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Air Pollution Tolerance Index of Selected Plants around a Gas Flow Station in Sapele, Delta State

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ABSTRACT: This study assessed the air pollution tolerance index (APTI) of four plants around the Seplat Gas Flow Station in Sapele, Delta State. Fresh leaves of the plants were collected, weighed, dried and extracts were made. Standardized procedures for determining APTI were adopted. The physio-biochemical characteristics of the four plant species ranged from; pH 4.57–5.36, chlorophyll content 0.17-0.45 mg/g, RWC 41.0%–80.0%, ascorbic acid: 0.91 – 1.58 mg/g, while APTI varied from 5.75 – 6.99. The result revealed that the APTI of all four plants fall into the sensitive category and the order of increasing sensitivity was *Megathyrsus maximus* > *Pennisetum purpureum* > *Ficus exasperate* > *Axonopus compressus*.

Keywords: APTI, Biochemical parameters, Bio-indicators, Flow Station, Plants

Introduction

Air pollution is now prominent in developing countries and is a serious challenge all over the world currently due to constant change in pollutants concentrations resulting from man's activities (Kanwar *et al*., 2016). Air pollution affects plant directly through the leaves and indirectly via soil acidification following wet deposition making them perfect tools for monitoring pollution (Tak and Kakde, 2017; Singh *et al*. 2019). Before any visible damages to plant parts like the leaves from atmospheric pollutants, innate physiological changes and adaptions would have been experienced (Liu and Ding, 2008). In evaluating the plant stimuli to pollution, several biochemical and physiological evaluations can be employed including total chlorophyll (Tchl) (Flower *et al*., 2007); leaf pH (Klumpp *et al*., 2000); ascorbic acid content (AAC) (Hoque *et al*., 2007), relative water content (RWC) (Rao, 2006). Degradation of Tchl has been widely utilized as indicator of atmospheric pollution. The presence of increased levels of pollutants can reduce chlorophyll of any plant. Elevated levels of pollution from automobiles have been found to reduce the chlorophyll of plants along roadsides (Kovats *et al*., 2021). Pollutant gases such as SO_2, NO_2, NO_3, and Ozone have been discovered to form oxyradicals when they react with plant wastes. Cellular membranes, polymers, and pigments like chlorophyll have all been damaged by these pollution gases. Plants pH can serve as air pollution indicator as sensitive plants are more predisposed to acidic pollutants (Achakzai *et al*., 2017). When the pH of the cell sap tends towards acidity, there is reduction in plant capability to convert hexose sugar to ascorbic acid (AA) (Escobedo *et al*., 2008). This obviously makes the reducing activity of AA to be pH dependent. It can be inferred that when the pH is high, the reducing activity of AA increases and vice versa, making ascorbic acid as a perfect indicator for measuring plant forbearance against pollutants. Relative water content (RWC) of plant leaf on one hand is the quantity of water present in relation to its full turgidity. High moisture content in plants assists in maintaining a balance in the physiology especially when the plant is in stress situations such as exposure to pollution with high transpiration rates. High RWC is beneficial to drought resistant plants. As result of air pollution, there is usually a drop in transpiration rate along

with damage to the leaf tissues which supports the absorption and movement of water up from the roots (Tripathi and Gautam 2007). However, the air pollution tolerance index (APTI) based on four parameters has been used for identifying tolerance levels of plant species (Bharti *et al*. 2018; Li *et al.*, 2018; Zenna *et al*., 2019; Vachler *et al*., 2021).
The APTI of several plants has been reported; woody plants (Bui *et al*., 2018), garden plants (Zenna *et al*., 2019), tropical trees (Ogunkunle *et al*., 2015; Roy *et al*., 2020) among others. Also, studies on APTI of some plants around gas flow station like the Otorogun Gas Plant, Otu-Jeremi, Delta State, Nigeria and Umuebulu Gas Flare Station in Rivers State, Nigeria have been documented (Agbaire and Esiefarienrhe, 2009; Tanee and Albert, 2013). However, the APTI of plants like *Megathyrsus maximus, Pennisetum purpureum, Axonopus compressus and Ficus exasperata* and their use as indicator of air pollution especially in around a gas flow station remain unknown. Therefore, this study aimed at determining the APTI of the above plants around Seplat Gas Flow station in Sapele, Delta State, Nigeria. Having this knowledge will eventually widen available information on plants tolerance and sensitivity levels to pollutants. This will also provide data for green belting projects around industries and highways.

Materials and methods

Study area: The study area was Sapele town in Delta State. Nigeria. Sapele is located between latitudes 5º54'N - 5º40' N and longitudes 5.900 °E - 5.667 °E. Two sites within Sapele were used. Site A which is the experimental site (ES) was around the Seplat Gas Flow Station and site B which is the control site (CS) was a garden 20 km from site A.
Samples collection and analysis: Four plants species *Axonopus compressus* (Sw.) P. Beauv. (Carpet grass), *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs (Guinea grass), *Pennisetum purpureum* Schumach (Elephant grass) and *Ficus exasperat*a Vahl (Sand paper tree) from Poaceae and Moraceae families respectively were chosen. The plants were identified by a plant taxonomist and counter checked using flora of West African plants. Matured fresh leaves of plants were collected early in the morning in five replicates and kept in polythene bags to minimize loss of moisture content. Before analysis, a composite sample of plants was obtained.
Determination of RWC: The RWC was obtained through the method and formula of Singh and Rao (1983). The fresh leaves were immediately weighed using a digital balance (Satorius II 623S) in the laboratory. The samples after fresh weight measurement were placed in water for 24 hours, blotted dry with absorbent paper and re-weighed to get turgid weight. The turgid leaves were dried in oven (Gallenkamp model) for seven days at 78 ºC to dry and weighed to obtain dry weight. Leaves RWC were then computed using the expression:

$$RWC = \frac{\mathrm{FW} - \mathrm{DW} \times 100}{\mathrm{TW} - \mathrm{DW1}}$$

Where:
FW = fresh weight (10 g)
DW = dry weight
TW = turgid weight

Determination of tTotal chlorophyll (Tchl): The Tchl was obtained by weighing 0.1 g of each leaf sample soaked in 20 mL of 50% acetone and allowed for five (5) days interval to form solution whose absorbance was taken at 645 nm and 660 nm using spectrophotometer. The Tchl was then obtained using the expression:

$$\mathrm{Tchl(mg/L)} = \frac{7.12 \times \text{optical density at 660nm} + 16.8 \times \text{optical density at 645nm}}{10}$$

Determination of pH: The pH of leaf extract was obtained by weighing and blending to powder 10 g of fresh leaf then homogenizing in 20 mL of distilled water. The mixture was filtered and pH of the filtrate taken after calibrating pH meter (Jennway 3015).
Determination of AAC: he AAC (mg/g) was obtained using indophenol acetic acid (IAA) method by weighing and crushing 0.1 g of fresh leaf. The crushed leaf was dissolved in 50 mL of distilled water and 10 mL acetic acid. The resulting mixture was titrated against 0.01% indophenol solution.

Determination of APTI: The APTI was obtained by the expression (Singh and Rao, 1983):

$$\text{APTI} = \frac{\text{AAC (Tchl + pH) + RWC}}{10}$$

Based on Bharti *et al*. (2018) categorization, APTI values ≤ 11 = sensitive, between 12 and 16 = intermediate and ≥ 17 = tolerant.

Statistical analysis: Data analysis was done using the IBM Statistical Product and Service Solutions (IBM SPSS version 25). Descriptive statistics such as mean and standard deviation were used. Also, t-test was used to determine if there was significant variation in the biochemical parameters between ES and CS. The level of significance adopted was 0.05. Pearson's correlation was used to determine association between the biochemical parameters and APTI.

Results

The results from this study are shown in Table 1 while Table 2 shows the correlation matrix between the parameters studied. From Table 1, the pH of the leaf extract of the plants from the ES ranged 4.57 to 5.23 while those from CS ranged from 4.72 to 5.36. The maximum and least pH was observed in *Axonopus compressus* and *Pennisetum purpureum* respectively in both sites. Tchl ranged from 0.24 mg/g in *Ficus exasperata* to 0.43 mg/g in *Axonopus compressus* for ES while for CS, the Tchl varied from 0.17 mg/g in *Megathyrsus maximus* to 0.45 mg/g in *Pennisetun purpureum*. The plants RWC ranged from 56 to 80 % and 41 to 70 % for ES and CS respectively. *Ficus exasperata* and *Pennisetun purpureum* have the maximum and least RWC respectively for both ES and CS. The AAC values of the plants from the ES ranged from 0.91 mg/g in *Ficus exasperata* to 1.0 mg/g in *Megathyrsus maximus* while those from CS ranged from 1.20 mg/g in *Ficus exasperata* to 1.58 mg/g in *Axonopus compressus*. The plants APTI ranged from 5.84 to 6.99 for ES and from 5.75 to 6.67 for CS. *Axonopus compressus* has the lowest APTI value for both ES and CS. However, *Megathyrsus maximus* and *Ficus exasperata* have the maximum APTI in ES and CS respectively.

Table 1: Biochemical parameters and APTI of plants studied

Plant sample	Study Area	pH	Tchl (mg/g)	RWC (%)	AAC (mg/g)	APTI (%)
Axonopus compressus	ES	5.23	0.43	58	0.99	5.84
	CS	5.36	0.27	53	1.58	5.75
Megathyrsus maximus	ES	4.73	0.38	64	1.00	6.99
	CS	5.23	0.17	57	1.21	6.35
Pennisetun purpureum	ES	4.57	0.41	56	0.99	6.62
	CS	4.72	0.45	41	1.30	6.03
Ficus exasperata	ES	4.96	0.24	80	0.91	6.50
	CS	5.17	0.22	70	1.20	6.67

* ES = experimental site, EC = control site

Table 2 showed that pH had negative correction with Tchl (r = -0.047), AAC (r = -0.233) and APTI (r = - 0.828) meaning that increasing the pH leads to a reduction in APTI, Tchl and AAC of the selected plants. Positive relationship was found for pH and RWC (r = 0.179), TChl and AAC (r = 0.940), RWC and APTI (0.193) and AAC and APTI (0.067) while all others were negative.

Table 2: Correlation matrix for the biochemical parameters and the APTI

	pH	Tchl	RWC	AAC	APTI
pH	1.000				
Tchl	-0.047	1.000			
RWC	**0.179**	-0.982	1.000		
AAC	-0.233	**0.940**	-0.910	1.000	
APTI	-0.828	-0.244	**0.193**	**0.067**	1.000

*positively correlated parameters in bold

Discussion

pH is a key parameter in plants physiological activities. pH influences the biological activities of organism and also when converting hexose sugar to AA (Escobedo *et al*., 2008). Plants photosynthetic efficiency decrease with decreasing pH (Liu and Ding, 2008). Acidic pollutants have been implicated for low pH of leaves extracts (Achakzai *et al*., 2017). This may be the reason why the pH of leaves extracts from the ES were significantly ($p < 0.05$) lower than those of the CS in this study. The pH of leaves extracts obtained in our study were in line with those reported by Agbaire (2009), Agbaire and Esiefarienrhe (2009) and Tanee and Albert (2013) for leaf extract plants at Erhioke-Kokori oil exploration site, Utorogu gas plant and Umuebulu gas fare station respectively but lower than those reported for brick kiln sites (Achakzai *et al*., 2017).

Tchl is an index of growth, productivity and photosynthetic activity (Agbaire and Esiefarienrhe, 2009). It depends on abiotic and biotic parameters, pollution extent and plant age (Achakzai *et al*., 2017) and while some pollutants increase the Tchl, others reduce it (Allen *et al*., 1987). The Tchl of the ES were above those of the CS except in *Pennisetum purpureum*. This observation may be attributed to greater degree of pollution around the gas flow station. The Tchl found in the present study were below those reported by Agbaire (2009), Agbaire and Esiefarienrhe (2009) and Tanee and Albert (2013) but similar to those reported by Achakzai *et al*. (2017).

The RWC of plants assists in the maintenance and to regulate plants physiology under a given stress condition (Agrawal and Tiwari, 1997). High RWC under stressful condition indicates tolerance in some plants (Paulsamy *et al*., 2000). The RWC obtained in plants from the ES were significantly ($p < 0.05$) above those of the CS. This may be caused by the elevated level of RWC in plants from ES than those from CS. The RWC found in this study were similar to those of other researchers (Agbaire, 2009; Agbaire and Esiefarienrhe, 2009; Tanee and Albert, 2013; Achakzai *et al*., 2017).

Ascorbic acid is a strong detoxicant and reductant that triggers the defence and physiological mechanisms of plants when stressed (Conklin, 2001). The reducing capability of AA is related to its concentration and pH (Raza and Murthy, 1988). Increase in AAC promotes plants tolerance. AAC was higher in plants from CS than from the ES. This may have resulted from differences in plants tolerance. That is, tolerant plants have higher AAC while sensitive plants have lower AAC (Achakzai *et al*., 2017). The AAC values obtained here were similar to those reported by Agbaire (2009), Agbaire and Esiefarienrhe (2009) and Tanee and Albert (2013).

No significant ($p > 0.05$) variation was observed in the APTI of plants from the ES and CS. The APTI of plants from the ES followed the order: *Megathyrsus maximus* > *Pennisetum purpureum* > *Ficus exasperate* > *Axonopus compressus* while those from CS followed the order: *Ficus exasperate* > *Megathyrsus maximus* > *Pennisetum purpureum* > *Axonopus compressus*. On the basis of Bharti *et al*. (2018) categorization, the APTI of plants recorded in this work falls into the sensitive category. The APTI values found in this study were lower than those of other researchers (Agbaire, 2009; Agbaire and Esiefarienrhe, 2009; Tanee and Albert, 2013; Achakzai *et al*., 2017). Some studies have earlier reported positive correlation between plants biochemical parameters and APTI (Singare and Talpade, 2013; Madan and Verma, 2015; Achakzai *et al*., 2017). For instance, Achakzai *et al*. (2017) reported strong positive association between APTI and pH, Tchl, RWC and AAC. AAC is a multiplier in the expression used in computing the APTI and hence, influence the APTI value greatly (Joshi and Swami, 2007). In our study, APTI correlates positively with AAC and RWC which agrees with the observation of the previous researchers. However, pH and Tchl correlates negatively with APTI and this was at variance with the findings of Achakzai *et al*. (2017).

Conclusion

The work has shown that the four plants (*Megathyrsus maximus*, *Pennisetum purpureum, Ficus exasperate* and *Axonopus compressus*) have the capability to function as bio-indicator and bio-monitor of air pollution. The plants are sensitive by virtue of their APTI ranges. More research is needed to include other plants. There is also need to know plants that are at the tolerance level to facilitate their use as green belts.

References

Achakzai K, Khalid S, Adrees M, Bibi A, Ali S, Nawaz R, Rizwan M: Air pollution tolerance index of plants around brick kilns in Rawalpindi, Pakinstan. J Environ Manag. 190: 252–258. 2017

Agbaire PO, Esiefarienrhe E: Air pollution tolerance indices (APTI) of some plants around Otorogun gas plant in Delta State, Nigeria. J Appl Sci. 13(1):11–14. 2009.

Agbaire PO: Air pollution tolerance indices (APTI) of some plants around Erhoike-Kokori oil exploration site of Delta State, Nigeria. Int J Phys Sci. 4: 366-368. 2009.

Agrawal S, Tiwari SL: Susceptibility level of few plants on the basis of air pollution tolerance index. Indian For. 123: 319-322. 1997

Allen (Jnr) LH, Boote KL, Jones JW, Valle RR, Acock B, Roger HH, Dahlmau RC: Response of vegetation to rising carbon dioxide photosynthesis, biomass and seed yield of soybeans. Global Biogeochem Cycles 1: 1-44. 1987

Bharti SK, Trivedi A, Kumar N: Air pollution tolerance index of plants growing near an industrial site, Urban Clim. 24: 820 – 829. 2018

Bui H, Odsuren U, Kwon K, Kim S, Yang J, Jeong N, Park B: Assessment of air pollution tolerance and particulate matter accumulation of 11 woody plant species, Atmosphere 12(8): 1067. 2021.

Conklin PL: Recent advances in the role and biosynthesis of ascorbic acid in plants. Plant Cell Environ. 24: 383-394. 2001.

Escobedo FH, Wagner JE, Nowak DJ, De Le Maza CL, Rodriguez M, Crane DE: Analysing the cost effectiveness of Santiago, Chiles policy of using urban forests to improve air quality. J Environ Manag. 86: 148-157. 2008

Flowers MD, Fiscus EL, Burkey KO: Photosynthesis, chlorophyll fluorescence and yield of snap bean (*Phaseolus vulgaris* L) genotypes differing in sensitivity to Ozone, Environ Exp Bot. 61:190-198. 2007.

Hoque MA, Banu MNA, Oluma E: Exogenous proline and glycinebetaine increase NaCl-induced ascorbate glythione cycle enzyme activities and praline improve salt tolerance more than glycinebetaine in tobacco bright yellow-2 suspension-cultural cells, J Plant Physiol. 164:1457-1468. 2007.

Kanwar K, Ohamale MK, Maskey BR: Air pollution tolerance index an approach towards the effective green belt around Kathmandu metropolitan city of Nepal. Nepal J Environ Sci. 4:23-29. 2016.

Klumpp G, Furlan CM, Domingos M: Response of stress indicators and growth parameters of *Tibouchina pulchra* Cogn. exposed to air and soil pollution near the industrial complex of Cubatao, Brazil, Sci Total Environ. 246:79-91. 2000.

Kovats N, Hubai K, Diosi D, Sainnokhoi T, Hoffer A, Toth A, Teke G: Sensitivity of typical European roadside plants to atmospheric particulate matter. Ecol Ind. 124: 107428 2021

Li Y, He NP, Hou JH, Xu L, Zhang JH: Factors influencing leaf chlorophyll content in natural forests at the biome scale, Front. Ecol Evol. 6: 64-68. 2018.

Liu Y, Ding H: Variation in air pollution tolerance index of plants near a steel factory: implication for landscape – plant species, selection for industrial areas, WSEAS Trans. Environ Dev. 4:24-32. 2008.

Madan S, Verma P: Assessment of air pollution tolerance index of some trees in Haridwar City. Uttarakhand. J Environ Biol. 36: 645-648. 2015

Ogunkunle CO, Suleiman LB, Oyedeji S, Fatoba PO: Assessing the air pollution tolerance index and anticipated performance index of some tree species for biomonitoring environmental health. Agrofor Syst. 89:447 – 454. 2015.

Paulsamy S, Sivakumar R, Latha N: Evaluation of air pollution tolerant tree species in Combatore city. J Ecol Res Biocon. 1: 20-23. 2000

Rao CS: Environmental pollution control engineering (Revised Second Edition). New Age International Publishers. India (New Delhi). pp 382-399. 2006.

Raza SH, Murthy MSR: Air pollution tolerance index of certain plants of Nacharam industrial area, Hyderabed, Indian J Bot 11(1): 91-95. 1988

Roy A, Bhattacharya T, Kumari M: Air pollution tolerance, metal accumulation and dust capturing capacity of common tropical trees in commercial and industrial sites. Sci Total Environ. 37622. 2020 doi:10.1016/j.scitotenv.2020.137622

Singare PU, Talpade SM: Physiological responses of some plant species as a bio-indicator of roadside automobile pollution stress using the air pollution tolerance index approach. Int J Plant Res. 3: 9-16. 2013

Singh SK, Rao DN: Evaluation of plants for their tolerance to air pollution. Proc Symp Air Pollut Cont. 1: 218-224. 1983

Singh SK, Singh RK, Singh RS, Singh KK: Screening potential plant species for arresting particulates in Jharia coal, India. Sustain Environ Res. 29: 37-39. 2019.

Tak AA, Kakde UB: Assessment of air pollution tolerance index of plants: a comparative study. Int J Pharm Sci. 9: 83-89. 2017.

Tanee FBG, Albert E: Air pollution tolerance indices of plants growing around Umuebulu gas flare station in Rivers State, Nigeria. Afr J Environ Sci Tech. 7(1): 1-8. 2013

Tripathi AK, Gautam M: Biochemical parameters of plants as indicators of air pollution, J Environ Biol. 28:127-132. 2007.

Vachher M, Yadav S, Gopal P, Chopra S, Grover N, Sharma S, Burman A, Trilok-Kumar G: A sustainable option of developing kitchen gardens based on air pollution tolerance index (APTI) method of plants with edible leaves for health and wellbeing, Indian J Nutr Diet. 58(1): 2021.

Verma A, Singh SN: Biochemical and ultrastructural changes in plant foliage exposed to auto-pollution. Environ Monit Assess. 120 (1-3): 585–602. 2006

Zenna FG, Taha LS, Shahin SM: Evaluation of some Japanese's garden plant species for its tolerance to air pollution by comparison of different species of the family grown in different parts of the garden, Egypt J Agric Res 97(4): 727 – 745. 2019.