Study on air pollution tolerance index in certain plants growing in polluted zone of Hyderabad, India

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Abstract

The pollutants travel through different media, by air and water currents, and also dispersion and deposition. Plants being the primary producers are greatly exposed in and to the environment and basically sharing a link with each being. A simple consideration indicates that there has never been a truly unpolluted atmosphere. The competence of plants against the pollution abuse due to plant tolerance. Plants are examined for their APTI scores for them to be categorized as sensitive, intermediate, and tolerant in order for them to be selected accordingly. For the current study, four plants were selected, are *Bougainvillea spectabilis, Polyalthia longifolia, Terminalia catappa, and Tridax procumbens* collected from the polluted zone of Hyderabad city. Among the selected plants *Bougainvillea spectabilis* and *Polyalthia longifolia* were under the intermediate category whereas *Terminalia catappa*, and *Tridax procumbens* are sensitive to air pollution. Tolerant plant species can also be used in Greenbelt development, as they tend to serve as barriers and act as a sink for air pollutants. Although studies have been carried out on responses of plants to air pollution yet a lacunae exists.

Key words: APTI, Chlorophyll, Ascorbic acid, Tolerance

Introduction

Invasion of the undesired materials and gases to the natural environment is known as the Pollution, and the elements causing pollution are known as the Pollutants. Pollutants can be both natural and a result of manmade activities. It is a global cause and caused globally too (E.C. Halliday 1961). The pollutants travel through air and water currents. Apart from transport the pollutants also move through dispersion and deposition. Developing technology has introduced new forms of pollution into the atmosphere and, on the other hand, town populations have become more intolerant of the types of pollution which they were breathing (E.C.Halliday, 1961).

Urban air pollution is one of the major atmospheric pollution issues that is getting worse with the growing urban population, increasing traffic density and industrialization (Gulia S, 2015). It deteriorates ecological conditions and can be defined as the fluctuation in any atmospheric constituent from the value that would have existed without human activity. Environmental stress, such as air pollution, is among the most important limiting factor for plant productivity and survival. In urban environments, trees play an important role in improving air quality by taking up gases and particles. Plants provide an enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollutant level in the environment (Khureshi S. G. D *et al*., 2013).

Plants also play their part in monitoring and maintaining the ecological balance by actively participating in the CO_2 and O_2 management. Plants absorb air pollutants such as SO_2, NOx etc. Particulate Matter, including dust settled on the leaves which provides an enormous surface for the accumulation of air pollutants. Increasing population explosion, automobiles, industrialization, urbanization is deteriorating the quality of air in the developing Cities in India. It is necessary to evaluate the status of urban air pollution continuously and to assess its impact on human health and Plants, so that proper initiative measures can be implemented (Shyamala. *et al*., 2015) Air pollutants affect plant growth adversely (Rao, 2006; Bhatia, 2006; Sodhi, 2007; Horsefall and Spiff 1998; Bhavika Sharma *et al*., 2017).

The exposure of plants to the polluted regions brings massive damage to their fragile structure and tests their tolerance. The air pollution tolerance index (APTI) as an air pollution monitoring tool is an empirical relation which evaluates the tolerance level of plant species towards air pollution by considering leaf biochemical parameters such as total chlorophyll, ascorbic acid, leaf extract pH, and relative water content (RWC). APTI has been used in studies like green belt development (Shannigrahi *et al*., 2004), traffic noise reduction (Pathak *et al*., 2008) and pollution mitigation along roadsides and around industries. (Bhavika *et al*., 2017). Several studies have shown the impacts of air pollution on plant biochemical parameters, such as the ascorbic acid content, chlorophyll content (Flowers *et al*., 2007), leaf extract pH (Klumpp *et al*., 2000) and relative water content (Rao 1977). The use of these different parameters has given conflicting results for the same species (Han *et al*., 1995). C. O. Ogunkunle *et al.,* (2015) therefore suggested that a single parameter may not provide a clear picture of the pollution-induced changes that may occur in plants. Therefore, The combination of biochemical and physiological parameters gave more reliable result than those of individual parameters. Since, they were computed together in a formulation to obtain an empirical value signifying the air pollution tolerance index (APTI) of species on the basis of earlier studies (G. Krishnaveni *et al*., 2017).

Various strategies exist for controlling atmospheric pollution, but vegetation provides one of the best natural way of cleaning the atmosphere by providing an enormous leaf area for invasion, absorption and accumulation of air pollutants level in the environment to a various extent. (Varshney 1985; Lui and Ding 2008; Escobedo *et al*., 2008; Das 2010). According to G. S. Mahecha, (2013) plants are very important for determining and maintaining ecological balance by actively participating in the cycling of nutrients and gases like carbon dioxide and oxygen etc., but air pollution can directly affect plants via leaves or indirectly via soil acidification (Steubing *et al*., 1989; Agbaire 2009; Kumar and Nandini 2013). Several contributors agree that air pollutants affect plant growth adversely (Rao 2006; Horsefall 1998). Plants act as the scavengers for air pollution as they are the initial acceptors (Joshi and Swami 2009, Randhi and Reddy 2012). Hence in the recent years urban vegetation became increasingly important not only for social reasons but mostly for affecting local and regional air quality.

The selected zones were polluted zone of Hyderabad, Trees act as air pollution sinks but the better performance comes from the pollution tolerant species (Miria and Khan 2013). By monitoring plants tolerance toward air pollution, they can be screened and can be employed as biological indicators or monitors of air pollution. Then they can be used effectively by planners and green belt developers in managing the urban air pollution. The present study was conducted to evaluate air pollution tolerance index (APTI) in some selected plants as a tool to monitor pollution and green belt development.

Relative water content of leaves is a measurement of its hydration status. According to Barrs (1968), the measurements of water content expressed on a tissue fresh or dry basis have been mostly replaced by measurements based on the maximum amount of water a tissue can hold is referred to as Relative water content The oldest method to check and measurement of water content in plants were based on water content which is expressed as a percentage of either dry or fresh weight. Moreover, the fresh weight is extremely insensitive to small changes in water content. Due to the difficulties faced during measurement of water content in dry and fresh weight leaves, the concept of expressing leaf water content as a percentage of turgid water content came to an existence. Formula for RWC (fresh weight – dry weight)/(turgid weight – dry weight) × 100 (Pieczynski *et al*., 2013).

The study is to determine the APTI scores in plants to know their tolerance/ sensitive level to analyze and compare the air pollution tolerance index of plants and categorize them for biomonitoring.

Materials and Methods

The assessment performed for the comparison of the tolerance values included plants viz: *Bougainvillea spectabilis, Polyalthia longifolia, Terminalia catappa, Tridax procumbens,* From two zones, polluted and control, namely Malakpet (9.5 km from the main campus of St. Ann's College for Women) and Shamshabad (20.2 km from the main campus of St. Ann's College for Women), respectively. Both the zones are 22.5 km apart from each other. The plants from these zones were gathered between 6-7 a.m. in the early morning.

It was observed that no detailed investigation has been taken up on the Biochemical aspects in the plants exposed to Air Pollution. In order for the comparative analysis of the biochemical parameters- Relative water content, Ascorbic acid, total chlorophyll and leaf pH were worked on.

Leaf extract

The fresh leaf materials were taken, washed, before they were transferred separately into different mortar pestle and grinded into a finely thin paste adding a pinch of Calcium carbonate and 10 ml of acetone. And only then the leaf filtrate was taken to perform the further experimentation for the said four biochemical parameters. They were all executed the same day.

Procedure

Relative water content (RWC): RWC (fresh weight – dry weight)/(turgid weight – dry weight) × 100 (Pieczynski et.al 2013) It is the overall quantity of water in a leaf relative to the maximal water a leaf can contain. The leaf materials were kept in petri plates in an oven at 105° C for 2 hrs and then removed to cool them in a desiccator and the weight was recorded (W1 g). Then 5gm of fresh leaf material is Weighed in petri plates and their weights are marked as (W2 g). The petri plates are now kept in the oven for 2hrs at 105°c. and then the leaf material is weighed and noted as (W3 g) . Now the loss of weight determined and the moisture content of the leaf material was calculated.

Ascorbic acid content: It is a component in plants present in an ample amount. It is present in different quantities in plants.1gm of leaf material is taken and ground with mortar and pestle with 10 ml of distilled water. 15 ml of filtrate is pipette out into a conical flask and

Glacial acetic acid is added and titrated against 2,6- D dye until the pale pink colour is observed.

Total chlorophyll content: It absorbs most of the energy from wavelengths of violet-blue and orange-red light and chlorophyll b absorbs light same to chlorophyll a. Fresh leaf material is taken and washed and blotted with blotting paper and then grinded with the help of mortar and pestle by adding a pinch of $CaCO_3$ and add 10 ml of acetone and then centrifuged it for 10 minutes and then transferred it into 100 ml std. flask volume, made mark by adding acetone. The leaf extract is taken into a cuvette and then the O.D is measured in a photometer at 645 nm and 663 nm for chlorophyll pigments 'a' and 'b'.

pH of leaf extract: All the living cells have their own pH and so do the cells present in the leaves of the plants. 1 gm of fresh leaf is taken and ground with the help of mortar and pestle with 10 ml of distilled water.1 ml of leaf extract is pipetted out and diluted with 10 ml distilled water. and 2 to 3 drops of universal indicator is and the colour is observed.

APTI: The air pollution tolerance indices often commonly available plants were determined by the following method by Singh and Rao (1983)

$$\frac{A(T+P)+R}{10}$$

Where, A is Ascorbic acid (mg/g fr. wt), T is Total chlorophyll (mg/g fr. wt), P is Leaf extracts pH and R is Relative water content (RWC) [(%) of the leaves], as mentioned above. The APTI values help to identify the tolerant, intermediate and sensitive plant species.

Results

Relative water content- Relative water content of leaves is a measurement of its hydration status. Poor water content causes defects in the physiology of plants. The values are as **polluted zone (polluted)** -*Tridax procumbens* (27.87) <*Terminalia catappa* (39.32) < *Bougainvillaea spectabilis* (59.74) < *Polyalthia longifolia* (74.21). The values are as shown in Table-1

Table- 1. Relative water content (%) of plant samples selected from polluted zone

S. No	Plant name	RWC
1.	*Bougainvillea spectabilis*	59.74

2.	*Polyalthia longifolia*	74.21
3.	*Terminalia catappa*	39.32
4.	*Tridax procumbens*	27.87

Ascorbic content - This study has revealed that ascorbic acid is lower in significant amounts in plant leaves at the polluted area when compared to the control area. The values shown by *Terminalia catappa* (5.4) < *Tridax procumbens* (8.8) < *Polyalthia longifolia* (8.9) <*Bougainvillea spectabilis* (9.3)

Table- 2. Ascorbic Acid Content (mg/L)of plant samples selected from polluted zone

S. No	Plant name	Ascorbic acid
1.	*Bougainvillea spectabilis*	9.3
2.	*Polyalthia longifolia*	8.9
3.	*Terminalia catappa*	5.4
4.	*Tridax procumbens*	8.8

Total chlorophyll content - The difference in leaf chlorophyll content can provide information about the physiological conditions and we can see that the chlorophyll content of plants in polluted zones has lower levels than compared to the controlled zone. The chlorophyll content values present in plants from polluted zone are, *Tridax procumbens* (0.146) <*Terminalia catappa* (0.155) <*Polyalthia longifolia* (0.225) <*Bougainvillaea spectabilis* (0.296). The values are as shown in the

Table- 3. Chlorophyll Content (mg/gfw)of plant samples selected from polluted zone

S. No	Plant name	Total chlorophyll (mg/gfw)
1.	*Bougainvillea spectabilis*	0.296
2.	*Polyalthia longifolia*	0.225
3.	*Terminalia catappa*	0.155
4.	*Tridax procumbens*	0.146

pH of leaf extract:

pH content determines the ion concentration and correlation of sensitivity to plants and it also determines if the leaf is acidic or basic in nature and its intensity. Photosynthesis is highly dependent on the pH of leaves. The increasing values of pH can be seen as follows, *Bougainvillea*(6.5) <*Tridax procumbens* (6.5) < *Polyalthia longifolia* (7) < *Terminalia catappa* (7) for polluted zone. The values are as shown in the Table - 4

Table- 4. pH of plant samples selected from polluted zone

S. No.	Plant name	pH of the leaf extract
1.	*Bougainvillea spectabilis*	6.5
2.	*Polyalthia longifolia*	7
3.	*Terminalia catappa*	7
4.	*Tridax procumbens*	6.5

Table- 5 APTI of selected plants from polluted zones

Plant name	APTI	Category
Bougainvillea spectabilis	12.28	Intermediate
Polyalthia longifolia	13.8	Intermediate
Terminalia catappa	7.79	sensitive
Tridax procumbens	8.6	sensitive

Discussion

Urbanization has led to deforestation and changing of forest land to agricultural lands, the development of cities has increased the rate of pollution which has caused many different types of problems towards the plants apart from deforestation, the physiology is also affected due the increasing pollution. Air pollution injury to plants can be evident in several ways. Injury to foliage may be visible in a short time and appear as necrotic lesions (dead tissue), or it can develop slowly as a yellowing or chlorosis of the leaf. APTI index shows the capability of a plant to fight against air pollution. The values are as shown in Table -5. Low-index plants exhibit susceptibility to air pollution. Plants are categorized as sensitive (< 12), intermediate (13–20), and tolerant (> 20) based on their APTI score. Plants are divided into three categories based on their APTI value: sensitive (< 12), intermediate (13–20), and tolerant (> 20) (Flowers - 2007).

This study suggests that *polyalthia longifolia* and *Bougainvillea spectabilis* fall under intermediate category of APTI index.

From the above results we have seen how much of impact pollution has on the water content in plants, Availability of water in plant cells associated with the protoplasmic permeability of cells and thus a loss in water content and nutrients from the cells resulted in senescence of leaf in very early stage of plant life (Masuch G et.al.1998, Agarwal S *et al*., 1997). One study has indicated that plants with higher RWC would have greater drought resistance, so it can be concluded that high water content in plants may lead the plant species to be tolerant (Dedio W et.al. 1975). So in this study we can see that *Polyalthia longifolia* has higher RWC value compared to the other plant-74.21% and all the selected plants from the polluted zone have high RWC values, this proves that the plants have shown resistance to the pollution.

Ascorbic acid content in the selected plant species is lower in polluted zone when compared with the controlled zone. Ascorbic acid plays a role in the cell wall synthesis, defense and cell division (Conklin PL. *et al*., 2001). It is also a strong reducer and plays an important role in photosynthetic carbon fixation (Pasqualini S et.al.2001). Moreover, its high level in plants indicated a high tolerance level of plant species against pollutions and its lower values rank the plants in a sensitive category against air pollution (Chaudhary CS *et al*.,1977, Varshney SRK *et al*., 1984). Thus, the decrease in the ascorbic acid content of plant species in polluted zones may be due to the continuous exposure to pollution.

Photosynthetic processes of plants mainly depend upon the chlorophyll content and development of biomass; it varies from plant to plant due to leaf age, biotic, abiotic conditions and pollution levels (Katiyar V *et al*., 2001). The disintegration of these pigments in plants exposed to pollution may occur due to atmospheric pollutants (Ninave SY *et al*., 2001). As the air pollutant directly enters in the tissues through stomata, causes partial denaturation of the chloroplast, and decreases the pigment content in the cells of polluted leaves. Degradation of photosynthetic pigments has been widely used as an indicator of air pollution (Ninave SY et.al 2001). So the lower levels of pollution indicates the higher levels of air pollution.

The pH values obtained in the result shows that the pH range in the polluted zone is acidic to neutral. The plants with high sensitivity to SO_2 and NO_2 close the stomata faster when they were exposed to pollutants (Thambavani S *et.al*., 2012). pH content determines the ion concentration and correlation of sensitivity to plants and it also determines whether the leaf is acidic or basic or alkaline in nature and its intensity photosynthesis is highly dependent on the pH of leaves. The lower pH values help us to maintain the physiological condition of plants. The higher pH ranges are also causing low photosynthesis or reduce the photosynthetic process.

Conclusion

This study disclosed that the plants vary in their sensitivity from species to species, having different degrees of tolerance. Plants with high resistance can be considered and planted to lessen the pollution while those with low APTI are used to measure the pollution levels. The study is a step towards monitoring and mitigating the enormously growing pollution. This method of calculating the APTI determining all the four biochemical parameters separately, is cost effective and hence the most used and favored. By the observations in this study, we can say that plants have the ability to serve as excellent quantitative and qualitative indices of pollution, fighting against the air Pollution impacts. The tolerant plant species can help in subduing the threatening health impacts from continuous exposure to air pollutants along with regulating ecosystem services and thus bettering the ecology. Tolerant plant species can also be used in Greenbelt development, as they tend to serve as barriers and act as a sink for air pollutants. They can be used for avenue plantation on the roadsides and in highly polluted areas like industrial areas or the busy roads of the city to control the pollution levels. can be used as the bioindicator to indicate the pollution levels in a particular area and can help to mitigate air pollution

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