any conflict of interest to declare.

Ethical issues: None

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