

**VISUAL SYMPTOMS EXPRESSED BY SOME RUDERAL PLANT SPECIES  
IN RESPONSE TO ANTHROPOGENIC AIR POLLUTION IN NIGERIA'S  
GUINEA SAVANNA  
BY**

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**ABSTRACT**

Plants, by virtue of their stationary growth habit are usually the first to respond to environmental stress factors including air pollution. Data on the visual symptoms exhibited by higher plants in response to anthropogenic air pollution under tropical Savanna conditions is lacking. In an attempt to document the patterns of visual injury induced by air pollution on foliage of higher plants, field observations were conducted. Preliminary data show that many of the ruderal plant species that grow in this ecosystem exhibited varying degrees and patterns of injury that appeared to be characteristic for each species. Such ranged from bleaching, to formation of necrotic lesions in varying visual patterns. Intensity of symptoms expressed generally suggested an increase with increased anthropogenic activity. The significance of these observations to developing a checklist of sensitive higher plants and their patterns of visual response that will serve as a field guide for use in assessment of environmental impacts of air pollution under tropical savanna ecosystems is discussed.

**Key words: Visual injury, higher plants, air pollution, Nigeria.**

**INTRODUCTION**

Vegetation growing under field conditions rarely experience optimal growth requirements. Therefore, the plants that make up these populations may be considered to be under stress. Effects of stress may be observed on the subsequent growth depending upon the magnitude of the stress factors (Matussek *et al.*, 1999), in relation to the tolerance limits of the species. Air pollution is one of the factors that induce stress on field growing

vegetation. There are both natural and anthropogenic sources of air pollution, although the contributions from anthropogenic sources are more pronounced than that from natural sources. Anthropogenic sources include automobile exhaust, industrial operations that produce gaseous emissions, and agricultural activities including burning of vegetation biomass (Davy *et al.*, 2012) which in Africa is frequently undertaken to clear land for cultivation, hunting, and

disposal of agricultural litter. Santoso *et al.*, (2011), identified five (5) contributing factors to air pollution as lead industry and road dust (12%), diesel vehicles (30%), oil and power plant (26%), road dust (17%) and biomass burning mixed with road dust (15%). In general, vegetation growing under conditions where other factors are optimal is most susceptible to air pollution (Bako, 2000). Response of plants to impact of air pollution may be expressed at the subcellular/molecular, whole plant/organismic, or ecosystem/community levels.

At the organismic level, plants exhibit foliar marking as a characteristic response to air pollution. Treshow, (1979) listed foliar symptoms of air pollutants as necrosis and bleaching of intercostal areas or of leaf margins, glazing or silvering of leaf surface, particularly the under surface, chlorosis or loss of chlorophyll and flecking or stippling on upper leaf surface. At the ecosystem level, wet and dry depositions of air pollutants alter nutrient cycling, and thus the ecosystem function that will translate to alterations in species composition and biodiversity (Stevens *et al.*, 2010; Bleeker *et al.*, 2011) that may translate into large scale forest declines.

The major air pollutants that affect plants are Sulphur dioxide, Ozone, PAN, Oxides of Nitrogen (NO<sub>x</sub>), Hydrogen sulfide, and Sulfuric acid (WRI, 1988). Plants by virtue of their stationary growth habit are the first to show symptoms of environmental stress. Generally, plants growing in the vicinity of emission sources exhibit characteristic symptoms earlier than those growing further away (Quan *et al.*, 2008; Quan and Zhang, 2008; Laffray *et al.*, 2010; Goodrich and Jacobi, 2011; Nikula *et al.*, 2011; Ahmad *et al.*, 2012).

Sulphur dioxide pollution effects have been observed in many sensitive

species of plants. Symptoms include bleached spots, bleached areas between veins, chlorosis, and insect injury. Age of leaves also influences sensitivity, middle aged are most sensitive, old leaves are least sensitive. SO<sub>2</sub> mostly affect mesophyll cells (WRI, 1991). Ozone is a strong photo oxidant gas, whose symptoms include flecks, stipple, bleached spotting, pigmentation, conifer needle tips become brown and necrotic. Ozone affects the palisade or spongy parenchyma in leaves with no palisade (Fangmeier *et al.*, 1994). PAN and ammonia have strong phytotoxic effects on plants. PAN symptoms in plants include glazing and silvering or bronzing on lower surface of leaves. Middle aged or young leaves are most sensitive. PAN mostly affects spongy cells, while ammonia's symptoms include turning green appearance of leaves into brown and blackening of all parts in some species. Mature leaves are most sensitive. Ammonia affects the epidermis and mesophyll cells (Mansfield and Pearson, 1993). In a study to evaluate the effects of urban vehicular emissions on wild plant species, Bell *et al.*, (2011) reported that NO<sub>x</sub> was the key phytotoxic component of exhaust emissions, and highlights the potential for detrimental effects of vehicle emissions on urban ecosystems. Nitrogen dioxide primarily causes irregular, white or brown collapsed lesions on the intercostal tissues and near leaf margins. Middle-aged leaves are most sensitive and it affects the mesophyll areas. Hydrogen fluoride primarily injures the epidermis and mesophyll cells. The tip and margin burn, dwarfing and leaf abscission also occurs. The narrow brown-red band separates necrotic from green tissue. Youngest leaves are most sensitive (WRI, 1988). Ethylene is believed to cause more damage to vegetation. It

injures all tissues of the plant. Symptoms include sepal withering, leaf abnormalities, flower dropping and failure of the leaf to open properly. Older species are affected most (Sawada and Totsuka, 1986). Chlorine causes bleaching between veins, tips and margins burns. The epidermis and mesophyll cells are affected in mature leaves (Hindawi, 1980). Hydrogen chloride affects the epidermis and mesophyll cells, thereby showing necrotic lesion symptoms. Older leaves are most sensitive (Hindawi, 1980). Sulfuric acid shows necrotic spots on the upper surface similar to caustic and acidic compound. It affects all cells and all stages of the leaves (Jacobson and Hills, 1989).

Air pollution modeling (APM) is being developed and used in order to better understand, investigate, assess, and regulate the quality of the atmospheric environment and the distribution of toxic pollutants which are often used in ecotoxicology. APM has progressed significantly during the last two decades, attracting the interest of various research groups and initiatives worldwide. It covers all aspects related to the life cycle of pollutants, starting from their emission or 'production' within the atmosphere, and ending with their impacts on man and the ecosystem (San José *et al.*, 2008). Research in this field has led to the cataloguing of plant responses and symptoms that help in predicting the environmental impacts of anthropogenic activities. However, data on the response of plants to anthropogenic modification of the environment, particularly in relation to soil and air pollution in northern Nigeria is scant and includes earlier assessments by Bako *et al.*, 2005; 2008; 2009a and b, and more recently 2013, in which an attempt was made to document the bioaccumulation and phytoremediation potentials of some

ruderal plant species in relation to air pollution as a step towards developing a reference for determining the impact of pollution events (Bako *et al.*, 2013).

This research therefore is an attempt to identify those plant species that are sensitive to the effect of air pollution, and to document any visual responses as an initial step towards developing a data base for use of higher plants in biomonitoring of atmospheric quality in the Nigerian Guinea Savanna.

## **MATERIALS AND METHODS CHARACTERISTICS OF THE SITES**

The study was carried out in Kaduna state. The study sites were located around Zaria, Birnin Gwari and Kaduna. Four sites were selected for the study. The first, Kamuku National Park Birnin Gwari was used as a control site where air pollution and farming activities are minimal. It is a pristine natural eco-system being devoted to recreation, eco-tourism, scientific research, medicine and for the promotion of culture, handcraft and other values (SITE A). Three other sites were selected, SITE B: was along Sokoto road, Shika Village. It was an abandoned farmland with low vehicular traffic level (traffic level was characterized low when there are 1000 automobiles which included city public transit and cargo transit between 6:00 a.m. and 12:00 noon). SITE C: was a cleared fruit garden along Kaduna road, Tukur Tukur Village. It had a high vehicular traffic level (traffic level was characterized high when it consisted of 4000 automobiles, which included city public transit and cargo transit between 6:00 a.m. and 12:00 noon). SITE D: This was a site directly behind Kaduna Refinery and Petrochemical Company. It was an abandoned farmland characterized as high because the industry (Kaduna Refinery and Petrochemical Company)

have highly placed emission stacks and sampling site was located close to industry. Each was categorized based on the nature of its emission sources (stationary or mobile emission sources), these sites have different sources and/levels of anthropogenic emissions, and farming activity.

Within each site, three replicates of 0.5 hectares were delimited. Each site was evaluated for number of species present, number of species that showed symptoms, and extent of symptoms shown by each sensitive species, on a three point scale as presented in table 1

## RESULTS AND DISCUSSION

Fewer species of plants were found to be sensitive to the effects of anthropogenic pollution in the reserved area (Table 2) than in the areas that had progressively higher anthropogenic activity (Tables 3, 4 and 5). The results from visible foliar injury indicated that as anthropogenic activity increased, there was an increase in the number of plants with foliar injury. Symptoms included chlorosis, stippling, necrosis and defoliation (Plates 1-4). Furthermore, intensity of symptoms varied from slight to moderate in the sites that had lower impact (Tables 2-4), as compared to the site with higher impact, where symptoms expressed were moderate to severe (Table 5). For species that were common to all the sites, (*Cassia tora* and *Sida acuta*), the symptoms varied clearly in severity with the level of pollution.

Previous reports have indicated that results of visible observation generally agree with qualitative estimation of chlorophyll contents (Hernandes *et al.*, 1986), and also correlate with concentration of air pollutants (Ali, 1993). The sensitivity of plants to pollutant damage depends on species (Saxe, 1994) and the progress of chlorotic symptoms may vary in extent and in proportion owing to the relative

sensitivity of the different types of pigments in the plants. The result showed that *Cassia tora* and *Sida acuta* were the most sensitive species as they exhibited visible foliar injury in all sites.

A large number of biological parameters have been used to assess the damage to plants caused by pollution including visible foliar injury (Davis and Wilhour, 1976). Reduction in pigment concentration has been noted as an indicator of leaf damage produced by pollution (Mehlhorn *et al.*, 1988). Chlorosis and necrosis are usually the result of reduction of pigment concentration. Chlorosis usually begins at the tips of the leaf before spreading to other parts. This usually interpreted to be a rapid loss of chlorophyll and its pattern is quite different from that seen during photo-oxidative degradation. Generally though, it is not until the more advanced stages of senescence that any appreciable differences in the kinetics of bleaching between the various pigments are seen (Young and Britton, 1990). Bleaching may or may not be accompanied by necrotic spots or streaks, but always culminates in the premature abscission of plant organs (Bako, 2000).

## CONCLUSIONS

It is clear from the results that recognizable visual symptoms can be expressed by plants encountered in this survey. Plants growing under natural conditions are presumed to be adapted to local climatic and soil variables. Therefore, in the absence of evidence of abnormal temperatures, poor water relations, mineral deficiencies, and insect or plant diseases, these generalized foliar markings may be assumed to be due to air pollution. However, because there may be uncertainties that arise as a result of human inconsistencies in assessment of visual symptoms (Bussotti *et al.*,

2006), it may often become necessary to conduct confirmatory chemical tests.

Table 1. Classification of sensitivity rating of some savanna plants in relation to anthropogenic air pollution.

Sensitivity rating	Extent of injury/symptom expressed
Slight	0-39% of foliage affected
Moderate	40-59% of foliage affected
Severe	60-100% of foliage affected

Table 2. Sensitivity of some Savanna plant species in relation to anthropogenic air pollution in Kamuku National Park, Birnin Gwari Kaduna state.

Species (Family)	Description of symptom	Injury class/scale	Species sensitivity (% Pop affected)
<i>Sida acuta</i>	Chlorosis	Slight	20-30
<i>Cassia tora</i>	Necrosis	Moderate	40-60
<i>Urena lobata</i>	Necrosis	Slight	40-60

Table 3. Sensitivity rating of plant species in relation to anthropogenic air pollution in Abandoned farmland Shika village Kaduna state.

Species (Family)	Description of symptom	Injury class/scale	Species sensitivity (% Pop affected)
<i>Clerodendrum spp</i>	Chlorosis Flecking/stipling	Slight	
<i>Sida acuta</i>	Chlorosis		
<i>Cassia tora</i>	Chlorosis		

Table 4. Sensitivity rating of plant species in relation to anthropogenic air pollution in Fruit Garden along Kaduna Road, Tukur Tukur Village, Kaduna state.

Species (Family)	Description of symptom	Injury class/scale	Species sensitivity (% Pop affected)
<i>Mangifera indica</i>	Chlorosis	Slight	1-20
<i>Sida acuta</i>	Chlorosis	Severe	90-100
<i>Cassia tora</i>	Chlorosis	Moderate	40-60
<i>Citrus sinensis</i>	Chlorosis	Slight	1-20
<i>Anacardium occidentale</i>	Chlorosis	Moderate	20-40

Table 5. Sensitivity rating of plant species in relation to anthropogenic air pollution in Abandoned Farmland behind Kaduna Refinery and Petrochemical Company (KRPC) Kaduna state.

Species (Family)	Description of symptom	Injury class/scale	Species sensitivity (% Pop affected)
<i>Hyptis suaveolens</i>	Purpling/Browning	Severe	80-100
<i>Sida acuta</i>	Chlorosis	Severe	90-100
<i>Cassia tora</i>	Defoliation	Moderate	80-100
<i>Combretum seriseum</i>	Necrosis	Moderate	60-80
<i>Urena lobata</i>	Necrosis	Moderate	20-40
<i>Vernonia ambigua</i>	Flecking/stipling	Severe	40-60
<i>Piliostigma thonningii</i>	Necrosis	Moderate	20-40
	Defoliation	Moderate	40-60



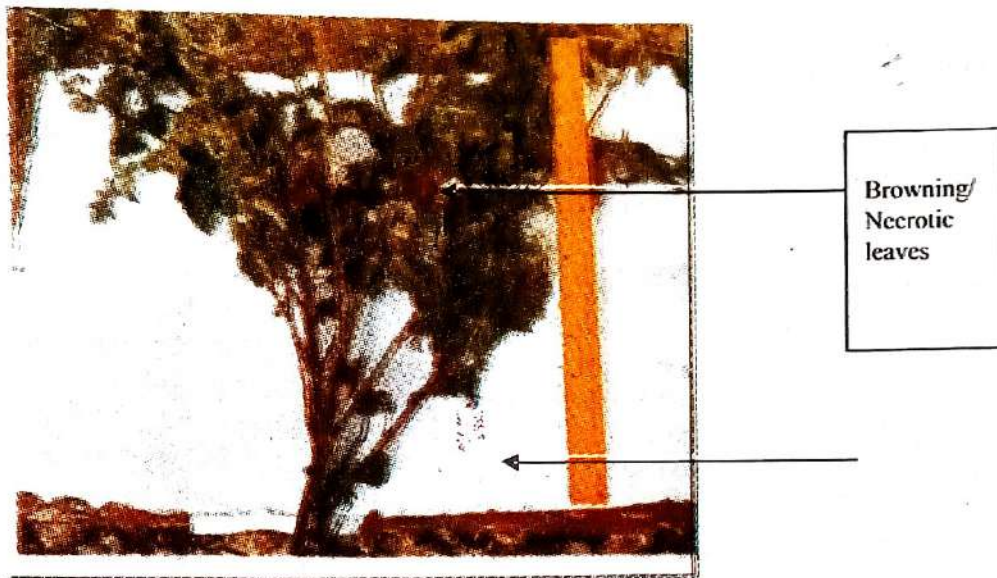
Plate 1. Detached shoot of *Cassia tora* showing chlorotic leaves in relation to normal Leaves



**Plate 2** Detached shoot of *Jatropha curcas* showing necrotic leaf in relation to normal leaves



**Plate 3** Detached shoot of *Urena lobata* showing necrotic leaves in relation to normal leaves.



**Plate 4 .** Detached shoot of *Hyptis suaveolens* leaves in relation to normal leaves showing browning/necrotic

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