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Evaluation of air pollution tolerance index of certain plant species grown alongside Parwanoo to Solan National Highway- 22 in Himachal Pradesh, India

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Abstract: The study examined the Air Pollution Tolerance Index (APTI) of selected plant species growing along national highway-22 from Parwanoo to Solan, falling in Solan district of Himachal Pradesh, India. Four species namely *Grewia optiva*, *Toona ciliata*, *Melia azedarach* and *Woodfordia floribunda* of uniform size, age, spread and common in occurrence on both sides of the highway are selected. Leaf samples were collected from selected species and used to estimate four physiological and biochemical parameters, namely; leaf relative water content (RWC), ascorbic acid content (AA), total leaf chlorophyll (TChl) and leaf extract pH were used to compute the APTI values. The trend of APTI recorded for various species was *Melia azedarach* (18.37) > *Grewia optiva* (8.77) > *Woodfordia floribunda* (7.43) > *Toona ciliata* (6.82). The APTI also varied with seasons of the year. The highest APTI was noticed in rainy followed by winter and summer season. The study indicated *Melia azedarach* as most tolerant and *Toona ciliata* as most sensitive species to air pollution.

Keywords: Air pollution tolerance index (APTI), Melia azedarach, Toona ciliata, Grewia optiva, Woodfordia floribunda

INTRODUCTION

Air pollution is a major problem arising mainly from industrialization, unplanned urbanisation, alarming increase in vehicle fleet and population growth which become a serious environmental stress to plants during the last few decades (Rajput and Agarwal, 2004). The particulates and gaseous pollutants, cause serious setbacks to the overall physiology of plants (Das and Prasad, 2010). The impact of air pollution on plant species is one of the major ecological issues as plants play an important role in monitoring and maintaining the ecological balance by actively participating in the cycling of nutrients and gases, provide enormous leaf area for the impringement, absorption and accumulation of air pollutants to reduce the pollution level in the air environment.

Sensitivity and response of plants to air pollutants is variable and are considers for investigation of effect of auto exhaust pollutants. The most obvious damage occurs in the leaves which include chlorosis, necrosis and epinasty (Prasad and Choudhury, 1992). The response of plants to air pollution may provide a simple method of monitoring air pollutants as well as providing the pollution abatement measures. The plant species which are more sensitive act as biological indicators of air pollution. Singh and Rao (1983) have suggested a method of determining Air Pollution Tolerance Index (APTI) by synthesizing the values of four different biochemical parameters i.e. leaf extract, ascorbic acid, total chlorophyll and relative water contents. Air pollution tolerance index has been used by landscapers to select and rank plant species in their order of tolerance to air pollution (Liu and Ding, 2008). So the present monitoring work was undertaken to determine the APTI values of selected plant species which are commonly occurred on the both sides of national highway-22 from Parwanoo to Solan. The study will also identify the plant species which are tolerant to the prevailing atmospheric conditions.

MATERIALS AND METHODS

Study area: The entire study area extended from Parwanoo to Solan, 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". The total distance of National Highway between Parwanoo to Solan is 41 kms. The National Highway on the way to Shimla, a famous tourist place is subjected to heavy traffic load. The climate of the district is sub-tropical in the valley and tends to be temperate in the hilltops. Average annual rainfall in the district is about 1100 mm with average of 64 rainy days and Mean maximum and minimum temperature ranges

between 34°C and 4°C. The Parwanoo-Solan national highway falling in Solan district of Himachal Pradesh is on the hilly terrain having loose strata and generally moderately to steeply sloped with number of curves with altitude ranging from 350 to 1800 meter above mean sea level.

Sampling: For conducting studies the whole area was divided in two parts, i) Parwanoo to Dharmpur ii) Dharmpur to Solan. The study was conducted during three seasons mainly winter (November, 2011), summer (May, 2012) and rainy (August, 2012). Four plant species viz. *Woodfordia floribunda, Toona ciliata, Melia azedarach* and *Grewia optiva* were selected at two distances (D1: 0-5 m and D2: 5-10 m) on the both sides of road for the present investigation. The plants selected for study were uniform with respect to their diameter at breast height (dbh), crown spread and were common in their occurrence on both sides of the highway. The relevant characteristic of these plants are shown in Table 1.

Biochemical analysis: Fully matured leaves from trees were collected in morning hours at diameter breast height (DBH) and from the shrubs 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 (Hiscox and Israeistam, 1979), ascorbic acid (A.O.A.C., 1980), leaf extract pH (Singh and Rao, 1983) and relative water content (Turner, 1981). By using the above parameters the air pollution tolerance index was computed by the method suggested by Singh and Rao (1983) using the equation.

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

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.

RESULTS AND DISCUSSION

The vegetation nearby national highway is exposed to dust pollution and chronic concentration of gaseous pollutants, which may affect the biochemical make up, and tolerance capability of plants to the air pollution. The biochemical characteristics and the APTI for plants are shown in Tables 2, 3, 4, 5 and 6 respectively.

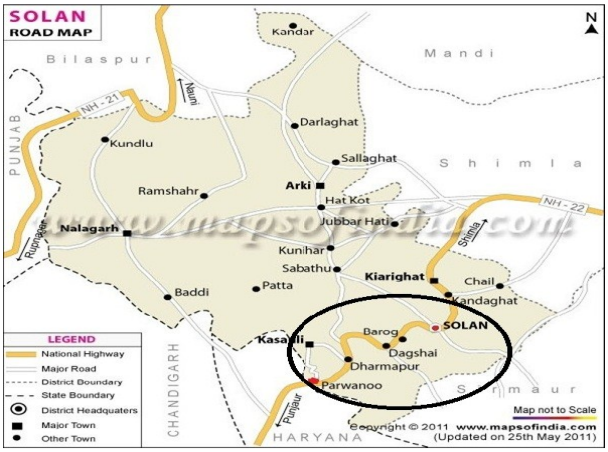

Fig. 1. *Map showing the study area.. Source: (www.mapsofindia.com).*

The total Chlorophyll content (Table 2) varied with species and seasons. The highest chlorophyll content was found in *M. azedarach* (7.18 mg g^{-1}) followed by *W. floribunda* (4.91 mg g^{-1}), *G. optiva* (3.54 mg g^{-1}) and *T. ciliata* (2.18 mg g^{-1}). The chlorophyll content in all the plants varied with the tolerance as well as sensitivity of the plant species to pollution load (Joshi *et al.,* 1993) and the high level of automobile pollution decreases chlorophyll content in higher plants near roadsides (Tripathi and Gautam, 2007). The chlorophyll content was observed highest among the plant species during rainy (4.90 mg g^{-1}) followed by winter (3.84 mg g^{-1}) and lowest in the summer season (3.63 mg g^{-1}). Similar results were obtained by Jyothi and Jaya (2010) who reported high chlorophyll content in plant species during rainy season which may be due to the washout of dust particles from the leaf surface, low level of pollution and water content of soil followed by winter may be due to the high pollution level, temperature stress, low sunlight intensity and short photoperiod and summer season may be due to high sunlight, reduce moisture content and high wind speed.

The concentration of ascorbic acid (Table 3) varied from species to species and season to season. The highest ascorbic acid content was found in *M. azedarach* (8.40 mg g^{-1}), *G. optiva* (3.62 mg g^{-1}), *W. floribunda* (2.79 mg g^{-1}) and lowest in *T. ciliata* (2.13 mg g^{-1}) indicating that the species with high ascorbic content is tolerant and lower ascorbic acid is sensitive to pollution (Prajapati and Tripathi, 2008)

Table 1. Characteristics of selected plants at study site from Parwanoo to Solan on national highway-22, India.

Name of Plant	Family	Common name	Habit	Leaf shape	Average Plant height approx. (m)
Woodfordia floribunda	Lythraceae	*Dhatki, Dhawai*	Shrub	Elliptical	3
Toona ciliata	Meliaceae	*Toon, Indian mahogany*	Tree	Elliptical (Leaflet-Imparipinnate)	25
Melia azedarach	Meliaceae	*Drek, Bead tree*	Tree	Elliptical (Leaflet-Tripinnate)	18
Grewia optiva	Tiliaceae	*Dhaman, Biul*	Tree	Ovate	12

Table 2. Season wise leaf chlorophyll content (mg g^{-1}) of selected plant species in relation to distance from roadside on Parwanoo to Solan national highway- 22, India.

Name of Species	Season									D1*	D2*	Mean
	Rainy			Winter			Summer					
	D1*	D2*	Mean	D1*	D2*	Mean	D1*	D2*	Mean			
Woodfordia floribunda	5.36	5.37	5.36	4.84	4.83	2.68	4.54	4.54	4.54	4.92	4.91	4.91
Toona ciliata	2.62	2.61	2.62	2.10	2.09	2.09	1.83	1.82	1.82	2.18	2.17	2.18
Melia azedarach	7.64	7.65	7.64	7.10	7.11	7.11	6.81	6.79	6.80	7.18	7.18	7.18
Grewia optiva	3.99	3.98	3.98	3.48	3.47	3.47	3.19	3.14	3.17	3.55	3.53	3.54
Mean	4.90	4.90	4.90	4.38	4.38	3.84	4.09	4.07	3.63	4.46	4.45	

*D1= 0-5 m and D2= 5-10 m are distances from the roadside

Table 3. Season wise leaf ascorbic acid content (mg g^{-1}) of selected plant species in relation to distance from roadside on Parwanoo to Solan national highway- 22, India.

Name of Species	Season									D1*	D2*	Mean
	Rainy			Winter			Summer					
	D1*	D2*	Mean	D1*	D2*	Mean	D1*	D2*	Mean			
Woodfordia floribunda	2.29	2.31	2.30	2.81	2.84	2.83	3.25	3.26	3.25	2.79	2.80	2.79
Toona ciliata	1.62	1.63	1.62	2.17	2.17	2.17	2.60	2.60	2.60	2.13	2.13	2.13
Melia azedarach	7.88	7.88	7.88	8.44	8.44	8.44	8.87	8.87	8.87	8.39	8.40	8.40
Grewia optiva	3.12	3.11	3.12	3.67	3.65	3.66	4.09	4.08	4.09	3.63	3.61	3.62
Mean	3.73	3.73	3.73	4.27	4.27	4.27	4.70	4.70	4.18	4.23	4.24	

*D1= 0-5 m and D2= 5-10 m are distances from the roadside

and also ascorbic acid content was recorded highest among the plant species during winter season (4.27 mg g^{-1}) followed by summer season (4.18 mg g^{-1}) and lowest in the rainy season (3.73 mg g^{-1}).

Variation was observed in pH of leaf extract (Table 4) of different species during different seasons. The highest pH was recorded in the rainy season followed by winter season and lowest in summer season. Among selected plant species leaf extract pH was highest in *M. azedarach* (7.66) followed by *G. optiva* (6.75), *T. ciliata* (6.60) and lowest in *W. floribunda* (5.85) indicating that *M. azedarach* with high pH is tolerant to acidic pollutants and *W. floribunda* having lowest pH is sensitive. The present results are in line with Jyothi and Jaya (2010) who reported that sensitive species has less pH and also the decline in pH is greater in sensitive species in the presence of an acidic pollutant and also reported the maximum pH during monsoon season with gradual reduction through winter and minimum in summer.

Table 4. Season wise leaf extract pH of selected plant species in relation to distance from roadside on Parwanoo to Solan national highway- 22, India.

Name of Species	Season									D1*	D2*	Mean
	Rainy			Winter			Summer					
	D1*	D2*	Mean	D1*	D2*	Mean	D1*	D2*	Mean			
Woodfordia floribunda	6.21	6.24	6.23	5.83	5.86	5.84	5.46	5.50	5.48	5.83	5.87	5.85
Toona ciliata	7.05	6.96	7.00	6.66	6.58	6.62	6.15	6.22	6.19	6.62	6.59	6.60
Melia azedarach	8.19	7.96	8.07	7.80	7.35	7.57	7.45	7.21	7.33	7.81	7.51	7.66
Grewia optiva	7.11	7.15	7.13	6.72	6.76	6.74	6.37	6.40	6.39	6.73	6.77	6.75
Mean	7.14	7.08	7.11	6.75	6.64	6.69	6.36	6.33	5.64	6.75	6.68	

*D1= 0-5 m and D2= 5-10 m are distances from the roadside

Table 5. Season wise leaf relative water content (%) of selected plant species in relation to distance from roadside on Parwanoo to Solan national highway- 22, India.

Name of Species	Season									D1*	D2*	Mean
	Rainy			Winter			Summer					
	D1*	D2*	Mean	D1*	D2*	Mean	D1*	D2*	Mean			
Woodfordia floribunda	56.42	58.45	57.43	39.65	41.65	40.65	34.82	35.87	35.35	43.63	45.32	44.48
Toona ciliata	61.63	63.92	62.77	44.48	47.15	45.81	39.34	42.07	40.70	48.48	51.05	49.76
Melia azedarach	73.11	71.39	72.25	56.36	54.63	55.49	50.98	49.56	50.27	60.15	58.52	59.34
Grewia optiva	61.34	65.79	63.56	44.67	49.07	46.87	39.39	43.86	41.63	48.47	52.91	50.69
Mean	63.13	64.89	64.01	46.29	48.12	47.21	41.13	42.84	37.32	50.18	51.95	

*D1= 0-5 m and D2= 5-10 m are distances from the roadside

Table 6. Season wise air pollution tolerance index (APTI) of selected plant species in relation to distance from roadside on Parwanoo to Solan national highway- 22, India.

Name of Species	Season									D1*	D2*	Mean
	Rainy			Winter			Summer					
	D1*	D2*	Mean	D1*	D2*	Mean	D1*	D2*	Mean			
Woodfordia floribunda	8.30	8.53	8.41	6.97	7.20	7.08	6.73	6.86	6.80	7.33	7.53	7.43
Toona ciliata	7.73	7.95	7.84	6.35	6.60	6.47	6.01	6.29	6.15	6.70	6.95	6.82
Melia azedarach	19.78	19.44	19.61	18.21	17.66	17.94	17.74	17.38	17.56	18.58	18.16	18.37
Grewia optiva	9.60	10.04	9.82	8.21	8.64	8.42	7.85	8.28	8.06	8.55	8.98	8.77
Mean	11.35	11.49	11.42	9.93	10.02	9.98	9.58	9.70	8.57	10.29	10.41	

*D1= 0-5 m and D2= 5-10 m are distances from the roadside

The study showed highest relative water content (Table 5) in *M. azedarach* (59.34%) followed by *G. optiva* (50.69%), *T. ciliata* (49.76%) and lowest in *W. floribunda* (44.48%). The relative water content was recorded highest during rainy season (64.01%) with a decline in the level during winter (47.21%) and lowest in the summer season (37.32%). This is in agreement with the findings of Jyothi and Jaya (2010) who reported that the plant with high relative water content under polluted conditions are tolerant to pollutants and also observed highest relative water content in monsoon season followed by winter and rainy season.

Air pollution tolerant index is an index denotes capability of a plant to combat against air pollution. Plants which have higher index value are tolerant to air pollution and can be caused as sink to mitigate pollution, while plants with low index value show less tolerance and can be used to indicate levels of air pollution. The trend of APTI (Table 6) for different plant species was *M. azedarach* (18.37) > *G. optiva* (8.77) > *W. floribunda* (7.43) > *T. ciliata* (6.82). The different plant species shows considerable variation in their susceptibility to air pollution. The plants with high and low APTI can serve as tolerant and sensitive species, respectively. The results are in consonance with the findings of Singh and Rao (1983) who reported that plants which have higher index value are tolerant to air pollution and can be used as sink to control pollution, while plants with low index value show less tolerance and can be used to indicate levels of air pollution. The APTI values varied significantly with different seasons. The highest APTI value was recorded in rainy (11.42) followed by winter (9.98) whereas, lowest was found in summer (8.57) season. The APTI value evaluated for the two distances varied significantly. The maximum APTI (10.41) was found at 5-10 m and minimum (10.29) at 0-5 m. Similar study of air pollution tolerance index was also conducted by Karthiyayini *et al.* (2005) on different species; *Azadirachta indica*, amongst trees, *Ricinus communis*, *Bougainvillea spectabilis*, *Calatropis gigantea*, amongst shrubs, *Amaranthus virdis*, *Datura stramonium*, amongst herbs, *Cucurbita pepo*, amongst climbers, Agbaire and Esiefarienrhe (2009) on different species; *Emilia Santifolia, Manihot esculenta, Psidium guayava, Eupatorium odoratum, Impereta cylindrical* and *Elaesis guineensis,* Tripathi *et al.* (2009) on tree species such as *Ficus rumphii*, *Pongamia pinnata*, *Alstonia scholaris*, *Holoptelea integrifolia*, *Saraca indica*, *Pithecolobium dulcis*, *Cassia simea*, *Bauhinia variegata*, *Azadirachta indica* and *Grewelia robusta* and Chauhan (2010) on different species like *Ficus religiosa, Mangifera indica, Polyalthia longifolia* and *Delonix regia*.

Conclusion

The present study indicated the suitability of selected plant species as tolerant or sensitive for air pollution as per their APTI values. It can be utilized for roadside plantation, urban plantation and green belt development to reduce the level of air pollution. It was also observed that the biochemical traits of selected species are one of the valuable sensitive indicators of air pollution. The APTI evaluation showed highest tolerance of *M. azedarach* to air pollution and the order of tolerance was *M. azedarach* > *G. optiva* > *W. floribunda* > *T. ciliata* among the selected plant species. Therefore, these plant species may be used as a biodiversity indicator which can alleviate air pollutants. However, more research is necessary on a wide variety of trees, shrubs, and herbs to prepare a biological sensitively map of flora. The vast database would be useful in identifying tolerant plants, sink plants and indicator species for effective air pollution management program.

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