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# IMPACT OF DUST POLLUTION FROM CEMENT PRODUCTION ON LEAF ANATOMICAL FEATURES OF SELECTED PLANT SPECIES IN OBAJANA CEMENT FACTORY SITE, KOGI STATE, NIGERIA

Owoleke Veronica Amina[1],Fatoba, P.O[2], Theophilus Boniface Momoh[1] ,Olubiyo Gloria Taiye[1] , Owoleke Oluwafemi Stephen[3] and Akanbi- Gada Mariam Abiola[4]

[1]Department of Plant Science and Biotechnology, Kogi State University, Anyigba, Kogi State, Nigeria.

[2]Department of Plant Biology, University of Ilorin, Nigeria

[3]School of General Studies, Kogi State Polytechnic, Lokoja, Nigeria

[4]Department of Plant and Environmental Biology, Kwara State University, Malete, Nigeria

Correspondence: Owoleke Veronica Amina Department of Plant Science and Biotechnology, Prince AbubakarAudu University, Anyigba, Kogi State, Nigeria. aminavera45@gmail.com +2348036334496

## *ABSTRACT*

*Production activities by cement factories pollute the atmosphere with cement dust. Studies have indicated that plants growing around cement factories absorb these pollutants through foliar surfaces. This study investigated the leaf epidermal responses of Abelmoschus esculentus, Zea mays, Mangifera indica and Carica papaya growing around Obajana cement factory (OCF) in Kogi state to cement dust pollution. Samples were collected 1-3km to the east, north and west axes of the factory. A total of 72 samples were collected from the vicinity of the factory site and prepared for microscopic observations following leaf maceration method. Control samples were collected from an agrarian community, a distance of about 47.5 km from the factory. Basic descriptive statistics revealed marked variations in stomatal complex type (SCT), trichomes density(TD), stomatal density (SD) and stomatal size (SS) of samples collected from the vicinity of the cement factory and samples collected from the control site.Abelmoschus esculentus was most impacted while Zea mays was least impacted by the cement dust pollution. The observed modifications in epidermal features expressed as decreased SS, increased TD and SD in plants growing around the cement factory are anatomical adaptations for survival in their cement dust laden environment. These alterations in anatomical features of the investigated species are majorly adaptations to prevent foliar damage by cement dust, thus could serve as bio indication of cement dust pollution.*

***Keywords:*** *Air pollution, cement dust, epidermal features, stomata density, trichome density*

## Introduction

Particulate emissions from industrial establishments are a major source of environmental pollution. Cement production has been implicated as a major contributor to particulate atmospheric pollution (Agrawal and Tiwari, 1997). The emitted cement dust is spread over large areas by wind and may accumulate on soils and plants. Cement dust as an air pollutant affects plant growth and productivity (Prasad and Inandar, 1991); species composition, cover and biodiversity (Hegazy, 1996). Particles of dust escapes from cement factories during the blasting of raw materials, grinding of cement clinkers and the packaging or loading of finished cement (Bankole, 2003) and are often transported by wind and deposited in areas close to and far from the factory (Oyedele, Aina, Oluwole, and Asubiojo, 1990). Adamson (1996) reported that cement production is one of the worst air polluters in the world. Today, there are several cement manufacturing companies in Nigeria with plants located in different parts of the country. Some of the leading companies include; Obajana Cement Industry, West African Portland Cement Company Plc, Calabar Cement Company Limited, Benue Cement Company Plc and Ashaka Cement Company Plc. Obajana cement plant in Kogi State, Nigeria is the biggest cement factory in Nigeria and in sub Saharan Africa with a production capacity of about 15.7 million metric tons of cement per annum as at 2018.

Stomata are microscopic pores on the surface of leaves. They are generally composed of two guard cells and a stoma. Stomata control the exchange of gasses between the interior of the leaf and the atmosphere (Hetherington and Woodward, 2003) and plays important roles in the process of transpiration, photosynthesis and respiration. Stomata also play an important role in plants' innate immunity (Melo, Castro, Soares, Melo, and Alves, 2007). The location of stomata on leaves differs among plants. Stomata can be located in both the upper and the lower leaf surfaces (amphistomatous), but in many plants they are found in the lower surface only (hypostomatous) while some others may have only in the upper surface (epistomatous) AbdulRahaman and Oladele (2003). Stomatal features have significant effects on some plant physiological processes such as transpiration, plant photosynthetic activities and responses to environmental stress as reported on field

crops such as rice and wheat (Choudri and Gajghate, 2000). Trichomes are tiny hairs on plant leaves that have been reported to be helpful in protecting plant leaves from the adverse effect of particulate air pollutants (Ogunkunl and Fatoba, 2013).

Accumulation of particulate matter and other contaminants interferes with; the usual metabolic processes in plants, causes direct injury and impair growth and efficiency, ultimately leading to a reduction in plant yield (El-Abbsay, Hassanien, Ibrahim, and Abdel-latif, 2011). Akeredolu Obioh, and Spyrou(1994) stated that cement companies are important sources of environmental pollution with harmful effects on plants and animals, especially in the Nigerian environment. Results of several studies have shown that cement dust pollution decreases the productivity in a variety of annual non-leguminous crops (Satao, Kene, Nalamwa, and Ulemale, 1993; Liu , Du-Mei, Chenshuyuan, and Ming, 1997). Also, studies have been conducted on the impact of cement dust on plants, such as the study of cement dust on conifers growing in Central European forests (Mandre and Ots, 1999; Lepedus, Cesar, and Suver, 2003). Effects of cement dust on vegetation in South West Nigeria (Salami, Farounbi, and Muoghalu 2002), response of maize to cement dust in India (Kumar and Pandey, 2011). Abdullah and Igbal (1991) reported the effect of cement dust on the stomatal clogging of the leaves of *Iphoniagrantioides*. Studies have been conducted on the effect of cement dust on soils and waterbodies (Ameh, Kolawole, and Imeokparia, 2011) around Obajanacement factory but its impact on the anatomical features of crops grown around this mega factory is yet to be reported. Considering the size of this massive cement factory with arable land in its vicinity on which subsistent farming of crops and fruit tress is extensively carried out, it is imperative to assess the impact of cement dust emanating from the factory on the anatomical features of some crops grown around it. These anatomical features (stomata and trichomes) have been proven to influence key physiological processes like photosynthesis and respiration which in turn determines the productivity and yield of such crops.

## *MATERIALS AND METHODS*

### *Study area*

The factory is located in Obajana in Lokoja Local Government Area of Kogi state, Nigeria. Obajana is located between Latitudes $6^0 24'$ N – $7^0 34'$ N, Longitudes $7^0 49'$E – $8^0 59'$E of the Greenwich meridian. The area is characterized by two types of landforms: domed shaped residual hills and river valleys (Afeni, Cowood, and Isiaka 2008). The study area has an estimated limestone deposit of about 450,000,000 tons with a depth of between 30 and 60 metres OCP (2005). It was as a result of the high concentration of limestone in Obajana community that resulted in the establishment of Obajana cement factory there. The area experiences both wet and dry seasons. The prevailing wind direction for the wet and dry seasons are southwesterly and northesterly respectively (Busuyi, *et al.*, 2008). The soil is generally very fertile and supports the growth of crops (Muhammed, 2006). The cement plant was a green field cement plant initiated in 2003 and commissioned in 2007 with an initial annual production capacity of 5 million tons as at 2008 (Vetiva, 2010). As at the time of this investigation (2018), the factory has a production capacity of about 15.7 million metric tons of cement per annum. Apart from gypsum which is sourced from other places, all other raw materials and natural additives such as limestone, clay, marl and laterite are found in the Obajana mines located about 8km away from the factory complex

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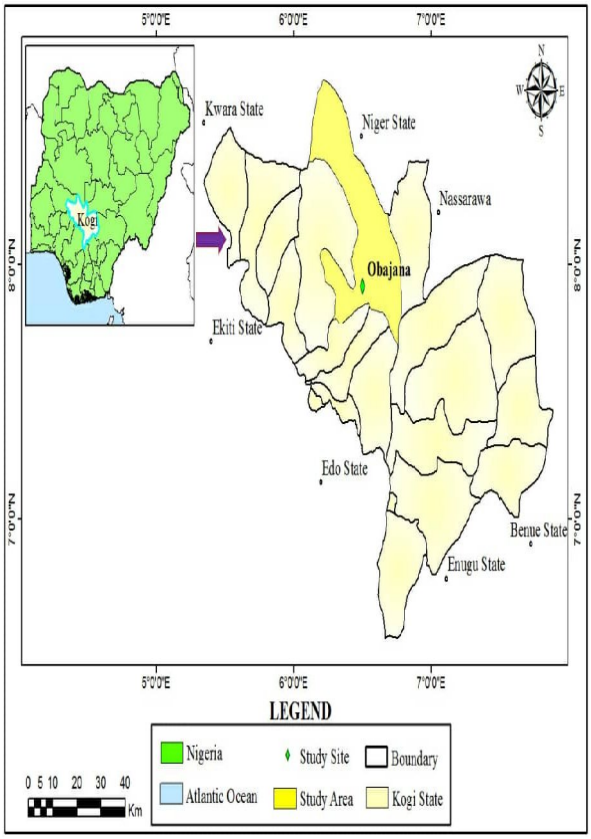



Fig.1: Nigeria showing Kogi state

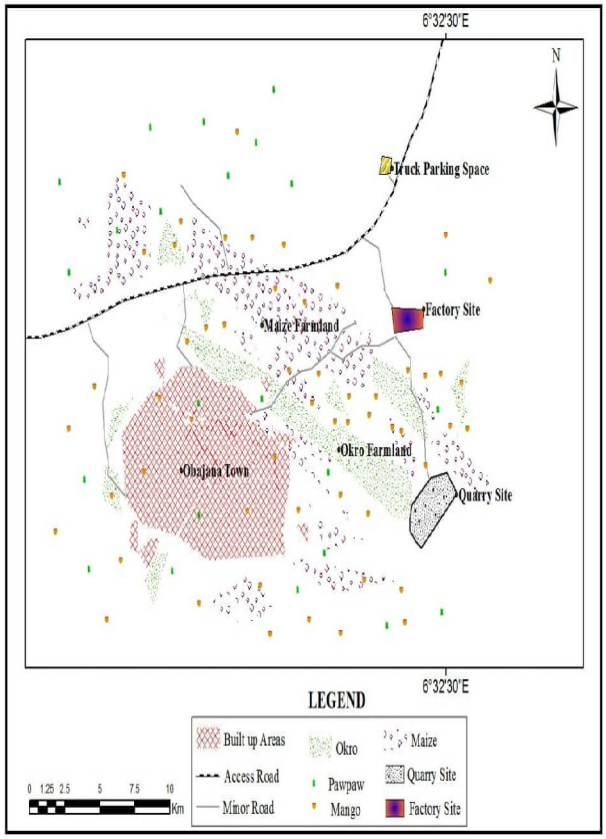



Fig. 2: Obajana and the samples collection points

*Samples Collection*

Fresh leaves of four crop plants; *Zea mays, Abelmuschus esculentus, Mangifera indica,* and *Carica papaya* growing around Obajana cement factory were collected for anatomical studies. Samples were collected around 9am. Control samples were collected from Agbaja village (an agrarian community with no cement dust pollution) a distance of 47.5km from the cement factory. These plants were chosen because they were readily available around the factory and produces fruits that serve as food to man and animals. Samples were collected in a complete randomised design. Samples were identified and authenticated in the Herbarium of the Department of Plant Biology, Federal University Lokoja, and Lokoja, Nigeria. The samples were wrapped in big brown envelopes with adequate room for air movement within the bag and appropriately labelled.

*Isolation of Leaf Epidermal Layers*

Leaf portions with an area of 1cm$^2$ were cut from the standard median levels (that is midway between the apex and the base) and immersed in concentrated $HNO_3$ for 8 minutes. The upper (adaxial) and lower (abaxial) epidermis of the leaves were then separated using dissecting needle and forceps and rinsed in water. The epidermal layers were stained with 1% aqueous safranin for 5 minutes and excess stain was rinsed off with water (Olofinobinu and Oladele 1997). The stained specimens were then mounted in glycerine for microscopic observations. Microscopic observations were done using Olumpus microscope fixed with Accu-Scope digital image 9.0 camera. Stomata, epidermal cells and trichome counts were taken from 20 samples for each studied plant species at 40x objective magnification.

The following were determined;

i. The frequency of stomata complex type was expressed as percentage occurrence of each complex type in a total of 35 fields of view (Obiremi and Oladele, 2001). While Metcalf and Chalk (1988) terminologies was used in naming the stomata complex types.

ii. Stomatal density (SD) was determined as the number of stomata per square millimetre (Stace, 1965).

iv. Stomatal area was determined by measuring the length and breadth of the guard cells. Then calculated using the formular below.

SA = L X B X K

Where SA = Stomatal area

L = Length of guard cell

B = Breadth of guard cell

K = Franco's constant = 0.78524 (Franco, 1939)

v. Trichome types; the shapes of trichomes were observed and named following Dilcher 1974

vi. Frequency of trichome types were computed following the formular;

Frequency (%) = {Nt/Tt} x 100 Metcalfe and Chalk, 1988

Where Nt = number of particular type

Tt = total number of trichome type

Data generated were analysed using SPSS 23.0 (SPSS Inc., USA) software. Data were subjected to descriptive statistics to reveal variations that occurred in the parameters measured in samples from the polluted and the unpolluted sites.

**Results and Discussion**

Leaf epidermal studies of *Abelmoschus esculentus, Zea mays, Mangifera indica and Carica papaya* leaves collected from the cement dust polluted site (OCF) were compared with the same species collected from the control site. The control samples were used in order to evaluate the responses of the diagnostic species to cement dust pollution in the study area. Foliar uptake through the stomata may be the principal routes for accumulation of air-borne pollutants in plants growing around such polluted areas. Reports shows that pollution stress alters leaf epidermal structures of plants exposed to air pollution (Gostin, 2009).The results of epidermal studies on the leaves of the studied plants are summarized in tables 1-4 and fig. 3-15. This includes; stomata type, stomata frequency, trichome type, trichome density, stomatal density and stomatal size.

*Stomatal complex types*

*Abelmoschusesculentus* stomata were composed of two bean shaped guard cells and a stomatal pore as shown on fig. 3. Figure 4, shows anisocytic stomata (AS), branchyparacytic stomata (BP), paracytic stomata (PS) and tetracytic stomata (TS) types in *Abelmoschus esculentus* leaf samples collected from the unpolluted site. *Zea mays* samples from the polluted and unpolluted sites had only paracytic stomata type (Fig.9-10). *Carica papaya* samples from the unpolluted site had Anisocytic, tetracytic and paracytic stomata types (Fig.14) while samples from the polluted site only had anisocytic and paracytic stomata types and glandular peltatetrichome (Fig.13). Figure 15 shows numerous Anomocytic and paracytic stomata types in *Musa indica* samples from the unpolluted site. The absence of some stomata types in plants of the same species collected from the polluted site can be attributed to the ability of cement dust to clog, denature and destroy plant stomata. Though these stomata types ought to have been naturally present in the sampled plant species, they are likely to have been destroyed or denatured by cement dust which was prevalent in the study area. This is in agreement with the findings of Vijaywargiya and Pandey (2003) who reported clogging of stomata, loss of one or both guard cells or total destruction of stomata apparatus caused by cement dust pollution in all three species of flowering plants studied by them. Likewise, Kumar and Sharma (2001) investigated the impact of stone crusher dust on *Mangifera spp.* and

reported loss of stomata in plants grown on the polluted locations.

Pictures of stomata and trichomes ofleaf samples collected from the polluted and unpolluted sites. Olumpus microscope fixed with Accu-Scope digital image 9.0 camera was used.

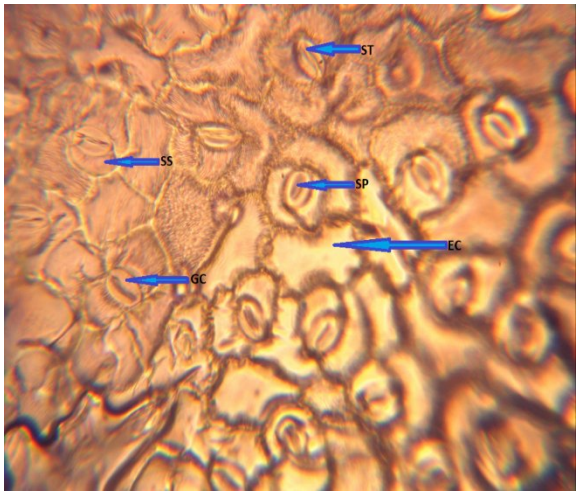



Fig.3: Abaxial epidermis of *A. esculentus* Leaf showing ST,SP,EC,GC. (400x)

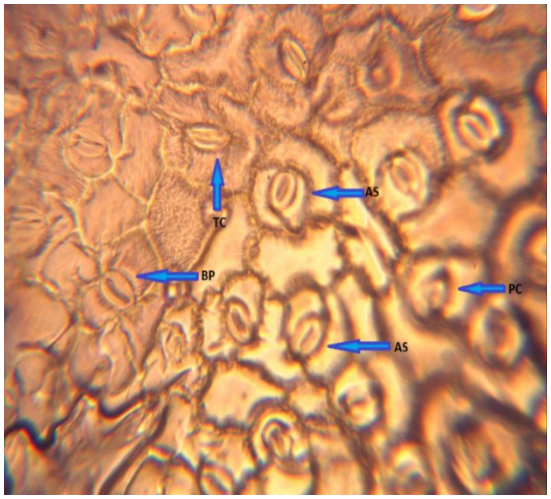



Fig.4: Abaxial epidermis of *A. esculentus* Leaf showing AM, AS, BP, PS, TS. (400x)

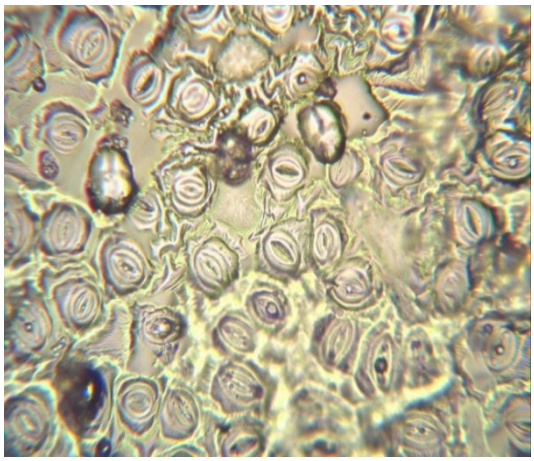


Fig.5: Many stomata on abaxial Leaf surface of *A. esculentus* from the unpolluted site, (400x).

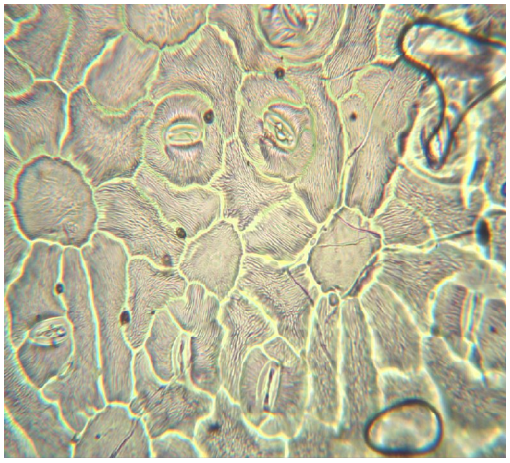


Fig.6: fewer stomata on abaxial leaf suface of *A. esculentus* from polluted site. (400x).

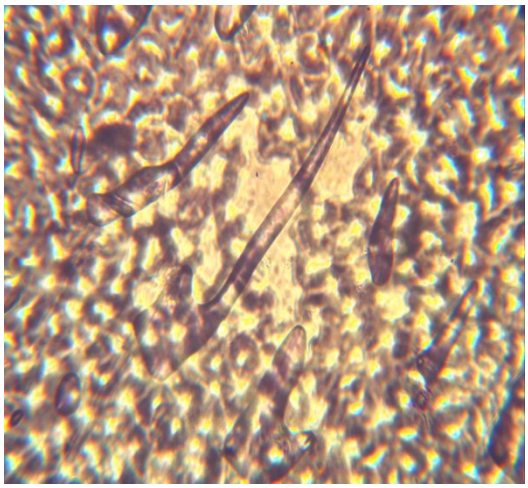


Fig. 7: Many trichomes on *A.esculentus* leaf from polluted site. (400x)

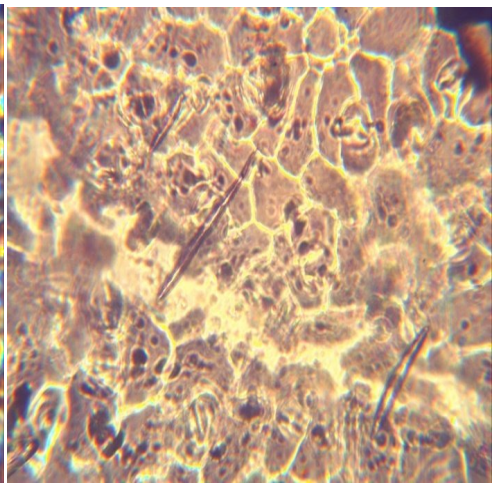


Fig.8: Fewer trichomes on *A. esculentus* leaf from unpolluted site (400x)

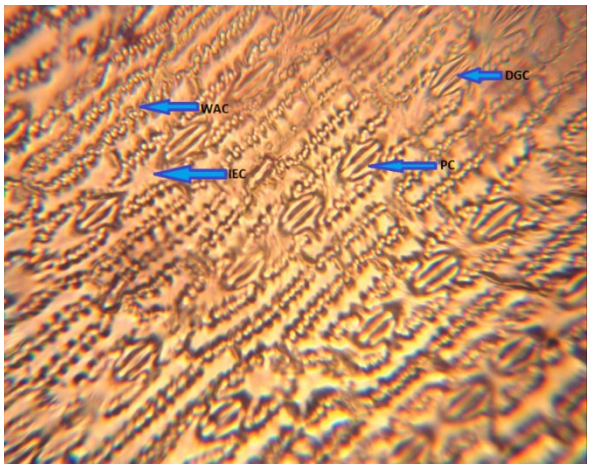



Fig. 9: Many stomata on abaxial leaf surface of *Zea mays* from unpolluted site. (400x)

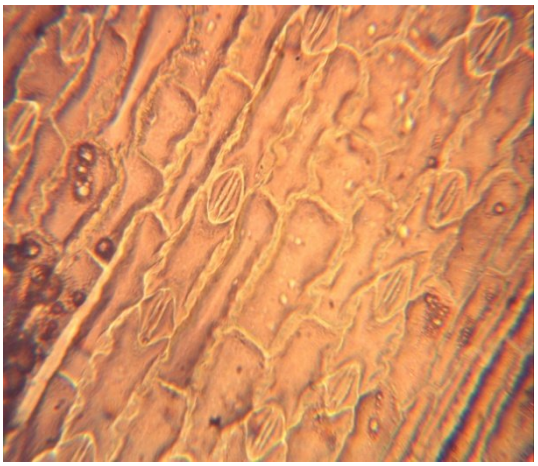


Fig.10: Fewer stomata on abaxial leaf surface of *Zea mays* from polluted site. (400x)

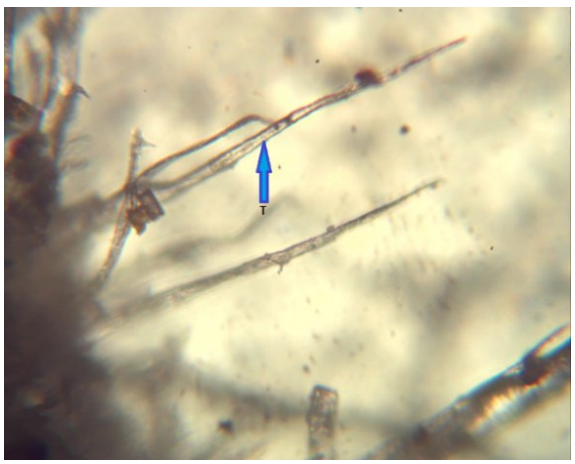



Fig. 11: Many trichomes on abaxial leaf surface of *Zea mays* from polluted site. (400x)

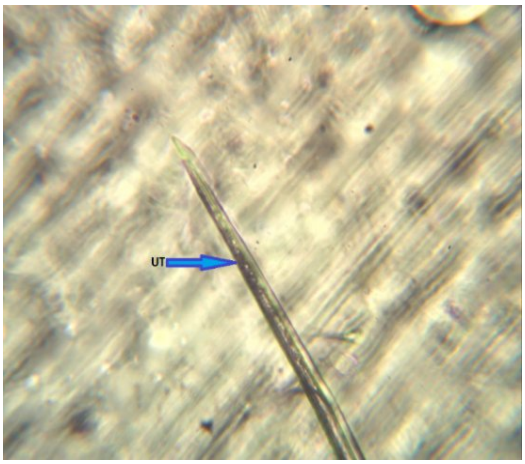



Fig.10: Single trichome on abaxial leaf surface of *Zea mays* from unpolluted site. (400x)

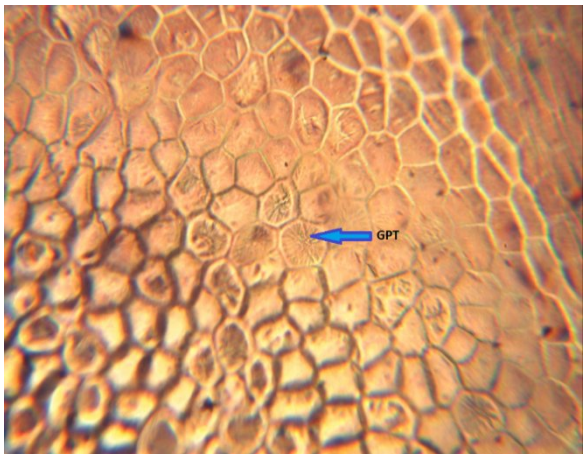



Fig. 13: Adaxial epidermis of *C. papaya* leaf showing AS, PS and Glandular peltatetrichome. (400x)

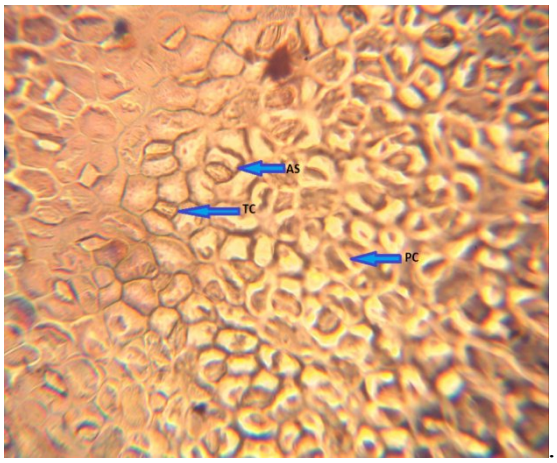



Fig.14: Abaxial epidermis of *C. papaya* leaf Showing AS, TS, PS stomata types. (400x)

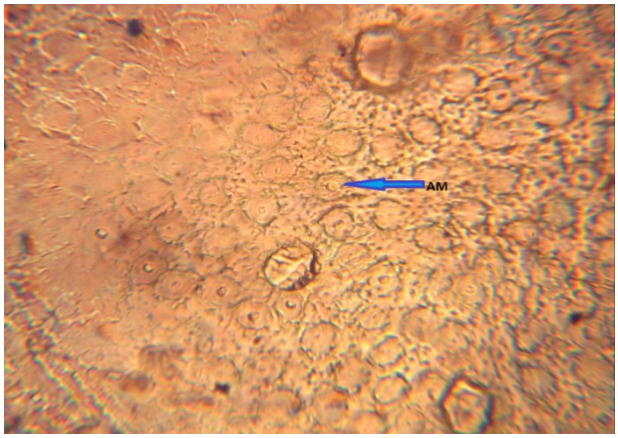



Fig.15: Abaxial epidermis of *Mangifera indica* leaf showing numerous, small anomocytic stomata

{*LEGEND; ST- stomata, SP- stomatal pore, EC- Epidermal cell, GC- Guard cell. AM – Anomocytic stomata, AS - Anisocytic stomata, BP -Branchyparacytic stomata, PS –Paracytic stomata ,TS–Tetracytic stomata*.}

*Trichome density*

Many long unicellular trichomeswere observed on the epidermis of *Abelmoschusesculentus*leaf samples obtained from the surroundings of OCF (polluted site) as shown on (Fig. 7). Few ertrichomes were observed on the epidermis of *Abelmoschus esculentus* leaf samples collected from the unpolluted site as shown on (Fig. 8). Trichome density in *Abelmoschus esculentus* samples from the polluted sites was higher (6) than trichome density in *Abelmoschus esculentus* samples from the control site. Trichome type in *Zea mays* was also unicellular in all the samples. Just like in *Abelmoschus esculentus*, trichome density in *Zea mays* was higher in the samples from the polluted site when compared to samples from the control site (Fig. 11-12). Stellate and unicellular trichome types were seen on *Carica papaya* leaves samples from the unpolluted site while only unicellular trichomes occurred in the polluted site samples (Table 1). Trichome density was generally higher in samples collected from the vicinity of OCF

(polluted site) than samples from the unpolluted site. This response could be an adaptive feature to tolerate the high cement dust pollution in the area. Sharma and Davis (2001) reported increased trichome density and reduction in epidermal wall undulation as responses of plants to cement pollution. This adaptation enhanced plants' survival in polluted environments. Moreover, increased number of trichomes could be helpful in filtering out particulate matter and protects the leaf surface from detrimental pollutants which otherwise may enter the leaf and disrupt metabolic activities in the plant tissues. Meanwhile, increased number of trichomes on the leaf of S. acutahas been reported by Ogunkunle*et al.*, (2013) as an adaptation to cement dust pollution. In *Zea mays* it was observed that the trichomes were completely absent in the unpolluted regions but in the polluted regions unicellular trichomes were developed in the abaxial surface and their development were maximum at epidermal cells near stomata (Kumar and Pandey, 2011). This suggests that trichomes acts as protective cover against atmospheric pollutants especially particulate matter, so the pollutant could not gain entrance through the stomatal opening.

**Table 1.** Stomata type, Stomata frequency, Trichome type and Trichome density

{*LEGEND; AM – Anomocytic stomata, AS - Anisocytic stomata, BP -Branchyparacytic stomata, PS –Paracytic stomata ,TS–Tetracytic stomata*.}

*Stomata density*

There were variations in the stomata density of samples collected from the vicinity of the cement factory and samples of same plant species collected from the unpolluted site. In *Abelmoschusesculentus,* stomata density on the abaxial epidermis (polluted site) ranged from 24.43-42.17 and 19.63-35.94 on the adaxial epidermis. Whereas, stomata density on the abaxial epidermis (unpolluted site) ranged from 16.63-19.62 and 12.25-14.93 on the adaxial epidermis

| Plant | Location | Stomata Type | Stomatal frequency (%) | Trichome type | Trichome density($mm^{-2}$) |
|---|---|---|---|---|---|
| *A. esculentus* | Polluted | AS, PS | 68%, 32% | Unicellular | 6 |
| | Control | AS,BP,PS,TS | 42%,12%,20%,16% | Unicellular | 3 |
| *Z. mays* | Polluted | PS | 100% | Unicellular | 5 |
| | Control | PS | 100% | Unicellular | 3 |
| *M.indica* | Polluted | PS | 100% | _ | _ |
| | Control | AM, PS | 46%, 54% | _ | _ |
| *C.papaya* | Polluted | AS, PS | 44%, 56% | Unicellular | 2 |
| | Control | AS, PS ,TS | 30%, 30%, 40% | Unicellular, Starlate | 1 |

(Table 2). In *Zea mays,* stomata density on the abaxial epidermis (polluted site) ranged from 21.47-28.50 and 16.37-24.56 on the adaxial epidermis. In the same vein, stomata density on the abaxial epidermis (unpolluted site) ranged from 15.48-16.62 and 12.43-15.48 on the adaxial epidermis (table 3). *Mangifera indica* had abaxial and adaxial stomata densities ranging from 28.51-37.78 and 23.70-31.54 for samples from the polluted sites while samples from unpolluted site had abaxial and adaxial stomata densities ranging from 21.62-25.38 and 17.59-21.63respectively as shown on table 4. Whereas, *Carica papaya,* stomata density on the abaxial epidermis (polluted site) ranged from 17.49- 29.43. While, stomata density on the abaxial epidermis (unpolluted site) ranged from 11.54-14.28 (Table 5). Stomata density was found to be higher on the abaxial epidermis than the adaxial epidermis. Likewise, stomata density was higher in samples from the polluted sites than the unpolluted sites for the studied plant species. The significantly higher stomatal density observed in both leaf surfaces of samples from the cement polluted site is yet another adaptive response to the cement dust pollution. Increased stomatal density is considered as adaptability indicator to polluted environment (Kapitonova, 2002; Gostin, 2009). According to Yunus and Ahmad (1979), high stomatal density of leaves in plants around polluted environments may be a response of the plants to the loss of matured and healthy stomata through the process of degradation caused by air pollution.

*Stomatal size*

Metcalfe and Chalk (1988) and Beerling and Woodward (1997) reported that larger stomata gave lower stomatal density, while, smaller stomata gave higher stomatal density. This statement holds true in the plants examined, as samples collected from the polluted site which had higher stomata density were observed to have smaller stomatal size while samples from the unpolluted site earlier reported to have lower stomatal density had larger stomatal size. As shown on table 1, stomata size in *Abelmoschus esculentus* collected from the vicinity of OCF had stomata size ranging from 31.59µm to 37.64µm and 41.67µm to 44.35µm for samples from the unpolluted site (Table 2). In *Zea mays,* stomatal size ranged from 41.79µm to 47.09µm in samples from the polluted site and 54.81µm to 57.36µm in samples from the control

(table 3). Stomatal size in *Mangifera indica* aranged from 23.85µm to 27.96µm (in samples from the polluted site) and 32.83µm to 34.26µm (in samples from the unpolluted site) as shown on table 4. Likewise, *Carica papaya* leaf samples collected from the polluted site had stomatal size ranging from 22.67µm to 28.31µm. and 32.81µm to 35.33µm in the unpolluted site (table 5).

A reduction in the stomatal size of leaves has been reported to be responses to environmental stress. This seems to be an important strategy for controlling the absorption of pollutants by plant leaves (Gostin, 2009). The studied plants have shown response to the air pollution status of the study area by the reduction of their stomatal size. This most likely is a strategy of reducing the amount of pollutants entering the stomata during gaseous exchange. This modification has been reported to be peculiar to plants growing in environment with polluted atmosphere (Amit, 2000; Ogunkunle*et al*., 2013). The decrease in the stomatal size may also be an evasion mechanism against the suppression effect of pollutants on physiological activities such as photosynthesis and also portends quicker response to external stimuli (Hetherington and Woodward, 2003; Verma et al., 2006).

Table 2. Stomatal density and stomata size in *A. esculentus* leaves

| Samples | Stomatal density ($mm^{-2}$) | | Stomatal Size (µm) |
|---|---|---|---|
| | Abaxial | Adaxial | |
| 1 | 28.43±2.25 | 21.43±1.93 | 32.53±3.54 |
| 2 | 24.45±2.06 | 21.65±2.43 | 37.64±3.43 |
| 3 | 39.87±3.62 | 35.94±2.54 | 34.28±2.94 |
| 4 | 26.51±2.64 | 22.05±2.70 | 33.12±3.54 |
| 5 | 42.17±2.04 | 33.62±3.54 | 35.37±2.54 |
| 6 | 27.04±2.50 | 24.73±2.41 | 34.65±2.48 |
| 7 | 26.93±2.32 | 22.40±2.34 | 31.59±2.98 |
| 8 | 40.62±3.64 | 31.51±2.04 | 33.66±3.76 |
| 9 | 29.41±2.43 | 19.63±2.47 | 36.39±1.54 |
| 10 | 27.30±2.12 | 21.08±2.50 | 31.93±2.65 |
| 11 | 24.43±1.63 | 20.80±1.56 | 34.56±2.54 |
| 12 | 28.38±2.30 | 23.65±2.41 | 33.75±1.97 |
| $C_1$ | 19.62±1.83 | 14.93±1.75 | 42.40±3.65 |
| $C_2$ | 17.94±1.43 | 12.25±2.54 | 41.67±3.54 |
| $C_3$ | 16.63±2.01 | 13.05±1.44 | 44.35±2.65 |

Values given are means ± standard deviation

Table 3. Stomatal density and stomata size of *Zea mays* leaves

| Samples | Stomatal density ($mm^{-2}$) Abaxial | Adaxial | Stomatal Size (µm) |
|---|---|---|---|
| 1 | 21.47±1.30 | 19.62±1.04 | 43.65±3.05 |
| 2 | 27.17±2.04 | 23.37±1.50 | 46.97±2.84 |
| 3 | 23.40±1.08 | 18.95±1.07 | 42.73±2.49 |
| 4 | 25.57±0.43 | 19.05±0.74 | 41.79±2.70 |
| 5 | 25.17±2.85 | 20.39±2.59 | 43.56±1.39 |
| 6 | 23.83±2.30 | 22.86±0.53 | 45.10±3.96 |
| 7 | 25.73±1.60 | 24.56±1.96 | 44.82±2.69 |
| 8 | 22.05±0.43 | 16.37±2.06 | 43.97±2.40 |
| 9 | 24.62±1.36 | 20.94±1.60 | 42.85±1.02 |
| 10 | 23.49±1.70 | 22.40±1.04 | 47.09±2.48 |
| 11 | 22.83±2.12 | 19.42±0.82 | 44.65±2.05 |
| 12 | 28.50±1.44 | 22.69±2.94 | 42.79±2.40 |
| $C_1$ | 15.48±1.56 | 12.43±1.05 | 54.81±3.79 |
| $C_2$ | 16.40±0.52 | 13.60±0.92 | 57.36±2.46 |
| $C_3$ | 16.62±0.97 | 15.48±1.23 | 55.99±3.17 |

Values given are means ± standard deviation

{$C_1$, $C_2$, and $C_3$ are samples collected from the control site}

Table 4. Stomatal density and stomata size in *Mangiferaindica* leaves

| | Stomatal density ($mm^{-2}$) | | Stomatal |
|---|---|---|---|
| Samples | Abaxial | Adaxial | Size (µm) |
| 1 | 32.43±3.54 | 27.67±2.45 | 25.53±1.45 |
| 2 | 37.78±2.08 | 30.47±2.68 | 23.85±2.58 |
| 3 | 29.47±2.56 | 24.83±1.68 | 26.39±1.95 |
| 4 | 30.09±3.60 | 26.76±2.54 | 26.75±2.06 |
| 5 | 29.84±2.05 | 25.73±2.09 | 24.70±2.85 |
| 6 | 31.60±2.70 | 25.90±1.60 | 26.96±1.57 |
| 7 | 28.51±1.56 | 24.54±2.78 | 24.83±2.00 |
| 8 | 33.60±3.06 | 26.62±2.86 | 25.64±2.05 |
| 9 | 35.53±2.64 | 31.54±2.05 | 27.07±2.68 |
| 10 | 30.39±2.94 | 23.70±1.57 | 26.56±1.59 |
| 11 | 29.70±1.70 | 24.94±2.49 | 24.48±1.06 |
| 12 | 32.60±2.05 | 25.85±1.89 | 27.96±2.50 |
| $C_1$ | 21.62±2.50 | 19.98±2.36 | 34.05±2.73 |
| $C_2$ | 25.38±2.59 | 21.63±2.07 | 32.83±2.97 |
| $C_3$ | 23.64±1.94 | 17.59±2.84 | 34.26±3.57 |

Values given are means ± standard deviation

Table 5. Stomatal index of *Carica papaya* leaves

| Samples | Stomatal density ($mm^{-2}$) | Stomatal Size (µm) |
|---|---|---|
| 1 | 21.35±1.45 | 24.82±2.54 |
| 2 | 22.86±1.85 | 25.36±2.93 |
| 3 | 25.30±2.59 | 22.71±1.83 |
| 4 | 21.16±2.43 | 23.90±1.40 |
| 5 | 29.43±1.05 | 26.31±2.05 |
| 6 | 19.70±1.94 | 23.75±1.04 |
| 7 | 20.50±1.45 | 25.94±2.40 |
| 8 | 21.95±0.93 | 22.67±1.95 |
| 9 | 17.49±0.37 | 28.31±1.79 |
| 10 | 18.05±1.94 | 25.80±1.04 |
| 11 | 20.54±1.64 | 26.35±2.95 |
| 12 | 19.35±0.63 | 24.90±1.57 |
| $C_1$ | 11.54±0.32 | 32.81±2.94 |
| $C_2$ | 14.28±1.43 | 35.33±1.94 |
| $C_3$ | 13.45±0.63 | 33.85±2.45 |

Values given are means ± standard deviation

According to Melo*et al*., (2007) increased stomatal density coupled with decreased stomatal size can serve as a strategy for the sufficient supply of $Co_2$ for photosynthesis without excessive transpiration. Thus, the higher stomatal density and the reduced stomatal size observed in this study may also be responses to the effects of cement dust pollution in the study area.

**Conclusion**

In this study, a total of 72 leaf samples from four different plant species were investigated for anatomical modifications induced by cement dust in the vicinity of Obajana cement factory. Cement dust induced anatomical modifications were observed in plants grown around the factory. Application of basic descriptive statistics revealed

modifications in the stomatal complex types, trichome density, stomatal density and stomata size of the studied plants. The variation in stomata complex types occasioned by denaturation and clogging of stomata by cement dust was more pronounced in *Abelmoschus esculentus* while *Zea mays* was least affected. Trichome density in *Abelmoschus esculentus and Carica papaya* grown around the factory increased by 100%.Stomatal density increased while stomatal size decreased in all for plant species that were investigated. All four species were impacted at differing extent by the cement dust pollution. However, *Zea mays* was least affected. These recorded modifications in the leaf anatomy of the sampled plants from the vicinity of the factoryare good indicators that the level of atmospheric cement dust pollution has began to impact on these species. The alterations in anatomical features of these species are majorly adaptations to prevent foliar damage by cement dust, thus it could serve as bio indication of cement dust pollution in the vicinity of Obajana cement factory.

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