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The Effects of Air Pollution on Plants around the Vicinity of the Delta Steel Company, Ovwian-Aladja, Delta State, Nigeria

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Abstract: *Air pollution is one of the serious problems faced globally today due to increased industrialization. Air pollution has been described as an additional stress on plants since they respond to it in the same way as they respond to drought and any other environmental stress. This paper studied the effect of air pollution on some physiological properties of some plants growing in the vicinity of the Delta steel company, Ovwian-Aladja, Delta State, Nigeria, using two sites; control(unpolluted) and within the vicinity of the steel company (polluted). The physiological parameters studied includes; leaf extract pH, total chlorophyll, relative water content, ascorbic acid content, soluble sugar and proline content. These variations can be used as indicators of air pollution for early diagnosis of stress as well as a marker for physiological damage to plants prior to the onset of visible injury symptoms. Plants at the polluted site showed higher physiological properties which is indicative of the fact that the plants made physiological adjustments to compensate for the environmental stress.*
Key words: *Air pollution, physiological properties, soluble sugar, proline, environmental stress.*

I. Introduction

Pollution can be defined as the presence of undesirable substances in quantities which are harmful to man, vegetation or properties. It is the introduction into the environment of substances that has harmful effects on the environment. Pollution can be broadly divided into air, water and land pollution. Air pollution has been defined as the fluctuation in any atmospheric constituent from the value that would have existed without human activity (Tripathi and Gautam 2007). The increasing anthropogenic activity intensifies the emission of various pollutants into the environment and introduces different types of harmful substances into the atmosphere. Air pollution is aesthetically unfriendly and can pose health hazards to human as well as plants. The major air pollutants are SO_x, NO_x, CO, particulate matter and sometimes heavy metals. It is also a known fact that the rapid industrialisation and addition of toxic substances to the environment are responsible for altering the ecosystem (Mudd and Kozlowski, 1975; Niragau and Dividson, 1986). Industrialisation with expansion of cities, increasing demand of energy and rapid economic development is said to increase air pollution (Oliva et al., 2007). Several contributors agree that air pollution affect growth adversely (Rao, 2006, Bhatia, 2006). Studies also shows the impacts of air pollution on the following properties in plants, the Ascorbic acid content (Hoque et al., 2007), Chlorophyll content (Flower et al., 2007), leaf extract pH (Klumpp et al., 2000), Relative water content (Rao 1979), Soluble Sugar content (Helle-bust and Graigie 1978; Assade et al., 2011), Proline content (Bates, et al., 1975). Biomonitoring with plants is low cost and valuable method to evaluate the effect of different air and environmental pollutants (Oliva et al., 2007). It has been reported that biological method can actually replace physical methods in places where there is limited use of detection of air pollution (Aksoy and Ozturk, 1997). The aim of this study therefore is to estimate the air pollution tolerant indices of some plants around the vicinity of Delta Steel Company, Ovwian-Aladja, Delta State, Nigeria as well as to determine the effects of air pollution on plants using some physiological parameters.

II. Materials And Methods

Sampling Site/ Samples collection

Delta Steel Company (DSC) is a Steel producing company located in Ovwian-Aladja in Udu Local government area of Delta State, Nigeria. It lies within longitude $5^o\ 28^l48.85^{11}$N and latitude $5^o\ 46^l08.99^{11}$E. It is an industrial area and because of the industrial activity, it is suspected to be polluted. This is therefore designed as polluted site. A site with similar ecological conditions but without industrial activity was selected and designed as control site. Five plant species were selected and matured leaves were collected from each plant. Three replicate of plant sample leaves were collected from both sites and were immediately taken to the laboratory for analyses.

Methods

Relative water content was determined as described by Liu and Ding (2008). Fresh leaves were weighed and then immersed in water over night, blotted dry and then weighed to get turgid weight. The leaves

were then dried overnight in an oven at 55°C and reweighed to get the dry weight. Relative water content was calculated using the formula below:

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

RWC = Relative Water Content
FW = Fresh Weight
DW = Dry Weight
TW = Turgid Weight

Total chlorophyll was determined as described by Linhtenthaler (1987). 0.2g fresh leaves were blended with a little quantity of distilled water and extracted with 10ml of 80% acetone and left for 15mins. The liquid portion was decanted into another test-tube and centrifuged at 2,500rpm for 3mins. The supernatant was then collected and absorbance measured at 645nm and 663nm with a spectrophotometer. Calculations were done with the formula below;

$$\mathrm{Chlorophyll_a} = (12.7\mathrm{Dy}_{663} - 2.69\mathrm{Dy}_{645} * \mathrm{V}/1000\mathrm{W})\ \mathrm{mg/g}$$

$$\mathrm{Chlorophyll_b} = (22.9\mathrm{Dy}_{645} - 4.68\mathrm{Dy}_{663} * \mathrm{V}/1000\mathrm{W})\ \mathrm{mg/g}$$

Dy = Absorbance of the extract at wavelength y
V = Total volume of the chlorophyll solution ml
W = Weight of the tissue extracted (g)
% Total chlorophyll = $\mathrm{Chlorophyll_a}$ + $\mathrm{Chlorophyll_b}$ mg/g

The pH of the leaf extract was done by homogenising about 4g of the fresh leaves in 10ml deionised water. This was then filtered and the pH determined after calibrating the pH meter with buffer 4 and 9.

Ascorbic acid content was determined using the spectrophotometric method (Bajaj and Kaur 1981). 1g of the fresh foliage was put in a test-tube, 4ml oxalic acid-EDTA extracting solution was added, then 1ml of orthophosphoric acid, 1ml 5% tetraoxosulphate (vi) acid were added to the mixture. 2ml of ammonium molybdate was then added and the 3ml of deionised water. The solution was then allowed to stand for 15mins. The absorbance at 760nm was then determined spectrophotometrically. The concentration of the ascorbic acid in the sample was the extrapolated from a standard curve.

The air pollution tolerance index were calculated using the formula below(Singh and Rao 1983)

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

A =Ascorbic acid
T =Total Chlorophyll
P = pH
R =Relative water content

Soluble sugar was determined based on the method of phenol-sulphuric acid (Helle-bust, 1978). 0.5g fresh weight of leaves was homogenised with deionised water, extract was filtered and treated with 5% phenol and 98% sulphuric acid. The mixture was then allowed to stand for 1hr and the absorbance taken at 485nm. Standard curve with glucose was prepared and the soluble sugar was calculated based on fresh weight.

Free proline was determined according to Bates et al., (1973) method. Approximately 0.2 leaf sample were homogenised in 10ml of 3% (v/v) aqueous sulfosalicylic acid. The homogenate was filtered and the filtrate acidified with glacial acetic acid and ninhydrin (1mL each). It was then heated in water bath at 100°C for 1hr and the mixture was then extracted with 5mL toluene. The upper (toluene) phase was then decanted into a glass cuvette and the absorbance measured at 520nm. The proline content was then calculated using proline standards (0-50µg/ml) in identical manner. Free proline contents were expressed in mg/g dry weight.

III. Results And Discussion

Table 1: Some physiological parameters of some plants in polluted and unpolluted (control) areas

specimen	Site	T	P	A	R	APTI	SS	PL
Psidiumguagava	Polluted	63.33±0.10	6.60±0.01	0.52±0.05	44.74±0.15	8.11	16.56±0.11	4.95±0.06
	Control	60.08±0.05	6.60±0.01	0.45±0.02	42.44±0.15	7.24	14.43±0.11	2.90±0.06
Manihotesculanta	Polluted	77.75±0.04	6.60±0.01	0.45±0.05	53.57±0.12	9.15	14.30±0.13	4.61±0.05
	Control	57.71±0.10	6.50±0.01	0.30±0.04	48.91±0.14	6.82	13.56±0.11	3.30±0.25
Carica papaya	Polluted	75.36±0.05	6.70±0.02	0.45±0.04	43.11±0.15	8.00	17.01±0.15	6.03±0.15
	Control	60.50±0.04	6.60±0.01	0.39±0.05	37.00±0.15	6.32	16.70±0.10	2.01±0.15
Mangiferaindica	Polluted	73.58±0.06	7.50±0.02	0.35±0.02	26.67±0.15	5.50	13.13±0.13	6.26±0.11
	Control	61.34±0.10	6.60±0.01	0.39±0.02	16.08±0.14	4.26	15.35±0.13	3.83±0.22
Vernoniaamygdalina	Polluted	29.48±0.08	6.60±0.01	0.42±0.04	51.78±0.14	6.70	16.53±0.11	3.95±0.10
	Control	38.16±0.10	6.50±0.01	0.39±0.04	40.76±0.15	5.82	15.80±0.10	2.96±0.10

T= Total chlorophyll mg/g FW
P= pH of leaf extract
A= Ascorbic acid content
R= Relative water content
APTI= Air pollution tolerant index
SS= Soluble sugar (mg/g)
PL= Proline content (mg/g)

Chlorophyll is one of the main essential parts of energy production in green plants and their amounts are significantly affected by environmental condition. Depletion in chlorophyll causes a decrease in productivity of plant and subsequently plant exhibit poor vigour. The total chlorophyll level in plants decreases under stress condition (Speeding and Thomas, 1973). Bell and Mudd (1976) opined that tolerance of plant to SO_2 might be linked with synthesis of degradation of chlorophyll. However plants maintaining their chlorophyll under polluted conditions are said to be tolerant (Singh and Verma 2008). From this study, it was observed that there was increase of the total chlorophyll content in polluted sites. This is an indication that these plants are tolerant to air pollution, they have adapted to the pollution. Photosynthetic efficiency is said to be strongly dependent on leaf pH. Photosynthesis is reduced in plants when the leaf pH is low (Turk and Wirth, 1975). Thus in the APTI formula the leaf pH was added to total chlorophyll and then multiplied with the ascorbic acid content. Scholz and Reck (1977) reported that in the presence of an acidic pollutant, the pH is lowered and that the decline is greater in sensitive plants. Therefore plants with high pH under pollution environment may be considered to be tolerant. With the results obtained from this study, the plants had pH values from 6.60 -7.50, which could be regarded to be neutral. Comparing the pH of plants from polluted environment with those from control, it was observed the decline was slight and so these plants could be considered tolerant.

The relative water content of plants under study was from26.67-53.57%. High relative water content within a plant body will help to maintain its physiological balance under stress condition. It has been reported that air pollutants increase cell permeability (Keller, 1986), which causes loss of water and dissolved nutrients, resulting in early senescence of leaves (Masuch et al., 1988; Agrawal and Tiwari 1997). Plants with high relative water content under polluted conditions are considered be tolerant to air pollutants. However the relative water contents of plants under study were not high so, on the basis of relative water content these plants may be regarded as sensitive.

Ascorbic acid plays an important role in cell wall synthesis, defence and cell division. It also plays an important role in photosynthetic carbon fixation (Lewin, 1976), so it has been given top priority and used as a multiplication factor in the formula. The ascorbic acid contents of plants from 0.35-0.52mg/g. Ascorbic acid is a natural detoxicant which prevent the damaging effect of air pollutants in plant tissues (Singh et al., 1991) and high amount favours pollution tolerance in plants (Keller and Schwager, 1977; Lee at et., 1984). Thus plants maintaining high ascorbic acid level even under pollution are considered to be tolerant to air pollution (Varshney and Varshney 1984; Keller and Schwager 1977). The study observed that the ascorbic acid content of plant around the company were higher than those from the control sites which indicates that these plants are tolerant

It has been reported that none of these biochemical factors independently gave reliable information about the tolerant status of plants, but the combination of all these factors into a formula known as the air pollution tolerance index gave a more reliable information (Sarala and Sabitha 2011). Air pollution tolerance index is an index that denotes capability of plant to combat air pollution. The air pollution index determination provides a reliable method for screening plants with respect to their susceptibility to air pollution. Plants with higher index are tolerant to air pollution and can act as sink to mitigate air pollution while those with lower index act as bio-indicators (Sarala and Sabitha 2011).The air pollution tolerant index of plants of area under study ranged from 4.26-9.15. The air pollution tolerant indices of plant from polluted environment were all higher than those from control sites showing some level of tolerant. The tolerant specie is considered as a sink for air pollutants while the sensitive ones as bio-indicators.

Soluble sugars have osmoprotectant and cryoprotectant roles and their presence is important for plasma membrane. They are important parts in plant structure and source of energy in all organisms. The concentration of soluble sugars are indicative of the physiological activity of a plant and is determines the sensitivity of plants to air pollution (Tripathi and Gautam 2007). Accumulation of sugars in different parts of plants is enhanced in response to the variety of environmental stresses (Prado, et al., 2000). Soluble sugars have been reported to play a protective role against stresses (Finkelstein and Gibson, 2001). In this study, there was an increase in soluble sugar in polluted sites indicative of stress.

Proline is a part of many proteins and enzymes and has important roles in plants as source of energy and osmoprotectant in stressed conditions (Huber, 1984). Proline accumulation in abiotic stress reduces degradation of other proteins (Thomas, 1991). Proline accumulation in the cells may happen because of decrease

in proline degradation, increase in proline synthesis and hydrolysis of protein (Fikriye, 2005). Accumulation of proline is related to increase of tolerance against salt and drought stress in many plants (Nayar, 2003). In this study, it was observed that there was an increase in the proline content in plants from polluted environment which demonstrate good resistance and tolerance of these plants to air pollution.

IV. Conclusion

The amount of chlorophyll, ascorbic acid, soluble sugar, proline and relative water content increased in polluted site indicative of the fact that these plants had good resistance and tolerance to air pollution.

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