Pak. j. sci. ind. res. Ser. B: biol. sci. 2017 **60**(3) 162-167

Vehicular Traffic Air Pollution as Expressed by Leaves of *Senna occidentalis* (L.) Link from Three Busy Roads in Nigeria

Jonathan Eromosele Otoide* and Patrick Olugbenga Tedela
Department of Plant Science and Biotechnology, Faculty of Science, Ekiti State University, Ado-Ekiti, Ekiti State, Nigeria

(received September 3, 2016; revised January 6, 2017; accepted February 22, 2017)

Abstract. Matured leaves of *Senna occidentalis* (L.) were collected along the sides of busy roads of Oluku, Agbor and Sapele in Benin city, Nigeria where they were constantly exposed to air pollution from vehicular traffic (polluted populations). Others were collected from forest areas of Ebvomodu, Ebvoneka and Eyaen villages, each located within the distances of 50-60 km away from Benin city, where there was no source of vehicular air pollution(non-polluted populations). Peelings of the adaxial (upper) and the abaxial (lower) leaf epidermis were stained and microscopic examination and line drawings results showed that the leaves of the polluted populations suffered epidermal cell aberrations which ranged from plugged stomata, epidermal cell erosion and occasional leaf perforations caused by the corrosive activity of some of the pollutants as they undergo chemical reactions. These forms of damages were not observed in the non-polluted populations which were healthy with opened stomatal pores. At the upper (adaxial) epidermis, the mean lengths (µm) of stomatal pores of leaves of non-polluted populations of collections were 0.64 ± 0.41, 0.76 ± 0.84 and 0.74 ± 0.92, respectively and at the lower (abaxial) epidermis, the mean lengths were 0.61 ± 0.81, 1.40 ± 0.95 and 0.71 ± 0.81 from Ebvomodu, Ebvoneka and Eyaen, respectively. In the same vein, the mean width (µm) of pores of stomata of the non-polluted leaves collected from Ebvomodu, Ebvoneka and Eyaen were 1.14 ± 0.16, 0.32 ± 0.63 and 0.32 ± 0.11, respectively, at the upper (adaxial) epidermis. At the lower (abaxial) epidermis, the mean width (µm) of pores were 0.22 ± 0.25, 0.30 ± 0.51 and 0.39 ± 0.16 for collections from Ebvomodu, Ebvoneka and Eyaen, respectively. The stomatal pores of leaves of the polluted populations on the other hand were impossible to be measured because they were plugged by particulate air pollutants from the busy roads. It was opined that the leaves of the polluted populations would suffer eco-physiological stress by virtue of their plugged stomatal pores.

Keywords: *Senna occidentalis* (L.), vehicular traffic, air pollution, physiological stress, leaves

Introduction

Senna occidentalis (L.) Link belongs to the family, Caesapiniaceae. It is an erect, hairless, undershrub, annual or biennial, growing to about 100 cm high and reproduces from seeds. It is a common weed in field crops, waste areas and roadsides in West Africa (Akobundu and Agyakwa, 1998).

One of the most types of stress that natural ecosystems have had to accommodate is air pollution. Pollutants are generally identified as primary and secondary, depending on how they are formed (Paryavaran, 2007). Primary pollutants are directly emitted into the atmosphere, predominantly in gaseous forms and they include sulphur dioxide (SO_2), nitrogen oxides and reactive hydrocarbons (RHC), which are carbon compounds and mixtures such as ethylene and gasoline (Beijing, 2008). The burning of fossil fuels, coal and natural gas produces a large portion of these pollutants. Industrial utility and power plants emit large quantities of the SO_2 and NOx. Mobile sources such as transportation vehicles are responsible for large amounts of NOx and RHCs. Petroleum refining and storage activities produce reactive hydrocarbons, although the majority are produced from numerous smaller sources. Metal ore smelters can release SO_2 in addition to toxic elements such as lead, cadmium, nickel and fluoride. Lead can also come from burning leaded gasoline (Bell *et al*., 2011).

Secondary, pollutants are formed during chemical reactions in the atmosphere involving the primary pollutants. One of the most commonly known is acidic deposition which is produced when SO_2 (sulphur dioxide) or NOx combines with oxygen in the air to form acidic gases or particulates (dry deposition) in combination with moisture. These processes can cause acid snow, hail, dew, fog, or rain (wet deposition or ‘acid rain’) (Beijing, 2008). Another type of secondary air pollutant is photochemical oxidants, which are

*Author for correspondence;
E-mail: jonathan.otoide@eksu.edu.ng

produced when energy provided by sun light triggers reactions involving NOx and atmosphere oxygen. Ozone (O_3), the most common oxidant is a gas that is extremely toxic to plants and humans (Beijing, 2008).

Leaves are often prone to the effect of air pollution than any other parts of the plant. The gaseous pollutants mentioned above enter leaves through stomata following the same diffusion pathway as carbon dioxide (CO_2). NOx dissolves in cells and gives rise to nitrite ions (NO^{-2}), which are toxic at high concentration and nitrate ions (NO^{-3}) that enter into nitrogen metabolism as if they had been absorbed through the roots. In some cases, exposure to pollutant gases, particularly SO_2, causes stomatal closure which protects the leaf against further entry of the pollutant but also curtails photosynthesis (Schroeder *et al*., 2001). In the cells, SO_2 dissolves to give bisulphate and sulphite ions. Sulphite is toxic but at low concentrations it is metabolized by chloroplasts to sulphate, which is not toxic (Heather, 2003). At sufficiently low concentrations, bisulphate and sulphite are effectively detoxified by plants and SO_2 air pollution then provides sulphur source to the plant (Bonnie and Joel, 2000). In urban areas, these polluting gases may be present in such high concentration that they cannot be detoxified rapidly enough to avoid injury. Many scientists also believe that air pollution could make a plant species more susceptible to natural stresses such as insects, diseases, drought, or winter frost damages (Rai *et al.*, 2013; Bell *et al*., 2011).

It has been established that individual organisms within a population vary in their ability to withstand the stress of environmental changes. According to Garner (2002) it is based on their genetic constitution (genotype), stage of growth at time of exposure, and microhabitat in which they are growing. Plants are exposed in their environment to numerous stress factors that may act either simultaneously or consecutively with different intensities and frequencies. According to Cynthia (2015) plants suffer stress from several environmental influences. Often, the leaves and the flowers were the first to show symptoms of air pollution which according to Marianne and Wayne (2007) include unusual discolorations, spotting, twisting or turning of leaves and abortion of flowers followed by poor growth. Previous study by San (2006) had revealed that increased carbon dioxide does not accelerate plant growth. It is now established that doubling the volume of atmospheric CO_2 is capable of causing leaf stomata to close by 20-40% in diverse plant species, thus reducing CO_2 intake.

The main sources of air pollution are the industries, agriculture, traffic and energy generators. During combustion and other production processes, substances that can pollute air are emitted. Reports from Lenntech (2005) revealed that, traffic is responsible for one-third of the greenhouse gas emissions. Emissions caused by traffic are mainly those of carbon dioxides, VOC (volatile organic compounds) and small dust particles.

In the recent times, Kayode and Otoide (2007a; 2007b; 2006) have investigated the effects of gaseous pollutants in form of soot on the leaves of *Chromolaena odorata, Newbouldia laevis* and *Amaranthus spinosus* growing along roadsides. They reported reduction in size of leaves and damage of leaf cuticles and epidermis on these plants (Otoide and Kayode, 2013). More recently, Otoide (2014) reported damages such as eroded epicuticular wax, epidermal cell alterations, plugged stomatal apertures, blurred epidermal surfaces, polluted cells, ruptured stomatal ledges and eroded cell walls observed on the leaf epidermis of *Polyalthia longifolia, Digitaria gayana* and *Trianthema portulacastrum* growing very close to exhaust-pipes of power generators. The present study aims at establishing damages in leaves of *Senna occidentalis* growing along the sides of busy roads with a view to ascertain its usefulness as bioindicator of environmental air pollution.

Materials and Methods

Collection of plant samples and description of sites. Matured leaves of *Senna occidentalis* were collected along busy roads: Benin-Lagos, Benin-Agbor and Benin-Sapele within the distance of 0-0.5 m from the tarred portions, at the outskirts of Benin city, Edo State, Nigeria. Another collection of leaves of same species was made in the forest areas of Ebvomodu, Ebvoneka and Eyaen villages which were 50-60 km away from those busy roads in Edo State. The collections from these busy road sides and the ones from the villages constituted the polluted and the non-polluted samples of *Senna occidentalis* accordingly.

The Benin-Lagos road (Oluku road) is a busy road with high vehicular traffic. The road linked Benin City with Lagos and other places in the south western region of Nigeria. Plant collections along this road were carried out at Oluku, a densely populated industrial settlement situated at about 10km away from Benin City. The industries along this road include bottling company, heavy duty vehicle service stations and agricultural farm estates and settlements. Agbor road on the other hand, is the only direct route that linked Benin City with Agbor (Delta state) and the eastern states of the country. Collection along this road was made at 10 km from Benin City. A petroleum mega station is located along this road. Similarly, Sapele road is the only direct route that linked Benin City with Warri and other State of the south-south region of the country. Collection was done at 10 km from Benin City along this road.

Preparation of slides. The epidermal peels of each leaf sample were obtained using the methods of Ogundipe and Kadiri (2013) with slight modifications. The leaves were placed, with the outer surface facing downward, on a flat surface and flooded with 8% sodium hypochlorite solution (NaOCl). An area of about 1cm square was removed from a central/standard position, always midway between the base and the apex of the leaves. The peels were mounted temporarily on slides. 10 slides (each of adaxial and abaxial surfaces) were prepared per population.

Data collection. The slides were examined under the light microscope using x20 and x10 objectives. Data were collected from 10 microscopic fields selected at random from each slide. The lengths and widths of stomatal pores and guard cells were measured using ocular micrometer. Data were collected from 50 stomata per leaf surface. This was done in 10 replications. Line drawings of the epidermal tissues using camera lucida are shown in figures as illustrations.

The data obtained were subjected to relevant statistics using mean and standard deviation.

Measurement of stomatal index (SI). The stomatal index was measured following Metcalfe and Chalk (1988):

$$SI = \frac{S}{E+S} \times \frac{100}{1}$$

where:

S = the number of stomata per unit area;
E = the number of epidermal cells of the same area.

Table 1. Leaf epidermal characteristics of *Senna occidentalis* from polluted populations

Descriptions	Surface	Polluted populations		
		Oluku road	Agbor road	Sapele road
Nature of epidermal cell wall	Ad	Straight	Straight	Straight
	Ab	Straight	Straight	Straight
Type of stomata	Ad	Anomocytic	Diacytic	Anomocytic
	Ab	Diacytic	Anomocytic	Diacytic
Stomata index (SI) (%)	Ad	45.46	39.45	42.21
	Ab	46.60	48.92	46.36
Mean length of stomatal pore (μm)	Ad	Plugged	Plugged	Plugged
	Ab	Plugged	Plugged	Plugged
Mean width of stomatal pore (μm)	Ad	Plugged	Plugged	Plugged
	Ab	Plugged	Plugged	Plugged
Mean length of guard cells (μm)	Ad	1.51±0.92	1.72±0.15	1.62±0.84
	Ab	1.85±0.40	1.12±0.64	1.71±0.46
Mean width of guard cells (μm)	Ad	1.44±0.14	1.09±0.26	1.11±0.19
	Ab	1.47±0.81	1.02±0.18	1.26±0.21

Ad = adaxial (upper) epidermis; Ab = abaxial (lower) epidermis.

Table 2. Leaf epidermal characteristics of *Senna occidentalis* from non-polluted populations

Descriptions	Surface	Non-polluted populations		
		Ebvomodu	Ebvoneka	Eyaen
Nature of epidermal cell wall	Ad	Straight	Straight	Straight
	Ab	Straight	Straight	Straight
Type of stomata	Ad	Anomocytic	Diacytic	Anomocytic
	Ab	Diacytic	Anomocytic	Diacytic
Stomata index (SI) (%)	Ad	39.61	38.46	42.85
	Ab	50.18	47.61	46.60
Mean length of stomatal pore (μm)	Ad	0.64±0.41	0.76±0.84	0.74±0.92
	Ab	0.61±0.81	1.40±0.95	0.71±0.81
Mean width of stomatal pore (μm)	Ad	1.14±0.16	0.32±0.63	0.32±0.11
	Ab	0.22±0.25	0.30±0.51	0.39±0.16
Mean length of guard cells (μm)	Ad	1.23±0.86	2.93±0.18	2.89±0.34
	Ab	1.40±0.91	2.12±0.41	2.01±0.60
Mean width of guard cells (μm)	Ad	1.01±0.29	1.48±0.49	1.47±0.51
	Ab	0.92±0.51	1.49±0.14	1.47±0.24

Ad = adaxial (upper) epidermis; Ab = abaxial (lower) epidermis.

Results and Discussion

The characteristics of the adaxial (upper) and abaxial (lower) epidermis for the polluted and non-polluted populations of *Senna occidentalis* are summarized in Tables 1-2 and illustrated in Fig. 1(a-l).

The epidermal cell walls on the upper and lower epidermis of both populations were observed to be straight. Stomata were present on both surfaces. At the upper surface, the stomata were of the anomocytic type, whereas, they were diacytic at the lower surface for both populations. The stomata index in polluted populations at the upper epidermis was 45.46, 39.45 and 42.21% while, at the lower epidermis it was 46.60, 48.92 and 46.36% at Oluku, Agbor and Sapele roads,

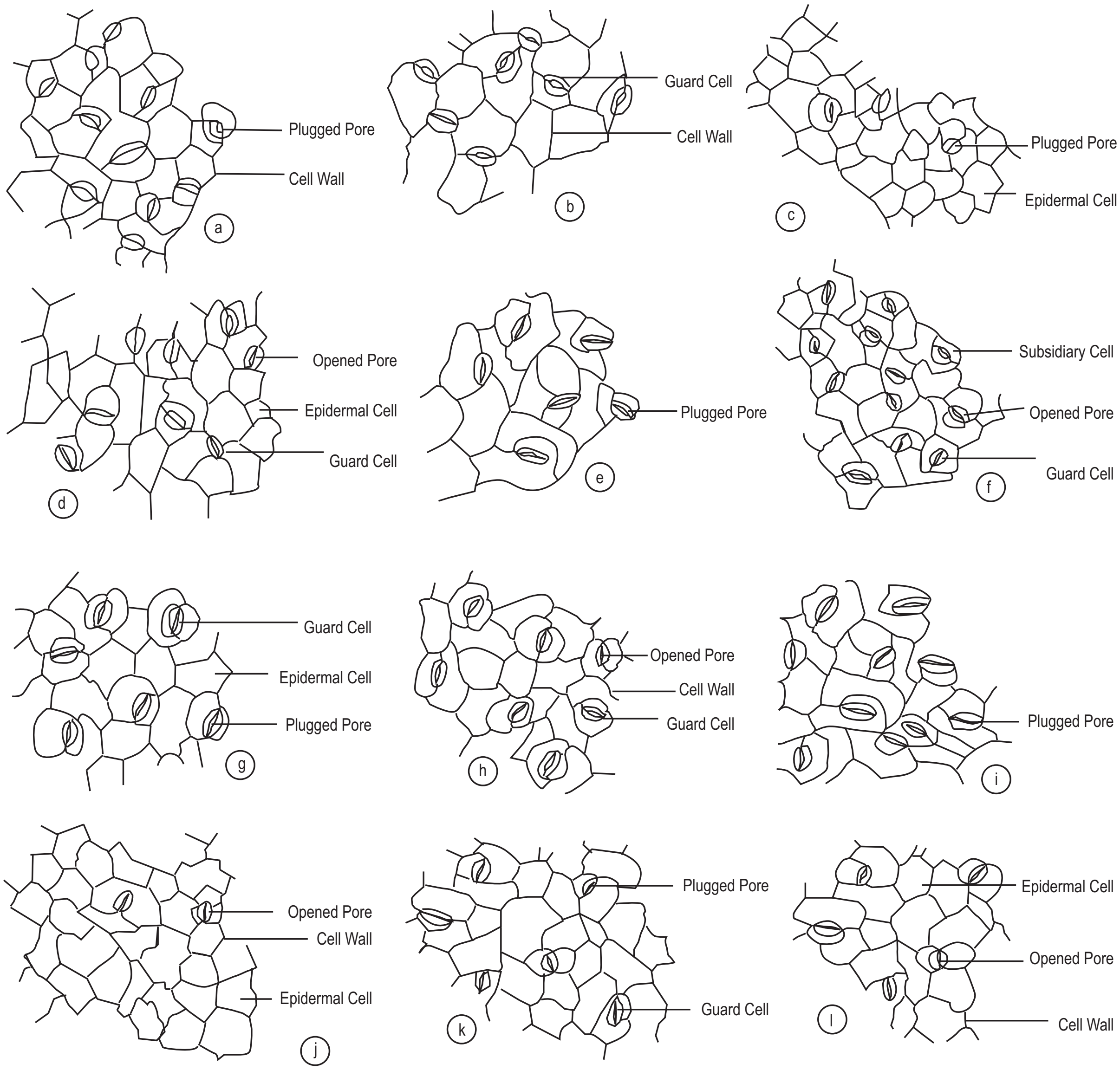

Fig. 1. (a) The abaxial edpdermis of *Senna occidentalis* from Oluku road.x100; (b) The abaial epidermis of *S. occidentalis* from Ebvomodu village.x200; (c) The adaxial edpdermis of *S. occidentalis* from Oluku road.x100; (d) The adaxial edpdermis of *S. occidentalis* from Ebvomodu village.x200; (e) The abaxial edpdermis of *S. occidentalis* from Agbor road.x200; (f) The abaxial edpdermis of *S. occidentalis* from Ebvoneka village.x100; (g) The adaxial edpdermis of *S. occidentalis* from Agbor road.x200; (h) The adaxial edpdermis of *S. occidentalis* from Ebvoneka village.x200; (i) The abaxial edpdermis of *S. occidentalis* from Sapele road.x400; (j) The abaxial edpdermis of *S. occidentalis* from Eyaen village.x100; (k) The adaxial edpdermis of *S. occidentalis* from Sapele road.x200; (l) The adaxial edpdermis of *S. occidentalis* from Eyaen village.x200.

respectively. In contrast, the stomata indexes of the non-polluted populations were 39.61 and 50.18% (upper and lower); 38.46 and 47.61% (upper and lower) and 42.85 and 46.60% (upper and lower) for Ebvomodu, Ebvoneka and Eyaen populations, respectively. These depict that in both populations, stomata were more on the lower epidermis than the upper epidermis. In the polluted populations, stomatal pores were observed to be plugged which made it impossible to determine their mean lengths and mean widths.

At the upper epidermis, the mean length (μm) of the pores were 0.64±0.41, 0.76±0.84 and 0.74±0.92 at Ebvomodu, Ebvoneka and Eyaen respectively while at the lower epidermis the pore lengths (μm) were 0.61±0.81, 1.40±0.95 and 0.71±0.81, respectively. Similarly, the mean widths (μm) of pores at the upper epidermis were 1.14±0.16, 0.32±0.63 and 0.32±0.11 at Ebvomodu, Ebvoneka and Eyaen respectively while at the lower epidermis, the width (μm) of pores were 0.22±0.25, 0.30±0.51 and 0.39±0.16, respectively. This is an indication that the pores of stomata in the leaves collected from the three villages were opened.

The mean lengths (μm) of guard cells at the upper epidermis were 1.51±0.92, 1.72±0.15 and 1.62±0.84 at Oluku, Agbor and sapele roads respectively while at the lower epidermis, the guard cell lengths were 1.85±0.40, 1.12±0.64 and 1.71±0.46, respectively. The widths (μm) of the guard cells at the upper epidermis were 1.44±0.14, 1.09±0.26 and 1.11±0.19 at Oluku, Agbor and sapele roads respectively, while at the lower epidermis, widths (μm) of guard cells were 1.47±0.81, 1.02±0.18 and 1.26±0.21, respectively.

On the other hand, the mean lengths (μm) of guard cells at the upper epidermis of the non-polluted populations, were 1.23±0.86, 2.93±0.18 and 2.89±0.34 at Ebvomodu, Ebvoneka and Eyaen respectively while at the lower epidermis the mean lengths (μm) were 1.40±0.91, 2.12±0.41 and 2.01±0.60, respectively. Similarly, the mean widths (μm) of guard cells at the upper epidermis were 1.01±0.29, 1.48±0.49 and 1.47±0.51 at Ebvomodu, Ebvoneka and Eyaen respectively while at the lower epidermis the widths (μm) of the guard cells were 0.92±0.51, 1.49±0.14 and 1.47±0.24, respectively.

Microscopic examination of the leaves of the polluted populations showed evidences of damage which ranged from plugged stomatal pores, epidermal cell aberrations and erosion and occasional leaf perforations on the two epidermal surfaces of the leaf blades. It is pertinent to suspect that the damages were caused by the polluted atmospheric condition that dominated the busy roads explored for the present study which was created by poisonous gaseous emissions from the exhaust-pipes of vehicles plying the roads. The previous reports of the author and his collaborators on the leaves of some plants growing naturally along busy roadsides and some growing close to exhaust-pipes of power generators such as *Chromolaena odorata* (Kayode and Otoide, 2006), *Amaranthus spinosus* and *Newbouldia laevis* (Kayode and Otoide, 2007a; 2007b), *Elaeis guineensis* (Otoide and Kayode, 2008), *Euphorbia heterophylla, Chromolaena odorata, Commelina diffusa* and *Kyllinga pumila* (Otoide and Kayode, 2013), *Polyalthia longifolia, Digitaria gayana* and *Trianthema portulacastrum* (Otoide, 2014) and *Urena lobata* (Otoide, 2015) lend credence to the suspicion above. In the same vein, the previous assertions of Cynthia (2015) and Milton (2015) that air pollutants injure plants by damaging their leaves and hinder the processes of photosynthesis equally support the above suspicion.

Observation of the leaves at the points of sample collections (i.e. polluted populations) in the field revealed that unhealthy, negatively impacted and scanty leaves were found on the branches of the species growing along the three roads (Oluku, Agbor and Sapele roads). This condition is traceable to the unfriendly and harsh weather created by particulate and poisonous air pollutants such as carbon dioxides, VOC (volatile organic compounds), dust particles, surphur dioxide, nitrogen oxides, ozone and peroxyacetylnitrates (PANs) resulting from automobile emissions. The poor and scanty foliage would not enable the plants to compete successfully with their counterparts in the same microhabitat as they do not have enough and healthy leaves to trap sunlight for the manufacture of food. This is a serious ecological disadvantage posed on this population of the species by automobile air pollution.

Contrary to this location leaves of the same species from Ebvomodu, Ebvoneka and Eyaen villages were green, healthy and numerous enough to trap sunlight for survival. Microscopic examination of the epidermis of the leaves revealed opened stomatal pores. These conditions might be because there was no source of air pollution in the villages where the species naturally grows.

In view of the foregoing, *Senna occidentalis*, a shrub, by virtue of its habit would easily "collect" or "receive" particulate air pollutants that dominate busy roadsides and as such could serve as marker of environmental air pollution.

Recommendations. Regular maintenance of motor vehicles should be encouraged in Nigeria as a whole and in Edo state in particular. This would reduce the rate at which smokes (black carbon) are produced by automobile engines since incomplete combustion of fuel in vehicles are facilitated by poor engine conditions. Plant species growing along busy roadsides will therefore, not experience plugged pores and perforations in their leaf blades. This will enable them to photosynthesize and live healthy.

Economic plants and plantations should not be established along roadsides because particulate pollutants that pre-dominate busy roadsides can cause injuries on the leaves. Injury in plant parts is one of the avenues for disease attacks in plants.

References

Akobundu, I.O., Agyakwa, C.W. 1998. *A Handbook of West African Weeds.* 564 pp., International Institute of Tropical Agriculture, Ibadan, Nigeria.

Beijing, 2008. *Beijing Reports Economic Losses Caused by Pollution*. http://en.beijing2008.cn/80/02/article 214020280.shtml.

Bell, J.N., Honour, S.L., Power, S.A. 2011. Effects of vehicle exhaust emissions on urban wild plant species. *Environmental Pollution*, **159:** 1984-1990.

Bonnie, A., Joel, K. 2000. Trees for Problem Landscape Sites-Air Pollution, *VCE Publications*/430/430-022.

Cynthia, M. 2015. *The Effects of Air Pollution on Plants*. http://www. livestrong.com/article/141726

Garner, J.H.B. 2002. Air pollutants, plant response, soil microbes and ecosystem biodiversity. *Environmental News*, **8:** 1-7.

Heather, G. 2003. *Effects of Air Pollution on Agricultural Crops*, *FACTSHEET*, ISSN: 1198-712X.

Kayode, J., Otoide, J.E. 2007a. Leaf cuticle variations in *Amaranthus spinosus* as indicators of environmental pollution. *Pakistan Journal of Scientific and Industrial Research*, **50:** 327-329.

Kayode, J., Otoide, J.E. 2007b. Environmental pollution and leaf cuticular variations in *Newbouldia laevis* seem, Ex Bureau. *Asian Journal of Plant Sciences*, **6:** 1024-1026.

Kayode, J., Otoide, J.E. 2006. The effect of vehicular pollution on the anatomical features of leaf of *Chromolaena odorata* (L.), In: *Proceedings of the 15th Annual BOSON Conference*, R. M. King (edn.), 97-99.

Lenntech, 2005. FAQ air pollution frequently asked questions. In: *The Question Library on Air Related Questions*. Lenntech Water Treatment and Air Purification Holdings, Lenntech BV, The Netherlands.

Marianne, A., Wayne, S.J. 2007. A review of factors affecting plant growth. pp. 1-3, Hydrofarm Incorporation, Petaluma, CA, USA.

Metcalfe, C.R., Chalk, L. 1988. *Anatomy of Dicotyledons. Wood Structure and Conclusion of the General Introduction*. vol. **2,** 2nd edition., Oxford University Press, Walton Street, Oxford, UK.

Milton, K. 2015. Long- Term Effects of Air Pollution. http: //www. Livestrong.com/article/213109-long-term-effects-of-air-pollution/

Ogundipe, O.T., Kadiri, A.B. 2013. Comparative foliar epidermal morphology of the west African species of Amaranthaceae Juss. *Feddes Repertorium*, **12:** 97-116.

Otoide, J.E. 2015. Study of the activity of air pollution on the leaves of *Urena lobata* growing along busy roads. *Donnish Journal of Agricultural Research*, **2:** 071-076.

Otoide, J.E. 2014. Observations on the polluted and non-polluted leaf epidermal surfaces of some plants. *Asian Journal of Biological and Life Sciences*, **3:** 65-69.

Otoide, J.E., Kayode, J. 2013. Threat of domestic power generators to terrestrial ecosystem as expressed in some plant species. *Journal of Agricultural Science and Technology*, **5:** 377-384.

Otoide, J.E., Kayode, J. 2008. The effects of gaseous pollutants from the exhaust-pipe of power generators on the epidermis of leaves of *Elaeis guineensis* Jacq. *African Journal of General Agriculture*, **4:** 61-64.

Paryavaran, M. 2007. Various Types of Environmental Pollution. http://www.paryavaranmitra.com/pollutiontypes.htm.

Rai, P. K., Panda, L.L.S, Chutia, B.M., Singh, M.M. 2013. Comparative assessment of air pollution tolerance index (APTI) in the industrial (Rourkela) and non industrial area (Aizawl) of India. An ecomanagement approach. *African Journal of Environmental Science and Technology*, **7:** 944-948.

San, D. 2006. Study Reveals How Plants Respond to Elevated Carbon Dioxide. *Science Daily*, May 3, pp. 1-3.

Schroeder, J.I., Allen, G.J., Hugouvieux, V., Kwak, J.M., Waner, D. 2001. Guard cell signal transduction. *Annual Review of Plant Physiology and Plant Molecular Biology*, **52:** 627-658.