Effects of Particulate Matter on the Anatomy of some Tropical Plants (Alchonea cordifolia, Musa paradisiaca, and Manihot esculenta)

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Abstract: The problem of impact of particulate matter on vegetation is quite complex. Relatively little attention is given to the effect of particulate matter on different tropical plants, compared to the effect on tropical animals. A comparative study aimed at showing the effect of asphalt particulate matter on the anatomical characteristics of some tropical plants was carried out. Samples from three plant species namely: *Manihot esculentus* Crantz (Cassava), family Euphorbiaceae; *Musa paradisiaca* L. (Plantain), family Musaceae; and *Alchornea cordifolia* (Schum. & Thonn.) Mull. Arg. (Christmas bush), family Euphorbiaceae, were collected from two sites designated as non-polluted site (Site 1), and asphalt polluted site (Site 2). Plant materials were fixed in FAA (Formalin: Acetic acid: alcohol) solution immediately after collection. For anatomical studies, free hand sectioning method was used, and photomicrographs of good sections taken with a Leitz Diaplan photomicroscope fitted with Leica WILD MPS 52 camera. The results showed that there was significant increase in the number of vascular bundles from plant samples collected at the polluted site. Possibly, this may be one of the adaptive features by these plants to reduce damage caused by asphalt particulate matter. However, the cortex, the epidermis, and pith tissues were unaffected and seem to be resistant to asphalt particulate matter. From the present study, it is apparent that the vascular bundles are more affected compared to other tissue systems. In other words, they are more sensitive to pollutants than other tissues. The different tissues of the same plant species differ in their responses to the same pollutant. This is a clear indication that particulate matter exercised a decisive influence on the different anatomical plant features

Key words: Anatomy, Ashpalt plant, Particulate matter, vascular bundles, plant, environment trichomes

1 INTRODUCTION

Air pollutants enter the plant systems through direct and indirect pathways. The outer surfaces of a leaf are covered by a layer of epidermal cells which help in moisture retention. Between the epidermal layers are themesophyll cells which comprise the spongy and palisade parenchyma. The leaf has a vascular bundle which carries water, minerals and carbohydrate throughout the plant. The Stomata of leaves are controlled by guard cells which can open and close and hence change air spaces in the interior of leaves. Particulate matter enters into leaves through stomata by diffusing into and out of leaves, more also Particulate matter transferred from the atmosphere may be deposited on plant parts and consequently exert some physical or chemical effects which may translate to physiological and anatomical changes in plant [1]. The effects off particulate matter deposited on plant are more likely to be associated with their chemistry than simply with the mass of deposited particles.

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Previous studies of the effects of chemicals in particulate matter deposited on foliage have found little or no effects on foliar processes unless exposure levels were significantly higher than typically would be experienced in the ambient environment. Majority of easily identified direct effects of particulate matter on plants occur in plants located in severely polluted area around heavily industrialized point sources such as limestone quarries, cement kilns, and smelting facilities for iron, lead, or various other metal [1]. The direct effects of particulate on foliar surfaces are characteristics of ambient airborne particles and the absence of a clear distinction between effects attributed to other forms of air pollutants. The majorities of studies dealing with direct effects of particulate dust and trace metals on vegetation has focused on responses of individual plant species and were conducted in the laboratory or in controlled environments [2]. However effects of particulate matter on plant also includes reduction in growth, yield, flowering as a result of the changes in physiology and the anatomy of the plant [2]. Evidence from studies on the effects of particulate matter deposition, specically chemically inert and active dust, indicates that tolerant individuals within a plant population exhibit a wide range of sensitivity that is the bases for the natural selection of tolerant individuals. Rapid evolution of certain populations of tolerant species at sites with heavy trace elements and nitrate deposition was observed [2]. Chronic pollutants injury to a forest community may result in the loss of sensitive species, loss of tree canopy, and maintenance of a residual cover of pollutant-tolerant herbs or shrubs that are recognized as successional species [3], [4]. The deposition of air pollutants on soils and plants can cause alteration of the nutrient content of the soil in the vicinity of the plant, which ultimately changes the soil conditions and hence leads to an indirect effect of air pollutants on vegetation and plants [5], extensive tissue collapse or necrosis resulting from injury to the spongy or palisade cells in the interior of the leaves [6]. This study is therefore designed to examine the ecological effects of particulate matter on the anatomy of some plants found within and outside Asphalt plant environment.

2 MATERIAL AND METHODS

The present study was carried out using Ignatius Ajuru University of Education main campus, situated at Rumuolumeni, Port Harcourt, Rivers State, Nigeria, as the control site or non-polluted site (Site 1), samples were collected from farm land surrounding an Asphalt plant owned by H x H Engineering in Mbiama, along the East West Road, Ahoada-West Local Government Area, Rivers State, Nigeria (Site 2), as shown in Table 1. The plant species used for the study were *Manihot esculentus* Crantz (Cassava), *Musa paradisiaca* L. (Plantain), and *Alchornea cordifolia* (Schum. & Thonn.) Mull. Arg. (Christmas bush). To carry out the anatomical investigations, fresh stems, leaves, and petioles were fixed in Formal –Acetic-Alcohol (FAA) solution for 48 hrs, washed in several changes of distilled water, dehydrated through alcohol series (30, 50, 70, 95 and 100 %), 2 hrs in each solution and embedded in wax. Transverse sections were obtained from the different plant parts used. All the sections were obtained by free hand sectioning. Sections were deposited in watch glasses containing 1% safranin for one minute. The stained sections were dehydrated through alcohol series and mounted on clean slides in 25 % glycerol. Photomicrographs of the anatomical sections were taken with a Leitz Diaplan photomicroscope fitted with Leica WILD MPS 52 camera.

Table 1. Sources of plant materials used for the study

Taxa	Accession No.	Collector & Collection Date	Locality
Alchornea cordifolia	Friday 001	09/02/2014	Asphalt plant in Usua farm land, along East-West road, Ukpeliede community, Ahoada-West, Rivers State, Nigeria
	Ajuru 113	15/02/2014	Main campus, Ignatius Ajuru University of Education, Rumuolumeni, Port Harcourt, Rivers State, Nigeria
Musa paradisiaca	Friday 002	09/02/2014	Same location as above
	Ajuru 116	21/02/2014	Same location as above
Manihot esculentum	Friday 003	09/02/2014	Same location as above
	Ajuru 118	23/02/2014	Same location as above

3 RESULT

Observations of the anatomical characteristics of the plant species studied are presented in Figures 1-3.

3.1 Stem Anatomy:

Comparative analysis of the anatomical features of *Alchornea cordifolia*, collected from the polluted and non-polluted sites showed no significant differences in the epidermal and cortex tissue systems. The epidermis in both samples consisted of one layer, followed by 5-6 layers of collenchyma cells, lacunate ground tissues made up of thin-walled parenchyma cells, followed by patches of sclerenchyma cells which surrounded the vascular bundles. There are primary and secondary vascular bundles, arranged at the peripheral and central regions of the stem respectively. The variation between the two samples of this species lies in the number of vascular bundles, and type of trichomes. Sample from the asphalt polluted site contained nineteen (19) primary vascular tissues and two (2) secondary vascular tissues, glandular trichomes at the pith cavity, and covering non-glandular trichomes at the epidermal region. The plant samples from the non-polluted site contained fourteen (14) primary vascular tissues and one secondary vascular tissue. Covering non-glandular trichomes were also found at the epidermal tissue, but there were no glandular trichomes at the pith cavity, as shown in Figures 1a & b. The analysis of the stem anatomy of *Manihot esculenta* from the samples at both sites also showed no significant differences in the epidermal and cortex regions. They both possessed a layer of epidermis, followed by 5-7 layers of collenchyma cells, then 5-6 layers of parenchyma cells, closely followed by 2-3 layers of sclerenchyma cells. The stem has five ridges and five furrows. In the plant sample from the polluted site, vascular tissues were only found in the ridges, seven (7) in number, while in the sample from non-polluted site, eight (8) vascular tissues were present in the furrows. The pith region in the two samples is completely filled with parenchyma cells, as shown in Figures 1c & d.

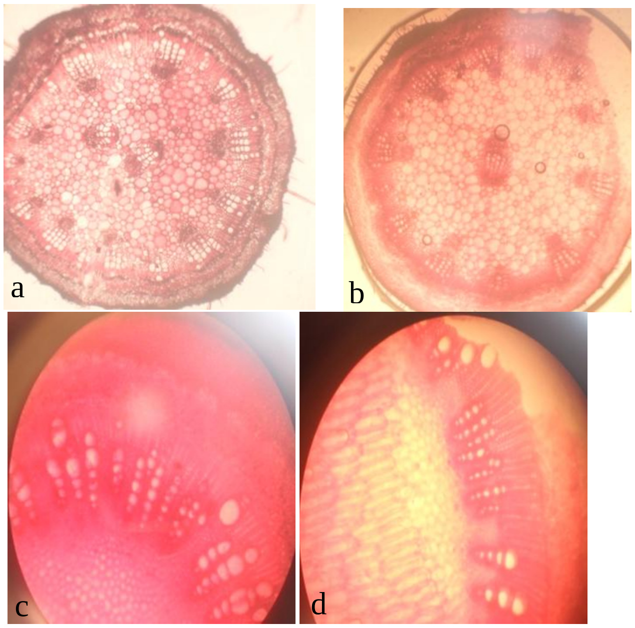

***Figure1**. Showing stem anatomical features of the plant species studied at the two sites; a-Alchornea cordifolia, from polluted site; b- A. cordifolia, from non-polluted site (X 40); c- Manihot esculenta from polluted site; d- M. esculenta from non-polluted site (X 100)*

Leaf Anatomy:
Analysis of the leaf anatomy of *Alchornea cordifolia*, collected at the polluted and non-polluted sites showed a lot of similarities. They both have single layered upper and lower epidermis, followed by the palisade mesophyll towards the adaxial region and spongy mesophyll towards the abaxial region. The vascular bundles were surrounded by schlerenchymatous bundle sheath. The number of bundles varied between the two collections. Sample from the polluted site contained three (3) vascular bundles, while the sample from non-polluted site contained two (2) bundles; the bigger one was towards the abaxial region while the smaller was towards the adaxial region. Another difference was the presence of covering trichomes on the lower epidermal layer in the non-polluted sample, which was absent in the polluted sample, as shown in Figures 2a & b. For *Manihot esculenta*, the upper and lower epidermis was single-layered, followed by the palisade and spongy mesophylls towards the upper and lower epidermis respectively in the samples from the two sites. The vascular bundles, arranged in a half ring, were surrounded by schlerenchymatous sheath. Sample from the polluted site contained four (4) bundles, while the sample from the non-polluted site contained only two (2) bundles, as shown in Figures 2c & d. Comparative study of the leaf anatomy of *Musa paradisiaca*, collected from the two sites, showed a lot of similarities. The upper and lower epidermis was single-layered, followed by the mesophyll, and two layers of parenchyma cells. The vascular bundles occurred at the periphery, beneath the parenchyma cells. The vascular bundles were all over the ground tissue, though the sample from the non-polluted site contained more bundles than the sample from the polluted site, as shown in Figures 2e & f.

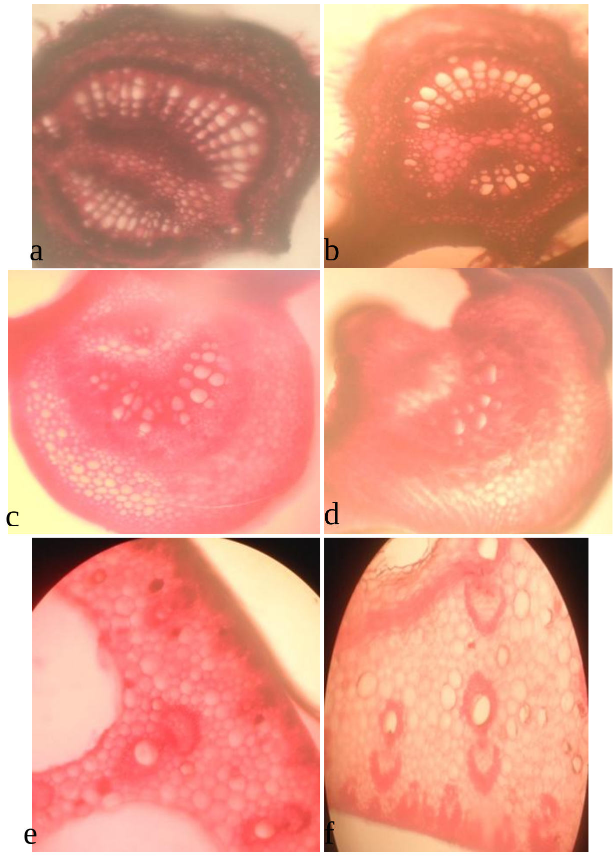

***Figure2.** Showing leaf anatomical features of the plant species studied at the two sites; a-Alchornea cordifolia, from polluted site; b- A. cordifolia, from non-polluted site (X 100); c- Manihot esculenta from polluted site; d- M. esculenta from non-polluted site (X 100); e- Musa paradisiaca from polluted site; f- M. paradisiaca from non-polluted site (X 100)*

3.2 Petiole Anatomy:
Similar to the stem anatomy of *Alchornea cordifolia*, comparative analysis of the anatomical features of the petiole samples, collected from the polluted and non-polluted sites showed no significant difference in the epidermal and cortex tissue systems. The epidermis in both samples consist of one layer, followed by 5-6 layers of collenchyma cells, lacunate ground tissues made up of thin-walled parenchyma cells, followed by patches of sclerenchyma cells which surrounds the vascular bundles. There are primary and secondary vascular bundles, arranged at the peripheral and central regions of the stem respectively. The variation between the two samples of this species lies in the number of vascular bundles, and type of trichomes. Sample from the asphalt polluted site contained twenty (20) primary vascular tissues and three (3) secondary vascular tissues, glandular trichomes at the pith cavity, and covering non-glandular trichomes at the epidermal region. The plant samples from the non-polluted site contained eleven (11) primary vascular tissues and one

secondary vascular tissue. Covering non-glandular trichomes were also found at the epidermal tissue, but there were no glandular trichomes at the pith cavity, as shown in Figures 3a & b. The analysis of the petiole anatomy of *Manihot esculenta* from the samples at both sites also showed no significant differences in the epidermal and cortex regions. They both possessed a layer of epidermis, followed by 5-7 layers of collenchyma cells, then 5-6 layers of parenchyma cells, closely followed by 2-3 layers of sclerenchyma cells. The vascular bundles were arranged in a ring towards the periphery. Sample from the polluted site contained ten (10) vascular bundles, while the sample from non-polluted site contained nine (9), as shown in Figures 3c & d.

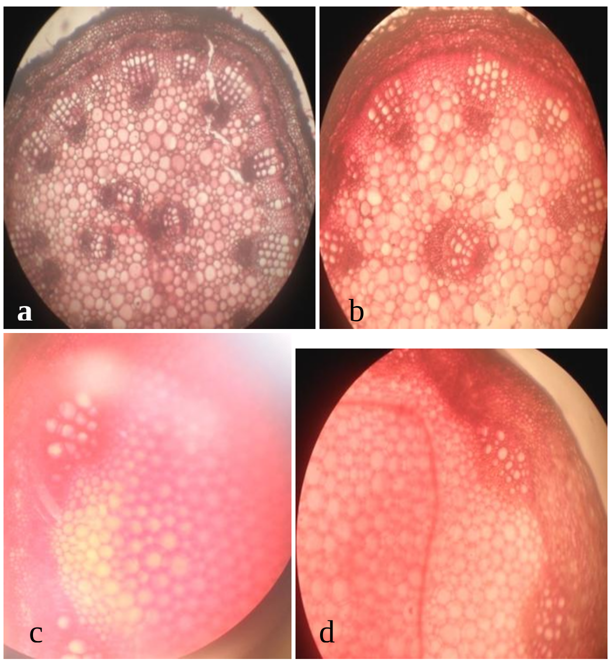

Figure3. *Showing petiole anatomical features of the plant species studied at the two sites; a-Alchornea cordifolia, from polluted site; b- A. cordifolia, from non-polluted site (X 100); c- Manihot esculenta from polluted site; d- M. esculenta from non-polluted site*

DISCUSSION

Most plants are highly sensitive to pollutants and this can present changes in their morphology, anatomy, physiology and biochemistry [7], [8], [9], [10], [11], [12], [13].. From the results, it is evident that there was significant increase in the number of vascular bundles from plant samples collected at the polluted site. Possibly, this may be one of the adaptive features by these plants to reduce damage caused by asphalt particulate matter. The increase in the number of vascular bundles in samples from the polluted site is in conformity with the observations made by [14], and [15]. The particulate matter from the asphalt factory is seen as a severe threat to the vegetation in the environment. However, the cortex, the epidermis, and pith tissues remained unaffected and seem to be resistant to asphalt particulate matter. From the present study, it is apparent that the vascular bundles are more affected compared to other tissue systems. In other words, they are more sensitive to pollutants than other tissues. The different tissues of the same plant species differ in their responses to the same pollutant. [16] studied the biochemical and morphological effect of environmental pollutants on wetland macrophytes. [17], illustrates that leaf surface features, including stomata and epidermal cells in plants growing along road sides are considerably modified due to the stress of automobile exhaust emission with high traffic density in urban areas. These changes could be considered as indicator of environmental stress.

CONCLUSION

From the results in the present study, there is clear indication that pollutants emitted from the industry exercised a definite influence on plant anatomy. It is also apparent that the vascular bundles are more affected than other tissues. In other words, the vascular bundles are more sensitive to pollutants. The different tissues of the same plant differ in their response to the same pollutants in a given concentration. Further researches on the morphology, stomatal characteristics, pollen characteristics, etc. in plants growing in polluted environment should be undertaken to provide more data for taxonomic purposes.

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