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REVIEW ARTICLE

Impact of air pollution on agricultural productivity in urban areas

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Abstract
Introduction: Air pollution in urban environments impacts biodiversity, and disrupts ecosystem services that are essential for urban dwellers. One of the significant impacts of air pollution is on agricultural productivity in urban areas. Methods: This study used a quantitative approach with a descriptive design. The aim was to analyze plant responses to air pollution. Results: Air pollutants such as tropospheric ozone can damage plant tissues and disrupt cell functions, including photosynthesis and respiration, resulting in decreased growth and yield. Air pollution can disrupt pollination and fruit and seed formation, reducing the quantity and quality of the crop. Pollutants such as carbon monoxide (CO), nitrogen dioxide (NO2), and sulfur dioxide (SO2) affect plant physiology and morphology, including stomata damage, decreased chlorophyll, and leaf growth. Conclusion: The results of the study indicate that air pollution can damage plant tissues and disrupt cell functions, including photosynthesis and respiration, resulting in decreased growth and yield.

Keywords: Air Pollution, Pollutants, Agricultural Productivity, Urban Areas.

INTRODUCTION

Air pollution in urban environments poses a threat to the environment and human health, and has significant impacts on flora and fauna. Low air quality contributes to a range of health problems such as respiratory diseases, heart disease and even premature death (Handayani et al., 2023). In addition, air pollution also affects urban ecosystems, threatening their sustainability, reducing biodiversity, and disrupting ecosystem services that are important for city dwellers (Pranyoto and AP, 2024). One of the significant impacts of air pollution is on agricultural productivity in urban areas (Risnawan et al., 2024).

Air pollution, especially ammonia and nitrogen dioxide, can affect the nutritional quality of crops, alter the mineral and nutrient content of crops, and negatively impact the nutritional value for humans and animals that consume them (Tosepu, 2024). Air pollution can carry heavy metal particles such as lead, cadmium, and mercury into the soil and crops (Fernando, 2024). Thus causing an increase in heavy metal content in food and potentially having a negative impact on human health. In addition, acid rain caused by air pollution can damage soil structure and remove important nutrients, reducing soil fertility which is essential for plant growth (Daud and Agustini, 2024). Plants exposed to air pollution can become more susceptible to disease and pest attacks, because air pollution can weaken the plant's defense system (Hermanto, 2021). Therefore, this study conducted an analysis of the impact of air pollution on agricultural productivity in urban areas.

MATERIALS AND METHODS

This study uses a quantitative approach with a descriptive design. The aim is to analyze plant responses to air pollution. Plant responses to pollution are measured through physiological and morphological analysis of leaves, including changes in color, texture, and leaf shape (Fadhilah, 2024). This method aims to provide a better understanding of how air pollution affects plant health and productivity in urban areas.

RESULTS AND DISCUSSION

Tropospheric ozone waste refers to the presence of ozone in the tropospheric layer, which is located between the Earth's surface to an altitude of about 10 km (Fabian and Dameris, 2014). Unlike stratospheric ozone, which protects the Earth from ultraviolet (UV) radiation, the troposphere is destructive and is one of the air pollutants that is harmful to human health and the environment (Gheorghe and Ion, 2011). Tropospheric ozone is formed through chemical reactions between air pollutants, such as nitrogen oxides (NOx) and volatile organic compounds (VOCs), in sunlight (Masdat et al., 2023). This process often occurs on hot, sunny days, so ozone levels can increase significantly, especially in urban areas.

Air pollutants such as tropospheric ozone can damage plant tissues and disrupt cell functions, including photosynthesis and respiration, resulting in physical damage to plants and reduced growth and yields (Dias, 2024). In addition, air pollution can inhibit crop production by disrupting the pollination process and the formation of fruits and seeds, thereby reducing the quantity and quality of the harvest (Arifien et al., 2022). Chemical compounds produced by air pollution can change the organoleptic characteristics of plants and make them less attractive to consumers (Renalda Putri, 2024).

Air pollution levels are negatively correlated with plant health, as seen from decreased photosynthesis and biomass production. Pollutants such as carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) affect plant physiology and morphology, including stomata damage, decreased chlorophyll, and leaf growth (Siregar, 2005). Locations close to pollution sources indicate poor soil quality, which can lead to low agricultural productivity or plant growth. Increased levels of carbon dioxide and other pollutants can reduce the efficiency of photosynthesis in plants (Saidal and Mar, 2020). Impact of exposure by carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) pollutants on plant physiology and morphology:

1. Stomatal deterioration
   Pollutants such as carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) damage stomata through the mechanism of toxic gas diffusion into leaf tissue, disrupting cellular functions (Munawwaroh et al., 2017). CO inhibits K^+ ion pump activity and abscisic acid (ABA) hormone signaling, causing stomatal closure that reduces gas exchange and transpiration. NO_2 increases nitrite/nitrate accumulation in chloroplasts, which is toxic and interferes with

photosynthetic enzyme activity (Gusti and Des, 2021). SO_2 lowers leaf tissue pH, converts chlorophyll to feophytin through the release of Mg^{2+} ions, while forming acids that erode the cuticle and damage stomatal structure (Waryanti et al., 2015). Pollutants also trigger the accumulation of reactive oxygen species (ROS) that damage stomatal cell membranes and mesophyll tissues, exacerbating morphological damage such as stomatal asymmetry or blockage (Hidayat et al., 2024). Although some plants adapt by increasing stomatal density in polluted areas, the cumulative effects of pollutants still reduce photosynthetic efficiency and leaf growth (Misya and Prasetya, 2024).

2. Decreasing chlorophyll content
   The decrease in chlorophyll content in plants due to CO, NO_2, and SO_2 pollutants occurs through biochemical mechanisms and metabolic disorders. SO_2 lowers the pH of leaf tissue, causes the release of Mg^{2+} ions from the chlorophyll structure, turning it into inactive feophytin (Rachmani, 2003). NO_2 increases the accumulation of nitrite and nitrate in chloroplasts which are toxic, inhibit photosynthetic enzyme activity and damage thylakoid membranes (Rizkiaditama et al., 2017). Heavy metal pollutants such as Pb from vehicle emissions interfere with the uptake of Mg and Fe elements essential for chlorophyll synthesis, causing degradation of green pigments (Karliansyah, 1997; Fathia et al., 2015). CO indirectly affects chlorophyll by inhibiting the uptake of K^+ ions required to maintain the turgor pressure of stomatal guard cells, reducing the efficiency of gas exchange for photosynthesis. Oxidative stress from pollutant-induced reactive oxygen species (ROS) damages chloroplast structure and inhibits chlorophyll biosynthesis. The cumulative effects are chlorosis (green color fading), necrosis (leaf tissue death), and decreased leaf area due to systemic metabolic disorders (Rizkiaditama et al., 2017).
3. Leaf growth impairment
   Leaf growth impairment due to CO, NO_2, and SO_2 pollutants occurs through complex interactions involving structural damage and metabolic disturbances. CO inhibits the uptake of K^+ ions necessary to maintain the turgor pressure of stomatal guard cells, reducing photosynthetic efficiency and transpiration vital for leaf growth (Anisa, 2019). NO_2 increases the accumulation of nitrite/nitrate in leaf tissue, which is toxic and disrupts enzyme activity and damages mesophyll cell membranes (Kvesitadze et al., 2006). SO_2 lowers the pH of leaf tissue through the formation of sulfuric acid, causing degradation of chlorophyll to feophytin and erosion of cuticle and epidermis. Heavy metal particles such as lead (Pb) carried by pollutants clog stomata and inhibit the absorption of essential nutrients such as Mg and Fe, aggravating metabolic deficiencies. Pollutant-induced oxidative stress from reactive oxygen species (ROS) damages DNA, proteins, and cell membranes, causing necrosis, chlorosis, and thinning of mesophyll tissue (Rachmani, 2003). The cumulative effect is smaller leaves, slower growth, and reduced biomass due to inhibition of photosynthesis and disruption of energy distribution (Saidal and Mar, 2020).

Table 1. Microplastic findings in previous studies

No	Pollution	Mechanism of impact of pollution exposure	Impact on plants
1	CO	Inhibits K^+ ion pump and ABA signaling	Stomatal closure, cuticle thinning (Nuryana et al., 2024)
2	NO_2	Increases nitrite/nitrate in chloroplasts	Cell toxicity, decreased chlorophyll (Winda, Kardhinata, Nurtjahja, Fauziah, 2024)
3	SO_2	Decrease the pH of leaf tissue	Conversion of chlorophyll to feophytin (Rachmani, 2003)

When plants are exposed to significant pollution, their ability to convert carbon dioxide into oxygen is reduced, which directly inhibits their growth (Saputri et al., 2022). The effects of air pollution on plants have an impact on morphological and physiological damage to plants. Air pollution can cause physical changes or damage to important parts of plants such as leaves, stems, and roots. Air quality in several cities is quite worrying, with relatively high levels of CO (Kariada, 2011). Urban vegetation plays an important role in mitigating air pollution by absorbing, settling, or decomposing pollutants through biological processes.

CONCLUSIONS

Phytoremediation is a green technology that uses plants to clean contaminated environments, such as soil and water, from harmful pollutants, including heavy metals and organic compounds. This process takes an average of 2 to 14 days, depending on the type of plant, the type of pollutant, and environmental conditions. Phytoremediation mechanisms include phytostabilization, where plants stabilize pollutants in the soil; phytodegradation, which involves breaking down pollutants into less harmful forms; and phytovolatilization, where pollutants are converted into gas and released into the atmosphere. The efficiency of phytoremediation is influenced by several factors, including the characteristics of the plants used, environmental conditions such as temperature and pH, and the nature of the pollutant itself, such as concentration and bioavailability. The level of efficiency of phytoremediation in reducing pollutants can be estimated using the percentage reduction formula. Observations on plant growth such as biomass weight, root length, and plant height are needed to evaluate plant health and possible phytotoxicity symptoms due to contact of contaminants on plants. Spectroscopic or chromatographic laboratory analysis is required to obtain quantitative data regarding the accumulation of heavy metals or other hazardous substances.

Author contributions

Nasya Aulia Fitriana, Nabilah Aminah Lutpi, Nour Salah Abdeljawad: conceptualization, analysis, draft writing, and editing.

Conflict of Interest

There is no conflict of interest in this study.

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Data availability

Data related to the findings of this study are available at the corresponding author.

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