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Comparative Seasonal Variation in Air Pollution Tolerance Index of some plant species growing in Tarapur industrial area (MIDC).

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Abstract

The present study was undertaken at Tarapur, Maharashtra Industrial Development Corporation which has bulk drug manufacturing units, specialty chemical manufacturing units, steel plants and some textile plants. This is one of the largest chemical industrial estates in the state of Maharashtra. The pollution induced changes in major biochemical parameters namely the total chlorophyll content of leaf (TCh), leaf extract pH, ascorbic acid content of leaf (AA) and relative water content of the leaf (RWC) were assessed. All these parameters were combined together in a formulation signifying the APTI values of the plant. For this purpose ten plant species were selected namely *Acacia auriculiformis, Artocarpus heterophyllous, Azadirachta indica, Cassia siamea, Ficus benghalensis, Ficus religiosa, Mangifera indica, Polyalthia longifolia, Terminalia catappa and Thevatia nerifolia*.
It was concluded that *Mangifera indica, Ficus benghalensis, Acacia auriculiformis, Azadirachta indica and Polyalthia longifolia* were tolerant, *Ficus religiosa, Artocarpus heterophyllous* and *Terminalia catappa* were moderately tolerant. The species like *Thevatia nerifolia* and *Cassia siamea* were sensitive to air pollution with respect to their average APTI values. Thus present findings show that the tolerant species can be grown in the industrial area which can be used as scavengers for combating air pollution.

Key words: Air pollution tolerance index (APTI), total chlorophyll content (TCh), ascorbic acid (AA), Tarapur.

1.Introduction

Air pollution is more complex than most other environmental challenges. No physical or chemical methodology is thought to ameliorate air pollution. Growing green plants in and around industrial and urban areas can serve as a suitable alternative (Shannigrahi *et al*, 2004; Ghose and Majee, 2001). Plants act as the scavengers for many air borne particulates in the atmosphere (Joshi and Swami, 2007).

All combustion release gases and particles into the air which includes Sulphur, NO_x , CO, and soot particle as well as smaller quantities of toxic metals, organic molecules and radioactive isotopes (Agbaire and Esiefarienrhe, 2009). A major cause of pollution is industrialization (Odilara *et al*, 2006). Plants offer a colossal leaf space for impingement, absorption and accumulation of air pollutants to reduce the pollutants level with in the setting with a varied extent (Lui and Ding, 2008).

Plants can be effectively used as bio indicators of air pollutants. The sensitivities of plants could vary with tolerant species showing no or minimal symptoms while sensitive ones showing symptoms even if the air pollutants increase in small amounts (Singh, 2003). The sensitivity and tolerance to air pollutants of plants varies with change in Leaf extract pH, Relative water contents, ascorbic acid content and Total Chlorophyll content (Lui and Ding, 2008; Singh and Verma, 2007).

The work has been carried out in this direction to study the sensitivity of plants based on selected parameters such as ascorbic acid (Bajaj and Kaur, 1981), relative water content (Singh, 1977), total chlorophyll content (Arnon, 1949) and leaf extract pH (Singh and Rao, 1983) were used to calculate air pollution tolerance index (Singh and Rao, 1983) as their relative significance in identifying the tolerance level of plant species. In view of this the present study was taken up to evaluate APTI of ten plant species of Tarapur industrial area with respect to different growing seasons in monsoon, winter and summer under various environmental conditions.

2.Materials and Methods

2.1Study area

Tarapur is a census town in Palghar district (earlier Palghar was taluka and has recently notified as district) of Maharashtra State, India. . It is an industrial town located some 45 km north of Virar, on the Western Railway line of Mumbai Suburban Division (Mumbai Suburban Railway).Located at 17.7º N, 75.47º E at an elevation of 456 meters (1496 feet). The area experiences tropical climate and show a considerable variation in seasons. Average rain fall in the area is 1955 mm and the average temperature is 26.5º C. Tarapur MIDC in-house major Industrial Estate of Maharashtra Industrial Development Corporation which has bulk drug producing unit's particularly chemical producing units, steel plants and some textile plants.

2.2Sample Collection

Leaf samples were collected from MIDC Tarapur at polluted site (PS). A site nearby with similar ecological conditions from Tarapur atomic power station colony (TAPS) was selected as the control site (CS). Samples were collected in triplicates in the morning hours from selected trees namely *Acacia auriculiformis, Artocarpus heterophyllous, Azadirachta indica, Cassia siamea, Ficus benghalensis, Ficus religiosa, Mangifera indica, Polyalthia longifolia, Terminalia catappa and Thevatia nerifolia*. They were brought to the laboratory in polythene bags and kept in an ice box to nullify the adverse effect of light intensity and temperature. The leaf fresh weight for the samples was taken immediately. Samples were preserved in refrigerator for other analysis.

2.3Methods

a) Total Chlorophyll Content (TCh)

This was estimated following the method of Arnon(1949) 100 mg of fresh leaf material was homogenized and extracted with 10ml of 80% acetone and centrifuged at 5000 rpm for 10 min. The supernatant was collected and absorbance were taken at 645nm and 663nm using a spectrophotometer. Calculations were made using the formula.

Chlorophyll a = [(12.7 x O.D at 663nm) - (2.69 x O.D. at 645nm)] x V/1000W mg/g

Chlorophyll b = [(22.9 x O.D at 645nm) – (4.68 x O.D at 663nm)] x V/1000W mg/g

Total chlorophyll (mg/g) = Chlorophyll a + Chlorophyll b

Where V = total volume of the chlorophyll solution (ml)
and W = weight of the tissue extract (g)

b) Leaf relative water content (RWC)

RWC was estimated by the method described by Singh (1977). Fresh weight was obtained by weighing the fresh leaves. The leaves were then immersed in water overnight, blotted dry and weighed to get turgid weight. The leaves were dried over night in an oven at 70º C and reweighed to get dry weight.

RWC = (FW – DW/ TW – DW) x 100

Where FW = Fresh Weight, DW= Dry Weight & TW= Turgid weight.

c) Leaf Extract pH (Singh and Rao; 1983)

0.5g of leaf material was ground to paste and dissolved in 50ml of DW and leaf extract pH was measured by using calibrated digital pH meter.

d) Ascorbic acid content (Bajaj and Kaur, 1981)

1gm of leaf sample was extracted with 4ml of oxalic acid –EDTA extracting solution and directly taken in centrifuge tube; 1ml of orthophosphoric was added followed by 1ml of 5% sulphuric acid. To this 2ml of ammonium molybdate and 3ml of distilled water was added. This solution was allowed to react for 15 minutes at room temperature. After incubation period the solution was centrifuged at 5000 rpm for 10 minutes, the supernatant was taken and the absorbance was measured at 760nm using spectrophotometer.

e) Air pollution tolerance index (APTI) determination.

APTI was done following the method described by Singh and Rao (1983). By the formula

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

Where A = Ascorbic acid content (mg/g), T = total chlorophyll (mg/g), P = pH of leaf extract and
R = relative water content of leaf (%)

3.Results and Discussions

Air pollution tolerance index (APTI)

Air pollution tolerance index (APTI) was analyzed by the method described by Singh and Rao (1983) for the ten plant species growing in the study area seasonally. Variations in Air pollution tolerance index (APTI) are due to the variations in any of the four biochemical parameters which govern the computation of the APTI. These four biochemical factors gave conflicting results as responded by Han et.al (1995). Therefore each parameter is discussed separately.

3.1. Relative Water Content (RWC)

Table no. 1. Relative water content of study area

PLANTS NAMES	MIDC Rainy	MIDC Winter	MIDC Summer	TAPS Rainy	TAPS Winter	TAPS Summer
Acacia auriculiformis	94.48	82.86	84.59	97.07	86.72	85.57
Artocarpus heterophyllus	91.29	75.14	74.02	92.74	77.58	74.08
Azadirachta indica	87.06	72.85	86.91	91.75	77.99	84.10
Cassia siamea	81.55	70.73	63.35	89.02	80.75	76.20
Ficus benghalensis	97.23	90.90	91.07	95.52	89.40	91.89
Ficus religiosa	89.11	82.21	89.97	91.20	83.21	90.40
Mangifera indica	93.79	81.54	87.85	95.58	87.18	89.66
Polyalthia longifolia	98.35	84.80	85.86	96.86	79.70	86.99
Terminalia catappa	83.79	73.40	88.63	93.91	87.14	92.70
Thevatia nerifolia	68.56	76.05	56.62	92.47	85.82	55.93

RWC of a leaf is the amount of water present in it relative to its full turgidity. Highest water content within plant body helps to take care of its physiological balance under stress conditions like exposure to air pollution once the transpiration when the transpiration rates are sometimes high.

Rainy season: The highest value for RWCwas seen in *Polyalthia longifolia* (98.35%) while the lowest was *Thevatia nerifolia* (68.56%) in polluted area. For control area highest values were in *Acacia* auriculiformis (97.07%) while the lowest was in *Cassia siamea* (89.02 %).

Winter season:. The highest value for RWCwas seen in *Ficus benghalensis* (90.90%) while the lowest was *Cassia siamea* (70.73%) in polluted area. For control area highest values were in *Ficus benghalensis* (89.40%) while the lowest was in *Artocarpus heterophyllus* (77.58 %)

Summer season: The highest value for RWCwas seen in *Ficus benghalensis* (91.07 %) while the lowest was *Cassia siamea* (63.35%) in polluted area. For control area highest values were in *Terminalia catappa* (92.70%) while the lowest was in *Thevatia nerifolia* (55.93 %).

The result shows high leaf RWC during the rainy with decline in the level during the summer followed by winter. (Table no.1) Similarly reported by Das and Prasad (2010) and Bhattacharya *et al*. (2013). The transpiration rate becomes high when plants are exposed to air pollution under these conditions. The physiological balance is maintained by the RWC within the plant body. Jissy and Jaya (2010) also reported the decline in RWC in plants under polluted conditions possibly tolerant to pollutants. High RWC helps to maintain physiological balance under stress (Buchchi et al., 2013). High RWC also dilutes acidity of cell sap and helps in tolerating drought (Palit et al., 2013)

3.2. Leaf extract pH.

Table no. 2. Leaf extract pH of study area

PLANTS NAMES	MIDC Rainy	MIDC Winter	MIDC Summer	TAPS Rainy	TAPS Winter	TAPS Summer
Acacia auriculiformis	6.31	6.45	5.66	6.45	6.29	5.75
Artocarpus heterophyllus	6.67	6.64	6.02	6.36	6.57	6.11
Azadirachta indica	6.60	6.52	5.73	6.03	6.10	5.87
Cassia siamea	3.69	5.17	4.52	4.42	4.50	4.53
Ficus benghalensis	8.51	6.85	8.69	8.33	7.19	8.63
Ficus religiosa	8.35	8.13	5.88	8.55	6.42	5.58
Mangifera indica	6.01	5.84	5.24	5.62	5.75	5.10
Polyalthia longifolia	6.50	6.12	5.46	5.85	6.11	5.50
Terminalia catappa	4.55	4.81	4.87	5.82	6.05	4.70
Thevatia nerifolia	5.34	6.57	5.65	6.68	6.56	6.00

Almost all the samples collected from polluted area and control area exhibited acidic pH. This may be due to the presence of air pollutants like SO_2 and NO_X in the ambient air.

Rainy season: The highest value for pH was seen in *Ficus benghalensis* (8.51) while the lowest was *Cassia siamea* (3.69) in polluted site. For control area highest values were in *Ficus religiosa* (8.55) while the lowest was in *Cassia siamea* (4.42).

Winter season: The highest value for pH was seen in *Ficus religiosa* (8.13) while the lowest was *Terminalia catappa* (4.81) in polluted site. For control area highest values were in *Ficus benghalensis* (7.19) while the lowest was in *Cassia siamea* (4.50).

Summer season: The highest value for pH was seen in *Ficus benghalensis* (8.69) while the lowest was in *Cassia siamea* (4.52) in polluted site. For control area highest values were in *Ficus benghalensis* (8.63) while the lowest was in *Cassia siamea* (4.53).

The result shows high pH during the summer with decline in the level during the rainy followed by winter. The photosynthetic efficiency strongly depends upon the leaf pH. Almost all pH values were found to be in the acidic range in all the three seasons. The presence of SO_2 and NO_x in the ambient air causes a change in pH of the leaf sap to acid range. The leaf pH is lowered in presence of acidic pollutants and the decline is greater in sensitive species as reported by Scholz and Reck (1977). Low pH value indicates the sensitivity of the plant species to air pollution (Singh et. al 1997).

3.3. Total chlorophyll content (TCh)

The chlorophyll content of the plant signifies its photosynthetic activity, growth and development of biomass. It varies from species to species depending upon the age of leaf and other biotic and abiotic factors. (Table no. 3)

Rainy season: The highest value for chlorophyll content was seen in *Polyalthia longifolia* (39.97 mg/gm) while the lowest was *Cassia siamea* (8.61 mg/gm) in polluted area. For control area highest values were in *Polyalthia longifolia* (41.28 mg/gm) while the lowest was in *Ficus benghalensis* (14.39 mg/gm).

Winter season: The highest value for chlorophyll content was seen in *Polyalthia longifolia* (55.23 mg/gm) while the lowest was *Cassia siamea* (14.58 mg/gm) in polluted area. For control area highest values were in *Polyalthia longifolia* (45.12 mg/gm) while the lowest was in *Acacia auriculiformis* (25.91 mg/gm).

Summer season: The highest value for chlorophyll content was seen in *Polyalthia longifolia* (45.37 mg/gm) while the lowest was *Ficus religiosa* (11.10 mg/gm) in polluted area. For control area highest values were in *Mangifera indica* (36.40 mg/gm) while the lowest was in *Cassia siamea* (18.39 mg/gm).

Table no. 3. Total chlorophyll content of study area

PLANTS NAMES	MIDC Rainy	MIDC Winter	MIDC Summer	TAPS Rainy	TAPS Winter	TAPS Summer
Acacia auriculiformis	20.76	33.36	21.42	27.05	25.91	20.21
Artocarpus heterophyllus	21.11	32.50	27.43	36.64	31.80	31.77
Azadirachta indica	22.84	34.04	21.76	25.37	27.07	22.89
Cassia siamea	8.61	19.03	19.63	30.04	39.06	18.39
Ficus benghalensis	11.09	20.87	15.01	14.39	39.03	22.03
Ficus religiosa	21.35	31.05	11.10	35.22	32.49	25.60
Mangifera indica	20.50	35.07	34.60	15.00	39.52	36.40
Polyalthia longifolia	39.97	39.06	45.37	41.28	45.12	31.81
Terminalia catappa	31.70	31.60	25.13	31.14	34.27	30.19
Thevatia nerifolia	12.58	27.53	16.67	29.48	35.07	25.69

All the plant species exhibited high TCh content during winter season followed by summer and rainy season. Photosynthetic pigment degradation has been widely considered as an indication of air pollution (Ninave et.al, 2001 and Bhattacharya et al, 2012). The plants having high chlorophyll content under field conditions are generally tolerant to pollutants.

3.4. Ascorbic acid (AA)

Ascorbic acid is an important metabolite in plants which activates the resistance mechanism in plants under stress condition. (Table no. 4)

Rainy season: The highest value for Ascorbic acid content was seen in *Mangifera indica* (0.609 mg/gm) while the lowest was *Azadirachta indica* (0.118 mg/gm) in polluted site. For control site highest values were in *Ficus benghalensis* (0.829 mg/gm) while the lowest was in *Ficus religiosa* (0.148 mg/gm).

Winter season: The highest value for Ascorbic acid content was seen in *Acacia auriculiformis* (0.684 mg/gm) while the lowest was *Ficus religiosa* (0.148 mg/gm) in polluted site. For control site highest values were in *Azadirachta indica* (0.927 mg/gm) while the lowest was in *Ficus religiosa* (0.158 mg/gm).

Summer season: The highest value for Ascorbic acid content was seen in *Mangifera indica* (0.637 mg/gm) while the lowest was *Ficus benghalensis* (0.147 mg/gm) in polluted site. For control site highest values were in *Azadirachta indica* (0.764 mg/gm) while the lowest was in *Terminalia catappa* (0.142 mg/gm).

Table no. 4. Total chlorophyll content of study area

PLANTS NAMES	MIDC Rainy	MIDC Winter	MIDC Summer	TAPS Rainy	TAPS Winter	TAPS Summer
Acacia auriculiformis	0.155	0.684	0.280	0.252	0.860	0.540
Artocarpus heterophyllus	0.192	0.167	0.177	0.189	0.179	0.151
Azadirachta indica	0.118	0.453	0.372	0.693	0.927	0.764
Cassia siamea	0.332	0.189	0.254	0.243	0.280	0.182
Ficus benghalensis	0.239	0.210	0.147	0.829	0.158	0.193
Ficus religiosa	0.199	0.148	0.165	0.148	0.176	0.153
Mangifera indica	0.609	0.336	0.637	0.526	0.508	0.616
Polyalthia longifolia	0.196	0.153	0.154	0.360	0.218	0.177
Terminalia catappa	0.181	0.191	0.165	0.195	0.180	0.142
Thevatia nerifolia	0.239	0.186	0.156	0.211	0.324	0.152

All the plant species exhibited high AA content during winter season followed by summer and rainy season. Ascorbic acid plays an important role in photosynthesis, cell division; defense and cell wall synthesis because it is a strong reducing agent and plays a important role in photosynthetic carbon fixation. It is a natural antioxidant, which naturally prevent the effect of air pollution in plant tissues as reported by Kuddus et.al., 2011; Deepalakhmi et al., 2013. The results are similar to those reported by Gholami et al. 2016; Ogunrotimi et al 2017. The plant species with high AA content are considered to be tolerant to air pollutants as reported by Keller and Schwager , 1977. In the present study *Mangifera indica and Azadirachta indica* had the highest AA values.

3.5. Air pollution tolerance index (APTI):

The results are shown in table no. 5, figure no.1. From the result it was evident that the plants showed varied degree of APTI to air pollution. APTI values are extensively used to rank the plant species in their order of tolerance or sensitivity to air pollution. The results of APTI calculated for ten plant species studied during different seasons are as follows:

Table no. 5. Total chlorophyll content of study area

PLANTS NAMES	MIDC Rainy	MIDC Winter	MIDC Summer	TAPS Rainy	TAPS Winter	TAPS Summer
Acacia auriculiformis	8.70	10.56	10.33	9.52	11.44	10.79
Artocarpus heterophyllus	8.05	9.82	7.97	8.57	9.85	8.09
Azadirachta indica	7.63	10.26	9.93	9.98	11.70	11.07
Cassia siamea	7.48	8.77	6.79	8.91	9.69	8.26
Ficus benghalensis	9.56	10.13	9.61	10.83	10.45	9.67
Ficus religiosa	8.81	9.56	9.25	8.98	9.72	9.59
Mangifera indica	9.76	12.01	10.11	9.82	12.38	11.09
Polyalthia longifolia	9.39	10.53	9.36	9.67	10.59	9.52
Terminalia catappa	8.00	8.98	9.43	9.44	9.96	9.90
Thevatia nerifolia	8.04	7.39	6.08	9.34	9.88	6.62

Rainy season: The APTI ranged between 7.48 and 9.76 in the polluted site while the control area ranged between 8.57 and 10.83. The highest APTI value was in *Mangifera indica* (9.76) followed by *Ficus benghalensis* (9.56). The lowest APTI value was observed in *Cassia siamea* (6.29) followed by *Azadirachta indica* (8.62) in the polluted area. For the control area the highest APTI value were in *Polyalthia longifolia* (10.83) followed by *Artocarpus heterophyllous* (9.98). The lowest APTI value was observed in *Cassia siamea* (8.57) followed by *Ficus religiosa* (8.91).

Winter season: The APTI ranged between 7.39 and 12.01 in the polluted area while the control area ranged between 9.69 and 12.38. The highest APTI value was in *Mangifera indica* (12.01 followed by *Acacia auriculiformis* (10.56). The lowest APTI value was observed in *Thevatia nerifolia* (7.39) followed by *Cassia siamea* (8.77) in polluted area. For the control area the highest APTI value were in *Mangifera indica* (12.38) followed by *Azadirachta indica* (11.70). The lowest APTI value was observed in *Cassia siamea* (9.69) followed by *Ficus benghalensis* (9.72)

Summer season: The APTI ranged between 6.08 and 10.33 in the polluted area while the control area ranged between 6.62 and 11.09. The highest APTI value was in *Acacia auriculiformis* (10.33) followed by *Mangifera indica* (10.11). The lowest APTI value was observed in *Thevatia nerifolia* (6.08) followed by *Cassia siamea* (6.79) in polluted area. For the control area the highest APTI value were in *Mangifera indica* (11.09) followed by *Azadirachta indica* (11.07). The lowest APTI value was observed in *Thevatia nerifolia* (9.11) followed by *Artocarpus heterophyllous* (9.27).

Based on the APTI values irrespective of the seasons the species *Mangifera indica, Ficus benghalensis, Acacia auriculiformis, Azadirachta indica and Polyalthia longifolia* were tolerant., *Ficus religiosa, Artocarpus heterophyllous* and *Terminalia catappa* were moderately tolerant. The species like *Thevatia nerifolia* and *Cassia siamea* were sensitive to air pollution. Different plant species show considerable variation in the order of tolerance. As reported by Raza et al (1985) and Das and Prasad (2010) the plant species known to be tolerant or sensitive in one area may behave differently in another area.

Conclusion

The present study concluded that all the biochemical parameters of the plant species play an important role in determining the sensitivity and tolerance of plants to air pollution. Results obtained from the present study provide information for the selection of tolerance species. APTI is good criteria to select plant species to mitigate air pollutants and it develops green belts. Tolerance species can improve local ecology in the industrial area and reduce the harmful effects on human health due to continuous exposure to air pollutants. On the whole the ecosystem can be maintained in a healthy state. Further planning of the landscape can be undertaken by growing tolerant species.

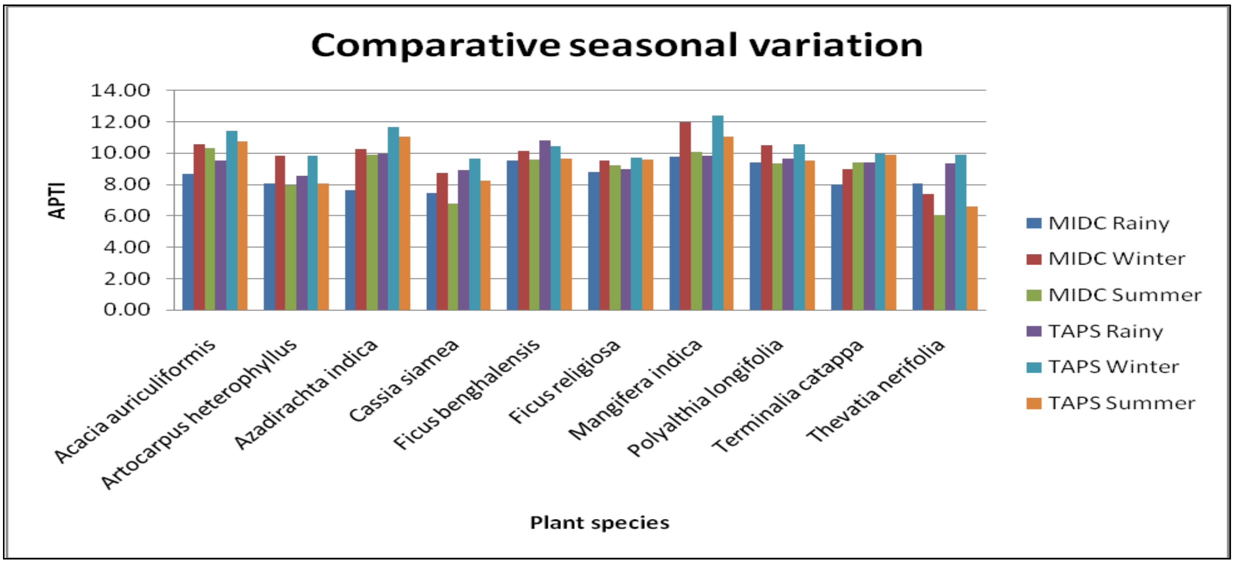

Figure no.1. Plant species with seasonal variation

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