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An Assessment Of Air Pollution Tolerance Indices Of Some Plant Species Grown In And Around An Industrial Area In Guwahati, Assam, India

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ABSTRACT

Air pollution tolerance index (APTI) of 24 plant species growing in a waste metal recycling industrial estate at Boragaon, Guwahati, Assam were determined for a period of 6 months by evaluating the relative water content, leaf extracts pH, total chlorophyll content and ascorbic acid content. The result indicates that different plants exhibit varying levels of tolerance and sensitivity to three major air pollutants (PM_{10}, SO_2 and NO_x). In the study, it was observed that highest values of APTI and ascorbic acid contents were recorded only in two plant species, *Catharanthus roseus* and *Melia azedarach* revealing the tolerant capacities of these plants to sustain their growth and survival in polluted environment as compared to other plant species.

Keywords – APTI, AQI, Ascorbic acid, biochemical parameters, PM_{10}

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I. INTRODUCTION

Living organisms, particularly human and their environment are interrelated and indispensable to each other. The environment influences the life of human beings and their activities modify the environment in a number of ways. The interrelationship had been considered to be in equilibrium in the past when the human population was less and their impact on the environment was lower. Today, with increasing anthropogenic activities all around, the ecological balance seems to be lost. Different activities in our day to day life pollute the environment which leads to a serious threat to human health and the environment. Out of several mitigation measures adopted to reduce the impact of air pollution, one such mitigation measure and management of air pollution is the large scale plantation of trees and other plants in polluted areas as well as in degraded lands. Plants provide enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollution level in the environment [1]. Different plants survive by tolerating high concentration and longer period of exposure while many plants die due to their inability to tolerate various air pollutants. Various studies have reported importance of different species of plant as bioindicators of air pollution in industrial areas as well as along highways from different parts of the country and other parts of the world. The response of plants to air pollution has been investigated in terms of air pollution tolerance index (APTI) by measuring four important parameters related to plant leaves namely; total chlorophyll content, leaf extracts pH, ascorbic acid content and relative water content [2]. Very scarce reports are available on such kind of studies from major cities of the north eastern region of India particularly in rapidly developing city like Guwahati in Assam. Therefore, the present study aims to study the tolerance and sensitivity of various plants growing in and around an industrial estate of Guwahati with an objective to identify tolerant and sensitive plant species as bioindicators of air pollution by measuring APTI as a universal index.

II. STUDY AREA

Guwahati, the gateway to North East of India is located between 26.148043° N latitude and 91.731377° E longitude at an elevation of 55 m from mean sea level. The climate of Guwahati is warm and temperate although rain occurs from April and generally continues till September. In course of the present work, initially several industrial units located in and around Guwahati were visited. After considering the pros and cons of the proposed work and feasibility of data collection, a small scale industry, Shiv Alloys Steel Pvt. Ltd. was selected as the study site. The site is located between 26.1164° N latitude and 91.6833° E longitude at Boragaon, Guwahati and is nearly 350 metres from NH 27. It process the used steel goods collected from different sources, melt them in the furnace and finally mould different goods like crusher machine jaw plate, toggle plate liner etc. But the manufacturing process adopted is very conventional as a thick cloud of smoke seems to engulf the surroundings of the site during the steel and iron melting phase. This smoke arising from the furnace gets scattered in the atmosphere and its impact is felt on man as well as the green vegetation growing in and around the industrial site So the present study is undertaken to know the effects of pollution caused by this industry and the behaviour of the plants which are tolerant as well as sensitive to pollution.

III. MATERIALS AND METHODS

The plants growing in and around the industrial site at Boragaon, Guwahati were selected by quadrat method [3], where a 1 m x 1m size wooden frame was placed on the ground and the different categories of plant coming under the purview of the quadrant were counted and noted. In this way, dominant and recessive plant species in a plot of land can be identified. In the present work, 24 plant species were selected and packed in clean PET bags and numbered serially as S1, S2…..S24. The species were preserved in a well insulated ice box so as to prevent any damage during its handling. So, the plant species selected for the study were *Mikania cordata, Cynodon plectostachyus, Mimosa pudica, Amaranthus spinosus, Gamochaeta spp., Lantana camara, Melia azedarach, Oxalis corniculata, Amaranthus aspera, Justicia, Catharanthus roseus, Labiata, Ocimum tenuiflorum, Alternanthera philoxeroides, Cajanus cajan, Ziziphus jujuba, Thysanolaena maxima, Dracaena fragrans, Ficus racemosa, Phylanthus niruri, Codiaeum variegatum, Polystichum munitum, Sonchus arvensis and Bryophyllum pinnatum.*

3.1 Relative Water Content (RWC)

Fresh weight (FW) of the leaf samples was taken and then the leaves were immersed in de-ionized water over night to get the turgid weight (TW). Again the leaves were dried at 105°C for two to three hours in a hot air oven to get the dry weight (DW). So, the RWC was calculated [4] as

$$RWC = [(FW-DW)/ (TW-DW)] \times 100 \qquad (1)$$

3.2 Leaf extracts pH

0.5 g of the leaves were taken and mixed thoroughly with de-ionized water. After that, it was filtered and the filtrate so obtained was tested [4] by a digital pH meter after calibrating it with standard buffer solution of pH 4, pH 7 and pH 9.

3.3 Total Chlorophyll Content (TChl Content)

0.5 g of the leaves were taken and diluted to 10 ml distilled water. Another 0.5 g of the leaves is dried in the hot air drying oven at 105^0C for two hours for obtaining the dry weight (DW). Now a 2.5 ml of this sample is taken and blended with 80% acetone and filtered. Then the filtrate is collected and centrifuged at 2500 rpm for 3 minutes. Now the supernatant so collected was transferred to a UV Spectrophotometer to know the absorbance at 645 nm and 663 nm wavelength [5].

$$C_T = 20.2 \ (D_{645}) \times 8.02 \ (D_{663}) \qquad (2)$$

where, C_T is the optical density of total chlorophyll, D_{645} and D_{663} are the optical densities of chlorophyll 'a' at 645 nm and chlorophyll 'b' at 663 nm wavelength.

$$\text{TChl content} = 0.1 \times C_T \times (\text{leaf DW / leaf FW}) \qquad (3)$$

3.4 Ascorbic Acid Content (AA Content)

Ascorbic acid was determined by the titrimetric method formulated by using 2,6-dichlorophenol-indo phenol dye [6]. 0.5g of the leaf sample was extracted with 4% oxalic acid solution and titrated against the dye until a pink colour appears. A separate 0.5g leaf sample is again extracted in with 4% oxalic acid and the volume is made upto 50ml and filtered to separate the solid particles present in leaf extract. A sub-sample of 5ml is taken and again titrated against the dye until a pale pink colour with bubbles is formed which marks the end point of titration.

3.5 Air Pollution Tolerance Index (APTI)

APTI is a parameter used to know about the plants' resistivity and susceptibility on being exposed to different air pollutants like PM_{10}, O_3, SO_2, CO, NO_x. The air pollution effects are high in sensitive plants and low in tolerance plant species [7]. APTI is determined by;

$$APTI = \frac{\{A(T+P)+R\}}{10} \qquad (4)$$

where, A is the ascorbic acid content (mg/g); T is the total chlorophyll content (mg/g); P is the leaf extracts pH & R is the relative water content (%).

Table 1: Range of APTI & plants' response

Range of APTI	Response
Less than 1	Very sensitive
Between 1 to 16	Sensitive
Between 17 to 29	Intermediately Tolerant
Between 30 to 100	Tolerant

IV. RESULTS & DISCUSSIONS

4.1 Relative water content calculation

The relative water content (RWC) of the leaf samples for six months showed highest value in *Bryophyllum pinnatum* (85.13%) and while lowest RWC was observed in *Ziziphus jujuba* (44.47%). A total of 16 plant species were found to have high RWC greater than 70%. The remaining 8 species showed a moderate RWC in the range of 50% to 60%. Similar results were also observed [5], [8] where the maximum and minimum RWC values are 62.2% and 89.5%. High RWC among the plants in polluted areas has been considered as an indication of tolerance to air pollution. It has been reported that high amount of water within a plant body serves as an indicator of drought resistance and helps to maintain its physiological balance under stress conditions such as exposure to air pollution when transpiration rates are usually high [9]. Low RWC in plant species indicates lesser availability of water in soil but a high rate of transpiration.

4.2 Leaf extracts pH calculation

The leaf extract pH values for six months showed the highest value in *Ficus racemosa* as most alkaline with an average pH of 8.88 and the least value in the species *Oxalis corniculata* as most acidic with average pH of 4.50. In all the 24 plant species, three leaf replicates were taken for each sample to see if there is any variation in the observed results and the average of the three were taken as the mean pH. The pH of the leaves was higher in winter months because of the foggy weather due to which the dust particles easily get accumulated on the leaf surface. The dust particles make the pH alkaline by the release of H^+ ions caused by their dissolution in the cell sap. During summer, rains do occur often and due to which, the dust particles are washed away from leaf surface, thus making the pH low [10]. Similar results were also observed [11], where the pH of most species in their study ranged between 4.4 in *Tamarindus indica* to 8.8 in *Ficus bengalensis* which is quite similar to the present study. pH can be used as an indicator for sensitivity of air pollution [12] for which the pH of the plants shift towards the acidic side due to the presence of acidic pollutant. Low leaf pH extract showed good correlation with sensitivity to air pollution and also reduces photosynthetic process in plants [5].

4.3 Total chlorophyll content calculation

The total chlorophyll (TChl) content of the leaf samples for six months showed the maximum value in *Melia azedarach* (0.52 mg/g) and minimum in *Oxalis corniculata* (0.06 mg/g). All other plants show TChl content in the range of 0.07 and 0.39 mg/g. In a similar study [13] it has been found that the minimum TChl content of plants is 0.011 mg/g in *Prunus armeniaca* and 0.071 mg/g in *azadirachta indica* (*Melia azedarach* being in the present study which belong to the same family). There exist a good correlation between TChl content and APTI (*r* = 0.66) for the plant species of *Melia azedarach.* The TChl content of plants signifies its photosynthetic activity as well as the growth and development of biomass. The TChl content of plants varies from species to species, age of leaf and level of pollution from different sources as well as with other biotic and abiotic conditions [14]. Degradation of photosynthetic pigment in leaves has been widely used as an indication of air pollution [15]. Previous studies have revealed that chlorophyll content in plant species varies with the pollution status of that area i.e. higher the pollution level, 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.

4.4 Ascorbic acid content calculation

Ascorbic acid is an essential ingredient of leaves as it plays an important role in cell wall division of plants, defense and cell wall synthesis. A high value of ascorbic acid is an indication of good tolerance of plant species against different air pollutants. The ascorbic acid content of the leaf samples for six months showed the maximum value of 12.64 mg/g in *Catharanthus roseus* and *Ficus racemosa* was found to have the least ascorbic acid content of 6.78 mg/g. Apart from these, the ascorbic acid content of *Melia azedarach* (12.61 mg/g) was noteworthy since ascorbic acid is a natural antioxidant in tolerating pollution [16]. Results observed by [13] showed the maximum and minimum ascorbic acid content as 0.23 and 0.12 and mg /g for *Ficus carica* and Melia *azadirachta* in polluted areas and 0.14 and 0.09 mg/g for *Ficus carica* and *Pistacia atlantica* in non-polluted areas. The presence of ascorbic acid influences the resistance of plants to adverse environmental conditions and being a strong reductant, its reducing power is directly proportional to its concentration [17] .But its reducing capacity is dependent on plant pH, being more at higher pH levels. Ascorbic acid has a major contribution in affecting the behaviour of plants in different seasons. A recent study also reported high positive correlation between APTI and ascorbic acid content of important plant species in highly polluted tropical cities [18] which is in conformity with the findings of the present study. The increased level of ascorbic acid in the plants could be a defense mechanism developed against stress due to accumulation of pollutants. Therefore, the ascorbic acid being an antioxidant serves as a defense system existing in plant tissue to protect cellular components from deleterious effects of pollutants and oxidants [19].

Table 2: RWC of the plant species throughout six months of study

PLANT SPECIES	Nov'16	Dec' 16	Jan'17	Feb'17	Mar'17	Apr'17	Average RWC (%)	SD (±)
1. *Mikania cordata*	99.80	43.4	80.81	61.57	74.98	76.77	72.90	18.98
2. *Cynodon*	95.28	66.2	83.98	50.32	75.68	72.06	73.93	15.36
3. *Mimosa pudica*	99.44	61.8	76.56	72.3	42.38	69.73	70.38	18.67
4. *Amaranthus*	92.23	14.9	77.4	41.66	81.67	80.82	64.78	29.92
5. *Gamochaeta spp.*	77.46	84.4	69.83	52.21	75.8	80.19	73.32	11.42
6. *Lantana camara*	91.33	24.7	66.08	52.17	68.2	63.04	60.94	21.87
7. *Melia azedarach*	99.49	21.3	63.52	78.38	75.91	61.61	66.71	26.05
8. *Oxalis*	98.68	31.4	74.74	62.38	80.98	83.41	71.95	23.08
9. *Amaranthus*	98.70	44.3	52.79	64.37	86.52	71.5	69.70	20.42
10. *Justicia*	99.18	38.8	99.4	71.85	78.95	71.63	76.64	22.39
11. *Catharanthus*	88.59	54.5	84.29	88.61	82.86	77.71	79.43	12.87
12. *Labiata*	99.32	11.4	98.14	77.47	64.25	74.28	70.82	32.19
13. *Ocimum*	89.46	88.9	66.48	56.91	79.27	81.42	77.09	12.94
14. *Alternanthera*	98.10	27.9	83.33	79.25	83.67	78.87	75.20	24.18
15. *Cajanus cajan*	96.98	11.6	55.41	67.09	60	67.71	59.81	27.69
16. *Ziziphus jujuba*	50.08	14.6	47.69	68.68	42.05	43.68	44.47	17.47
17. *Thysanolaena*	99.14	48.9	72.43	61.96	51.37	52.81	64.44	19.09
18. *Dracaena*	98.42	48.3	82.57	59.7	88.3	88.98	77.72	19.39
19. *Ficus racemosa*	99.07	41.4	97.96	65.35	66.23	59.39	71.58	22.69
20. *Phylanthus*	95.03	63.6	78.91	66.64	60.66	57.07	70.32	14.23
21. *Codiaeum*	84.83	41.0	66.25	69.09	77.58	83.54	70.40	16.19
22. *Polystichum*	84.26	37.9	47.1	67.18	49.91	63.08	58.25	16.64
23. *Sonchus*	90.03	28.7	68.41	81.87	75.52	86.54	71.85	22.50
24. *Bryophyllum*	97.56	59.6	91.25	72.23	95.38	94.69	85.13	15.51

*SD: Standard Deviation

Table 3: Leaf extracts pH of the plant species throughout six months of study

PLANT SPECIES	Nov'16	Dec'16	Jan'17	Feb'17	Mar'17	Apr'17	Average pH	SD (±)
1. Mikania cordata	7.21	7.26	7.22	7.39	7.26	7.49	7.31	0.11
2. Cynodon plectostachyus	7.31	7.01	6.95	6.07	7	7.03	6.90	0.42
3. Mimosa pudica	7.4	7.19	7.6	9.49	7.64	7.98	7.88	0.83
4. Amaranthus spinosus	7.5	7.67	8.4	9.51	8.14	8.18	8.23	0.71
5. Gamochaeta spp.	7.15	7.14	7.15	9.3	7.62	7.53	7.65	0.84
6. Lantana camara	7.87	7.77	7.7	8.74	8.6	8.66	8.22	0.49
7. Melia azedarach	7.28	7.57	7.86	9.58	7.74	7.7	7.96	0.82
8. Oxalis corniculata	4.84	4.55	4.63	4.73	4.12	4.11	4.50	0.31
9. Amaranthus aspera	7.61	7.06	7.71	8.75	7.47	7.41	7.67	0.57
10. Justicia	7.31	7.22	7.32	8.16	7.16	7.2	7.40	0.38
11. Catharanthus roseus	7.23	7.36	7.66	8.88	7.52	7.47	7.69	0.60
12.Labiata	6.75	6.74	6.82	6.14	6.22	6.17	6.47	0.33
13. Ocimum tenuiflorum	7.33	7.64	7.77	8.12	7.43	7.44	7.62	0.29
14. Alternanthera	6.24	6.82	6.71	6.69	6.76	6.78	6.67	0.21
15. Cajanus cajan	7.09	7.54	7.56	8.49	7.7	7.65	7.67	0.46
16. Ziziphus jujuba	6.91	6.89	6.57	6.81	6.44	6.49	6.69	0.21
17. Thysanolaena maxima	7.03	7.25	8.17	9.15	7.52	7.56	7.78	0.77
18. Dracaena fragrans	6.78	6.78	6.46	6.73	6.4	6.33	6.58	0.21
19. Ficus racemosa	7.83	9.01	8.66	9.59	9.11	9.08	8.88	0.59
20. Phylanthus niruri	6.62	6.76	6.67	6.88	6.41	6.44	6.63	0.18
21. Codiaeum variegatum	7.31	7.78	7.42	9.06	8.88	8.9	8.23	0.81
22. Polystichum munitum	7.28	7.85	8.24	8.66	8.36	8.31	8.12	0.49
23. Sonchus arvensis	7.04	7.49	8.03	7.93	7.86	7.83	7.70	0.37
24. Bryophyllum pinnatum	5.38	6.06	6.17	5.8	5.63	5.58	5.77	0.30

Table 4: Total Chlorophyll (TChl) Content of the plant species throughout six months of study

PLANT SPECIES	Nov'16	Dec'16	Jan'17	Feb'17	Mar'17	Apr'17	Avg. TChl content (mg/g)	SD (±)
1. Mikania cordata	0.17	0.06	0.08	0.39	0.07	0.05	0.14	0.13
2. Cynodon plectostachyus	0.5	0.24	0.11	0.08	0.08	0.05	0.18	0.17
3. Mimosa pudica	0.09	0.44	0.19	0.07	0.05	0.05	0.15	0.15
4. Amaranthus spinosus	0.23	0.24	0.22	0.36	0.2	0.05	0.22	0.12
5. Gamochaeta spp.	0.17	0.12	0.22	0.12	0.13	0.08	0.14	0.07
6. Lantana camara	0.55	0.29	0.23	0.55	0.48	0.23	0.39	0.20
7. Melia azedarach	1.02	0.45	0.2	0.58	0.36	0.49	0.52	0.32
8. Oxalis corniculata	0.07	0.04	0.03	0.08	0.09	0.05	0.06	0.03
9. Amaranthus aspera	0.13	0.04	0.49	0.42	0.15	0.1	0.22	0.19
10. Justicia	0.26	1.37	0.24	0.86	0.15	0.12	0.50	0.50
11. Catharanthus roseus	0.17	0.47	0.34	0.18	0.17	0.16	0.25	0.15
12.Labiata	0.14	0.12	0.39	0.31	0.12	0.12	0.20	0.13
13. Ocimum tenuiflorum	0.09	0.02	0.07	0.22	0.07	0.06	0.09	0.07
14. Alternanthera philoxeroides	0.24	0.12	0.1	0.15	0.11	0.05	0.13	0.08
15. Cajanus cajan	0.62	0.46	0.32	0.28	0.13	0.08	0.32	0.22
16. Ziziphus jujuba	0.16	0.23	0.17	0.07	0.37	0.2	0.20	0.12
17. Thysanolaena maxima	0.4	0.09	0.56	0.36	0.14	0.08	0.27	0.21
18. Dracaena fragrans	0.52	0.35	0.15	0.28	0.03	0.01	0.22	0.20
19. Ficus racemosa	0.17	0.18	0.25	0.07	0.51	0.11	0.22	0.16
20. Phylanthus niruri	0.37	0.10	0.18	0.19	0.2	0.11	0.19	0.11
21. Codiaeum variegatum	0.27	0.15	0.11	0.13	0.47	0.11	0.21	0.15
22. Polystichum munitum	0.53	0.42	0.46	0.33	0.21	0.13	0.3	0.19
23. Sonchus arvensis	0.22	0.03	0.14	0.6	0.1	0.07	0.19	0.20
24. Bryophyllum pinnatum	0.17	0.02	0.07	0.1	0.02	0.02	0.07	0.06

Table 5: Ascorbic Acid (AA) Content of the plant species throughout six months of study

PLANT SPECIES	Nov'	Dec'16	Jan'17	Feb'17	Mar'17	Apr'17	Avg. AA content(mg/g)	SD (±)
1. *Mikania cordata*	14.67	4.62	5.26	8.18	4.62	9	7.73	3.88
2. *Cynodon plectostachyus*	6.89	6.15	4.21	6.36	10.77	7	6.90	2.15
3. *Mimosa pudica*	14.67	3.08	7.37	12.73	12.31	8	9.69	4.31
4. *Amaranthus spinosus*	13.33	9.23	8.42	6.36	15.38	9	10.29	3.37
5. *Gamochaeta spp.*	16	7.69	4.21	6.36	16.92	6	9.53	5.49
6. *Lantana camara*	12	4.62	3.16	13.64	7.69	11	8.69	4.22
7. *Melia azedarach*	12	15.38	9.47	14.55	9.23	15	12.61	2.79
8. *Oxalis corniculata*	8.46	6.15	7.37	13.64	6.15	9	8.46	2.79
9. *Amaranthus aspera*	8	7.69	10.53	7.27	27.69	5	11.03	8.35
10. *Justicia*	9.33	10.77	3.16	10.91	6.15	6	7.72	3.11
11. *Catharanthus roseus*	6.67	24.62	12.63	5.45	18.46	8	12.64	7.57
12. *Labiata*	5.33	9.23	4.21	7.27	23.08	17	11.02	7.45
13. *Ocimum tenuiflorum*	5.33	6.15	6.32	10	9.23	12	8.17	2.63
14. *Alternanthera philoxeroides*	5.33	9.23	7.37	11.82	16.92	6	9.45	4.35
15. *Cajanus cajan*	8	12.31	5.26	7.27	15.38	5	8.87	4.14
16. *Ziziphus jujuba*	2.67	7.69	14.74	4.55	13.85	10	8.92	4.88
17. *Thysanolaena maxima*	4	9.23	9.47	6.36	20	11	10.01	5.50
18. *Dracaena fragrans*	6.67	7.69	11.58	7.27	4.62	7	7.47	2.28
19. *Ficus racemosa*	2.67	4.62	6.32	15.45	7.62	4	6.78	4.59
20. *Phylanthus niruri*	4	9.23	16.84	14.55	13.85	8	11.08	4.82
21. *Codiaeum variegatum*	4	6.15	2.11	18.18	21.54	8	10.00	7.96
22. *Polystichum munitum*	2.67	7.69	5.26	11.82	23.08	9	9.92	7.17
23. *Sonchus arvensis*	6.67	3.08	6.32	7.27	15.38	6	7.45	4.15
24. *Bryophyllum pinnatum*	9.33	4.62	13.68	8.18	24.62	5	10.91	7.48

Table 6: APTI of the plant species throughout six months of study

PLANT SPECIES	Nov'16	Dec'16	Jan'17	Feb'17	Mar'17	Apr'17	Average APTI	SD (±)
1. *Mikania cordata*	20.8	7.33	11.92	12.52	10.88	14.46	12.99	4.49
2. *Cynodon plectostachyus*	14.91	11.09	11.37	8.94	15.19	12.16	12.28	2.40
3. *Mimosa pudica*	20.9	8.54	13.4	19.4	13.70	13.40	14.89	4.53
4. *Amaranthus spinosus*	19.5	8.79	15	10.44	20.99	15.49	15.04	4.81
5. *Gamochaeta spp.*	19.5	14.03	10.09	11.21	20.69	12.59	14.69	4.41
6. *Lantana camara*	19.2	6.2	9.11	17.89	13.80	16.08	13.71	5.11
7. *Melia azedarach*	19.9	14.47	13.98	22.62	15.07	18.45	17.42	3.47
8. *Oxalis corniculata*	14.02	5.97	10.91	12.8	10.69	12.09	11.08	2.79
9. *Amaranthus aspera*	16.1	9.89	13.91	13.1	29.75	10.91	15.61	7.27
10. *Justicia*	17	13.14	12.33	17.03	12.39	11.56	13.91	2.46
11. *Catharanthus roseus*	13.8	24.73	18.53	13.8	22.48	13.88	17.87	4.85
12. *Labiata*	13.6	7.48	12.85	12.44	21.06	18.12	14.26	4.75
13. *Ocimum tenuiflorum*	12.9	13.61	11.6	14.03	14.85	17.14	14.02	1.88
14. *Alternanthera philoxeroides*	13.3	9.2	13.35	16.01	19.99	11.99	13.97	3.69
15. *Cajanus cajan*	15.9	11.02	9.69	13.08	18.04	10.64	13.06	3.29
16. *Ziziphus jujuba*	6.9	6.94	14.7	10	13.64	11.06	10.54	3.28
17. *Thysanolaena maxima*	12.9	11.67	15.51	12.24	20.46	13.69	14.41	3.25
18. *Dracaena fragrans*	14.7	10.32	15.91	11.07	11.80	13.34	12.86	2.18
19. *Ficus racemosa*	12	8.39	15.43	21.46	13.95	9.62	13.48	4.71
20. *Phylanthus niruri*	12.3	12.69	19.43	16.95	15.22	10.95	14.59	3.21
21. *Codiaeum variegatum*	11.5	8.99	8.21	23.62	27.90	15.56	15.96	8.12
22. *Polystichum munitum*	10.5	10.16	9.29	17.34	24.77	13.90	14.33	5.93
23. *Sonchus arvensis*	13.8	5.19	12	14.39	19.79	13.39	13.09	4.71
24. *Bryophyllum pinnatum*	14.9	8.78	17.66	12.05	23.45	12.27	14.85	5.16

4.1 Correlation of APTI with the bio-chemical parameters

The statistical analysis revealed that ascorbic acid content is the dominating factor in changing the behaviour of different plants on a monthly basis since it is a major metabolite in plants and protects the plants from oxidative damage resulting from aerobic metabolism, photosynthesis and a range of pollutants. Greater the ascorbic acid content in plants, greater is its potential to tolerate pollution. Ascorbic acid showed significant positive correlation with APTI (R^2 = 0.569, $r= 0.75$, $p\leq$ 0.01) compared to correlation between APTI and leaf extract pH (R^2= 0.232, $r= 0.48$, $p\leq$ 0.01) and correlation between APTI and total chlorophyll content (R^2= 0.106, $r= 0.33$, $p\leq$ 0.01) as shown in Fig(s). 1-4. The RWC (R^2= 0.089, $r= 0.30$, $p\leq$ 0.01) did not showed any significant correlation with APTI.

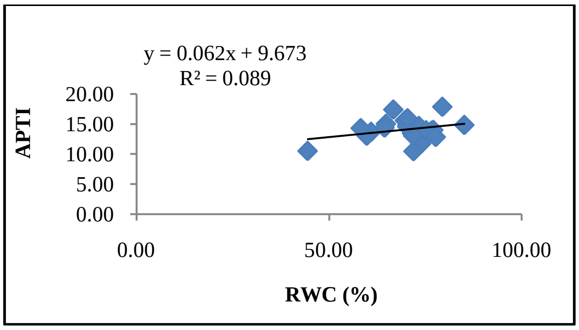

Fig. 1 Correlation between RWC and APTI

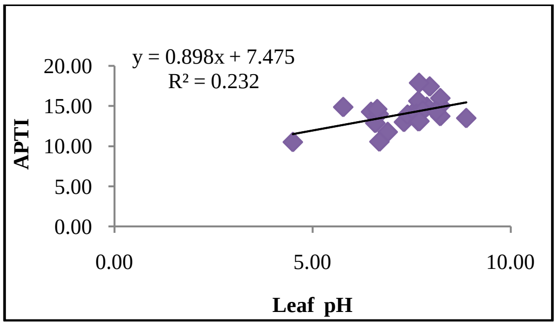

Fig. 2 Correlation between pH and APTI

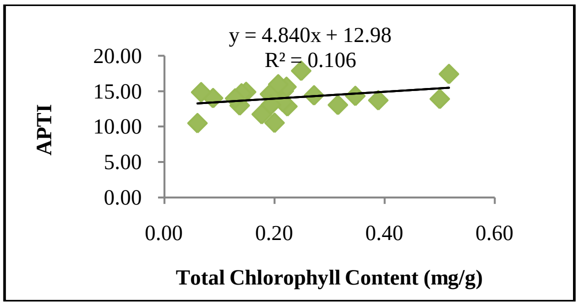

Fig. 3 Correlation between TChl and APTI

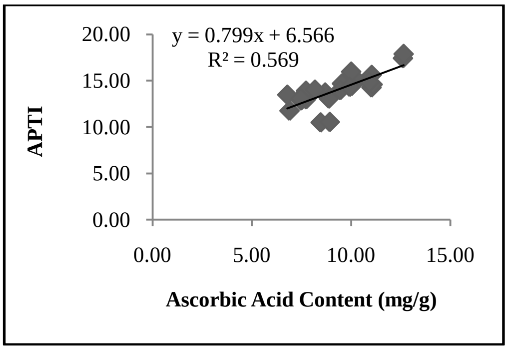

Fig. 4 Correlation between AA and APTI

4.2 Average monthly concentration of major air pollutants (PM_{10}, SO_2 and NO_x) in the Boragaon Industrial Area, Guwahati

The average monthly data of the three major air pollutants (PM_{10}, SO_2 and NO_x) for the reported period of 6 months are shown in Fig(s). 5-7. The concentration of PM_{10} was maximum (187.26 µg/m^3) in March, 2017 while lowest of 84.51 µg/m^3 was recorded in the month of November, 2016. There was a pattern on increase in the concentration of PM_{10} from November 2016 to March, 2017 followed by decline in April, 2017. The concentration of SO_2 was highest (11.18 µg/m^3) in December, 2016 and lowest was recorded in the month of April, 2017. The SO_2 concentration showed declining trend from highest during December, 2016 to lowest (7.05 µg/m^3) in April, 2017 even though its concentration was a bit low (10.85 µg/m^3) in November, 2016 compared with December, 2016. The NO_x concentration was highest (20.85 µg/m^3) in the month of January, 2017 while lowest of 16.99 µg/m^3 was recorded from in April, 2017. The concentration of NO_x remained nearly stable throughout the study period despite slight increase in the month of January, 2017 [20].

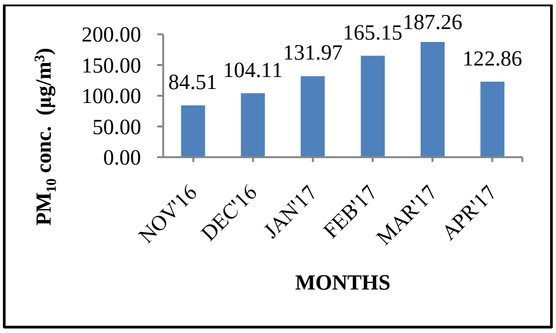

Fig. 5 Monthly concentration of PM_{10} during the study period

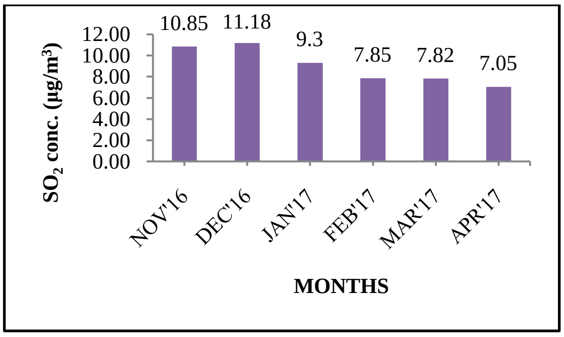

Fig. 6 Monthly concentration of SO_2 during the study period

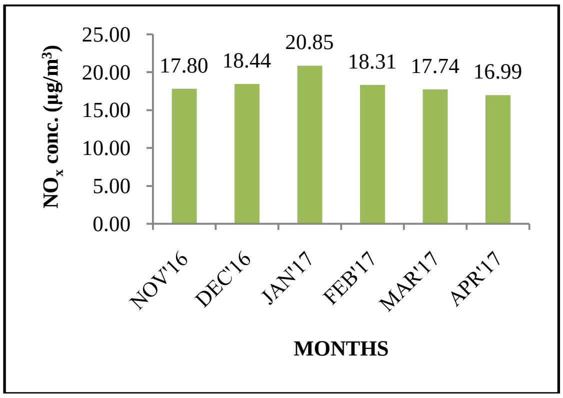

Fig. 7 Monthly concentration of NO_x during the study period

(Data Source: State Pollution Control Board, Assam)

4.3 Air Quality Index at Boragaon & Guwahati

Air quality index (AQI) values of the study area (Boragaon) and Guwahati are shown in Fig.8 The AQI was lowest in the month of November 2016 and increased to highest in the month of March, 2017 in both Boragaon and Guwahati. There was no significant variation in the AQI valued of the two areas reported in the study period. The AQI values indicates that both Boragaon and Guwahati falls under moderately polluted condition (101 - 200) which is associated with breathing discomfort to the humans with possible heart disease in children and older adults.

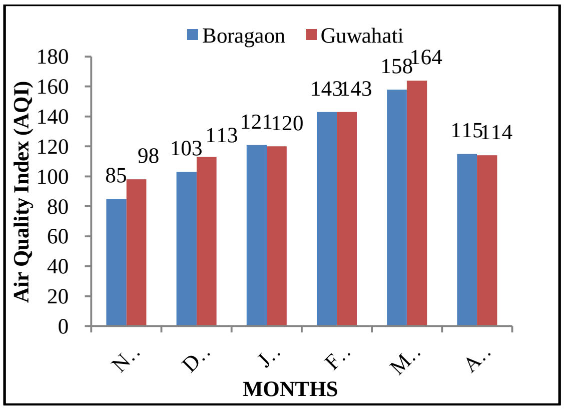

Fig. 8 AQI index at Boragaon and Guwahati

4.4 Correlation between APTI and the concentration of air pollutants

The relationship between average air pollution tolerance index (APTI) of all plant species with the average concentration of the three major pollutants (PM_{10}, SO_2 and NO_x) revealed no statistically significant relationship as shown in Fig(s) 9-11. The correlation co-efficient (r) values were less than 0.707 ($p \leq 0.05$) for all the three pollutants (r = 0.69 for PM_{10}, r = 0.50 for SO_2 and r = 0.28 for NO_x, $p \leq 0.05$).

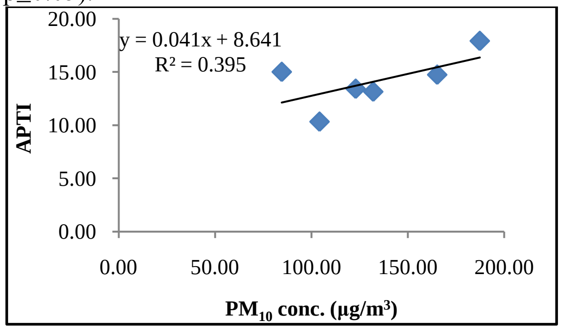

Fig. 9 Correlation between APTI and PM_{10} conc.

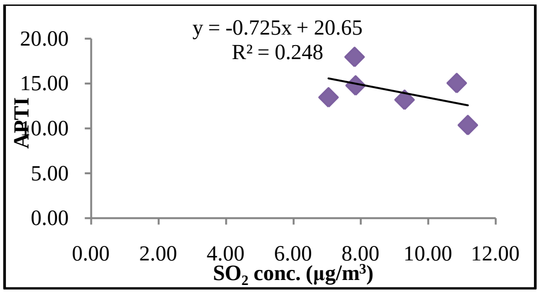

Fig. 10 Correlation between APTI and SO_2 conc.

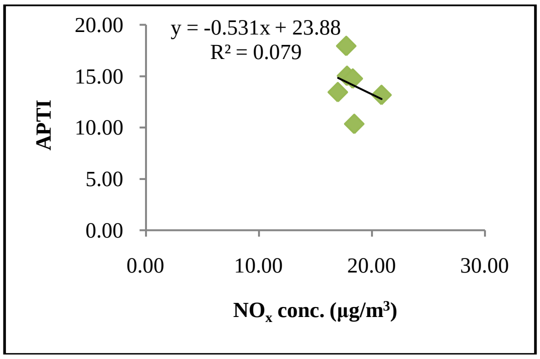

Fig. 11 Correlation between APTI and NO_x conc.

4.5 Correlation between air pollutants (PM_{10} , SO_2 and NO_x) and biochemical properties of plant species

The concentration of PM_{10} was not correlated with the three biochemical parameters (RWC, TChl and pH) as shown in Fig(s) 12-15. However, the AA content was found to show significant positive correlationship (R^2=0.69, r = 0.83, $p \leq 0.05$) to the concentration of PM_{10}. The concentrations of SO_2 and NO_x did not show any significant relationship with any of the four biochemical parameters.

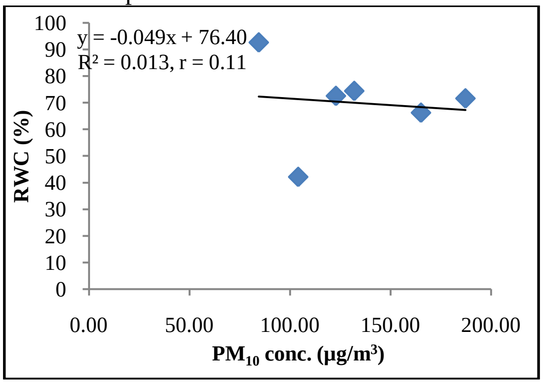

Fig. 12 Correlation between RWC and PM_{10} conc.

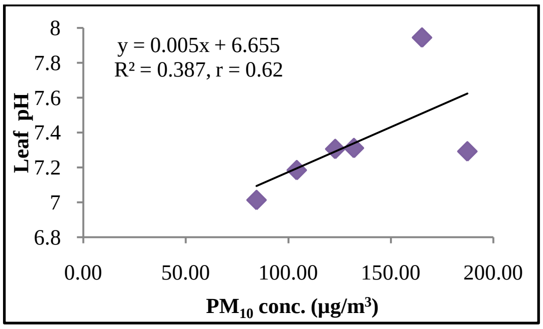

Fig. 13 Correlation between pH and PM_{10} conc.

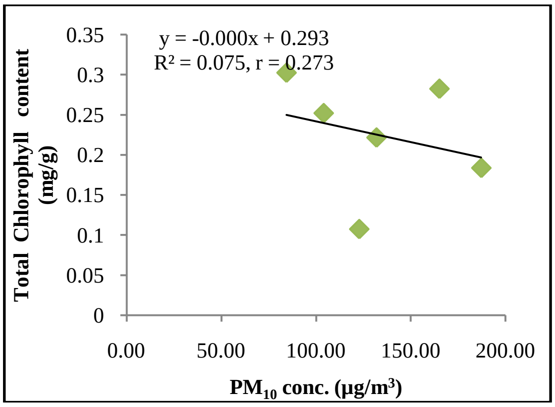

Fig. 14 Correlation between TChl and PM_{10} conc.

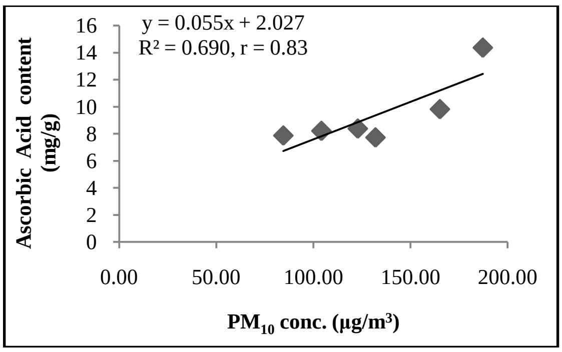

Fig. 15 Correlation between AA and PM_{10} conc.

V. CONCLUSIONS

The findings of this study revealed that that the APTI values of different plant species were primarily influenced by increase in ascorbic acid content as a result of exposure to high concentration of a major air pollutant, PM_{10}, as majority (92%) of the plant species (22 nos.) were categorized into sensitive group of plants while only 2 plant species (8%) were found to be moderately tolerant species to air pollution. The average APTI values of all plants for 6 months revealed lowest in *Ziziphus jujuba* (10.54) while highest were recorded in *Catharanthus roseus* (17.87) and *Melia azedarach* (17.42). Moreover, *Sonchus arvensis* was recorded with lowest (5.19) value of APTI in the month of December, 2016 while highest was recorded in *Amaranthus aspera* (29.75) during March, 2017. Also, different plant species exhibited varying levels of tolerance and sensitivity to three major air pollutants. The concentration of three major air pollutants (PM_{10}, SO_2 and NO_x) and air quality index (AQI) of the industrial site revealed highest values during March, 2017 and lowest during November, 2016. The AQI and concentration of PM_{10} were found highest (AQI =158 and PM_{10} =187.26 $\mu g/m^3$) in the month of March, 2017 while lowest was recorded during November, 2016. Further significant correlationship was observed between average APTI value and ascorbic acid content (R^2= 0.569, $r = 0.75$; $p \leq 0.01$) while other three biochemical parameters showed no significant correlationship with APTI. The average APTI values were also found to have positive correlation with the concentration of PM_{10}. So, it can be inferred that the increased concentration of ascorbic acid in the plant leaves could be related to enhanced cellular anti-oxidant activities of the plants to protect various metabolic processes such as photosynthesis and respiration as survival strategies against stress caused by increased concentration of air pollutants because from the observations of the study, highest values of APTI's and ascorbic acid contents were recorded only in two plant species, *Catharanthus roseus* and *Melia azedarach* revealing the tolerance capacities of these plants to sustain their growth and survival in polluted environment. Therefore, these two plants mentioned above could be recommended for permanent vegetation cover for improved and sustainable management of environment in air pollution prone areas such as waste metal recycling industries in the country.

VI. SCOPE FOR FURTHER STUDY

Though the present study was a pioneer work in the field of air pollution mitigation and environmental management with reference to waste metal recycling industries in the region, the period of study was limited to only a period of 6 months,

further study for longer period may be done while considering the following points:
(a) The number of similar industrial sites may be increased to evaluate reproducibility and validity of the findings.
(b) Other analytical parameters such as important physico-chemical and biological properties of soil and water within and surrounding industrial area may be incorporated to observe impact of air pollution in soil and water.
(c) The potential health impacts of air pollution on the employees of the industry, particularly those involved in direct handling and processing of waste metals may be included in the investigation to understand direct effect of major air pollutants.

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