Biomonitoring of Air Quality in the Industrial Town of Asansol using the Air Pollution Tolerance Index Approach

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Abstract

Asansol city is an industrial urban area which is also part of the Raniganj Coalfield area and is located in the Burdwan district of West Bengal. Over the last five years there was hectic development in the area in terms of industries, vehicles and infrastructures. These have resulted in significant rise of the air pollutants over the city atmosphere; which is affecting human population, other animals and also the plant community. Although vegetation can absorb particulate and other gaseous pollutants into their system, but they also have some limitation and tend to show symptoms of damages after prolonged exposure. Based on this absorbing power and tolerance limit, vegetations can be classified as Highly Tolerant, Moderately Tolerant and Sensitive. This has been incorporated by scientists into a quantitative value of Air Pollution Tolerance Index (APTI), depending on the score of the plant physiology indicators, namely Leaf Extract pH, Relative Water Content, Ascorbic Acid and Chlorophyll Content. The vegetation monitoring in terms of its APTI acts as a 'Bioindicator' of air pollution and can be incorporated into assessment studies. A total of thirty plant species (trees, herbs & shrubs) available in the area were screened; sampled in polythene bags; tagged, brought to the laboratory and analyzed for pH, Relative Water Content, Ascorbic Acid and Chlorophyll content. The results were used to calculate the APTI for each plant and then their tolerance/sensitivity was assessed. The APTI score of <10 is considered 'sensitive'; value within 10-16 is considered as 'intermediate' and >17 is 'tolerant'. The pH value ranged between 5.53 (Psidium guajava) and 7.60 (Osimum sanctum); Total Chlorophyll content varied between 7.4 and 14.3 mg/g. The Ascorbic Acid content ranged between 2.89 to 9.1 mg/g, where as the Relative Water Content varied between 35% and 91.5%. Based on the APTI score, which ranged between 4.50 and 18.5, it is observed that about 55 % of the studied species of plants are 'Sensitive' to air pollution. Among them Thevetia peruviana and Rosa cinensis showed lowest APTI values and can be used as 'Bioindicator'. Plant species like Mangifera, Azadirachta, Ficus, Psidum, Eucalyptus, Alstoni and Delonix were in the intermediate to tolerant zone of the index. Based on the investigation a green belt development plan for the polluted zoned of the city has been suggested.

Keywords: Air Pollution Tolerance Index, Plant Physiology, Asansol, Industrial area.

Introduction

In recent times there has been significant development activity in terms of industrialization, urbanization etc. in almost all medium & small towns and cities in India. Significant growth is also observed in the automobile sector. The combined effect of the enhanced industrialization coupled with sharp increase in vehicular population, has taken its toll on the environment with special reference to the atmospheric system. In most areas in India & other countries the environment has reached its carrying capacity in terms of air pollutants like NOx, SO_2, CO, CO_2, suspended particles & the toxic heavy metals like lead. Some contributions are also from domestic & agriculture/farming. The impact of such anthropogenic emission into the atmosphere and there movement into the biosphere by transformation, reaction and modification is responsible for a variety of chronic and acute diseases at the local, regional, & global scale. Impact on the plant community has also been studied world wide in terms of plant – environment interactions, since the plants are much more sensitive in comparison to other organism.

The symptoms or effect including changes in the plant anatomy, physiology or biochemistry indicate a polluted environment. Since the plants major systems and organs are exposed to the atmosphere and the leaves continuously exchange gases in and out of the systems, any change in the atmosphere is reflected on the plant health. Thus the regular monitoring of certain parameters of the plants physiology can indicate air pollution in terms of its severity and degree. These plants can be effectively used as bioindicators of the air pollutants. Although the sensitive to air pollutants varies across the plant community with some being 'tolerant' showing no or minimal symptoms and other being 'sensitive' that shows symptoms even if the air pollutants increase in small amounts. The impact can be used for monitoring of air pollutants in medium to large towns & cities in terms of air pollutant concentration to observe the air quality in the locality. The plants response to air pollutant varies from species to species and also in terms of type of pollutant, its reacting mechanism, concentration and duration of exposure. The pollutants enter into the plants and react in a variety of ways before being removed or absorbed that may include accumulation, chemical transformation and incorporation into the metabolic system. In the process some plants are injured, while others show minimal effects. The type of plants species is helpful in evaluating its usefulness for use in green belt development for the prevention and screening of air pollutants from the atmosphere.

The study of response of plants to air pollution by analysis of certain biochemical parameters like leaf extract pH, ascorbic acid content, relative water content and chlorophyll content and calculation of an 'Air Pollution Tolerant Index' (APTI) has been done in many parts of the world and also in India, where by the different types of studied species of a geographic location have been categorized according to this APTI values into tolerant and sensitive species[1-5].

Asansol city situated in the western part of Burdwan district of West Bengal in eastern India is the second largest city of the state. The city is an industrial belt and also forms part of the Raniganj Coal Field area. The region has urbanized due to rapid industrialization in the last ten years. In the last six years the air pollution situation in the city has reached to harmful levels[6, 7]. A variety of industries are present in and around the city like steel plant, cement, silicate, glass, distillery, refractory, sponge, alloys along with large number of open and underground coal mines. Emission from these industries has taken its toll on the local air quality.

Material and Methods

A total of thirty plant species were selected for the study from a residential area of Asansol city during the summer of 2007 (March – June). The screening and selection of the plant species was partly based on literature survey of similar work and guidelines of Central Pollution Control Board[8]. The 'Air Pollution Tolerant Index' (APTI) was developed by analyzing the biochemical parameters of leaf materials, namely pH, ascorbic acid, relative water content, total chlorophyll[9]. The pH values were estimated by using a digital calibrated pH meter. Ascorbic acid was estimated by titrimetric method using the 2, 6, Dichlorophenol-indophenol method. Total chlorophyll of leaf extract was estimated by using spectrophotometric method by extraction with 80% acetone. Relative water content was estimated by gravimetric method by determining the leaf weight under different condition like initial, turgid and dry weight. The formula used to determine the 'Air Pollution Tolerance Index' (APTI) using the four parameter is given by[10]

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

where, A = Ascorbic acid content (mg/g); T = Total chlorophyll content of leaf (mg/g); P = pH of the leaf extract and R = Relative water content of leaf extract (%).

Based on the development and evaluation of APTI values among the samples they were categorized into three groups, namely < 10 is sensitive species, $> 10 < 16$ is intermediate species and > 17 is tolerant species

Results and Discussion

The impacts of various air pollutants on plant are given in table 1. The characteristic of the plant species considered for the study is given in the table 2. The analyzed value of the four biochemical parameter along with the calculated APTI for the samples is given in table 3. It is observed from table 3 that the pH of the leaf extracts ranges from 5.53 to 7.37 with the *Murraya paniculata* and *Calotropis gigantea* having highest value and *Psidium guayava* having lowest values. The result shows an acidic leaf extract content in most of the sampled plants. The more acidic nature demonstrates that the air pollutants, mostly gaseous types, namely SO_2, NOx, diffuse and form acid radicals in the leaf matrix by reacting with cellular water. This further effects the chlorophyll molecules[10]. The concentration of SO_2 and NOx in the surrounding air affects the pH as well as chlorophyll content and thus sensitive plants. The frequency distribution of pH values shows that the majority have a pH range of 6 - 6.5. The Relative Water Content (RWC) of leaves is an indicator of the plants water status with respect to its physiological consequences of cellular water and it ranged between 35.50% and 91.51% among the studied plants. Highest value was found in *Artocarpus heterophyllus* and lowest in *Zizyphus mauritiana*. The Relative Water Content indicates change in leaf matrix hydration condition and will generate higher acidity condition when RWC is low. More water content will dilute acidity. The chlorophyll content is affected by pH in leaves and ranges between 7.41mg/gm to 14.28 mg/gm.

The highest chlorophyll content is observed in *Rosa sinensis* and lowest in *Ocimum sanctum* sp. The ascorbic acid content, a stress reducing factor is a strong reducing agent and is associated with tolerant plants. It reduces the effect of SO_2 and acts as an antioxidant. A high content of ascorbic acid in plant leaf is related to biochemical and physiological species of a particular environment. In the present study it varied between 3.64 mg/gm and 9.14 mg/gm, with Rosa scinensis having lowest value and Psidium guayava having highest content. The calculated APTI associated with the sampled vegetation ranges between 12.94 and 25.13. The frequency distribution show that 26.7 % of plants show APTI of less than 17, representing sensitive response to air pollution. Plants falling in this group were *Polyanthia, Anona, Zizyphus, Rosa, Ocimum, Bauhinia, Lantana* and *Poinciana sp.* in this group. The rest of 73.3 % of samples fall in the tolerant range of > 17 APTI and include Mangifera, Azadirachta, Alstonia, Ficus, Butea, Psidium, Moringa, Dalbergia, Artocarpus, Hibiscus, Calotropis, Ricinus, Murraya, Citrus, Aegle, Eucalyptus, Ixora, Nerium, Tamarindus, Thevetia and Tabernaemontana sp. These species having high value of APTI, greater than 17 demonstrate a tolerant mechanism to air pollution in the area. Among them highest tolerance is associated with *Mangifera indica.* Overall the lowest APTI was observed in the *Rosa scinensis.* This species along with those having less than 17 APTI values can be utilized as bio-indicator of the air quality in the study area, while those species in the tolerant group can be used for development of greenbelt around sources, transmission path and/or receptor based.

The correlation matrix given in table 4 shows the association of the four biochemical parameters among themselves and also with the dependent parameter APTI whereas the figure 1 shows the linear regression plots individual variables with APTI. It is observed that a high positive correlation exists between APTI and Relative Water Content, Chlorophyll content and Ascorbic Acid values and insignificant low correlation with pH values. It indicates that Ascorbic acid and Relative water content of leaf are the most significant and determining factors on which the Tolerance depends. Although correlation among the four variables are strong but low association between Ascorbic acid and RWC exists. Multiple regression analysis using SPSS 12 was used to develop the model that can predict the values of APTI.

APTI = 0.102 x Relative Water Content + 0.0641 x Chlorophyll + 0.790 x pH + 1.831 x Ascorbic Acid – 12.884.

The model shows a R^2 value of 0.996 and is found to be significant.

Conclusion

Based on the study it can be said that the Air Pollution Tolerance Index (APTI) values estimated using the four biochemical parameter in plant leaves, namely Relative Water Content, Chlorophyll, pH and Ascorbic Acid, can be used as a predictor of air quality. These parameters are significant in studies between plant-environment interactions and used for development of bioindicator groups. The APTI

Table I
Impact of selected air pollutants on plant health

S No.	Pollutant	Threshold Dose	Plant Injury/ Symptoms
1	Sulphur dioxide	0.70 ppm (1820 μg/m^{-3}) for 1 hr.; 0.18 ppm (468 μg/m^{-3}) for 8hr.; 0.008-0.017 ppm (21/44 μg/m^{-3}) for growing season.	Interveinal necrotic blotches. Red brown dieback or banding in pines.
2.	Nitrogen dioxide	20 ppm (38 x 10^3 μg/m^{-3}) for 1hr.; 1.6-2.6 ppm (3000 -5000 μg/m^{-3}) for 48 hr.; 1 ppm (1900 μg/m^{-3}) for 100 hr.	Interveinal necrotic blotches similar to those by SO_2.
3.	Fluoride	< 100 μg/m^{-1}) fluoride	Red brown distal necrosis in pines.
4.	Ammonia	55 ppm (38 x 10^3 μg/m^{-3}) for 1 hr.	Tip and margin necrosis.
5	Chlorine	0.5-1.5 ppm (1400-4530 μg/m^{-3}) for 0.5 -3 hr.	Interveinal necrotic blotches similar to those by SO_2. Distal necrosis in pines.
6.	Ethylene	Variable, undetermined	Chlorosis, necrosis, abscission, Dwarfing premature defoliation.
7.	Hydrogen Sulphide	100 ppm (14 x 10^4 μg/m^{-3}) for 5 hr.	Interveinal necrotic blotches. Details necrosis in pines.
8.	Trace Metals	Variable , undetermined	Interveinal Chlorosis, tip and margin necrosis, Distal necrosis.
9.	Ozone	0.2-0.30 ppm (392 – 588 μg/m^{-3}) for 2-4 hr.; some confers 0.08 ppm (157 μg/m^{-3}) for 12-13 hr.	Upper surface flecks Distal necrosis and stunted needles in pines.
10.	Peroxy acetyl nitrate	0.02 -08. ppm (989-3958 μg/m^{-3}) for 8 hr.	Lower surface bronzing, Chlorosis, early senescence.
11.	Acid rain	pH < 3.0	Necrotic spots, Distal necrosis pines.

of a particular geographic area can be used for biomonitoring of air quality. Plant species like Mangifera, Azadirachta, Alstonia, Ficus, Butea, Psidium, Moringa, Dalbergia, Artocarpus, Hibiscus, Calotropis, Ricinus, Murraya, Citrus, Aegle, Eucalyptus, Ixora, Nerium, Tamarindus, Thevetia and Tabernaemontana whose APTI values indicate them to be Tolerant species can be identified for use in greenbelt development in polluted areas.

Table II
Vegetation characteristics of selected species studied in Asansol

S.No	Scientific Name	Common Name	Family	HA	HT (m)	GR	E/D	CSA (m^2)
1	*Mangifera indica*	Mango	Anacardiaceae	T	15	Q	E	21435.38
2	*Azadirachta indica*	Neem	Meliaceae	T	20	Q	E	300445.3
3	*Alstonia scholaris*	Chattiyan	Apocynaceae	T	15	Q	E	241680.5
4	*Ficus benghalensis*	Banyan	Moraceae	T	20	Q	E	236493.67
5	*Ficus relegiosa*	Peepal	Moraceae	T	20	M	E	144868.7
6	*Polyanthia longifolia*	Devdaru	Anonaceae	T	15	Q	E	10976.62
7	*Butea monosperma*	Palash	Fabaceae	T	10	S	D	38592.1
8	*Psidium guayava*	Guava	Myrtaceae	T	5	Q	E	9243.1
9	*Moringa oleifera*	Sajina	Moringaceae	T	10	Q	D	23450.1
10	*Dalbergia sisoo*	Sissoo	Fabaceae	T	10	M	E	5848.5
11	*Anona squamosa*	Custard apple	Anonaceae	T	10	F	E	2178.21
12	*Artocarpus heterophyllus*	Jackfruit	Urticaceae	T	10	S	E	196419.1
13	*Zizyphus mauritiana*	Ber	Rhamnaceae	T	10	Q	E	2638.17
14	*Hibiscus rosasinensis*	Joba	Malvaceae	S	3	Q	E	61.47
15	*Calotropis gigantea*	Akand	Asclepiadaceae	S	5	Q	E	47.5
16	*Rosa scinensis*	Rose	Malvaceae	S	-	-	E	-
17	*Ricinus communis*	Bheranda	Euphorbiaceae	S	6	Q	E	942.56
18	*Murraya paniculata*	Kamini	Rutaceae	S	5	Q	E	1354.61
19	*Ocimum sanctum*	Tulsi	Lamiaceae	H	-	-	E	-
20	*Citrus aurantium*	Nebu	Rutaceae	T	5	Q	E	494.9
21	*Aegle marmelos*	Beal	Rutaceae	T	12	S	E	26547.19
22	*Bauhinia acuminate*	Kanchan	Caesalpinaceae	T	3	S	D	109.8
23	*Eucalyptus*	Eucalyptus	Myrtaceae	T	20	Q	E	52447.63
24	*Ixora coccinea*	Rangan	Rubiaceae	T	6	Q	E	183.26
25	*Lantana camara*	Lantana	Verbenaceae	S	3	Q	E	324.58
26	*Nerium indicum*	Karabi	Apocynaceae	S	5	Q	E	5747.63
27	*Poinciana pulcherrima*	Krishnachura	Caesalpinaceae	S	3	Q	E	8034.67
28	*Tamarindus indica*	Tentul	Caesalpinaceae	T	20	Q	E	276839.5
29	*Thevetia peruviana*	Korubi	Apocynaceae	S	6	Q	E	21775.22
30	*Tabernaemontana divaricata*	Tagar	Apocynaceae	S	3	Q	E	128.67

Source: CPCB 2007; HA – Habitat (T-Tree, S-Shrub, H-Herb); HT- Height; GR-Growth rate (Q-Quick, M-Moderate, S-Slow); E D- Evergreen / Deciduous; CSA- Crown Surface Area ; CS – Crown Shape (O-Oblong, R-Round, S-Spreading, C-Conical, Ov – Ovoid); LA- Leaf Area and SI – Stomatal Index.

Table III

Values of APTI along with biochemical properties of analyzed samples

S.N.	Sample Code	Local Name	*Scientific Name*	Relative Water Content (%)	Chloro-phyll (mg/gm)	pH	Ascorbic Acid (mg/gm)	APTI
1	RES/01/11-06	Mango	*Mangifera indica*	89.72	14.13	5.56	8.21	**25.1**
2	RES/02/11-06	Neem	*Azadirachta indica*	73.50	11.92	7.01	8.42	**23.3**
3	RES/03/11-06	Chattiyan	*Alstonia scholaris*	83.52	8.70	5.87	7.11	**18.7**
4	RES/04/11-06	Banyan	*Ficus benghalensis*	78.39	10.41	6.70	9.01	**23.2**
5	RES/05/11-06	Peepal	*Ficus relegiosa*	86.45	12.29	7.02	8.53	**25.1**
6	RES/06/11-06	Devdaru	*Polyanthia longifolia*	65.30	10.66	5.69	5.52	**15.6**
7	RES/07/11-06	Palash	*Butea monosperma*	72.02	9.98	6.92	7.11	**19.2**
8	RES/08/11-06	Guava	*Psidium guayava*	81.26	12.57	5.53	9.14	**24.7**
9	RES/09/11-06	Sajina	*Moringa oleifera*	75.83	13.72	6.27	7.27	**22.1**
10	RES/10/11-06	Sissoo	*Dalbergia sisoo*	84.87	11.36	6.67	8.89	**24.5**
11	RES/11/11-06	Custard apple	*Anona squamosa*	66.61	10.33	5.89	6.15	**16.6**
12	RES/12/11-06	Jackfruit	*Artocarpus heterophyllus*	91.51	11.64	6.98	8.28	**24.6**
13	RES/13/11-06	Ber	*Zizyphus mauritiana*	35.50	10.14	6.72	7.27	**15.8**
14	RES/14/11-06	Joba	*Hibiscus rosasinensis*	61.50	13.74	7.06	5.93	**18.5**
15	RES15/11-06	Akand	*Calotropis gigantea*	70.04	11.62	7.37	8.16	**22.5**
16	RES/16/11-06	Rose	*Rosa scinensis*	76.64	14.28	6.22	3.64	**15.1**
17	RES/17/11-06	Bheranda	*Ricinus communis*	62.06	14.02	6.15	6.23	**18.8**
18	RES/18/11-06	Kamini	*Murraya paniculata*	83.53	12.78	7.37	7.24	**22.9**
19	RES/19/11-06	Tulsi	*Ocimum sanctum*	60.13	7.41	7.61	4.62	**12.9**
20	RES/20/11-07	Nebu	*Citrus aurantium*	78.10	10.21	6.86	7.14	**20.0**
21	RES/21/11-08	Beal	*Aegle marmelos*	82.96	11.67	6.94	7.80	**22.8**
22	RES/22/11-09	Kanchan	*Bauhinia acuminate*	81.54	7.87	6.95	5.93	**16.9**
23	RES/23/11-10	Eucalyptus	*Eucalyptus citriodora*	64.41	9.64	6.01	8.43	**19.6**
24	RES/24/11-11	Rangan	*Ixora coccinea*	70.45	13.21	7.08	6.09	**19.4**
25	RES/25/11-12	Lantana	*Lantana camara*	56.36	8.53	6.88	7.02	**16.5**
26	RES/26/11-13	Karabi	*Nerium indicum*	76.34	12.34	7.23	8.47	**24.2**
27	RES/27/11-14	Krishnachura	*Poinciana pulcherrima*	87.32	10.49	6.63	4.72	**16.8**
28	RES/28/11-15	Tentul	*Tamarindus indica*	78.26	12.31	6.26	8.51	**23.6**
29	RES/29/11-16	Korubi	*Thevetia peruviana*	72.46	10.15	5.92	6.05	**17.0**
30	RES/30/11-17	Tagar	*Tabernaemontana divaricata*	65.22	12.64	7.36	8.93	**24.4**

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Table IV
Correlation matrix of biochemical variables and APTI of analysed samples

	RWC	Chlorophyll	pH	Ascorbic Acid	APTI
RWC	1	0.214	-0.105	0.229	0.559(**)
Chlorophyll		1	-0.117	0.155	0.500(**)
pH			1	0.045	0.088
Acsorbic Acid				1	0.864(**)
APTI					1

** Correlation is significant at the 0.01 level (2-tailed)

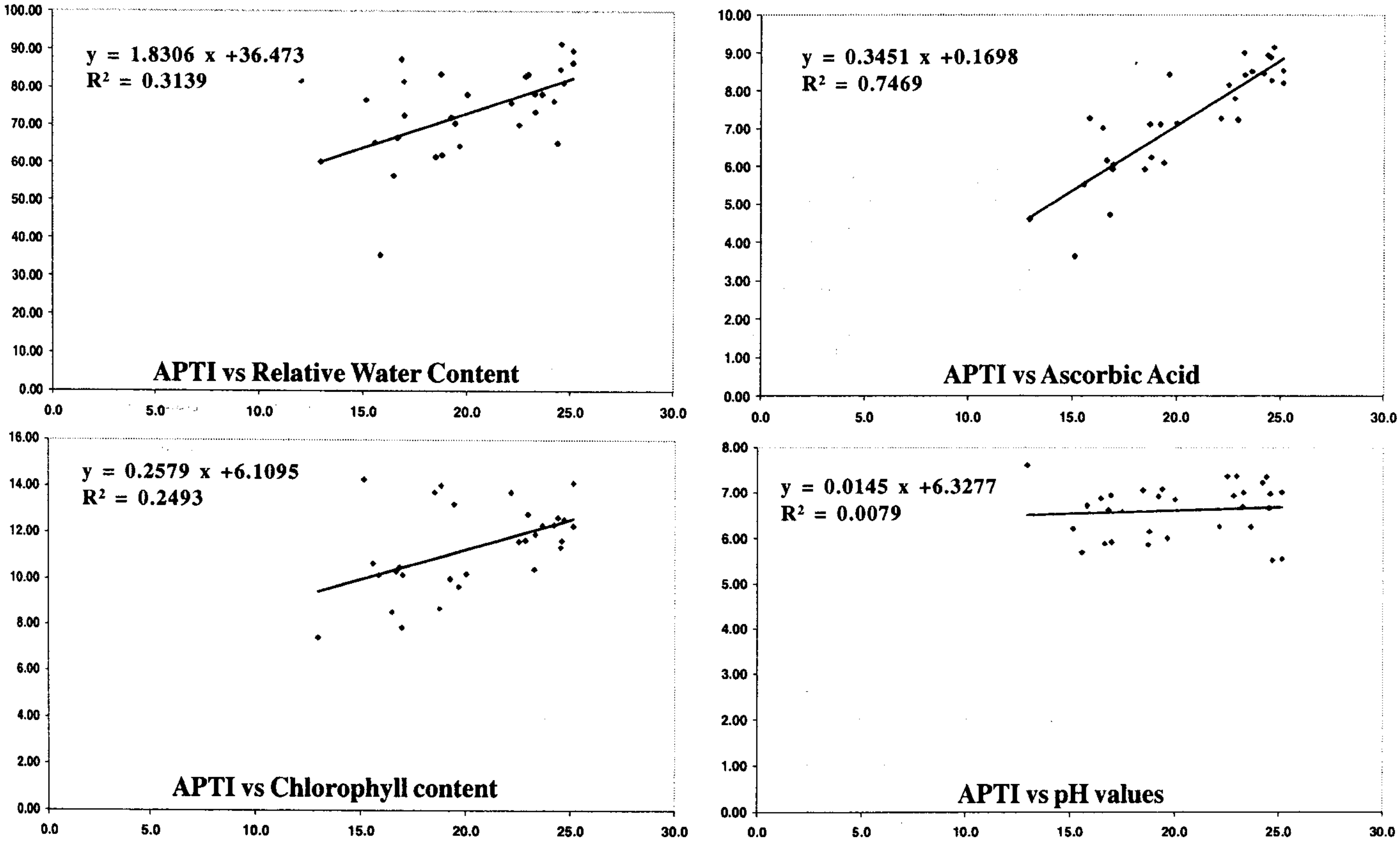

Fig. 1: Scatter Plot of various biochemical parameters with APTI values based on present study

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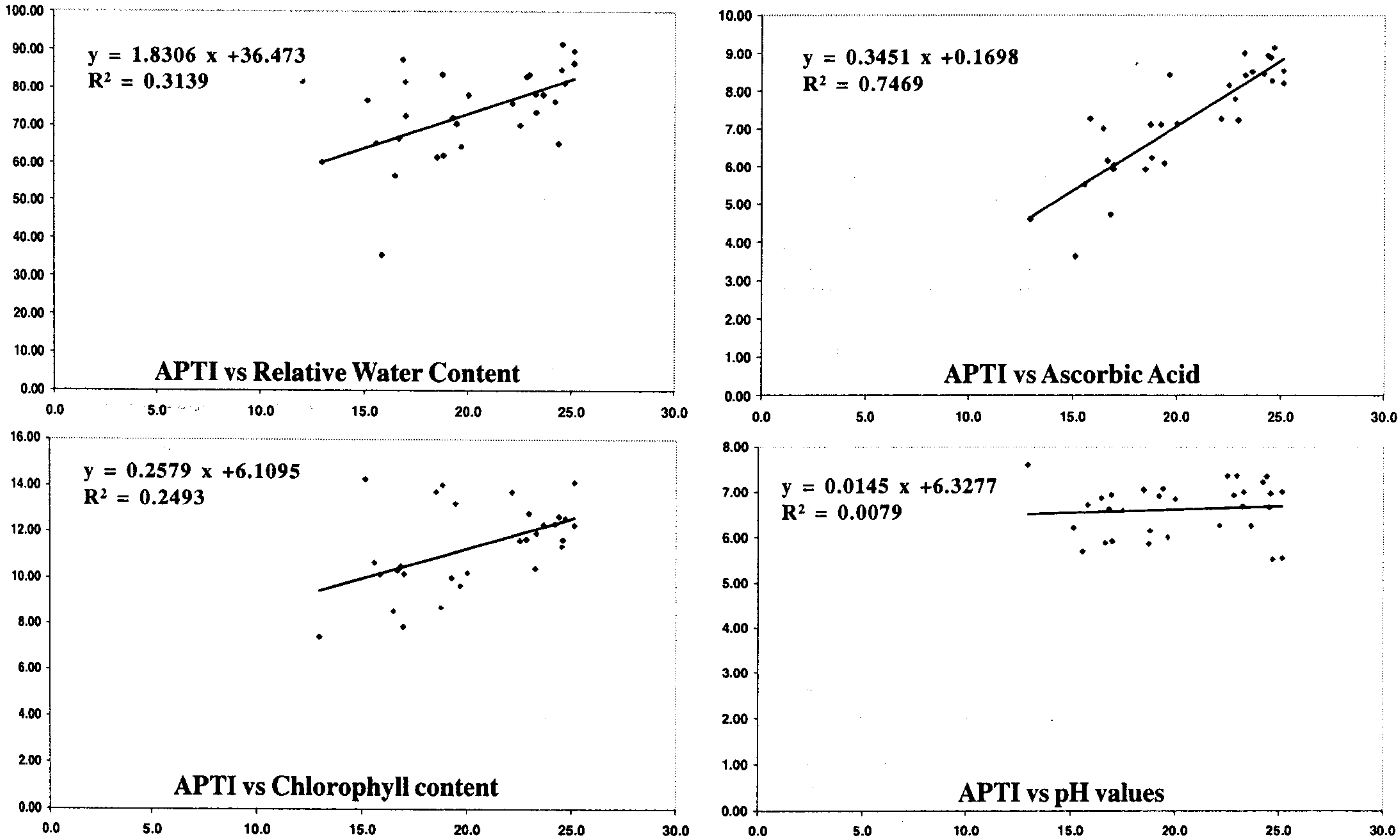
Table IV
Correlation matrix of biochemical variables and APTI of analysed samples

	RWC	Chlorophyll	pH	Ascorbic Acid	APTI
RWC	1	0.214	-0.105	0.229	0.559(**)
Chlorophyll		1	-0.117	0.155	0.500(**)
pH			1	0.045	0.088
Acsorbic Acid				1	0.864(**)
APTI					1

** Correlation is significant at the 0.01 level (2-tailed)



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