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Research Article

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Evaluation of Anticipated Performance Index of Plant Species for Green Belt Development to Mitigate Air Pollution

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Abstract

Anticipated Performance Index (API) is an innovative ecological approach in selecting plant species for reducing air pollution, using Air Pollution Tolerance Index (APTI) and socio-economic parameters. The present study evaluated API of 11 plant species (6 trees and 5 shrubs) for the recommendation of green belt establishment near the national highway expansion region of the Kiratpur-Nerchowk expressway. The scrutiny of the results revealed that the tolerance capacity of plant species along with their performance grade is a justified approach for selecting the most suitable plant species, which can act as sink for air pollution. API on the other hand, can also help to distinguish the sensitive plant species, which can act as bio-monitors. The results showed that among all plant species *Leucaena leucocephala* and *Toona ciliata* (API=5) qualify as 'very good' performers in green belt development, while *Dalbergia sisso* (API=4) is a 'good' performer. *Grewia optiva* and *Ficus palmata* were judged as 'moderate' performers (API=3). Whereas, all other remaining investigated trees and shrubs having lesser API values can act as bio-indicators and particularly are very less recommended for green belt establishment. Hence, on the basis of amalgamation of APTI values together with other socio-economic and biological parameters, API significantly is considered as one of the best approaches identified and recommended for long-term refinement of air quality.

Keywords: Plant species, APTI, API, green belt management

1. Introduction

Air Pollution is a major problem arising mainly from increase in traffic load, urbanization and industrialization (Patel and Kumar, 2018). The gaseous pollutants such as sulphur dioxide (SO_2), oxides of nitrogen (NO_x) and suspended particulate matter (SPM) are emitted from the combustion of fuel, which play a great role in deteriorating the ambient air quality (Gautam and Bolia, 2020). In India, 60-70 per cent of the urban air pollution load is caused by motor vehicles (Ghafari et al., 2020) and increasing concentrations of these pollutants in the atmosphere causes harm or discomfort to living organisms (Sarasamma and Narayanan, 2014).

Plants species play a significant role in intercepting the air pollutants as well as act as essential component of water and nutrient cycle by providing food, habitat to different organisms as well as have landscape

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appeal (Smith and Staskawicz, 2020). Also plants have a great potential in absorption, adsorption and accumulation of pollutants on their leaf surface (Kaur and Nagpal, 2017). Also, some plants are very fragile or sensitive that they can act as biological indicators or monitors of air pollution (Nouchi, 2002; Esfahani et al., 2013). With continuous exposure to vehicular pollution, plants show different levels of responses; some can tolerate high pollution load while some show sensitivity leading to decrease in chlorophyll content and hence reduced plant growth (Skrynetska et al., 2018). Moreover, most of the plant species continuously exchange different gaseous pollutants in and out of the foliar system, which further undergoes different structural and functional changes (Sen et al., 2017). From this perspective, it has been emerged air pollution may inhibit plant growth, fitness and capacity to resist other environmental stresses (Winner and Greitner, 2000).

Monitoring of air pollution by using a biological monitoring indicator is considered as one of the best and convenient methods with minimum expenditure (Rai et al., 2013). Since, there are several ecological factors which regulate plant resistance to air pollution (Singh and Verma, 2007). In addition, suitability of plants for the pollution abatement depends on how fast they are efficiently able to absorb pollutants from the atmosphere and metabolize or detoxify them at cellular levels (Yannawar and Bhosle, 2014).

Development of green belt by plantation of pollution tolerant plant species, not only mitigates air pollution to a certain level, but also acts as landscaping component for beautification of that area and for this, selection of plant species is an important factor to be considered (Uka et al., 2019; Alotaibi et al., 2020). For selection of plants, one of the commonly used index is air pollution tolerance index (APTI), which is effective in evaluating the effect of pollutants only on biochemical parameters (Chaudhary and Rathore, 2019; Molnar et al., 2020; Roy et al., 2020).

In order to combat air pollution using green belt, some socio-economic and biological characteristics are also considered to develop the anticipated performance index (API) (Pathak et al., 2011; Kaur and Nagpal, 2017, Banerjee et al., 2019; Sahu et al., 2020; Javanmard et al., 2020). This API is an improvement tool over the APTI, which has been used as an indicator to assess the capability of predominant species in the clean-up of atmospheric pollutants (Rai et al., 2013; Karmakar and Padhy, 2019). Some, socio-economic and biological characteristics (such as plant height, canopy structure, plant size, texture, hardness and economic value) are considered to develop the anticipated performance index, which further helps in the categorization of plants as very good, good, moderate, poor and very poor sensitive categories (Prajapati and Tripathi, 2008). Thus evaluation of API helps to assess the capability of the plant species to reduce the atmospheric pollution and indicate their socio-economic benefits as well.

2. Materials and Methods

2.1. Site description

The present work was conducted during the year 2016-17 on the Kiratpur - Nerchowk Expressway (NH-154). The study area from Garamoura in Bilaspur to Nerchowk in Mandi district under consideration of Himachal Pradesh is situated between North latitude of 31°21’64” to 31°38’56” and East longitude of 76°56’77” to 76°46’46”. The study sites experiences sub-tropical climate and has an average annual rainfall of about 1200 mm and average maximum and minimum temperature varies from 17.45 to 35.27°C and 1.44 to 21.93°C.

2.2. Plants under study

Eleven commonly growing plant species viz. *Dalbergia sisso*, *Grewia optiva*, *Leucaena leucucephala*, *Toona ciliata*, *Morus alba*, *Ficus palmate*, *Adhatoda vasica*, *Vitex negundo*, *Murraya koenigii*, *Carissa opaca* and *Debregeasia hypoleuca* were selected for the present study. On the basis of questionnaire socio-economic importance of the plant species was recorded by the local inhabitants of the study area.

2.3. Experimental details

2.3.1. Air pollution tolerance index estimation

The air pollution tolerance index (APTI) is 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) (Table 1).

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

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

2.3.2. Determination of API (Anticipated Performance Index)

Table 1: Air pollution tolerance index of selected plant species growing alongside National Highway

Species	TC	AA	pH	RWC	APTI
Dalbergia sisso	3.08	3.90	5.99	70.33	10.56
Grewia optiva	3.14	2.90	5.96	73.32	9.94
Leucaena leucucephala	3.08	3.85	6.04	75.43	11.05
Toona ciliata	3.81	4.42	6.11	81.48	12.53
Ficus palmata	2.69	2.93	5.93	67.97	9.33
Morus alba	2.69	2.61	6.09	67.33	9.02
Murraya koenigii	2.17	2.55	5.95	64.04	8.47
Vitex negundo	1.65	2.34	5.90	60.38	7.79
Adhatoda vasica	2.89	3.55	5.97	68.35	9.98
Carissa opaca	1.95	2.81	5.63	58.28	7.96
Debregeasia hypoleuca	2.20	2.89	5.87	56.64	7.98

TC: Total chlorophyll (mg g^{-1}); AA: Ascorbic Acid (mg g^{-1}); RWC: Relative water content (%); Source: Sharma et al. (2018)

To work out API, socio-economic importance of the plants growing alongside the road was studied by taking interviews/interactions with local people of the study area and from the available literature. By combining the biological and socio-economic characters like plant habit, canopy structure, type of plant, laminar structure and economic value and the resultant APTI; the API was calculated for the selected species. Based on these characters, different grades (positive or negative) were allotted to plants and then were scored according to their grades as per the procedure outlined by Kaur and Nagpal (2017) presented in Table 2 and 3.

Table 2: Gradation of plant species based on air pollution tolerance index (APTI) as well as biological parameters and socio-economic importance

Grading characters		Pattern of assessment	Grade allotted
1) Tolerance	APTI	8.5–9.0	Positive
		9.1–9.5	Two positive
		9.6–10.0	Three positive
		10.1–10.5	Four positive
		10.6–11.0	Five positive
2) Biological and socio-economic	Plant habit	Small	Negative
		Medium	Positive
		Large	Two positive
	Canopy structure	Sparse/ irregular/ globular	Negative
		Spreading crown/open/ semi-dense	Positive
		Spreading dense	Two positive
	Type of plant	Deciduous	Negative
		Evergreen	Positive
3) Laminar structure	Size	Small	Negative
		Medium	Positive
		Large	Two positive
	Texture	Smooth	Negative
		Coriaceous	Positive
	Hardiness	Delineate	Negative
		Hardy	Positive
	Economic value	Less than three uses	Negative
		Three or four uses	Positive
		Five or more uses	Two Positive

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

Source: Kaur and Nagpal (2017)

3. Results and Discussion

3.1. APTI of the plant species

Air pollution tolerance index plays a significant role in screening out pollution tolerant plant species, which maintain ecological homeostasis by actively contributing in the cycling of nutrients and gases like carbon dioxide, oxygen and also provide enormous leaf area for absorption, adsorption and accumulation of air pollutants to reduce the pollution level in the atmosphere (Escobedo et al., 2008).

Higher values of chlorophyll content significantly reports that plant has high tolerance to air pollutants. But high pollution level, high moisture content and blockage of the stomatal pores on the leaf surface due to dust accumulation might be the reason behind the low chlorophyll content in leaf samples (Kaur and Nagpal, 2017). High ascorbic acid content observed in leaf samples of the plant species; indicates more air pollution tolerance in plants. Since, ascorbic acid can prevent plant tissues from the harmful effects of air pollutants thereby playing an important role in air pollution tolerance (Tripathi and Gautam, 2007).

Leaf extract pH of plant species significantly found to be of acidic nature. This acidic nature of pH may be due to diffusion of gaseous air pollutants in the cell sap and their conversion into acid radicals (Scholz and Reck, 1977). Relative water content plays a key role in maintaining the physiological balance of plants under stress conditions of air pollution and its high content is advantageous for drought resistance in plants (Singh et al., 1991).

The plant species growing alongside the highway were found to have significant variations in the APTI values (Table 1). The APTI of tree species followed the order of *Toona ciliata>Leucaena leucocephala>Dalbergia sisso>Grewia optiva>Ficus palmata >Morus alba* with their respective values of 12.53, 11.05, 10.56, 9.94, 9.33 and 9.02. Also, the APTI of most shrubs was higher than those tree species such as *Adhatoda vasica>Murraya koenigii>Debregeasia hypoleuca>Carissa opaca>Vitex negundo* with their respective values of 9.98, 8.47, 7.98, 7.96 and 7.79; suggesting that shrubs in general, were more tolerant to air pollution than trees (Sharma et al., 2018). Higher values of APTI represent the potential of plants to facilitate in polluted areas and contribute as an air controller (Joshi and Swami, 2007; Sharma et al., 2017; Pandey et al., 2015).

3.2. Anticipated performance index (API) of plant species

Plant species for green belt development along the highway were evaluated on the basis of their APTI and relevant socio-economic as well as biological parameters. These parameters were subjected to a grading scale to determine the anticipated performance of plant Singh and Rao, 1983). The grading pattern of 11 plant species evaluated is presented in Table 4 and the one which have higher grades has been recommended (Table 5) for plantation in a roadside area.

Leucaena leucocephala and *Toona ciliata* showed the highest grade (75%) each, followed by *Dalbergia sisso* (62%), *Grewia optiva* and *Ficus palmata* (56.25%) each. While the other plant species were of low grade (Table 4). The above said species have a dense canopy and most of them are evergreen, which are normally more suitable to control air pollution. The aesthetic and economic value of these trees is well known and can be recommended for green belt development (Sharma et al., 2019).

Table 4: Evaluation of plant species based on their APTI values and some biological and socio-economic characters

Sr. No.	Plant species	Assessment parameters				Laminar structure				Grade allotted	
		APTI	Tree habit	Canopy structure	Type of tree	Size	Texture	Hardiness	Economic value	Total plus (+)	% scoring
1.	*Dalbergia sisso*	++	++	+	+	-	+	++	+	10	62.50
2.	*Grewia optiva*	+	+	+	+	+	+	+	++	9	56.25
3.	*Leucaena leucocephala*	+++++	+	++	-	-	+	+	++	12	75.00
4.	*Toona ciliata*	+++++	++	+	-	++	+	-	+	12	75.00
5.	*Ficus palmata*	+++	+	+	-	+	+	-	++	9	56.25
6.	*Morus alba*	++	+	+	-	-	+	-	+	6	37.50
7.	*Murraya koenigii*	+	-	+	+	-	-	-	++	5	31.25
8.	*Vitex negundo*	+	-	-	-	-	+	+	++	5	31.25
9.	*Adhatoda vasica*	+++	-	-	+	+	-	+	++	8	50.00
10.	*Carissa opaca*	+	+	++	+	-	-	+	+	7	43.75
11.	*Debregeasia hypoleuca*	+	+	+	+	+	+	+	-	7	43.75

Table 5: Anticipated performance index (API) value of the studied plant species

Sr. No.	Plant species	Grade		API value	Assessment
		Total Plus (+)	Percentage		
1.	*Leucaena leucocephala*	12	75.00	5	Very Good
2.	*Toona ciliata*	12	75.00	5	Very Good
3.	*Dalbergia sisso*	10	62.50	4	Good
4.	*Grewia optiva*	9	56.25	3	Moderate
5.	*Ficus palmata*	9	56.25	3	Moderate
6.	*Adhatoda vasica*	8	50.00	2	Poor
7.	*Carissa opaca*	7	43.75	2	Poor
8.	*Debregeasia hypoleuca*	7	43.75	2	Poor
9.	*Morus alba*	6	37.50	1	Very Poor
10.	*Murraya koenigii*	5	31.25	1	Very Poor
11.	*Vitex negundo*	5	31.25	1	Very Poor

The scrutiny of Table 5 showed that out of 11 plant species, *Toona ciliata* and *Leucaena leucocephala* were found to be ‘very good’ performers and suitable plant species for green belt development. *Dalbergia sisso* was judged to be ‘good’ performer and considered efficient in controlling air pollution

(Kapoor et al., 2013). While *Grewia optiva* and *Ficus palmata* qualified for the 'moderate' performer category, which are also preferred for roadside plantation. Moreover, the remaining 6 species i.e. *Carissa opaca*, *Adhatoda vasica* and *Debregeasia hypoleuca* qualified in 'poor' category and *Morus alba*, *Murraya koenigii*, *Vitex negundo* assessed as 'very poor' category, which were found to be unsuitable for controlling air pollution because of their lower anticipated performance score. Thus, an evaluation of anticipated plant performance might be very useful in the selection of such appropriate species for green belt development and considering it beneficial for heavy traffic areas or planting along roadsides (Pandey et al., 2015; Mohammadi et al., 2018).

Moreover, such types of physiological surveys should be repeated, so as to have availability of more information regarding sensitivity and tolerance of different plant species, which can be utilized for mitigation of air pollution of that area.

4. Conclusion

The study inferred that all the plant species showed great variability in API, which will respond differently in controlling air pollution. Plants with higher API values can be recommended best for green belt development, whereas plants with lesser API values can act as bio-indicators for identifying regions having bad air quality. Among all selected trees, *Leucaena leucocephala* and *Toona ciliata* registered highest API values, which can be used as bio-accumulators and best performers in controlling air pollution.

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