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Performance evaluation of selected tree species growing alongside state highway, Himachal Pradesh, India

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Abstract
The response of plants to air pollution at physiological and biochemical levels can be understood by analyzing the factors that determine resistance and susceptibility. Thus field study helped in understanding the seasonal variation in the biochemical parameters and evaluating the performance of the common tree species growing around the Nauni-Solan State Highway of Himachal Pradesh. The assessment of the API with respect to the selected plant species was observed to lie in the range poor to excellent. Among the selected species the order of API was: *Toona ciliata* >*Pinus roxburghii* = *Pistacia integerrima* > *celtis australis* = *Jacaranda mimosifolia* = *Grewia optiva.* However, certain plants like *Toona ciliata* have shown their adaptability to the stress caused by the pollution. Hence, *Toona cliata* with higher tolerance and anticipated performance index can be suggested for plantations alongside the State Highway so as to intercept the air pollutants which are hazardous to human and other living organisms.

Keywords: APTI, biochemical parameters, chlorophyll content, leaf abstract pH, relative water content, ascorbic acid content, API

Introduction
Plants are essential component of all the ecosystems which are most likely to be affected by air pollution. The leaves, abundant and primary receptors of the air pollutants, are more evidently affected by the global menace. Plants have been categorized based on their level of tolerance towards air pollutants. These levels of tolerance vary from species to species, depending on the ability of plants to withstand the effect of pollutants by simply impeding few of their physiological processes. The response of plants to air pollution at physiological and biochemical levels can be understood by analyzing the factors that determine resistance and susceptibility. Over the years there has been great development on and alongside State Highways due to indiscriminate migration of people from villages to near and alongside State highways for the better living conditions. Due to these human activities atmosphere around the Highways had changed considerably. Roadside vegetation can directly and indirectly affect local and regional air quality by altering the surrounding atmosphere.

Trees eliminate gaseous air pollutants by leaf stomata and other particles by interception. Thus, biomonitoring of plants plays an important role in evaluating the impact of air pollution. By analyzing morphological, physiological, and biochemical parameters, an early diagnosis of air quality may be evaluated and eco-sustainable mitigation approaches or options may be investigated (Panda and Rai 2015) [2]. Ascorbic acid is an antioxidant, which contributes in protecting the plants against oxidative damage resulting from aerobic metabolism, photo-synthesis and a range of pollutants. The water content of the plant tissues helps to maintain the physiological balance of the plant when subjected to the stress of air pollution. Hence, the water content is related to the degree of pollution. The pH of the plant tissue is also related to the degree of air pollution since air pollutants interact with rainwater to form mixtures and solutions with pH, depending on the type of pollutant. Chlorophyll is involving in the productivity of the plants and its level is a direct measure of leaf damage by pollution. Its measurement is an important tool for evaluating the effects of air pollutants on plants since it plays an essential role in plant metabolism and any reduction in chlorophyll content corresponds directly to plant growth (Aji *et al.* 2015) [3].

Air Pollution Tolerance Index (APTI) is an index which denotes capability of a plant to adapt air pollution. It is a unique index that helps in determining the tolerance or sensitivity of a plant towards air pollution. Higher ascorbic acid content of leaves might be an effective strategy to protect thylakoid membranes from oxidative damage under such stresses including pollution (Tambussi *et al.* 2000) [4], as ascorbic acid is critically involved in the defense against ROS produced by the photosynthetic apparatus (Smirnoff 1996). Anticipated Performance Index (API) is an index that determine relative performance of a plant against air pollution. Apart from the biochemical parameters biological characters of a plant also influence the performance of the plant towards varying environment. Thus on the basis of resultant APTI and some relevant biological and socioeconomic characters, the anticipated performance index (API) of various plant species can be determined for green belt development. These studies provided valuable information for landscapers and greenbelt designers to select the sensitive as well as tolerant varieties of plant species for using them to identify the pollution loads of State Highways and also to use the tolerant varieties for

curbing the menace of air pollution.

Materials and method

The study was conducted in Solan, one of the South west district of the Himachal Pradesh having geographical area of 1,936 sq km. It is nestled on the lap of the Shiwalik Ranges at an elevation of 1580 m. In order to conduct the study, a preliminary survey in the State Highway from Nauni to Solan was done. Based on the survey a stretch of 15km from Nauni to Solan was selected. In the selected stretch of the highway vegetation distribution was studied by using quadrat method. The commonly occurring six plant species namely *Toona ciliata, Pinus roxburghii, Grewia optiva, Celtis australis, Jacaranda mimosifolia and Pistacia integerrima* were selected for the study. To meet the objective of the study the 15 km stretch of State Highway from Nauni to Solan was divided into three equal parts of five kilometres each. 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 and 5-10m were selected from both sides of the road. The plants growing at selected horizontal distances on both sides of the road at isoecological 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 sesaons viz post-monsoon (October-November) and pre-monsoon (April-May) were considered.

Collection of samples

In order to study various parameters for calculating the air pollution tolerance index leaf samples from the selected plant species were collected as per the standard procedure. 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.

Biochemical analysis

Fully matured leaves from plants were collected in morning hours at diameter breast height (DBH) of almost same height and care was taken so that the samples from study site were collected from plants growing in isoecological conditions. Fresh leaves were taken to the laboratory in ice box and were analyzed for total chlorophyll, ascorbic acid, leaf extract pH and relative water content.

Chlorophyll content

The leaf chlorophyll content was estimated by using method given by Hiscox and Israeistam (1979). The O.D. values of the extract made were recorded on Spectrophotometer (Model-Spectronic-20) at 645 and 663 nm wavelength against Dimethyle sulphoxide blank.

Ascorbic acid content

The ascorbic acid content was estimated by using A. O. A. C. (1980) method.

Leaf extracts pH

Recently matured leaves (5 g) were homogenized in 10 ml deionised water and supernatant obtained after centrifugation was collected for determination of pH. The leaf extract pH was estimated by using pH meter of Model- ESICO 1013 by standardising with buffer solution of pH 4 and 9.

Relative water content

The relative water content was estimated by using the method prescribed by Turner (1981). After taking fresh leaf weight the leaves were immersed in water over night, blotted dry and then weighed to get turgid weight. The leaves were then dried over night in an oven at 70°C and reweighed to obtain the dry weight

Air pollution tolerance index (APTI)

By using the parameters like chlorophyll content, leaf pH extract, relative water content and ascorbic acid content, the air pollution tolerance index was computed by the method suggested by Singh and Rao (1983) using the following equation:

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

Anticipated Performance Index (API)

By combining the resultant APTI values with some relevant biological and socio-economic characters (plant habit, canopy structure, type of plant, laminar structure and economic value), the API was calculated for different plant species. Based on these characters, different grades (+ or -) were allotted to plants. Different plants are scored according to their grades. Gradation of plant species on the basis of APTI and other biological and socio-economic characters are given in table 2.Socio-economic importance of the selected plant species was studied from the available literature and also by gathering information from the local people and subject experts.

Table 1: Rating used for anticipated performance index of plant species

Grade	Score	Assessment category
0	Up to 30	Not recommendation for plantation
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

Table 2: Gradation of plant species on the basis of air pollution tolerance index (APTI) and other biological and socioeconomic characters.

Grading character	Pattern of assessment	Grade allotted*
Air pollution tolerance index (APTI)	6.0-7.0	+
	7.0-8. 0	++
	8.0-9.0	+++
	9.0-10.0	++++
	10.0 - 11.0	+++++
(b) Tree habit	Small	-
	Medium	+
	Large	++
(c) Canopy structure	Sparse/Irregular/Globular	-
	Spreading	+
	crown/open/semi dense Spreading dense	++
(d) Type of tree	Deciduous	-
	Evergreen	+
(e) Laminar Characters (i) Size	Small	-
	Medium	+
	Large	++
(ii) Texture	Smooth	-
	Coriaceous	+
(f) Hardiness	Delineate	-
	Hardy	+
(g) Economic value	Less than three uses	-
	Three of four used	+
	Five or more used	++

*Maximum score that can be attained: 16

Statistical Analysis

Seasonal variation of different biochemical parameters and their significance level were computed using Analysis of Variance Technique (Three-factor analysis).The significance of the analysed data was tabled at 5% level of significance.

Results and discussion

Biochemical Parameters

Chlorophyll content: Chlorophyll content of plant signifies its photosynthetic activity as well as the growth and development of biomass. The selected plant species growing alongside the State Highway were found to exhibit significant seasonal variation in their leaf chlorophyll content (Figure 1). The leaf chlorophyll content of the selected plant species varies from 0.56-2.26 mg $g^{-1.}$ The variation in the leaf chlorophyll content of the leaves of selected plant species may be due to their inherent capacity to tolerate the pollution stress along roadside. The genetic variation in the tolerance of biotic and abiotic stress conditions has also been reported by Katiyar and Dubey (2001) [9].

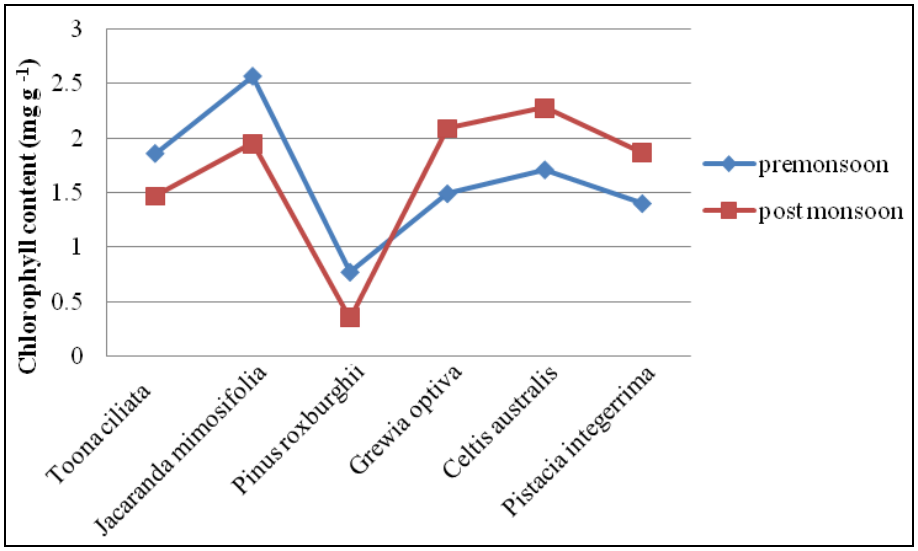

Fig 1: Seasonal variation of leaf chlorophyll content (mg g^{-1}) in different selected species of the Nauni-Solan State Highway

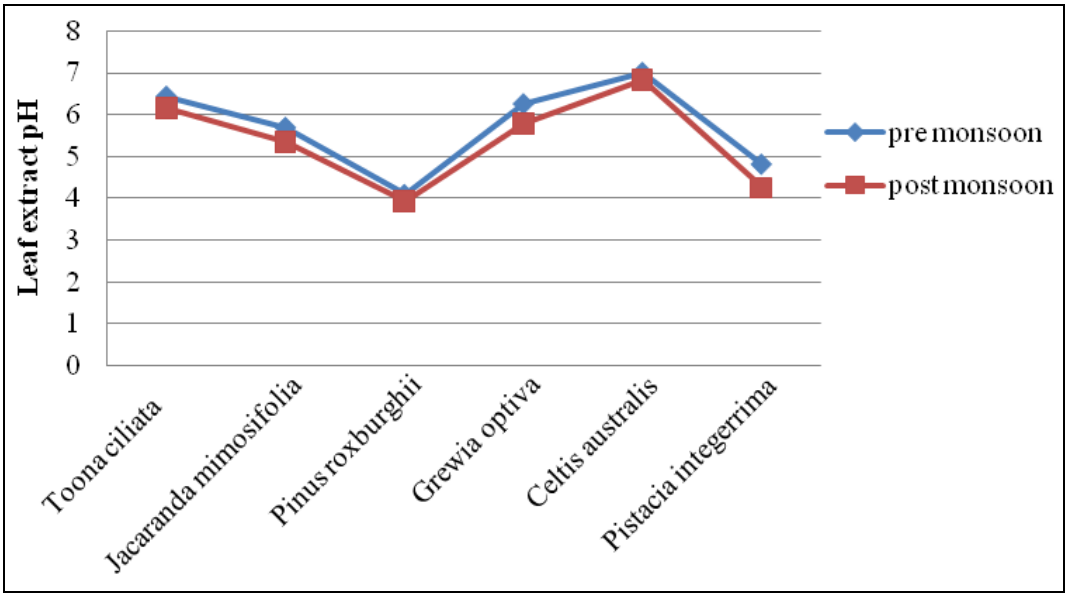

Fig 2: Seasonal variation of leaf extract pH of selected plant species growing alongside the Nauni-Solan State Highway

Leaf extract: The range of the leaf extract pH among selected plant species was from 3.99 to 6.93. Maximum leaf extract pH of 6.93 was recorded in *Celtis australis*, whereas, minimum was noticed in *Pinus roxburghii* (3.99). This can be attributed to the varied genetic composition of the selected plant species. The range of leaf extract pH in selected plant species was in accordance with the results of Kaler (2012) [8] who reported the same range of leaf extract pH in case of *Grewia optiva.*

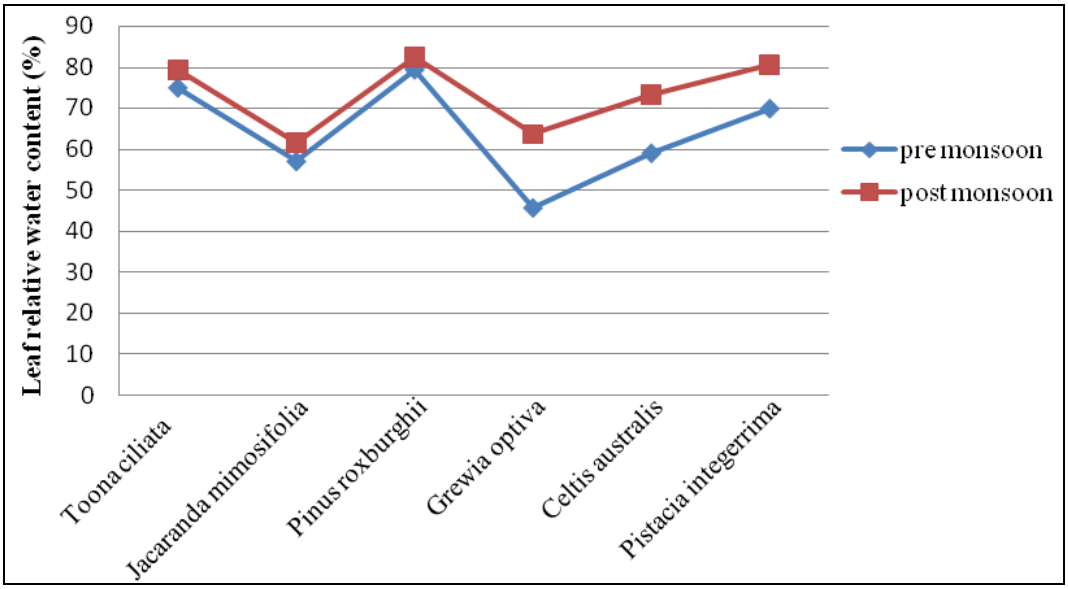

Fig 3: Seasonal variation in leaf Relative water content of selected plant species growing alongside Nauni -Solan State Highway

Relative water content: Relative water content of a leaf is the water present in it relative to its full turgidity. Relative water content is associated with protoplasmic permeability in cells causes loss of water and dissolve nutrients, resulting in early senescence of leaves. Irrespective of season and horizontal distance table 3 shows a significant variation in the relative water content among the selected species that varies from 80.87-54.72%. Among the six plant species studied maximum leaf relative water content was registered in *Pinus roxburghii* (80.87%) and minimum was recorded in *Grewia optiva* (54.72%)

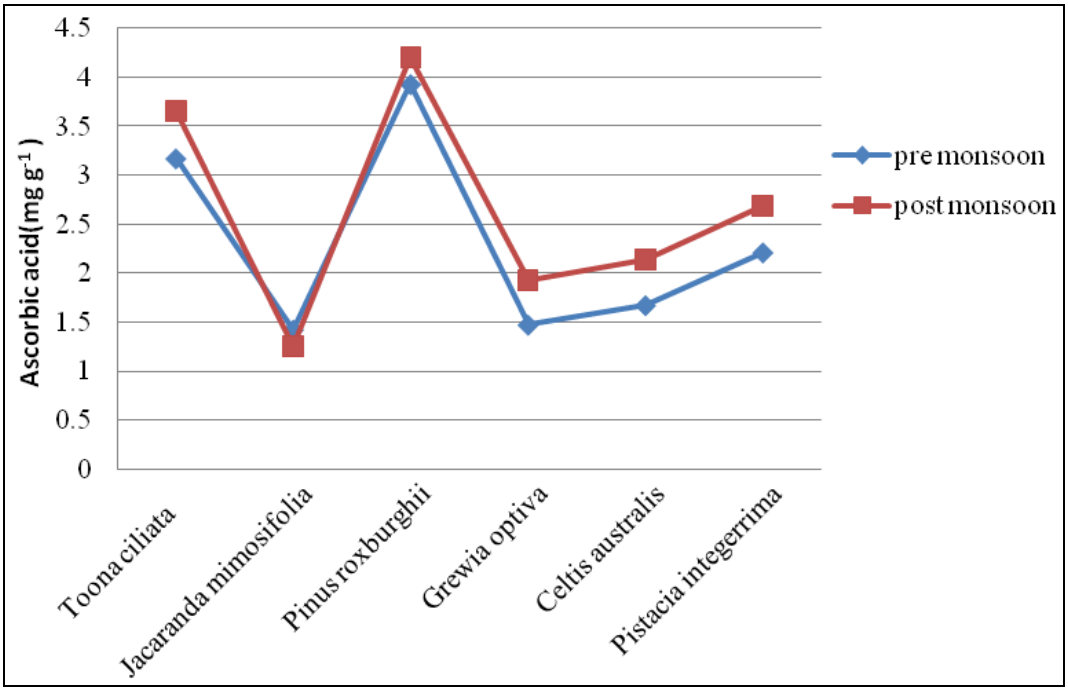

Fig 4: Seasonal variation in Ascorbic acid (mg g $^{-1}$) of selected species growing alongside Nauni-Solan State Highway.

Ascorbic acid is natural antioxidant which maintains stability of the plant cell membranes during pollution stress and scavenges cytotoxic free radicals. The selected plant species of the Nauni-Solan State Highway varied significantly in their ascorbic acid content that ranged from 1.33-4.06 mg g^{-1}(Table3). Among the six plant species selected maximum ascorbic acid was recorded in *Pinus roxburghii* (4.06 mg g^{-1}) and minimum was recorded in *Jacaranda mimosifolia* (1.33 mg g^{-1}).

Table 3: Variations in the biochemical parameters and APTI values of selected plant species

Plant Samples	Biochemical Parameters				
	Chlorophyll (mg g^{-1})	Leaf extracts pH	Relative water content (%)	Ascorbic acid content(mg g^{-1})	APTI
Toona ciliata	1.66	6.30	77.08	3.41	10.40
Jacaranda mimosifolia	2.26	5.52	59.34	1.33	6.97
Pinus roxburghii	0.56	3.99	80.87	4.06	9.92
Grewia optiva	1.79	6.02	54.72	1.70	6.79
Celtis australis	1.99	6.93	66.14	1.91	8.31
Pistacia integerrima	1.64	4.52	75.17	2.44	9.01

The APTI of selected plant species varied from 6.79-10.40.The maximum APTI of 10.40 was recorded in *Toona ciliata* among the selected plant species whereas, minimum of 6.79 was noticed in *Grewia optiva*. The trend of APTI of the selected plant species was *Toona ciliate* (10.40) > *Pinus roxburghii* (9.92)> *Pistacia integerrima* (9.01) > *Celtis australis* (8.31)> *Jacaranda mimosifolia* (6.97) > *Grewia optiva* (6.79) (Table 3).

Table 4: Evaluation of plant species on the basis of APTI value and some biological and socio-economic characteristics

Plant Species	Toona ciliata	Jacaranda mimosifolia	Pinus roxburghii	Grewia optiva	Celtis australis	Pistacia integerrima	Plant Species
APTI	+++++	+	++++	+	+++	++++	APTI
plant habit	++	+	++	+	+	+	plant habit
Canopy structure	+	-	-	+	-	+	Canopy structure
Type of tree	-	-	+	-	-	-	Type of tree
Leaf Size	++	++	+	+	-	++	Leaf Size
Leaf Texture	+	+	-	+	+	-	Leaf Texture
Hardiness	-	+	+	+	-	+	Hardiness
Economic value	+	+	+	+	++	++	Economic value
Grade	12	7	10	7	7	11	Grade
%	75	43.75	62.5	43.75	43.75	68.75	%
API grade	5	2	4	2	2	4	API grade

Table 5: Anticipated performance index (API) of selected plant species

Sr. No.	Plant species	Total grade allotted	% Score	API Grade	Assessment
1.	*Toona ciliata*	12.00	75.00	5.00	Excellent
2.	*Jacaranda mimosifolia*	7.00	43.75	2.00	Poor
3.	*Pinus roxburghii*	10.00	62.50	4.00	Moderate
4.	*Grewia optiva*	7.00	43.75	2.00	Poor
5.	*Celtis australis*	7.00	43.75	2.00	Poor
6.	*Pistacia integerima*	11.00	68.75	4.00	Moderate

The assessment of the API with respect to the selected plant species growing around the Nauni-Solan State Highway was observed to fall in the range of poor to excellent (Table 5). Among the six plant species categorised, *Toona ciliata* fall in the excellent category followed by *Pinus roxburghii* and *Pistacia integerrima* which were found in 'Moderate' category. High API of Toona ciliata is due to its tolerance level with maximum APTI value among species studied in the study. High API of *Toona ciliata* may also be attributed to its larger size and better laminar characteristics like larger area and texture along with the high economic value. *Toona ciliata* is grown for its versatile timber which is used for construction and high value furniture. Apart from the timber flower yield a reddish dyestuff and bark is used to tan leather and produce strings in musical instruments. Various parts of plants, chiefly the bark and leaves are used in medicinal and pharmaceutical industries. The leaves are widely used as an animal fodder also. *Toona ciliata* is commonly cultivated as an avenue tree. Thus, *Toona ciliata* is of great importance in socio-economic aspect also.

Conclusion

Variation in the biochemical, physiological and tolerance level of the selected plant species growing alongside the State Highway indicated that vehicular pollution emitted on the roads have started impacting the vegetation growing alongside the road. However, certain plants like *Toona ciliata* have shown their adaptability to the stress caused by the pollution. Hence, *Toona cliata* with higher tolerance and anticipated performance index can be suggested for plantations alongside the State Highway so as to intercept the air pollutants which act as health hazards to the people of the region.

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