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Evaluation of Air Pollution Tolerance Index and Anticipated Performance Index of Plants and their Role in Development of Green Belt along National Highway-22

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ABSTRACT

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Plants play an important role in mitigating air pollution. In such a scenario where problems due to air pollution are faced worldwide screening of sensitive and tolerant plants which acts as a bio indicator and sinks for air pollution is extremely significant. Therefore, present study was designed to evaluate the Air Pollution Tolerance Index (APTI) of six roadside plant species namely *Cassia fistula*, *Grevillea robusta*, *Grewia optiva*, *Leucaena leucocephala*, *Toona ciliate* and *Woodfordia floribunda* growing alongside a selected stretch of National Highway 22 (Datiyar to Solan) in Himachal Pradesh, India. The Anticipated Performance Index (API) of these plant species was also calculated by considering their APTI values with biological and socio-economic characters (plant height, canopy structure, type of plant, lamina characteristics, texture, hardness and economic value). The study indicated that *Cassia fistula* with highest APTI value of 23.5 and highest API score is best for green belt development.

Introduction

The blooming growth in Indian economy in terms of industrialization, urbanization and modernization has led to increase in various economic activities, where road development has become an integral part, ameliorating the efficient connectivity, financial and social welfare of the people. But such activities go hand in hand causing damage to the natural assets of the environment to a greater or a lesser extent by disturbing the existing ecosystem. Air pollution due to expansion and vehicular emissions has become one of the most serious problems and has resulted in

huge threat to both the environment and the health of living organisms like plants, animals and humans (Kaur and Nagpal, 2017). The combustion activities also adds toxic gases like SOX, NOX, CO and particulate matter into the air which includes soot particles as well as smaller quantities of toxic metals, organic molecules and radioactive isotopes (Bhattacharya *et al.*, 2013). Plants growing along the roadsides get affected at the maximum as they are the primary recipients to different air pollutants and show varied levels of tolerance and sensitivity and also plays an important role in monitoring and maintaining the ecological balance by actively

participating in the cycling of nutrients and gases like carbon dioxide and oxygen (Mahecha *et al.*, 2013). The air pollutant once released into the atmosphere cannot be traced or identified by any device chemically or mechanically, only plants can absorb and metabolise these pollutants from the atmosphere. Therefore, the role of plants in assessing the air pollution is being increasingly recognised and is used in evaluating the Air Pollution Tolerance Index which is a species dependent plant attribute and expresses the inherent ability of plant to encounter stress arising from air pollution and helps in identifying the tolerance levels of plant species based on biochemical parameters viz. ascorbic acid, pH of leaf extract, total chlorophyll and relative water content (Shannigrahi *et al.*, 2003).

Plants with higher APTI value are tolerant to air pollution and can be used to mitigate air pollution while those with low index value show less tolerance and can be used to signify levels of air pollution (Madan and Chauhan, 2015). The APTI index evaluates the effect of pollutants only on biochemical parameters, but in order to combat air pollution using green belt development, some biological and socio-economic characteristics are also considered and used to develop the anticipated performance index (API) (Govindaraju *et al.*, 2012).

The expansion of NH-22 from Timber-Trail resort in Datiyar to Solan has deteriorated the air quality as being perceived by urban dwellers because of developmental activity and large vehicular density in the area, as the road stretch being a part of tourist route and connecting the cities of Chandigarh, Ambala, Kalka, Parwanoo and Shimla the state capital city of Himachal Pradesh carries a significant heavy traffic to and fro from Shimla and other parts of the State. Hence all these activities have highly deteriorated the air quality.

Therefore, the present study can help in screening out the air pollution tolerant plant species and calculating their anticipated performance index (API) which can be used as an indicator to assess the capability of predominant species for cleaning up of the atmospheric pollutants and in development of the green belt along the National Highway.

Materials and Methods

Study area

The entire study area extends on National Highway-22 which connects Firozpur, Punjab in the North end to Shipki La, Sino-Indian border to the South end. The study area covers a part of NH-22 of Solan district from Timber-Trail resort in Datiyar to Solan covering a distance of about 40 kms. The Highway lies between North latitude of 30°44'53" to 31°22'01" and East longitude of 76°36'10" to 77°15'14". The study area has high vehicular density as it is a major part of tourist route connecting the cities of Chandigarh, Ambala, Kalka, Parwanoo and Shimla, the capital city of Himachal Pradesh.

Survey of the study area

In order to study the distribution of plants growing alongside the national highway and to screen out the most tolerant plants species to pollution a detail survey of National Highway-22 was conducted from Datiyar to Solan. The vegetation distribution study was carried by using quadrat method and in order to maintain the uniformity, plants of same age and spread growing at iso-ecological conditions were selected for the study.

The commonly occurring plant species identified and selected were *Cassia fistula*, *Grevillea robusta*, *Grewia optiva*, *Leucaena leucocephala*, *Toona ciliate* and *Woodfordia floribunda*.

Experimental details

In order to conduct the present study the National Highway 22 was divided into four uniform segments based on distance and each segment was considered as one replication. The six commonly growing plant species viz. *Cassia fistula*, *Grevillea robusta*, *Grewia optiva*, *Leucaena leucocephala*, *Toona ciliate* and *Woodfordia floribunda* were selected from both the sides of the National Highway. In total there were 24 treatment combinations (6 x 4) which were replicated four times under factorial Randomized Block Design. The data for the two sides (left and right) of the national highway was clubbed for statistical analysis and the results were statistically analyzed and interpreted by using Statistical Package Software version 21.

Sample collection and analysis

To assess the APTI based on the four parameters namely leaf ascorbic acid, leaf extract pH, total chlorophyll, and relative water content fully matured leaves of selected plant species were collected randomly from both sides of the road in the morning hours at almost same diameter at breast height (DBH). The leaf samples were then transported to the laboratory in ice – box and washed with normal water and then with 0.1N HCL followed by washing with distilled water. Further, the analysis of physiological and biochemical parameters of leaf samples were carried out as per the standard procedures as mentioned below:

Analysis of biochemical parameter

Ascorbic acid

To estimate leaf ascorbic acid content of selected plant species 10g of the sample was taken. The sample was homogenized in metaphosphoric acid (3%) and filtered. The

volume of the filtrate was made to 100ml by metaphosphoric acid (3%). The aliquot measuring 10ml was taken and titrated against standardized dye to an end point of pink colour as per the standard procedure outlined by Association of Official Agricultural Chemists (1980). The ascorbic acid content was expressed in milligrams per grams (mg g^{-1}).

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Dye factor} \times \text{Titre reading} \times \text{Volume made} \times 100}{\text{Weight of leaves taken} \times \text{Volume taken for estimation}}$$

Leaf extract pH

Leaf extract pH of the sample was analyzed by the method suggested by Barrs and Weatherly (1962). Fresh leaf sample (10g) was homogenized using deionised water (50ml) and the supernatant obtained after centrifugation was collected for the determination of pH using a digital pH meter.

Total chlorophyll

For the estimation of total chlorophyll content of the leaves, 10mg of the leaf sample was homogenized with 7ml dimethyl-sulphoxide and was kept in oven at a temperature of 60-65°C for 30-35mins.

The samples were filtered and volume was made to 25ml by dimethyl-sulphoxide. The absorbance was measured at 663nm and 645nm in spectrophotometer and chlorophyll was estimated using the following equation given by Hiscox and Istaelstam (1979)

$$\text{Total chlorophyll (mg g}^{-1}\text{)} = \frac{20.2 A_{645} + 8.02 A_{663}}{a \times 1000 \times w} \times V$$

Where;

V is volume of extract made
a is length of light path in cell (usually 1cm)
W is weight of sample
A₆₄₅ is absorbance at 645nm
A₆₆₃ is absorbance at 663nm

Relative water content

Relative water content of the samples was estimated using the method proposed by Singh (1977) and was computed by using following equation

$$\text{RWC} = \frac{(\text{FW} - \text{DW})}{(\text{TW} - \text{DW})} \times 100$$

Where;

RWC is relative water content (%)
FW is fresh weight of leaf sample
DW is dry weight of leaf sample
TW is turgid weight of leaf sample

Air pollution tolerance index (APTI)

The Air pollution tolerance index based on leaf biochemical parameters was computed by using the following formulae given by Singh and Rao (1983).

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

Where;

A is ascorbic acid (mg g⁻¹) of leaf sample
T is total chlorophyll (mg g⁻¹) of leaf sample
P is leaf extract pH of leaf sample
R is relative water content (%) of leaf sample

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 -) are allotted to plants. Different plants are scored according to their grades as per the procedure outlined by Mondal *et al.*, (2011).

Results and Discussion

Biochemical parameters

Leaf ascorbic acid content

The different plant species growing along National Highway -22 were found to exhibit significant variations in leaf ascorbic acid content Fig.1. The ascorbic acid content of selected plant species varied from 2.85 to 10.22 mg g⁻¹. Among the selected plant species the highest ascorbic acid content was recorded in *Cassia fistula* (10.22 mg g⁻¹). Whereas, lowest was observed in *Grewiallia robusta* (2.85 mg g⁻¹). The order of ascorbic acid content in leaves of selected plant species was *Cassia fistula* (10.22 mg g⁻¹) > *Leuceana leucocephala* (9.58 mg g⁻¹) > *Woodfordia fruticosa* (7.33 mg g⁻¹) > *Toona ciliata* (5.26 mg g⁻¹) > *Grewia optiva* (5.18 mg g⁻¹) > *Grewiallia robusta* (2.85 mg g⁻¹). Ascorbic acid is a natural antioxidant that influences the resistance of plants against adverse environmental conditions and helps in pollution tolerance (Subramani and Devaanandan, 2015). Different developmental activities and vehicular emissions leads to air pollution especially in areas with high traffic and higher commercial activities and enhances production of more antioxidants in response to stress conditions. The results are in conformity with the findings of Prajapati and Tripathi (2008). Higher ascorbic acid content in the leaves of *Cassia fistula* may probably be due to improvement in the defence mechanism of the plants which has been reported to be

different for different plant species by (Chen *et al.*, 2007). Trees under stress improve their ascorbic acid content to improve their capacity to fight against adverse conditions. The results are in line with the findings of Yannawar and Bhosle (2013) who have also reported higher ascorbic acid content in the leaves of the plants growing near roadside due to higher pollution stress

Total chlorophyll content

The leaf Chlorophyll content of the different plant species varied significantly from 9.18 mg g⁻¹ to 1.36 mg g⁻¹ along the National Highway 22 Fig.1. In the selected stretch, among the six selected plant species highest leaf chlorophyll content was recorded in *Cassia fistula* (9.18 mg g⁻¹) whereas lowest was recorded *Woodfordia fruticosa* (1.36 mg g⁻¹). The order of leaf chlorophyll content in the leaves of selected species was *Cassia fistula* > *Leuceana leucocephala* > *Toona ciliata* > *Grewiallia robusta* > *Grewia optiva* > *Woodfordia fruticosa*. The leaf Chlorophyll content of plants signifies its photosynthetic activity as well as the growth and development of biomass. The chlorophyll content varies from species to species and also with the pollution level as well as with other biotic and abiotic conditions (Begum and Harikrishna, 2010). Higher the chlorophyll contents higher the tolerance to pollution (Joshi *et al.*, 1993).

The chlorophyll content in all the plants varied with the tolerance as well as sensitivity of the plant species to pollution load *i.e.* higher the sensitive nature of the plant species lower the chlorophyll content. These results are supported by the findings of Joshi *et al.*, (1993). Further, automobile exhaust and other anthropogenic activities at traffic site are responsible for reduced concentration of chlorophyll. The variation in chlorophyll content in the leaves of selected plants species

could be attributed to their inherent capacity to tolerate the pollution stress along roadside as well as due to vehicular pollution in the selected stretch of the National Highway. The results are in line with the findings of Ninave (2001). Higher the level of automobile pollution higher is the decrease in leaf chlorophyll content of plants near roadside (Mir, 2008).

Leaf extract pH

The different plant species along National Highway 22 were found to exhibit significant variations in leaf extract pH of selected plants species. Figure 1 indicates that leaf extract pH of different plant species along National Highway varied from 5.82 - 6.77. Among the selected species *Cassia fistula* was noticed to have maximum leaf extract pH of 6.77. Whereas, minimum was observed in *Grewiallia robusta* (5.82). The order of leaf extract pH of selected plant species was *Cassia fistula* (6.77) followed by *Leuceana leucocephala* (6.46), *Grewia optiva* (6.33), *Toona ciliata* (6.20), *Woodfordia fruticosa* (5.85), *Grewiallia robusta* (5.82). The variations in leaf extract pH in selected plants along National Highway could be attributed due to the varied genetic composition of the plant species. Higher level leaf extract pH in *Cassia fistula* indicates the tolerance of plant under polluted conditions. The results are in line with (Gholami *et al.*, 2016) who stated that the reduction in pH value is more in sensitive plants compared to those in tolerant plants. Further, lower value of leaf extract pH in selected plants species growing at traffic and commercial areas may be ascribed due to highest level of vehicular pollution and developmental activities in these areas. Similar results were also observed by Singare and Talpade (2013) who also reported that the leaf extract pH tend to decrease with the increase in pollution with respect to non-polluted site.

Table.1 Gradation of plant species based on air pollution tolerance index as well as morphological parameters and socio-economic importance

Grading Character		Pattern of assessment	Grade allotted	
Tolerance	APTI	9.0–12.0	+	
		12.1–15.0	++	
		15.1–18.0	+++	
		18.1–21.0	++++	
		21.1–24.0	+++++	
Biological and socio-economic	Plant habit	Small	-	
		Medium	+	
		Large	++	
	Canopy Structure	Sparse/irregular/globular	-	
		Spreading crown/open/semi-dense	+	
		Spreading dense	++	
		Type of plant	Deciduous	-
		Evergreen	+	
	Laminar structure	Leaf size	Small	-
			Medium	+
Large			++	
Texture		Smooth	-	
		Coriaceous	+	
Hardiness		Delineate	-	
		Hardy	+	
Economic value	Less than three uses	-		
	Three or four uses	+		

Table.2 Anticipated performance index (API) 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

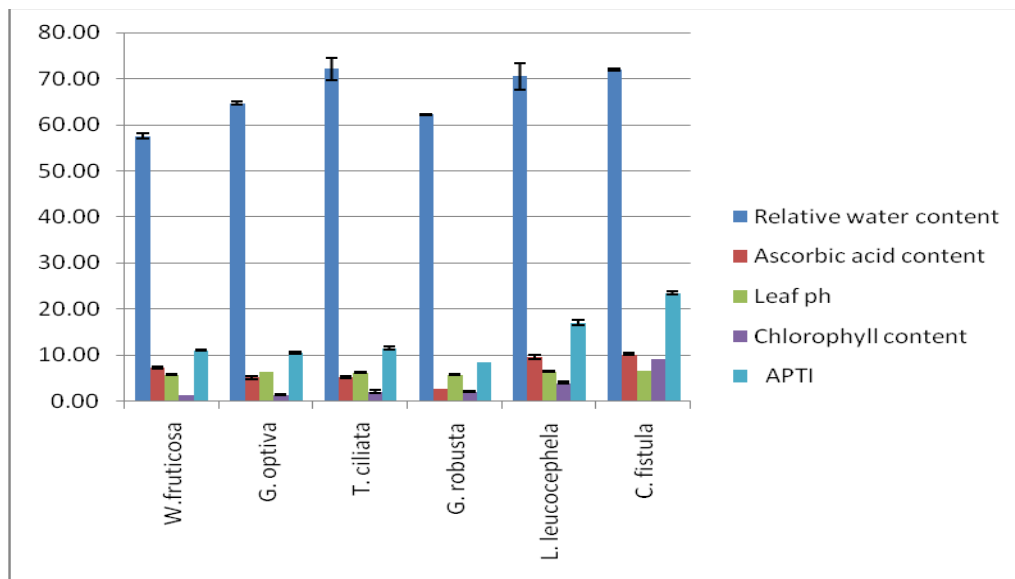
Table.3 Evaluation of API of plant species based on their APTI values and some other biological and socio-economic characters

Sr. No.	Plant species	Total grade allotted	% Score	API value	Assessment
1.	<i>Woodfordia fruticosa</i>	3	18.75	0	Not recommended
2.	<i>Grewia optiva</i>	8	50.00	2	Poor
3.	<i>Toona ciliata</i>	10	62.50	4	Good
4.	<i>Grewiallia robusta</i>	8	50.00	2	Poor
5.	<i>Leuceana leucocephela</i>	8	50.00	2	Poor
6.	<i>Cassia fistula</i>	10	62.50	4	Good

Table.4 Assessment based on anticipated performance index of selected plant species

Plant species	Assessment parameters				laminar structure				Grade allotted		
	APTI	TREE HABIT	CANOPY STRUCTURE	TREE TYPE	SIZE	TEXTURE	HARDINESS	ECONOMIC IMPORTANC	TOTAL PLUS	% SCORING	API GRADE
<i>Woodfordia fruticosa</i>	+	-	-	-	+	-	+	-	3	18.75	0
<i>Grewia optiva</i>	+	+	+	-	+	+	+	++	8	50.00	2
<i>Toona ciliata</i>	++	++	+	-	++	+	+	+	10	62.50	4
<i>Grewiallia robusta</i>	+	++	+	+	++	-	+	-	8	50.00	2
<i>Leuceana leucocephela</i>	+++	+	-	-	++	-	-	++	8	50.00	2
<i>Cassia fistula</i>	+++++	+	-	+	++	-	-	+	10	62.50	4

Fig.1 Variations in the biochemical parameters and APTI values of selected plant species



Leaf relative water content

The relative water content varied significantly among the different plant species growing along the National Highway -22. The relative water content of selected plant species varied from 72.07-57.58% (Fig. 1). Among the six selected species *Toona ciliata* was found to have maximum (72.07%) relative water content while the minimum of 57.58% was observed in *Woodfordia fruticosa*. The order of relative water content in the leaves of selected plant species was *Toona ciliata* > *Cassia fistula* > *Leuceana leucocephala* > *Grewia optiva* > *Grewiallia robusta* > *Woodfordia fruticosa* with the respective values of 72.07%, 72.02%, 70.47%, 64.65%, 62.27%, 57.58%. The variation in RWC in plants may be due to difference in plants species (Nwadinigwe, 2014). The leaf relative water content is the amount of moisture a plant holds and is an indicator of hydration condition in the leaf matrix. The highest value of relative water content in *Toona cilata* may be ascribed due to its higher resistant capacity to stress conditions and maintenance of relative water content under polluted conditions by the plant may determine its relative tolerance to pollution (Verma, 2003; Gholami *et al.*, 2016). Plants at polluted site absorbed more water this could be a physiological mechanism of the plants to withstand the effect of pollution in its environment (Tanee *et al.*, 2014). The trend of higher RWC in the plants growing alongside the National Highway may be ascribed to relatively lower rate of transpiration at polluted sites which might have resulted in the leaves of the plants. The results are in line with Bora and Joshi (2014).

Air pollution tolerance index

The plant growing alongside the National Highway-22 varied significantly in their tolerance levels. Among the selected species

the highest APTI of 23.50 was recorded for *Cassia fistula* which was followed by *Leuceana leucocephala* (17.10), *Toona ciliata* (11.61), *Woodfordia fruticosa* (11.04), *Grewia optiva* (10.50) while the lowest value of 8.50 was noted in *Grewiallia robusta*. Fig.1. The variation in the tolerance of the trees of a region to air pollution has also been reported by Lakshmi *et al.*, (2008); Agbaire and Esiefarienrhe (2009). The higher value of APTI in *Cassia fistula* may be due to increased production of ascorbic acid and higher relative water content during pollution stress (Kuddus *et al.*, 2011). The highest APTI of the plants near the highway may be ascribed to the reason that the trees in order to adapt the stress due to auto exhaust pollution improve their tolerance capacity. Tolerance to air pollution alters from species to species depending on plants capacity to endure the effect of pollutants (Gholami *et al.*, 2016). The higher APTI adjacent to National Highway showed higher tolerance of plant species to air pollutants (Jyothi and Jaya, 2010). It has been reported that tolerance of plant towards air pollutants is specific to a site and depends on the type and level of pollution (Noor *et al.*, 2015).

Anticipated performance index

API is used as an indicator to assess the capability of predominant species for the abatement of the atmospheric pollutants and in green belt development. The anticipated performance index calculated by evaluation and grading of tree species based on their APTI and some biological and socio-economic characters showed a variation from not recommended category to the category good. The highest values of API (4) were calculated in *Cassia fistula* and *Toona ciliata* and were considered as Good for Green belt development and *Leuceana leucocephala*, *Grewia optiva* and *Grewiallia robusta* with API value of (2) were assessed as poor

whereas *Woodfordia* with APII value of zero was assessed as not recommended Table.4. The highest API of *Cassia fistula* may be due to its high APTI. API value is more for the species with higher APTI having better plant and leaf characteristics (Prajapati and Tripathi, 2008). Among all the plant species *Cassia fistula* was the most tolerant species and also this species has the high economic and aesthetic value. Hence it can be recommended for the plantation in the polluted areas. From the present investigation it can be concluded that all the biochemical, physiological, biological as well as socioeconomic parameters of the plant species play an important role in determining the sensitivity and tolerance of plants to air pollution with reference to their tolerance and performance index. The study indicated that *Cassia fistula* should be considered for plantation alongside the National Highway 22 because of its highest tolerance capacity to pollution and high anticipated performance index among the commonly growing species. Tsega and Deviprasad (2014) also concluded that plant species with high API values should be recommended for establishment of the green belts.

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