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Full length research paper

Studies on air pollution tolerance of selected plants in Allahabad city, India

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Screening of plants for their sensitivity/tolerance level to air pollutants is important because the sensitive plants can serve as bio-indicator and the tolerant plants as sink for controlling air pollution in urban and industrial areas. In order to evaluate the susceptibility level of plants to air pollutants, four parameters namely ascorbic acid, chlorophyll, relative water content and leaf extract pH were determined and computed together in a formulation signifying the air pollution tolerance index (APTI) of plants. APTI values of seven economically important plant species growing in the urban-industrial region of Allahabad were estimated. The order of tolerance is as follows: *Artocarpus* sp. < *Eucalyptus* sp. < *Citrus lemon* < *Azadirachta indica* < *Rosa indica* < *Aegle marmelos* < *Mangifera indica*. Among the plant studies, *Mangifera indica* (APTI value 18.51) is considered as a relatively tolerant species and *Artocarpus* sp. (APTI value 8.75) as most sensitive to air pollutants. The sensitive (*Artocarpus* sp.) and tolerant species (*Mangifera indica*) can be used as bio-indicators and as a sink for air pollutants, respectively. The technique provides a reliable method for screening sensitive/tolerant plants under field condition where the air-shed is contaminated by a variety of pollutants.

Keywords: APTI; Air pollution; Ascorbic acid; Chlorophyll; *Mangifera indica.*

INTRODUCTION

Rapid industrialization and vehicular traffic especially in the urban areas of India is a great threat to air quality. The identification and categorization of plants into sensitive and tolerant groups is important because the former can serve as indicators and the latter as sinks for the air pollutants in urban and industrial habitats. Lots of work has been done to study the response of traffic load on plants (Angold, 1997) and also the impact of industries on plants (Chaphekar, 1972; Dwivedi and Tripathi, 2007). Indian cities like Allahabad have high emission of air pollutants, which is degrading the ambient air quality day by day. The degradation of air quality is a major environmental problem that affects many urban and industrial sites and the surrounding regions worldwide.

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Major air pollutants identified in Allahabad city limits are CO, NO_x, SO_x, Pb and hydrocarbons (Agrawal et al., 2004). There is now great concern that air pollutants (especially sulfur dioxide, ozone, and oxides of nitrogen) can alter the physiological processes of plants, thereby affecting patterns of growth. Air pollutants cause damage to leaf cuticles and affect stomatal conductance. They can also have direct effects on photosynthetic systems, leaf longevity, and patterns of carbon allocation within plants. Pollutants interact with other environmental factors, and may alter plant-environment relationships on a regional scale (Winner, 1981). Various strategies exist for controlling atmospheric pollution, but vegetation provides one of the natural ways of cleansing the atmosphere by absorption of gaseous and some particulate matter through leaves (Varshney, 1985). Recent studies have explored the possibility to find out the ability of plants to remove pollutants from the air and act as sink for air contaminants (Sunita and Rao, 1997;

Dwivedi and Tripathi, 2007; Tripathi and Gautam, 2007). On the basis of air pollution indices like adsorption/absorption, different plant groups were categorized into sensitive, intermediate, moderately tolerant plant groups (Singh et al., 1991).

To screen plants for their sensitivity/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 (Winner, 1981; Keller and Schwager, 1977; Sivakumaran and Hall, 1978; Farooq and Beg, 1980; Eckert an Houston, 1982; Choudhary and Rao, 1977; Singh et al., 1991; Tripathi et al., 1991; Namita et al., 2009; William and Christopher, 1986). To indicate the susceptibility level of plant, pollution-induced changes in individual parameters are usually quantified and correlated with the level of plant response. The combination of the biochemical and physiological parameters gave a more reliable result than those of individual parameter. Therefore, combination of parameters like ascorbic acid, chlorophyll, relative water content and leaf extract pH to pollution tolerance in plants were considered in the study. 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 (Singh and Rao, 1983; Lakshmi et al., 2008; Choudhury and Banerjee, 2009). In the present study, the susceptibility levels of different plants with economical importance growing in the urban and industrial region of Allahabad city were evaluated on the basis of their APTI values.

MATERIALS AND METHODS

The city of Allahabad (25º28'N latitude and 81º54'E longitude, 98.00 m above mean sea level) is located in the eastern Gangetic Plain. The air environment of the Civil line region is contaminated with different concentration of air pollutants. SO_2, NO_2 and O_3 in ambient air were found in the ranges between 2.5 to 42.5, 10.13 to 65.04 and 3.33 to 30.83 µg/m^3, respectively (Agrawal et al., 2004). The major sources of pollutants in Allahabad city are automobile exhaust, small industries, railway traffic, and domestic heating. A total of seven plants species comprising shrubs, deciduous and evergreen trees from Civil line region, which is the heart and prime commercial area of the Allahabad city, were investigated with respect to their biochemical characteristics and APTI values.

For this purpose, the mature leaf samples (fifth from top) of the most common plants in the region such as *Azadirachta indica* (Neem), *Mangifera indica* (Mango), *Eucalyptus* sp. (Eucalyptus), *Citrus lemon* (Lemon), *Artocarpus* sp. (Jackfruit), *Aegle marmelos* (Bel) and *Rosa indica* (Rose), were collected in the month of February-March. For each species, five individuals were identified and each sample was taken in triplicate. Care was taken to see that all plants had, as far as possible, the same ecological condition with respect to light, water, soil and pollutant exposure. The collected samples were analyzed for ascorbic acid, chlorophyll, relative water content and leaf extract pH. The mean values of different parameters were used for computing the index.

Total chlorophyll content was estimated using the method of Singh et al. (1991). Briefly, 200 mg of leaf material directly harvested from the plants was ground in mortar and pestle with a small quantity of acid washed sand in 80% acetone. The absorbance of the filtered extract was measured through spectrophotometer (Genesis 6, Thermo Electron) at 645 nm and 663 nm. Equation 1 was used to calculate total chlorophyll.

$$\text{Total chlorophyll (mg/g)} = (20.2 \times A_{645} + 8.02 \times A_{663}) \times \frac{V}{1000 \times W} \quad (1)$$

Where,
A_{645} = Absorbance at 645nm
A_{663} = Absorbance at 663nm
V = Total volume of extract
W = Weight of leaf material in gram

The ascorbic acid was estimated following the method of Keller and Schwager (1977). In brief, 0.5 g of fresh leaf sample was homogenized with 20 ml of extracting solution (5 g oxalic acid + 0.75 g EDTA in 1000 ml of distilled water). It was centrifuged for 15 min at 6000xg and the supernatant collected. The supernatant (1 ml) was added to 2,6-dichlorophenol indophenol (DCPIP) (5 ml of 20 µg/ml), the solution was turning pink. The optical density of the mixture was taken at 520 nm (Es). After taking the optical density (OD) of the mixture one drop of ascorbic acid was added to bleach the pink colour and again the OD was taken at the same wavelength (Et). The OD of DCPIP solution was also taken at 520 nm (Eo). The standard curve was prepared by using different concentration of ascorbic acid by following the same method. Concentration of ascorbic acid is calculated by using the equation 2.

$$\text{Ascorbic acid (mg/g)} = \frac{[Eo - (Es - Et)] \times V}{W \times V_1 \times 1000} \quad (2)$$

Where,
W = Weight of the fresh leaf taken
V_1 = Volume of the supernatant taken
V = Total volume of the mixture

Value of [Eo – (Es – Et)] is estimated by the standard curve

Relative water content (RWC) was determined by following the method of Sivakumaran and Hall (1978). Individual leaves of different plant species were excised and weighed immediately. They were dipped into water in a beaker. After 8 hr the leaves were blotted and reweighed before being dried at 80ºC for 24 hr and reweighed. The present RWC was determined by using the equation 3.

$$\text{RWC (\%)} = \frac{\text{Initial weight} - \text{Dry weight}}{\text{Saturated weight} - \text{Dry weight}} \times 100 \qquad (3)$$

For determination of leaf pH, 5 g of leaf samples was well homogenized with 50 ml deionized water and pH of the suspension was measured with a digital pH meter (Hanna Instrument, Germany). Air pollution tolerance index (APTI) of a species was determined by using the formula developed by Singh and Rao (1983) and given as:

$$\text{APTI} = \frac{[A\,(T + P)] + R}{10}$$

Where, A is ascorbic acid content of leaf in mg/g dry weight, T is total chlorophyll content of leaf in mg/g dry weight, P is leaf extract pH and R is % relative water content of leaf. The total sum is divided by 10 to obtained APTI.

RESULTS AND DISCUSSION

The total chlorophyll content, ascorbic acid content, relative water content, pH and air pollution tolerance index values are presented in Table 1. Total chlorophyll was found to be higher in *Aegle marmelos* and least in *Eucalyptus* sp. The chlorophyll level in plants decreases under pollution stress (Speeding and Thomas, 1973). Bell and Mudd (1976) suggested that tolerance of plants to SO_2 might be linked with synthesis or degradation of chlorophyll. Thus, plants having high chlorophyll content under field conditions are generally tolerant to air pollutants.

As shown in Table 1, *Rosa indica* showed higher amount of ascorbic acid content and *Artocarpus sp.* showed low amount of ascorbic acid content. The ascorbic acid is natural detoxicant, which may prevent the damaging effect of air pollutants in plant tissues (Singh *et al.*, 1991) and high amount of this substance favours pollution tolerance in plants (Keller and Schwager, 1977; Lee et al., 1984). Earlier report shows that a definite correlation between ascorbic acid content and resistance to pollution exist in plants (Varshney and Varshney, 1984). Resistant plants contain high amount of ascorbic acid, while sensitive plants possess a low level of ascorbic acid. The level of this acid declines on pollutant exposure (Keller and Schwager, 1977). Thus, plants maintaining high ascorbic acid level even under polluted conditions are considered to be tolerant to air pollutants.

Relative water content value (Table 1) of *Mangifera indica* was found to be higher than other plant species and found to be least in *Artocarpus* sp. It has been reported that air pollutants increases cell permeability (Keller, 1986), which causes loss of water and dissolved nutrients, resulting in early senescence of leaves (Masuch et al., 1988). It is likely therefore that plant with high RWC under polluted conditions may be tolerant to pollutants.

The pH of leaf extract (Table 1) was found to be greater in *Citrus lemon* and least in *Rosa indica*. It has been reported that in the presence of an acidic pollutant, the leaf pH is lowered and the decline is greater in sensitive than that in tolerant plant (Scholz and Reck, 1977), thus higher level of leaf extract pH in plants under polluted condition may increase their tolerance level to air pollutants.

Air pollution tolerance index values were found to be greater in *Mangifera indica* followed by *Aegle marmelos* and least in *Artocarpus* sp. *Azadirachta indica*, *Rosa indica*, *Eucalyptus* sp. and *Citrus lemon* have almost same tolerance index values. Among the plant studied, *Mangifera indica* is considered as most tolerant species based on its high tolerance index value and less degradation of chlorophyll. *Artocarpus* sp. is considered as relatively sensitive species because of its least tolerance index value. The presence of high amount of ascorbic acid and the chlorophyll content also indicate the tolerance ability of *Mangifera indica*. However, Jyothi and Jaya (2010) suggested that among the species studied for APTI at Thiruvananthapuram, Kerala, *Mangifera indica* was susceptible to the automobile pollutants; so it can be used as biomonitor of vehicular pollution stress in that particular area. The study conducted by Das and Prasad (2010) at the industrial area of Rourkela, India showed near about similar APTI value (12.94) for *Azadirachta indica*. In case of *Azadirachta indica,* Horaginamani and Ravichandran (2010) also reported the similar APTI value (12.95) during the study conducted at Tiruchirappalli, India. They also concluded that *Mangifera indica* and *Azadirachta indica* are the tolerant species among the plants taken for study.

It is evident from Table 1 that no species have the maximum value for all the four parameters, and that each parameter plays a distinctive role in the determination of the susceptibility of plants. Thus, the combination of four parameters is suggested as representing the best index of the susceptibility levels of plants under field conditions. The APTI values obtained for different plants were

Table 1: Plant species of Civil line region (Allahabad city) arranged in the decreasing order of their air pollution tolerance index (values are average of three individual experiments)

Plants	T	P	A	R	APTI
Mangifera indica	12.28	7.4	4.84	89.86	18.51
Aegle marmelos	11.98	7.3	3.64	74.78	14.49
Rosa indica	07.12	7.0	3.92	72.55	12.79
Azadirachta indica	05.90	7.9	3.84	69.76	12.29
Citrus lemon	07.36	8.3	2.72	80.18	12.27
Eucalyptus sp.	04.03	7.1	3.82	73.26	11.54
Artocarpus sp.	05.70	7.9	1.63	65.34	08.75

T = Total chlorophyll (mg/g dry weight); P = Leaf extract pH; A = Ascorbic acid (mg/g dry weight); R = Percent relative water content; APTI = Air pollution tolerance index

compared to find out the sensitivity/tolerance of these plants. It was reported that plants with relatively low index value are generally sensitive to air pollutants and *vice versa* (Singh et al., 1991).

The APTI determination provides a reliable method for screening large number of plants with respect to their susceptibility to air pollutants. The method is simple and convenient to adopt under field conditions without adopting any costly environmental monitoring gadgets. Among the seven tree species studied *Mangifera indica* was considered as relatively resistant and *Artocarpus* sp. as relatively sensitive to air pollution. The sensitive species can be used as bio-indicators and tolerant species can be used as a sink for air pollutants.

Conclusion

APTI determinations are of importance because with increased industrialization, there is increasing danger of deforestation due to air pollution. The results of such studies are therefore handy for future planning and may be helpful to bring out possible control measures. It is worth noting that combining a variety of parameters gave a more reliable result than when based on a single biochemical parameter.

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