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AIR POLLUTION TOLERANCE OF ORNAMENTAL TREES IN AN INDUSTRIAL CITY

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ABSTRACT : Deteriorating air quality is peril to human health in urban areas. Vehicular traffic is the major contributor to air pollution in cities. Street trees, being nearest to the source, can effectively reduce pollutants from ambient air. Pollution tolerant species can be more effective in this process with minimal physiological damage to their system. Pollution tolerance of the abundant street tree species in Ludhiana was studied and most of them were found to have intermediate tolerance. 17.27 per cent of the trees were tolerant and 20.4 per cent were sensitive. The most abundant species, *Alstonia scholaris* was sensitive to air pollution and can be used as indicator. More number of pollution tolerant species should be planted in industrial and commercial areas which have higher pollution load.

Keywords: *Pollution tolerance, street trees, abundance.*

Urbanization is a global phenomenon with a higher rate in developing nations. It has brought immense benefits to human society and resulted in a higher living standard. However, it has also caused a large scale negative impact on the global environment including increased pressure on natural resources and natural habitats, reduction in native biodiversity, unprecedented increase in production of waste and pollution. Air pollution is one of the biggest hazards of urban living. It has both acute and chronic effects on humanhealth, affecting a number of different systems and organs (Kampa and Castanas, 11). Most of the people at risk are urbandwellers in developing countries, especially China and India (Soubbotina and Sheram, 23). Industry and transportation sector are major contributors to air pollution load mainly in metropolitan cities (Prakash and Yunus, 15)

Urban trees can improve air quality for many different air pollutants incities, and consequently can help improve human health (Nowak *et al.,* 13). Trees remove gaseous air pollution mainly by stomatal uptake, though plant surface also removes some gases. Once inside the leaf, gases diffuse into intercellular spaces and may be absorbed by water film to form acids or react with inner-leaf surfaces (Smith, 22). The combined total effect of trees on air pollutants is significant enough that urban tree management could provide a viable means to improve air quality and help to meet clean air standards.

Studies that have examined gradients in pollutants as a function of distance from busy roadways have indicated exposure zones for traffic-related air pollution in the range of 50 to 1500 m from highways and major roads, depending on the pollutant and the meteorological conditions (HEI, 9). Street trees being nearest to the source can be more effective in curbing vehicle generated air pollution (Baldauf *et al.,* 3). Atmospheric pollution can cause stress to the trees characterized by early senescence,changes in plant-water relations and generally poor growth. Growth reduction depends on many factors, including the nature of the pollutant, its concentration, the duration of exposure and the plant species involved (Roberts, 16). Tree species tolerant to air pollution can perform better in streets and industrial areas, playing active role in cleaning the air.

Ludhiana being an industrial hub is the most thickly populated city of Punjab. It has earned the status of one of the most polluted cities in the world due to large number of industries and very high vehicle density. Pollution tolerance of abundant ornamental tree species of Ludhiana was studied to ascertain the ornamental sustainability of existing tree population.

MATERIALS AND METHODS

Species abundance was recorded in 5 per cent randomly selected streets of Ludhiana in accordance with method proposed by Sun and Basuk (24). Tree species with more than one per cent abundance were selected for this study. Industrial area A was selected as representative polluted site and Punjab Agricultural University Campus was selected as representative control site. The fully expanded leaves from randomly

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selected street trees at polluted and control site were collected in polythene bags and transported to laboratory in a cool box filled with ice. The leaves were washed out thoroughly with distilled water. Three replicates were used for each species. Following biochemical parameters were worked out:-

Ascorbic acid content : Ascorbic acid content was measured by Titrimetric method using 2, 6, Dichlorophenol indophenol dye. Ascorbic Acid (AA) is a strong reducing agent and is oxidized in the presence of the dye to dehydro ascorbic acid (Sadasivam and Manickam, 17). At the same time ascorbic acid reduces the dye to a colourless compound so that the endpoint can be easily determined.

Amount of ascorbic acid mg/g of sample

$$= \frac{0.5\,\text{mg} \times V_2 \times 100\,\text{ml}}{V_1 \times 5\,\text{ml} \times \text{Wt. of sample}}$$

Where V_1 was volume of dye used for standard ascorbic acid solution and V_2 was volume of dye used for sample.

Chlorophyll content : Chlorophyll content was determined using at Leaf chlorophyll meter (FTC Green LLC, USA). The chlorophyll content reading in mg/cm2was converted to mg/g of dry weight by measuring dry weight of 0.8462 cm^2 leaf disks.

Estimation of Leaf-extract pH : 0.5 g of leaf material was ground to paste and dissolved in 50 ml of distilled water and leaf-extract pH was measured by using calibrated digital pH meter (Singh and Rao, 19).

Relative water content : The relative water content (RWC) was calculated by using the formula of Pathak *et al.* (14).

$$\text{RWC}\,(\%) = \frac{\text{fresh weight} - \text{dry weight}}{\text{turgid weight} - \text{dry weight}} \times 100$$

Fresh weight was obtained by weighing the fresh leaves which were then immersed in water over night, blotted dry and weighed to get turgid weight. The turgid leaves were dried over in an oven at 70°C for 24 hours and reweighed to obtain the dry weight.

Air pollution tolerance index (APTI) of trees was worked out by the formula developed by Singh and Rao (19).

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

Where, *A* is the ascorbic acid content of leaf in mg/g dry weight, *T* is the total chlorophyll of leaf in mg/g dry weight, *P* is the leaf extract pH and *R* is the per cent relative water content of leaf tissue. The total sum was divided by 10 to obtain a manageable figure. Species with APTI values less than 11 were classified as sensitive, 11-15 as intermediate and more than 16 as tolerant. Statistical analysis of the data was performed using Minitab 16.

RESULTS AND DISCUSSION

Ludhiana had 105 species of street trees of which 24 had an abundance of more than one per cent. Data on biochemical parameters and APTI of abundant species at control site has been presented in Table 1. Ascorbic acid content was found to be highest in *Cassia fistula* (3.73 mg/g) which was significantly higher than other species. Lowest ascorbic acid content was recorded in *Alstonia scholaris* (1.13 mg/g). *Eucalyptus tereticornis* had the highest relative water content (95.58%) which was at par with Terminalia arjuna (95.27%) and *Polyalthia longifolia* (95.12%). Lowest relative water content was found in *Dalbergia sissoo* (77.89%). *Azadirachta indica* had the significantly higher total chlorophyll content (7.97 mg/g) which was at par with *Melia azedarach* (7.95 mg/g) and *Polyalthia longifolia* (7.85 mg/g) whereas *Eucalyptus tereticornis* had the lowest total chlorophyll content (2.36 mg/g). Leaf extract pH was maximum in *Polyalthia longifolia* (6.75) which was at par with *Azadirachta indica* (6.71) and significantly higher than other species. Minimum leaf extract pH was recorded in *Cassia siamea* (4.10). Highest APTI at control site was calculated for *Cassia fistula* (14.63) which was significantly higher than other tree species whereas lowest APTI was calculated for *Dalbergia sissoo* (9.00).

Tree species planted in polluted sites responded differently to the stress resulting in changes in biochemical characteristics as evident from Table 2. Highest ascorbic acid content was recorded in *Azadirachta indica* (4.96 mg/g) which was at par with *Cassia fistula* (4.93 mg/g) and *Ficus religiosa* (4.92 mg/g). Other species had significantly lower ascorbic acid with *Syzygium cumini* having the minimum content (1.73 mg/g). Ascorbic acid plays a significant role in light reaction of photosynthesis, activates defence mechanism and under stress condition, it can replace water from light reaction II. Due to its multiple role in metabolism and defence of plants, ascorbic acid is used as a very reliable parameter to denote tolerance level of plants against stress, especially the pollution stress (Singh and Verma, 21). Ascorbic content in tree leaves was invariably found higher at polluted site than at control site. The results are in conformity with earlier findings of Agarwal (2) and Chauhan (5).

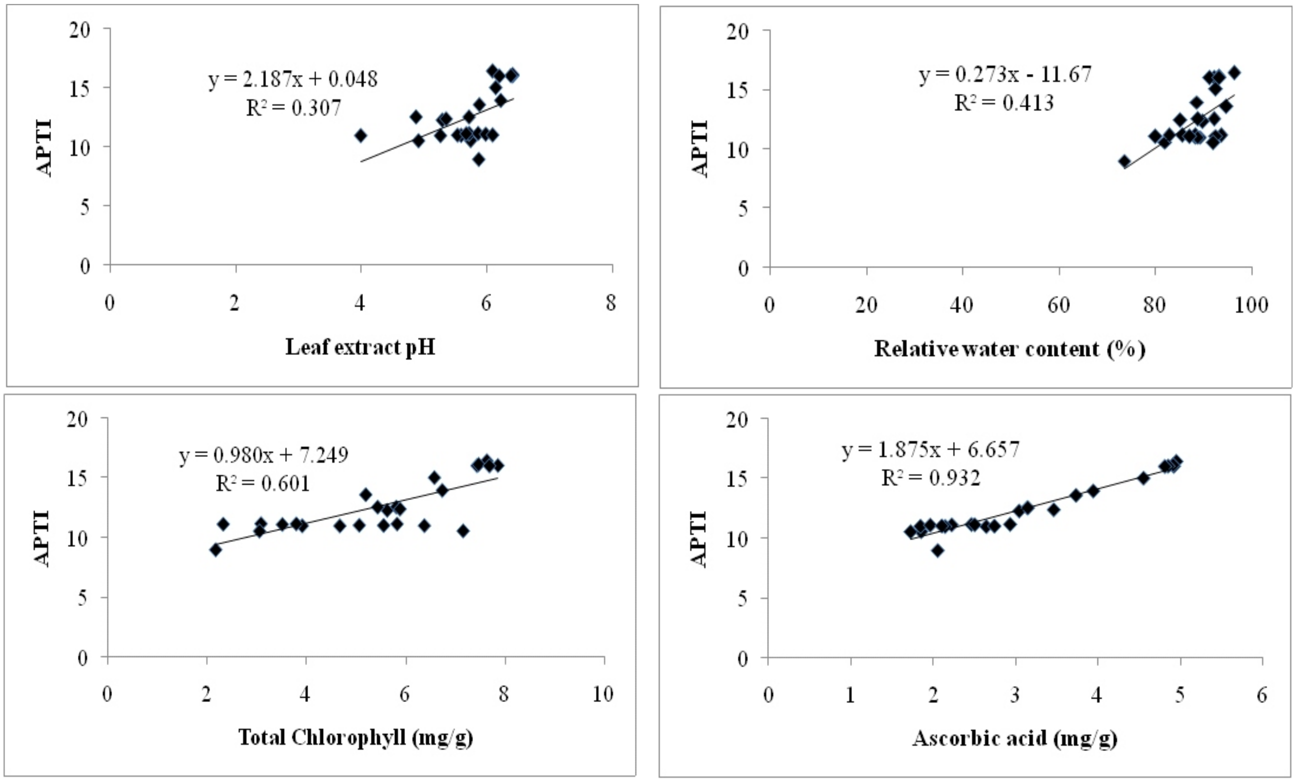

Figure 1: Evaluation of physiological parameters as predictor of air pollution tolerance index.

Relative water content was found to be highest in *Azadirachta indica* (96.3%) which was significantly higher than other species whereas *Dalbergia sissoo* had lowest RWC (73.44%). Transpiration rate remains very high under pollution stress which may lead to desiccation and maintenance of relative water content (RWC) by the plant may decide the relative tolerance of plants to air pollution (Singh and Verma, 21). RWC of the tree species was found to be variable. It increased in some species and decreased in other species. Urban areas have highly variable moisture availability which is affected by varying soil compaction as well as underground utilities like sewer and water supply lines. The species which could maintain their RWC in polluted sites were found to have higher APTI value in this study. Similar results have been obtained by Chandawat *et al*. (4) and Mishra and Pandey (12).

Total chlorophyll content of all the tree species decreased at polluted site. Maximum total chlorophyll was recorded in *Melia azedarach* (7.85 mg/g) whereas minimum was recorded in *Dalbergia sissoo* (2.17 mg/g). Decrease in chlorophyll causes a loss of productivity in plant and consequently it exhibits poor vigour.Therefore, plants maintaining their chlorophyll level under pollutedenvironment are considered to be tolerant (Joshi, 10). Total chlorophyll content of tree species in Ludhiana was highly variable and was probably a species specific character. Chlorophyll content decreased in polluted areas for all the tree species. Trees which could maintain their chlorophyll level nearest to that in control sites had higher APTI value (Chauhan, 5; and Govindaraju *et al.,* 8).

Plants with lower leaf extract pH were found more susceptible to air pollution, while those with pH around 7were found to be more tolerant. Strong correlation between the pH values of leaf-extract and tolerancelevel of plants of Indian origin was found by Farooq *et al*. (7). Leaf extract pH of abundant tree species at polluted site in Ludhiana was found to be lower than those at control cites. Trees with pH near 7 were found to have higher APTI values.The activity of ascorbic acid is also pH controlled, being more at higher and less at lower pH, Hence, the leaf-extract pH, on the higher side, gave tolerance to plants against air pollution (Agarwal, 1).

Air pollution tolerance index of all the species increased at the polluted site. Significantly higher APTI was calculated for *Azadirachta indica* (16.45) which was at par with *Ficus religiosa* (16.14), *Melia azedarach* (16.04), *Cassia fistula* (16.04) and *Polyalthia longifolia* (16.02). *Dalbergia sissoo* had lowest APTI of 9.01. *Syzygium cumini* (10.57) and *Alstonia scholaris* (10.59) also had relatively lower APTI.Significant correlationwas found between APTI and all the physiological parameters (Fig. 1). Ascorbic

Table 1: Biochemical parameters and air pollution tolerance index of abundant species at control site in Ludhiana.

Tree species	Ascorbic acid (mg/g)		Relative Water Content (%)		Total chlorophyll (mg/g)		Leaf extract pH		Air pollution tolerance index	
Azadirachta indica	3.38 ± 0.02	B	89.55 ± 0.57	E F	7.97 ± 0.05	A	6.71 ± 0.04	A	13.91 ± 0.12	B
Ficus religiosa	2.86 ± 0.01	E F	94.74 ± 0.38	A B	7.52 ± 0.03	B C	6.52 ± 0.03	B	13.49 ± 0.07	C
Melia azedarach	2.92 ± 0.01	E	92.15 ± 0.41	C D	7.95 ± 0.03	A	6.53 ± 0.03	B	13.44 ± 0.08	C
Cassia fistula	3.73 ± 0.01	A	93.80 ± 0.33	A B C	7.53 ± 0.03	B C	6.54 ± 0.02	B	14.63 ± 0.07	A
Polyalthia longifolia	3.05 ± 0.02	D	95.12 ± 0.61	A	7.85 ± 0.05	A	6.75 ± 0.04	A	13.96 ± 0.12	B
Terminalia arjuna	3.35 ± 0.02	B	95.27 ± 0.55	A	6.82 ± 0.04	D E	6.28 ± 0.04	C D	13.91 ± 0.10	B
Haplophragma adenophylum	2.72 ± 0.01	G	91.26 ± 0.29	D E	6.96 ± 0.02	C D	6.42 ± 0.02	B C	12.76 ± 0.05	D
Psidium guajava	3.14 ± 0.02	C	87.75 ± 0.42	F	5.44 ± 0.03	G H	6.04 ± 0.03	F	12.38 ± 0.08	E
Chukrasia tabularis	2.82 ± 0.01	F	87.96 ± 0.34	F	5.94 ± 0.02	F G	5.12 ± 0.02	J	11.91 ± 0.06	F
Thevetia peruviana	2.53 ± 0.01	H	87.99 ± 0.39	F	6.17 ± 0.03	E F	5.86 ± 0.03	G H	11.84 ± 0.07	F
Mimusops elengi	2.26 ± 0.01	I	92.80 ± 0.30	B C D	5.96 ± 0.02	F G	6.23 ± 0.02	D E	12.03 ± 0.05	E F
Mangifera indica	1.75 ± 0.01	K	92.63 ± 0.59	B C D	4.19 ± 0.03	J	6.04 ± 0.04	F	11.05 ± 0.08	G H
Grevillea robusta	1.89 ± 0.01	J	84.51 ± 0.32	G	4.75 ± 0.02	I J	6.10 ± 0.02	E F	10.50 ± 0.05	K L M
Tabernaemontana divaricata	1.75 ± 0.01	K	87.83 ± 0.48	F	6.48 ± 0.60	D E F	6.15 ± 0.03	D E F	10.89 ± 0.07	G H I J
Eucalyptus tereticornis	1.86 ± 0.01	J	95.58 ± 0.43	A	2.36 ± 0.01	L	6.01 ± 0.03	F G	11.11 ± 0.06	G
Morus alba	1.35 ± 0.01	N	88.16 ± 0.36	F	4.16 ± 0.02	J K	6.00 ± 0.03	F G	10.19 ± 0.05	M
Pongamia pinnata	1.56 ± 0.01	M	92.00 ± 0.47	C D	5.09 ± 0.03	H I	6.40 ± 0.03	B C	10.99 ± 0.06	G H I
Murraya koenigii	1.58 ± 0.01	M	88.43 ± 0.40	F	6.25 ± 0.03	E F	6.47 ± 0.03	B	10.85 ± 0.06	G H I J K
Ficus benjamina	1.35 ± 0.01	N	92.15 ± 0.23	C D	6.53 ± 0.02	D E F	6.48 ± 0.02	B	10.97 ± 0.03	G H I
Cassia siamea	1.72 ± 0.01	K	92.30 ± 0.59	C D	4.60 ± 0.03	I J	4.10 ± 0.03	K	10.72 ± 0.08	H I J K L
Plumera rubra	1.65 ± 0.01	L	88.40 ± 0.45	F	5.23 ± 0.03	H I	5.60 ± 0.03	I	10.63 ± 0.06	I J K L
Alstonia scholaris	1.13 ± 0.01	P	88.33 ± 0.39	F	8.50 ± 0.04	A	5.80 ± 0.03	H	10.45 ± 0.06	L M
Syzygium cumini	1.25 ± 0.01	O	94.08 ± 0.30	A B C	3.51 ± 0.01	K	5.71 ± 0.02	H I	10.56 ± 0.04	J K L M
Dalbergia sissoo	1.36 ± 0.01	N	77.89 ± 0.50	H	2.65 ± 0.02	L	6.09 ± 0.04	E F	9.00 ± 0.07	N

P = 0.000, Means that do not share a letter are significantly different.

acid content was found to be the most reliable predictor of APTI followed by total chlorophyll content. Relative water content and leaf extract pH had relatively weak correlation with APTI.

Amongst the abundant street trees of Ludhiana, *Azadirachta indica, Ficus religiosa, Melia azedarach, Cassia fistula* and *Polyalthia longifolia* were found to be tolerant. Combined abundance of these tree species was 17.27 per cent. *Dalbergia sissoo, Syzygium cumini* and *Alstonia scholaris* were sensitive and together had a share of 20.4 per cent. Other abundant species had intermediate tolerance to pollution. Similar results for these species have been reported by Singh *et al* (20), Singh and Verma (21) and Dhanam *et al*. (6). *Alstonia scholaris* was the most abundant street tree but considering its sensitive nature it should not be used in industrial and commercial areas where pollution load is high. Moreover, its relative abundance is already more than generally accepted norm of 10 per cent of any one species recommended by Santamour (18). The other two susceptible species, *Dalbergia sissoo* and *Syzygium cumini* had low relative abundance in streets. Amongst the high abundance species, more of *Melia azedarach* and *Azadirachta indica* can be planted in polluted area since their abundance was below recommended level. *Polyalthia longifolia* seems to be hitherto unexploited species for pollution amelioration. It was found to be tolerant to air pollution

Table 2: Biochemical parameters and air pollution tolerance index of abundant species at polluted site in Ludhiana.

Tree species	Ascorbic acid (mg/g)		Relative Water Content (%)		Total chlorophyll (mg/g)		Leaf extract pH		Air pollution tolerance index	
Azadirachta indica	4.96 ± 0.03	A	96.30 ± 0.62	A	7.63 ± 0.05	B	6.10 ± 0.04	C D	16.45 ± 0.15	A
Ficus religiosa	4.92 ± 0.02	A B	93.11 ± 0.37	B C D	7.46 ± 0.03	C	6.42 ± 0.03	A	16.14 ± 0.09	A
Melia azedarach	4.86 ± 0.02	B C	91.25 ± 0.41	D E F	7.85 ± 0.03	A	6.39 ± 0.03	A B	16.04 ± 0.10	A
Cassia fistula	4.93 ± 0.02	A B	92.10 ± 0.32	C D	7.43 ± 0.03	C	6.42 ± 0.02	A	16.04 ± 0.08	A
Polyalthia longifolia	4.82 ± 0.03	C	93.26 ± 0.60	B C D	7.68 ± 0.05	B	6.21 ± 0.04	C	16.02 ± 0.15	A
Terminalia arjuna	4.56 ± 0.03	D	92.41 ± 0.53	B C D	6.57 ± 0.04	F	6.15 ± 0.03	C	15.04 ± 0.12	B
Haplophragma adenophylum	3.95 ± 0.01	E	88.52 ± 0.28	G H	6.73 ± 0.02	E	6.25 ± 0.03	B C	13.98 ± 0.06	C
Psidium guajava	3.74 ± 0.02	F	94.64 ± 0.45	A B	5.19 ± 0.03	J	5.89 ± 0.03	E F	13.61 ± 0.09	C
Chukrasia tabularis	3.15 ± 0.01	H	92.13 ± 0.35	C D	5.81 ± 0.02	H	4.88 ± 0.02	L	12.58 ± 0.06	D
Thevetia peruviana	3.47 ± 0.02	G	85.12 ± 0.38	I	5.88 ± 0.03	H	5.36 ± 0.03	K	12.41 ± 0.07	D
Mimusops elengi	3.05 ± 0.01	I	89.71 ± 0.29	E F G	5.62 ± 0.02	I	5.30 ± 0.02	K	12.31 ± 0.05	D
Mangifera indica	2.94 ± 0.02	J	85.56 ± 0.55	I	3.08 ± 0.02	N	5.87 ± 0.04	E F G	11.19 ± 0.09	E
Grevillea robusta	2.47 ± 0.01	M	88.23 ± 0.34	G H	3.79 ± 0.02	L	5.73 ± 0.02	G H I	11.18 ± 0.05	E
Tabernaemontana divaricata	2.51 ± 0.01	M	82.75 ± 0.45	J	5.82 ± 0.03	H	5.68 ± 0.03	H I J	11.16 ± 0.08	E
Eucalyptus tereticornis	2.23 ± 0.01	N	93.55 ± 0.42	B C	2.32 ± 0.01	O	5.72 ± 0.03	H I	11.15 ± 0.06	E
Morus alba	1.97 ± 0.01	Q	92.52 ± 0.38	B C D	3.51 ± 0.02	M	5.99 ± 0.03	D E	11.13 ± 0.06	E
Pongamia pinnata	2.11 ± 0.01	O P	87.06 ± 0.44	H I	5.06 ± 0.03	J	6.10 ± 0.03	C D	11.06 ± 0.07	E
Murraya koenigii	2.75 ± 0.01	K	80.00 ± 0.36	K	5.55 ± 0.03	I	5.54 ± 0.03	J	11.05 ± 0.06	E
Ficus benjamina	1.85 ± 0.01	R	88.17 ± 0.22	G H	6.37 ± 0.02	G	5.60 ± 0.01	I J	11.03 ± 0.03	E
Cassia siamea	2.65 ± 0.02	L	89.12± 0.57	F G H	3.91 ± 0.03	L	4.02 ± 0.03	M	11.02 ± 0.08	E F
Plumera rubra	2.15 ± 0.01	N O	88.69 ± 0.45	G H	4.67 ± 0.02	K	5.27 ± 0.03	K	11.01 ± 0.07	E F
Alstonia scholaris	1.86 ± 0.01	R	81.90 ± 0.37	J K	7.15 ± 0.03	D	5.75 ± 0.03	F G H	10.59 ± 0.06	F G
Syzygium cumini	1.73 ± 0.01	S	91.95 ± 0.29	C D E	3.05 ± 0.01	N	4.92 ± 0.02	L	10.57 ± 0.04	G
Dalbergia sissoo	2.06 ± 0.03	P Q	73.44 ± 0.47	L	2.17 ± 0.01	P	5.88 ± 0.04	E F G	9.01 ± 0.07	H

P = 0.000, Means that do not share a letter are significantly different.

and had relatively low abundance (1.7%) thus can be planted in larger number. *Terminalia arjuna* and *Haplophragma adenophylum* were also potential species for planting in polluted areas as they had a higher APTI value.

CONCLUSION

Pollution tolerant trees formed a small proportion of street trees in Ludhiana and most of the abundant species had intermediate tolerance. The most abundant species, *Alstonia scholaris* was found to be sensitive to air pollution and can be used as indicator. More number of pollution tolerant species should be planted in industrial and commercial areas which have higher pollution load. However, none of the species should exceed the generally accepted limit of 10 per cent.

Table 3: Change in biochemical parameters and air pollution tolerance index of abundant species on exposure to polluted air at Ludhiana.

Tree species	Relative abundance	Pollution tolerance
Azadirachta indica	5.98%	Tolerant

Ficus religiosa	2.77%	Tolerant
Melia azedarach	5.59%	Tolerant
Cassia fistula	1.23%	Tolerant
Polyalthia longifolia	1.70%	Tolerant
Terminalia arjuna	1.22%	Intermediate
Haplophragma adenophylum	1.17%	Intermediate
Psidium guajava	6.09%	Intermediate
Chukrasia tabularis	5.10%	Intermediate
Thevetia peruviana	3.13%	Intermediate
Mimusops elengi	2.63%	Intermediate
Mangifera indica	1.37%	Intermediate
Grevillea robusta	1.43%	Intermediate
Tabernaemontana divaricata	3.58%	Intermediate
Eucalyptus tereticornis	1.94%	Intermediate
Morus alba	5.34%	Intermediate
Pongamia pinnata	2.24%	Intermediate
Murraya koenigii	1.32%	Intermediate
Ficus benjamina	5.49%	Intermediate
Cassia siamea	1.16%	Intermediate
Plumera rubra	1.88%	Intermediate
Alstonia scholaris	17.29%	Susceptible
Syzygium cumini	1.62%	Susceptible
Dalbergia sissoo	1.49%	Susceptible
Other species	17.23%	-NA-

NA–Not analyzed

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