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Seasonal Variation in Air Pollution Tolerance Index of Various Plant Species of Baroda City

Tanushree Bhattacharya[1*], Leena Kriplani[2], Sukalyan Chakraborty[3]

1,3 Environmental Science and Engineering Group, Birla Institute of Technology, Mesra Ranchi, Jharkhand-835215
2 Department of Environmental Science, Institute of Science and Technology For Advanced Studies and Research, Vallabh Vidyanagar, Gujarat-388120

***Corresponding Author's: tanu_shreeb@yahoo.com, tbhattacharya@bitmesra.ac.in**

Abstract:

Clean air, pure water and nutritious food are basic amenities of life but the quality of air, water and land is deteriorating continuously. Air Pollution is any atmospheric condition in which certain substances are present in such concentration that can produce undesirable effects on man & its environment Industrial air pollution is more complex than most other environmental challenges. Air pollution tolerance level differs from plant to plant. To evaluate the tolerance level of plant species to air pollution, four leaf parameters are used to drive an empirical number indicating the Air Pollution Tolerance Index (APTI). Air pollution tolerance index has also been used to rank plant species in their order of tolerance to air pollution. The aim of this study is therefore to determine the APTI values of six plants species which were collected from 9 sites of Baroda city. Leaf samples of selected plant species found at all the sampling sites were collected i.e *Azadirachta indica, Polyalthia longifolia, Ficus bengalensis, Mangifera indica, Acacia arabica & Peltophorum pterocarpum* in three different seasons (Monsoon, Winter& Summer). Chlorophyll value was highest during monsoon season & decreased in winter and summer. All the plant samples collected from polluted site exhibited a pH towards acidic side. Present study showed higher leaf relative water content in all the species was in monsoon season. Whereas the higher average ascorbic acid concentration was found in winter season followed by summer and least in monsoon. Based on the highest calculated APTI irrespective of the season the plants were found to having the following order *Polyalthia longifolia>Azadirachta indica>Ficus bengalensis> Acacia Arabica>Peltophorum pterocarpum>Mangifera indica*. But if the average APTI values of all the season is to be considered then the order will be as follows: *Azadirachta indica>Polyalthia longifolia>Mangifera indica>Ficus bengalensis> Acacia arabica>Peltophorum pterocarpum.* Except *Acacia* all the other species showed insignificant seasonal variation in APTI according to ANOVA, α=0.05. So far, this aspect of pollution management was not studied in the study area. So, this study may particularly be helpful for the air pollution management of the city specially during aforestation programmes.

Keywords: APTI, air pollution, Baroda city, Gujarat, seasonal variation, tolerance

1.0 Introduction:

Urban air pollution is a serious problem in both developing and developed countries. The increasing number of industries and automobile vehicles are continuously adding toxic gases and other substances to the environment. Over the years, there has been a continuous increase in human population, road transportation, vehicular traffic and industries which has resulted in further increase in the concentration of gaseous and particulate (Agbaire and Esiefarienrhe, 2009). All combustion releases gases and particles into the air. These can include oxides of sulphur and nitrogen, carbon monoxide and soot particles, as well as trace quantities or toxic metals, organic molecules and radioactive isotope (Agrawal and Tiwari, 1997). Plants exhibit many physiological changes in response to air pollution. With season the pollution load and the physiological response of the plants changes. By monitoring plants tolerance towards air pollution they can be screened and can be employed as biological indicators or monitors of air pollution.

Then they can be used effectively by planners and green belt developers in managing the urban air pollution. Response of plants towards air pollution can be determined by finding air pollution tolerance index of each plant species. The air pollution tolerance index (APTI) based on four parameters has been used for identifying tolerance levels of plants species (Beg *et al,* 1990; Chauhan, 2010). The four parameters are: Chlorophyll, Ascorbic acid, pH, and Relative water content (RWC). The aim of this study is therefore to determine the seasonal APTI values of commonly growing plant species in the heavily trafficked area of Baroda city, Gujarat and recommend the most suitable plants for the aforestation purposes.

2.0 Materials and Methods:

2.1 Study Area

Vadodara, formerly known as Baroda, is the third most populated city in the Indian State of Gujarat. Vadodara is one of India's most cosmopolitan cities. Vadodara is located at 22.30°N 73.19°E in western India at an elevation of 39 meters (123 feet). It is the 18th largest city in India with an area of 148.95 km².

2.2 Sampling Sites

Nine sampling sites were chosen based on the traffic density and industrial activities. GIDC area and Nandesari are dominated with industrial activities while, other sites like Alkapuri, Dandia Bazaar Nyay Mandir, Mandvi, Railway Station, Fatehgunj, Raopura are mainly commercial areas and highly trafficked.

Leaf samples of selected plant species were collected from all the sites. The species found were *Azadirachta indica, Polyalthia longifolia, Ficus bengalensis, Mangifera indica, Acacia arabica & Peltophorum pterocarpum.* The availability of these species along with the sites and site code is shown in Table 1.

The sampling was done in 3 phases, 1st phase sampling has been done in the month of August in the monsoon .The 2nd phase sampling has been done in December which was post monsoon phase & 3rd phase sampling has been done in May; in pre-monsoon. Leaf samples were collected in air tight plastic bags. The leaf fresh weight was taken immediately upon getting to the laboratory. Then samples were preserved in refrigerator at 0^{o}C for biochemical analysis.

The samples were estimated for Leaf-extract pH (Singh *et al,* 1991), relative moisture content(Weatherly, 1965**)**, total chlorophyll**(**Arnon, 1949) and ascorbic acid(Keller and Schwanger, 1977**).**

2.3Estimation of Leaf-extract pH

0.5 g of leaf material was ground to paste and dissolved in 50 ml of deionized water and Leaf-extract pH was *measured by using calibrated digital pH meter (model).*

2.4 Estimation of relative moisture content

Fresh leaf samples collected from the study area were brought immediately to the laboratory and washed thoroughly. The excess water was removed with the help of blotting paper. The initial weight of samples were taken and kept in oven at 60^{o}C until constant weight was obtained and the final weight was taken.

2.5 Estimation of Total Chlorophyll and Ascorbic acid

Chlorophyll was estimated by acetone extraction method and ascorbic acid was estimated by 2, 6-dichlorophenol-Indophenols's dye method. APTI given by APTI = $\{[A (T + P) + R] / 10\}$.Where A is the ascorbic acid in mg/g; T is the total chlorophyll in mg/g; P is pH of leaf sample; and R is relative water content (RWC) of leaf (%). Based on the APTI grouping, the plants were grouped as follows (Chaudhary and Rao, 1977). APTI index range: <1=very sensitive, 1 to 16=sensitive, 17-29=intermediate, 30-100=tolerant. Correlation and ANOVA was performed using Excel Statistical analysis tool pack, 2007.

3.0 Results and Discussion:

3.1 Changes in the Total Chlorophyll

Chlorophyll content of plants signifies its photosynthetic activity as well as the growth and development of biomass. It is well evident that chlorophyll content of plants varies from species to species; age of leaf and also with the pollution level as well as with other biotic and abiotic conditions (Abida, and Harikrishna, 2010). The total chlorophyll content of selected species during monsoon, winter & summer are illustrated graphically in Fig.1 a, b, c, d, e and f respectively. Among the tree species, *Ficus bengalensis* showed higher of total chlorophyll of about 4.7 mg /gm followed by *Azadirachta indica* and *Polyalthia longifolia.* Regarding the study sites, the chlorophyll content of the species varied. Chlorophyll value was highest during monsoon season & decreased in winter and summer. Irrespective of study sites, higher levels of total chlorophyll was observed in *Ficus bengalensis.* However, according to two-way ANOVA at 0.05 level of significance the site-wise and season wise variation was non-significant for *Azadirachta indica.* But for *Polyalthia longifolia* site-wise variation was non-significant but seasonal variation was significant. Again, *Ficus bengalensis* and *Acacia Arabica* showed significant site wise and seasonal variations. Whereas, *Mangifera indica* showed significant seasonal variation and non-significant site-wise variation. For *Peltophorum pterocarpum* site-wise variation was significant but seasonal variation was non-significant.

3.2 Changes in Ascorbic Acid Content

Among the tree species studied, *Azadirachta indica* showed higher levels of Ascorbic Acid content. Figure 2a, b, c, d, e and f are the graphical illustration of leaf ascorbic acid contents in the selected species during monsoon, winter and summer. The higher average ascorbic acid concentration was found in winter season followed by summer and least in monsoon. However the site wise variation in all the three seasons were found insignificant according to ANOVA at α=0.05 level. Seasonal variation was only found significant in *Polyalthia longifolia, Acacia arabica* and *Peltophorum pterocarpum.*

Table 1: .Species availability in all the sampling sites

Site Code	Sites	*Azadirachta indica*	*Polyalthia longifolia*	*Ficus bengalensis*	*Mangifera indica*	*Acacia arabica*	*Peltophorum pterocarpum*
1	GIDC	+	+	+	+	+	-
2	Alkapuri	+	+	+	+	-	+
3	Dandia Bazaar	+	+	-	-	+	-
4	NyayaMandir	+	+	-	-	+	+
5	Nandesari	+	-	+	+	+	+
6	Mandvi	+	+	-	-	-	+
7	Railway Station	+	+	+	+	+	-
8	Fatehgunj	+	+	+	+	-	-
9	Raopura	+	+	+	-	+	+

3.3 Changes in leaf extract pH

All the plant samples exhibited an acidic pH. The pH results are shown in Table 2 to 7. In most of the plant samples it was observed that pH was less in monsoon followed by winter and summer. In monsoon, due washing of leaves there was least dust accumulation whereas, in winter and summer dust accumulation is more which can cause dust particle dissolution in cell sap and increasing the pH (Katiyar, and Dubey, 2001). However, seasonal variation was found significant only in *Azadirachta indica, Mangifera indica,* and *Acacia arabica* (α=0.05). Although the sitewise variation was nonsignificant for all the species.

3.4 Changes in Relative water content

The leaf Relative water content values of the selected plant species for different seasons are depicted in Table2-7. Relative water content was found higher in the monsoon season in all the species studied. In *Acacia Arabica* and *Peltophorum pterocarpum* least average RWC was found in winter and in the rest of the species in summer. Seasonal variation was significant (α=0.05) in *Ficus bengalensis* and *Acacia Arabica.* Site wise variation was significant in *Mangifera indica, Acacia arabica* and *Peltophorum pterocarpum.*

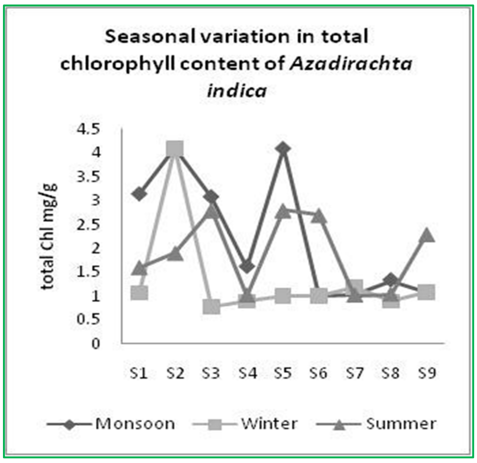
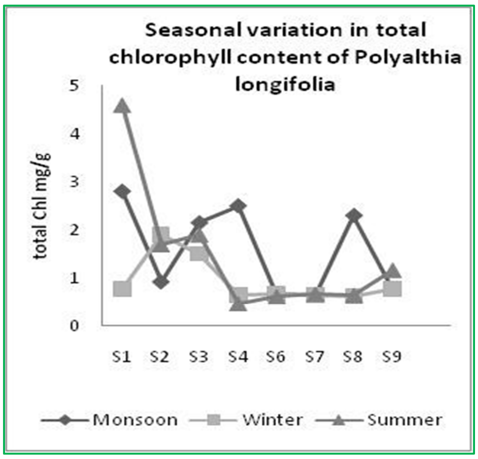


Figure 1a



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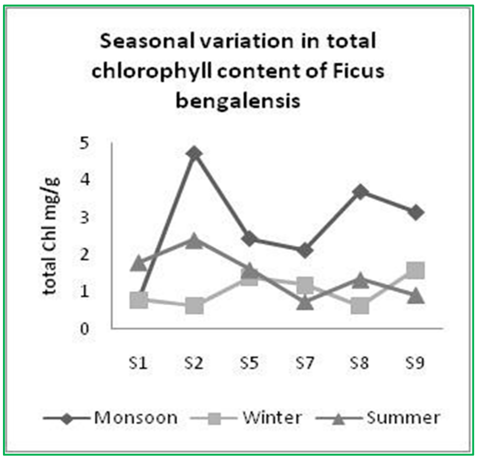

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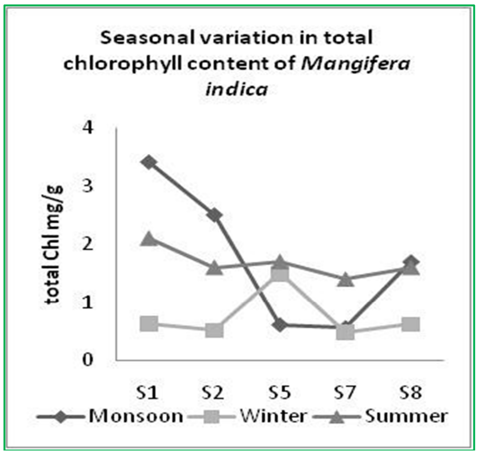

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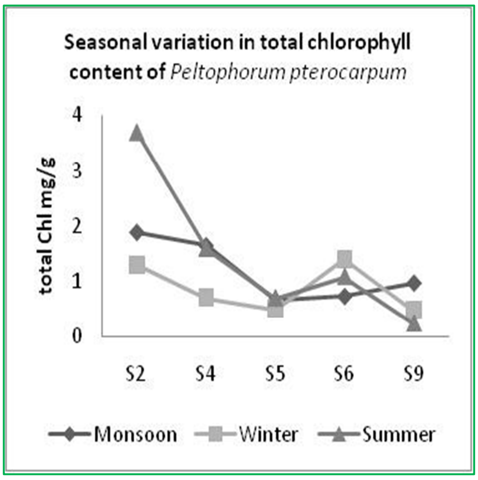


Figure 1e

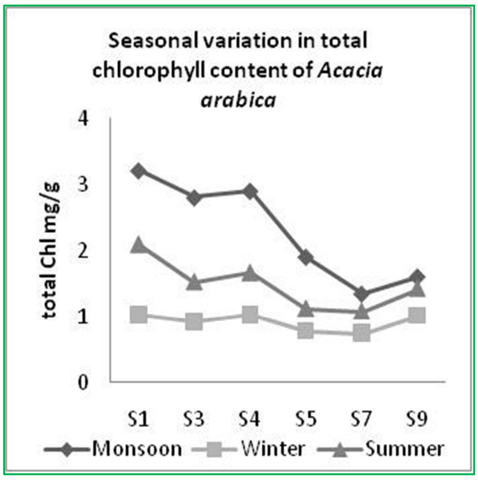


Figure 1f

Figure1a to f: seasonal variation in total chlorophyll content.

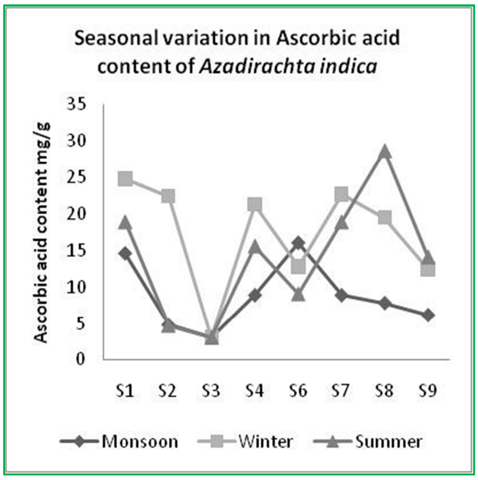


Figure 2a

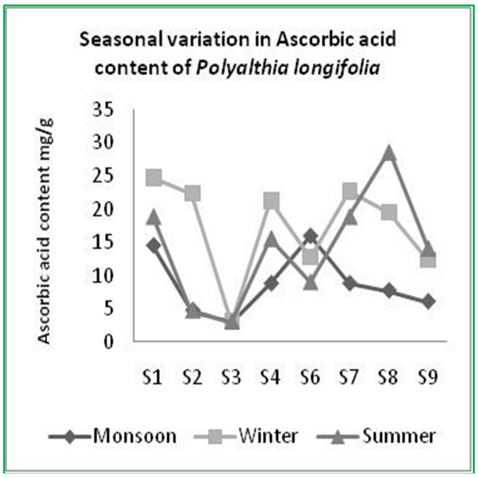
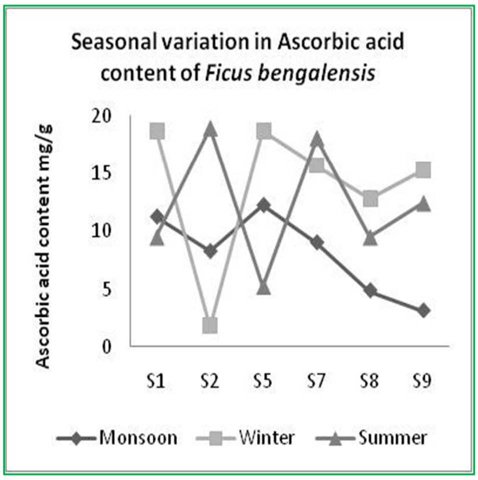


Figure 2b



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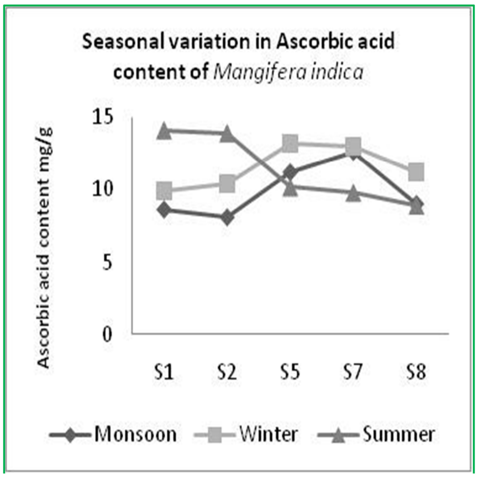
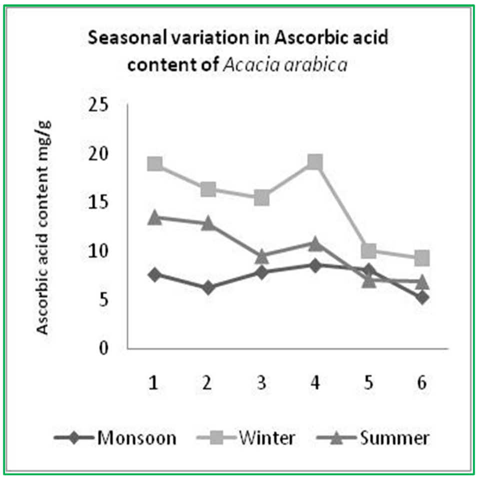


Figure 2d



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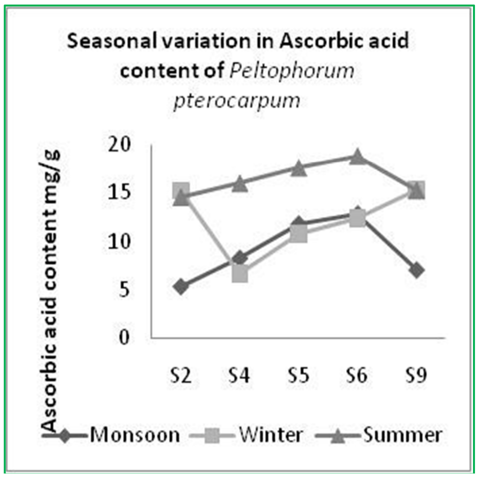

Figure 2f

Figure 2a to f: seasonal variation in ascorbic acid content.

Table 2: Seasonal variation of RWC and pH of *Azadirachta indica*

Site Code	RWC (%)			pH		
	Monsoon	Winter	Summer	Monsoon	Winter	Summer
1	88.8	76	86.04	4.9	4.6	6
2	98.7	78.5	87.8	4.04	4.7	6.1
3	94.3	59.25	69.56	6.7	4.5	5.9
4	84.8	83.72	71.09	5.2	4.2	5.2
5	82.4	71.09	74.32	4.05	5.4	4.8
6	90.2	78.63	77.29	6.1	4.2	5.4
7	87.5	75.04	77.29	4.6	3.2	6.2
8	71.1	77.2	81.43	6.4	5.5	6.1
9	88.8	84.34	73.45	4.37	5.3	5.9
ANOVA, Within Sites, F=1.11, Fcrit=2.59 α=0.05				ANOVA, Within Sites, F=0.95		
Within season, F=6.80, Fcrit=3.63				ANOVA, Within Season, F=4.55		

Table 3: Seasonal variation of RWC and pH of *Polyalthia longifolia*

Site Code	RWC (%)			pH		
	Monsoon	Winter	Summer	Monsoon	Winter	Summer
1	91	61.2	61.22	4.3	4.5	6.5
2	96.4	90.9	75	5.3	6.9	5.7
3	90.8	69.5	56.87	4.5	5.1	5.7
4	90.6	81.92	75.54	4.8	5.7	6.7
6	89.6	79	65.86	5.2	5.6	4.2
7	74.3	74.5	80.29	5.5	5.8	5.8
8	89	87.3	74.12	4.7	4.7	4.5
9	89.5	79.7	59.78	6.7	6.1	4.3
ANOVA, Within Sites, F=1.70, Fcrit=2.76 α=0.05				ANOVA, Within Sites, F=0.88		
Within season, F=14.75, Fcrit=3.73				ANOVA, Within Season, F=0.51		

Table 4: Seasonal variation of RWC and pH of *Ficus bengalensis*

Site Code	RWC (%)			pH		
	Monsoon	Winter	Summer	Monsoon	Winter	Summer
1	86.9	79.1	85.71	4.5	5.6	5.6
2	84.3	89.7	77.14	5.8	5.9	6.2
5	86.2	57.8	78.63	5.12	5.5	5.6
7	92.2	67.0	72.00	5.9	4.6	4.9
8	85.6	89.8	67.87	4.2	4.9	6.4
9	87.9	82.6	71.34	4.4	4.5	6.2
ANOVA, Within Sites, F=0.51, Fcrit=2.59 α=0.05				ANOVA, Within Sites, F=0.81		
Within season, F=2.74, Fcrit=3.63				ANOVA, Within Season, F=2.70		

Table 5: Seasonal variation of RWC and pH of *Mangifera indica*

Site code	**RWC (%)**			**pH**		
	Monsoon	Winter	Summer	Monsoon	Winter	Summer
1	95.4	83	79.1	5	6	5.7
2	96.4	81	74	5.1	6.4	5.9
5	98.7	84	75	5.29	6.1	6.1
7	98.4	75.5	79.59	5.03	4.9	6.3
8	97.1	89	80	5.3	5.1	6.4
ANOVA, Within Sites, F=0.91, Fcrit=2.76 α=0.05				ANOVA, Within Sites, F=0.40		
Within season, F=44.99, Fcrit=3.73				ANOVA, Within Season, F=4.96		

Table 6: Seasonal variation of RWC and pH of *Acacia arabica*

Site code	**RWC (%)**			**pH**		
	Monsoon	Winter	Summer	Monsoon	Winter	Summer
1	72.7	84	84.37	3.6	5.1	6.2
3	75.6	85	86.1	4.1	5.6	6.1
4	72.1	89	83.2	4.7	6.1	5.7
5	77.2	77	83.72	3.4	5.4	5.5
7	74	80	84	5	6	6.3
9	76	88	87	4.7	5.7	6.9
ANOVA, Within Sites, F=3.5, Fcrit=2.76 α=0.05				ANOVA, Within Sites, F=2.59		
Within season, F=39.0, Fcrit=3.73				ANOVA, Within Season, F=0.73		

Table 7: Seasonal variation of RWC and pH of *Peltophorum pterocarpum*

Site code	**RWC (%)**			**pH**		
	Monsoon	Winter	Summer	Monsoon	Winter	Summer
2	88.4	77.14	59.25	6.1	4.6	4.2
4	86	50.9	53.14	4.9	4.9	5.6
5	88	50.2	55.82	5.1	5.1	5.1
6	77.5	53.1	70.29	6.5	6.5	5.6
9	90.8	71.56	76.34	5.6	5.8	5.6
ANOVA, Within Sites, F=3.5, Fcrit=2.76 α=0.05				ANOVA, Within Sites, F=2.59		
Within season, F=39.0, Fcrit=3.73				ANOVA, Within Season, F=0.73		

Table 8: The range of APTI

Plant species	Monsoon	Winter	Summer
Azadirachtaindica	9.45-25.26	12.91-25.94	10.30-26.54
	18.00	**18.71**	**14.73**
Polyalthialongifolia	11.09-19.47	8.94-28.8	7.98-27.10
	14.74	**19.04**	**16.49**
Ficusbengalensis	11.16-17.89	10.15-19.88	11.61-23.98
	14.96	**16.36**	**16.43**
Mangiferaindica	15.81-16.91	14.54-18.43	15.10-18.91
	16.41	**15.68**	**16.54**
*Acacia Arabica**	10.94-13.21	14.77-19.97	13.63-19.64
	11.40	**18.09**	**16.46**
Peltophorumpterocarpum	13.15-17.04	8.84-16.75	15.81-19.65
	13.75	**16.75**	**16.57**
**according to ANOVA, α=0.05seasonal variation is significant. Bold values represent average APTI of all the sampling sites*			

3. 5 Air Pollution Tolerance Index

The range of air pollution tolerance index [APTI] calculated for each plant species studied at different seasons are represented in Table 8. Based on the highest calculated APTI irrespective of the season the plants were found to having the following order *Polyalthia longifolia>Azadirachta indica>Ficus bengalensis> Acacia arabica>Peltophorum pterocarpum>Mangifera indica*. But if the average APTI values of all the season is to be considered then the order will be as follows: *Azadirachta indica>Polyalthia longifolia>Mangifera indica>Ficus bengalensis> Acacia Arabica>Peltophorum pterocarpum.* All the species showed higher average APTI values in winter season. Except *Mangifera indica* which showed minimum value in summer all the other species show minimum APTI in monsoon. Except *Acacia* all the other species showed insignificant seasonal variation in APTI according to ANOVA, $\alpha=0.05$

For determining APTI the four biochemical parameters plays significant role and their values gives indication of specific physiological response triggered by the pollution status and seasonal changes and several other factors. So, each of the parameters are discussed separately.

Degradation of photosynthetic pigment has been widely used as an indication of air pollution (Bhattacharya *et al*, 2012). Present study revealed that chlorophyll content in all the plants varies with the pollution status of the area i.e. higher the pollution level in the form of vehicular exhausts lower the chlorophyll content. It also varies with the tolerance as well as sensitivity of the plant species i.e. higher the sensitive nature of the plant species lower the chlorophyll content. Studies) also suggest that high levels of automobile pollution decreases chlorophyll content in higher plants near roadsides (Chandawat*et al*, 2011; Adamsab*et al*, 2011). In all the plant species, chlorophyll content was higher in monsoon season which might be due to the washout of dust particles from the leaf surface (which will increase photosynthetic activity) (Dwivedi and Tripathi, 2007). Low chlorophyll content in winter season might be due to the high pollution level, temperature stress, low sunlight intensity and short photoperiod. Present study revealed that chlorophyll content in all the plants varies with the pollution status of the area i.e. higher the pollution level in the form of vehicular exhausts lower the chlorophyll content. It also varies with the tolerance as well as sensitivity of the plant species i.e. higher the sensitive nature of the plant species lower the chlorophyll content.

Ascorbic acid is a strong reductant and it activates many physiological and defence mechanism. Its reducing power is directly proportional to its concentration (Gaikwad*et **al***, 2006). Being a very important reducing agent, ascorbic acid also plays a vital role in cell wall synthesis, defense and cell division (Joshi and Swami, 2007). Pollution load dependent increase in ascorbic acid content of all the plant species may be due to the increased rate of production of reactive oxygen species (ROS) during photo-oxidation of SO_2 to SO_3 where sulfites are generated from SO_2 absorbed (Jyothi and Jaya, 2010). Also, higher ascorbic acid content of the plant is a sign of its tolerance against sulphur dioxide pollution. In the present study also we found that the ascorbic acid content was higher in winter, as the pollution load increases in this season due to meteorological conditions, whereas in summer heat stress is more and in monsoon due to was down the pollutant load decreases and hence the ascorbic acid content.

The pH of leaf extract was found acidic in all the seasons and in all the species, however they varied more or less with change of season. The changes in leaf-extract pH might influence the stomata sensitivity due to air pollutants. The plants with high sensitivity to SO_2 and NO_2 closed the stomata faster when the exposed to the pollutants (Thambavani and Prathipa, 2012). Consequently, sensitive plants had higher leaf-extract pH than tolerant plants. High pH may increase the efficiency of conversion from hexose sugar to Ascorbic acid, while low leaf extract pH showed good correlation with sensitivity to air pollution (Varshney, 1992). Among the species the Relative water content decreased in the following order *Mangifera indica>Polyalthia longifolia>Azadirachta indica≥Ficus bengalensis>Peltophorum pterocarpum>Acacia arabica*. The high water content in monsoon was due to high soil water availability and less evaportranspiration. However, leaf water status depends upon several physiological factors such as leaf turgor, growth, stomatal conductance, transpiration, photosysnthesis and respiration. The large quantity of water helps plant to combat stress and maintain its physiological balance under air pollution (Chouhan*et al*, 2012). APTI changes with season were found not prominent as suggested by statistical analysis. However, in winter season the plants were found with more APTI values. This can be due to the more pollution load in the atmosphere and seasonal stress induced by low temperatures. Better tolerant species were *Azadirachta indica, Polyalthia longifolia, and Mangifera indica.* Similar findings were also reported by several researchers (Agbaire and Esiefarienrhe, 2009; Beg *et al,* 1990; Chauhan, 2010; Bhattacharya *et al*, 2012; Dwivedi and Tripathi, 2007; Chandawat*et al*, 2011; Adamsab*et al*, 2011; Chouhan*et al*, 2012).

4. 0 Conclusion:

Air Pollution Tolerance Index determination is of utmost importance because with increased vehicular movements, urbanization and rapid increase in small scale industries the pollution load is on rise. Vegetation naturally cleanses the atmosphere by absorbing gases and some particulate matter through leaves. Plants have a very large surface area and their leaves function as an efficient trapping device. Some plants have been classified according to their degree of sensitivity and tolerance towards various air pollutants.

An overview of the entire result obtained from the study reveals that different plants respond differently to air pollution; hence the plants have potential to serve as excellent quantitative and qualitative indices of pollution. Since biomonitoring is an important tool to evaluate the impact of air pollution on plants*, Peltophorum pterocarpum, Acacia arabica can* be used as biomonitors of vehicular pollution stress. Among the other plant species*, Polyalthia longifolia*, *Azadirachta indica*, *Mangifera indica* showed high APTI value compare to other species, hence these species work as sink of air pollutants.

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