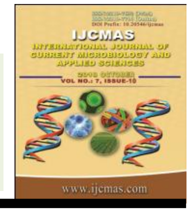
Int.J.Curr.Microbiol.App.Sci (2018) *7*(10): 79-93

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 7 Number 10 (2018)**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2018.710.010

Assessment of Air Pollution Tolerance Index and Anticipated Performance Index of Plants Growing Alongside the Roads in Sub-Temperate Condition of Himachal Pradesh, India

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Keywords

Air pollution tolerance index, Anticipated performance index, Biochemical parameters

Article Info

Accepted:
04 September 2018
Available Online:
10 October 2018

A B S T R A C T

The investigation was carried out during the year 2017-2018 to study the air pollution tolerance index and anticipated performance index of three tree species growing alongside three selected roads in the sub-temperate condition of Himachal Pradesh. The selected tree species were *Toona ciliata*, *Ficus palmata* and *Grewia optiva*. In the selected species chlorophyll content and leaf abstract pH varies from 1.28-2.04 mg g^{-1} and 5.69-6.38, respectively which increased with increasing distance from the highways. Whereas, relative water content and ascorbic acid decreased with increasing distance from the road with respective values of 72.12-63.86 per cent and 2.86-1.87 mg g^{-1}. The trend of APTI of the selected plant species was *Toona ciliata* (9.98) > *Ficus palmata* (8.53) > *Grewia optiva* (6.93). The highest APTI was noticed in post monsoon months followed by pre monsoon months. The assessment of the API with respect to the selected plant species was observed to lie in the range poor to very good. Hence, *Toona ciliata* with higher tolerance and anticipated performance index can be suggested for plantation alongside the State Highways so as to intercept the air pollutants which act as health hazards to the people of the region.

Introduction

Air pollution has turn into an important problem in environmental degradation by increasing the concentration of gases and introducing the suspended particulate matter to the atmosphere. Particulate matter is of great concern in relation to their adverse impact on human health and vegetation (Rai 2013). Air pollution has both direct and indirect impact on animal and plant physiology by disturbing normal respiratory mechanism and changing the morphological and biochemical characteristics (Govindaraju *et al.*, 2010).

As the foliage being continually exposed to the atmosphere, absorb, collect and integrate pollutants impinging on their foliar surface, continually they show visible or stubble changes depending on their sensitivity level. Trees remove air pollutants by three means: assimilation by the leaves, deposition of particulates and aerosols over leaf surface, and fallout of particulates on the leeward side of the foliage (Tewari 2006). As air pollutant once released into the environment cannot be treated or recognized by any device chemically or mechanically, only vegetation can be helpful in adsorbing and metabolizing these released pollutants from the air.

Air pollution tolerance index (APTI) is an distinctive index, which incorporates four biochemical parameters viz. Total chlorophyll, P^H of leaf extract, ascorbic acid and relative water content (RWC) (Shannigrahi *et al.*, 2003). By combining the resultant APTI values with some appropriate biological and socioeconomic characters, the API was calculated for different tree species.

Himachal Pradesh is a hilly state of our country and has achieved significant growth in terms of infrastructure especially roads. The heavy traffic load on the roads has degraded the ecosystem services of the surrounding environment.

Hence the present study can help to screen out the tolerant plant species, which can further help to screen out the tolerant plant species, which can further help in the formation of green belt development in the study area, so as to reduce the impact of air pollution.

Materials and Methods

Site description

The study was conducted in three selected roads geographically located in Solan district which lies between North latitude 30°44’53” to 31°22’01” and East longitude 76°36’10” to 77°15’14” (Figure 1). The Solan is South-West district of Himachal Pradesh bounded by Bilaspur district in North-West, Mandi district in the North, Shimla and Sirmour district in East and South-East, respectively.

The climate of the Solan is characterized as sub-temperate type wherein seasonal variation occurs to a greater extent. In the region May and June are the hottest months, whereas, December and January are the coldest months. The city receives 70 per cent of its water through rainfall during monsoon i.e. June to September. The annual rainfall in and around the State Highway is about 1100 mm with average of 64 rainy days.

Survey of the study area

In order to conduct the study, three roads have been selected. Nauni – Solan State Highway Nauni – Pabiyana State Highway, Kumarhatti – Bhojnagar State Highway. In order to conduct the present study the detailed survey of the three roads was conducted. During the survey the distribution of plant species along both sides of State Highway was recorded and three commonly growing species were identified and selected for the study. The plants selected for the study were *Toona ciliata*, *Ficus palmata* and *Grewea optiva*. In order to maintain uniformity, plants of same age and spread growing at isoecological conditions were selected.

Experimental details

Each selected stretch of the highway was considered as one replication. In order to study the impact of dust and other pollutants generated by vehicular activities on the plants, the horizontal distance of 0-5 m, 5-10 m and 10-15 m were selected from both sides of the road.

The plants growing at selected horizontal distances on both sides of the road at all sites having approximately same size, spread and age were considered to maintain the uniformity. To study the effect of seasons on plant response to pollution two seasons viz. post monsoon (October-November) and pre monsoon (April-May) were considered. Therefore, the study was conducted by taking three plant species, two seasons and three horizontal distances as treatments.

In total there were 18 treatment combinations, which were replicated thrice under RBD factorial. Under each replication three plants of each selected species were taken randomly from both sides of the road at the respective horizontal distances of 0-5 m, 5-10 m and 10-15m.

Collection of samples

In order to study various parameters for calculating the air pollution tolerance index, leaf samples from the selected tree species were collected.

The leaf samples were then transported to the laboratory in ice – box and washed with ordinary water and then with 0.1N HCL followed by washing with distilled water.

Sample analysis

The leaf samples were analysed for total chlorophyll, ascorbic acid, leaf extract pH and relative water content by using following standard procedures.

Relative water content

Relative water content of the samples was estimated using the method proposed by Singh (1991) and was computed by using following equation:

$$Relative\ Water\ Content\ (\%) = \frac{FW - DW}{TW - DW} \times 100$$

Where,

RWC- Relative water content (%) FW- Fresh weight, TW- Turgid weight, DW- Dry weight of leaf samples

Leaf extract pH

Recently matured leaves (5 g) were homogenized in 10 ml deionised water and supernatant obtained after centrifugation was collected for determination of pH by using pH meter (Model- ESICO 1013) with buffer solution of pH 4 and 9 (Barrs and Weatherly, 1962)

Ascorbic acid

The ascorbic acid content was estimated by using A. O. A. C. (1980) method. Fresh leaves (10 g) were homogenized in metaphosphoric acid solution with volume of 100 ml and were titrated against indophenols dye. Appearance of rose pink colour was the end point. The amount of ascorbic acid in milligrams per hundred grams was calculated by using formula:

$$\text{Ascorbic acid (mg g}^{-1}\text{)} = \frac{\text{Dye factor} \times \text{Titre reading} \times \text{Volume made}}{\text{Weight of leaves taken} \times \text{Volume taken for estimation}}$$

Chlorophyll content

The leaf chlorophyll content was estimated by using method given by (Hiscox and Israeistam, 1979). The fresh leaves were chopped to fine pieces under subdued light, 100 mg of chopped leaf samples was placed in vials containing 7 ml of Dimethyl sulphoxide, the vials were incubated at 65°C for half an hour, extract was then transferred to graduated test tube and the final volume was made to 10 ml with Dimethyle sulphoxide.

The O.D. values of the above extract were recorded on Spectrophotometer (Model-Spectronic-20) at 645 and 663 nm wavelength against Dimethyle sulphoxide blank.

The total chlorophyll content was calculated by using formula:

Total chlorophyll (mg g^{-1}) = $\frac{20.2\,A645 + 8.02\,A\,663}{a \times 1000 \times w}$ x 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 645nm, A663 is absorbance at 663nm

Air pollution tolerance index

The air pollution tolerance index (APTI) was estimated by considering four biochemical parameters namely ascorbic acid, total chlorophyll, leaf extract pH and relative water content and was computed by using the following equation given by Singh and Rao (1983).

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

Where, A-ascorbic acid (mg g^{-1} FW), T- total chlorophyll (mg g^{-1} FW), P- leaf extract pH, R- relative water content (%) of the leaves

Anticipated Performance Index (API)

To work out API, socio-economic importance of the plants growing alongside the roads will be studied through field survey and from the available literature. In order to study socio-economic importance characters like plant habit, canopy structure etc will be considered.

By combining the biological and socioeconomic characters (like plant habit, canopy structure, type of plant, laminar structure and economic value) mentioned above and resultant APTI worked out, the API will be calculated for the selected species. Based on these characters certain grades (+ or -) are allotted to plants and plants are scored according to their grades.

Anticipated Performance Index (API) $= \frac{\text{no of "+" obtained}}{\text{Total no of "+"}} \times 100$

Results and Discussion

Biochemical parameters

Leaf relative water content

Relative water content of a leaf is the water present in it relative to its full turgidity. It is related with protoplasmic permeability in cells, which cause loss of water and dissolves nutrients, resulting in early senescence of plant leaves. An important variation in leaf relative water content of selected tree growing at different horizontal distance and season was noticed around the study area. Among all the tree species, the highest relative water content (76.50 per cent) was recorded in *Toona ciliata*, followed by *Ficus palmata* with value of 69.73 per cent and the lowest content of 56.29 per cent was recorded in *Grewia optiva* (Table 1). The difference in the relative water content among the tree species may be due to the dissimilarity in their inherent capacity to tolerate stress condition. The present results are in concord with the study conducted by Dedio (1975). The table 1 revealed that relative water content in the leaves followed a decreasing trend of 72.12 > 66.54 > 63.86 percent with increasing distance of 0-5, 5-10 and 10-15 m in the study area. The results are in agreement with the findings of Rai and Panda (2014) who have previous reported the increase in relative content of leaves of the trees growing adjacent to the road. He further pointed out clogging of stomata of plants alongside roads by pollutants thereby reducing transpiration rate which ultimately increase the relative water content in polluted areas. Similar findings were also reported by Jyothi and Jaya (2010) who pointed out that the trees exposed to air pollution in order to maintain their physiological balance under stress conditions contained higher relative water content in their leaves. The perusal of the data in table 1 revealed that plants growing in study area exhibited highest relative water content of 69.79 percent during post monsoon season, whereas lowest of 65.22 percent was noticed during pre-monsoon season. The increased amount of relative water content during post monsoon season may be attributed to better soil moisture conditions and less evaporation due to relatively low temperature during post monsoon months. In the similar study Jyothi and Jaya (2010) have reported high relative water content during rainy season followed by winter and summer season because of higher availability of water during rainy days (Fig. 2–4).

Leaf extracts pH

The plant species growing in study area exhibited statistically significant variation in the leaf extract pH. The range of the leaf extract pH among selected plant species was from 6.16 to 6.57 (Table 2). The highest leaf extract pH of 6.57 was recorded in *Toona ciliata* whereas, lowest leaf extracts pH was noticed in *Grewia optiva* (6.16). The present results are in congruence with Tiwari and Tiwari (2006) and Gholami *et al.,* (2016) who reported that leaf pH is reduced in the presence of acidic pollutant and the reducing rate is more in sensitive plants compared to that in tolerant plants. 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. The table 2 showed that pH increased with an increase in horizontal distance which was recorded highest of 6.38 at the distance of 10-15 m from the roadside. Whereas, lowest leaf extract pH of 5.69 was recorded at a distance of 0-5 m from the roadside. The lowest value of pH in case of plants growing near the study area may be attributed to high level of vehicular pollution. These results are in similar line with findings of Ramakrishnaiah and Somashekhar (2003) and Subramani and Devanandan (2015) who reported that pH followed an exponential decrease with increase in traffic pollution and drifted towards acidic range. Seasons were also found to influence the leaf extract pH of the selected plant species in the present study (Table 2). The highest leaf extract pH was recorded during post monsoon months (6.49) whereas; lowest pH of 5.98 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. This is in accordance with the study conducted by Jyothi and Jaya (2010) who reported higher pH during post monsoon season due to the washing of acidic pollutants by rain. The species x season interaction had significant influence on the leaf extract pH of trees. The highest value of 6.63 was recorded in *Toona ciliata* during post monsoon season and lowest 5.46 was observed in *Ficus palmata* during pre-monsoon. The interaction between species and distance showed significant influence having highest value of 6.57 was found in *Toona ciliata* at a distance of 10-15 m and the lowest (5.90) was observed in *Ficus palmata* at a distance of 0-5 m. The horizontal distance and season interaction also resulted in significant influence on leaf extract pH of plant species. The highest content of 6.49 was found in plants growing at the distance of 10-15 m in the post monsoon season and the lowest (5.33) was recorded in the plants growing at the distance of 0-5 m in the pre-monsoon season. The species x seasons x distance interaction was also statistically significant. *Toona ciliata* found growing at the control site (10-15m) exhibited the highest leaf extract pH value of 6.63 during post monsoon. The lowest (5.46) value was observed for *Ficus palmata* at 0-5 m distance during the pre-monsoon months.

Ascorbic acid content

The selected plant species in the study area varied significantly in their ascorbic acid content (Table 3). Among the three selected plant species, highest ascorbic acid was recorded in *Toona ciliate* (2.90 mg g^{-1}) and lowest was recorded in *Grewia optiva* (1.67 mg g^{-1}). The order of ascorbic acid content in the leaves of selected species was *Toona ciliata* (2.90 mg g^{-1}) > Ficus palmate (2.26 mg g^{-1}) *Grewia optiva* (1.67 mg g^{-1}). The variation in the ascorbic acid content may be due to their inherent capacity to tolerate stress conditions. The increase in leaf ascorbic acid may also be due to improvement in the defence mechanism of the plants which has been reported to be different for each plant species by Cheng *et al.,* (2007). The higher amount of ascorbic acid in the leaves of *Toona ciliata* can be due to its higher adaptive ability to tolerate pollution and other stress conditions as compared to other species. This is in agreement with the Zhang *et al.,* (2011) who recorded higher adaptive phenotypic variation or stress-tolerance ability of conifer species. The leaf ascorbic concentration of the selected plant species growing at different State Highways also varied significantly with seasons having highest amount of leaf ascorbic acid content (2.32 mg g^{-1}) during post monsoon months whereas, lowest amount of ascorbic acid (2.24 mg g^{-1}) was noticed during pre-monsoon months. The increase in leaf ascorbic acid content during post monsoon months may probably be due to more production of antioxidants (ascorbic acid) under stress conditions. The higher ascorbic acid content in the post monsoon season may be also 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) who pointed out that plants under stress improve in their ascorbic acid content to fight adverse conditions.

A significant variation was noticed in the leaf ascorbic acid content of selected plant species growing at different horizontal distances (Table 3). The plants growing at distance of 0-5m recorded the highest leaf ascorbic acid content (2.86 mg g^{-1}) which was found to decrease with increasing distance along the road. The higher pollution adjacent to the road might have hastened the synthesis of this biomolecule in the plants as a part of their defence mechanism. The results are in accordance with the findings of Yannawar and Bhosle (2013) who have also reported higher ascorbic acid content in the leaves of the plants growing near the roadside. The results are also in conformity with Conklin (2001) who advocated that higher ascorbic acid content of the plant is a sign of its tolerance against pollution.

The interaction between species and seasons was also found to statistically significant. The leaves of *Toona ciliata* were found to contain highest ascorbic content of 3.02 mg g^{-1} during post monsoon season. Whereas the lowest content of 1.63 mg g^{-1} was noticed in *Grewia optiva* during post monsoon. A significant influence of distance and season's interaction on the ascorbic acid content of the plant species was notice alongside the road. The highest ascorbic content of 2.87 mg g^{-1} was recorded in the plants growing near the selected State Highways at a distance of 0-5 m in the post monsoon, followed by those growing at 5-10 and 10-15 m distance in the pre-monsoon season with respective values 2.01 and 1.85 mg g^{-1}.

The species x seasons x distance interaction was statistically significant with respect to the ascorbic acid content of selected plant species. The leaves of *Toona ciliata* were found to have the highest ascorbic content of 4.12 mg g^{-1} at a distance of 0-5m during post monsoon. The lowest content of 1.44 mg g^{-1} was recorded in the leaves of *Grewia optiva* at the control site during post monsoon season. The interactive effect of the genetic variation, dust accumulation and the leaf extract pH might have affected the ascorbic acid content in *Toona ciliata* at 0-15m during post monsoon season.

Total chlorophyll content

Among the three plant species, *Toona ciliata* was noticed to have highest chlorophyll content of 1.86 mg g^{-1} in their leaves and it was significantly different from all other values (Table 4). This was followed by *Ficus palmata*, *Grewia optiva*, with respective values of 1.70, 1.41 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 leaf chlorophyll content of plant species may vary with the pollution status of the area as well as the tolerance and sensitivity of the plant species. These results are in line with the findings of Mir *et al.,* (2008) and Chandawat *et al.,* (2011) who reported that leaf chlorophyll content varied with tolerance as well as the sensitivity of the plant species to the pollution load of the road.

The results are also supported by findings of Begum and Harikrishna (2010) 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. Variation in chlorophyll content among the tree species in the study area may be owing to species tolerant nature, age genetic makeup and other environmental circumstances in addition to pollution effect as also reported by Kumar and Nandini (2013).

Table.1 Seasonal variation in relative water content (per cent) of plant species growing at different horizontal distances

Species	Pre monsoon				Post monsoon				Mean			
	Horizontal Distance (metre)											
	0-5	5-10	10-15	Mean	0-5	5-10	10-15	Mean	0-5	5-10	10-15	Mean
Toona ciliate	79.39	73.42	69.36	74.06	83.41	78.25	75.19	78.95	81.40	75.84	72.28	76.50
Ficus palmate	72.32	66.58	64.67	67.85	75.07	71.25	68.49	71.61	73.70	68.92	66.58	69.73
Grewia optiva	59.24	52.37	49.64	53.75	63.27	57.37	55.83	58.82	61.26	54.87	52.74	56.29
Mean	70.31	64.12	61.22	65.22	73.92	68.96	66.50	69.79	72.12	66.54	63.86	67.51

CD(0.05)			
Species	0.40	Species x Season	0.56
Season	0.33	Species x Distance	0.69
Distance	0.40	Season x Distance	0.56
Species x Season x Distance NS			

Table.2 Seasonal variation in leaf extract pH of plant species growing at Different horizontal distance

Species	Pre monsoon				Post monsoon				Mean			
	Horizontal Distance (metre)											
	0-5	5-10	10-15	Mean	0-5	5-10	10-15	Mean	0-5	5-10	10-15	Mean
Toona ciliata	6.24	6.38	6.48	6.37	6.60	6.63	6.66	6.63	6.42	6.50	6.57	6.50
Ficus palmata	4.54	5.83	6.01	5.46	4.94	6.11	6.38	5.81	4.74	5.97	6.19	5.64
Grewia optiva	5.83	6.14	6.33	6.10	5.97	6.27	6.42	6.22	5.90	6.21	6.38	6.16
Mean	5.53	6.12	6.27	5.98	5.84	6.34	6.49	6.22	5.69	6.23	6.38	6.10

CD(0.05)			
Species	0.02	**Species x Season**	0.03
Season	0.02	**Species x Distance**	0.04
Distance	0.02	**Season x Distance**	0.03
Species x Season x Distance 0.06			

Table.3 Seasonal variation in ascorbic acid (mg g^{-1}) of plant species growing at different horizontal distances

Species	Pre monsoon				Post monsoon				Mean			
	Horizontal distance (metre)											
	0-5	5-10	10-15	Mean	0-5	5-10	10-15	Mean	0-5	5-10	10-15	Mean
Toona ciliata	3.96	2.28	2.13	2.79	4.12	2.63	2.29	3.02	4.04	2.46	2.21	2.90
Ficus palmata	2.66	2.01	1.95	2.21	2.71	2.25	1.96	2.31	2.68	2.13	1.96	2.26
Grewia optiva	1.94	1.73	1.46	1.71	1.78	1.68	1.44	1.63	1.86	1.70	1.45	1.67
Mean	2.85	2.01	1.85	2.24	2.87	2.19	1.90	2.32	2.86	2.10	1.87	2.28

CD(0.05)			
Species	0.02	**Species x Season**	0.03
Season	0.02	**Species x Distance**	0.03
Distance	0.02	**Season x Distance**	0.03
Species x Season x Distance 0.04			

Table.4 Seasonal variation in leaf chlorophyll content (mg g^{-1}) of plant species growing at different horizontal distance

Species	Pre monsoon				Post monsoon				Mean			
	Horizontal distance (meter)											
	0-5	5-10	10-15	Mean	0-5	5-10	10-15	Mean	0-5	5-10	10-15	Mean
Toona ciliata	1.35	1.78	1.96	1.69	1.83	1.96	2.31	2.03	1.59	1.87	2.13	1.86
Ficus palmata	0.85	1.23	1.78	1.28	1.06	1.59	1.95	1.53	0.95	1.41	1.86	1.41
Grewia optiva	1.15	1.72	2.16	1.68	1.45	1.66	2.07	1.73	1.30	1.69	2.12	1.70
Mean	1.12	1.58	1.96	1.55	1.44	1.74	2.11	1.76	1.28	1.66	2.04	1.66
CD(0.05)												
Species	0.02	Species x Season	0.03									
Season	0.02	Species x Distance	0.03									
Distance	0.02	Season x Distance	0.03									
Species x Season x Distance 0.05												

Table.5 Seasonal variation in APTI of plant species growing at different horizontal distances

Species	Pre monsoon				Post monsoon				Mean			
	Horizontal distance (metre)											
	0-5	5-10	10-15	Mean	0-5	5-10	10-15	Mean	0-5	5-10	10-15	Mean
Toona ciliata	10.94	9.20	8.73	9.62	11.40	10.06	9.55	10.34	11.17	9.63	9.14	9.98
Ficus palmata	8.66	8.08	7.99	8.24	9.13	8.86	8.48	8.82	8.90	8.47	8.24	8.53
Grewia optiva	7.27	6.59	6.20	6.69	7.64	7.07	6.80	7.17	7.46	6.83	6.50	6.93
Mean	8.96	7.96	7.64	8.19	9.39	8.66	8.28	8.78	9.18	8.31	7.96	8.48
CD(0.05)												
Species	0.05	Species x Season	0.06									
Season	0.04	Species x Distance	0.08									
Distance	0.05	Season x Distance	0.06									
Species x Season x Distance 0.11												

Table.6 Evaluation of plant species on the basis of APTI value and some biological and socio-economic characteristics

Plant species	APTI	TREE HABIT	CANOPY STUCTURE	TREE TYPE	SIZE	TEXTURE	HARDINESS	ECONOMIC IMPORTANC	TOTAL PLUS	% SCORING	API GRADE
Toona ciliata	+++++	++	+	-	++	+	-	+	12	75.00	5
Ficus palmata	+++	-	+	-	+	+	-	+	7	43.75	2
Grewia optiva	+	+	+	-	+	+	+	++	8	50	2

Table.7 Anticipated performance index (API) of selected plant species

Sr. No.	Plant species	Total grade allotted	% Score	API Grade	Assessment
1.	*Toona ciliata*	12	75.00	5	Very good
2.	*Ficus palmata*	7	43.75	2	Poor
3.	*Grewia optiva*	8	50	2	Poor

Fig.1 Map showing the study area

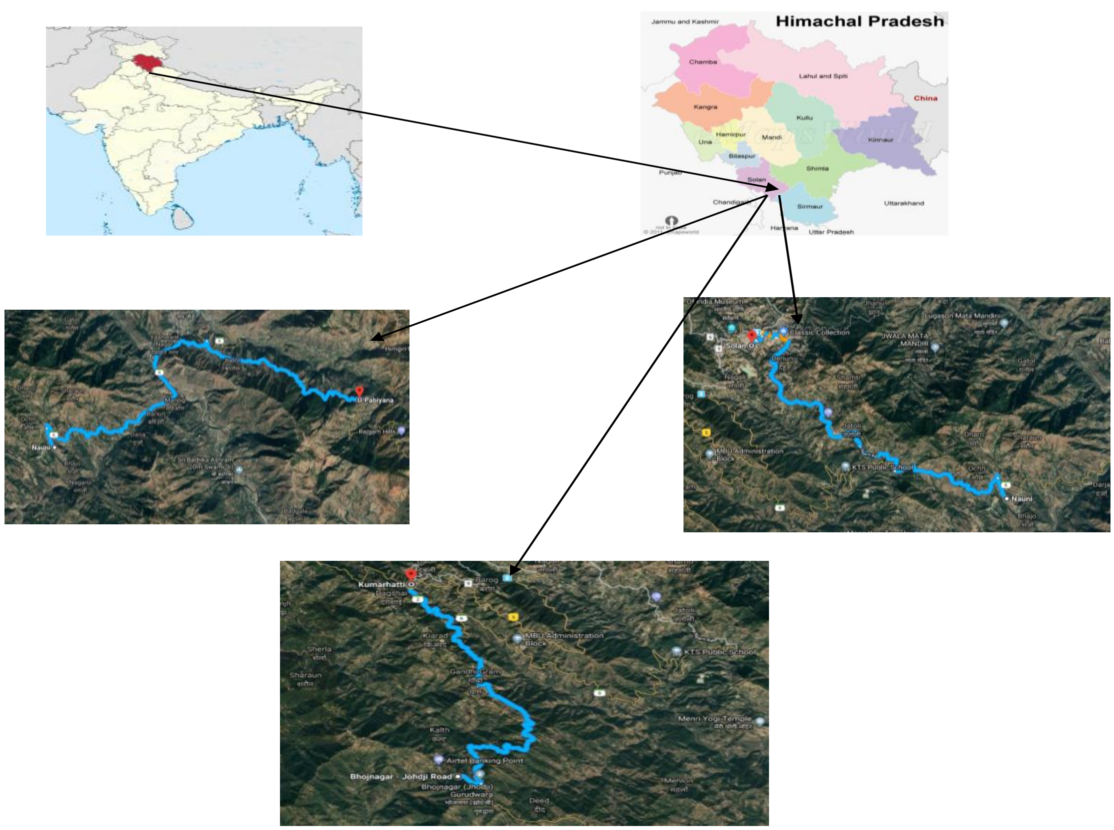

Fig.2 *Toona ciliate*

Fig.3 *Ficus palmate*

Fig.4 *Grewia optiva*

In the selected plant species season wise leaf chlorophyll content ranged from 1.76 to 1.55 mg g^{-1}. The highest leaf chlorophyll content was noticed during post monsoon whereas, lowest 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).

The season × species interaction exerted a significant variation in leaf chlorophyll content of the plant species of the studied area (Table 4). Among the selected species *Toona ciliata* was found to register highest leaf chlorophyll content (2.03 mg g^{-1}) during post monsoon season and lowest leaf chlorophyll content was noticed in *Ficus palmata* (1.28 mg g^{-1}) in pre monsoon season.

The species x distance exerted a significant influence on the leaf chlorophyll content. Among the selected plant species *Toona ciliata* was found to register highest leaf chlorophyll content (2.13) at a distance of 10-15 m. The lowest chlorophyll content of 1.30 mg g^{-1} was recorded in the leaves of *Grewia optiva* at a distance of 0-5 m. The season and distance interaction was also found significant influence on the chlorophyll content of the plant species. Among the species having highest leaf chlorophyll content (2.11 mg g^{-1}) during post monsoon season and the lowest 1.12 mg g^{-1} during pre-monsoon at the distance of 0-5 m.

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 (Table 4). The highest (2.31 mg g^{-1}) value was recorded in *Toona ciliata* at a distance of 10-15m, in the post monsoon season. This may be attributed to relatively less stress conditions during the post monsoon and at control site 10-15m. The lowest value of 0.85 mg g^{-1} was recorded in *Ficus palmata* at 0-5 m distance in pre monsoon.

Air pollution tolerance index (APTI)

The selected tree species growing at different horizontal distances alongside the road were found to have significant variations in the air pollution tolerance index (Table 5). The maximum APTI of 9.98 was recorded in *Toona ciliata* among the selected plant species whereas; minimum of 6.93 was noticed in *Grewia optiva*. The trend of APTI of the selected plant species was *Toona ciliate* (9.98) > *Ficus palmate (8.53)* > *Grewia* *optiva* (6.93). The data, therefore, indicated that there is a variation in the tolerance level of the selected plant species commonly growing along the selected State Highways. The variation in the tolerance of the plants of a region to air pollution has also been reported by Lakshmi *et al.*, (2008), Agbaire and Esiefarienrhe (2009), Chauhan (2010), Begum and Harikrishna (2010). The higher APTI of *Toona ciliata* may be attributed to its higher tendency to synthesize ascorbic acid and maintain relative water content during stress conditions created by the vehicular pollution. The present results are in accordance with the Mohammed Kuddus *et al.,* (2011) who recorded higher leaf ascorbic acid and relative water content in plant species with high APTI.

Seasonal variations of the air pollution tolerance index of selected plants alongside the selected State Highways were found to be significant (Table 5). The data indicated that all the selected plant species exhibited relatively higher APTI values (8.78) in post monsoon season as compared to pre monsoon months (8.19). The higher APTI values during post monsoon season may be attributed 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 State Highway. The highest APTI of 9.18 was recorded at a distance of 0-5 m whereas, lowest APTI of 7.96 was recorded at a distance of 10-15 m. The highest APTI of the plants growing at the horizontal distance of 0-5 m may be attributed to capacity of plants to adapt to stress conditions created by vehicular pollution. These results are in corroboration with the findings of Jyothi and Jaya (2010) who have pointed that higher APTI values are associated with higher tolerance of plant species to air pollutants (Noor *et al.,* 2015).

The species x distance x season interaction had a significant effect on the APTI of the selected plant species growing alongside the selected State Highways (Table 6). *Toona ciliata* was found to have the highest APTI of 11.40 at a distance of 0-5m in the post monsoon season. The lowest value of 6.20 was recorded in *Grewia optiva* growing at control site in pre monsoon 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 0-5 m during post monsoon.

Among the selected plants, *Toona ciliate* with highest API grade (5) was in Very good of plants followed by *Ficus palmata and Griwea optiva* with API grade (2) was in Poor (Table 7). The highest value of API of *Toona ciliata* may be due to its high APTI. 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 very good. 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 fall in not recommended category. These findings are in accordance with Prajapati and Tripathi (2008) who have also reported more value of API for the species with higher APTI having better plant and leaf characteristics.

The study inferred that the tree species growing alongside the State Highways varied in their response to the vehicular and dust pollution. The vehicular emissions have started impacting the biochemical, physiological and tolerance characteristics of the selected tree species. The commonly growing tree species around the study areas varied in their tolerance level. The high air pollution tolerance index of tree species was recorded in *Toona ciliate* with mean value of 9.98. In the region *Toona ciliata* was noticed to have best anticipated performance index and emerged as the tolerant species since found to accumulate higher ascorbic acid (2.90 mg g^{-1}) and relative water content (76.50 per cent) which are the factors of higher tolerance and *Grewia optiva* as the sensitive species with poor anticipated performance index. Therefore, for the green belt development, *Toona ciliata* can be suggested for plantations alongside the selected state highways.

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How to cite this article:

Lakshmikanta Panda, L.R. and Aggarwal, R.K. 2018. Assessment of Air Pollution Tolerance Index and Anticipated Performance Index of Plants Growing Alongside the Roads in Sub-Temperate Condition of Himachal Pradesh, India. *Int.J.Curr.Microbiol.App.Sci.* 7(10): 79-93.
doi: https://doi.org/10.20546/ijcmas.2018.710.010