International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133; Print ISSN: 2664-7125; Impact Factor: RJIF 5.28
Received: 20-11-2020; Accepted: 04-12-2020; Published: 20-12-2020
Volume 2; Issue 4; 2020; Page No. 757-765

Estimation of anticipated performance index and air pollution tolerance index of vegetation around the national highway, India

Shreya Handa[1], RK Aggarwal[1], SK Bhardwaj[1], DR Bhardwaj[2]
[1] Department of Environmental Science, Dr Y S Parmar University of Horticulture and Forestry, Nauni-Solan, Himachal Pradesh, India
[2] Department of Silviculture and Agro-Forestry, Dr Y S Parmar University of Horticulture and Forestry, Nauni-Solan, Himachal Pradesh, India

Abstract
Industrialization and globalization are the foremost cause of soil, air, and water pollution. Among all these, air pollution has produced much interest, later it has a main impact on the transboundary diffusion of pollutants worldwide. Mitigating air pollution is a great challenge, in such a situation, screening of plants as a bio-monitor is enormously significant. The present study has been considered to assess the Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API) of the common flora along highways. Five common plant species from amongst tree, herb and shrubs namely *Eucalyptus spp.* (myrtaceae), *Mangifera indica* (Anacardiaceae), *Grewia optiva* (malvaceae), *Ficus roxburghii* (moraceae) and *Morus alba* (moraceae) were carefully chosen growing frequently in the vicinity of the National Highway-88. APTI and API of selected plant species were examined by defining significant biochemical parameters like ascorbic acid, total chlorophyll content, leaf extract pH and relative water content. Besides, the selected vegetation was considered for physiological, economic, morphological as well as biological characteristics. It was found that two of the selected plants were sensitive to air pollution. Though, *Mangifera indica* and *Ficus roxburghii* showed the highest API and hence, suggested for plantation in a pollution stress area.

Keywords: apti, API, ascorbic acid, chlorophyll, rwc, ph, greenbelt and air pollution

Introduction

Pollution directly or indirectly changes metabolism in any organism. The rapid growth of industries and ever increasing vehicular density are the primary causes behind the intensification in environmental air pollution in urban areas (Hamraz *et al*., 2014) [8]. The rising cities in developing countries are at the receiving end as they face the rage of air pollution. Trees play a vital role in refining air quality by exchanging gases and perform as a sink for the air pollutants. They eliminate particulate matter by acting as living filters to reduce air pollution. Trees that have experience to environmental pollutants absorb, accumulate and integrate these pollutants into their systems, dependent on their sensitivity level. Plants show visible damages, which would consist of a variation of the biochemical processes or accumulation of individual metabolites. These changes are used for assessing the APTI of plants (Khureshi *et al*., 2013) [15].

Acceptance to air pollution modifies from species to species mostly depending on the plant's capacity to bear the effect of pollutants (Gholami *et al*., 2016) [7]. It is an index that used to assess the resistance of plants for air pollutants and to regulate against air pollution. The plant growing along the highway varied knowingly in their tolerance levels. Several researchers have examined air pollutants through plants when exposed to air pollution (Hasegawa *et al*., 2002; Simon *et al*., 2006) [9, 28]. Maximum plants experience physiological changes before exhibiting visible damage to leaves (Dohmen *et al*., 1990) [5]. According to responses of plants towards air pollution, analysis of some biological parameters of each species helps in defining tolerance level. The impacts of air pollution on ascorbic acid Content (Hoque *et al*., 2007) [11], chlorophyll content (Flowers *et al*., 2007) [6], and leaf extract pH (Klumpp *et al*., 2000) [16] and relative water content (Rao, 1979) [26] have been broadly analyzed. Each plant species have a tendency to respond differently to climatic conditions and for diverse pollutants. Biological monitoring of plant tolerance towards air pollution helps in selecting sensitive and tolerant plants as a bio-indicator of air pollution. The plants with the minimum tolerance index are sensitive to air pollution whereas, the plants with utmost tolerance index are tolerant to air pollution. Tolerant species help in altering air pollution while a lesser amount of tolerant species act as an indicator. APTI regulates the plant's reaction to air pollution and the plant's capacity to fight against air pollution (Vinita *et al*., 2011) [33].The plants which can resist higher pollutant concentrations can assist as tolerant species and might be recommended to act as pollution scavengers (Sharma *et al*., 2017) [27].

In the present study, four parameters (ascorbic acid, total chlorophyll content, leaf extract pH and relative water content) were investigated and expressed together in one formula to evaluate the sensitivity of plants to air pollutants (Kotecha *et al*., 2014) [17] to understand the adaptableness and resistance of plants towards air pollution.

The susceptibility levels of generally growing tree species on the roadside exposed to vehicular air pollution have been determined based on their air pollution tolerance indices. Greenbelt developers can employ the results of the study in managing urban air pollution.

Materials and Methods
Study area and sample collection
The 60 km stretch of the National Highway-88 from Hamirpur to Ghagus was divided into four equal parts of fifteen kilometers Each (Fig. 1).

To study the impact of vehicular activities on the plants, the plants were selected from 0-10 m and 10-20 m horizontal distances from both sides of the road >20m.

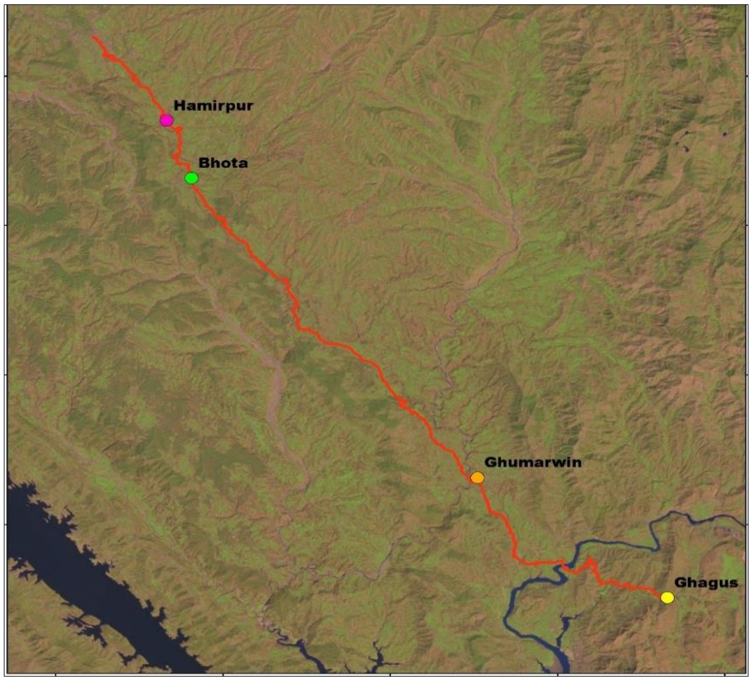

Fig 1: Selected sites of plant species alongside National Highway

The commonly occurring plant species i.e. *Eucalyptus spp.*, *Mangifera indica*, *Grewia optiva*, *Ficus roxburghii*, and *Morus alba* were selected for the study (Table 1).Three samples from healthy and fully matured leaves of each plant were gathered through the random selection from the lowermost position of a canopy at the height of 1.8-2.1 m from ground level. All collected leaf samples were washed with the running tap water, rinsed with distilled water and then used for further analysis to determine ascorbic acid content, total chlorophyll content, leaf extract pH and relative water content. Dimethyl sulphoxide acetone, distilled water, standard pH solution (buffer), metaphosphoric acid pellets, indophenols dye were used in the experiment. The methodology to determine content of various parameters has been described in this section.

Relative water content (RWC)
Fresh weight was obtained by weighing the fresh leaves. The leaves were then immersed overnight in water blotted, dry and then weighed to get the turgid weight. The leaves kept to dry overnight in an oven at 70 °C and reweighed to obtain the dry weight. RWC was determined and calculated by using the method of Chouhan *et al*. (2012) [3] as follows:

RWC (%) = [(FW-DW)] / [(TW-DW)] x 100

Where,

FW is Fresh weight,

DW is Dry weight, and

TW is turgid weight.

Total Chlorophyll Content
Total chlorophyll content was estimated as per the Spectrophotometric method of Hiscox and Israeistam (1979) [10] by placing 100 mg of chopped leaf samples in vials containing 7 mL dimethyl sulphoxide.

The vials were incubated for half an hour at 65 °C and then the final volume of extract was made to 10 mL with dimethyl sulphoxide. The absorbance values of the above extract were recorded at 645 and 663 nm wavelength.

Leaf Extract pH
Recently matured leaves (5 g) were homogenized in 10 mL deionized water and the supernatant obtained after centrifugation was collected for determination of pH by using pH meter (Model-ESICO 1013) with a buffer solution of pH 4 and 9.

Ascorbic Acid Content
Ascorbic acid content was estimated by using A.O.A.C (1980) [1] method. Fresh leaves (10 g) were homogenized in metaphosphoric acid solution. The volume was made to 100 mL. This solution was titrated against indophenols dye with the appearance of rose pink colour as the endpoint.

Air Pollution Tolerance Index (APTI)
By using the above parameters the air pollution tolerance index was computed by the method suggested by Singh and Rao (1983) [30] using the equation:

APTI = [A x (T+P) + R] / [10]

Where, A is Ascorbic acid (mg/g),

T is Total chlorophyll (mg/g),

P is Leaf extracts pH and

R is Relative water content (RWC) [(%) of the leaves]

Anticipated Performance Index

By combining the resultant APTI values with some relevant biological and socioeconomic characters (plant height, canopy structure, plant size texture, hardness, and economic value) the API was calculated for different plant species. Based on these characters, different grades (+ or -) were allotted to plants. Different plants were scored according to their grades as per the procedure outlined by Mondal *et al*., 2011 [19] (Table 2&3).

Table 1: Details and morphological characteristics of selected plants growing in the study area

Plant species	Habit	Common name	Family	Leaf shape	Leaf texture
Eucalyptus spp.	Tree	Safeda	Myrtaceae	Stringy	Smooth
Mangifera indica	Tree	Amm	Anacardiaceae	Lanceolate to elongated-elliptic	Coarse
Grewia optiva	Tree	Bihul	Malvaceae	Ovate to broadly ovate	Rough
Ficus roxburghii	Tree	Trimmal	Moraceae	Cordate exstipulate	Smooth
Morus alba	Tree	Toot	Moraceae	Cordate	Glossy, medium

Table 2: Gradation of plant species based on APTI as well as biological parameters and socio-economic importance

Grading character	Pattern of assessment	Grade allotted
Air Pollution Tolerance Index (APTI)	8.0-8.5	+
	8.6-9.0	++
	9.1-9.5	+++
	9.6-10	++++
	10.1-10.5	+++++
Plant habit	Small	-
	Medium	+
	Large	++
Canopy structure	Sparse/irregular/globular	-
	Spreading crown/open/semi dense	+
	Spreading dense	++
Type of plant	Deciduous	-
	Evergreen	+
Laminar characteristics Size Texture	Small	-
	Medium	+
	Large	++
	Smooth	-
	Coriaceous	+
Hardiness	Delineate	-
	Hardy	+
Economic value	Less than three uses	-
	Three or four uses	+
	Five or more uses	++

Table 3: Anticipated Performance Index (API) of plant species

Grade	Score (%)	Assessment category
0	Up to 30	Not recommended
1	31–40	Very poor
2	41–50	Poor
3	51–60	Moderate
4	61–70	Good
5	71–80	Very good
6	81–90	Excellent
7	91-100	Best

Results and Discussion

The impacts of vehicular air pollution on the biochemical parameters of the studied plants growing alongside National Highway have been discussed in this section.

Ascorbic Acid Content

The selected plant species varied significantly in their ascorbic acid content ranged from 1.16 to 3.88 mg g^{-1} among the selected five species, the highest (3.42 mg g^{-1}) ascorbic acid content was recorded in *Ficus roxburghii* and lowest (1.25 mg g^{-1}) was recorded in *Eucalyptus spp.* (Table 4). The leaf ascorbic content of the selected plant species growing at different sites also varied significantly with seasons having highest (2.40 mg g^{-1}) leaf ascorbic acid content during post-monsoon season whereas, lowest (2.37 mg g^{-1}) ascorbic acid was noticed during pre-monsoon season. The increase in leaf ascorbic acid content during post-monsoon season may be due to more production of antioxidants (ascorbic acid) under stress conditions. The higher ascorbic acid content in the post-monsoon season may also be attributed due to lesser rainfall in the study area as compared to the pre- monsoon.

The results are in conformity with the findings of Prajapati and Tripathi (2008) [25] who pointed out that plants under stress improve in their ascorbic acid content to fight adverse conditions. Ascorbic acid content decreased with an increase in horizontal distance with the highest of 2.58 mg g^{-1} at the distance of 0-10 m, 2.40 mg g^{-1}at 10-20 m and lowest of 2.17 mg g^{-1} at a distance of >10-20 m from the national highway (Fig 2a). Yannawar and Bhosle (2013) [34] have also reported higher ascorbic acid content in the leaves of the plants growing near the roadside due to higher pollution stress. The higher ascorbic acid content in the leaves of *Ficus roxburghii* may probably be due to improvement in the defense mechanism of the plants, which has been reported to be different for different plant species by (Cheng *et al*., 2007) [4].

A significant variation was noticed in the ascorbic acid content of selected plant species growing at different horizontal distances. The plants growing at distance of 0-10 m distance recorded the highest leaf ascorbic acid content of 2.56 mg g^{-1} which was found to decrease with increasing distance along the road.

The results are in line with the findings of Yannawar and Bhosle (2013) [34] who have also reported higher ascorbic acid content in the leaves of the plants growing near the roadside. The interaction between species and seasons was also found to be statistically significant. The leaves of *Ficus roxburghii* were found to contain highest ascorbic content of 3.44 mg g^{-1} during post-monsoon season. Whereas, the lowest content of 1.24 mg g^{-1} was noticed in *Eucalyptus spp.* during pre-monsoon season. The present results are in accordance with the Mohammed Kuddus *et al*., (2011) [18] who recorded higher leaf ascorbic acid content in plant species with high APTI. Further, distance × season interaction on the ascorbic acid content of the plant species was notice alongside the road. The highest ascorbic content of 2.61 mg g^{-1} was recorded in the plants at a distance of 0-10 m in the post-monsoon season and lowest of 2.16 mg g^{-1} at a distance of >20 m in the pre-monsoon season.

The species x seasons x distance interaction was found to be non-significant.

Table 4: Seasonal variation in ascorbic acid content (mg g^{-1}) of plant species growing at different horizontal distances

Plant species	Pre-monsoon				Post-monsoon				Mean			
	Horizontal Distance (m)											
	0-10	10-20	>20	Mean	0-10	10-20	>20	Mean	0-10	10-20	>20	Mean
Eucalyptus spp	1.32	1.24	1.16	1.24	1.36	1.29	1.17	1.27	1.34	1.26	1.16	1.25
Mangifera indica	3.03	2.98	2.48	2.83	3.07	2.99	2.51	2.86	3.05	2.98	2.49	2.84
Grewia optiva	1.40	1.32	1.12	1.28	1.46	1.36	1.17	1.33	1.43	1.34	1.14	1.30
Ficus roxburghii	3.82	3.31	3.06	3.42	3.88	3.37	3.08	3.44	3.85	3.34	3.07	3.42
Morus alba	3.21	3.06	2.98	3.08	3.26	3.11	2.99	3.12	3.23	3.08	2.98	3.10
Mean	2.56	2.38	2.16	2.37	2.61	2.42	2.18	2.40	2.58	2.40	2.17	2.38

Table 5: Seasonal variation in total chlorophyll content (mg g^{-1}) of plant species growing at different horizontal distances

Plant species	Pre-monsoon				Post-monsoon				Mean			
	Horizontal Distance (m)											
	0-10	10-20	>20	Mean	0-10	10-20	>20	Mean	0-10	10-20	>20	Mean
Eucalyptus spp	1.42	1.50	1.53	1.48	1.46	1.57	1.58	1.54	1.44	1.53	1.55	1.51
Mangifera indica	1.48	1.67	1.72	1.62	1.51	1.69	1.77	1.66	1.49	1.68	1.74	1.64
Grewia optiva	1.29	1.39	1.46	1.38	1.33	1.43	1.49	1.42	1.31	1.41	1.47	1.40
Ficus roxburghii	1.57	1.75	1.92	1.75	1.59	1.79	1.97	1.78	1.58	1.77	1.94	1.76
Morus alba	1.51	1.72	1.89	1.71	1.57	1.78	1.93	1.76	1.54	1.75	1.91	1.73
Mean	1.45	1.61	1.70	1.59	1.49	1.65	1.75	1.63	1.47	1.63	1.72	1.61

Total Chlorophyll Content

It is evident from the Table 5 that among the selected plant species, *Ficus roxburghii* was noticed to have highest chlorophyll content of 1.76 mg g^{-1} and it was significantly different from all other values followed by *Morus alba*, *Mangifera indica, Eucalyptus spp.* and *Grewia optiva* with respective values of 1.73, 1.64, 1.51 and 1.40 mg g^{-1}. The variation in the chlorophyll content of the leaves of selected plant species may be attributed to the genetic variations of the plant species. Further, the variations in chlorophyll content of plant species may vary with the pollution status of the area and the tolerance as well as sensitivity of plant species. The results are supported by findings of Begum and Hari Krishna (2010) [2] who reported that chlorophyll content varies from species to species and also with the pollution level as well as with other biotic and abiotic conditions. In the selected plant species, season wise leaf chlorophyll content ranged from 1.59 to 1.63 mg g^{-1}. The highest (1.63 mg g^{-1}) leaf chlorophyll content was noticed during post-monsoon season whereas, lowest (1.59 mg g^{-1}) was observed during pre-monsoon season. The season wise variation in chlorophyll content may be ascribed due to more temperature stress on the plant species in the pre-monsoon season. This may be due to higher value of maximum temperature of the study area in pre-monsoon as compared to the post-monsoon season. The results are in line with the findings of Jyothi and Jaya (2010) [13].

The season × species interaction found to be a significant variation in leaf chlorophyll content of the plant species. Among the selected species *Ficus roxburghii* was found to be highest leaf chlorophyll content of 1.78 mg g^{-1} during post-monsoon season and lowest (1.38 mg g^{-1}) was found in *Grewia optiva* in pre-monsoon season. The species x distance exerted a significant influence on the leaf chlorophyll content. Among the selected plant species *Ficus roxburghii* was found to have highest leaf chlorophyll content of 1.97 mg g^{-1} at a distance of > 20 m and the lowest of 1.29 mg g^{-1} was recorded in *Grewia optiva* at a distance of 0-10 m. The season and distance interaction was also found significant influence on the chlorophyll content of the plant species. Among the selected plant species having highest leaf chlorophyll content of 1.75 mg g^{-1} during post-monsoon season at a distance >20 m and the lowest of 1.45 mg g^{-1} during pre-monsoon season at a distance of 0-10 m. Further, the species x distance x seasons interaction was found to be statistically significant with respect to chlorophyll content in the leaves of selected plant species.

The highest (1.97 mg g^{-1}) was recorded in *Ficus roxburghii* at a distance >20 m, in the post-monsoon season. This may be attributed to relatively less stress conditions during the post-monsoon season. The lowest value of 1.29 mg g^{-1} was recorded in *Grewia optiva* at a distance of 0-10 m in the pre-monsoon season (Fig 2b), It might be due to the destruction of chlorophyll, inhibition of RuBp carboxylase (Horsman and Wellburn, 1975) [12] and reversible swelling of thylakoids in polluted conditions.

Table 6: Seasonal variation leaf extract pH of plant species growing at different horizontal distances

Plant species	Pre-monsoon				Post-monsoon				Mean			
	Horizontal Distance (m)											
	0-10	10-20	>20	Mean	0-10	10-20	>20	Mean	0-10	10-20	>20	Mean
Eucalyptus spp	6.58	6.59	6.71	6.63	6.59	6.60	6.78	6.66	6.58	6.59	6.74	6.64
Mangifera indica	6.64	7.00	7.16	6.93	6.66	7.02	7.19	6.96	6.65	7.01	7.17	6.94
Grewia optiva	6.69	6.78	6.86	6.78	6.71	6.79	6.88	6.79	6.70	6.78	6.87	6.78
Ficus roxburghii	6.66	7.05	7.14	6.95	6.69	7.07	7.19	6.98	6.67	7.06	7.16	6.96
Morus alba	6.60	7.00	7.09	6.90	6.64	7.03	7.12	6.93	6.62	7.01	7.10	6.91
Mean	6.63	6.88	6.99	6.83	6.66	6.90	7.03	6.86	6.64	6.89	7.01	6.85

Leaf Extract pH

The plant species growing around the highway exhibited statistically significant variation in the leaf extract pH. The range of the leaf extract pH among the selected species was 6.64- 6.96 (Table 6). The highest leaf extract pH of 6.96 was recorded in *Ficus roxburghii* whereas, lowest of 6.64 was recorded in *Eucalyptus spp.* (Fig 2c). The leaf extract pH of plant species growing at different horizontal distances in the study area showed a significant variation in the leaf extract pH. It increased with an increase in horizontal distance which was recorded highest (7.01) at the distance of >20 m from the roadside and lowest of 6.64 recorded at a distance of 0-10 m. Seasons were also found to influence the leaf extract pH of the selected plant species in the present study. The highest (6.86) leaf extract pH was recorded during post-monsoon whereas, lowest of 6.83 was noticed during pre-monsoon season. These values are significantly different from each other. The higher leaf extract pH during post-monsoon season may be due to high amount of rainfall during monsoon season, which might have washed away the acidic pollutants by rain. The results are in line with the findings of Jyothi and Jaya (2010) [13] who reported higher pH during post-monsoon season due to the washing of acidic pollutants by rain. Further, the species x season interaction had significant influence on the leaf extract pH. The highest pH of 6.98 was recorded in *Ficus roxburghii* during post-monsoon season and lowest of 6.63 was recorded in *Eucalyptus spp.* during pre-monsoon season.

The species × distance interaction showed significant influence having highest pH of 7.19 was found in *Ficus roxburghii* at a distance of >20 m and the lowest of 6.58 was found in *Eucalyptus spp.* at a distance of 0-10 m. The distance × season interaction also found to be significant influence on leaf extract pH of plant species. The highest content of 7.03 at the distance of >20 m in the post-monsoon season and the lowest of 6.63 was recorded at the distance of 0-10 m in the pre-monsoon season. The species x seasons x distance interaction was also found to be statistically significant. *Ficus roxburghii* at a distance >20 m exhibited the highest leaf extract pH of 7.19 during post-monsoon season and the lowest of 6.58 was observed for *Eucalyptus spp.* at 0-10 m distance during the pre-monsoon season. The higher level of pH in leaf extract indicated that the plants were tolerant under polluted conditions.

The variation in leaf extract pH in the selected plant's species along the National Highway could be attributed due to the varied genetic composition of the species. According to Gholami *et al*., (2016) [7] the leaf pH reduces in the presence of acidic pollutant and the reducing rate is more in sensitive plants compared to that intolerant plants.

The leaf extract pH tends to decrease with the increase in pollution for the non-polluted sites (Singare and Talpade, 2013) [29]. This showed that pH followed an exponential decrease with an increase in traffic pollution and drifted towards acidic range (Subramani and Devaanandan, 2015) [31].

Table 7: Seasonal variation in relative water content (%) of plant species growing at different horizontal distances

Plant species	Pre-monsoon				Post-monsoon				Mean			
	Horizontal Distance (m)											
	0-10	10-20	>20	Mean	0-10	10-20	>20	Mean	0-10	10-20	>20	Mean
Eucalyptus spp	81.27	79.99	79.11	80.12	81.30	80.02	79.17	80.16	81.28	80.01	79.14	80.14
Mangifera indica	82.04	79.99	79.16	80.40	82.09	80.01	79.19	80.43	82.06	80.00	79.17	80.41
Grewia optiva	70.49	70.12	70.02	70.21	70.53	70.17	70.08	70.26	70.51	70.14	70.05	70.23
Ficus roxburghii	82.32	81.06	80.78	81.37	82.37	81.09	80.82	81.43	82.34	81.07	80.80	81.40
Morus alba	82.16	80.01	79.74	80.64	82.19	80.07	79.79	80.68	82.17	80.04	79.76	80.66
Mean	79.66	78.23	77.76	78.55	79.70	78.27	77.81	78.60	79.68	78.25	77.78	78.57

Relative Water Content (RWC)

It is evident from the Table 7, that among the selected plant species, *Ficus roxburghii* was noticed to have highest water content of 81.40 per cent and it was significantly different from all other values followed by *Morus alba*, *Mangifera indica*, *Eucalyptus spp.* and *Grewia optiva* with respective values of 80.66, 80.41, 80.14 and 70.23 per cent. The variation in the relative water content of the leaves of selected plant species may be attributed to the genetic variations of the plant species. Further, the variations in RWC of plant species may vary with the pollution status of the area and the tolerance as well as sensitivity of plant species. In the selected plant species season wise RWC ranged from 78.55 to 78.66 per cent (Fig. 2d). The highest (78.66 %) RWC was noticed during post-monsoon season whereas, lowest (78.55%) was observed during pre-monsoon season. The season × species interaction found to be a significant variation in RWC of the plant species. Among the selected species *Ficus roxburghii* was found to be highest RWC (82.37%) during post-monsoon season and lowest (70.02%) was found in *Grewia optiva* in pre-monsoon season.

The species x distance exerted a significant influence on the RWC. Among the selected plant species *Ficus roxburghii* was found to have highest RWC of 82.37 per cent at a distance of 0-10 m and the lowest of 70.02 per cent was recorded in *Grewia optiva* at a distance of >20 m. The season and distance interaction was also found significant influence on the RWC of the plant species. The selected plant species have highest RWC (79.70%) during post-monsoon season at a distance of 0-10 m and the lowest of 77.76 per cent during pre-monsoon season at a distance of >20 m. Further, the species x distance x seasons interaction was found to be statistically significant with respect to RWC in the leaves of selected plant species. The highest (82.37%) RWC was recorded in *Ficus roxburghii* at a distance of 0-10 m in the post-monsoon season. The relative water content of a leaf is the water present in it relative to its full turgidity. Nwadinigwe, (2014) pointed out the variation in the relative water content in plants due to differences in plant species. Plants at the polluted sites absorb more water because of a physiological mechanism of the plants to withstand the effect of pollution in its environment (Tanee *et al*., 2014) [32]. These results are in line with the finding of Pandit *et al*., (2017) [24] who also reported that distance wise species, RWC was 85.80 per cent at 0-10 m and 81.97 per cent at 10-20 m distances.

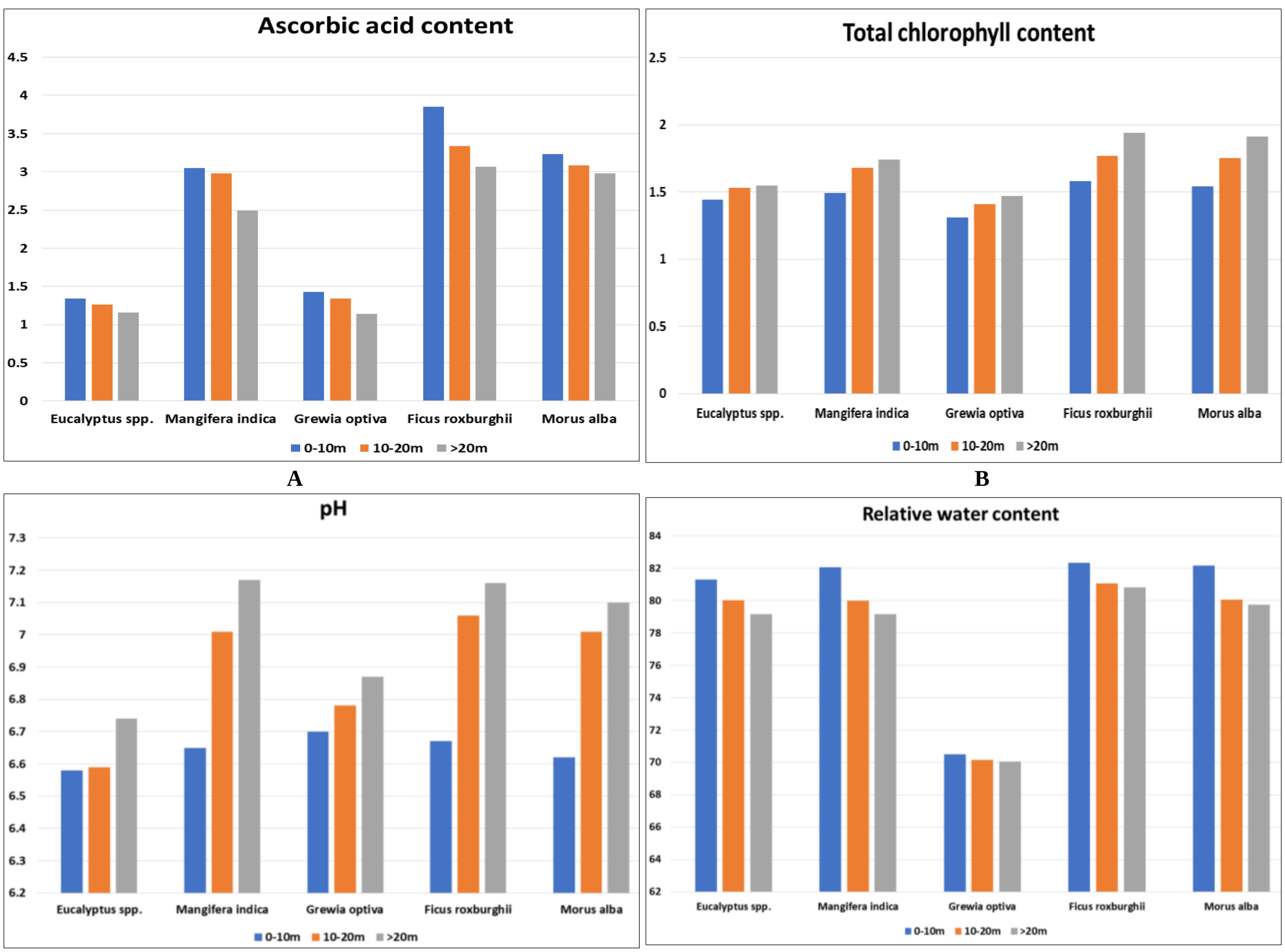

Fig 2: Variation in (a) ascorbic acid content, (b) total chlorophyll content, (c) pH and (d) relative water content of plants at different horizontal distances from the National Highway.

Air pollution tolerance index (APTI)

It is evident from the Table 8 that mean order of tolerance at a horizontal distance of 0-10 m was *Ficus roxburghii* (11.41)> *Morus Alba* (10.87)> *Mangifera indica.* (10.69)> *Eucalyptus spp.* (9.20) and> *Grewia optiva* (8.20). The order of tolerance at a horizontal distance of 10-20 m was *Ficus roxburghii* (11.05)> *Morus Alba* (10.70)>*Mangifera indica* (10.59)> *Eucalyptus spp.* (9.02) > *Grewia optiva* (8.11) whereas, the order of tolerance at a horizontal distance of >20 m was *Ficus roxburghii* (11.05)> *Morus Alba* (10.66)> *Mangifera indica* (10.14)> *Eucalyptus spp.* (8.88) > *Grewia optiva* (7.96). The highest APTI in *Ficus roxburghii* (11.41) at a distance of 0-10 m. These results are in conformity with the findings of Panda and Aggarwal (2018) [22, 23] and Panda *et al*., (2018) [22, 23] who have also reported higher APTI values are associated with higher tolerance of plant species to air pollutants

Table 8: Seasonal variation in APTI of plant species growing at different horizontal distances

Plant species	Pre-monsoon				Post-monsoon				Mean			
	Horizontal Distance (m)											
	0-10	10-20	>20	Mean	0-10	10-20	>20	Mean	0-10	10-20	>20	Mean
Eucalyptus spp	9.18	9.00	8.87	9.02	9.22	9.05	8.90	9.06	9.20	9.02	8.88	9.03
Mangifera indica	10.66	10.58	10.12	10.45	10.72	10.60	10.17	10.50	10.69	10.59	10.14	10.47
Grewia optiva	8.17	8.09	7.93	8.06	8.23	8.13	7.99	8.12	8.20	8.11	7.96	8.09
Ficus roxburghii	11.37	11.02	10.85	11.08	11.45	11.09	10.90	11.16	11.41	11.05	10.87	11.11
Morus alba	10.85	10.66	10.65	10.72	10.90	10.75	10.68	10.78	10.87	10.70	10.66	10.74
Mean	10.05	9.87	9.68	9.87	10.10	9.92	9.73	9.92	10.07	9.89	9.70	9.89

Seasonal variations of the APTI of selected plants alongside the selected sites were found to be significant (Table 8). The data indicated that all the selected plant species exhibited relatively mean higher APTI values of 9.92 in post-monsoon season as compared to pre-monsoon season (9.87).

The higher APTI values during post-monsoon season may be ascribed to the adaptive capacity of plant species to combat stress in this season. Further, such stress conditions have been noticed to enhance ascorbic acid content in the selected plant species during the said season. The air pollution tolerance index of the selected plant species varied with different horizontal distances from the highway. The highest APTI of 10.07 was recorded at a distance of 0-10 m whereas, lowest APTI of 9.70 was recorded at a distance >20 m. The highest APTI of the plants growing at the horizontal Distance of 0-10 m might be attributed to capacity of plants to adapt to stress conditions created by vehicular pollution. These results are in line with the findings of Jyothi and Jaya (2010) [13] who have pointed that higher APTI values are associated with higher tolerance of plant species to air pollutants (Noor *et al*., 2015) [20]. The species x distance x season interaction had a significant effect on the APTI of the selected plant species growing alongside the selected highway (Table 8). *Ficus roxburghii* was found to have the highest APTI of 11.45 at a distance of 0-10 m in the post-monsoon season and the lowest value of 7.93 was recorded in *Grewia optiva* growing at distance >20 m in pre-monsoon, it may be due to its higher capacity to adapt to pollution stress by maintaining high relative water content and synthesizing more ascorbic acid at a distance of 0-10 m during post-monsoon season.

Table 9: Evaluation of plant species based on APTI and some biological and socio-economic characteristics

Plant species	Assessment parameters				Laminar structure				Grade allotted		
	APTI	Plant Habit	Canopy structure	Tree type	Size	Texture	Hardiness	Economic importance	Total plus	% Scoring	API Grade
Eucalyptus spp	+++	++	+	_	+	+	_	+	9	56.25	3
Mangifera. Indica	+++++	++	+	+	++	_	+	++	14	87.50	6
Grewia optiva	+	+	+	_	+	+	+	++	8	50.00	2
Ficus roxburghii	+++++	++	+	_	++	_	+	++	13	81.25	6
Morus alba	+++++	+	++	_	+	_	+	++	12	75.00	5

Anticipated Performance Index (API)

API is used as an indicator to assess the capability of predominant species in the cleanup of atmospheric pollutants. The evaluation and grading of tree species based on their APTI and some biological and socio-economic characters have been presented in Table 9. Among the selected plants, *Ficus roxburghii* and *Mangifera indica* with highest API (6) was excellent grade of plants followed by *Morus alba* (5) very good, *Eucalyptus spp.* (3) moderate and *Grewia optiva* with API of 2 was in poor grade (Table 9). The highest value of API of *Ficus roxburghii* may be due to its high APTI value. Further, the better laminar characteristics like leaf size, texture, canopy structure along with the high economic value might have enhanced its API value towards the excellent. Whereas, the small leaf size, smooth surface of leaf and comparatively less economic importance have perhaps decreased the API value of *Grewia optiva* making it to non-recommended category. These findings are in accordance with Prajapati and Tripathi (2008) [25] who have also reported more value of API for the species with higher APTI having better plant and leaf characteristics.

Table 10: Anticipated performance index (API) of selected plant species

Plant species	Total grade allotted	% scoring	API grade	Assessment
Eucalyptus spp	9	56.25	3	Moderate
Mangifera indica	14	87.50	6	Excellent
Grewia optiva	8	50.00	2	Poor
Ficus roxburghii	13	81.25	6	Excellent
Morus alba	12	75.00	5	Very good

The anticipated performance index of the selected plant species ranged from the very poor category to the excellent category. The excellent (6) API was found in *Mangifera indica* and *Ficus roxburghii* > *Morus alba* (very good-5) > *Eucalyptus spp.* (moderate-3) > *Grewia optiva* (poor-2) (Table 10). The excellent API in *Mangifera indica* and *Ficus roxburghii* may be due to their high values of APTI. API of 6 was for the species (*Ficus roxburghii*) with higher APTI of 11.11 (Table 8) having better plant and leaf characteristics (Prajapati and Tripathi, 2008) [25] hence recommended for greenbelt alongside highways as suggested by Tsega and Devi prasad (2014). Higher values of APTI represent potential of plants species to grow in the polluted areas, which may be act as air pollution sink (Sharma *et al*., 2017) [27]. Hence, the variation in the tolerance of the plants of a region to stress conditions has also been reported by Kapoor and Bhardwaj (2016) [27] and Pandit *et al*. (2017) [24].

Conclusion

The study indicated that the plant growing alongside National Highway varied in their response to vehicular pollution. *Ficus roxburghii* and *Mangifera indica* with high APTI value and high API scores were found to be the most tolerable species in the selected sites. Thus, these plant species can be planted alongside the National Highway for green belt improvement and to withstand the impact of pollution in that area. The study revealed that the combination of APTI and API can be of immense importance for recommending plant species for ecological purposes.

Acknowledgment

The facilities provided by the Professor and Head, Department of Environmental Science, Dr Y S Parmar University of Horticulture & Forestry, Nauni-Solan, India are highly acknowledged.

Conflict of interest

There is no conflict of interest.

References

1. AOAC. Official methods of analysis chemist, 13th ed. (W. Horwitz, ed.) Association of analytical chemists. 1980; 83:617-623.
2. Begum A, Hari krishna S. Evaluation of some tree species to absorb air pollutants in three industrial locations of South Bengaluru, India. Journal of Chemistry. 2010; **7**(1):151-156.
3. Chouhan A, Joshi PC. Effect of ambient air pollution on photosynthetic pigments on some selected trees in urban area. Ecology, Environment and Conservation. 2012; 14:23-27.
4. Cheng FY, Burkey KO, Robinson JM, Booker FL. Leaf extracellular ascorbic in relation to O3 tolerance of two soybean cultivars. Environmental Pollution. 2007; 150:355-362.
5. Dohmen GP, Loppers A, Langebartels C. Biochemical response of Norway spruce towards 14 mo exposure to ozone and acidmist, the effect on an amino acid, glutathione and polyamine titers. Environmental Pollution. 1990; 64:375-383.
6. Flowers MD, Fiscus EL, Burkey KO. Photosynthesis, chlorophyll fluorescence and yield of snap bean (*Phaseolus vulgaris* L.) genotypes differing in sensitivity to ozone. Environmental and Experimental Botany. 2007; 61:190-198.
7. Gholami A, Mojiri A, Amini H. Investigation of the air pollution tolerance index using some plant species in Avhaz region. Journal of Animal and Plant Sciences. 2016; 26(2):475-480.
8. Hamraz HA, Sadeghi-Niaraki, Omati M, Noori N. GIS-based air pollution monitoring using static stations and mobile sensor in Tehran/Iran. International Research Journal of Environmental Science. 2014; 2:435-448.
9. Hasegawa YH, Uchida S, Asada T, Katsube, Oyabu T. Investigation of air pollution purification process by a bioelectrical potential analysis. Proceedings Indoor Air Health Prospect. 2002; 27:139-147.
10. Hiscox JD, Israelstam GF. A method for the extraction of chlorophyll from leaf tissue without maceration. Canadian Journal of Botany. 1979; 57:1332-1334.
11. Hoque MA, Banu MNA, Oluma E. Exogenous proline and glycine betaine increase NaCl-induced ascorbate-glythionecycleenzyme activities and praline improves salt tolerances more than glycine betaine in tobacco bright yellow-2 suspension cultural cells. Journal of Plant Physiology. 2007; 164:1457-1468.
12. Horsman D, Wellburn A. Synergistic effect of SO_2 and NO_2 polluted air upon enzyme activity in pea seedlings. Environment Pollution. 1975; 8:123-133.
13. Jyothi JS, Jaya DS. Evaluation of air pollution tolerance index of selected plant species along roadsides in Thiruvanthapuram, Kerala. Journal of Environmental Biology. 2010; 31:379-386.
14. Kapoor T, Bhardwaj SK. Assessment of air pollution tolerance index of plants growing alongside National Highway (21) of Himachal Pradesh in India. The Eco. 2016; 10(3, 4):419-426.
15. Khureshi SGD. Air pollution tolerance indices (APTI) of some plants around Ponnur, Guntur (Dist.). International Journal of Engineering Research and Technology. 2013; 2:2366-2375.
16. Klumpp G, Furlan CM, Domingos M. Response of stress indicators and growth parameters of Tibuchina Pulchra Cogn exposed to air and soil pollution near the industrial complex of Cubatao, Brazil. Science of the Total Environment. 2000; 246:79-91.
17. Kotecha MK, Naik, Abraham L. Study of the air pollution tolerable index (APTI) and distribution pattern by using importance value index (IVI) of plants in the disturbed and undisturbed locality around Anand city (India). Carpathian Journal of Earth Environmental Science. 2014; 9:163-169.
18. Kuddus M, Kumari R, Ramteke PW. Studies on air pollution tolerance of selected plants in Allahabad city, India. Journal of Environmental Research and Management. 2011; 2(3):42-46.
19. Mondal D, Gupta S, Kumar JD. Anticipated performance index of some tree species considered for green belt development in an urban area. International Research Journal of Plant Science. 2011; 2(4):99-106.
20. Noor MJ, Sultana S, Fatima S, Ahmad M, Zafar M, Sarfraz M, *et al*. Estimation of Anticipated Performance Index and Air Pollution Tolerance Index of vegetation around the marble industrial areas of Potwar region: bioindicators of

plant pollution response. Environmental Geochemistry and Health. 2015; 37(3):441-455.
21. Nwadinigwe AO. Air pollution tolerance indices of some plants around Ama industrial complex in Enugu State, Nigeria. African Journal of Biotechnology. 2014; 13(11):1231-1236.
22. Panda LR, Aggarwal RK. Assessment of Air Pollution Tolerance Index and Anticipated Performance Index of Plants Growing Alongside the Roads in Sub-Temperate Condition of Himachal Pradesh, India. International Journal of Current Microbiology and Applied Sciences. 2018; 7:10.
23. Panda LR, Aggarwal RK, Bhardwaj DR. A review on Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API). Current World Environment. 2018; 13(1):55-65.
24. Pandit J, Sharma AK, Sood A, Bhardwaj SK. Assessment of the air pollution tolerance index and anticipated performance index of commonly growing plant species along the national highway (nh-7) in Nahan to Paonta Sahib stretch in Himachal Pradesh, India. Pollution research. 2017; 36(1):97-103.
25. Prajapati SK, Tripathi BD. Seasonal variation of leaf dust accumulation and pigment content in plant species exposed to urban particulates pollution. Journal of Environmental Quality. 2008; 36:704-705.
26. Rao DN. Plant as a pollution-monitoring device. Fertilizer News. 1979; 24:26-28.
27. Sharma B, Sharma S, Bhardwaj SK, Kaur L, Sharma A. Evaluation of Air Pollution Tolerance Index (APTI) as a tool to monitor pollution and green belt development: A review. Journal of Applied and Natural Science. 2017; 9(3):1637-1643.
28. Simon E, Simini M, DecoTeau DR. Using plants to monitor air pollution: Purdue Univ West Lafayette, India. 2006; 4:70-77.
29. Singare PU, Talpade MS. Physiological responses of some plant species as a bio indicator of roadside automobile pollution stress using the air pollution tolerance index approach. International Journal of Plant Research. 2013; 3(2):9-16.
30. Singh SK, Rao DN. Evaluation of plants for their tolerance to air pollution. In: Proceedings symposium on air pollution control held at New Delhi, 1983, 218-224.
31. Subramani S, Devaanandan S. Application of air pollution tolerance index in assessing the air quality. International Journal of Pharmacy and Pharmaceutical Sciences. 2015; 7(7):216-221.
32. Tanee FBG, Albert E, Amadi BR. Biochemical properties and Air pollution tolerance indices of plants in Port Harcourt city, Nigeria British. Journal of Applied Science and Technology. 2014; 4(34):4835-4845.
33. Vinita P, Tripathi BD, Mishra VK. Evaluation of anticipated performance index of some tree species for green belt development to mitigate traffic generated noise. Urban Forestry Urban Greening. 2011; 10:61-66.
34. Yannawar VB, Bhosle AB. Air pollution tolerance index of various plant species around Nanded city, Maharashtra, India. Journal of Applied Phytotechnology in Environmental Sanitation. 2013; 3(1):23-28.