Assessing the impact of air pollution on trees and crops in the Eastern Gangetic Plains of India

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Air pollution is one of the environmental concerns which is a threat to the health of our plants and animals. Little knowledge exists in the literature about its impact on trees and crops. The objective of the present study was to assess the impact of air pollutants on the biochemical parameters of 19 tree and crop species from five different locations in Patna, Bihar, India. Air pollution tolerance index value showed that *Ficus religiosa*, *Zea mays*, *Carthamus tinctorius* and *Cajanus cajan* were more tolerant compared to the other crops. Anticipated performance index value showed that trees like *F. religiosa*, *Azadirachta indica* and *Mangifera indica* and crops like *C. cajan*, *Z. mays* and *Triticum aestivum* were most suitable under air pollution condition.

Keywords: Air pollution tolerance index, anticipated performance index, particulate matter, trees and crops.

INDIA is the third most polluted country in the world after Bangladesh and Pakistan in terms of particulate matter ($PM_{2.5}$) concentration. Average 24-h $PM_{2.5}$ concentration in India is 51.90 $\mu g/m^3$, which puts the air quality under 'very poor' category[1]. Moreover, India has the highest annual average ambient $PM_{2.5}$ exposure levels. According to the World Health Organization (WHO), Geneva, Switzerland, air pollution is a silent killer causing around 7 million premature deaths per year globally, including those of 0.6 million children. It is also one of the major hazards for crops and trees. Most air pollutants in general, and particulate matter in particular, get deposited on the leaf surface. They negatively impact the growth and development of crops and trees[2], causing injury to the leaves, damage to the stomata leading to early leaf senescence, reduced photosynthetic activity and reduced membrane permeability[3]. Some studies have shown the impact of air pollution on chlorophyll content[4,5], relative water content (RWC)[6], ascorbic acid[7] and pH[8,9]. Few studies have determined the impact of particulate matter pollution on biochemical parameters of trees and crops[10–12]. However, the results of these studies are not decisive. Motor vehicles are the major contributors to air pollution, including emissions from industries, construction activities, burning of garbage, agricultural residue burning, etc.[13].

Trees and crops act as biofilters and help lower the impact of air pollution by absorption and adsorption of air pollutants[14]. Air pollution tolerance index (APTI) and anticipated performance index (API) are used to assess the tolerance capacity of tree and crop species against air pollution[14]. This method helps in the identification of trees and crops which are susceptible and/or tolerant to air pollution. The stakeholders can use the information in strategically selecting trees and crops with higher APTI/API to minimize yield loss. In the current Indian scenario, where increasing air pollution is a serious concern, the conscious selection of less susceptible trees and crops towards air pollution would be an eco-friendly management strategy. Such species also serve to lower and remove pollutants from the atmosphere.

The tolerance of plants towards air pollution varies spatially[15] and season also plays a role. The effect of ambient air pollution is generally high in winter due to unfavourable synoptic-scale (anti-cyclonic circulation) and local meteorological conditions (very low temperature, low wind speed and surface layer inversion). These contribute towards increased air pollution levels during winter[16]. Therefore, the present was undertaken to assess the tolerance and performance of tree and crop species to air pollution during the winter season in Patna district, Bihar, India, using APTI/API method.

Materials and methods

Study area

Patna city (the capital of Bihar) was chosen as the study area. It is among the most polluted cities in India and the world, ranking 22nd among the world's most polluted cities with a pollution index of 89.20 (https://www.numbeo.com/pollution/rankings.jsp). Patna covers an area of 3202 km^2 with a population of 2.5 million (https://patna.nic.in). The

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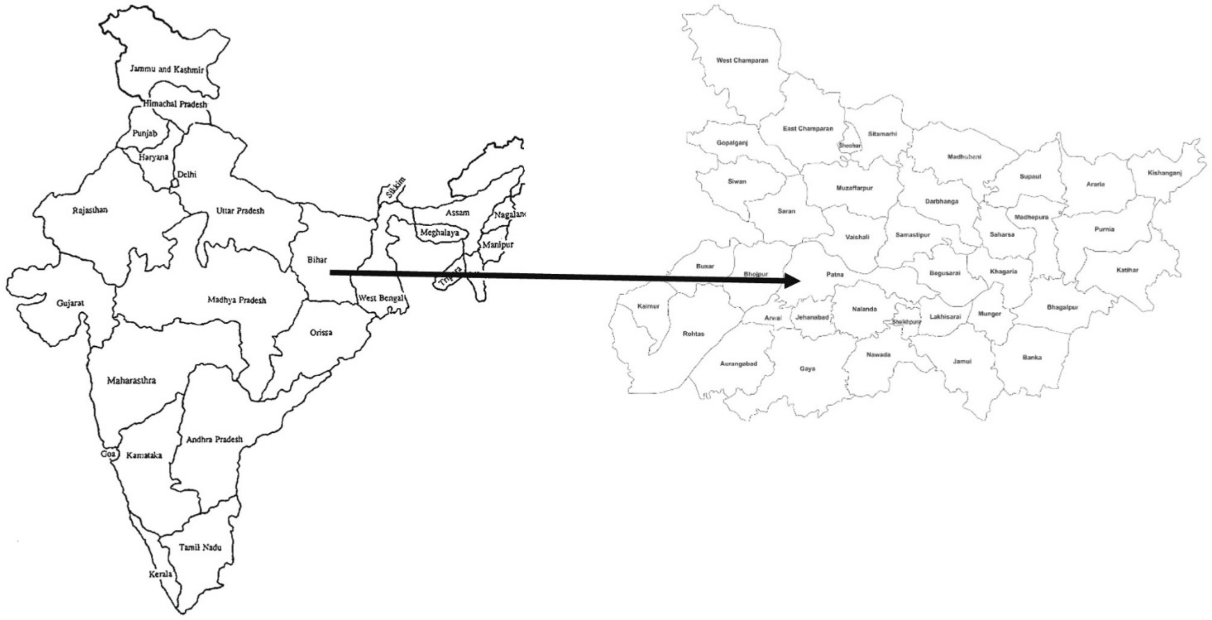

Figure 1. Location of the study area near Jay Prakash Narayan International Airport, Patna, Bihar, India.

Table 1. Selected sites along with latitude and longitude

Sampling location (distance from airport area, km)	Latitude	Longitude
1.0	25°35′44.1″N	85°05′32.6″E
2.0	25°35′33.0″N	85°05′06.3″E
2.3	25°35′33.2″N	85°05′16.8″E
3.9	25°35′29.9″N	85°04′55.5″E
5.7	25°35′13.4″N	85°04′49.4″E

climatic conditions are subtropical monsoon with the hottest (June) and coolest (January) month temperatures of 31.2°C and 15.6°C respectively. Five sites in Patna (Table 1) were selected to collect trees and crop samples from the field and near the Patna airport (Figure 1).

Sampling

Nineteen species of trees and crops were selected for assessment during 2020–21. These included seven trees – *Litchi chinensis*, *Mangifera indica*, *Psidium guajava*, *Ficus religiosa*, *Azadirachta indica*, *Bougainvillea glabra* and *Polyalthia longifolia*; three cereals – *Triticum aestivum*, *Oryza sativa* and *Zea mays*; six pulses – *Cicer arietinum*, *Cajanus cajan*, *Lens culinaris*, *Vicia faba*, *Pisum sativum* and *Lathyrus sativus* and three oilseeds – *Brassica nigra*, *Linum usitatissimum* and *Carthamus tintorius.* Preference was given to the crops and trees, which were most common in the eastern region of India. The leaves were selected randomly, detached carefully from the plant, and kept in separate sealed sampling polythene bags to reduce loss of dust from the leaf surface, they were maintained at 4°C before further analysis.

Monitoring of ambient air pollutants

Data on ambient air pollutants, viz. primary and secondary pollutants, were obtained from the air monitoring station at IGSC Planetarium Complex, Patna (under the Bihar State Pollution Control Board). During the winter months from November 2020 to March 2021, daily data on nitrogen dioxide (NO_x), sulphur dioxide (SO_2) and suspended particulate matter (SPM) were recorded at 24 h intervals. Based on the recorded data from the air monitoring stations, air quality index (AQI) was calculated according to the following formula[17]

$$\mathrm{AQI} = \frac{1}{3}\left(\frac{\mathrm{SO_2}}{S_{\mathrm{SO_2}}} + \frac{\mathrm{NO}_x}{S_{\mathrm{NO}_x}} + \frac{\mathrm{SPM}}{S_{\mathrm{SPM}}}\right) \times 100,$$

where SO_2, NO_x and SPM refer to individual concentrations, while S_{SO_2}, S_{NO_x} and S_{SPM} refer to the ambient air quality standards respectively, according to the Central Pollution Control Board (CPCB) guidelines[18].

Air pollution tolerance index

For assessing APTI, pH, RWC, ascorbic acid and total chlorophyll content were estimated. For pH, leaf samples and double-distilled water were added to a centrifuge tube in 1 : 8 volume ratio[19]. Thereafter, the mixture was shaken at 250 rpm for 1 h. The samples were centrifuged at 13,000 rpm for 5 min and pH was recorded (Systronics, model 361, India). For assessing RWC of the collected samples, measurement of their fresh weight, turgid weight and dry weight was done[3]. The chlorophyll content of different samples was also evaluated[20]. Absorbance was recorded using a spectrophotometer. The amount of chlorophyll was calculated according to the formulas given below

Chlorophyll a = [(12.7 * OD value at 663) – (2.69 * OD value at 645)] * 0.2 (mg/g fresh weight (FW)).

Chlorophyll b = [(22.9 * OD value at 645) – (4.68 * OD value at 663)] * 0.2 (mg/g FW).

Total chlorophyll = Chlorophyll a + Chlorophyll b (mg/g FW).

Dinitrophenyl hydrazine method was used to assess the ascorbic acid (AA) content of different plant sample[21]. It was calculated using the following formula

AA = (0.004 * OD value) + 0.027
= reading * 2 (μmol/g FW).

APTI calculation: Air pollution tolerance is an inbuilt attribute of trees and crops to deal with air pollution, which is the main issue in urban localities. Tree or crop species with APTI value ≤11 are considered to be sensitive; those with APTI values from 12 to 16 are classified as intermediate, while those with APTI value ≥17 are considered to be tolerant. APTI was calculated using the following formula[22]

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

where A is the ascorbic acid content of leaves (mg/g), P the pH of leaf extract, R the RWC of leaves (%) and T is the total chlorophyll content of leaf extract (mg/g).

Anticipated pollution index

API values were calculated based on morphological parameters (plant type, growth habit, morphology, etc.) and socio-economic factors (plants use, shading habit and economic value). For this, grades were assigned[23]; the maximum grade limit was 16. The percentage score for any plant species was the grade obtained by any tree species divided by maximum possible grade any tree species can obtain. The final grading was done ranging from very poor, poor, moderate, good and very good to excellent.

Statistical analysis

Descriptive statistics and statistical analysis were done using R-Studio (ver. 1.4.1106). For air quality index (AQI), average concentration of CO, NO_x, SPM and ozone were taken over a standard time interval for the entire study period.

Results and discussion

General characteristics of air quality

Air quality data of Patna was monitored and recorded daily. $PM_{2.5}$ was in the range 39.7–176.86 μg/m^3. According to WHO, 24 h mean limit is 25 μg/m^3. The $PM_{2.5}$ value was not under the limit on any day during the study period, showing a high level of pollution in the city. Similarly, PM_{10} was in the range 133.31–339.39 μg/m^3, which was higher than the value recommended by WHO (50 μg/m^3) (24 h mean). Similarly, N_2O varied from 17.68 to 73.36 μg/m^3; however, most of the values were found within the permissible limit of 200 μg/m^3 (1 h mean). Observations on air quality parameters indicated that the main reason for bad air quality was particulate matter. Most particles form in the atmosphere because of complex reactions of chemicals such as sulphur dioxide and nitrogen oxides emitted from power plants, industries and automobiles[24]. AQI ranged from 72.95 to 182.13 with an average of 123.85 (Table 2), which indicates moderate air pollution[18].

Chlorophyll

Significant variation (1.392e-07) was observed in the chlorophyll content of seven trees chosen for the study. Total chlorophyll content was highest in *F. religiosa* and lowest in *P. longifolia* (Table 3). *M. indica* and *L. chinesis* had the same chlorophyll content and ranked second after *F. religiosa* (Table 3). Amongst cereals, total chlorophyll content varied from 1.51 ± 0.46 mg/g (*O. sativa*) to 3.71 ± 0.19 mg/g (*Z. mays*) (Table 3). Significant variation (0.000215) was observed among cereals with a mean square error of 0.082. Total chlorophyll content was highest in *Z. mays*, which differed statistically from *T. aestivum* and *O. sativa* (Table 3). Standard deviation was found to be highest in *O. sativa* (0.45). In oilseeds, total chlorophyll content varied from 1.92 to 5.65 mg/g with mean square error of 0.199. Total chlorophyll content was highest in *C. tinctorius* followed by *L. usitatissimum* and *B. juncea*. Chlorophyll content in *C. tinctorius* was statistically significant (*P*-value of 0.00216) compared to *B. juncea* and *L. usitatissimum* (Table 3). Total chlorophyll content was highest in *C. cajan* and lowest in *L. culinaris* (Table 3). The chlorophyll content of *C. cajan* was statistically similar to that of *V. faba* (4.39 mg/g) and *C. arietinum* (4.23 mg/g). Cleaner the leaf surface, greater will be chlorophyll content[25]. Increased pollution levels and deposition of dust on the leaf surface lead to impairment in the photosynthetic machinery, thus lowering the chlorophyll content[11]. High air pollution, especially particulate matter, replaces the magnesium ion with two hydrogen ions in the chlorophyll molecules, leading to its degradation into the pheophytin[11,26], thus reducing the photosynthetic capacity and, ultimately the yield. In this study, trees had higher chlorophyll content compared to field crops which

Table 2. Comparison of air quality data (μg/m^3) of the study area during winter of 2020–21* with the Central Pollution Control Board (CPCB) range

$PM_{2.5}$	PM_{10}	NO_2	NO	SO_2	CO	Ozone	Benzene	AQI	Category	Data
103.8	206.74	39.7	16.21	8.02	1.38	13.63	3.89	123.85	Unhealthy	Study area
61–90	101–250	81–180	–	81–380	2.1–10	101–168	–	101–200	Moderately polluted	CPCB range

*Average values from November 2020 to March 2021.

Table 3. Biochemical parameters and air pollution tolerance index (APTI) for different tree and crop species at the selected site

	Total chlorophyll (mg/g)	Relative water content (%)	pH	Ascorbic acid (mg/g)	APTI
Trees					
Azadirachta indica	4.35 ± 1.02	87.13 ± 2.79	5.89 ± 0.06	5.93 ± 0.04	14.79 ± 0.85^{b}
Bougainvillea glabra	5.03 ± 0.61	76.65 ± 1.24	5.83 ± 0.14	2.77 ± 0.28	10.67 ± 0.45^{def}
Ficus religiosa	9.24 ± 0.56	96.61 ± 0.57	7.22 ± 0.09	6.89 ± 0.28	20.99 ± 0.22^{a}
Litchi chinensis	5.50 ± 0.54	76.90 ± 1.23	6.18 ± 0.14	3.92 ± 0.60	12.25 ± 0.44^{c}
Mangifera indica	5.91 ± 0.47	78.35 ± 3.74	6.05 ± 0.14	5.17 ± 0.08	14.02 ± 0.33^{b}
Psidium guajava	4.26 ± 0.40	82.21 ± 3.57	6.22 ± 0.18	2.85 ± 0.57	11.23 ± 1.00^{d}
Polyalthia longifolia	2.88 ± 0.22	81.55 ± 0.59	5.91 ± 0.04	3.21 ± 0.07	10.97 ± 0.10^{de}
Cereals					
Oryza sativa	1.51 ± 0.45	68.21 ± 1.88	5.86 ± 0.06	1.43 ± 0.04	7.88 ± 0.10^{j}
Triticum aestivum	2.11 ± 0.09	73.20 ± 0.97	6.26 ± 0.02	1.54 ± 0.06	8.61 ± 0.07^{ij}
Zea mays	3.71 ± 0.19	76.77 ± 0.86	6.27 ± 0.04	2.13 ± 0.08	9.81 ± 0.14^{fgh}
Oilseeds					
Brassica juncea	1.92 ± 0.32	79.66 ± 1.69	6.17 ± 0.03	1.39 ± 0.02	9.09 ± 0.20^{hi}
Carthamus tinctorius	3.52 ± 0.20	82.59 ± 0.54	5.90 ± 0.02	2.05 ± 0.09	10.19 ± 0.05^{efg}
Linum usitatissimum	2.03 ± 0.67	80.21 ± 0.94	6.11 ± 0.04	2.03 ± 0.12	9.67 ± 0.20^{gh}
Pulses					
Cicer arietinum	4.23 ± 0.21	69.04 ± 3.31	5.46 ± 0.21	1.16 ± 0.02	8.03 ± 0.^{32j}
Cajanus cajan	5.72 ± 0.83	87.52 ± 1.36	6.59 ± 0.23	3.07 ± 0.11	12.53 ± 0.29^{c}
Lens culinaris	1.75 ± 0.30	71.98 ± 2.09	6.25 ± 0.27	1.12 ± 0.03	8.10 ± 0.18^{j}
Lathyrus sativus	3.70 ± 0.41	76.49 ± 0.95	6.19 ± 0.22	2.21 ± 0.09	9.83 ± 0.17^{fgh}
Pisum sativum	3.35 ± 1.27	67.85 ± 0.98	6.07 ± 0.05	1.16 ± 0.04	7.88 ± 0.22^{j}
Vicia faba	4.39 ± 0.21	81.70 ± 3.56	6.07 ± 0.05	1.25 ± 0.05	9.48 ± 0.42^{ghi}

± Shows the value of standard deviation.
Values in the last column are means with the same letter are not significantly different according to the DMRT test.

could be ascribed to the longer life cycle of trees, helping them adjust to a given environment and optimize photosynthesis[27].

RWC

Statistically significant variation (5.211e-07) for RWC was observed among tree species. RWC of trees ranged from 76.9% to 96.6% (Table 3). Highest RWC was found in *F. religiosa* and lowest in *B. glabra*. In cereals, RWC varied significantly, with *Z. mays* having 4.88% and 12.57% higher values than those of *T. aestivum* and *O. sativa* respectively (Table 3). RWC in oilseeds did not show significant variation and exhibited a narrow range (85.2–93.9%). It varied significantly (1.185e-06) among pulses with a mean square error of 5.29. *C. cajan* recorded the highest RWC followed by *V. faba* and *L. sativus* (Table 3). The lowest RWC was found in *P. sativum*. RWC affects cell-wall permeability, the photosynthetic mechanism and many enzymatic activities. It helps in the water balance of crops, which is usually needed for any plant process to function smoothly. In this study, trees had a high RWC percentage compared to crops, which indicated that trees have more capacity to withstand air pollution[15]. Under stress, plants need more water to overcome stress, like air pollutants[28].

pH

Results showed that pH of leaf extract of trees was below 7.0 in all cases, except in *F. religiosa* (Table 3). Significant variation (1.886e-08) was found in different tree species. *P. guajava* and *L. chinensis* had similar pH, while the pH values of *L. chinensis*, *M. indica*, *P. longifolia* and *A. indica* were statistically non-significant. Among all the tree species under study, *B. glabra* recorded the lowest pH of 5.83, making it the most susceptible to air pollution. In case of cereals, pH differed significantly (3.569e-05). The pH of all three cereals under study was lower than 7.0; however, the lowest pH was recorded for *O. sativa* (Table 3). The pH in oilseeds showed statistically significant (7.414e-05) variation. *C. tinctorius* had the lowest pH, which was significantly different from *B. juncea* and *L. usitatissimum*

(Table 3). Leaf extract pH of pulses showed significant variation with values below 7.0 for all cases. Although the pH of *C. cajan* was highest among all pulses, it was statistically at par with *V. faba* and *C. arietinum* (Table 3). Lowest pH of 1.76 was observed in *L. culinaris*. When pollutants like sulphur dioxide or nitrogen dioxide are absorbed onto the leaf surface or crop plants, they get converted into sulphuric or nitric acid, which lowers the pH of the cell sap[12]. High pH of leaf extract indicates more tolerance to air pollutants[3], indicating that in areas where air pollution level is higher, leaf pH will be less.

Ascorbic acid

Ascorbic acid content among trees showed a wide range (2.127e-09) with a mean square error of 0.122. In the present study, it was found to be highest in *F. religiosa* (6.88 mg/g) followed by *A. indica* and *M. indica* which showed similar levels. Lowest content of ascorbic acid was found in *B. glabra*, which was similar to *P. guajava.* Among cereals, ascorbic acid was found to be highest in *Z. mays* showing significant variation (1.528e-05 at *P* of 0.01) compared to *T. aestivum* and *O. sativa* (Table 3). In oilseeds, *C. tinctorius* and *L. usitatissimum* had similar level of ascorbic acid; however, the values were significantly higher than *B. juncea* (Table 3). Among pulses, *C. cajan* had the highest ascorbic acid level followed by *L. sativus*. Ascorbic acid levels of *V. faba*, *C. arietinum*, *P. sativum* and *L. culinaris* did not vary significantly from each other (Table 3). Ascorbic acid is an antioxidant that scavenges free radicals under any adverse condition, including air pollution[24]. Hence, the concentration of ascorbic acid decreases after the removal of free radicals. Therefore, lower the ascorbic acid content, more susceptible is the species to air pollutants.

Air pollution tolerance index

Based on the above biochemical parameters, APTI was calculated. Results show that APTI values among 19 species of trees and crops varied from 7.87 to 20.98 (Table 3). Among trees, *F. religiosa* had the highest APTI. Among cereals, the APTI values were also found to vary significantly (4.617e-05), with the highest value in *Z. mays*. In oilseeds, *C. tinctorius* recorded the highest APTI value, which was statistically insignificant from the other oilseeds (Table 3). Pulse crops had significant APTI variation (4.506e-08) with the highest value in *C. cajan*. *F. religiosa* had the highest APTI among all crops selected in this study, while *O. sativa* had the least APTI value (7.87) (Table 3). For trees, APTI value greater than 13 was considered tolerant[24], while in crop species APTI value of more than 10 was considered tolerant[15]. Accordingly, among trees *F. religiosa*, *A. indica* and *M. indica* were considered as tolerant species. Similar results have been reported in the literature[22,29] where *F. religiosa* was found to be the most tolerant species against air pollutants[15]. In crop species, *C. cajan* and *C. tinctorius* were found to be the most tolerant, indicating that they could bear stress and can be used as tolerant crop species. *O. sativa* was found to have the lowest APTI value followed closely by *T. aestivum* and *B. juncea*, indicating their susceptibility towards air pollutants[15,29].

Anticipated performance index

F. religiosa, *A. indica* and *M. indica* were found to be the most suitable for the study region under air pollution stress load. Other trees like *L. chinensis*, *P. guajava*, *P. longifolia* and *B. glabra* were rated very good, good, moderate and poor respectively. Among crops, *C. cajan* performed the best, whereas *Z. mays* was categorized as excellent and *T. aestivum* as very good under air pollution load, indicating that these crops are better performers in terms of air pollution stress tolerance. Other crops like *O. sativa*, *C. arietinum*, *L. sativus*, *V. faba* and *L. usitatissimum* were rated as good. *L. culinaris* fell under the moderate category, while *B. nigra* and *P. sativum* fell into the poor category (Table 4). Thus, among trees, *F. religiosa*, *A. indica* and *M. indica* and in crops, *C. cajan*, *Z. mays* and *T. aestivum* are best suited to the study area from an environmental point of view to mitigate air pollution load. *M. indica*, *A. indica* and *F. religiosa* were the most tolerant tree species in the Jharkhand and Bihar area[30], while *T. aestivum*, *O. sativa* and *P. glaucum* were the most tolerant crops[15].

Correlation coefficient analysis and principal component analysis

Figure 2 shows the Pearson correlation coefficient of various biochemical parameters. For trees, a significant ($P < 0.05$) positive correlation was found between total chlorophyll and pH ($r = 0.83$), pH and RWC ($r = 0.73$), RWC and ascorbic acid ($r = 0.73$). However, the degree of association between ascorbic acid and pH ($r = 0.59$), ascorbic acid and total chlorophyll ($r = 0.67$), and RWC and total chlorophyll ($r = 0.59$) was not strong compared to the previous ones. In case of cereals, correlation of total chlorophyll and ascorbic acid was highly significant ($r = 0.97$), while total chlorophyll and RWC ($r = 0.82$), total chlorophyll and pH ($r = 0.70$), and ascorbic acid and pH ($r = 0.85$) were also in good correlation with each other. Total chlorophyll and RWC were significantly correlated ($r = 0.72$) in oilseeds. However, pH showed a negative correlation with ascorbic acid ($r = –0.68$); total chlorophyll ($r = –0.91$) and RWC ($r = –0.86$) (Figure 2 *c*). In pulses, RWC and ascorbic acid were significantly positively correlated ($r = 0.74$). Total chlorophyll and RWC ($r = 0.60$), total chlorophyll and ascorbic acid ($r = 0.61$), pH and RWC ($r = 0.59$), and pH and ascorbic acid ($r = 0.60$) were positively correlated with each other. However, pH and total chlorophyll correlation were statistically insignificant (Figure 2 *d*). In all cases,

Table 4. Gradation of crop/tree species based on APTI and other biological and social characteristics for the anticipated performance index development

Plant species	APTI	Morphological parameters Plant height	Canopy type	Plant type	Laminar structure Size	Texture	Hardness	Economic use	Total	Score (%)	API grade	Category
Trees												
L. chinensis	+++	++	+	++	+	–	+	++	12	75	5	Very good
M. indica	+++++	++	++	++	+	–	+	++	15	93.75	7	Best
P. guajava	++	++	+	++	+	–	+	++	11	68.75	4	Good
P. longifolia	+	++	+	++	+	–	+	+	9	56.25	3	Moderate
A. indica	+++++	++	++	++	+	–	+	++	15	93.75	7	Best
B. glabra	+	++	+	++	–	–	+	+	8	50	2	Poor
F. religiosa	+++++	+++	++	++	+	–	–	++	15	93.75	7	Best
Crops												
T. aestivum	++	++	+	+	++	+	–	++	12	75	5	Very good
Z. mays	+++	+++	+	+	++	+	–	+++	14	87.5	6	Excellent
O. sativa	+	++	+	+	++	+	–	++	10	62.5	4	Good
P. sativum	+	+	+	+	+	+	–	++	8	50	2	Poor
L. culinaris	++	+	+	+	+	+	–	++	9	56.25	3	Moderate
C. arietinum	++	++	+	+	+	+	–	++	10	62.5	4	Good
L. sativus	+++	++	+	+	+	+	–	++	10	62.5	4	Good
V. faba	+++	++	+	+	+	+	–	++	11	68.75	4	Good
C. cajan	+++++	++	+	++	++	+	–	++	15	93.75	7	Best
B. nigra	+++	+++	+	+	++	+	–	+++	8	50	2	Poor
L. usitatissimum	+++	++	+	+	+	+	–	++	11	68.75	4	Good
C. tintorius	++++	++	+	+	++	++	+	+++	15	93.75	7	Best

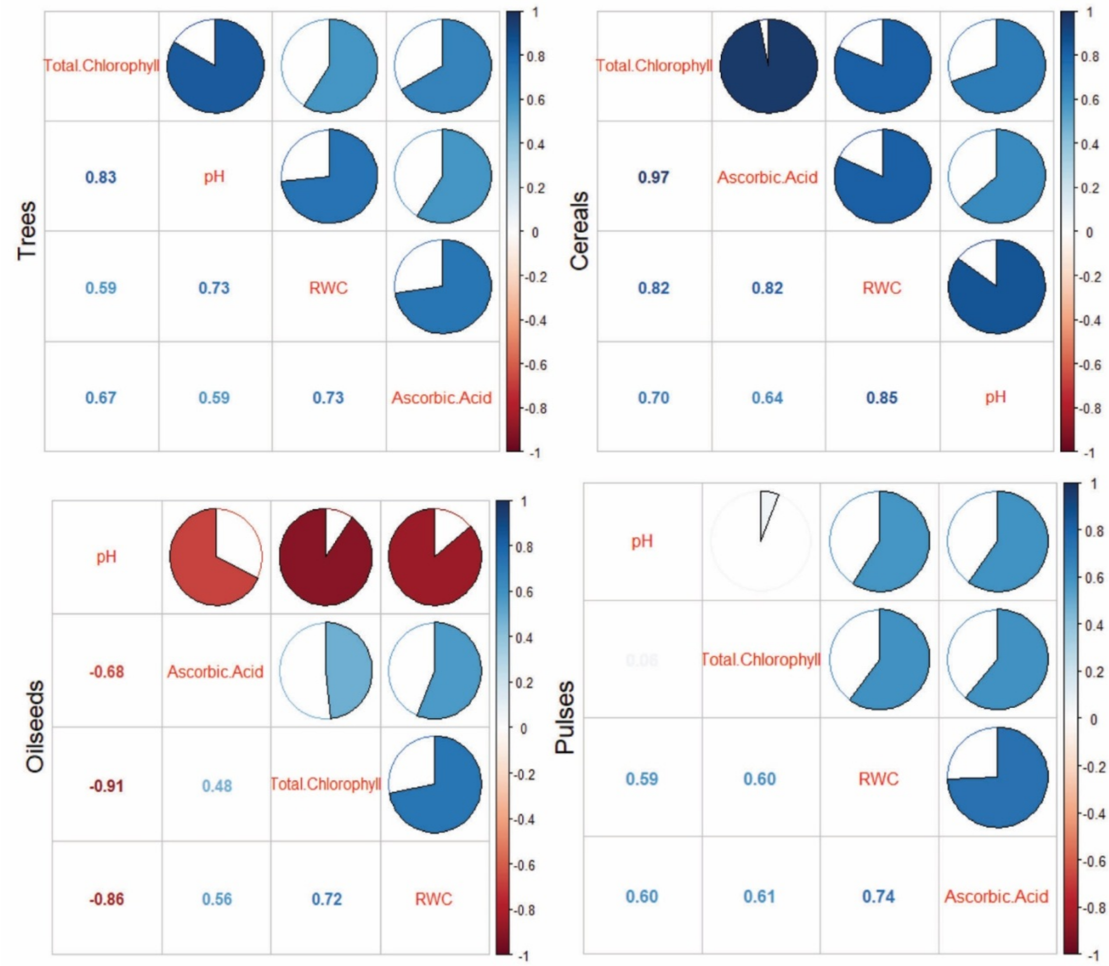

Figure 2. Correlation coefficient of biochemical parameters in trees, cereals, oilseeds and pulses.

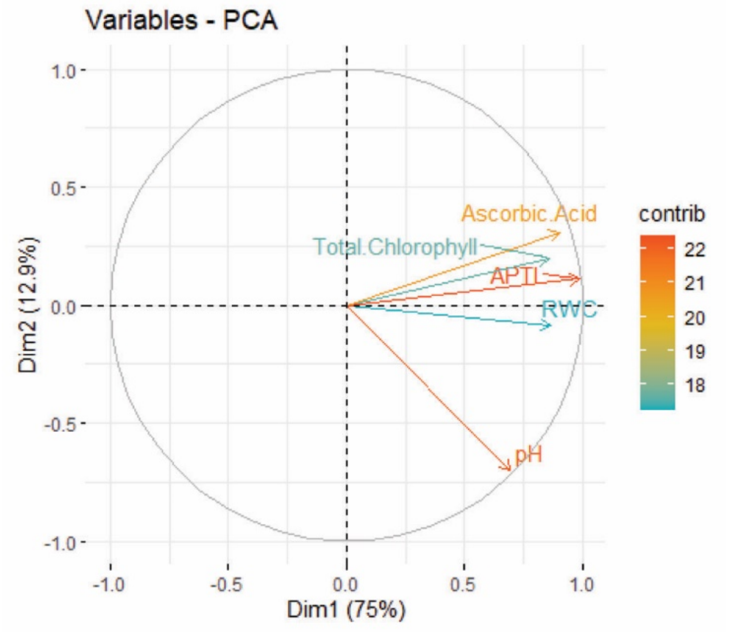

Figure 3. Principal component analysis showing the contribution of different air pollutants.

ascorbic and total chlorophyll were the determining factors showing a strong correlation with each other, signifying that in APTI, ascorbic acid and total chlorophyll are the most significant determining factors. Our findings are also substantiated by many other reports[3,11,15]. Air pollutants that impact biochemical parameters of a tree/crop were analysed using principal component analysis, which accounted for 87.9% of the variation. Dimension 1 (PC 1 variance of 75%) included parameters like APTI, total chlorophyll and ascorbic acid, while Dimension 2 included parameters like pH and RWC whose variance was 12.9% as shown in Figure 3, indicating that their impact on API is less compared to other parameters.

Conclusion

Air pollution is a global threat with India having some of the worst levels in the world. Patna city in the Indo-Gangetic belt is one of the world's most polluted cities, which requires more focus towards air pollution-related causes and their remediation. One of the best remediation options is urban forestry and agriculture, which not only adds beauty to the environment but also helps in combating air pollution. The present study reveals that different trees and crop species respond differently towards air pollution. Among trees, *F. religiosa* and crops like *Z. mays*, *C. tintorius* and *C. cajan* had the highest APTI values. API values showed that trees like *F. religiosa*, *A. indica* and *M. indica* and crops like *C. cajan*, *Z. mays* and *T. aestivum* are best suited under air pollution load. APTI and API values serve as selection tools, where we can choose higher value tree and crop species as bio-accumulators and lower value species as sensitive ones. This present study is a step towards assessing air pollution tolerance in Patna, which will help in better urban planning and management.

Conflict of interest: The authors declare that they have no conflict of interest.

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