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Study on Spatial and Seasonal Variation in APTI of Tree Species along Roads of Shivalik Foothills in Himachal Pradesh

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Abstract

The present study was conducted during the year 2018-2019 to determine the impact of road on Air Pollution Tolerance Index (APTI) of plants growing along the road. A comparative study was done between three roads *viz*., National highway, State highway and Link Road. Among three roads, link road can be considered as control because vehicular emissions were minimal or non-existent. Three plants (*Dalbergia sisso, Mangifera indica* and *Ficus palmata*) were selected as per their uniform presence along all three roads. Four biochemical parameters *viz*., ascorbic acid, total chlorophyll, leaf extract pH and relative water content were used to calculate the air pollution tolerance index. Season wise maximum ascorbic acid, leaf extract pH and relative water content was observed during post monsoon season whereas total chlorophyll content was observed during pre monsoon season. The APTI of the selected plant species ranged from 8.23 to 10.76 during pre-monsoon and 9.03 to 11.09 during post-monsoon. Anticipated Performance Index (API) was in order of *Mangifera indica* with highest API grade (6) and it was excellent among plants followed by *Dalbergia sisso* (5) in very good and *Ficus palmata* (3) in moderate. Student t-test analysis of seasonal variation of biochemical parameters in leaf of selected tree species was carried out and it was observed that there was significant seasonal effect on mean values of ascorbic acid content and APTI whereas there was no impact of seasons on total chlorophyll content, leaf extract pH and relative water content.

Keywords: APTI, API, green belt, roadside plants, vehicular emissions

1. Introduction

The Himalayan ecosystem is particularly vulnerable to the effects of climate change and aggressive road and dam building. The infrastructural development like roads construction has caused air pollution due to dust, suspended particles and vehicular emissions. The persistent danger to ambient air quality has been posed by the ever-increasing automobile emissions. High traffic congestion, ageing vehicles, low fuel quality, poor road, and inadequate inspection and maintenance programmes all contribute to poor roadside air quality (Wang et al., 2010). Although, such economic activities have brought material well-being to the hitherto backward areas, it has also consequently created an ecological imbalance and caused disasters in already fragile Himalayan ecosystem. Many hazardous pollutants, as well as secondary pollutants, generate severe fog conditions in northern India throughout the winter

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season (Tyagi et al., 2017) Current study has been conducted along the national highway, state highway and link road along Shivalik ranges of Himachal Pradesh to measure the impact of air pollutants on trees in the vicinity of the roads.

Vegetation acts as a pollutant sink, lowering pollution levels in the atmosphere (Hamraz et al., 2014). By absorbing particle debris and smoke, plants naturally purify the air. Sensitive tree species are considered bio-indicators (Rawal et al., 2001; Raina and Sharma, 2006). Plant leaves are an effective pollutant trapping medium, because of their wide surface area and numerous exposed sections (Prajapati and Tripathi 2008; Rai 2019). Several researchers have confirmed that vegetation, shrubs, plants, and trees are a green strategy to address the challenge of ambient air pollution (Anake et al., 2019). Various studies have shown the effects of air pollution on plant's biochemical parameters like the chlorophyll content (Flowers et al., 2007), ascorbic acid content (Hoque et al., 2007), leaf extract pH (Klumpp et al., 2000). Therefore, Air Pollution Tolerance Index which is based on above-mentioned parameters has been used for discovering tolerance levels of plant species (Panda et al., 2018). The APTI index describes a plant's ability to counter air pollution. Plant leaves are the ones that come into close contact with pollutants in the air (Punit and Rai, 2021). The ability to identify and classify plants into tolerant and sensitive groups is critical because sensitive plants can serve as an indicator and tolerant plants can serve as a sink for pollutants in urban and developed ecosystems (Kuddus et al., 2011). Tolerant plants are often used for the development of green belts across busy roads. The air pollution response of each plant varies with species and location. Plants are classified as tolerant, moderate, sensitive, or most sensitive based on their APTI scores. Such data could be used to plan a tree plantation at various polluted locations in order to combat air pollution (Sharma et al., 2019). Plants with low APTI value show less tolerance to pollution and can be used to evaluate levels of air pollution while those with higher index value are tolerant to air pollution and can be used to reduce air pollution (Madan and Chauhan, 2018).

In global urbanised areas, air pollution removal via trees is acknowledged as an economically viable component of pollution reduction strategies (Nowak et al., 2006; Yang et al., 2008; Morani et al., 2011; Yadav and Pandey, 2020). The APTI is a reliable tool for measuring tree species sensitivity as biofilter performance for managing ambient air quality (Kwak et al., 2020) whereas, the Anticipated Performance Index (API) score has been developed to assess the suitability of the plant species to combat air pollution using APTI with some other biological and socio-economic parameters. (Govindaraju et al., 2012). The API has been used as a tool to quantify the ability of dominant species to clean up contaminants in the atmosphere (Ogunkunle et al., 2015). In view of above-mentioned facts, the current study was undertaken to evaluate seasonal variation in Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API) of some plant species along national highway, state highway and link road in the foothills of Shivalik ranges of Kangra, Himachal Pradesh.

2. Materials and Methods

Three different roads viz., National highway NH-154 (Jassur to Shahpur) (Longitude 32° 16′55″N Latitude-75°51′32″ E), State highway SH-28 (Nurpur to Lahru) (Longitude-32° 19′44″N Latitude-75°54′29″ E) and Link Road (Longitude-32° 18′07″N Latitude-75°52′21″ E) in Shivalik foothills of Kangra district of Himachal Pradesh, India were selected for the present study. The selected stretches (National and State Highways) are from part of route connecting both towns (Dharamshala and Dalhousie) with each other and also with Pathankot city of Punjab state. Moreover, routes are subjected to heavy traffic load besides tourism, it is also used as a corridor to transport vegetables, fruits and other goods and services to these towns. Link roads connects villages to each other and with main roads (NH or SH). The present study was conducted during the year 2018-2019 and data was collected during pre-monsoon (March-April) and post-monsoon (October-November) seasons and presented in the form of mean of both years.

The climate of district Kangra is warm and temperate. Winter season commences from December to February, spring season falls from March to May, followed by summer season which remains from June to August and autumn season prevails till month of November. In this region 83 per cent of rains are received during monsoon months. The average annual rainfall in the district is about 1751 mm. The average temperature ranges from 0°C to 38°C. June is the hottest month and January is the coldest one.

Three plant species were taken for study that were present uniformly along the roadside of study area- *Dalbergia sisso*, *Mangifera indica* and *Ficus palmata*

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):

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

Where,

A: Ascorbic acid (mg g^{-1}) of leaf sample

T: Total chlorophyll (mg g^{-1}) of leaf sample

P: Leaf extracts pH of leaf sample

R: Relative water content (%) of leaf sample

2.5. Statistical analysis

The dust accumulation pattern, APTI and its relationship to physiological and biochemical parameters (ascorbic acid content, chlorophyll content, leaf extract pH and relative water content) of the leaves of selected plant species, as well as their significance level, were calculated under Randomized Block Design. Analysis of variance (ANOVA) was performed and critical difference at 5% level of significance was calculated as proposed by Cochran and Cox (1957). To compare the means of two groups in case of leaf dust accumulation and APTI, Student t-test was applied.

3. Results and Discussion

3.1. Ascorbic acid content

The ascorbic acid content in leaves of tree species during pre monsoon changed significantly with sites, species and distances (Table 1). During pre monsoon *Dalbergia sisso* had the highest ascorbic acid content (3.36 mg g^{-1}), followed by *Mangifera indica* (2.45 mg g^{-1}) and *Ficus palmata* (2.42 mg g^{-1}). The leaf ascorbic acid content of the selected plant species growing at different sites also varied significantly, with the highest (3.07 mg g^{-1}) ascorbic acid content observed at NH, followed by SH (2.77 mg g^{-1}) and LR (2.43 mg g^{-1}). Similar trend was observed in case of ascorbic acid content in leaves of tree species during the post monsoon season with the change in species and sites. The highest (3.36 mg g^{-1}) and lowest (3.01 mg g^{-1}) ascorbic acid content was found in *Dalbergia sisso* and *Ficus palmata*, respectively. The leaf ascorbic content of the selected plant species growing at different sites also varied Significantly, with highest (3.38 mg g^{-1}) leaf ascorbic acid content was found at NH followed by SH (3.21 mg g^{-1}) and lowest (2.96 mg g^{-1}) ascorbic acid was noticed at LR.

Table 1: Variation in ascorbic acid content in tree species growing along highways of Shivalik foothills during pre and post monsoon season

Sites	Pre monsoon			Post-monsoon			Pooled	
	Plant species							
	MI*	FP*	DS*	MI*	FP*	DS*	Pre monsoon	Post-monsoon
NH	2.76±0.01	2.80±0.01	3.63±0.01	3.42±0.01	3.13±0.01	3.60±0.01	3.07±0.16	3.38±0.08
SH	2.59±0.01	2.37±0.01	3.34±0.01	3.16±0.04	3.08±0.04	3.38±0.02	2.77±0.17	3.21±0.05
LR	2.09±0.01	2.10±0.01	3.10±0.02	2.95±0.02	2.81±0.01	3.11±0.01	2.43±0.19	2.96±0.05
Mean	2.45±0.01	2.42±0.01	3.36±0.01	2.98±0.01	3.01±0.01	3.36±0.03	2.75±0.17	3.18±0.06
CD (p=0.05)								
Species	0.02				Species	0.05	MI*- Mangifera indica	
Site	0.03				Site	0.06	FP*- Ficus palmata	
Species×Site	0.04				Species × Site	0.04	DS*-Dalbergia sisso	

Mean±SE (Standard error) of three values

The results are in line with the findings of Yannawar and Bhosle (2013) who have reported that leaves of plants growing along the roadside have a higher concentration of ascorbic acid. The higher ascorbic acid content in the leaves of *Dalbergia sisso* could indicate that the plant's defense mechanisms have improved, as reported by Cheng et al. (2007). The present results are in accordance with the finding of Mohammed Kuddus et al. (2011), that plant species with high APTI have higher leaf ascorbic acid content. Higher ascorbic content of the plant is a symbol of its resistance to air pollution, according to Chaudhary and Rao (1977). Ascorbic acid content in the leaves of tree species was observed highest (3.18 mg g^{-1}) during post monsoon whereas in pre monsoon season it was 2.75 mg g^{-1}. The higher ascorbic acid content in the post monsoon season could be due to less rainfall in the study area than in the pre monsoon season. The findings are consistent with those of Prajapati and Tripathi (2008), who found that plants under stress increase their ascorbic acid content in order to combat adverse conditions

3.2. Total chlorophyll content

The highest chlorophyll content (3.34 mg g^{-1}) was reported in *Dalbergia sisso*. followed by *Ficus palmata* (2.89 mg g^{-1}) and lowest (1.70 mg g^{-1}) was recorded in *Mangifera indica* (Table 2). The leaf chlorophyll content of the selected plant species growing at different sites also differed significantly, with the highest (2.77 mg g^{-1}) chlorophyll content observed at LR, followed by SH (2.65 mg g^{-1}) and NH (2.51 mg g^{-1}). Similar trend of chlorophyll content in leaves of tree species was observed during the post monsoon season with the change in species, sites and horizontal distances. The chlorophyll content of the selected plant species varied significantly, ranging from 1.47 to 3.51 mg g^{-1}, with *Dalbergia sisso* having the highest (3.37 mg g^{-1}) and *Mangifera indica* having the lowest (1.72 mg g^{-1}) chlorophyll content. The genetic variations of the plant species may be responsible for variation in the chlorophyll content of the leaves of selected plant species. Furthermore, variations in chlorophyll content of plant species may differ depending on the level of pollution in the region as well as the tolerance and sensitivity of the plant species. (Katiyar and Dubey, 2001; Harikrishna and Begum, 2010). Total chlorophyll content in the leaves of tree species was observed more during post monsoon season (2.67 mg g^{-1}) whereas in pre monsoon season it was 2.64 mg g^{-1}. The season wise variation in chlorophyll content may be ascribed due to more temperature stress on the plant species in the pre monsoon season.

Table 2: Variation in total chlorophyll content in tree species growing along highways of Shivalik foothills during pre and post monsoon season

Sites	Pre monsoon			Post-monsoon			Pooled	
	Plant species							
	MI*	FP*	DS*	MI*	FP*	DS*	Pre monsoon	Post-monsoon
NH	1.59±0.02	2.76±0.01	3.17±0.02	1.62±0.01	2.84±0.01	3.29±0.01	2.51±0.27	2.58±0.29
SH	1.71±0.01	2.88±0.01	3.37±0.01	1.73±0.01	2.89±0.02	3.34±0.01	2.65±0.28	2.65±0.28
LR	1.81±0.01	3.04±0.01	3.47±0.01	1.83±0.01	3.07±0.01	3.49±0.01	2.77±0.29	2.79±0.29
Mean	1.70±0.01	2.89±0.01	3.34±0.01	1.72±0.01	2.93±0.01	3.37±0.00	2.64±0.28	2.67±0.28
CD (*p*=0.05)								
Species	0.18			Species		0.20	MI*- *Mangifera indica*	
Site	0.12			Site		0.14	FP*- *Ficus palmata*	
Species×Site	0.22			Species × Site		0.20	DS*-*Dalbergia sisso*	

Mean±SE (Standard error) of three values

3.3. Leaf extract pH

The leaf extract pH of tree species during pre monsoon changed significantly with sites, species (Table 3). The leaf extract pH of the selected plant species varied significantly, ranging from 6.53 to 7.00. The highest (6.96) leaf extract pH was recorded in *Dalbergia sisso*, followed by *Ficus palmata* (6.89), and the lowest (6.78) was recorded in *Mangifera indica*. This showed that as traffic emissions decreased a high pH level improves air pollution tolerance (Agarwal 1986, Yan-ju and Hui 2008). The leaf extract pH of the selected plant species growing at different sites also varied significantly with highest (6.99) leaf extract pH at LR followed by SH (6.89) and lowest (6.76) leaf extract pH was noticed at NH.

Similar trend of leaf extract pH in leaves of tree species was observed during the post monsoon season with the change in species, sites. The leaf extract pH of the selected plant species varied significantly, ranging from 6.61 to 7.09. The highest (7.03) leaf extract pH was recorded in *Dalbergia sisso*, while the lowest (6.81) was recorded in *Mangifera indica*. The leaf extract pH of the selected plant species growing at various sites also differed significantly, with the highest (6.98) leaf extract pH at LR followed by SH (6.95) and lowest (6.87) leaf extract pH was noticed at NH. Leaf extract pH in the leaves of tree species was observed higher during post monsoon (6.93) whereas in pre monsoon season it was 6.88. The findings are consistent with those of Jyothi and Jaya (2010), who found a higher pH during the post monsoon season as a result of acidic contaminants being washed away by rain.

Table 3: Variation in leaf extract pH of tree species growing along highways of Shivalik foothills during pre and post monsoon season

Sites	Pre monsoon			Post-monsoon			Pooled	
	Plant species							
	MI*	FP*	DS*	MI*	FP*	DS*	Pre monsoon	Post-monsoon
NH	6.68±0.02	6.77±0.03	6.85±0.02	6.78±0.02	6.87±0.01	6.96±0.02	6.76±0.03	6.87±0.03
SH	6.77±0.04	6.90±0.01	6.99±0.01	6.82±0.03	6.95±0.01	7.08±0.01	6.89±0.04	6.95±0.04
LR	6.91±0.02	7.03±0.01	7.05±0.02	6.86±0.02	7.03±0.01	7.06±0.01	6.99±0.03	6.98±0.04
Mean	6.78±0.02	6.89±0.02	6.96±0.01	6.81±0.02	6.95±0.01	7.03±0.01	6.88±0.03	6.93±0.04
CD (*p*=0.05)								
Species	0.08			Species		0.09	MI*- *Mangifera indica*	
Site	0.12			Site		0.11	FP*- *Ficus palmata*	
Species×Site	0.13			Species × Site		0.12	DS*-*Dalbergia sisso*	

Mean±SE (Standard error) of three values

3.4. Relative water content

The relative water content of tree species during pre monsoon changed significantly with sites, species (Table 4). *Mangifera indica* had the highest relative water content (77.27%), followed by *Dalbergia sisso* (66.70%), and *Ficus palmata* had

Table 4: Variation in relative water content (%) in tree species growing along highways of Shivalik foothills during pre and post monsoon season

Sites	Pre monsoon			Post-monsoon			Pooled	
	Plant species							
	MI*	FP*	DS*	MI*	FP*	DS*	Pre monsoon	Post-monsoon
NH	80.31±0.35	66.57±0.63	69.52±0.87	80.59±0.69	66.93±0.70	70.37±0.67	72.13±2.41	72.53±2.37
SH	79.08±0.93	65.92±0.56	67.91±0.73	79.30±0.65	66.15±0.69	69.99±0.68	70.97±2.36	71.37±6.76
LR	72.44±0.71	63.37±0.59	62.67±0.71	73.69±0.73	64.10±0.68	63.72±0.38	66.16±1.82	66.95±5.65
Mean	77.27±0.04	65.28±0.20	66.70±0.29	77.86±0.25	65.72±0.39	68.02±0.12	69.75±2.18	70.28±6.44
CD (p=0.05)								
Species	0.04				Species	0.18	MI*- *Mangifera indica*	
Site	0.08				Site	0.12	FP*- *Ficus palmata*	
Species×Site	0.09				Species × Site	0.22	DS*-*Dalbergia sisso*	

Mean±SE (Standard error) of three values

the lowest relative water content (65.78%). The relative water content of the selected plant species growing at different sites also differed significantly, with the highest relative water content (72.13%) at NH, followed by SH (70.97%), and the lowest relative water content (66.16%) at LR. Plants at polluted sites consumed more water as a result of their physiological mechanisms for coping with contaminants in their atmosphere (Tanee et al., 2014). Pandit et al., (2017) found that relative water content was 85.80% at a distance of 0-10 m and 81.97% at a distance of 10-20 m. Similar trend of relative water content in leaves of tree species was observed during the post monsoon season with the change in species, site *Mangifera indica* had the highest relative water content (77.86%) and *Dalbergia sisso* had the lowest relative water content (67.26%). The relative water content of the selected plant species growing at different sites also varied significantly with highest (72.53%) relative water content was observed at NH followed by SH (71.37%) and lowest (66.95%) relative water content was noticed at LR. Relative water content in the leaves of tree species was observed higher during post monsoon (70.28%) whereas in pre monsoon season it was 69.75%. The results are in line with the findings of Jyothi and Jaya (2010) who reported higher relative water content during post monsoon season as compared to pre monsoon season.

3.5. APTI

Along the different sites, the APTI of selected plants showed maximum value at NH (10.07) followed by SH (9.75) and LR (9.00) (Table 5). With increasing horizontal distances from the highway, the air pollution tolerance index of the selected plant species varied. Panda et al., (2018) stated higher APTI values associated with higher tolerance of plant species to air pollutants. The capacity of plants to respond to stress conditions produced by vehicular pollution may be attributed to the highest APTI of plants growing at a horizontal distance of 0-20 m. These results are in line with the findings of Jyothi and Jaya (2010) who have pointed higher APTI values associated with higher tolerance of plant species to air pollutants (Noor et al., 2015). Along the different sites, the APTI of selected plants showed maximum results at NH (10.07) followed by SH (9.75) and LR (9.00). With increasing horizontal distances from the highway, the air pollution tolerance index of the selected plant species varied. APTI of selected plants alongside the selected sites was observed more during post monsoon (10.06) as compared to pre monsoon (9.61). The results showed that in the post monsoon season, all of the selected plant species had higher mean APTI values of 9.52 than in the pre monsoon season (9.40). The higher APTI values during the post monsoon season can be attributed to plant species' adaptive capacity to combat stress during this time

Table 5: Evaluation of plant species based on APTI and some biological and socio-economic characteristics growing along highways of Shivalik foothills

Sites	Assessment parameters				Laminar structure				Grade allotted		
	APTI	Plant Habit	Canopy structure	Tree type	Size	Texture	Hardiness	Economic importance	Total plus	% Scoring	API Grade
Mangifera indica	+++++	++	+	+	++	-	+	++	14	87.50	6
Ficus palmata	+++	+	+	-	+	+	-	++	9	56.25	3
Dalbergia sisso	+++++	+	+	-	+	+	+	++	12	75.00	6

of year. Mean values of both season was collectively taken for the evaluation of APTI. Based on assessment parameters, selected plant species was analyzed. Among the selected plants, *Dalbergia sisso, Mangifera indica* showed highest API grade of 6 (excellent) followed by *Ficus palmata* (3) (moderate)

API is used as an indicator to assess the capability of predominant species in the cleanup of atmospheric pollutants. *Dalbergia sisso* and *Mangifera indica* have the highest API values, which may be attributed to their high APTI values (Table 6). Better laminar characteristics such as leaf size, texture, and canopy structure, as well as a high economic value, may have boosted its API value to an excellent level *(Dalbergia sisso and Mangifera indica*).

Table 6: Anticipated performance index (API) of selected plant species along highways of Shivalik foothills

Plant species	Total plus	% Scoring	API grade	Assessment
Mangifera indica	14	87.50	6	Excellent
Ficus palmata	9	56.25	3	Moderate
Dalbergia sisso	12	75.00	5	Very good

Ficus palmata, on the other hand, has a low API value due to its small leaf size, smooth leaf surface, and comparatively low economic significance, making it fall into the not recommended group. These findings support those of Karthiyayini et al. (2005) and Prajapati and Tripathi (2008), who discovered that species with higher APTI have better plant and leaf characteristics and hence have a higher value of API. API grade 6 for *Mangifera indica* and *Dalbergia sisso*, with higher APTI likely due to better plant and leaf characteristics (Prajapati and Tripathi, 2008), and thus recommended for greenbelt alongside highways, as suggested by Tsega and Deviprasad (2014). Higher APTI values indicated the ability for plant species to flourish in contaminated areas, potentially polluting the air.

Statistical significance (student t-test) of seasonal variation of biochemical parameters in leaf of selected tree species alongside the different roads in the study area was carried out for the combined data of pre and post monsoon (Table 1-6), which is presented in Table 7. The critical value (the difference of means between pre and post monsoon) at 34 degree of freedom was 1.68. Since the tabulated t-values of ascorbic acid content and APTI is greater than critical value, these are significant at 5% level. Hence, the results clearly indicated that there was significant seasonal effect on mean values of ascorbic acid content and APTI whereas there was no impact of seasons on total chlorophyll content, leaf extract pH and relative water content.

Table 7: Student t-test of seasonal variation between different parameters

Parameters	Calculated t-value	Tabulated t-value at 0.05 level	Significant/ Non-significant	Assessment
Ascorbic Acid Content	1.68	2.70	Significant	Excellent
Total Chlorophyll Content	1.68	0.13	Non-Significant	Moderate
Leaf Extract pH	1.68	0.91	Non-Significant	Very good
Relative Water Content	1.68	0.25	Non-Significant	
APTI	1.68	1.93	Significant	

4. Conclusion

Road activities are responsible for introducing pollutants to environment in its vicinity. comparative study detailed that the road activities on NH have significantly affected the plant health as compared to SH and LR. The anticipated performance index of the selected plant species ranged from moderate to excellent. Among all three selected plant species, *Mangifera indica* was categorized as excellent with high grade of 6 API and scoring 87.50%, hence resulted to be most tolerant species to pollution in the study area.

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