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Evaluation of Air Pollution Tolerance Index of different Tree Species Growing in Jhansi City of Uttar Pradesh

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Abstract: The present study was conducted to screen the pollution tolerant index of nine trees species namely *Azadirachta indica, Cassia fistula, Delonix regia, Dalbergia sissoo, Ficus benghalensis, Ficus religiosa, Holoptelia integrifolia, Nerium indicum,* and *Pongamia pinnata* which are growing either naturally or planted in the Jhansi city of Uttar Pradesh. Samples were collected from the polluted areas of Jhansi city and their test results were compared with the samples collected from the trees growing in the campus of Rani Lakshmi Bai Central Agricultural University Jhansi. The parameters analyzed were total chlorophyll content, ascorbic acid content, relative water content and leaf extract pH. Present study revealed that ascorbic acid content ranged from 0.26 mg/g-3.93 mg/g in polluted sites while under controlled sites ranged from 0.009 to 2.56 mg/g. The highest ascorbic acid content was in *Cassia fistula* (3.94 mg/g) and least in *Dalbergia sissoo* (0.27 mg/g). The total chlorophyll content varied from 0.72-2.20 mg/g. Maximum chlorophyll content was in *A. indica* (2.21 mg/g), whereas, *F. benghalensis* showed least (0.73 mg/g). Under university campus (controlled) conditions *A. indica* recorded with highest total chlorophyll (2.90 mg/g) content and least in *N. indicum* (1.53 mg/g). For leaf extract pH of tree species under study varied from 6.33-8.24. Under Jhansi city sites *F. benghalensis* recorded highest leaf extract pH (8.24) and least was observed in *C. fistula* (6.33). Under controlled condition *F. benghalensis* recorded highest leaf extract pH value 8.09 and lowest in *N. indicum* (6.07). Relative water content of tree species varied from 59.69-84.0%. Jhansi city the highest relative water content was observed for *Ficus religiosa* (84%) and minimum for *A. indica* (59.69%). Under controlled conditions *P. pinnata* recorded highest relative water content of 67.3% and the lowest was found in *A.indica* (46.7%). On comparing the results from two studied sites it was highest APTI values was observed for *C. fistula* (10.30) followed by *F. religiosa* and *F. benghalensis.*

Keywords: Air pollution tolerant index, Trees, Relative water content, Ascorbic acid, Chlorophyll

Air pollution has become an ominous situation to the world. According to the World Health Organization (WHO), each year air pollution is responsible for nearly seven million deaths around the globe. The increased intensity of urban air pollution has become a global issue. The loss of vegetation cover has resulted from the rapid pace of urbanization. Over the last few decades, urban areas have faced increasing environmental stress, particularly from poor air quality, excessive noise, and traffic congestion (Sanesi and Chiarello 2006). The impact of climate change has also increased stress. Road traffic is regarded as one of the most significant sources of air and noise pollution, both of which have negative effects on human health. Pollutant levels in urban air are frequently high, endangering human health and well-being (Kanakidou et al 2011). Plants play an important role in monitoring and maintaining the ecological balance by actively participating in the cycling of nutrients and gases like carbon dioxide, oxygen and also provide enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollution level (Karthiyayini et al 2005, Bemmansou et al 2021). Trees affect air quality through the direct removal of air pollutants, altering local microclimates and building energy use, and through the emission of volatile organic compounds (VOCs), which can contribute to O_3 and Particulate matter (PM) 2.5 formation . Leaves absorb air pollutants through their stomata and catch particles onto their leaves and branches. Numerous reports confirm that the number and size of leaf stomata changes depending on the degree of air pollution and types of pollutant (sulphur, nitrogen oxides and ozone) (Mulgrew and Williams 2000, Shweta 2012). Stomatal response to air pollution is very complex and depends not only on air pollutant concentration and type, but is also very selective depending on plant species (Abeyratne and Ileperuma 2006). An index uses to identify the tolerance of air pollutants was developed which is known as Air Pollution Tolerance Index (APTI). APTI is a species-dependent plant attribute and expresses the inherent ability of plant to encounter stress arising from air pollution. It is mainly based on four major properties of leaves namely ascorbic acid content, relative water content, total chlorophyll content and leaf extract pH . Plant's tolerance to air pollutants generally varies with these parameters. APTI provides a reliable method for screening large number of plants with respect to the vulnerability to different pollutants. Measuring the air pollution tolerance indices of different plant species has become necessary to mitigate the increased air pollution in urban areas. For this classification of tree species as sensitive or tolerant is critical because susceptible plant species can be used as indicators, whereas tolerant plant species can be used as sinks to monitor air pollution in urban areas (Aghaiee et al 2019). Keeping the above view of importance of tree species to mitigate air pollution in Urban cities, the present study was conducted with the objectives to conduct a survey to identify the air pollution tolerant tree species of Jhansi city and screening out the air pollution tolerance index of selected tree species.

MATERIAL AND METHODS

Study was conducted in Jhansi city and the campus of Rani Lakshmi Bai Central Agricultural University, Jhansi. Jhansi city is located at 25º 43' 33" N to 78º 58' 33" E. A field survey was conducted at three polluted sites of Jhansi city *i.e.* site-I (Railway station), site-II (Bus stand) and site-III (Jhansi zone of Kanpur highway) (Table 1) of Jhansi city to identify the tree species with highest pollution tolerance index.

To study the air pollution tolerance index of selected tree species, 45 leaf samples were collected each tree from a height of 1.5 meters above the ground. The analytical results obtained for the samples collected from the different sites of Jhansi city were also compared with the results obtained for the trees growing under the controlled conditions of RLBCAU, Jhansi. The various studied parameters were total chlorophyll, ascorbic acid, leaf extract pH and relative water content.

The ascorbic acid content was estimated by using method (AOAC 1980).

$$\text{Ascorbic Acid (mg/g)} = \frac{\text{Dye factor} \times \text{Titre reading} \times \text{Volume made}}{\text{Weight of leaves taken} \times \text{Volume taken for estimation}}$$

Leaf extracted pH were estimated by using pH meter (Model- ESICO 1013) with buffer solution of pH 4 and 9 (Barrs and Weatherly 1962). The Total leaf chlorophyll content was estimated using method (Hiscox and Israeistam 1979) using formula:

$$\text{Total chlorophyll content (mg/g)} = \frac{20.0A_{645} + 8.02A_{663}}{a \times w \times 1000} \times V$$

Where, V = Volume of extract made; a = Length of light path in cell (usually 1cm); w = Weight of the sample taken; A645 is absorbance at 645 nm; A663 is absorbance at 663 nm.

Relative water content of the samples was estimated using the method proposed (Singh 1977)

$$\text{Relative water content (\%)} = \frac{FW - DW}{TW - DW} \times 100$$

Where, FW= Fresh weight, TW=Turgid weight, DW= Dry weight of leaf samples

Air pollution tolerance index is an empirical relation which evaluates the tolerance level of plant species towards air pollution from leaf biochemical parameters such as ascorbic acid, total chlorophyll content, leaf extract pH and relative water content and is computed by using the following equation (Singh and Rao 1983).

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

Table 1. Coordinates of study area in Jhansi city and RLBCAU campus

Plant species	Jhansi city area			University area (Control)
	Site- I	Site- II	Site- III	
Dalbergia sissoo	25°26'39.1"N 78°34'47.9"E	25°27' 04.6"N 78°34'07.8"E	25°28'08.6"N 78°37' 34.9"E	25º30'42"N, 78º32'32"E
Cassia fistula	25°26'39.7"N 78°34'57.3"E	25°27' 07.7"N 78°34'09.8"E	25° 28'07.3"N 78°37' 36.2"E	25º30'42"N, 78º32'30"E
Ficus religiosa	25°26'36.7"N 78°34'54.3"E	25°27'09.5"N 78°34'1.8"E	25° 28'08.1"N 78°37' 34.4"E	25º30'42"N, 78º32'30"E
Ficus benghalensis	25°26'34.7"N 78°34'57.3"E	25°27'08.7"N 78°33'04.8"E	25° 28'07.3"N 78°37' 34.4"E	25º30'45"N, 78º32'35"E
Azadirachta indica	25°26'35.7"N 78°34'57.3"E	25°27'07.7"N 78°34'09.8"E	25° 28'04.7"N 78°37' 34.2"E	25º30'43"N, 78º32'32"E
Delonix regia	25°26'52.7"N 78°35'48.5"E	25°27'03.5"N 78°34'09.8"E	25° 28'1.3"N 78°37' 39.7"E	25º30'59"N, 78º32'53"E
Holoptelia integrifolia	25°26'34.7"N 78°34'52.3"E	25°27'52.1"N 78°37'22.9"E	25° 28'01.3"N 78°37' 34.9"E	25º30'47"N, 78º32'37"E
Pongomia pinnata	25°26'39.1"N 78°34'47.9"E	25° 27' 26.9"N 78°36'50.8"E	25° 28'04.7"N 78°37' 34.9"E	25º30'50"N, 78º32'41"E
Nerium indicum	25°26'39.7"N 78°34'57.3"E	25°27'07.7"N 78°34'09.8"E	25° 28'1.23"N 78°37' 38.9"E	25º30'50"N, 78º32'37"E

Where, A = Ascorbic acid (mg/g); T = Total Chlorophyll Content; P = Leaf Extract pH; R = Relative Water Content.

RESULTS AND DISCUSSION

Ascorbic acid: Ascorbic acid is important in plant cell wall synthesis, photosynthetic carbon fixation, and cell division. It also serves as a natural antioxidant that has to protect plant tissue from the damaging effects of air pollutants. Because of the high concentration of ascorbic acid, plants are more tolerant to pollution (Agbaire and Esiefarienrhe 2009). There was wide variation in ascorbic acid (mg/g) concentration was among different tree species and the site of sample collection (Table 2). Among the samples collected from the university campus the highest ascorbic acid (2.56 mg/g) was in *Cassia fistula* followed by *Azadirachta indica*, *Holoptelia integrifolia*, *Delonix regia*, *Nerium indicum*, *Ficus benghalensis*, in descending order, respectively. In Jhansi city, site-1 *Cassia fistula* showed highest ascorbic acid content (3.73 mg/g) and minimum was recorded in *Dalbergia sissoo* (0.24 mg/g). *Holoptelia integrifolia* and *Delonix regia, Ficus religiosa, Ficus benghalensis* and *Nerium indicum* had values at par with each other. The result pertaining to site–II varied significantly and the highest value of ascorbic acid was in *Cassia fistula>Azadirachta indica>Delonix regia>Holoptelia integrifolia > Ficus benghalensis> Nerium indicum>Pongomia pinnata>Dalbergia sissoo, respectively*. Data obtained from site-III revealed that highest ascorbic acid concentration was in *Cassia fistula* (4.12 mg/g) which was significantly higher than other species. On comparing trees grown on different sites, the highest ascorbic acid content (0.30 mg/g) was in *D. sissoo* samples collected from Jhansi city, site –III. The minimum was observed in the trees grown in university campus (0.009 mg/g). *Cassia fistula* recorded the highest ascorbic acid value (4.12 mg/g) in Jhansi city, site–III and the minimum (2.56 mg/g) was observed in the trees of same species grown in university campus. *Ficus religiosa* had highest value (0.45 mg/g) in Jhansi city, site –III and the minimum value was observed in university campus (0.009 mg/g).

Ficus benghalensis had the highest value (0.72 mg/g) in the samples collected from Jhansi city site –II. For this species the minimum value was observed in trees growing in university campus (0.31 mg/g). *Nerium indicum* had highest value (0.61 mg/g) at Jhansi city, site –III. The minimum value was observed in university campus (0.36 mg/g). *Delonix regia* had highest value (0.99 mg/g) at Jhansi city, site–I. The minimum value is observed in university campus (0.73 mg/g). *Holoptelia integrifolia* had highest value (1.00 mg/g) at Jhansi city, site –III. The minimum value was observed in university campus (0.764 mg/g). *Pongomia pinnata* had significantly higher value at all sites in Jhansi city compared to campus site. In Jhansi city sites ascorbic acid values were at par with each other. *Azadirachta indica* had highest value (0.99 mg/g) at Jhansi city, site–I. The minimum value was observed in university campus (0.73 mg/g). *Holoptelia integrifolia* showed the highest value (2.13 mg/g) at Jhansi city, site-III. The minimum was observed in university campus (1.7 mg/g). Bharti et al (2018) observed that average ascorbic acid content (mg/g) was in range of 0.6 to 19.6 mg/g. Similar trend was observed by Begum and Harikrish (2010). The trees grown in the polluted site (Jhansi city) had higher ascorbic acid content than the trees grown in control site (University campus). This suggests that trees develop greater tolerance to pollution by increasing ascorbic acid synthesis when exposed to polluted environments (Yannawar and Bhosle 2013, Sahu et al 2020). The significant correlation of ascorbic acid with the APTI value in both the experimental and control sites results are in agreement with other reported studies

Table 2. Ascorbic acid (mg/g) content of tree species in university campus area and Jhansi city area

Plant species	University campus area (Control)	Jhansi city areas		
		Site I	Site II	Site III
Dalbergia sissoo	0.009 ± 0.0001^{iC}	0.24 ± 0.01^{fB}	0.24 ± 0.01^{fB}	0.30 ± 0.08^{eA}
Cassia fistula	2.56 ± 0.0200^{aC}	3.73 ± 0.12^{aB}	3.96 ± 0.01^{aA}	4.12 ± 1.15^{aA}
Ficus religiosa	0.14 ± 0.001^{hC}	0.49 ±0.01^{dA}	0.31 ± 0.01^{fB}	0.45 ± 0.12^{deA}
Ficus benghalensis	0.31 ± 0.001^{fD}	0.49 ± 0.01^{dC}	0.72 ±0.06^{dA}	0.63 ± 0.16^{dB}
Nerium indicum	0.36 ± 0.011^{eD}	0.45 ± 0.02^{dC}	0.56 ± 0.02^{eB}	0.61 ± 0.16^{dA}
Delonix regia	0.73 ± 0.005^{dC}	0.99 ± 0.01^{cA}	0.92 ± 0.03^{cB}	0.95 ±0.26^{cAB}
Holoptelia integrifolia	0.764 ± 0.001^{cB}	1.03 ± 0.03^{cA}	0.99 ± 0.06^{cA}	1.00 ± 0.26^{cA}
Pongomia pinnata	0.22 ± 0.001^{gB}	0.33 ± 0.03^{eA}	0.29± 0.05^{fA}	0.355 ±0.07^{eA}
Azadirachta indica	1.7 ± 0.030^{bC}	1.89 ±0.03^{bAB}	2.04 ±0.15^{bAB}	2.13 ± 0.58^{bA}

Different superscripts (capital alphabets) in a column indicates that they are significantly ($p \leq 0.05$) different to each other determined by Duncan's tests; Different superscripts (small alphabets) in a column indicates that they are significantly ($p \leq 0.05$) different to each other determined by Duncan's tests.

(Agbaire and Esiefarienrhe 2009, Meerabai et al 2012, Rupa and Venkatachalam 2017).

Total chlorophyll content Degradation of chlorophyll has been widely used as an indication of air pollution (Ninave et al 2001). In university campus condition highest chlorophyll content was in *Azadirachta indica* (2.88 mg/g) followed by *Cassia fistula*, *Dalbergia sissoo*, *Holoptelia integrifolia*, *Delonix regia* and *Ficus religiosa* in descending order, respectively. At site- I the maximum chlorophyll content was observed in *Dalbergia sissoo* (2.31 mg/g). The chlorophyll content of *Azadirachta indica* and *Cassia fistula* was at par with each other. *Ficus religiosa, Ficus benghalensis* and *Nerium indicum* had least chlorophyll content. At Jhansi city, site- II maximum chlorophyll content was found in *Azadirachta indica* (2.48 mg/g). *Ficus religiosa* and *Nerium indicum* had chlorophyll at par with each other. *Ficus benghalensis* (0.62mg/g) showed least value among all the plant species growing in site II. At site-III the maximum chlorophyll was observed in *Azadirachta indica* (2.21 mg/g) and minimum in *Ficus benghalensis* (0.73 mg/g).

On comparing trees grown on different sites, tree species growing in university campus showed significant lower values for chlorophyll content compared to tree species growing at Jhansi city sites. On the comparative analysis of the chlorophyll content of the tree species from different sites, *Dalbergia sissoo* (2.31mg/g) had maximum value at site-I and minimum was at site-II (1.65 mg/g). The values for *Cassia fistula* were at par for the trees from site-II and site-III. *Ficus religiosa* had maximum chlorophyll content for the samples collected from site-II and minimum was for the samples collected from site-I. For *Ficus benghalensis* site- I and site III had at par values. Total chlorophyll in *Nerium indicum* varied significantly among all sites having maximum (1.31 mg/g) at the site-II and minimum at site- I (0.99 mg/g). *Delonix regia* also followed the same trend as *Nerium indicum*. *Pongamia pinnata* had not shown any significant critical difference in site- III and site- I. *Azadirachta indica* had the highest value at the site-II (2.48 mg/g). The total chlorophyll content was highest in the leaf samples collected from the trees growing in university campus. Tripathi and Gautam (2007) and Mir (2008) also reported a decrease in chlorophyll content in the roadside trees and plants. Air pollutants move into the tissues through stomata and cause partial denaturation of the chloroplast and lessen the pigment content in the cells of polluted leaves of flora. On a comparative analysis of tree species the minimum total chlorophyll content was in leave samples of *Ficus benghalensis* collected from site-II. Similar results were documented by Sinha et al (2017) for *Ficus religiosa* growing at ISBT and Clock Tower which are highly polluted than other sites having lower chlorophyll content than the other species.

Relative water content (%): Relative water content plays a very important role in cell integrity during pollution stress, and in the same way, leaf relative water could have diluted chemical effects of pollutants absorbed by plants during physiological activity to maintain optimum physiological pH for metabolism (Singh and Verma 2007). Among the sample collected from university campus site, maximum value of relative water content was observed in *Pongomia pinnata* (67.3 %) and minimum (46.5 %) in *Azadirachta indica.* In site-I, Relative Water Content maximum was in *Dalbergia sissoo* (87.7%) and *Ficus religiosa* (86%). Both trees had at par value with each other. Minimum value was observed in *Delonix regia* (54.6%). Under site- II condition of Jhansi city area maximum had observed in *Ficus religiosa* (90%) followed by *Ficus benghalensis* (76%) and then *Pongomia pinnata* (71.28%), respectively. *Azadirachta indica* (45.22%) and *Dalbergia sissoo* (45. 88%) showed lowest value in site-II with their value at par with each other. In site-III maximum relative water content observed in *Ficus benghalensis*

Table 3. Total chlorophyll (mg/g) content of plant species in university campus area and Jhansi city area

Plant species	University campus area (Control)	Jhansi city areas		
		Site I	Site II	Site III
Dalbergia sissoo	2.54 ±0.003^{cA}	2.31 ± 0.24^{aB}	1.65 ± 0.02^{dD}	1.98 ± 0.03^{cC}
Cassia fistula	2.56±0.002^{bA}	1.89 ± 0.26^{bB}	1.64 ± 0.14^{dC}	2.03 ± 0.02^{bB}
Ficus religiosa	2.11±0001^{fA}	0.83± 0.16^{eD}	1.34 ± 0.03^{eB}	1.08 ± 0.01^{hC}
Ficus benghalensis	1.95±0.003^{hA}	0.84 ± 0.13^{eB}	0.62 ± 0.02^{fC}	0.73 ± 0.02^{iB}
Nerium indicum	1.53±0.004^{iA}	0.99 ± 0.02^{eD}	1.31 ± 0.02^{eB}	1.15 ± 0.01^{gC}
Delonix regia	2.19±0.0002^{eA}	1.34 ± 0.02^{dD}	1.91 ±0.03^{bcB}	1.62± 0.03^{fC}
Holoptelia integrifolia	2.22±0.0002^{dA}	1.70 ±0.02^{bcC}	1.96 ± 0.17^{bB}	1.83 ± 0.03^{dBC}
Pongomia pinnata	2.03±0.0002^{gA}	1.63 ± 0.02^{cD}	1.77 ±0.03^{cdB}	1.70 ± 0.03^{eC}
Azadirachta indica	2.88±0.0002^{aA}	1.94 ± 0.01^{bD}	2.48 ± 0.22^{aB}	2.21± 0.02^{aC}

(79.2%) followed by *Ficus religiosa* and *Dalbergia sissoo*. *Ficus religiosa* (76%) and *Dalbergia sissoo* (75.6%) showed their values at par with each other and no critical difference was found. On comparing trees grown on different sites, In Jhansi city site-I, *Dalbergia sissoo* showed significantly highest values (87.7%) compare with the all other site. *Cassia fistula* showed significant values at all sites and highest was in site-I (81%) and lowest (45.8%) in site- II. For *Ficus religiosa* had the highest value (90%) in site- II followed by site-I (86%), site-III (76%) and university area (56%) in descending order, respectively. In *Ficus benghalensis* site-I and site-II had higher values that are at par with each other and minimum value in university campus site (50.51%). *Nerium indicum* had significant value at all sites with maximum in site- II and minimum in site-I. *Delonix regia* also follows the same trend as *Nerium indicum*. *Pongomia pinnata* have at par vales in site-III and site-I. For *Azadirachta indica* had highest value at site-I (75%) followed by site III (58.85%). The water content is higher in polluted site as compared to that of controlled site (Table 4). Tanee et al (2014) reported that plant found near polluted area absorbed more water to sustain physiological activity of the plants to withstand the effect of pollution in its environment. Different finding also suggest that higher relative water content helps plants in maintaining the physiological balance under stress condition. Finding of our studies goes well with earlier findings (Babu et al 2013, Bharti et al 2018, Balasubramanian et al 2018) while comparing Relative water content in polluted site and control site.

Leaf extract pH: pH also influences the photosynthetic efficiency rate in leaves, photosynthetic rate increases in leaves with high pH and reduce in leaves with lower pH value (Lohe et al 2015). High pH may increase the efficiency of conversion from hexose sugar to ascorbic acid, while low leaf extract pH shows a good correlation with sensitivity to air pollution (Escobedo et al 2008,Rehman and Gul 2015,). Thus, the pH of the foliar extract is an indicator of the development of detoxification mechanism in plants necessary for tolerance (Ninave et al 2001). Study have reported that in presence of an acidic pollutant, the leaf extract pH was lowered, and the decline was greater in sensitive species (Scholz and Reck 1977). In university condition *Ficus benghalensis* had highest value (8.03) among all the tree species growing in university campus and Jhansi city sites. *Ficus religiosa* and *Holoptelia integrifolia* was at par value within species. For *Dalbergia sissoo* and *Pongomia pinnata* have not shown any critical difference in their values hence they were at par with each other. *Nerium indicum* (6.07) had least value among all species in university area. In site-I, *Ficus religiosa* (8.33) had a significantly higher value compared with *Ficus benghalensis* (8.12). For *Holoptelia integrifolia, Azadirachta indica, Pongomia pinnata* and *Dalbergia sissoo* shad their values at par with each other. *Nerium indicum, Delonix regia* and *Cassia fistula* had shown lower value without showing any critical difference between eachother. In site-II, *Ficus benghalensis* had highest value followed by *Ficus religiosa* and *Holoptelia integrifolia* with their values at par with each other. leaf extract pH value in site- III was found significantly, highest value was found in *Ficus benghalensis* (8.24 and minimum value (6.32) was recorded in *Cassia fistula*.

On comparing trees grown on different sites, tree growing in campus had shown significantly higher value for *Dalbergia sissoo* than tree growing at Jhansi city area. At Jhansi city *Dalbergia sissoo* had maximum in site -I (7.18). For *Ficus benghalensis* site -II (8.37) show highest value followed by site III (8.24) and then site I (8.12) and lowest value was observed in university area (8.03). *Nerium indicum* had highest value at site-III (6.56) followed by site I (6.41) while site II and university campus showed values at par with each other. *Pongomia pinata* also showed significant value with highest value at site I (7.14) and lowest at site II (6.47). For *Delonix regia* showed highest value in site- II (6.39) and site - III (6.42) with their values at par with each other. In case of *Azadirachta indica* had maximum leaf extract pH value was

Table 4. Relative water content of trees species in university campus area and Jhansi city area

Plant species	Control	Site I	Site II	Site III
Dalbergia sissoo	63.48 ± 1.63^{cC}	87.7 ± 1.22^{aA}	45.8 ± 0.65^{gD}	75.6 ± 0.89^{bB}
Cassia fistula	66.78 ± 1.64^{abC}	81 ± 1.23^{bA}	55.5 ± 0.66^{fD}	73.7 ± 0.85^{cB}
Ficus religiosa	56 ± 1.63^{deD}	86 ± 1.22^{aB}	90 ± 0.61^{aA}	76 ± 0.87^{bC}
Ficus benghalensis	50.51 ± 1.63^{fC}	78 ± 1.24^{cAB}	76 ± 0.65^{bB}	79.2 ± 0.89^{aA}
Nerium indicum	57.32 ± 1.66^{dC}	63 ± 1.21^{eB}	67.8 ± 0.64^{dA}	51 ± 0.91^{gD}
Delonix regia	53.67 ± 1.68^{eC}	54.6 ± 1.22^{fC}	62.8 ± 0.65^{eB}	65.18 ± 0.86^{eA}
Holoptelia integrifolia	64.3 ± 1.63^{bcC}	78.42 ± 1.21^{cA}	67.82 ± 0.63^{dB}	61.2 ± 0.89^{fD}
Pongomia pinnata	67.3 ± 1.62^{aC}	73.65 ± 1.22^{dA}	71.28 ± 0.62^{cB}	69.87 ± 0.88^{dB}
Azadirachta indica	46.5 ± 1.63^{gC}	75 ± 1.24^{dA}	45.22 ± 0.65^{gC}	58.85 ± 0.89^{fB}

found in site- I (7.25) followed by site III (6.73). Least value was observed in university area (6.16) (Table 4). The leaf extract pH of plant species had higher values in polluted site (Jhansi city) as compare to the control site (university campus). This suggest that high leaf extract pH which helps in the conversion of hexose sugar to ascorbic acid, thereby improving resistance to stress caused by air pollution/pollutants improve the resistance against the pollution (Singh and Verma 2007, Miria and Anisa 2013). Findings of studies was also in corroboration to the findings of earlier researchers (Tripathi et al 2020, Muhammed Aji et al 2015, Balasubramanian et al 2018).

Air pollution tolerance index: Air Pollution Tolerance Index (APTI) was significantly higher in Jhansi city when compare with same tree species growing university campus area. At Jhansi city area *Cassia fistula* (10.23) and *Ficus religiosa* (8.77) had maximum at par and minimum (6.47) was recorded in *Nerium indicum*. In case of *Ficus benghalensis* (8.33), *Holoptelia integrifolia* (7.85), *Azadirachta indica* (7.79), *Pongomia pinnata* (7.44), *Dalbergia sissoo* (7.21) and *Delonix regia* (6.85) was at par with each other. In university campus area (control site) *Cassia fistula* (8.90) had highest value among all nine trees taken into consideration. *Holoptelia integrifolia* (7.13), *Pongomia pinnata* (6.92) and *Dalbergia sissoo* (6.36) came after *Cassia fistula* without any critical difference among them having at par value. APTI value of *Azadirachta indica* (6.19), *Nerium indicum* (6.01), *Delonix regia* (5.98) and *Ficus religiosa* (5.73) had lowest values showed at par with each other.

Regional variation of trees toward air pollution was also reported (Lakshmi et al 2008, Agbaire and Esiefarienrhe 2009). The higher APTI value in *Cassia fistula* may be due to increased ascorbic acid production and higher relative water content during pollution stress. The ascorbic acid is the primary factor of defense, and it acts against any oxidative damage to plants in the water stress condition and helps in the synthesis of the cell wall, facilitating cell division. It also helps in photosynthesis and is intricately related to the chlorophyll content of the leaf and hence directs the productivity in plants (Sahu et al 2020). Nayak et al (2015) found that *Cassia fistula* having highest APTI value among different plant species around industrial area and Navsari Agricultural University campus. Similar finding was done by Walia et al 2019 recorded high APTI value of *Cassia fistula* among the selected roadside tree species growing at NH-22 in Himachal Pradesh. Lower APTI value of *Azadirachta indica*, *Nerium indicum*, and *Delonix regia* were also line with the values reported from the trees near cement plant in Coimbattore (Radhapriya et al 2012) and in Visakhapatnam industrial areas (Lakshmi et al 2008).

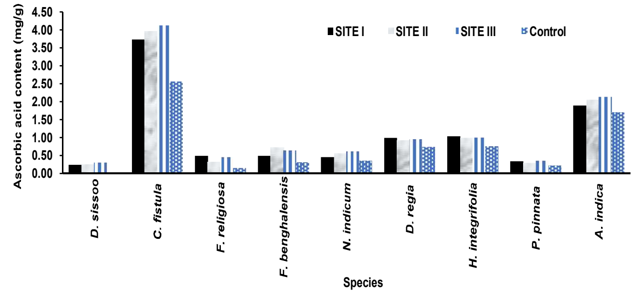

Fig 1. Ascorbic acid content of plant species

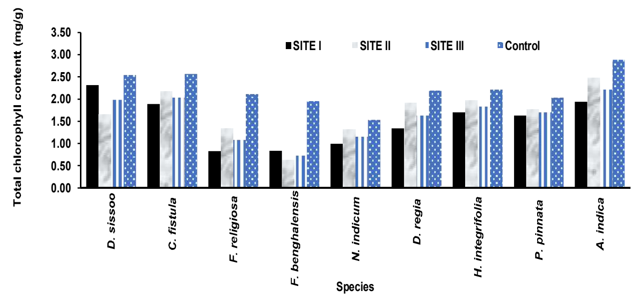

Fig. 2. Total chlorophyll content of plant species

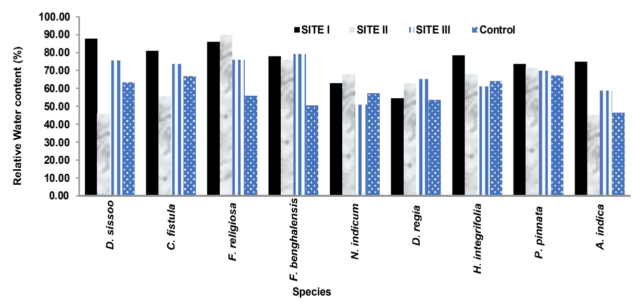

Fig. 3. Relative water content of plant species

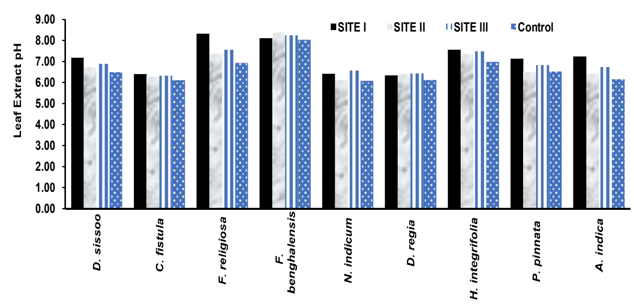

Fig. 4. Leaf extract pH content of plant species

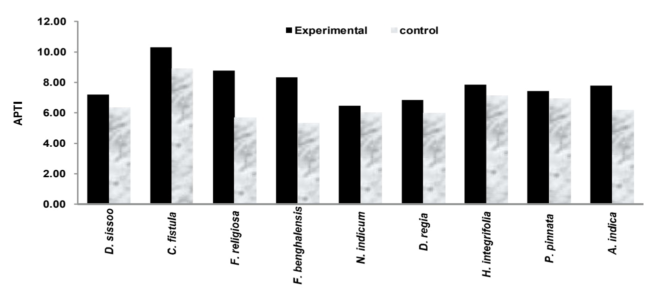

Fig. 5. Air pollution tolerance index of tree species

Table 5. Leaf extract pH of tree species in university campus area and Jhansi city area

Plant species	Control	Site I	Site II	Site III
Dalbergia sissoo	6.49 ± 0.03[cD]	7.18 ± 0.03[dA]	6.72 ± 0.02[cC]	6.88 ± 0.02[dB]
Cassia fistula	6.1 ± 0.02[dBC]	6.4 ± 0.20[eA]	6.28 ± 0.1[eAB]	6.32 ± 0.02[iAB]
Ficus religiosa	6.93 ± 0.04[b]	8.33 ± 0.2[aA]	7.35 ± 0.01[b]	7.56 ± 0.04[bB]
Ficus benghalensis	8.03 ± 0.03[aD]	8.12 ± 0.02[bC]	8.37 ± 0.02[aA]	8.24 ± 0.03[aB]
Nerium indicum	6.07 ± 0.01[eC]	6.41 ± 0.01[eB]	6.09 ± 0.02[fC]	6.56 ± 0.02[gA]
Delonix regia	6.11 ± 0.04[deC]	6.34 ± 0.02[eB]	6.39 ± 0.02[dA]	6.42 ± 0.02[hA]
Holoptelia integrifolia	6.98 ± 0.03[bC]	7.56 ± 0.03[cA]	7.33 ± 0.1[bB]	7.48 ± 0.03[cA]
Pongomia pinnata	6.52 ± 0.02[cC]	7.14 ± 0.01[dA]	6.47 ± 0.02[dD]	6.83 ± 0.03[eB]
Azadirachta indica	6.16 ± 0.03[dD]	7.25 ± 0.01[dA]	6.4 ± 0.1[dC]	6.73 ± 0.01[fB]

Table 6. Air Pollution Tolerance Index of plant species in university campus area and Jhansi city area

Plant species	Jhansi city	University campus
Dalbergia sissoo	7.21±2.18[b]	6.36±0.08[b]
Cassia fistula	10.23±1.35[a]	8.90±0.17[a]
Ficus religiosa	8.77±0.68[a]	5.73±1.10[c]
Ficus benghalensis	8.33±0.14[b]	5.37±0.55[d]
Nerium indicum	6.47±0.82[c]	6.01±0.12[c]
Delonix regia	6.85±0.56[b]	5.98±0.44[c]
Holoptelia integrifolia	7.85±0.88[b]	7.13±0.44[b]
Pongomia pinnata	7.44±0.20[b]	6.92±0.44[b]
Azadirachta indica	7.79±1.45[b]	6.19±0.31[c]
CD (p=0.05)	1.79	0.77

CONCLUSION

According to the findings of this study, all biochemical, physiological, biological, and of plant species play an important role in determining plant sensitivity and tolerance to air pollution, as measured by their tolerance and performance index. Air pollution in urban areas of Jhansi city can be mitigated by developing urban forest or green belts in the city by choosing air pollution tolerant trees. Present study revealed that *Cassia fistula* (10.30), *Ficus religiosa* (8.77) and *Ficus benghalensis* (8.33) would be excellent performers in Jhansi city area. Planners and developers can therefore recommend planting of these tolerant plant varieties for pollution mitigation and greenery enhancement in a Jhansi urban- industrial area.

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