

Fading Fertility: Investigating the Effect of Urban Pollution on Seed Formation in *Caesalpinia Pulcherrima*

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Abstract

Caesalpinia pulcherrima, or the peacock flower, is a striking ornamental plant known for its adaptability to different environments. However, its reproductive success under pollution stress remains a key concern. This study examines the impact of environmental pollution on seed production by comparing plants in a well-maintained garden with those growing along a polluted roadside. Our findings reveal significant differences between plants in the garden and the roadside plants. The plants in the garden produced more pods and seeds, with an average of 9 ± 1.2 seeds per pod, of which 6 ± 1.1 were fully developed. In contrast, roadside plants, exposed to vehicle emissions and industrial pollutants, produced 20-30% fewer pods and seeds, averaging 7 ± 1.4 seeds per pod, with only 4 ± 0.9 reaching full maturity. This decline is linked to pollutants such as sulfur dioxide (SO₂), nitrogen oxides (NO_x), and heavy metals, which interfere with plant metabolism, pollination, and seed development. Pollution-induced stress appears to shift the plant's resource allocation. Energy that would typically support reproduction is redirected toward survival mechanisms. Understanding these changes is crucial for urban biodiversity and conservation efforts. Reducing pollution and enhancing green spaces can help plants like *C. pulcherrima* sustain their reproductive success in urban environments.

Keywords: seed viability, pollution, urban ecology, plant reproduction, environmental stress

1. Introduction

Caesalpinia pulcherrima, commonly known as the peacock flower, is a tropical ornamental plant widely cultivated for its striking flowers and ecological adaptability. It belongs to the *Fabaceae* family and is known for its ability to thrive in diverse environmental conditions. This species is characterized by bright orange-red flowers, bipinnate leaves, and woody seed pods. The plant typically grows as a shrub or small tree, reaching heights of 3–5 meters. It is commonly found in gardens, roadsides, and disturbed habitats, exhibiting high tolerance to drought and urban stress [1]. *C. pulcherrima* produces elongated pods that contain multiple seeds. Each pod undergoes a developmental phase where some seeds fully mature while others remain undeveloped. The extent of seed development can be influenced by genetic

factors, resource allocation, and environmental conditions. Seed formation is a crucial process that determines the reproductive success of a species, ensuring its propagation and ecological stability [2].

Caesalpinia pulcherrima is a fast-growing, evergreen shrub or small tree that can be found in tropical and subtropical regions. It has bipinnate compound leaves with small, oval leaflets arranged symmetrically. The plant is primarily known for its vibrant, showy flowers, which are usually bright red, orange, or yellow. The flowers appear in clusters, making the plant highly attractive to pollinators such as bees and butterflies. The reproductive structures of *C. pulcherrima* include elongated, flat pods that turn brown upon maturity [3]. Each pod contains several seeds that vary in development based on environmental conditions. The seeds are hard and round, adapted for dispersal by natural forces like wind and gravity. The plant propagates effectively in well-drained soils with ample sunlight, but its seed viability can be significantly affected by pollution and environmental stressors. *C. pulcherrima* is often planted in gardens where it receives adequate care, including regular watering, nutrient-rich soil, and minimal exposure to air pollution. Such conditions support optimal growth and reproductive efficiency. In contrast, plants growing along roadsides are exposed to high levels of pollutants, including vehicular emissions, heavy metals, and industrial waste. These environmental factors can negatively impact plant health, leading to decreased flowering, pod formation, and seed viability [4].

Pollution is a growing environmental concern that affects plant health, growth, and reproduction. Air pollutants such as nitrogen oxides (NO_x), sulfur dioxide (SO₂), particulate matter, and heavy metals can disrupt physiological processes like photosynthesis, nutrient uptake, and hormonal regulation. Soil contamination with industrial waste, vehicle emissions, and other pollutants can further impact plant metabolism and reproductive efficiency. Studies suggest that pollution can lead to reduced flower production, lower fruit and seed set, and increased seed abortion rates.

This study was undertaken to investigate the impact of pollution on seed production in *C. pulcherrima*. By comparing seed formation patterns in plants growing in a regular garden versus those in a polluted roadside environment, we aim to understand how pollution stress affects pod and seed development. This information is vital for assessing the reproductive potential of *C. pulcherrima* in urban landscapes and for developing conservation strategies for plants exposed to environmental stressors.



Figure 1. *C. pulcherrima* plants at different areas.

2. Methods

2.1 Sampling and Data Collection

A total of 50 mature pods were sampled from *C. pulcherrima* trees in a regular garden with minimal environmental stress at University College Garden, Mangalore. A comparable set of 50 pods was collected from trees growing in a polluted urban area at Highway at Mangalore, characterized by high vehicular emissions, industrial pollutants, and soil contamination. The total number of seeds per pod, fully developed seeds, and undeveloped seeds were recorded for both environments [5].

2.2 Data Analysis

Descriptive statistics were used to calculate the total and average number of pods per plant, total seeds per pod, proportion of fully developed seeds, and proportion of undeveloped seeds. The data were analyzed using a t-test to assess significant differences between the two environments. A p-value of <0.05 was considered statistically significant. The correlation between pollution levels and seed viability was also explored.

3. Results

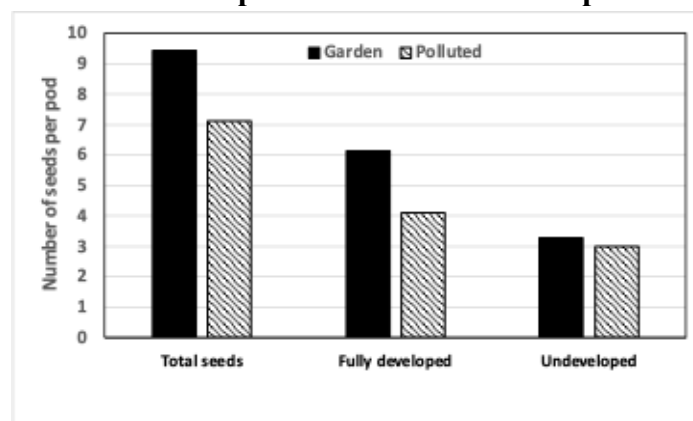
3.1 Seed Distribution in Regular Garden

The analysis of 50 pods from the regular garden showed an average of 9 ± 1.2 seeds per pod, with 6 ± 1.1 fully developed seeds and 3 ± 2.8 undeveloped seeds per pod. The number of fully developed seeds varied across individual pods, with some pods containing up to 10 viable seeds, while others had a mix of viable and non-viable seeds [6].

Table.1 Comparative Data Table for Seeds produced in Garden and polluted area

Environment	Avg. Pods per Tree	Avg. Seeds per Pod	Fully Developed Seeds	Undeveloped Seeds
Regular Garden	High	9 ± 1.2	6 ± 1.1	3 ± 2.8
Polluted Area	20 –30% Less	$7 \pm 1.4^*$	$4 \pm 0.9^*$	3 ± 1.1

Figure 2. Total seeds produced in Garden and polluted area.

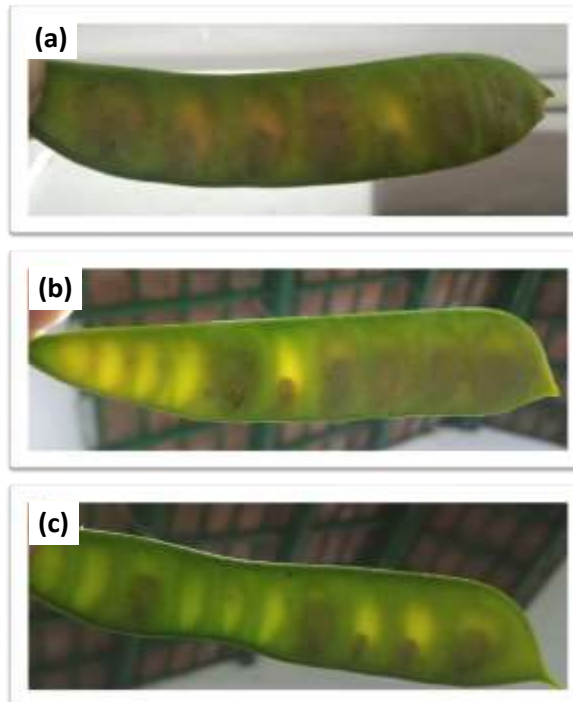


3.2 Seed Distribution in Polluted Area

In contrast, trees from the polluted area produced 20–30% fewer pods and seeds. The average number of seeds per pod was 7 ± 1.4 , with 4 ± 0.9 fully developed seeds and 3 ± 1.1 undeveloped seeds. The

proportion of undeveloped seeds was slightly lower than in the garden-grown plants, but the overall reduction in pod and seed numbers indicates an adverse effect of pollution on reproductive efficiency.

Figure 3. Pods with different seed numbers, a) fully formed seeds, b) 4 undeveloped seeds c) 5 undeveloped and 2 underdeveloped seeds.



4. Discussion

4.1 Garden Conditions vs. Roadside Polluted Conditions

In the garden environment, *C. pulcherrima* receives adequate water, nutrients, and sunlight, which supports optimal reproductive development. Soil quality is maintained, and air pollution levels are minimal, allowing for proper physiological processes such as photosynthesis, nutrient uptake, and hormone regulation [7].

In contrast, the roadside polluted environment exposes plants to high levels of vehicular emissions, dust, and industrial pollutants. These factors contribute to reduced photosynthetic efficiency, increased oxidative stress, and impaired nutrient absorption [8]. The presence of heavy metals in the soil can lead to toxicity, further affecting root function and overall plant health. The combined impact of these stressors results in lower pod production and reduced seed viability.

4.2 Reasons for Reduction in Pod or Seed Formation

Air pollutants can affect pollinator activity and reduce successful fertilization rates. Pollutants such as particulate matter and heavy metals can interfere with the olfactory cues that attract pollinators, leading to decreased pollination success [9]. Pollutants induce oxidative damage in plant cells, affecting flower and seed development. Reactive oxygen species (ROS) generated by pollutants can cause cellular damage, leading to impaired seed formation and increased seed abortion rates [10]. Pollution can disrupt plant hormone levels, particularly auxins and gibberellins, which regulate seed formation. Exposure to pollutants can lead to altered hormone signaling, resulting in reduced seed viability and abnormal pod development [11]. Heavy metals and chemical contaminants interfere with root function, reducing nutrient and water uptake. Soil contamination with pollutants such as lead (Pb) and cadmium (Cd) can inhibit root growth and function, leading to nutrient deficiencies and impaired seed development [12]. Plants under stress may prioritize survival mechanisms over reproductive investment, leading to fewer seeds. Under polluted conditions, plants may allocate more resources towards stress responses, such as the production of stress-related proteins and antioxidants, at the expense of reproductive processes [13].

4.3 Chemicals Causing Reduced Yield and Their Structures

Many chemicals are known to cause reduced yield and affect seed viability in plants. Sulfur dioxide affects photosynthesis by damaging chloroplast structures and reducing ATP synthesis. Exposure to SO₂ can lead to chlorosis, a condition characterized by yellowing of leaves due to the loss of chlorophyll [14]. Nitrogen oxides alter nitrogen metabolism, leading to nutrient imbalances that impact seed development. NO_x can inhibit nitrate reductase activity, leading to reduced nitrogen assimilation and impaired seed formation [15]. Ozone causes oxidative damage and disrupts stomatal function, reducing overall energy availability. O₃ exposure can lead to the production of ROS, causing cellular damage and reducing photosynthetic efficiency [16]. Heavy metals interfere with enzyme activity and hormonal balance, negatively affecting reproductive processes. Pb and Cd can bind to essential enzymes, inhibiting their activity and leading to impaired seed development [17]. Polycyclic Aromatic Hydrocarbons (PAHs) are organic pollutants from vehicle emissions that induce genetic mutations and hormonal disruptions in plants. PAH exposure can lead to the formation of DNA adducts, causing mutations and affecting seed viability [18].

5. Conclusion

The findings of this study highlight the significant impact of environmental pollution on seed production and viability in *C. pulcherrima*. Understanding these patterns is crucial for conservation efforts and urban planning. By reducing pollution levels and implementing habitat restoration measures, we can enhance the reproductive success of plant species like *C. pulcherrima*, ensuring their continued survival in both natural and urban landscapes.

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