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RESEARCH ARTICLE

A COMPARATIVE STUDY OF AIR POLLUTION INDUCED STRESS TOLERANCE OF SELECTED TREE SPECIES IN A DISTURBED AND UNDISTURBED PLANT COMMUNITY

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ABSTRACT

Assessment of Air Pollution Tolerance Index (APTI) of selected 10 tree species found in vicinity of quarrying area in Thelliyoor (Pathanamthitta dist., Kerala) was done. Based on the selected dominant trees from disturbed site, same tree species were spotted from a undisturbed area of St. Thomas College, Kozhencherry Campus. Present study showed the impact of air pollution on ascorbic acid content, chlorophyll content, leaf extract pH and relative water content. These separate parameters gave conflicting results for same species. However the Air Pollution Tolerance Index (APTI) based on all four parameters has been used for identifying tolerance levels of plant species. The order of tolerance was as follows: *Mangifera indica* Linn. < *Cinnamomum iners* Blume. < *Polyalthia longifolia* Sonn. < *Syzygium samarangense* Blume. < *Hevea brasiliensis* Willd. < *Psidium guajava* Linn. < *Artocarpus hirsutus* Lam. < *Garcinia gummigutta* (L.) Roxb. < *Swietenia macrophylla* King. < *Tectona grandis* Linn.

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INTRODUCTION

The atmosphere is a complex dynamic natural gas system that is essential to all living things. This gaseous mantle around us is getting continuously polluted mainly due to industrialization (Odilora, 2006). All combustion releases gases and particles into the air. These can include sulphur and nitrogen oxides, carbon monoxide and soot particles, as well as smaller quantities of toxic metals, organic molecules and radioactive isotopes. Pollutants that directly pollute the air are called primary pollutants, while those that are formed in the air when primary pollutants react or interact are known as secondary pollutants. Population growth and underestimated future plan of city development are the major triggers for the increases in the air pollution level in cities (Jayanthi & Krishnamoorthy, 2006). Air pollution can directly affects plants via leaves or indirectly via soil acidification. Plants are an integral basis for all ecosystems and almost likely to be affected by airborne pollution which are identified as the organisms with most potential to receive impacts from ambient air pollution. Also the effects are most often apparent on the leaves which are usually the most abundant and most obvious primary receptors of large number of air pollutants.

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Biomonitoring of plants is an important tool to evaluate the impact of air pollution (Jyothi & Jaya, 2009). In terrestrial plant species, the enormous foliar surface area acts as a natural sink for pollutants especially the gaseous ones. The harmful effects of air pollution on vegetation have already been well documented (Agarwal *et al.,* 1991, Rayappa & Singaracharya, 1993). Bannett and Hill (1973) have recorded the ability of plants to reduce air pollution. The efficiency of plants in absorbing pollutants is such that it can produce pocket of clean air (Gilbert, 2000). Plants growing in air polluted environment often respond and showed significant changes in their morphology, physiology and biochemistry. Plants developed characteristic response and symptoms in response to different types of pollutants and level of air pollution. Such information can be used in the field surveys of air pollution. The concept of plants as indicators of air pollution was firstly developed by Clements (1920). To screen plants for their sensitivity or tolerance level to air pollutants, large number of plants parameter has been used including leaf or stomatal conductance, ascorbic acid, relative water content, membrane permeability, peroxidase activity, chlorophyll content and leaf extract pH (Yusup, 2013). Vegetation naturally cleans the atmosphere by absorbing gases and particulate matter through leaves as plant leaf may act as a persistent absorber when exposed to the polluted environment. Sensitive plant species are suggested as bio-indicators (Tripathi *et al.,* 1999; Raina & Sharma 2006).

Different plant species showed a different behaviour for different pollutants and any plant part could be indifferently used as biomonitors (Mingorance, 2007). It has also been reported that when exposed to air pollutants most plant experience physiological changes before exhibiting visible damage to leaves. Previous studies also showed the impact of air pollution on ascorbic acid content, chlorophyll content, leaf extract, pH and relative water content. However the air pollution tolerance index (APTI) based on all four parameters has been used for identifying tolerance levels of plant species. The aim of the study is to compare the APTI values of important tree species of an air pollution stressed and non stressed community.

MATERIALS AND METHODS

For the present study, two communities were selected, in order to compare the Air Pollution Tolerance Index of the dominant tree species. First plant community selected was in the vicinity of a stone quarry in Thelliyoor (Puramattom Panchayath, Pathanamthitta district) Kerala State. This area was subjected to high level of air pollution due to the stone crushing unit and other quarrying activities, hence denoted as a disturbed site for the present study. This site is geographical located at 9° 44" N latitudes and 76° 66" E longitudes. Ten tree species were selected based on their predominance in pollution stressed quarry area. For the undisturbed community, the selection was done based on fact the ecosystem should be least polluted and hence plant community will be least under the pollution stress. Based on the dominant tree species found in the disturbed community, same tree species were identified and selected from the undisturbed site for the comparison. Hence for the present study of undisturbed site, the area around the green house of St. Thomas College, Kozhencherry i.e. geographically located at 9°33"N and 76° 71" E was selected.
The leaf samples of selected trees from the site of study i.e disturbed and undisturbed site were collected in the morning hours. Fully mature leaves in triplicates were collected from the selected tress of almost same DBH (Diameter at Breast Height). The fresh leaf samples were analyzed for pH of leaf extract (Arnon, 1949) total chlorophyll content (Sadasivam, & Manickam, 1996) ascorbic acid content (Varshney, 1992) and relative water content (Barr & Weatherly, 1962) using standard procedures. The obtained results culminated in the evaluation of APTI (Air Pollution Tolerance Index) following the method of Singh and Rao, 1983.

The formula of APTI is given as:

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

Where,

A = Ascorbic acid content (mg/g)
T = Total chlorophyll (mg/g)
P = pH of leaf extract
R = Relative water content of leaf (%)

RESULTS

All the parameters studied exhibited significant variation from species to species. Air Pollution Tolerance Index (APTI) proved as effective tool in calculating the tolerance level of different tree species when compared to individual bio-chemical parameters such as pH of the plant extract, relative water content, ascorbic acid content and chlorophyll content. Based on the predominance of occurrence in the disturbed site, 10 tree species selected for the present study were *Artocarpus hirsutus* Lam., *Cinnamomum iners* Blume., *Garcinia gummigutta* (L) Roxb., *Hevea braziliensis* Willd., *Mangifera indica* Linn., *Polyalthia longifolia* Sonn., *Psidium guajava* Linn., *Syzygium samarangense* Blume., *Syzygium samarangense* Blume. and *Tectona grandis* Linn. Leaf samples collected from the selected trees found in disturbed and undisturbed site were subjected to estimation of various biochemical parameters such as ascorbic acid, total chlorophyll content, leaf extract pH and relative water content. The results obtained from the biochemical estimation are discussed here below. Ascorbic acid which is known as stress hormone, was found to be higher in the tree species of disturbed site as compared to the tree species of the undisturbed site. The ascorbic acid content among of the trees of undisturbed area varied between 5.18 mg/ml to 8.28mg/ml, while of the undisturbed area ranged between 3.89 to 7.15 mg/ml. Among all the selected trees, high levels of ascorbic acid content was observed in *Tectona grandis* Linn. of disturbed area and lowest level was found in *Polyalthia longifolia* Sonn. of undisturbed site (Table 1). Also the maximum increase in the ascorbic acid content from undisturbed area to disturbed area was seen in *Garcinia gummigutta* (L) Roxb (2.33 mg/ml). The total chlorophyll content of *Polyalthia longifolia* Sonn of undisturbed area (0.76 mg/g) as well as disturbed area was found to be highest as compared to all other selected trees (Figure 3). In all the selected trees, total chlorophyll content was found to be much lower in disturbed site as compared to undisturbed site.

The pH values of the disturbed sites trees were more acidic as compared to the undisturbed tree species. The pH values of *Hevea brasiliensis* Willd, *Cinnamomum iners* Blume, *Tectona grandis* Linn and *Garcinia gummigutta* (L) Roxb of the disturbed site was found to be much lower. While for the undisturbed site the pH values of all the tree species fell around the normal pH range viz. between 6.83 to 7.67 (Figure 4). The relative water content of the *Cinnamomum iners* Blume. was found to be highest 88.79 % of disturbed area followed by *Tectona grandis* Linn. and *Garcinia gummigutta* (L) Roxb. In trees such as *Cinnamomum iners* Blume, *Garcinia gummigutta* (L.) Roxb., *Psidium guajava* Linn., *Swietenia macrophylla* King. and *Tectona grandis* Linn. the RWC increased under stress condition as it is known to balance the stress. After all the biochemical estimations APTI was calculated i.e. air pollution tolerance index (Table 3). Among the selected trees, except two trees viz. *Cinnamomum iners Blume* & *Polyalthia longifolia Sonn* all other species showed an increase in the APTI values in all the disturbed sites. While, in *Mangifera indica Linn* APTI values in the disturbed and undisturbed site was more or less the same. Among all the species, *Tectona grandis Linn., Swietenia macrophylla King., Garcinia gummigutta (L) Roxb* showed the highest APTI values.

DISCUSSION

Ascorbic acid or vitamin C is a sugar acid. It is required for normal formation of connective tissue collagen, specifically for hydroxylation of certain porline and lysine residues. It is also required for iron metabolism. It is strong reducing agent losing hydrogen atom readily to become dehydroascorbic acid which has also vitamin C activity. Ascorbic acid acts as antioxidants and protects the cell membrane from the toxic action of

Figure 1. Map of India and Kerala State State

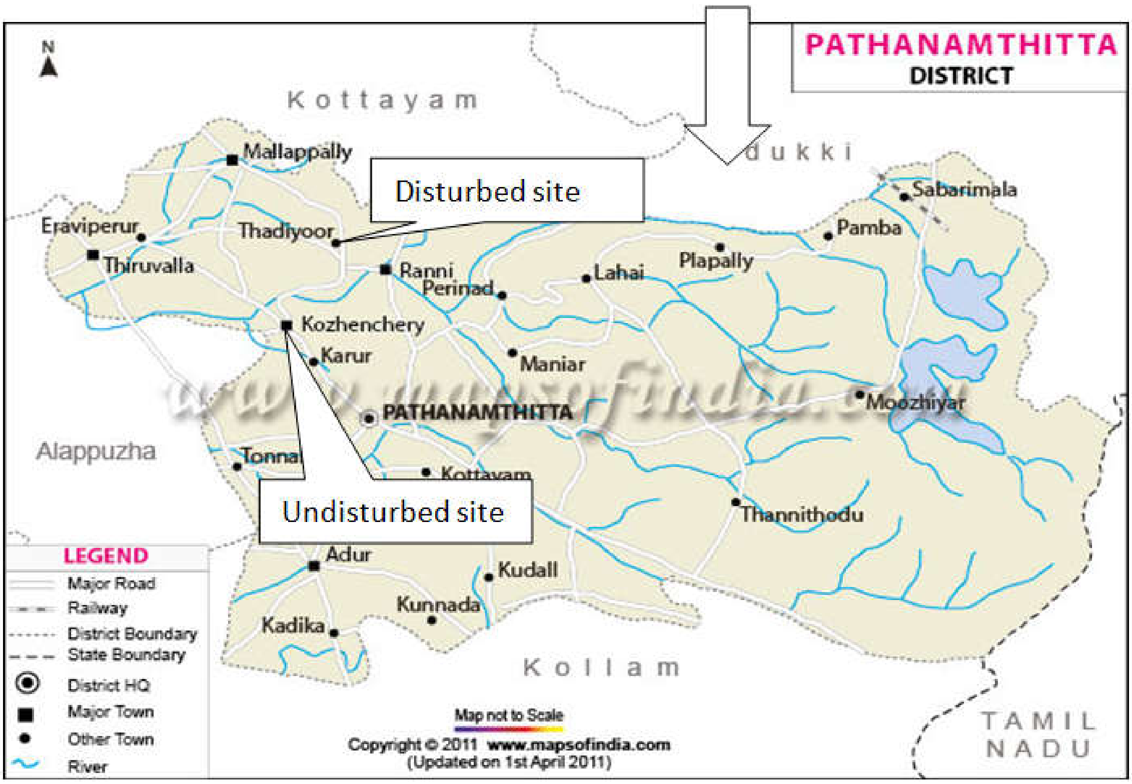

Figure 2. Site of Study

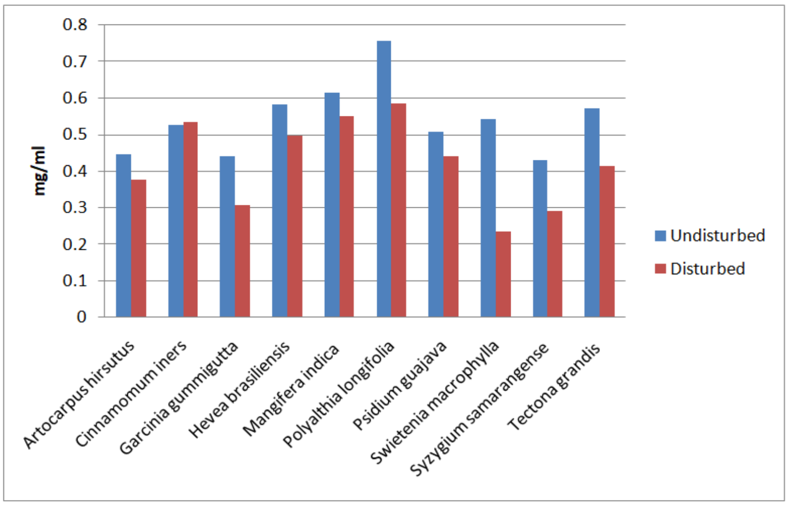

Figure 3.Total Chlorophyll Content of Tree Species of Disturbed and Undisturbed Area

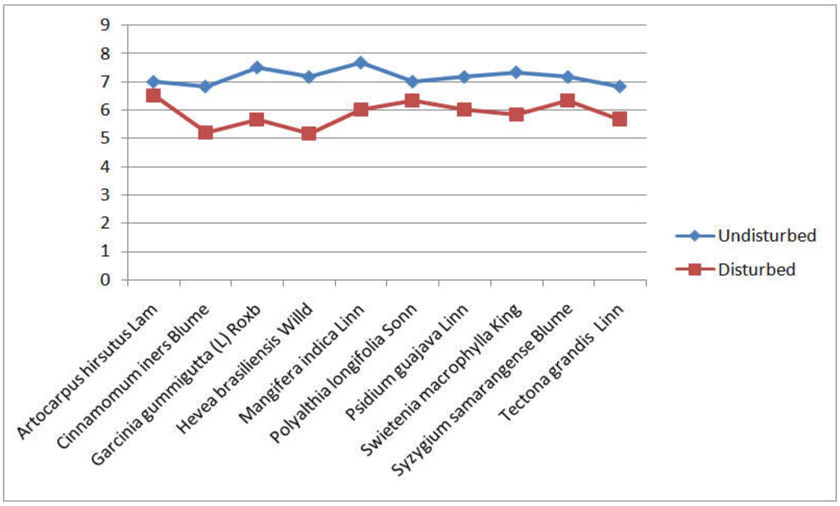

Figure 4. Variations in pH levels in Tree Species of Disturbed and Undisturbed Area

Table 1. Ascorbic Acid Content in Selected Trees Species of Disturbed and Undisturbed Area

No.	Tree Species	Ascorbic Acid (mg/ml)	
		Undisturbed	Disturbed
1.	*Artocarpus hirsutus* Lam	4.91±1.92	6.36±2.08
2.	*Cinnamomum iners* Blume	5.91±0.43	7.11±2.22
3.	*Garcinia gummigutta* (L) Roxb	5.47±1.60	7.80±0.48
4.	*Hevea brasiliensis* Willd	4.95±1.76	6.32±0.33
5.	*Mangifera indica* Linn	4.34±1.50	5.18±1.07
6.	*Polyalthia longifolia* Sonn	4.79±1.08	5.62±0.97
7.	*Psidium guajava* Linn	3.89±1.08	5.31±0.45
8.	*Swietenia macrophylla* King	4.29±1.09	5.32±2.33
9.	*Syzygium samarangense* Blume	7.15±1.80	7.55±1.18
10.	*Tectona grandis* Linn	6.51±1.18	8.28±0.51

Table 2. Variations in RWC levels in Tree Species of Disturbed and Undisturbed Area

Tree Species	RWC(%)	
	Undisturbed Site	Disturbed Site
Artocarpus hirsutus Lam	82.37	78.98
Cinnamomum iners Blume	80.52	88.79
Garcinia gummigutta (L) Roxb	83.53	85.80
Hevea brasiliensis Willd	80.22	73.60
Mangifera indica Linn	79.36	71.55
Polyalthia longifolia Sonn	83.20	80.36
Psidium guajava Linn	78.33	80.59
Swietenia macrophylla King	81.98	84.38
Syzygium samarangense Blume	83.31	80.85
Tectona grandis Linn	79.05	86.90

Table 3. APTI values of selected trees of disturbed and undisturbed areas

Name of Tree Species	APTI		Difference
	Undisturbed	Disturbed	
Artocarpus hirsutus Lam	11.34	12.86	1.52
Cinnamomum iners Blume	11.76	11.07	-0.69
Garcinia gummigutta (L) Roxb	12.17	12.87	0.70
Hevea brasiliensis Willd	11.64	11.98	0.34
Mangifera indica Linn	10.19	10.18	-0.01
Polyalthia longifolia Sonn	11.68	11.54	-0.13
Psidium guajava Linn	11.65	12.39	0.74
Swietenia macrophylla King	12.94	13.76	0.82
Syzygium samarangense Blume	10.65	11.84	1.18
Tectona grandis Linn	12.49	14.65	2.16

powerful oxidising agent. Ascorbic acid is found abundantly in berries, fresh fruits like citrus, guavas, chillies and green leafy vegetables. Its strong ability to work under stress condition is well depicted from the results as the trees species viz. *Tectona grandis* Linn and *Garcinia gummigutta* (L) Roxb showed high levels under pollution stress in disturbed site in the present work. Also the role of ascorbic acid in cell wall synthesis during cell division and also as a strong reductant during defence mechanism is well documented (Raza and Murthy, 1988). It plays important roles in photosynthetic carbon fixation, with the reducing power directly proportional to its concentration. So it has been given top priority and used as a multiplication factor in the formula. However it's reducing activity is pH dependent, being more at higher pH levels. That may be reason that the *Tectona grandis* Linn the most tolerant species of the disturbed site show higher pH as compared to other tree species of the same site. High pH may increase the efficiency of conversion from hexose sugar to amino acid, while low leaf extract pH showed good correlation with sensitivity to air pollution (Kuddus *et al.,* 2011). Measurement of pH is one of the most common and useful analytical procedures in biochemistry since the pH determines many important aspects of structure and activity of biological macromolecules. Many dyes such as phenol red, litmus, and phenolphthalein are that change colour at characteristic pH values. In our study of APTI of disturbed and undisturbed area the pH of the tolerant species was found to be slightly acidic. The total chlorophyll content of the plants in disturbed sites was found to be much lower than the plants found in disturbed site. Photosynthetic efficiency was noted strongly dependent on leaf pH. Photosynthesis reduced in plants when the leaf pH was low. Our results are well supported by earlier reports, that photosynthetic efficiency of plant species strongly depends upon the leaf pH. Thus, in the APTI formula, P, the leaf extract pH and T, the TCh have been added together and then multiplied with AA content (Singari & Talpadez, 2013).

High water content within a plant body will help to maintain its physiological balance under stress condition such as exposure to air pollution when the transpiration rates are usually high. High RWC favors drought resistance in plants. If the leaf transpiration rate reduces due to the air pollution, plant cannot live well due to losing its engine that pulls water up from the roots to supply photosynthesis. Then, the plants neither bring minerals from the roots to leaf where biosynthesis occurs, nor cool the leaf. Therefore, the product of AA and sum of leaf extract pH and total chlorophyll is added with R, the RWC in the APTI formula. The relative water content in a plant body helps in maintaining it's physiological balance under stress conditions of air pollution (Mahecha, *et al.,* 2013); Relative water content of the tolerant species of undisturbed area is higher than that of disturbed area.

In the present study it was found that *Cinnamomum iners* Blume. showed much higher RWC when compared to all other plants indicating its drought resistant property. The observations in this study suggest that plants have the potential to serve as excellent quantitative and qualitative indices of pollution. Since biomonitoring of plants is an important tool to evaluate the impact of air pollution on plants. Thus the results of the study reveal that the tolerant plant species serve as sink to air pollutants as well as indicators.

Conclusion

APTI determinations are of importance because with increase industrialization, there is increasing danger of deforestation due to air pollution. It is worth noting that combining a variety of parameters gave a more reliable result than when based on a single biochemical parameter. Certain species have maximum value for a single parameter among the four parameters specific for APTI, and that each parameter plays a distinctive role in the determination of susceptible nature of plants towards pollution and also in identifying the polluted/contaminated area. Thus the combination of four parameters is suggested as the best index for the identification of susceptibility levels of plants. Thus from the present study it could be concluded that pollution stress triggered the increased the tolerance of some species such as *Tectona grandis* while other species such as *Mangifera indica* showed no effect to combat the pollution stress. By these studies we can conclude that choice of tree species for plantations be done based on their tolerance level to such pollution stress. The results of such studies are therefore handy for future planning.

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