Journal of Research in Forestry, Wildlife & Environment Vol. 11(3) September, 2019
http://www.ajol.info/index.php/jrfwe
jfewr ©2019 - jfewr Publications
E-mail:jfewr@yahoo.com
ISBN: 2141 – 1778
Akomolafe et al., 2019

COMPARATIVE ANATOMICAL STUDIES OF RESPONSES OF SOME ROADSIDE PLANTS TO HIGHWAY AUTOMOBILE EXHAUSTS

Akomolafe, G. F.[1*], David O. A.[2] and A. J. Nkemdy[1]

[1]Department of Botany, Federal University of Lafia, P.M.B. 146, Lafia, Nigeria
[2]Department of Plant Science and Biotechnology, Federal University Oye-Ekiti, Ekiti, Nigeria
[*]**Corresponding author email:** *gfakomolafe@yahoo.com*; +2348068997606

ABSTRACT

Urena lobata and Hyptis suaveolens growing along busy roadsides in Lafia, Nigeria were carefully sampled. This was with a view to investigate the effect of continuous impact of automobile exhausts on internal structures of the plants. Three major highways were chosen for study in Lafia. Plant samples were systematically collected in replicates from 0 m, 10 m and 20 m away from defined points of the roadsides. Leaf and stem anatomical sections were prepared for microscopic examinations following established procedures. The plants were observed to have more stomata and smaller area of guard cells at 0 m than those away from the roadsides. For H. suaveolens, the thickness of epidermis, thickness of vascular bundles, length and number of trichomes at 0 m are higher than those at 10 m and 20 m. The reverse was observed for U. lobata. However, U. lobata showed high number of parenchyma cells closer to the roadsides than those father away. Consequently, H. suaveolens seemed to have ability to withstand and thrive well in areas of heavy air pollution. These anatomical changes were described to be distinct with regards to individual species and could have been as a result of cumulative effects of air pollutants.

Keywords: Air pollutants, Anatomy, *Hyptis suaveolens*, Lafia, *Urena lobata*

INTRODUCTION

The consequence of civilization in the world has been described as the corresponding influence of pollutants on plants (Cvetanovska *et al*., 2010). Plants are prone to several unfavourable environmental conditions regarded as stresses which do alter their internal structures, metabolisms, growth and resulting yield (Reddy *et al*., 2004). One of those environmental stresses is pollutants from several sources. Güvenç and Duman (2010) reported that a lot of ecological factors do influence some anatomical features related with mesophyll cells and supporting tissues in plants. These anatomical structures vary in plants of different species under the same stress conditions (Makbul *et al*., 2008).

The ability of different plant species to withstand environmental stresses has been linked with their respective genetic constituents and growth stage at time of exposure (Garner, 2002). The effects of air pollutants are usually easily noticed on the leaves and flowers of plants with symptoms such as strange colourations, twisting of leaves and relative stunted growth (Otoide and Kayode, 2016). Air pollutants could get to plants from various sources such as industrial exhausts, agricultural discharges, household power generators, traffic / automobile exhausts and so-on (Otoide, 2015). However, a larger percentage of these pollutants has been reported to be from automobile exhaust. Some of the pollutants from automobile exhausts include carbon oxides, volatile organic carbons and particulate matters (dusts) (Otoide, 2015).

In this study, we investigated the anatomical responses of *Hyptis suaveolens* and *Urena lobata* to air pollutants from automobile exhausts. These two plants are found to be the most common plants growing along roadsides in North Central Nigeria.

MATERIALS AND METHODS

Study Site

The study was carried out in Lafia, Nasarawa State, Nigeria located in the North Central zone (Figure 1). Its climatic weather is characterized by rainy and dry season. The geographical coordinates and elevations of the sample collection points were taken with the aid of a GPS Garmin eTrex 10 device (Table 1).

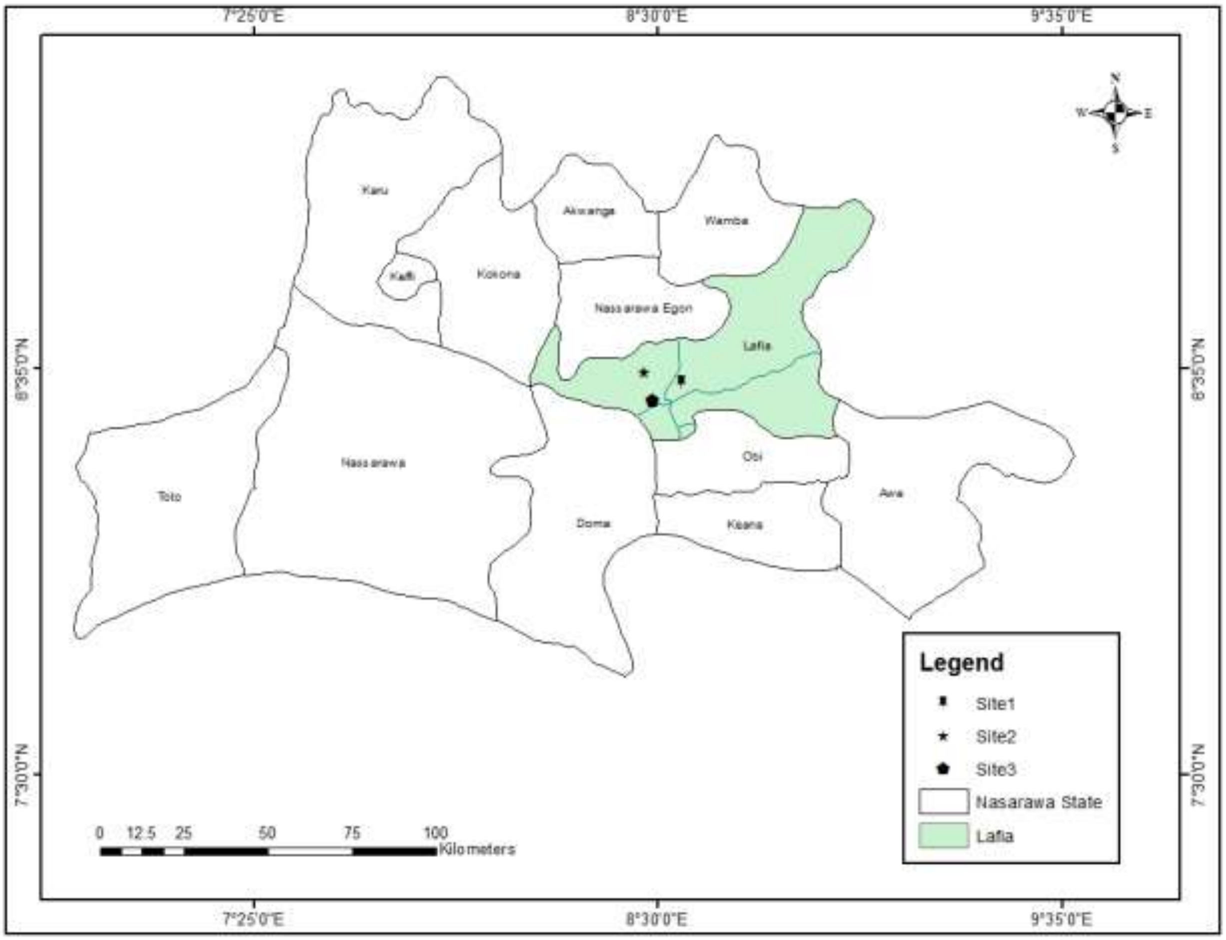

Figure 1: Study area map of Lafia showing the sampling locations

Table 1: The geographical coordinates of sampling locations

Distance from the road (m)	Site 1 (Lafia-Abuja road)			Site 2 (Lafia-Makurdi road)			Site 3 (Lafia-Doma road)		
	Latitude(N)	Longitude (E)	Elevation (m)	Latitude (N)	Longitude (E)	Elevation (m)	Latitude (N)	Longitude (E)	Elevation (m)
0	08.56322^0	008.54637^0	163	08.46281^0	008.57277^0	190	08.48666^0	008.49741^0	165
10	08.56311^0	008.54650^0	163	08.46283^0	008.57271^0	191	08.48654^0	008.49734^0	170
20	08.56316^0	008.54666^0	161	08.46282^0	008.57267^0	195	08.48643^0	008.49736^0	163

Plant Sample Collection

The road side plants used for this study include *Hyptis suaveolens* and *Urena lobata*. The plant samples were collected from three different locations/highways which were regarded to be highly busy with vehicular movements. The highways include Makurdi-Lafia road, Lafia-Doma road and Lafia-Abuja road. The approximate distance between each road location is 10,000 meters. At each roadside, plants were collected in different places i.e. 0m (close to the road), 10m away from the road and 20m away from the road. These samples were taken to the laboratory for further observations.

Anatomical Studies

For anatomical studies, the leaves and stems of 18 samples were assessed as follows:

Leaf Anatomical Study

Matured leaves were cut from the standard median positions and subjected to clearing process following the methods of Oloyede *et al*. (2011). These leaves were cleared by decolorizing in boiled 70% ethanol at 60ºC for 5-10 minutes and then rinsed with water. Theereafter, they were boiled in 2% sodium hydroxide for about 3-5 minutes and then further transferred into Petri dishes containing 2% Potassium hypochlorite. After they have been completely cleared, all traces of potassium hypochlorite were removed with water. The specimens were then stained with Safranin O and mounted on clean sides containing drops of 25% glycerol. The mounted specimens were observed with the aid of a digital compound photomicroscope. The leaf anatomical features observed include the intervenal distance, number of trichomes, length of trichomes, stomata frequency, length of guard cells and breath of guard cells.

Stem Anatomical Study

This was done using the methods of Akomolafe *et al*. (2017b). Free-hand fresh transverse sections of the stems of the two plants collected at different locations were made using a dissecting blade. They were stained using 2 drops of 1% Safranin O on clean slides and then rinsed with water. Thereafter, the specimens were mounted on 25% glycerol and observed using digital compound photomicroscope. The observed features include thickness of epidermis, thickness of cortex, diameter of vascular bundles, number of trichomes, length of trichomes and number of cells per mm.

Statistical Analysis

Each of the anatomical parameters of each plant between the locations (0m, 10m and 20m) was subjected to non-parametric Kruslal Walis test for significance differences at $P \leq 0.05$. The analysis was done using PAST software version 3.

RESULTS

The Effects of Air Pollutants on the Leaf Anatomy of Plants

The results of the leaf anatomy of plants at site 1 are shown in Table 2 and Plate 1. For *U. lobata*, the leaf intervenal distance (4.50 mm) at 20 m away from the road was higher than those of 10 m (1.99 mm) and 0 m (3.78 mm). The lengths of trichomes also differ in which 0 m had the lowest (1.38 mm), compared to (2.85 mm) at 10 m and (5.19 mm) at 20 m. The area of guard cell increased progressively from 0 m to 20 m. The stomata frequency of *U. lobata* at 10 m was the highest (4.33) while 0 m was the lowest (3.00). For *H. suaveolens*, the intervenal distance of the leaves at 10 m (8.24 mm) was the highest while 0 m had the lowest (2.74 mm). The length of trichomes observed at 0 m (3.21 mm) was higher than others. *H. suaveolens* at 10 m had more trichomes than those at 0 m and 20 m. However, the ones at 20 m had more stomata than those at 0 m and 10 m. The differences in the leaf anatomical features of the two plants between the locations are significant except for number of trichomes and stomata frequency.

Table 2: The effects of air pollutants on leaf anatomy of plants at site 1

Distance from the Road (m)	*Urena lobata*					*Hyptis suaveolens*				
	Intervenal distance (mm)	**Length of trichomes (mm)**	**Number of trichomes**	**Area of guard cell (mm^2)**	**Stomata frequency**	**Intervenal distance (mm)**	**Length of trichomes (mm)**	**Number of trichomes**	**Area of guard cell (mm^2)**	**Stomata frequency**
0	3.78± 0.44	1.38± 0.21	17.00± 3.51	0.09± 0.03	3.00± 1.00	2.74± 0.11	3.21± 1.15	4.67± 2.33	0.00± 0.00	3.67± 1.76
10	1.99± 0.21	2.85± 0.16	16.33± 6.33	0.57± 0.08	4.33± 0.88	8.24± 0.49	3.11± 1.10	26.33± 10.37	0.15± 0.03	4.67± 0.88
20	4.50± 0.41	5.19± 0.92	26.00± 3.06	0.13± 0.03	3.67± 0.88	4.83± 0.60	2.00± 0.76	19.33± 5.81	0.00± 0.00	6.67± 2.84

Values represent mean ± SE

Table 3: The effect of air pollutants on leaf anatomy of plants at site 2

Distance from the Road (m)	*Urena lobata*					*Hyptis suaveolens*				
	Intervenal distance (mm)	**Length of trichomes (mm)**	**Number of trichomes**	**Area of guard cell (mm^2)**	**Stomata frequency**	**Intervenal distance (mm)**	**Length of trichomes (mm)**	**Number of trichomes**	**Area of guard cell (mm^2)**	**Stomata frequency**
0	3.39± 0.51	3.16±1.21	28.33±1.20	0.13±0.00	7.33± 2.73	5.43±0.58	5.45±1.32	38.33±10.99	0.13±0.04	8.00±2.52
10	5.54±1.08	1.22±0.18	15.67± 2.33	0.19± 0.05	5.33± 3.33	7.91± 0.67	4.38±0.34	19.33±3.48	1.10±0.30	0.67± 0.67
20	4.50±1.00	1.81±0.21	14.33±3.18	0.28± 0.08	4.00± 3.06	9.41± 2.10	1.42±0.55	16.67±8.29	0.12±0.01	5.00±2.00

Values represent mean ± SE

Table 4: The effect of air pollutants on leaf anatomy of plants at site 3

Distance from the Road (m)	*Urena lobata*					*Hyptis suaveolens*				
	Intervenal distance (mm)	**Length of trichomes (mm)**	**Number of trichomes**	**Area of guard cell (mm^2)**	**Stomata frequency**	**Intervenal distance (mm)**	**Length of trichomes (mm)**	**Number of trichomes**	**Area of guard cell (mm^2)**	**Stomata frequency**
0	2.98± 0.14	1.22±0.26	16.33±2.03	0.02± 0.00	3.00±1.53	4.44±0.23	1.37± 0.15	16.00±2.08	0.14±0.02	1.33± 0.33
10	6.43± 1.10	3.25±0.71	31.33± 8.17	0.04± 0.01	3.00±1.73	9.11±1.77	0.83± 0.13	8.33±2.33	0.17±0.03	5.00±2.87
20	4.05± 0.80	2.22±0.48	29.00± 6.66	0.26± 0.03	2.00±0.57	2.79±0.32	0.78± 0.11	18.00±5.86	0.09±0.02	1.33± 0.88

Values represent mean ± SE

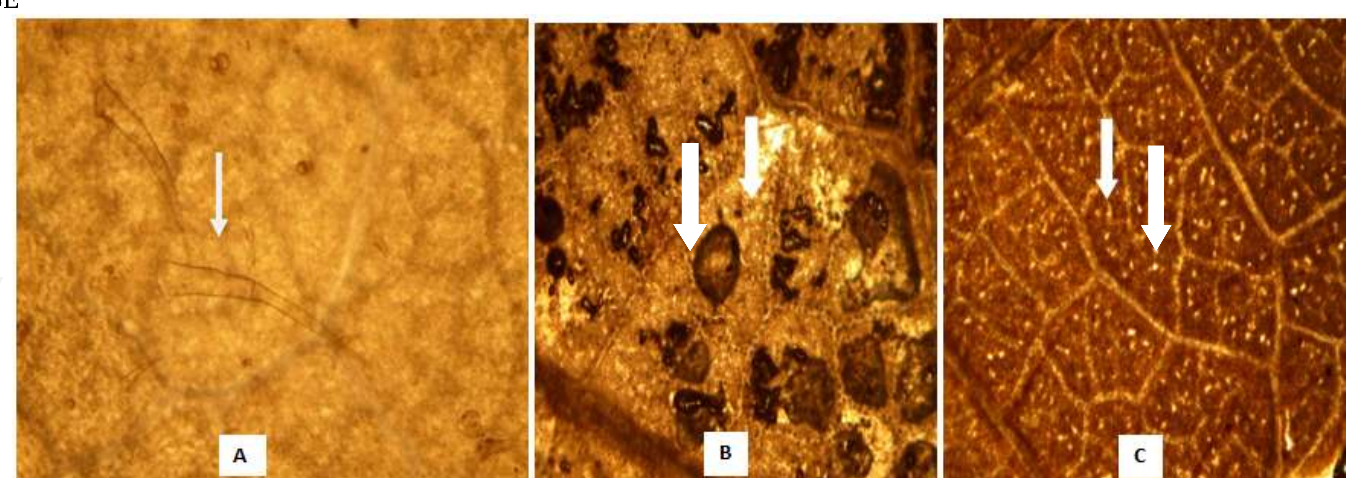

Plate 1: The leaf anatomy of: A. *Hyptis suaveolens* at 0 m showing trichomes (x40). B. *Urena lobata* at 0 m showing distorted veinlets (x40). C. *Urena lobata* at 10 m showing the veinlets (x40).

In site 2, the intervenal distance of *U. lobata* leaves at 10 m (5.54 mm) was higher than the others (Table 3). The length and number of trichomes at 0 m were the highest compared with those at 10 m and 20 m. The reverse was observed in the area of guard cell where 20 m (0.28 mm^2) is higher than those at 10 m (0.19 mm^2) and at 0 m (0.13 mm^2). However, the stomata frequency at 0 m the highest (7.33). For *H. suaveolens*, the intervenal distance of the leaves increased from 0 m to 20 m (Table 3). The length and number of trichomes at 0 m were higher than those at 10 m and 20 m. The area of guard cells at 10 m (1.10 mm^2) was higher than those at 0 m (0.13 mm^2) and at 20 m (0.12 mm^2). While the stomata frequency at 0 m was the highest. The differences in the leaf anatomical features of the two plants between the locations were significant ($P \leq 0.05$) except for intervenal distance and area of guard cells.

Considering *U. lobata* in site 3, the leaf intervenal distance, number of trichomes and length of trichomes at 10 m were the highest, while the lowest were at 0 m (Table 4). The area of guard cell increased from 0 m to 20 m. For *H. suaveolens*, the leaf intervenal distance at 10 m (9.11 mm) was highest, while the lowest was at 20 m (2.79 mm). The length of trichomes and area of guard cell at 20 m were the lowest. The number of trichomes and stomata frequency at 10 m were the lowest while the highest were at 20 m. The anatomical features of the two plants between the locations were significantly different at $P \leq 0.05$ except for number of trichomes and stomata frequency.

The Effects of Air Pollutants on the Stem Anatomy of Plants

In site 1, the thickness of stem epidermis (0.34 mm), cortex (0.42 mm), number of trichomes (27.33), length of trichomes (2.39 mm) and vascular bundles (4.04 mm) of *U. lobata* at 20 m were the highest compared to others (Table 5, Plate 2). The number of cell per area at 0 meter (40.00) was the highest. Those of *H. suaveolens* were entirely different, as the thickness of epidermis (0.31 mm), thickness of cortex (0.56 mm), number of trichomes (17.00) and length of trichomes (7.96 mm) at 0 m were the highest as compared with others (Table 5, Plate 2). The thickness of vascular bundles (2.98 mm) at 10 m was higher than that of 0 m (2.05 mm) and 20 m (1.29 mm). Also, the number of cells per area at 10 m (30.33) was the highest. The differences in the stem anatomical features of the two plants between the locations were significant ($P \leq 0.05$).

Table 5: The effect of air pollutants on stem anatomy of plants at site 1

Distance from the Road (m)	*Urena lobata*						*Hyptis suaveolens*					
	TOEPD (mm)	TOCT (mm)	TOVB (mm)	NOTCH	LOTCH (mm)	NOCPA	TOEPD (mm)	TOCT (mm)	TOVB (mm)	NOTCH	LOTCH (mm)	NOCPA
0	0.14 ±0.01	0.17±0.01	3.41±0.16	1.33 ±1.33	0.26 ±0.03	40.00±20.81	0.31 ±0.01	0.56± 0.09	2.05± 0.43	17.00± 4.58	7.96± 3.20	20.00±4.62
10	0.26 ±0.09	0.21±0.02	2.88±0.27	3.00 ±3.00	0.68 ±0.46	13.67 ±1.20	0.29 ±0.08	0.32± 0.06	2.98± 0.28	11.67± 4.41	0.83± 0.13	30.33±3.18
20	0.34 ±0.05	0.42±0.05	4.04±0.59	27.33 ±6.84	2.39± 0.57	20.00 ±5.77	0.05± 0.01	0.07± 0.02	1.29± 0.08	5.33± 1.45	2.27± 0.66	20.00±2.89

Values represent mean ± SE

KEY: TOEPD: Thickness of epidermis, TOCT: Thickness of cortex, TOVB: Thickness of Vascular bundle; NOTCH: Number of trichomes, LOTCH: Length of trichomes, NOCPA: No of cell per area

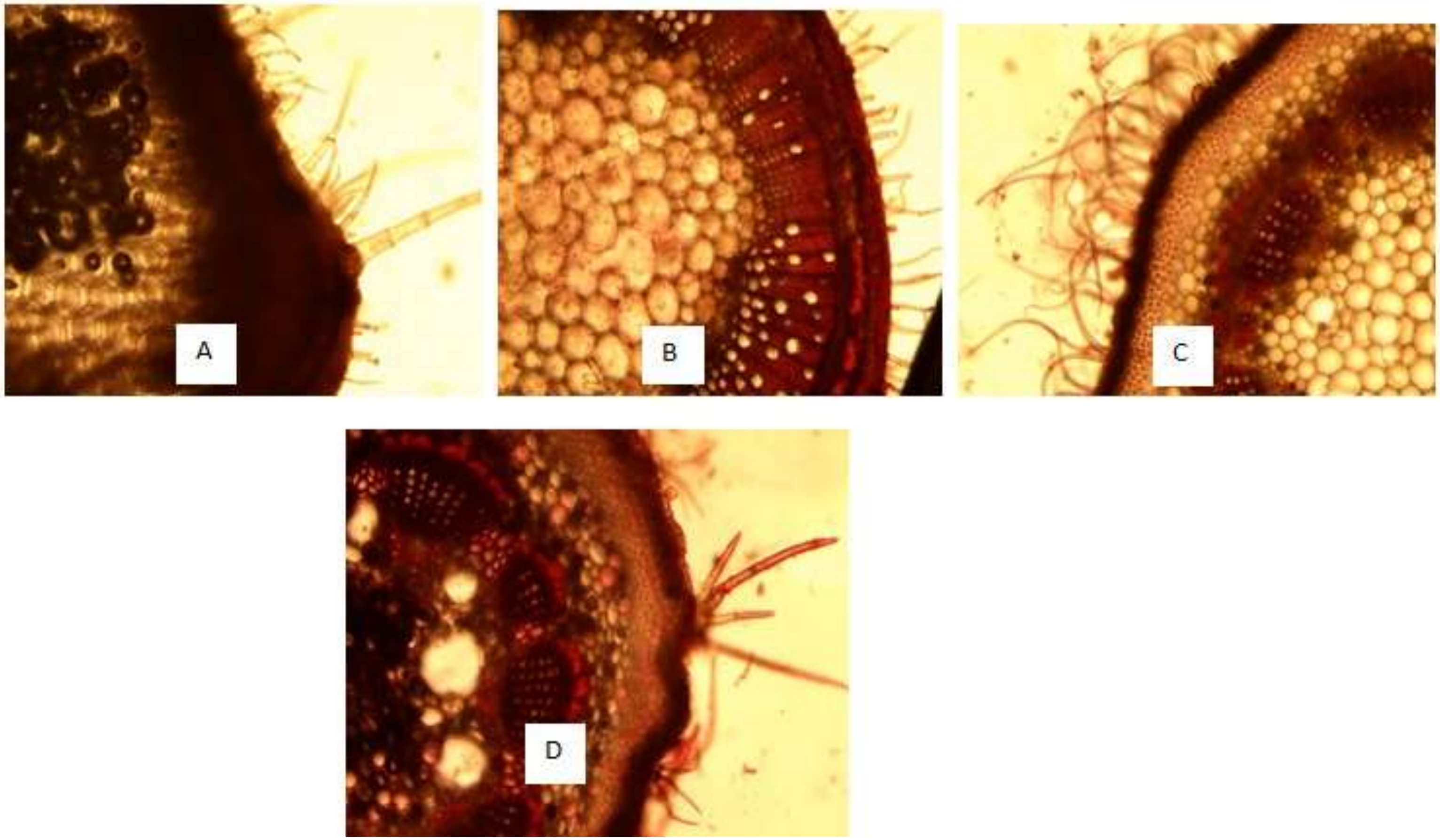

Plate 2: Stem anatomy of: A. *Hyptis suaveolens* at 0 m (x100). B. *Hyptis suaveolens* at 10 m (x100). C. *Urena lobata* at 0 m (x100) D. *Hyptis suaveolens* at 10 m (x100)

Also, the stem anatomical features of *U. lobata* and *H. suaveolens* at site 2 were presented in table 6. For *U. lobata*, the thickness of epidermis at 0 m (0.94 mm) and number of cells per area (15.67) were the highest. The length of trichomes, number of trichomes, thicknesses of cortex and vascular bundles at 10 meters were higher than others. The differences in these features of *U. lobata* were not significant ($P \leq 0.05$) except thickness of vascular bundles. In *H. suaveolens*, the thickness of epidermis, thickness of vascular bundles, number of trichomes and length of trichomes at 0 meter were the highest compared with others (Table 6). The thickness of cortex at 0 meter (1.54 mm) was the lowest while the highest is at 10 meters (1.77 mm). Number of cells per area also decreased from 0 meter to 20 meters. The differences in these features of *H. suaveolens* between the locations were significant ($P \leq 0.05$) except length of trichomes and number of cells per area.

Table 6: The effect of air pollutants on stem anatomy of plants at site 2

Distance from the Road (m)	*Urena lobata*						*Hyptis suaveolens*					
	TOEPD (mm)	**TOCT (mm)**	**TOVB (mm)**	**NOTCH**	**LOTCH (mm)**	**NOCPA**	**TOEPD (mm)**	**TOCT (mm)**	**TOVB (mm)**	**NOTCH**	**LOTCH (mm)**	**NOCPA**
0	0.94± 0.31	1.76±0.36	4.04±0.20	0.67± 0.67	1.08± 0.62	15.67±2.33	0.69± 0.04	1.54± 0.19	3.74± 0.52	7.33± 1.20	3.81± 1.82	37.33± 4.44
10	0.46± 0.18	1.38±0.13	2.44±0.14	7.33± 2.60	1.87± 0.47	7.67± 1.45	0.52± 0.05	1.77± 0.33	1.80± 0.37	0.00± 0.00	0.00± 0.00	29.00± 7.81
20	0.59± 0.07	2.13± .34	3.18±0.09	7.00± 3.79	1.82± 0.39	8.67± 3.48	0.38± 0.03	0.42± 0.03	1.14± 0.21	2.00± 1.15	1.29± 0.85	18.33± 4.41

Values represent mean ± SE

KEY: TOEPD: Thickness of epidermis; TOCT: Thickness of cortex; TOVB: Thickness of Vascular bundle; NOTCH: Number of trichomes; LOTCH: Length of trichomes; NOCPA: No of cell per area

Table 7: The effect of air pollutants on stem anatomy of plants at site 3

Distance from the Road (m)	*Urena lobata*						*Hyptis suaveolens*					
	TOEPD (mm)	**TOCT (mm)**	**TOVB (mm)**	**NOTCH**	**LOTCH (mm)**	**NOCPA**	**TOEPD (mm)**	**TOCT (mm)**	**TOVB (mm)**	**NOTCH**	**LOTCH (mm)**	**NOCPA**
0	0.54± 0.03	0.34±0.07	3.16±0.18	8.00± 2.08	1.20± 0.10	6.33± 2.73	0.71± 0.16	0.65± 0.06	2.08± 0.44	15.67± 4.33	3.62± 1.10	19.00±5.57
10	0.52± 0.06	1.00±0.04	3.43±0.18	8.00± 2.08	5.80± 2.19	4.67±2.73	0.75± 0.05	0.40± 0.05	3.03± 0.13	2.00± 0.58	2.30± 0.61	21.67±6.01
20	0.22± 0.10	0.25±0.03	3.28±0.32	8.67± 2.33	1.78± 0.30	12.67±3.71	0.27± 0.02	0.31± 0.02	3.39± 0.07	3.33± 0.88	1.39± 0.66	22.67±9.33

Values represent mean ± SE

KEY: TOEPD: Thickness of epidermis; TOCT: Thickness of cortex; TOVB: Thickness of Vascular bundle; NOTCH: Number of trichomes; LOTCH: Length of trichomes; NOCPA: No of cell per area

The anatomical features of *U. lobata* at site 3 followed different trend compared with other sites (Table 7). The thickness of epidermis and vascular bundles at 0 m were the lowest. Number of cells per area at 20 m (12.67) was higher than those at 0 m (6.33) and at 10 m (4.67). All these anatomical features between the locations were significantly different at $P \leq 0.05$ except thickness of vascular bundle, number of trichomes and number of cells per area. For *H. suaveolens*, the thickness of epidermis at 10 m (0.75 mm) was the highest, while the lowest was at 20 m (0.27 mm). The thickness of cortex, thickness of vascular bundles and number of cells per area increased from 0 m to 20 m. The number and length of trichomes decreased from 0 m to 20 m. All these anatomical features between the road distances were significantly different at $P \leq 0.05$ except length of trichomes and number of cells per area.

DISCUSSION

The use of plants as indicators of air pollution has been widely studied and accepted. Leaves were more susceptible to pollutants due to their conspicuous nature and structures (Majernik and Mansfield, 1970). Considering the structure of a leaf, the epidermis which is the outermost layer is relatively more targeted by air pollutants than other tissues. Some anatomical features like thickness of epidermal cells, stomata frequency, trichomes, idioblasts and cuticular thickening are the traits which could be used to determine the responses of plants to environmental stresses and hence useful as bio-indicators of air pollution (Yunus *et al*., 1979).

In this study, the leaves of *Hyptis suaveolens* and *Urena lobata* at the 0 meter which were observed to be smaller and having dark spots compared to those at 10 and 20 meters away from the road could be attributed to heavy pollutants absorbed from automobiles on the busy roads. This is supported by Otoide (2015) who observed that the leaf area of plants from polluted microhabitats were smaller than those of the non-polluted microhabitats. Microscopic observations of the leaves at 0 meter from the road of *H. suaveolens* and *U. lobata* showed that the stomatal pores were covered a little (sunken). This could be an implication of the effects of air pollutants that inhabit busy roads where these plants are found growing.

Futhermore, the two plants were observed to have more stomata at 0 meter but smaller areas of guard cells. This could be an adaptive strategy of the plants in reducing the surface area to volume ratio in order to limit the amount of pollutants entering into their cells. The relevance of stomata in protecting plants against pollutants has been studied by Mansfield and Majernik (1970), who reported that stomata closure do protect plants from pollution damage. Trichomes or clothing hairs which usually serve as defensive structures were found to be more on the leaves of *H. suaveolens* closer to the roadsides than in *U. lobata*. According to Azmat *et al*. (2009), plants undergoing stress do exhibit higher number of trichomes and reduced stomata sizes than those in normal environmental conditions. Also, higher number of trichomes could also aid the plants from damage caused by solar radiation and oxidative stress (David *et al*., 2017; Skaltsa *et al*., 1994).

Our results also showed that the two plant species exhibited different stem anatomical responses to the air pollutants along the roadsides studied. These variations were of no doubt due to their distinct inherent biological make-ups (Khakwani *et al*., 2012). For instance, while *U. lobata* showed higher thickness of epidermis, thickness of vascular bundles, number of trichomes and length of trichomes far from the roadside, the reverse was the case for *H. suaveolens* which tends to exhibited higher protective covering of its internal structures closer to the roadside. Increase in wall thickness and vascular bundle thickness have been attributed to plants growing in stressed conditions and these features are mainly for protection and adaptability of the plants to such stresses (Guerfel *et al*., 2009; Makbul *et al*., 2011). Our work also agrees with previous reports that cuticle and mesophyll thickness of plants decreased with increase in pollution levels (Stevovi, 2010; Akomolafe *et al*., 2017a).

One of the main functions of trichomes is to act as defensive mechanism for plant against external influences. In this regard, *H. suaveolens* could be described to have developed higher number and length of trichomes closer to roadside to prevent or limit the impact of pollutants on its internal tissues. Similarly, *U. lobata* closer to the roadside exhibited higher rate of cell proliferation represented by the number of parenchyma cells compared with *H. suaveolens*. Parenchyma cells are known to be active and mainly used for storage. This could mean that *U. lobata* was able to adapt better to pollutions along roadside by engaging in more active production of cells than *H. suaveolens*. All these anatomical alterations could be regarded as being caused by modifications in the metabolisms of plants exposed to environmental pollution (Cvetanovska *et al*., 2010).

CONCLUSION

This study has revealed that both leaves and stems of *Urena lobata* and *Hyptis suaveolens* growing along busy roadsides in Lafia, Nigeria were negatively affected, especially with respect to their anatomical features. *Hyptis suaveolens* with high number of trichomes, thick epidermis and thick vascular bundle closer to the roadside can be regarded as well adapted to these automobile pollutants. Also, *U. lobata* exhibited another level of adaptation to the environmental stress as shown by the rate of cell proliferation. These anatomical changes are obviously as a result of cumulative effects of these pollutants from roadsides. The same plants growing far away from the roadsides showed lesser degree of alterations.

REFERENCES

Akomolafe, G.F., Oloyede, F.A. and Onwusiri KC (2017a). Impact of Arsenic Stress on Leaflets and Stipes (Frond Petiole) Anatomy of *Pteris vittata* Linn. and *P. ensiformis* Burm. *International Journal of Plant & Soil Sciences*, 17(2): 1-9

Akomolafe, G.F., Omojola, J., Joshua, E.S., Adediwura, S.C., Adesuji, E.T., Odey, M.O., Dedeke, O.A. and Labulo, A.H. (2017b). Growth and Anatomical Responses of *Lycopersicon esculentum* (Tomatoes) under Microgravity and Normal Gravity Conditions. *International Journal of Biological., Biomolecular, Agricultural, Food & Biotechnological Engineering*, 11(5): 367-370

Azmat, R., Haider, S., Nasreen, H., Aziz, F. and Riaz, M. (2009). A viable alternative mechanism in adapting the plants to heavy metal environment. *Pakistan Journal of Botany*, 41(6): 2729-2738

Cvetanovska, L., Klincharska-Jovanovska, I., Dimeska, G., Srbinoska, M. and Cvetanovska, A. (2010). Anatomic and physiological disorder after intoxication with heavy metals in tobacco (Nicotiana tabacum L.). *Biotechnology & Biotechnological Equipment*, 24 (sup1): 4-9

David, O., Osonubi, O., Olaiya, C., Agbolade, J., Ajiboye, A., Komolafe, R., Chukwuma, D. and Akomolafe, G. (2017). Anatomical response of wheat cultivars to drought stress. *Ife Journal of Science*, 19(2): 323-331

Garner, J. (2002). Air pollutants, plant response, soil microbes and ecosystem biodiversity. *Environmental News*, 8(3): 127-132

Guerfel, M., Baccouri, O., Boujnah, D., Chaïbi, W. and Zarrouk, M. (2009). Impacts of water stress on gas exchange, water relations, chlorophyll content and leaf structure in the two main Tunisian olive (Olea europaea L.) cultivars. *Scientia Horticulturae,* 119(3): 257-263

Güvenç. A. and Duman, H. (2010): Morphological and anatomical studies of annual taxa of *Sideritis* L.(Lamiaceae), with notes on chorology in Turkey. *Turkish Journal of Botany*, 34(2): 83-104

Khakwani, A., Dennett, M., Munir, M. and Baloch, M. (2012). Wheat yield response to physiological limitations under water stress condition. *The Journal of Animal & Plant Sciences*, 22(3): 773-780

Majernik, O. and Mansfield, T. (1970). Direct effect of SO2 pollution on the degree of opening of stomata. *Nature*, 227(5256): 377-378

Makbul, S., Güler. N.S., Durmuş, N. and Güven, S. (2011). Changes in anatomical and physiological parameters of soybean under drought stress. *Turkish Journal of Botany*, 35(4): 369-377

Makbul, S., Türkmen, Z., Coskunçelebi, K. and Beyazoglu, O. (2008). Anatomical and pollen characters in the genus Epilobium L.(Onagraceae) from Northeast Anatolia. *Acta Biologica Cracoviensia Series Botanica*, 50(1): 51-62

Oloyede, F., Akomolafe, F. and Oladipo, O. (2011). Comparative foliar anatomical and morphological studies of *Nephrolepis biserrata* (swartz) Scott and *N. undulata* (Swartz) J. Sm. in Nigeria. *Journal of Science & Technology (Ghana)*, 31(2): 1-10

Otoide, J. (2015). Study of the Activity of Air Pollution on the Leaves of Urena lobata Growing along Busy Roads. *Donnish Journal of Agricultural Research*, 2(8): 071-076

Otoide, J. and Kayode, J. (2016). Presentation of plugged stomatal pores in the leaf of Sida acuta. *Journal of Botanical Papers*, 1(2)

Reddy, A.R., Chaitanya, K.V. and Vivekanandan, M. (2004). Drought-induced responses of photosynthesis and antioxidant metabolism in higher plants. *Journal of plant physiology*, 161(11): 1189-1202

Skaltsa, H., Verykokidou, E., Harvala, C., Karabourniotis, G. and Manetasi, Y. (1994). UV-B protective potential and flavonoid content of leaf hairs of Quercus ilex. *Phytochemistry*, 37(4): 987-990

Stevovi, S. (2010). Environmental impact on morphological and anatomical structure of Tansy. *African Journal of Biotechnology*, 9(16): 2413-2421

Yunus, M., Ahmad, K. and Gale, R. (1979). Air pollutants and epidermal traits in *Ricinus communis* L. *Environmental Pollution*, 20(3): 189-198