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Phytotoxicity and Morpho-anatomical Deformation in *Corchorus olitorius* and *Senna occidentalis* Correlating with Industrial Effluent Contaminating Soil

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ABSTRACT

Environmental pollution from food or related industries via effluent discharge is a global threat to plants and animals and may ultimately threaten the quality of human. The present study aimed at evaluating the dangerous effect of industrial effluent on the toxicity and morpho-anatomical deformations of *Corchorus olitorius and Senna occidentalis.* The study was a split plot complete randomized design with two factors, each comprising of four treatments and three replicates which lasted for a period of three month. Treatment details include T_0 = Tap water (control), T_1= 25% pollutant + 75% tap water, T_2= 50% pollutant + 50% tap water, T_3= 75% pollutant + 25% tap water, T_4= 100% pollutant. The result showed that a significant concentration of nickel, copper, lead, cadmium, chromium and iron were detected in the pharmaceutical effluent while copper, lead, cadmium, chromium, iron and mercury were detected in the soap and detergents effluent. A significant inhibition was observed at 100% concentration of the seedling growth parameters (stem length, leaf size, number of leaves and root length) in both *Corchorus olitorius* and *Senna occidentalis* while a significant reduction in leaf size was observed with increasing concentration of the industrial effluents. Anatomically, there was no difference in the epidermal cell size and the effluents increased some stomatal parameters such as stomatal density at 25% and 50% concentrations and decrease from 75% and 100% effluent concentration. It also increases the stomatal index and size at high or low concentrations. This study has shown that the two industrial effluents contained some harmful pollutants which are dangerous to life of the plants, adversely affected germination, growth and development at higher concentrations than lower concetrations, they also modified several anatomical structure in the leaf epidermis of *Corchorus olitorius* and *Senna occidentalis.*

Key words: pollution, effluent, epidermal cell.

INTRODUCTION

Environmental pollution is a matter of great concern and has been accepted as a global problem because of its adverse effects (Irshad *et al*., 1997). Effluents are wastes produced from industries and they vary depending on the human activities that produce them. Production of these wastes is an integral part of industrial activities, but unfortunately our inability to anticipate or predict the types and magnitude of undesired consequences of the unbridled release of effluents in our environment, coupled with the growth of industrialization have resulted in massive and destructive operations in our ecosystems. Although industrial processes are desirable, at the same time, the serious and irreversible damage done to the environment through their apparently innocuous discharges of effluents is unquantifiable.

The most potential and hazardous source of water and soil pollution are industrial effluents. These contain heavy metals, poisonous compounds and nutrients, which affect plant and soil in a number of ways (Dhevagi and Oblisami, 2002). Toxic chemicals present in effluents like cyanides, chlorine, hypo chlorites, phenols and heavy metals, caused a reduction in cell activities, retardation of growth, various deficiencies and diseases when accumulated in cells of living being (Kabir *et al*., 2008). Industrial effluents are usually considered as undesirable for arable soil, plants, animals and human health. The unplanned disposal of these effluents has increased the threat of environmental pollution.

In Nigeria, most of the urban farmers divert effluents (either known to be treated or untreated) to farmlands to irrigate their vegetable farms to meet up with the rising demand for fresh vegetables (Uaboi-Egbenni *et al.*, 2009; Fatoba *et al.*, 2011). Reports have it that in Nigeria, vegetables are produced throughout the year e.g. Fatoba *et al.* (2011) due to the availability of industrial effluent to irrigate. Many pollutants such as pesticides, oil, hydrocarbons, heavy metals and trace metals (like Cr, Mn, Fe, Cu, Co, Zn, Ni, As, Cd and Pb) as well as thermal and radioactive pollutants can get into aquatic environments direct or indirect release from industries, agriculture and households, and are allowed to spread on agricultural lands (Fathi *et al*., 2008).

Corchorus olitorius, commonly known as jute or Jew's mallow, belong to the family of flowering plant called Tiliaceae (now Malvaceae), native to tropical and subtropical regions throughout the world. It is an annual/perennial growing to 3.5m at a fast rate. Its leaves are consumed in the cuisines of various countries. It has a mucilaginous (somewhat slimy) texture, similar to okra, when cooked. The seeds are used in flavoring, and herbal tea is made from the dried leaves. The leaves of this vegetable are rich in beta-carotene, iron, calcium and vitamin C.

Senna occidentalis commonly known as coffee senna, Nigerian senna, septic weed, stink weed, stinking pea, etc is a member of the family Caesalpiniaceae, sub family Caesalpinioideae, native to the tropical and subtropical regions of the America. A common weed of roadsides, waste areas, disturbed sites, pastures, grasslands, open woodlands, coastal environs and crops in tropical, subtropical and semi-arid regions, *Senna occidentalis* is an unarmed slender upright and short-lived (annual or biennial) shrub, 0.5-2.5 m tall, distinguished by fetid odor. It can be used as a coffee substitute in spite of the fact that the seeds are reported to be toxic to cattle (Barth *et al*., 1994). It has medicinal and insect antifeedant properties.

Considering all the good and bad effects of industrial effluents on crop plants, the present study was conducted by using effluents obtained from the pharmaceutical industry and soap and detergent industry as a source of water to germinate seedlings of *Corchorus olitorius and Senna occidentalis* and its effect was observed on toxicity, morphological characters and anatomical deformations.

MATERIALS AND METHODS

Source of soil and effluent

Pot experiment was carried out on the Farm of the Faculty of Agriculture University of Ilorin. The soil of 0-15cm depth was obtained from the same study site while the Industrial effluents were collected from two (2) selected Industries namely Global Soap industry, Asa Dam area, Ilorin and Peace Pharmaceutical industry, Olorunsogo area, Ilorin. The effluent samples were collected in plastic container. The containers used were carefully washed with 1% HNO3 acid and rinsed with distilled water. It was drained before the samples were collected after rinsing with the wastewater sample.

Sources of experimental seeds

Corchorus olitorius seeds were obtained from the International Institute of Tropical Agriculture, Ibadan. *Senna occidentalis* seeds were obtained around banking area, University of Ilorin Area. Both seeds were authenticated at University of Ilorin Herbarium with voucher number UILH/001/1298/2020 and UILH/002/154/2020 for *Senna occidentalis* and *Corchorus olitorius* respectively.

Physico-chemical analysis of effluents

Filtrates were used for chemical analysis to determine total soluble salts (TSS) by gravimetric method, pH by using pH meter. Electrical conductivity (EC) of the effluents was determined by using conductivity meter. Alkalinity was determined by titration method while the Total dissolved solid was determined using gravimetric analysis. The heavy metal analysis was done using Atomic Absorption Spectrophotometry. Chloride, Calcium and Potassium concentrations were also determined.

Soil texture in terms of the percentage of sand, silt and clay was determined using a hygrometer. Soil pH was determined using a pH meter; the electrical conductivity (EC) of soil was measured using an EC meter. The extractable sodium, potassium, phosphorus and soil organic content were also determined using Azeez *et al.*, (2013) method.

Soil preparation

The perforated planting pots were filled with approximate amounts of the disinfected soil, which was previously mixed with organic manure. The polluted soil was left for one week after pollution before the experimental seeds were sown in the soil at the rate of 20 seeds per pot at 2 cm depth. The pots were 5cm apart.

Sowing of seeds and application of effluent

The effluents collected from the two (2) sources were considered as 100% concentrated. It was diluted to 75%, 50% and 25% with distilled water. These dilutions of effluents along with distilled water (control) were used as a growth medium for seed germination by using standard technique. There were three replicates each with 20 seeds in a completely randomized design. The named pollutant was applied to each pot after making different concentrations from 0-100% as given below.

T_0 = Tap water (control)
T_1= 25% pollutant + 75% tap water
T_2= 50% pollutant + 50% tap water
T_3= 75% pollutant + 25% tap water
T_4= 100% pollutant

The irrigation was scheduled to keep the soil moisture content similar to field capacity and seedlings were irrigated once a week. The experiment was laid out in a completely randomized design with three replicates.

Macromorphometric studies/germination pattern

Data were collected on the following; stem length (cm), number of leaves, leaf area (cm^2), root length (cm), chlorophyll contents (mg/L), fresh and dry weight (g) of seedlings.

Analytical quality assurance

Each soil sample solution reagent blank was replicated three times for quality assurance and to ensure analytical precision. Flame Atomic Absorption Spectrophotometer (FAAS) was calibrated using standard solutions traceable to the National Institute of Standards and Technology (NIST). Similarly, the reliability of the digestion method was ensured by including blanks with every batch of plant samples digested. Each sample and reagent blank analysis repeated three times for precision using methods specified in the FAAS operating manual. Control standard solutions were ran at the start, middle, and at the end of sample analysis to ensure accuracy of the instruments. All glassware were washed with 0.1N HNO_3 before use. All reagents were pure and double distilled water was employed throughout.

Isolation of leaf epidermal layers

A leaf segment of an area of 1cm square from each specimen was cut and immersed in concentrated solution of nitric acid for maceration. The upper (adaxial) and the lower (abaxial) surfaces were separated with dissecting needle and forceps and rinsed with clean water. The specimen was stained with safranin and mounted on glycerine for microscopic observation using an Olympus research microscope fixed with an Amscope camera (FM A050).

Determination of stomatal density and stomatal index

The stomatal density (SD) was determined as number of stomatal per square millimetre (Stace, 1965).

SD= number of stomata in $0.152mm^2$ field of view

Stomatal Index (SI) was determined as follows:

$SI= S/E+S \times 100$

Where SI= stomata index

S= number of stomata per square millimetre

E= number of ordinary epidermal cell per square millimetre

Determination of stomatal size

The mean stomatal size of each species was determined by multiplying length and breadth guard cells with Franco's constant using an eyepiece micrometre. A sample of 30 stomata was used. The method follows those of Franco (1939).

$SS= L \times B \times K$

L= length

B= breadth

K= Franco's constant (0.78524)

Determination of epidermal cell size

Epidermal cell size was determined as product of length and breadth of cell using eye piece micrometer and a sample size of 30 cells was used.

Statistical Analysis

Data was analysed using the statistical package SPSS. After testing the homogeneity of variance and normality of data, ANOVA was performed. A p-value of $<$ 0.05 was considered significantly different. The comparison of treatment means was drawn using Duncan Multiple Range Test at α= 0.05. All data presented were expressed as mean $\pm$ standard error.

RESULTS AND DISCUSSION

The physico-chemical analysis of the two Industrial effluents is mentioned in Table 1. Some heavy metals present in the pharmaceutical effluents include Nickel, Copper, Lead, Cadmium, Chromium and Iron while those present in the soap and detergents effluent include Copper, Lead, Cadmium, Chromium, Iron and Mercury. Pharmaceutical effluent is acidic and that of the soap and detergents effluent is alkaline.

Table 1: Physico-Chemical Characteristics of the Two Industrial Effluents

Parameters	Units	Effluent from soap and detergents industry	Effluent from pharmaceutical

			industry
Colour		Deep blue	Whitish
Odour		Foul odour	Foul odour
pH		11.20	5.72
Total dissolved solids (TDS)	mg/L	240	115
Chloride	mg/L	0.05	1.74
Electrical conductivity (EC)	μS/cm	151	297
Alkalinity	mg/L	4	7.6
Calcium	mg/L	0.04	0.85
Nickel	mg/L	ND	0.945
Copper	mg/L	0.076	0.072
Lead	mg/L	0.029	0.26
Cadmium	mg/L	0.071	0.55
Chromium	mg/L	ND	0.89
Iron	mg/L	0.332	6.64
Mercury	mg/L	0.0015	ND

*ND: not detected

The physico-chemical analysis of the experimental soil mentioned in Table 2 revealed that the soil is acidic. The sandy composition of the soil is the highest (63.52%) while the lowest composition is silt (6.48%).

Table 2: Analysis of soil organic content/soil composition

Parameters	**Experimental soil**
P^H	5.32
Electrical conductivity ($\mu S/cm$)	12
Sand (%)	63.52
Silt (%)	6.48
Clay (%)	50.56
Organic Nitrogen (%)	2.17
Available phosphorus (ppm)	0.14
Exchangeable K^+	0.15
Exchangeable Na^+	0.70

Growth and morphology

Stem length

At 2WAP *Corchorus olitorius*, no significant difference exists between the control and the pharmaceutical effluent-induced seedlings. However, the significant difference exists between the control and the soap and detergents effluent-induced seedlings. At 4WAP, tallest stem length was recorded in 25% pharmaceutical effluent (19.67±0.67cm) followed by the control (18.67±0.33cm) while shortest length was recorded in 100% of both effluent treated seedlings respectively. At 6WAP, the trend was still maintained in which the tallest stem length was recorded in 25% pharmaceutical effluent-induced seedlings (56±0.58cm) and the shortest in undiluted concentrations of both effluent treated seedlings i.e. (47.70±0.33cm). A significant difference exists between control and the pharmaceutical soap and detergents effluent in their effect impacted on the stem length of *Corchorus olitorius* at higher concentrations, but no such difference was observed between the seedlings of the control and the two industrial effluent-induced seedlings at lower concentrations.

Table 3: The Effect of Industrial Effluent on the Stem Length (cm) of the Plant *Corchorus olitorius*

Concentrations	**2WAP**	**4WAP**	**6WAP**	**8WAP**
Control	6.00±0.00[a]	18.67±0.33[a]	54.00±0.00 [ab]	66.67±2.33[a]
25% Peace	5.67± 0.67[a]	19.67±0.67[a]	56.00±0.58[a]	69.00±2.67[a]
50% Peace	5.00± 0.58[a]	18.00±0.67[a]	53.67±0.66[b]	62.56±1.08[ab]
75% Peace	5.00±0.66[a]	15.33±0.33[b]	50.33±0.33[c]	57.00±0.69[c]
100% Peace	5.00±0.66[a]	13.00±0.00[c]	47.70±0.33[d]	56.34±0.53[c]
25% Global	4.67±0.67[b]	17.00±0.57[ab]	53.00±0.00[a]	63.59±1.56[ab]
50% Global	4.67±0.67[b]	17.67±0.67[ab]	52.33±0.67[b]	59.33±1.03[b]
75% Global	4.00±0.00[b]	14.33±0.33[c]	49.33±0.67[c]	55.00±0.00[c]
100% Global	4.00±0.00[b]	13.00±0.00[c]	47.00±0.66[c]	51.56±0.89[d]

*WAP= Weeks after planting

Values with same letter(s) in the same column are not significantly different at $p > 0.05$

Similarly, at 4WAP the tallest stem length was observed on the 25% pharmaceutical effluent treatment (15.33±0.56cm) while the shortest on 100% soap and detergents effluent (9±0.33cm). Also at 6WAP, 25% pharmaceutical effluent-induced seedling still record the highest stem length (33±0.78*cm*) with the shortest stem length was recorded in 100% soap and detergents seedling treatment (22±0.73*cm*). Significant difference exists between the seedlings of *Senna occidentalis* treated with the pharmaceutical effluent (at lower concentration) and soap and detergents effluent in their effect on stem length

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Table 4: The Effects of Industrial Effluent on the Stem Length (cm) of *Senna occidentalis*

Concentrations	**2WAP**	**4WAP**	**6WAP**	**8WAP**
Control	6.00±0.58[a]	13.67±1.20[ab]	29.15±0.75[ab]	45.41±0.77[ab]

25% Peace	7.67±0.33[a]	15.33±0.56[a]	33.00±0.78[a]	49.67±0.97[a]
50% Peace	6.67±0.33[a]	13.00±0.53[ab]	31.67±0.20[ab]	46.21±0.92[ab]
75% Peace	5.67±0.00[ab]	12.67±0.20[ab]	26.00±0.88[b]	39.15±0.72[c]
100% Peace	5.00±0.00[ab]	11.00±0.58[b]	24.33±0.53[c]	39.09±0.63[c]
25% Global	6.00±0.58[a]	12.67±0.88[ab]	30.87±0.58[b]	47.00±0.00[b]
50% Global	5.67±0.58[b]	11.67±0.33[b]	28.00±0.00[c]	46.48±0.98[b]
75% Global	5.33±0.33[b]	10.67±0.33[c]	23.67±0.33[cd]	40.32±0.88[c]
100% Global	5.00[b]±0.00 [b]	9.00±0.33[c]	22.01±0.73[d]	36.54±0.59[d]

*WAP= Weeks after planting

Values with same letter(s) in the same column are not significantly different at p>0.05

Generally, seedlings treated with pharmaceutical effluents were taller than those treated with soap and detergents effluents at low concentration.

Leaf size

From the values obtained in Table 5, it was noted that there was a marked reduction in leaf sizes of the effluent-induced plants with increased concentrations. The maximum leaf size at 4WAP was recorded in 25% pharmaceutical effluent treatments (12.33cm^2) while the minimum size occurred in undiluted soap and detergents effluent-induced *C. olitorius* plant (7cm^2). At 6WAP, the maximum leaf size of *Corchorus olitorius* was recorded in 50% peace effluent (36.88±0.78cm^2) while the minimum size was found to occur in the neat (undiluted) global effluent treatment (20cm^2). At 8WAP however, seedlings treated with 25% pharmaceutical effluent recorded the maximum leaf size while the minimum was still maintained in the seedlings exposed to undiluted soap and detergents effluent.

Table 5: The Effect of Industrial Effluent on the Leaf Size (cm^2) of the Plant *Corchorus olitorius*

Concentrations	2WAP	4WAP	6WAP	8WAP
Control	5.33±0.33[a]	12.00±0.00[a]	31.10±1.00[a]	40.44±3.36[b]
25% Peace	5.03±0.67[a]	12.33±0.00[a]	34.21±2.03[a]	46.33±2.15[a]
50% Peace	5.33±0.67[a]	10.12±0.00[ab]	36.88±0.78[ab]	43.10±0.00[ab]
75% Peace	3.67±0.67[a]	7.00±0.00[c]	21.00±0.00c	37.85±1.58[cd]
100% Peace	4.67±0.00[a]	6.67±1.03[c]	21.21±2.00[c]	32.09±1.12[d]
25% Global	5.67±0.00[a]	11.32±1.56[ab]	32.33±1.33[ab]	44.23±2.52[ab]
50% Global	5.67±0.67[a]	10.33±1[ab]	30.67±1.15[ab]	42.36±2.25[b]
75% Global	4.00±0.00[a]	6.67±0.33[c]	23.67±0.67[cd]	32.00±0.00[d]
100% Global	4.30±0.33[a]	7.00±0.00[c]	20.00±0.00[d]	31.00±0.00[d]

*WAP= Weeks after planting

Values with same letter(s) in the same column are not significantly different at p>0.05

From Table 6, it can be observed that there was marked reduction in its leaf size at higher concentrations of the two effluent treatments. At 2WAP, the control recorded the maximum leaf size (8.33±1.20cm^2) followed by 25% (7±1.73cm^2) and 50% pharmaceutical effluent treatment (7±1.15cm^2) while the minimum size was recorded on 100% global (3cm^2). Also at 8WAP, seedlings treated with 25% of the pharmaceutical effluent recorded the maximum leaf size (43.28±1.69cm^2) while the minimum leaf size was still observed in the seedlings treated with neat soap and detergents effluent.

Table 6: The Effect of Industrial Effluent on the Leaf Size (cm^2) of *Senna occidentalis*

Concentrations	2WAP	4WAP	6WAP	8WAP
Control	8.33±1.20^a	16.21±2.64^a	36.33±5.30^a	42.56±1.53^a
25% Peace	7.13±1.73^{ab}	15.67±2.73^a	37.20±2.30^a	43.28±1.69^a
50% Peace	7.08±1.15^{ab}	14.33±3.67^a	36.33±3.67^a	40.57±1.42^{ab}
75% Peace	4.33±1.45^c	8.33±2.03^{bc}	31.41±4.73^b	36.00±0.00^c
100% Peace	4.65±2.4^c	8.48±6.00^{bc}	30.33±7.88^b	34.37±0.59^c
25% Global	5.67±2.19^b	13.17±1.76^{ab}	35.20±2.00^a	43.00±0.00^a
50% Global	4.00±0.00^c	12.12±1.73^{ab}	33.67±0.67^b	41.56±1.55^{ab}
75% Global	3.67±1.2^c	6.67±2.19^c	28.13±1.15^c	35.59±1.88^c
100% Global	3.00±0.00^c	6.00±0.00^c	28.05±0.58^c	34.00±0.00^c

*WAP= Weeks after planting
Values with same letter(s) in the same column are not significantly different at $p>0.05$

Generally, significant differences exist between the seedlings treated with the pharmaceutical and soap and detergent effluent in the effect they impact on leaf sizes of *Corchorus olitorius* and *Senna occidentalis*.

Number of leaves
Table 7 indicates the effect of the two industrial effluents on the leaf numbers of *Corchorus olitorius*. It was observed that undiluted effluents from the two sources showed greater significantly reduction of leaf number as compared to 25%, 50% and control at 4WAP and 8WAP respectively.. It was observed that the number of leaves was significantly higher in the control compared to higher concentrations (75% and 100%) of the two Industrial effluents.

Table 7: The Effect of Industrial Effluent on the Number of Leaves of *Corchorus olitorius*

Concentrations	2WAP	4WAP	6WAP	8WAP
Control	7.33±0.00^a	18.67±0.33^{ab}	29.67±0.33^a	37.22±1.87^a
25% Peace	7.00±0.00^a	19.01±0.58^a	29.33±0.88^a	39.23±1.99^a
50% Peace	7.00±0.00^a	17.00±0.00^{ab}	20.67±0.67^c	37.00±0.00^b
75% Peace	5.67±0.00^b	14.05±0.33^c	29.00±0.00^a	32.68±1.25^c
100% Peace	5.67±0.00^b	12.05±0.33^c	26.33±0.67^{ab}	31.99±1.00^c
25% Global	6.33±0.33^a	16.01±0.58^b	29.67±0.33^a	40.06±2.08^a
50% Global	6.05±0.33^a	16.05±0.33^b	27.09±0.88^{ab}	36.39±1.56^{ab}

75% Global	5.67±0.00[b]	9.05±0.33[cd]	27.04±0.33[ab]	33.44±1.22[c]
100% Global	5.07±0.58[b]	6.67±0.33[d]	22.02±0.33[c]	31.27±1.25[c]

*WAP= Weeks after planting

Values with same letter(s) in the same column are not significantly different at p>0.05

From the values obtained in Table 8, it was observed that lower concentrations of the two industrial effluents lead to significantly higher leaf production as compared to higher concentrations of these effluents which bring about reduction in the number of leaves. This observation is similar to what was noticed in the effect of these industrial effluents on leaf numbers of *Corchorus. olitorius*.

Table 8: The Effect of Industrial Effluent on Number of Leaves of *Senna occidentalis*

Concentrations	2WAP	4WAP	6WAP	8WAP
Control	8.56±0.88[a]	21.33±2.19[a]	24.67±1.86[b]	29.67±2.33[b]
25% Peace	7.76±0.73[a]	22.67±1.33[a]	28±1.53[ab]	33.67±1.33[ab]
50% Peace	6.89±0.37[ab]	22±2.3[a]	24.67±1.45[b]	29±1.53[b]
75% Peace	4.88±0.21[c]	20.67±1.20[b]	30±0.58[b]	35±0.58[a]
100% Peace	4±0.22[c]	19±0.58[b]	25±0.58[b]	31±1.20[ab]
25% Global	7±0.00[a]	16.67±0.88[ab]	22.67±0.88[a]	24.67±0.88[ab]
50% Global	7±0.38[a]	16.67±1.45[ab]	22.67±0.88[a]	23.67±0.88[b]
75% Global	5.11±0.46[c]	17.33±0.67[ab]	15.33±0.67[b]	12.33±0.88[c]
100% Global	4±0.00[c]	10±0.58[c]	8.33±0.67[c]	6.35±0.33[d]

*WAP denotes week(s) after planting

Values with same letter(s) in the same column are not significantly different at p>0.05

Root length

Table 9 shows that at higher concentration, the root length was significantly reduced in the pharmaceutical effluent-induced plant compared to the other treatment level. In the soap and detergents effluent, however, there is no significant difference between varying concentrations in the effect impacted. A significant difference exists between control seedlings and the two industrial effluents induced seedlings in the effect they impact on the root length of *Corchorus olitorius.*

Table 9: The Effect of Industrial Effluent on the Root Length (cm) of *Corchorus olitorius*

Concentrations	8WAP
Control	9.67±0.33[a]
25% Peace	7.30±0.58[b]
50% Peace	7.30±0.58[b]
75% Peace	5.33±0.33[c]
100% Peace	5.33±0.33[c]
25% Global	7.30±0.58[b]

50% Global	7.30±0.58[b]
75% Global	7.30±0.33[b]
100% Global	7.30±0.58[b]

*WAP= weeks after planting

Values with same letter(s) in the same column are not significantly different at $p>0.05$

Data presented in table 10 showed that there was a marked reduction in the root length with increased concentration of effluent (pharmaceutical) as compared to control. The root length of the control is 20.67±0.88cm while the plant treated with undiluted effluent from the two sources has the root length 10.67±0.67cm and 7.30±0.58cm respectively. A significant difference ($p<0.05$) exists between the root length for the control and the plant exposed to various concentrations of both effluents.

Table 10: The Effects of Industrial Effluents on the Root Length (cm) of *Senna occidentalis*

Concentrations	**8WAP (cm)**
Control	20.67±0.88[a]
25% Peace	15.33±0.67[b]
50% Peace	13.67±0.33[bc]
75% Peace	11.30±0.58[c]
100% Peace	10.67±0.67[c]
25% Global	7.30±0.58[b]
50% Global	7.30±0.58[b]
75% Global	7.33±0.33[b]
100% Global	7.30±0.58[b]

*WAP= weeks after planting

Values with same letter(s) in the same column are not significantly different at $p>0.05$

Fresh and dry weight

There was a marked reduction in the fresh and dry weight of *Corchorus. olitorius* treated with the pharmaceutical and soap and detergents effluent with increased concentration as compared to the control. The control had 3.59g of fresh weight while the plant treated with undiluted effluents of soap and detergents and pharmaceutical had 2.00g and 3.00g fresh weight respectively. The significant difference exists between the control seedlings and the two industrial effluent treatments in the effect they impacted on fresh and dry weight

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Table 11: The Effect of Industrial Effluent on the Fresh and Dry Weight (g) of *Corchorus olitorius*

	8 WAP	
Concentration	Fresh weight (g)	Dry weight (g)
Control	3.59	1.20
25% Peace	2.26	1.10

50% Peace	2.00	0.89
75% Peace	2.20	0.98
100% Peace	2.00	1.00
25% Global	3.59	1.60
50% Global	3.40	1.50
75% Global	3.00	1.49
100% Global	3.00	1.45

*WAP= weeks after planting

From the data recorded in table 12, it was observed that seedlings treated with soap and detergents effluent have more weight (fresh and dry) than those treated with the pharmaceutical effluents. The soap and detergents effluent-induced seedlings weigh more than even the control seedlings at low concentrations. Seedlings of the control plant weigh 6.35g while seedlings treated with the soap and detergents effluent at the lowest concentration (25%) weigh 7.07g while that treated with the pharmaceutical effluents at 25% weigh 5.25g

Table 12: The Effect of Industrial Effluent on the Fresh and Dry Weight (g) of *Senna occidentalis*

	8WAP	
Concentration	Fresh weight (g)	Dry weight (g)
Control	6.35	1.40
25% Peace	5.25	1.30
50% Peace	5.00	1.35
75% Peace	4.67	1.40
100% Peace	4.00	1.30
25% Global	7.07	1.20
50% Global	7.00	1.22
75% Global	7.00	1.21
100% Global	6.00	1.20

*WAP= weeks after planting

Total chlorophyll content

A perusal look at table 13 revealed that the effects of the soap and detergents effluent on the total chlorophyll content of *Corchorus olitorius* leaf was directly reverse of the pharmaceutical effluent treatment. There was a reduction in the total chlorophyll content with increased concentration of the global effluents showing significant difference from the control. In the effect of the peace effluent, however, highest total chlorophyll contents were recorded with highest concentrations showing no significant difference from the control. The total chlorophyll for the control was 0.290mg/L while total chlorophyll obtained from the leaf of pharmaceutical effluent-induced plants and soap and detergents effluent-induced plants at the highest concentration (100%) are 0.0304mg/L and 0.0283mg/L respectively

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Table 13: The Effect of Industrial Effluent on the Chlorophyll Content (mg/L) of *Corchorus olitorius*

8 WAP			
Concentration	Chlorophyll a (mg/L)	Chlorophyll b (mg/L)	Total chlorophyll (mg/L)
Control	0.013	0.017	0.029
25% Peace	0.013	0.017	0.030
50% Peace	0.013	0.018	0.031
75% Peace	0.013	0.019	0.032
100% Peace	0.014	0.019	0.032
25% Global	0.013	0.015	0.028
50% Global	0.013	0.014	0.027
75% Global	0.013	0.013	0.026
100% Global	0.013	0.012	0.025

From the values obtained in table 14, it was observed that there was marked increment in the total chlorophyll content of *Senna. occidentalis* plant treated with pharmaceutical effluents at lower concentrations compared to control plant. However, with the soap and detergents effluent-induced plant, marked reductions were observed at varying concentrations compared to the control. The control plant had 0.331mg/L total chlorophyll while the plant treated with undiluted pharmaceutical effluents and soap and detergents effluent had 0.0390mg/L and 0.0174mg/L respectively

Table 14: The Effect of Industrial Effluent on the Chlorophyll Content (mg/L) of *Senna occidentalis*

8 WAP			
Concentration	Chlorophyll a (mg/L)	Chlorophyll b (mg/L)	Total chlorophyll (mg/L)
Control	0.014	0.019	0.033
25% Peace	0.081	0.018	0.099
50% Peace	0.016	0.019	0.034
75% Peace	0.015	0.019	0.034
100% Peace	0.015	0.023	0.039
25% Global	0.010	0.013	0.023
50% Global	0.009	0.012	0.021
75% Global	0.009	0.010	0.019
100% Global	0.008	0.009	0.017

Anatomy of *Corchorus olitorius* leaves

Leaves of *Corchorus olitorius* is amphistomatic (i.e. having stomata on the adaxial and abaxial leaf surface). The stomata complex types present are anisocytic, diacytic and paracytic (Figs 1a-f). Stomatal density of the abaxial surface recorded no significant difference compared to the control while the observed significant difference was recorded in the adaxial surface of the treatments. Stomatal density was significantly the same in the control and 25% pharmaceutical effluent treatment and significantly increases in higher concentration of 50% of the pharmaceutical effluent treatments but significantly decrease from 75% and 100% concentration. However, the soap and detergents effluent have almost similar effect with the pharmaceutical though significant increment was observed compared to the control from 25% effluent treatment on the adaxial surface. Different twist was observed in the effect these two industrial effluents have on the stomatal size of *Corchorus olitorius*. On both leaf surfaces, significant reduction was observed compared to the control even from the 25% to higher concentrations of both effluent treatments. The largest stomatal size (37.14$\pm 7.19 \mu m^2$) on the abaxial surface was recorded in the control while the lowest (20.09$\pm$4.49μm^2) was observed in undiluted soap and detergents effluent. The epidermal cell size in both leaf surfaces seems to be unaffected by both effluent treatments (Tables 15 and 16).

Table 15: Stomatal Features of the Leaves of *Corchorus olitorius* Irrigated with Various Concentrations of Pharmaceutical Effluent

Treatments	Surface of Leaf	Stomatal density (mm^2)	Stomatal index (%)	Stomatal size (μm^2)	Epidermal cell size (μm^2)
Control	Adaxial	13.79$\pm$3.09^b	8.93	25.56$\pm$5.72^a	44.43
	Abaxial	23.13$\pm$5.17^b	18.41	37.14$\pm$7.19^a	43.29
25%	Adaxial	15.08$\pm$3.37^b	10.09	23.39$\pm$5.23^b	46.22
	Abaxial	22.00$\pm$2.92^b	19.03	22.67$\pm$6.34^b	44.98
	Adaxial	21.00$\pm$24.70^a	17.67	22.00$\pm$4.92^b	44.25
50%	Abaxial	24.67$\pm$5.52^{ab}	17.23	19.56$\pm$4.38^b	45.88
75%	Adaxial	12.09$\pm$2.7^c	21.00	23.06$\pm$5.16^b	43.76
	Abaxial	26.00$\pm$5.82^a	15.56	21.05$\pm$4.71^b	47.65
100%	Adaxial	11.00$\pm$2.46^c	26.89	24.00$\pm$5.37^{ab}	46.23
	Abaxial	26.06$\pm$5.83^a	14.90	19.08$\pm$4.27^b	44.82

Table 16: Stomatal features of the leaves of *Corchorus olitorius* irrigated with various concentrations of soap and detergents effluent

Treatments	Surface of Leaf	Stomatal density (mm^2)	Stomatal index (%)	Stomatal size (μm^2)	Epidermal cell size (μm^2)
25%	Adaxial	21.89$\pm$3.18^a	9.35	23.22$\pm$5.23^b	44.34
	Abaxial	24.03$\pm$5.38^{ab}	11.23	24.56$\pm$5.49^b	42.13
50%	Adaxial	21.05$\pm$3.59^a	15.52	23.38$\pm$5.23^b	44.98
	Abaxial	22.00$\pm$4.92^b	16.56	22.76$\pm$5.09^b	42.19
75%	Adaxial	11.56$\pm$ 2.58^a	13.45	24.67$\pm$5.56^b	43.33
	Abaxial	25.71$\pm$5.75^a	19.52	22.23$\pm$4.97^b	41.20
100%	Adaxial	10.56$\pm$2.360^c	16.99	25.00$\pm$5.59^{ab}	46.56
	Abaxial	25.00$\pm$5.59^a	15.23	20.09$\pm$4.49^b	46.29

Anatomy of *Senna occidentalis* leaves

Leaves of *Senna occidentalis* is amphistomatic (i.e having stomata on both leaf surface). The stomatal complex types present are the paracytic and anisocytic types (Figs g-l). From Tables 17 and 18, the stomatal density is more on the abaxial surface than on the adaxial surface of both industrial effluent treatments except at the 75% treatment. Compared with the control on the adaxial surface, seedlings treated with pharmaceutical effluent showed a marked increment in the stomatal density from 50% concentrations and above. Seedlings treated with soap and detergents effluent also showed a significant increment in the stomatal density of the leaf but from 25% concentration. On the abaxial surface, however, no significant difference was observed between the control and plant treated with the two industrial effluents. The stomata of *S. occidentalis* leaf treated with both industrial effluents showed either increment or reduction in sizes as compared to control on the adaxial surface. However, only 75% concentration of pharmaceutical effluent showed reduction in stomatal size as compared to control, other concentrations of these effluents when applied to the plant showed a significant increment. In the seedlings treated with soap and detergents effluent, various concentrations of this effluent also showed either an increase or reduction in the stomatal size when compared to control. There seems to be no significant difference in the effect of these effluents impacted on the epidermal cell sizes as compared to the control on both leaf surfaces.

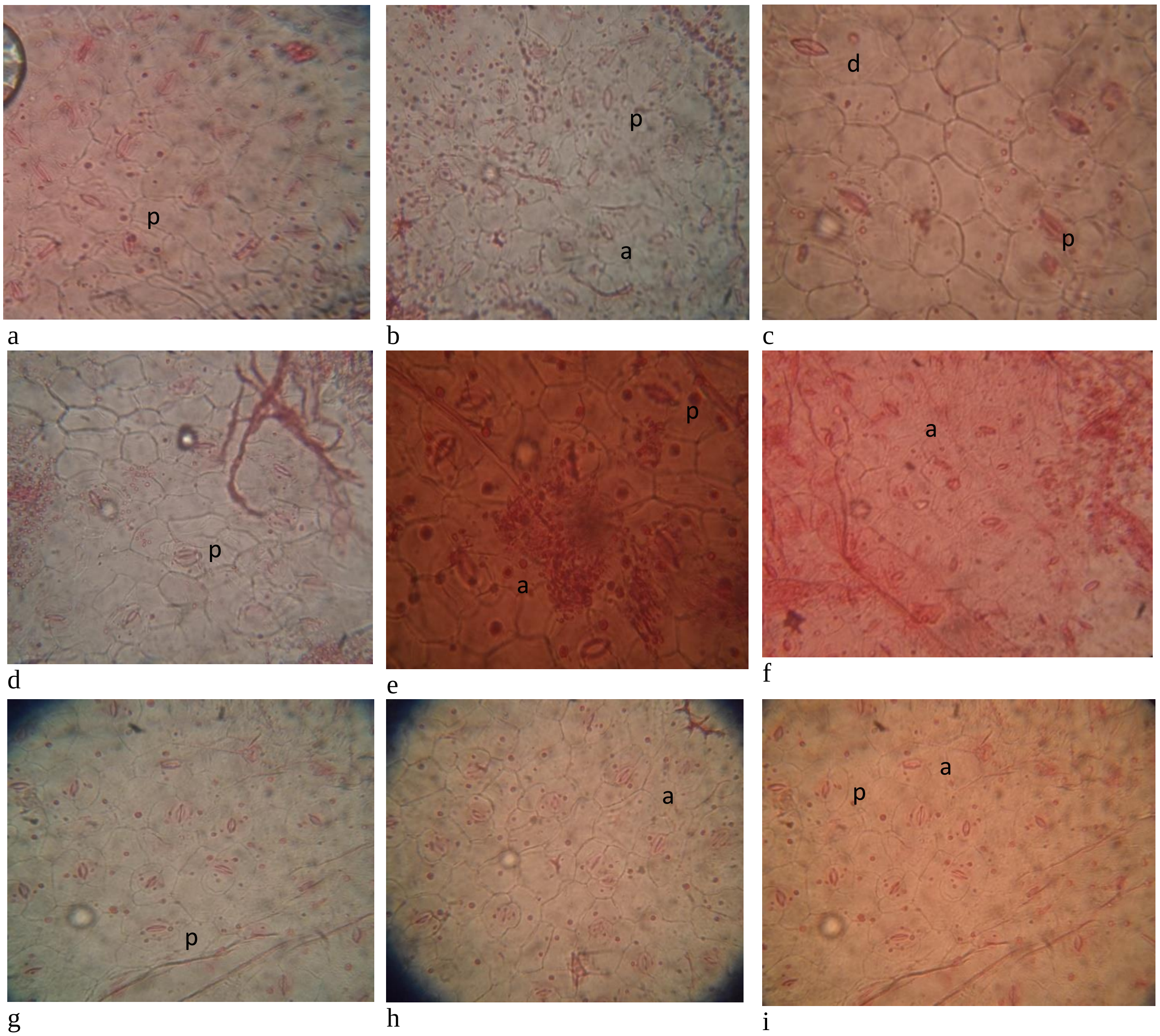
Table 17: Stomatal features of the leaves of *Senna occidentalis* irrigated with various concentrations of pharmaceutical effluent

Treatments	**Surface of Leaf**	**Stomatal density (mm^2)**	**Stomatal index (%)**	**Stomatal size (μm^2)**	**Epidermal cell size (μm^2)**
Control	Adaxial	32.02±7.16^c	21.70	13.50±3.02^{cd}	36.53
	Abaxial	41.23±9.22^b	28.92	14.32±3.20^{cd}	35.33
25%	Adaxial	35.23±7.88^c	25.56	19.36±4.36^{ab}	39.33
	Abaxial	55.45±12.40^a	32.00	14.76±3.30^{cd}	35.54
50%	Adaxial	53.57±11.98^{ab}	29.34	13.56±3.03^{cd}	36.87
	Abaxial	55.96±12.52^a	31.86	11.87±2.66^d	35.92
75%	Adaxial	61±13.65^a	26.45	10.56±2.36^d	37.45
	Abaxial	49.34±11.04^{ab}	23.22	12.43±2.78^d	38.00
100%	Adaxial	44.36±9.92^b	26.88	13.56±3.03^{cd}	39.29
	Abaxial	50.92±11.39^{ab}	27.56	18.22±4.08^{ab}	38.53

Table 18: Stomatal features of leaves of *Senna occidentalis* irrigated with various concentrations of soap and detergents effluent

Treatments	**Surface of Leaf**	**Stomatal density (mm^2)**	**Stomatal index (%)**	**Stomatal size (μm^2)**	**Epidermal cell size (μm^2)**
25%	Adaxial	49.23±11.01^b	26.92	22±4.92^a	39.78

	Abaxial	57.36±12.83[a]	34.56	17.32±4.32[b]	36.32
50%	Adaxial	56.24±12.58[ab]	28.34	15±3.36[cd]	35.17
	Abaxial	56.91±12.73[a]	30.56	13.87±3.10[cd]	36.67
75%	Adaxial	63. 56 ± 14.22[a]	24.78	12.22±2.73[d]	38.99
	Abaxial	52.20±11.67[ab]	27.32	14±3.13[cd]	39.00
100%	Adaxial	42.53±9.51[b]	24.99	15.56±3.48[cd]	38.56
	Abaxial	51.92±11.61[ab]	27.67	21.29±4.76[a]	39.32



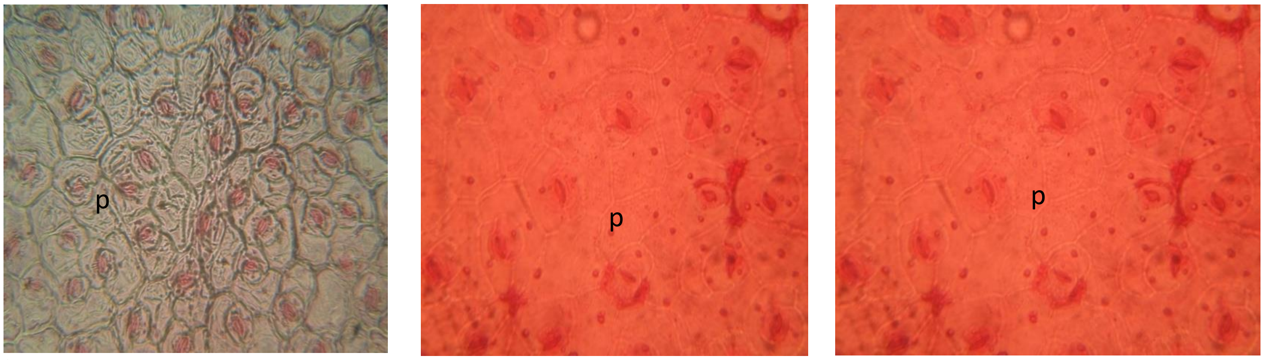


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Figure 1: Leaf epidermis of *Corchorus olitorius* (control: abaxial-a, adaxial-b; pharmaceutical effluent: abaxial-c, adaxial-d; soap and detergent effluent: abaxial-e, adaxial-f) and *Senna occidentalis* (control: abaxial-g, adaxial-h; pharmaceutical effluent: abaxial-i, adaxial-j; soap and detergent effluent: abaxial-k, adaxial-l) showing paracytic (p), diacytic (d) and anisocytic (a) stomatal complex types ×400

DISCUSSION

Physico-chemical analysis of effluents

Analysis of various physico-chemical characters of the two industrial effluents is mentioned in Table 1. Colour of the soap and detergents effluent is deep blue while that of the pharmaceutical effluent is whitish. Both effluents gave a foul odour. The pH of the pharmaceutical effluents (5.72) falls within the permissible limit of FEPA (1991) while that of soap and detergent effluent was higher (11.2). There were marked variations in the chloride concentration, electrical conductivity, alkalinity and total dissolved solids for the pharmaceutical and soap and detergents effluents are 1.74 and 0.05mg/L, 297 and 151µS/cm, 7.6 and 4mg/L, 115 and 240mg/L respectively. The presences of heavy metals Cu, Mg, Pb, Cd could be as a result of the pH as reported by Mojeed et al. (2018) that the pH are known to affect the availability of micronutrient as well as trace and heavy metal which could cause toxicity to aquatic life and accumulate in excessive concentrations in river sediments. However the Cu concentration was higher in soap and detergents effluents than in the pharmaceutical effluents. Reverse is the case in Fe, Pb and Cd concentration as it is higher in the pharmaceutical effluents than in the soap and detergents effluents. Ni and Co are not detected in the soap and detergents effluents while Mn is not detected in the pharmaceutical effluent. The soils of the experimental sites were texturally sand clay loam (Table 2). Potassium, phosphorus, and sodium were considered moderate.

Effects of industrial effluents on growth morphology of plant

Supply of undiluted (100%) effluents from the two industry produced significant inhibition in the seedling growth parameters (stem length, leaf size, number of leaves and root length) in both *Corchorus olitorius* and *Senna occidentalis*. Also affected are the total chlorophyll of the leaves and weight of seedlings (both fresh and dry). Even though less severe, the inhibitory effect of the 1:1 diluted (50%) effluent was also significant. It was however observed that compared to *Senna occidentalis, Corchorus olitorius* was more sensitive to the inhibitory effect of the effluents. *Corchorus olitorius* seedlings irrigated with the undiluted (100%) soap and detergents effluent also developed visible symptoms. Most conspicuous of those were burning of leaf tips and formation of loops on leaflets. These leaves failed to expand, resulting in marked decrease in leaf size. Irrigation with dilute (75%) effluents produced similar but less severe results. Somewhat similar effects were produced in *Senna occidentalis*. Inhibition of growth in response to irrigation with industrial effluents at high concentrations on varieties of plants have been reported by many workers (Azra *et al*., 2011; Oladele *et al*., 2011; Pandey, 2006; Ramasubramaniam *et al*, 1993 and Uaboi-Egbenni *et al*., 2009).

On the leaf size of *Corchorus olitorius* and *Senna occidentalis*, it was observed that there was a marked reduction in leaf sizes with increased concentration of the industrial effluents. However, low concentration of the two industrial effluents tends to favour the expansion of the leaves. The leaves of these plants treated with undiluted (100%) soap and detergents effluent inhibits the expansion of the leaf size of the two experimental plants, however lower concentration treatment of this effluent favour expansion of leaf size though not as pronounced as in that of the pharmaceutical effluent at lower concentration. A significant difference ($p< 0.05$) exist between leaf size for the control and various higher concentrations of the effluents. Only effluents at low concentration showed the non-significant difference ($p> 0.05$) from the control. Also, the inhibitory effects of high concentration of effluents are more pronounced in soap and detergents effluent treated plant compared to pharmaceutical effluent. Also the decrease in number of leaves of these plants as a result of application of the industrial effluents showed that pharmaceutical and soap and detergents effluents in high concentration is toxic to plants. There was also marked reduction in stem length of these plants when treated with the two industrial effluents at high concentrations. This correspond with the work of by Ogbuehi *et al*, (2011) who reported a decrease in leaf size, stem length and number of leaves of *Arachis hypogea* on application of spent oil with increased concentrations.

Results obtained in Table 10 and 11 depicted that with increased concentrations of these effluents, there was a marked reduction in the root length of these plants. Also from Table 12 and 13, it was noted that there was a marked reduction in the fresh weight of seedlings treated with both effluents with increased concentrations as compared to the control. A significant difference ($p<0.05$) exists between the fresh weight for the control and the plants exposed to various concentrations of both effluents. However the effluents from soap and detergents industry enhance more weight (fresh and dry) to the seedlings of both plants than that from pharmaceutical industry. Also marked reduction was observed in the total chlorophyll content with increased concentration of both industrial effluents. This was in consonance with the work of Oladele *et al*., 2011 when reporting on the effects of three industrial effluents on growth and development of *Vigna unguiculata*.

Effect of industrial effluents on leaf epidermal features

The use of industrial effluents for irrigation of plants poses several overt anatomical alterations to the crop plants. Leaf epidermis of the experimental plants showed varied responses to the various concentrations of the two industrial effluents. There was no difference in the epidermal cell size. Anatomically, the industrial effluents increased some stomatal parameters such as stomatal density, index and size at high or low concentrations.

The stomatal density also appeared to increase significantly at 25% and 50% concentrations when treated with the experimental plants and decrease from 75% and 100% effluent concentration. This may be as a result of modification mechanism of these plants to survive in the polluted substrate by replenishing dead stomata due to the toxic effects of the effluents. Increased stomatal density is considered as adaptability indicator to a polluted environment (AbdulRahaman *et al*., 2013; Gostin, 2009, and Kapitonova, 2002). This modification method was impossible for these two plants treated with 75% and 100% effluent concentrations due to high toxicity effect of the effluent.

The decreased stomatal size of *Corchorus olitorius* on both leaf surfaces in all the treatments aside the control is an indication of these plants' survival strategy in the presence of pollutants present in these effluents. Reducing stomatal size helps in increasing the rate of photosynthesis without excessive transpiration. This was in harmony with the works of AbdulRahaman *et al*. (2013) and Melo *et al*. (2007).

The study has shown that the two industrial effluents contained some harmful pollutants such as heavy metals which are dangerous to life of plants. It has revealed that pharmaceutical and soap and detergents effluent adversely affected germination, growth and development of *Corchorus olitorius* and *Senna occidentalis*. The damages done to the plants at higher concentrations of the industrial effluents treatment are more severe than at lower concentrations. These effluents also portend toxic effects on the anatomy of *Corchorus olitorius* and *Senna occidentalis* in such a way that several anatomical structures were modified as found in the leaf epidermis. It is evidently clear that low concentrations of this effluent can be non-toxic to plants growth. Also other industrial effluents apart from the ones used in this experiment can be used with varying concentration of the effluents for more accuracy. The various parameters in *Corchorus olitorius* and *Senna occidentalis* may constitute methods of environmental assessment.

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