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Feasibility Study of Planting and Developing Atlas Plants (*Petunia hybrida* L.) and Chrysanthemums (*Chrysanthemum morifolium* L.) in Urban Streets of Karaj Considering the Effects of Light Pollution

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ABSTRACT

Light pollution is the effect of inefficient and unnecessary artificial lighting in outdoor spaces. Each plant requires a certain amount of light for its life and photosynthesis processes to continue. Petunia, scientifically known as *Petunia hybrida* L., is an annual plant belonging to the Solanaceae family and is a short-day plant photo periodically. Chrysanthemum, scientifically known as Chrysanthemum morifolium L., belongs to the Asteraceae family and is a long-day plant photo periodically. These two plant species, Petunia and Chrysanthemum, which are planted in urban green spaces, were selected for the current study to determine the effects of nighttime light radiation. The present research was conducted during the year 1041 in the research greenhouse of Kharazmi University, Karaj campus, to investigate the effect of light pollution with 3 treatments: control, 44 lux, and 1344 lux, each replicated 3 times. Then, the results of morphological and physiological traits were examined. In Petunia, the results of the analysis of variance showed that most morphological traits of the light pollution treatment significantly differed from the control treatment, while no significant effect was observed for physiological traits. The 44-lux treatment had the most significant effect on plant height, root length, wet and dry stem weight, leaf surface area, chlorophyll a, chlorophyll b, total chlorophyll, and flavonoid. In Chrysanthemum, the analysis of variance results indicated that light pollution had a significant effect on some morphological traits. Overall, in this plant, stem and root length decreased compared to the control plant when light pollution was introduced. Overall, it can be concluded from the analysis of the data obtained from the experiment with a minimum of 3 replications using Duncan's multiple range test based on a completely randomized design that light pollution had a positive effect on Petunia (a long-day plant) at 44 lux. However, no specific effect was observed in Chrysanthemum (a short-day plant).

Keywords- Light pollution, Petunia, Chrysanthemum.

I. INTRODUCTION

Light pollution can be defined as excessive artificial light or incorrect lighting (Hollan, 2007). It is broadly categorized into two types: astronomical and ecological light pollution. Astronomical light pollution refers to excessive lights that can significantly hinder astronomical studies. Ecological light pollution usually refers to the impact of excessive light on the environment (Longcore and Rich, 2004). Various sources contribute to light pollution, including industrial centers, residential areas, shopping centers, recreational facilities, advertising, street lighting, security lights, vehicles, and homes. Among these sources, street lighting is a major concern for light pollution, serving as a primary source of illumination in urban areas (Khorram et al., 2014). Light pollution, resulting from the excessive use of artificial light at night, is a global phenomenon and one of the fastest-growing environmental changes caused by humans (Grubisic et al., 2017). It harms mammals, birds, amphibians, insects, fish, and plants (Gallaway et al., 2010). Light is a crucial environmental factor that regulates the growth and development of plants. Photosynthesis is the only biological process that can directly utilize this energy. A significant portion of Earth's energy sources (fossil fuels) is derived from

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recent or ancient photosynthetic activities of plants (Smith, 1982). Plants not only need light for photosynthesis but also for regulating growth and development. Ultraviolet, blue, and red light have better photomorphogenic responses, such as seed germination, vegetative growth, flowering, and branching. Light has two main functions in plants: firstly, it stimulates plant growth through the process of photosynthesis, converting solar energy into chemical energy, resulting in plant growth. Secondly, light plays a role in producing or stimulating physiological responses such as seed germination, flowering, senescence, gland and root formation, and photoperiodism (Wilkins and Dole, 2005). To determine the required amount of light for plants, three factors need to be measured: color, intensity, and duration of light. Color, or light quality, refers to the wavelength of light. Plants respond differently to various wavelengths of light. Mature plants grown under predominantly blue light wavelengths tend to be shorter, have darker green coloration, and exhibit more branching (Cerny et al., 2003). Two plant species, Petunia and Chrysanthemum, which are commonly planted in urban green spaces, were selected for the present study. Chrysanthemum (Chrysanthemum morifolium L.) is a short-day plant belonging to the Asteraceae family. It is native to Asia, especially China, and northeastern Europe, and is considered one of the top ten traditional ornamental flowers worldwide (Wilkins and Dole, 1999). Petunia (Petunia hybrida L.) is an annual plant belonging to the Solanaceae family (Power et al., 1997). Petunias are long-day plants photoperiodically. Chrysanthemums, on the other hand, are short-day plants photoperiodically. The reason for choosing these two plants is that they are widely planted in parks and urban green spaces, and their light requirements are usually different. Chrysanthemums are short-day plants and require long nights for flowering, while petunias are long-day plants and need short nights to flower. By using artificial lighting sources, the study aimed to investigate the effects of nighttime lighting on these plants.

II. IMPORTANCE AND OBJECTIVES OF THE EXPERIMENT

Depending on the geographical location and climatic conditions, parks and gardens are constructed in various styles. Simultaneously with the establishment of private and public gardens, the issue of lighting in such place's during darkness has been raised. However, indiscriminate lighting in urban green spaces, streets, and parks has brought about detrimental effects, to the extent that the annual cycle of growth, regeneration, and successful wintering of plants has been challenged. Excessive increase in leaf surface, weakness of root systems, lack of leaf shedding in autumn, increase in harmful substances such as nitrates in leafy vegetables, increased sensitivity to air pollution, and water hardness are prominent effects of improper lighting. Therefore, the use of suitable lamps and plants in green spaces is one of the solutions that can reduce the detrimental effects of lighting on plant life.

Light Pollution: Light pollution at night has become a significant concern. For centuries, greater and better illumination at night in urban areas was largely perceived as desirable and necessary. However, following the rapid expansion of electric lighting during the twentieth century, the effects of artificial light at night have transformed into a subject of research interest or, indeed, concern in various fields. Nighttime illumination consumes significant amounts of energy, incurring billions of dollars in costs, harming ecosystems, and negatively impacting human health. With this newfound knowledge, continuing with the same patterns of usage and other regulatory strategies is no longer justifiable. There needs to be a reassessment of nighttime illumination in urban areas. However, some artificial light at night remains desirable and necessary.

Sources of Light Pollution: There are multiple sources of light pollution. The largest source of light pollution is derived from street lighting. Other sources include industrial facilities, residential areas, shopping centers, architectural lighting, advertising, roads, street lighting and transportation, security lights, recreational facilities (such as sports stadiums), vehicles, and homes. The complete list of sources of light pollution is much larger.

III. TYPES OF LIGHT POLLUTION

Light pollution is generally categorized into two main types: astronomical and ecological. Astronomical light pollution refers to excessive lights that obscure the night sky, posing serious obstacles to astronomical observations. Ecological light pollution typically refers to the impact of excessive light on the environment, particularly on humans (Rich and Longcore, 2004).

Some of the most important types of light pollution include:

1. Skyglow: Skyglow is light that is directly or indirectly emitted upward, scattered in the atmosphere, and causes artificial brightness in the environment, reducing the visibility of stars.
2. Glare: Glare occurs when excessive brightness reduces visibility, similar to glare from a flashlight.
3. Light Trespass: Light trespass refers to unwanted or unintentional light, such as light shining through bedroom windows at night.
4. Clutter: Clutter from excessive artificial sources of light (such as signs and advertisements) contributes to light pollution.
5. Excessive Illumination: Excessive illumination refers to the inactive use of light, where more light is used than necessary.
6. Flicker: Flickering lights, continuously turning on and off for advertising or attention-grabbing purposes (Arns and Lechner, 2013).

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www.jrasb.com
https://doi.org/10.55544/jrasb.2.6.40

IV. EFFECTS OF LIGHT POLLUTION ON THE ENVIRONMENT

Light pollution, when it contains harmful and disruptive elements and interferes with natural views, is detrimental to the ecosystem. Today, 38% of Americans, 28% of Europeans, and 8% of Chinese people are unable to see stars. Regarding the effects of light pollution on human and natural environments, the first impact is on natural resources. Artificial light contributes to the production of greenhouse gases, acid rain, and smog. Additionally, one-third of artificial light at night enters the environment and causes its degradation (Bell, 2006).

The Impact of artificial light on the environment includes mortality and structural-related deaths due to disorientation and effects on light-sensitive cycles of many species. Significant costs associated with light pollution include adverse effects on health, wildlife, astronomy, and energy waste. The annual cost of light pollution in the United States is estimated to be close to $7 billion. Light pollution resulting from poor lighting design leads to energy waste, increased carbon dioxide emissions, and global warming. Another effect of light pollution is on the nocturnal environment and the life of nocturnal creatures and their habitats. In general, the effects of light pollution on the environment can be divided into five categories, including impacts on human and animal life, plant life, energy wastage, and the loss of the night sky.

Light pollution affects approximately 22% of the world's population, and more than 99% of the United States population, as well as residents of Europe, live under light-polluted skies. Moreover, the trend of light pollution in Europe has been increasing over the past 15 years towards brighter skies. (Falchi et al., 2016)

In Iran, areas with light pollution include Tehran, southern and southwestern cities due to the presence of refineries, major cities like Isfahan, Mashhad, and areas with high population density and various industries. (Tizro et al., 1391)

V. COMMON UNITS OF MEASURING LIGHT POLLUTION

Common units of measuring light pollution include lumens, which measure the total light output from a light source. If a lamp has a glass bulb around it, the light flux from the lamp through the glass bulb is measured in lumens. Essentially, lumens measure the flow of energy.

Candela and lux are units that indicate the light intensity falling on a surface. Candela is an old unit based on English measurements and is equal to one lumen per square foot. Candela is being replaced by lux. A general term used for lux or candela is illuminance, which is used by relevant engineers, but usually lux or candela units are used. (Hoff, 1999)

Light

Plants require a sustainable source of energy, which they receive from light. In nature, plants receive this light from the sun. During certain seasons, especially late autumn and winter, the days are short, and artificial light sources (various types of lamps) can be used to increase the duration of daylight.

Light and plant

Light is essential for photosynthesis, flowering, germination, and growth of plants. However, it’s not easy to overlook the assistance of artificial light, which provides an easy way for the robust growth of green seedlings. Sunlight has a full spectrum of light, and all its colors are utilized by plants, but red and blue lights play the most significant role in photosynthesis. Red light promotes plant growth and flowering. If a plant receives only red light, it grows longitudinally but remains weak. Blue light also stimulates plant growth but receiving it alone leads to short and thickening of plant branches and leaves. Using a combination of blue and red light increases photosynthesis in plants. (EbrahimZadeh, 1996) Each plant requires a certain amount of light for its life and photosynthesis to continue. Photosynthesis and transpiration are two important processes that receive their energy from sunlight. In these processes, a considerable amount of light energy is consumed, but only in photosynthesis is the energy used for future consumption. Some processes affected by light include germination, growth stages, and pigment production, which consume a small amount of light energy.

The importance of light can be attributed to several factors:

1. Energy Source: Light serves as the primary energy source for plants through photosynthesis, enabling their growth and development.
2. Regulation of Growth: Light regulates the growth and development of plants at various levels. Plants have the ability to perceive various parameters of light signals in their environment, including light quantity, quality (wavelength), direction, and duration.
3. Signal Perception: Plants can perceive light signals through at least four distinct families of light receptors, including phytochromes, cryptochromes, phototropins, and unidentified ultraviolet-B receptors
4. Seasonal Sensing: Many flowering plants utilize light receptors such as phytochromes or cryptochromes to sense seasonal changes throughout the day or photoperiod, using them as signals for flowering.
5. Impact on Flowering: Changes in the length of the day or even light integrals significantly affect the flowering process.
6. Three Aspects of Light: The intensity, quality, and duration of light are all crucial factors for its effect on plant growth and productivity. All three factors must be regulated simultaneously to influence plant growth and yield effectively.

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Volume-2 Issue-6 || December 2023 || PP. 286-291
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https://doi.org/10.55544/jrasb.2.6.40

Overall, light plays a pivotal role in regulating various physiological processes in plants, ultimately influencing their growth, development, and productivity. As a key parameter, light intensity plays a fundamental role in independently regulating the timing of flowering. Specifically, changes in light intensity can lead to significant alterations in many physiological processes of the plant. While it's well known that excessive light can have a substantial impact on plant growth and development, the precise molecular mechanisms underlying this phenomenon remain poorly understood. Adaptation to excessive light increases the rate of photosynthesis, resulting in faster plant growth. Additionally, plants growing in high light conditions usually mature earlier and tend to flower much sooner than those growing in low light conditions. However, recent discoveries indicate that the regulation of plant growth dependent on high light is more complex and involves multiple cellular signaling pathways. The plant's response to the duration of consecutive light exposure is termed photoperiodism. Light serves as a primary environmental factor regulating the timing of flowering, thus ensuring the reproductive success of plants. Despite our detailed understanding of light quality and photoperiodic mechanisms, the molecular basis of flowering induction with high light remains ambiguous. Plants require a sustainable energy source, which they derive from light. In nature, plants receive this light from the sun. However, during certain seasons, especially late autumn and winter, days are shorter, and artificial light sources (various types of lamps) can be used to increase the duration of daylight. However, other factors such as ambient temperature must also be considered when using artificial light sources.

Essentially, different plants require different day lengths for flowering, broadly categorized into three important groups:

1. Short-day Plants: These plants require short days and, in fact, long nights for flowering. Therefore, they are often referred to as long-night plants. The duration of darkness required for these plants varies from 13 to 16 hours, depending on the specific species. If the night length is below this range, they won't flower.
2. Long-day Plants: These plants require long days and short nights for flowering.
3. Day-neutral Plants: These plants are not sensitive to day or night length and can flower regardless of the day length.

In summary, light intensity independently regulates the timing of flowering in plants, and understanding its effects on plant physiology is essential for optimizing growth and production

Atlas plant

The Petunia, scientifically known as Petunia hybrida, belongs to the Solanaceae family and includes 34 species. It is an annual herbaceous ornamental plant that, in the absence of low temperatures, will grow as a perennial plant. The Petunia, in terms of photoperiodism, is an optional long-day plant, although some types are obligatory long-day plants. It requires short nights. This plant needs supplemental lighting during times when environmental photoperiods are short or light levels are low. (Warner, 2010)


Atlas plant

Origin

The first discovered species of Petunia, named. P nyctaginiflora or. P Axillaris, dates back to 1829, and its primary origin is Argentina, Brazil, and Uruguay. This plant is perennial in warm regions, while it is cultivated as an annual in moderate and cold regions. (Ando et al., 2005).

Botanical Characteristics

The leaves of the Petunia plant are sticky, slightly wrinkled, oval-shaped, sharp-tipped, and without stems. Its funnel-shaped flowers, with a diameter of about 0 centimeters, come in various colors such as purple, pink, red, white, etc., appearing successively in summer and autumn. The flower consists of 5 sepals, 5 petals, free stamens, superior ovaries, and two ovaries with numerous ovules. In all species except one, the number of chromosomes is 10. Pollination in this plant mostly occurs through insects (Samiei, 2001).

Factors Affecting Flowering

The flowering of Petunia is influenced by factors such as light, temperature, day length, carbon dioxide, and nutrition. Increasing temperature, day length, and light intensity accelerate flowering. When the day length increases, fewer days are needed for Petunia growth.

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However, it should be noted that short day's result in the growth of shorter plants, while long days lead to the growth of plants with fewer lateral branches, which have less commercial value (Kalani et al., 2003). An increase in carbon dioxide leads to a positive response in short-day plants compared to long-day plants (Reekie et al., 1997). The optimal temperature conditions for flowering are around 20 degrees Celsius, and flowering decreases in extreme heat (Moshtaghian et al., 2018).

Care and Maintenance

Petunia plants are sensitive to cold and prefer warm and sunny locations. In areas where summers are cold and humid, sturdy bushes with long branches are formed, but they produce fewer flowers. Petunias require regular watering and moist soil. Pruning branches


Reproduction

The reproduction of the Atlas plant is carried out by two methods, namely seed sowing and cutting. The seeds of the Atlas plant are cultivated annually, and they are very small and require abundant light for germination. In the first to second weeks, they are placed at a temperature of 21 degrees Celsius. Some seeds of this plant variety may require a temperature range of 27 to 23 degrees Celsius for germination in light and high temperature. The suitable substrate for seeds is lightweight substrates, and the substrate should always be moist during germination (Wilkins & Dole, 2004).

Some types of this plant produce seeds in small quantities, in which case propagation can be done through cutting in late summer and autumn using healthy lateral branches without flowers. Lateral branches easily root in lightweight and always moist substrates after two to three weeks. Then they can be transferred to main pots (Tehrani, 1393).

Davids's plant

Chrysanthemum morifolium, belonging to the Asteraceae family, is commonly known as the Chrysanthemum, also referred to as the "Queen of Autumn." This plant is native to Asia, especially China and northeastern Europe, and is highly valued for its ornamental significance, being considered one of the top ten traditional flowers in the world. Between 144 to 244 different species of this plant have been reported (Arora, 1990).

Davids's plant

Origin

The word "Chrysanthemum" is a combination of two Greek words, "chrysos" meaning gold and "anthemon" meaning flower. The initial report about Chrysanthemums dates back to about 344 years before Christ, mentioned in Chinese poetry, indicating its origin in China with a long cultivation history of over 3444 years (Liang et al., 2013). Its flower, known as "Ju Hua" in Chinese, is widely used in food supplements and herbal teas and has been recorded in Chinese medicine since 1907 (Chang et al., 2019). Chrysanthemums quickly spread to other Asian countries, including Japan, becoming a cultural symbol there. It entered Holland in 1088 and was introduced to Western society (Anderson, 2006). Currently, Chrysanthemums rank second in cut flower production after roses (Serak et al., 2006).

Botanical Characteristics

The height of Chrysanthemum plants varies from 4 to 144 centimeters, and the flowers bloom in early winter with a wide range of colors, shapes, and sizes. This highly attractive plant exhibits short-day characteristics and behaves as both an annual and perennial flowering plant. It can be cultivated throughout the year in various natural and artificial controlled environments (Kang et al., 2019). This herbaceous plant has white stems and alternating smooth or serrated oval-shaped leaves. It blooms annually with compound flower heads (capitula) consisting of ray florets (male flowers) and disc florets (female flowers). The flowers vary in size among species, but the minimum diameter of the flower head is 15 centimeters. Chrysanthemums exhibit a wide range of colors, including pink, purple, white, yellow, red, and orange (Langton, 1989).

Factors Affecting Flowering

Light is one of the most important factors affecting photosynthetic activity. Due to genetic factors, Chrysanthemum varieties exhibit a wide range of traits, resulting in flowers of different sizes ranging from 2 to 15 centimeters.

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Care and Maintenance

Stressful environments, especially heat stress, can reduce the longevity of Chrysanthemum plants, resulting from delayed flowering and deterioration in flower quality. Due to its sensitivity to high temperatures, Chrysanthemum is severely restricted under heat stress conditions, primarily delaying plant growth and causing defects in the flowers (Kang et al., 2019).

Propagation

Chrysanthemums are propagated through seed sowing, cutting, tissue culture, bush division, and recently, tissue culture. (She, 2008)

VI. CONCLUSION

In Petunia, a facultative long-day plant, the results indicate significant differences in most morphological traits between light pollution-treated and control groups. Efficient utilization of solar energy by green tissues, especially leaves, is crucial for optimal photosynthesis. The treatment with 44 lux had the most significant impact on plant height, root length, stem fresh weight, stem dry weight, leaf area, chlorophyll a content, chlorophyll b content, and total chlorophyll content. No significant differences were observed in physiological traits.In Chrysanthemum, a short-day and long-night plant, variance analysis of light pollution effects showed significant differences in some morphological traits. Generally, light pollution led to a reduction in stem and root length compared to the control. Stem fresh weight decreased, while stem dry weight increased under light pollution, with the highest leaf area belonging to the 44-lux treatment, showing a significant difference. Additionally, in physiological traits, the treatment with 44 lux exhibited the highest flavonoid content, while the lowest was observed in Petunia. Carotenoid concentration decreased with increasing light pollution. In summary, it can be concluded that light pollution at 44 lux had a positive effect on Petunia (a long-day plant), while no negative effect was observed in Chrysanthemum (a short-day plant).

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