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Assessing the effectiveness of green belt zones with plant species in combating urban air pollution

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ABSTRACT

Air pollution poses a significant threat to both human health and the environment. Plants have the capacity to absorb pollutants and act as living filters, thus playing a crucial role in reducing air pollution. The present study aimed to assess the air pollution tolerance index of Terminalia catappa, Phyllanthus emblica, Syzygiumcumini, Eucalyptus globulus Labill. Biochemical analysis, namely, pH of the leaf extract, relative water content, total chlorophyll content and ascorbic acid content were analyzed and air pollution tolerance index was calculated as per standard guidelines. The antioxidant enzymes were also assessed. The present study revealed that the chlorophyll content in the plants varied from 1.6 to 0.8mg/g in unpolluted leaf samples and 1.0 to 0.6mg/g in polluted sites. The leaf extract pH ranged from 7.35- 5.21. Syzygiumcumini showed the greatest RWC (90%) in unpolluted sites. The ascorbic acid level was found to be high in Phyllanthus Emblica.The Air Pollution Tolerance Index (APTI) is a scientific tool used to quantify the tolerance levels of plants to air pollution.The APTI values were in the order Phyllanthus Emblica 15.4, Terminalia catappa 14.3, Syzygiumcumini13.97,Eucalyptus globulus Labill 12.54 in unpolluted leaves and in polluted leaves APTI values were 12.69 for Phyllanthus emblica, 11.85 for Terminaliacatappa, 10.77 for Syzygiumcumini and 10.26 for Eucalyptus globulus Labill respectively. As key components of green belt enhancement, plants not only contribute to reduction of air pollution but also offer additional benefits such as biodiversity preservation and aesthetic enhancement. Therefore, there is a compelling need to promote and develop green belt zones in urban areas affected by high levels of air pollution.

Keywords: APTI; Total chlorophyll; Air pollution; Antioxidants; Greenbelt

INTRODUCTION

The rapid expansion of India's economy, driven by industrialization and urbanization, has necessitated extensive road development, crucial for enhancing connectivity and socioeconomic growth. However, this development comes at a cost to the environment, particularly in terms of urban air pollution. (Singh *et al.,* 2023). Environmental pollution occurs when there are detrimental alterations in our environment that have adverse impacts on both humans and other living organisms, encompassing plants and animals. A pollutant is defined as a substance that plays a role in causing pollution. Pollutants are compounds found in elevated concentrations compared to their natural levels and can originate from either human actions or natural phenomena. Urban air pollution, stemming from a myriad of sources including industrial activities, vehicular emissions, and household combustion, poses significant threats to both human health and environmental well-being (Woo and Je 2006; Tripathi and Gautam 2006; Hoque *et al.* 2007; Joshi and Swami 2009; Rai 2011a, b, 2013). An air pollutant refers to any substance, whether it's chemical, physical, or biological, that alters the fundamental characteristics of the atmosphere. Particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulphur dioxide are among the primary pollutants of concern, contributing to respiratory and other health disorders. Life on Earth depends on the existence of plants. In recent years, there has been a growing recognition of the pivotal role played by plants in mitigating air pollution. Plants act as natural filters, absorbing pollutants and enhancing air quality in urban areas (Horaginamani and Ravichandran 2010). According to Kuddu*et al.* (2011), it is important to screen plants for their level of sensitivity and tolerance to air pollutants since the sensitive plants can serve as bio-indicators while the tolerant plants can operate as a sink for pollutants in urban and industrial areas. How

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well a plant can manage air pollution is measured by an air pollution tolerance index. The research study aims to evaluate the air pollution tolerance index (APTI) of four plant species commonly found along Indian roadsides: Terminalia catappa, Phyllanthus emblica, Syzygiumcumini, and Eucalyptus globulus Labill. This assessment is conducted by measuring chlorophyll content, leaf pH, and relative water content which provides insights into each species ability to withstand air pollution stress. By quantifying the APTI of these plants, the study aims to identify species that are particularly resilient to urban air pollution and thus it can serve as valuable indicators for monitoring environmental quality.

MATERIALS AND METHODS

Sample preparation

Fresh leaves of Terminalia catappa, Phyllanthus emblica, Syzygiumcumini and Eucalyptus globulslabillwere collected from the polluted sites of Ambattur Industrial estate, Chennai (13.0892° N, 80.1613° E) and Thiruverkadu, Chennai (13.0734° N, 80.1269° E)(Unpolluted site) during the month of December to March(spring/ winter season). Fresh leaves were used in accordance with the normal procedures. The entire study was conducted with aqueous extract.

Biochemical analysis

Determination of pH of leaves

The pH of leaf extract was evaluated according to the protocol of Prasad and Rao (1982).

Total chlorophyll Content

Chlorophyll content was estimated by Arnon's method (Arnon 1949). Using visible spectrophotometer, the absorbance of chlorophyll a, b was measured at 645 nm and 663 nm.

Chlorophyll -a (mg/g tissue) =12.7 (Abs663) - 2.69 (Abs 645) X VX W /1000

Chlorophyll -b (mg/g tissue) =22.9 (Abs 645) - 4.68 (Abs 663) X VX W / 1000

Total chlorophyll: Chlorophyll a + Chlorophyll b

Relative water content

RWC was measured by following the procedure of Singh (1977).

RWC= (F_W-D_W/T_W-D_W) x 100.

FW stands for fresh weight, DW for dry, and TW for turgid weight.

Ascorbic acid content

Ascorbic acid content was measured colorimetrically using the method followed by Omayeet al (2018).

Air Pollution tolerance index

The air pollution tolerance indices for the selected plants were calculated using (Singh and Rao's 1991).

APTI = (A (T+P) + R) /10

A- Ascorbic acid, T- Total chlorophyll, P=pH of the leaf extract, R=Relative water content of leaf (percent).

RESULTS AND DISCUSSION

Chlorophyll content in leaves of *Terminalia catappa, Phyllanthus emblica, Syzygiumcuminiand Eucalyptus globulus Labill*collected from unpolluted and polluted sites is shown in Table1.

Table 1: Chlorophyll content in leaves of *Terminalia Catappa, Phyllanthus emblica, Syzygiumcumini and Eucalyptus globulus Labill* collected from unpolluted andpollutedsites

S. No	Plant name	Unpolluted Chlorophylla	Unpolluted Chlorophyllb	Total Chlorophy ll (mg/g)	Polluted Chlorophylla	Polluted Chlorophy ll b	Total Chlorophy ll (mg/g)
1	*Terminalia catappa*	0.835	0.168	1.003	0.485	0.187	0.672
2	*Phyllanthus emblica*	1.285	0.362	1.647	0.840	0.241	1.081
3	*Syzygiumcumini*	0.701	0.186	0.887	0.562	0.217	0.779
4	*Eucalyptus globulusLabill*	0.963	0.289	1.252	0.531	0.169	0.700

The present study revealed that the chlorophyll content in the plants varied from 1.6to 0.8 mg/g in unpolluted leaf samples and 1.0 to 0.6 mg/gin polluted sites. The amount of chlorophyll decreases as the pollution level rises.

From the study carried out, *Phyllanthus emblica showed* the highest total chlorophyll content of 1.647 mg/g, *Eucalyptus globulus Labill1.252* mg/g, *Terminalia catappa*1.003mg/g while *Syzygiumcumini*showed lowest chlorophyll content 0.887mg/gin leaves collected from unpolluted sample.The total chlorophyll content in polluted sample was found to be highest in *Phyllanthus Emblica*(1.081 mg/g), *Syzygiumcumini* (0.779 mg/g),followed by *Eucalyptus globulus Labill(0.700*mg/g*)* and *Terminalia catappa* (0.672mg/g) respectively. The total chlorophyll content decreased in polluted samples than in unpolluted samples. Chlorophyll is one of the primary components of energy production in green plantsand environmental conditions have a big impact on how much of it is present. The change in total chlorophyll content may be due to the interference of various enzymatic activities. The functional -SH group of the enzyme that synthesizes chlorophyll may interact with heavy metals to cause chlorophyll sensitivity (Sharma *et al.,* 2020). Plants become less productive because of chlorophyll depletion, and this results in weaker growth. Under Stressful conditions, plants overall chlorophyll levels drop (Speeding and Thomas 1973).

Table 2: pH of the leaf extracts of *Terminalia catappa, Phyllanthus emblica, Syzygiumcumini and Eucalyptus globules Labill* collected from unpolluted and polluted sites

S.No	Plantname	Non-Polluted	Polluted
1	*Terminalia catappa*	6.20	5.87
2	*Phyllanthus emblica*	7.35	7.00
3	*Syzygiumcumini*	6.05	5.21
4	*Eucalyptusglobulus Labill*	6.75	6.11

Bell and Mudd (1976) suggested that the production or breakdown of chlorophyll may be related to a plant's resistance to SO2. While chlorophyll is crucial to plant metabolism, measuring it is a crucial step in determining how air contaminants affect plants. A decrease in chlorophyll content results from the loss of magnesium ions, which causes chlorophyll to degrade into phaeophytin.At varying levels of pollution stress and varying climatic circumstances, the amount of chlorophyll may change over time.At the polluted sites, the amount of chlorophyll a and chlorophyll in both plants was drastically reduced.

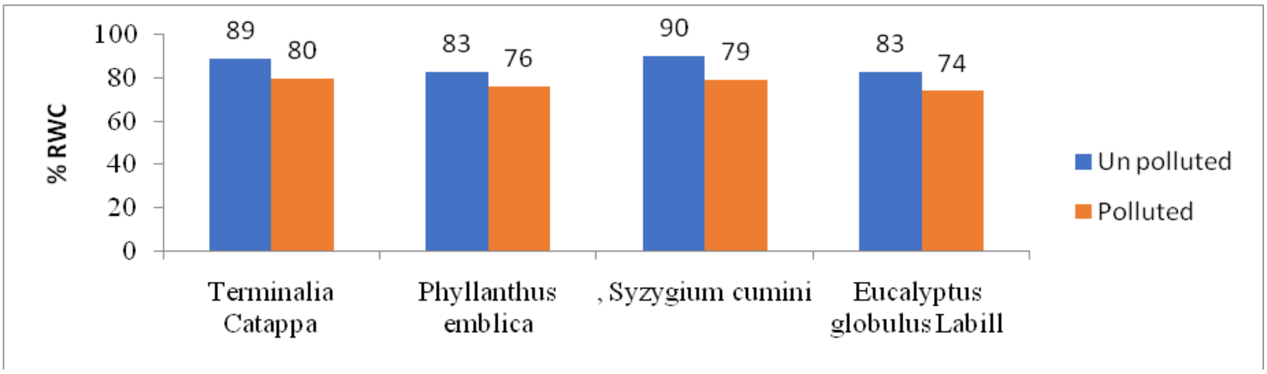

Fig 1: RWC (%) of plant species

Compared to Plants with low pHs, Plants which have leaf extract pH of 7 or above are more tolerant of air pollution (Singh *et al.,* 1991). The majority of the plant species chosen for this study had pH levels between 6- 7 in unpolluted sites and between 5.2- 7 in polluted sites. The pH of the leaf extract is lower in plants that have been exposed to acidic pollutants SOx, NOx, andCO_2. (Karmakar *et al.,*2021).

pH of the plant species collected from unpolluted and polluted site is given in the table2. The leaf extract pH of the plant species collected from unpolluted site ranged from7.35-6.05 and in polluted samples it was found to be between 7.00 to 5.21. The highest pH was observed in *Phyllanthus emblica* (7.35) followed by *Eucalyptus globules Labill* (6.75), *Terminalia catappa* (6.20) and *Syzygium cumini (6.05)* in unpolluted leaf samples. There was a slight decrease in the pH values of plants exposed to air pollutants. The pH value of *Phyllanthus emblica* in polluted sample was found to be 7.00 followed by *Eucalyptus globules Labill* (6.11), *Terminalia Catappa (5.87)* and *Syzygium cumini* (5.21). The pH range of soil in agricultural area is found to be 4.15-6.4 and forest soil is 3.86- 5.64 (Durai *et al.,*2023). The Relative Water Content of the *Terminalia catappa, Phyllanthus emblica, Syzygiumcuminiand Eucalyptus globulus Labill* collected from unpolluted and polluted sites is shown in Figure1. *Syzygiumcumini showed* the greatest RWC (90%) followed by *Terminalia catappa* 89%, *Phyllanthus emblica andEucalyptus globulus Labill* by 83% RWC in leaves collected from unpolluted sites. In this study it was surprising to note that there was around 30%decrease in RWC of *Phyllanthus emblica* and around 10% increase in RWC of *Terminalia catappa leaves* collected from polluted sites.

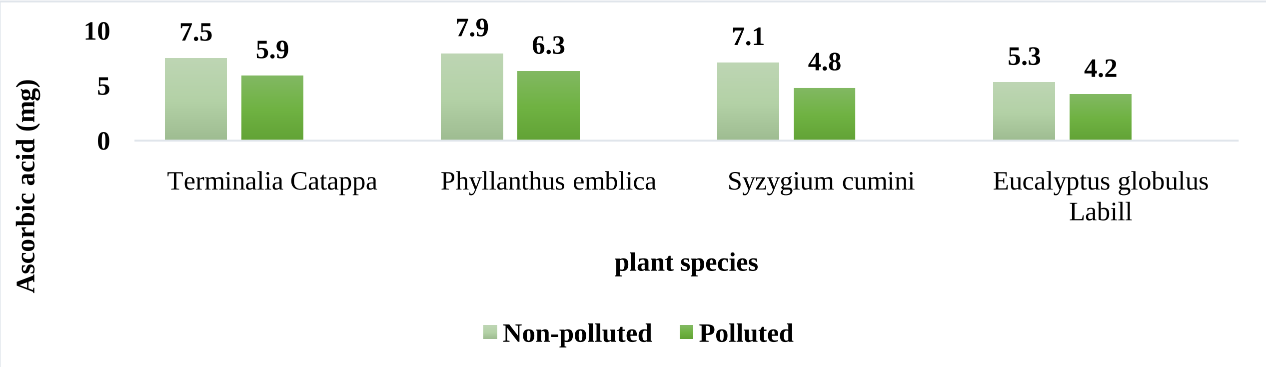

Figure 2: Ascorbic acid content *Terminalia Catappa, Phyllanthus emblica, Syzygium cumini and Eucalyptus globulus Labill* collected from unpolluted and polluted sites

The changes in the sampling period, place, Irradiance, temperature, humidity and soil salinity may have contributed to the observed discrepancies (Ksenzhek, 1998) Stomatal conductance and CO_2 assimilation are both lowered by decreasing RWC (Lawlor, 2002) Net CO_2 exchange, CO_2 assimilation and photosynthetic potential become zero at very small RWC (approx40%) (Lawlor,2002). Plants may produce more transpiration when under stress, such as when exposed to air pollution. A higher RWC gives plants a better tolerance capacity against air pollution (Singh *et al.,* 1991; Shrestha *et al.,* 2021)

Ascorbic acid content in *Terminalia catappa, Phyllanthus emblica, Syzygium cumini and Eucalyptus globulus Labill* collected from unpolluted and polluted sites is shown in figure 2. From this study it was observed that there was change in the ascorbic levels of polluted and unpolluted leaves. The ascorbic acid level was found to be 7.9 mg/gin Phyllanthus *emblica*, 7.5 mg/g in *Terminalia catappa*, 7.1 mg/g and 5.3 mg/g in *Eucalyptus globulus Labill* in unpolluted plants. The Ascorbic acid content was between 4.2 mg/g to 6.3mg/g in leaves collected from polluted sites.

Ascorbic acid in plant leaves has multiple functions to perform through cell wall synthesis, cell division, photosynthetic carbon fixation and acts as a strong reducer protecting the plants against reactive oxygen species (ROS), increasing the trees capacity to withstand air pollution. Ascorbic acid content rises along with pollution levels to help with stress management (Bharti *etal.* 2018). Ascorbic acid content rises along with pollution levels to help with stress management. It acts as a powerful reductant (RudolphandBukatsch, 1966) electron donor, scavenges free oxygen radicals, facilitates the reduction of sulphite to hydrogen sulphide and reduces the toxicity of SO2.Highascorbicacidplantsareresistantto O2 (Varsney, Varshney 1984).

The APTI values were in the order *Phyllanthus emblica* (15.4) >*Terminalia catappa* (14.3)>*Syzygium cumini* (13.97) >*Eucalyptus globulus Labill* (12.54) in unpolluted leaves and in polluted leaves APTI values were 12.69 for *Phyllanthus emblica*,11.85 for *Terminalia catappa*,10.77 and 10.26 for *Syzygium cumini* and *Eucalyptus globulus Labill* respectively.

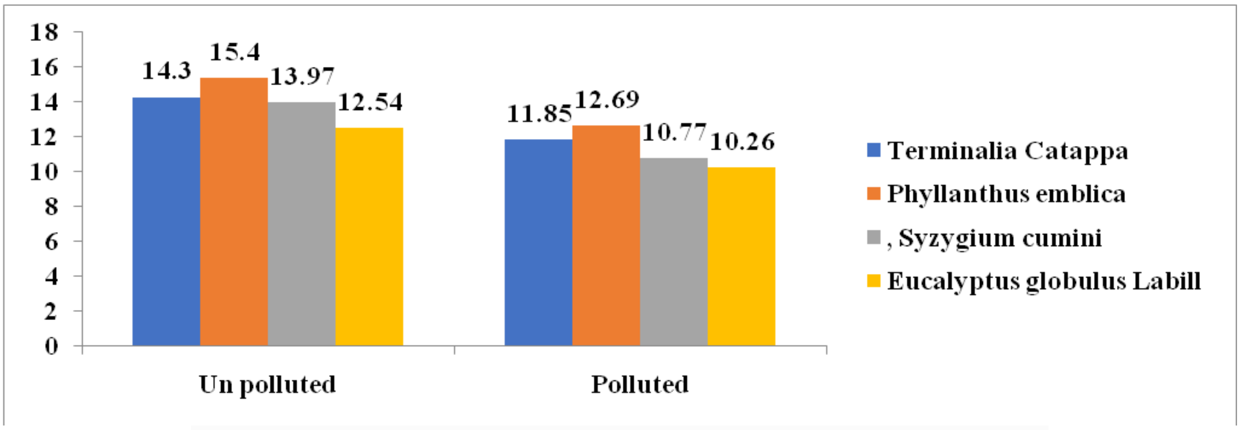

Figure 3: APTI values of selected polluted and non-polluted plants

CONCLUSION

Plants with an APTI value of less than 11 are thought to be sensitive, those between 12 and 16 are classified as intermediate, and those with an APTI value of more than 17 are thought to be tolerant. It is evident that *M. indica* is quite tolerant. Also, it is understood that the other plants employed in the study are occasionally tolerant. Plants operate as a key green belt enhancement component and as living filters to limit air pollution. Thus, attention is needed to promote and develop green belt zones in polluted areas. By using plants like *Terminalia catappa, Phyllanthus emblica, Syzygium cumini,* and *Eucalyptus globulus Labill* in urban areas, air pollution can be reduced, according to the findings of this study.

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