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Full Length Research Paper

Effect of industrial effluents on the growth and anatomical structures of *Abelmoschus esculentus* (okra)

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The authors investigated the impact of industrial effluents from 5 different industrial concerns in Lagos, Nigeria on Okra (*Abelmoschus esculentus*). During the study, it was observed that these effluents induced detrimental effects on the flowering, fruiting, stem length, leaf width and leaf length of okra. Other parameters analysed were pH, electrical conductivity, total dissolved solids, chemical oxygen demand (COD), biological oxygen demand (BOD) and oil level. Results obtained show that the main drain (MD) had the highest electrical conductivity (1961 µs, pH 10.43), as well as total dissolved solids (TDS, 977 mg/l). Effluent from toiletries had the highest concentration of oil (0.121) and the lowest pH (2.75). All effluents affected the time of flowering and fruiting of okra when compared with the control. The mean number and mean weight of fruits produced were also affected, although the extent varies from effluent to effluent. The effect was more pronounced in toiletries and plastic effluents where the mean values for fruit numbers was 3 and mean weight of 17.4 g. However, the mean weight for paint was higher than toiletries. Cross-sections of the experimental okra plants showed that the effluent affected the anatomical structures of the plant; the effect being more pronounced on okra grown on MD. The anatomy of the control grown okra was not affected. The leaves of okra grown on toiletries effluent had a less mean leaf length than those grown on the rest effluents. The same trend was recorded for the mean leaf width. The stem length of okra grown on paint effluent had the least mean value and hence most affected. The highest value for all parameters studied was recorded for the control. There was a significant difference between the means of length of leaf, stem and leaf width and those of the control, signifying the effects which industrial effluents could have on the growth and productivity of plants.

Key words: *Abelmoschus*, anatomy, effluent, cross-section, fruiting.

INTRODUCTION

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 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 are unquantifiable. Until now, effluents are discharged into rivers, estuaries, lagoons, or

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the sea without any form of treatment. However, despite the treatment being employed by some industries, it is still impossible to remove all undesirable properties from effluents.

In Nigeria today, the Federal Environmental Protection Agency (FEPA) is doing everything possible to see that various industries comply with the standard required of their effluents before they are discharged into the environment. NEST (1991) studied the effect of thick black effluent from 2 breweries on Ikpoba River in Benin City, Nigeria and concluded that there was a decrease in dissolved oxygen, an increase in BOD, a massive increase in COD and an equally massive increase in total suspended solids, all of which have effect on the flora and fauna of aquatic life. Today in Nigeria, industrial effluents especially from textile mills have turned the water of River Iya Alaro and Shasha permanently bluish-green as well as increased the pH, sodium compounds and lead content to an unimaginable level (NEST, 1991).

In Lagos and adjoining towns, vegetable gardens are springing up in every available land. Farmers irrigate their gardens with water obtained from rivers and streams, which receive effluents from these industries. This practice has been on for a very long time unabated. This research is therefore aimed at studying the effect of effluent from various industries, which are frequently discharged into streams and rivers on the germination, growth, flowering and fruiting of *Abelmoschus esculentus* (okra) and to advice the appropriate government agencies to monitor the activities of these farmers effectively and discourage them from using effluents from industries as irrigational means.

Crowe et al. (2002) in their study observed that exposure of oil sand effluents had an inhibitory effect on the germination (percent and/or rate) of several plant species (tomato, clover, wheat, rye, pea, reed canary grass, loblolly pine). In addition, they observed that clover and tomato seeds' germination were most affected. Powell et al. (1996) also observed that fresh weights of seedlings were significantly reduced by treatment waters, while dry weights were generally unaffected when these plants were exposed to pollution stress. Caywela et al. (1996) and Zheng et al. (1998) found that seeds in iron-rich media germinated later than the control and showed physiccal deformities at the seedling stage. Soil kept moist with high sulphate waters (>1200 ppm) had a negative impact on the rate or percent of germination of barley and reed canary grass seeds, as compared to controls (Golden Associates Ltd, 1997).

A. esculentus commonly known as okra belong to the phylum-Spermatophyta, family-Malvaceae, class-Angiospermae, order-Malvales, genus - *Abelmoschus* and species-*esculentus*. It is found both in tropical and temperate regions of the world. *A. esculentus* is a fibrous perennial herb, which grows up to 3 m high. Members of the family, which *A. esculentus* belong are deep rooting and can withstand drought and it is not usually transplanted (Steentoft, 1988).

The plant flowers booms for only a day and eventually forms the okra pod. The fruit when young is green in colour and this is the form in which it is eaten as a fruit vegetable. Most variety of okra will start yielding fruits about 60 days after planting (Steentoft, 1998).

In most African countries, okra is usually cultivated for its tender pods, which are very rich sources of carbohydrates, proteins and vitamins. It also provides essential amino acids. The high mucilage content of pods impact a glutinous consistency to soups and gravies and gives them a desirable "draw quality", which facilitates swallowing of relatively rough or coarse textured "eba" from garri or other starchy foods (Okigbo, 1975).

Okra is self-pollinated and a short duration vegetable with considerable variation within species in plant height, fruit size, leaf size and shape, mucilage content and chemical composition. The different species available in Nigeria are Jokoso, Tae 38, v35 and NHAe 47 (NIHORT, 1990). Most varieties are vulnerable to predominant attacks by such insects as flea, beetles, grasshoppers and white flies. Okra generally has an indeterminate growth habit. Oyenuga (1968) in his study on the chemical composition of some Nigerian vegetables emphasized on the beneficial contribution of okra to low-income group. Furthermore, he observed that amino acid of okra as well as that of egusi (melon) kernel compares favourably with those of soybean meal and poultry egg. Okra fruits can readily supply the essential amino acid required by the body. Most farmers interplant okra with such major crops as maize, yam and cassava as well as other vegetables such as amaranthus and melon e.t.c. Whether okra is grown as a sole crop or intercropped, the problem of weed interference persist and this affects the vegetable's reproductive growth. So, the type of weeds is therefore as important as the removal of weeds itself (Agamalian, 1981).

Evan (1972) in his work observed that parts of the okra plant itself may react on its surroundings to produce environmental changes, which may immediately affect other parts of the same plant or produce effects later on with time. Acutis (1993) used the effect of different temperature range to assess the performance of rice (*Oryza sativa*). Sona et al. (1995) chose light as their own environmental condition, while studying the growth stages in *Eugenia dysenterica*.

The effect of effluents has been used by some workers on some plant varieties. Ramasubramaniam et al. (1993) observed that germination percentage and seedling length of *Phaseolus mungo* grown in sand culture decreased with an increase in the concentration of effluents obtained from match and dye industries. They in addition, observed that decrease in plant's fresh and dry weight paralleled a decrease in leaf pigment (chlorophyll a and b carotenoids). They attributed this to the degradation of chlorophyll caused by increased peroxidase activity.

Parday (1994) observed that low effluent concentration

(10%) of distillery effluent enhanced the germination of all species of forest seeds used relative to control values, but that high effluent concentrations (20-80%) totally inhibited germination in all species. The result indicated that seeds of *Acasia catechu* were more resistant and more vigorous than those of *Dalbergia sissoo* and *Monus alba*. Srivastava (1991) used effluents from paper mill industries to show the effect of effluent on seed germination and early growth performance of radish and onion. He found out that germination and early growth (root and shoot length, number of secondary roots) were decreased by chloro-alkali plant effluent. There was a negative correlation between germination and early growth with increase in concentration of all 3 effluent used. He attributed decreases in germination and early growth to high quantities of total suspended solids in all the effluents and high concentration of mercury metal and chloride in chloro-alkali plant effluent. Wang et al. (1991) used some higher plants like duck weed (*Lemma minor*), lettuce and rice to assess the toxicity of industrial and municipal effluents. A pre-treated industrial sample of a metal processing plant exhibited 98% inhibitory effect on *L. minor* but was not toxic to lettuce or rice germination, whereas a sample from a dairy plant caused 100% inhibition respectively in lettuce, rice and duck weed. Vijayarengan and Lakshmanachary (1993) used textile mill effluent on green gram seedling to show the effect on their growth and development.

Cargill and Jefferies (1994) observed that the range of substances capable of adversely affecting plant growth is enormous and inevitably the specific effects of these toxins are too numerous. Foy et al. (1978) suggested that aluminium alone in high concentrations might fix phosphate on root surfaces accompanied by a resultant decrease in root respiration, cell division, cell wall rigidity and the uptake and utilization of calcium, magnesium, phosphate, potassium and water. Healer and Waryne (1985) also observed from their experiments that aluminium causes a reduction in calcium uptake. Both workers observed that cotton roots exposed to aluminium concentration between 0.15 and 0.30 mg/l resulted in reduced uptake of calcium, magnesium, potassium, phosphate, nitrate and water. This shows that aluminium caused some fundamental damage to the cell membrane. Malabika (1987) studied the effect of industrial waste waters on the root meristem cell of *Allium sativum*. This study was done with effluents from a distillery, cycle factory and steel and tar plant. The effluents caused cytological abnormalities, which differ markedly, indicating that the constituent com-ponents of the effluent affected the metabolic pathway differently. Agrawal and Agrawal (1991) showed that factory effluent decreased chlorophyll a and b and also reduced the carotenoid content of plants. Ajmal (1984) studied the physiochemical characteristics of dairy processing effluent and the effect of its discharge on fertile soil and on kidney bean and pearl millet. While the undiluted effluent restricted the germination of kidney beans that of pearl millet was enhanced. Nennah and Kebbia (1983) showed that grasses were tolerant to arsenate after studies on soil with mine wastes. They also observed that effluents from an integrated pulp paper mill used for irrigation of sugarcane increased yields to about 20%.

MATERIALS AND METHODS

Materials

Materials used for the study include okra seeds, industrial effluent, perforated bags, loamy soil, metre rule, hydrochloric acid, aqueous iodine, new blade, Canada balsam and microscope with camera.

Sources of industrial effluent

The industrial effluents used in this study were obtained from 5 different sources viz: paint industry at Ikeja Lagos, Nigeria (Eagle Paint Nigeria Limited); toiletry section of PZ Nigeria PLC, Ikorodu extension, Ikorodu Lagos, Nigeria where products such as hair relaxer, body cream, toothpaste e.t.c are produced; soaps and detergents section (PZ Nigeria PLC, Ikorodu extension, Ikorodu Lagos, Nigeria; plastic industry at Ilupeju (PZ Thermocool Department, manufacturers of refrigerators, freezers and air-conditioners), specfically the plastic section and; the main drain which is the main collection point where all the effluents meet and dilution is enhanced.

Each of the effluent was analysed for colour, pH, conductivity, total dissolved solid, COD, BOD and oil level.

Source of plant materials

The okra seeds were obtained from the International Institute for Tropical Agriculture (IITA), Ibadan, Oyo State, Nigeria.

Source of soil

The loamy soil used in this study was obtained from the Botanical garden of Yaba College of Technology, Yaba Lagos, Nigeria.

Soil preparation

The soil used in this study was loamy soil as okra is known to grow well in it. Six nursery polythene bags were disinfected with 70% alcohol and cleaned aseptically, perforated and labelled accordingly as; (1) control, (2) MD (main drain), (3) DB (detergent bar), (4) toiletries, (5) plastic and (6) paints, signifying the origin of the effluent. The bags were filled with approximate amounts of loamy soil, which has previously been mixed with manure and mixed thoroughly with 2 L of each of the effluent respectively. The control was mixed with water.

Sowing and wetting

4 healthy seeds of okra were planted in 4 different spots on each of the bags. The seeds were wetted with the different effluent as labelled on the bag and the control was wetted with water every 3 days. At every wetting, 200 ml of the effluent was used on each of the bag apart from the control for 3 months 3 weeks.

Weeding

Hand weeding was done at 3 days interval during which period

Table 1. Time of fruiting.

Effluent used	Time/date of fruiting
Main drain	1/07/05 (81 days)
Detergent bar	27/06/05 (79 days)
Toiletries	18/07/05 (114 days)
Plastic	15/07/05 (111)
Paints	28/06/05 (80days)
Control	18/06/05 (70 days)

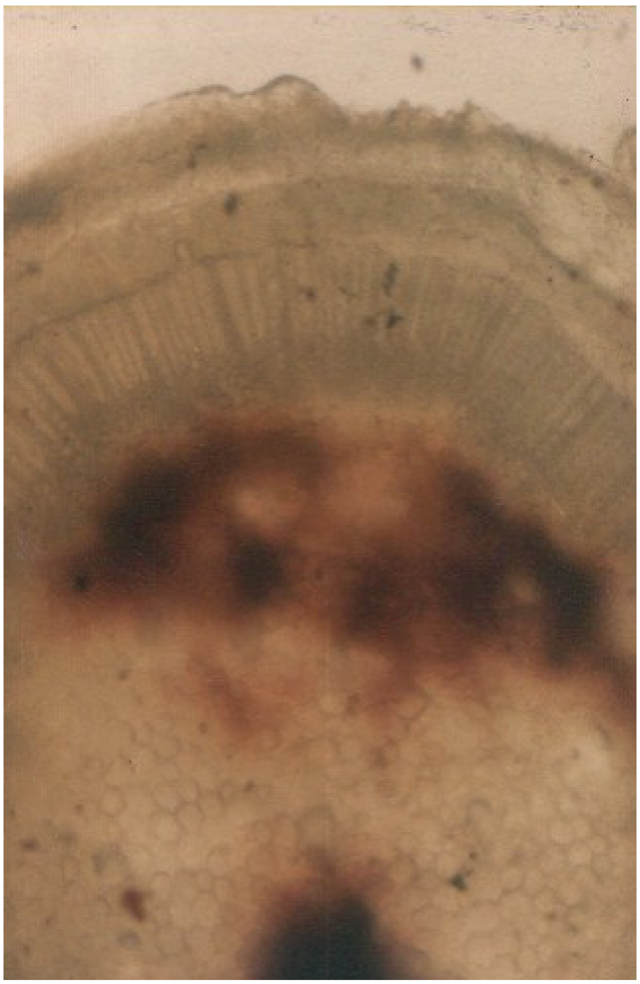

Figure 1. Cross section of Abelmoschus esculentus grown on tap water. Cork cells, xylem, and phloem as well as pith cells were well formed. No pathology condition was observed in the anatomy of the plant cross-section.

wetting of the plants was done. This helped to eliminate weeds growing along with the okra.

Effect of effluents, data collection, observation and analyses

The effect of the effluents were measured in terms of length of plant stem, (measured to the nearest 1.0 cm with a metre rule starting from the base of the plant above the root (soil level) to the apex of the plant), leaf length, leaf width (measured to the nearest cm), time of fruiting, number of fruits, weight of fruits and other pathological observations from cross-sections of the stems.

The growth of the okra was monitored for 3 months 3 weeks. All observations and measurements are as presented in the result section. The results were similarly subjected to statistical analyses using analysis of variance (ANOVA) and student t-test to determine; (1) if there was any significant difference between the stem length, leaf length and width of the okra plants for the different effluents; (2) if differences in effluent sources were responsible for observed phenomenon; (3) if effluent sources have a direct bearing on the weights of the okra fruits observed for each effluent.

Slide preparation for cytological examination of okra tissues

The transverse section of the stem was made in different sizes of very minimal thickness and the best section was selected and put on a slide. The prepared section was washed with alcohol to dehydrate the shiny material on the prepared tissues. Thereafter, it was stained with hydrochloric acid, followed by the addition of iodine and allowed to dry for 2-3 min. It was then washed with tap water and dehydrated with 70, 90 and absolute alcohol for few seconds. The slides were then blotted with filter paper after which a drop of Canada balsam was added on top of the tissue and then covered with a cover slip. The preparation was then put on a hot plate to dry and then observed under the microscope and photographs taken. The procedure was repeated for the okra in all the effluents as well as the control.

RESULTS

Time of fruiting

Planting was done with all effluents on the same day-8th April, 2005. The results obtained for time of fruiting for each effluent studied are as presented in the Table 1. The species of okra used in this study (NHAe 47) is expected to start fruiting after 2 months 10 days (70 days).

Cytological studies of the cross-section of stems of *A. esculentus* (okra) grown on different effluents.

Main drain (MD): Analysis of the cross-section of the stem of plants grown in the presence of the effluent from the main drain (Plate 1) reveals cytological death of tissues (parenchyma tissues) in the pith. The rings indicating the arrangement of the phloem and xylem tissues was tremendously reduced compared to the control (Figure 1). The phloem and xylem appeared to be reduced in size compared to the control (Figure 1).

Detergent and bar (DB): Cross-section of plants grown in the presence of this effluent showed pathological death of the xylem and phloem tissues within the matrix. The boundary between the phloem and xylem tissues is not discernible as a result of the effect of the effluent. Some of the parenchyma cells in the pith also appear morbid (Figure 2).

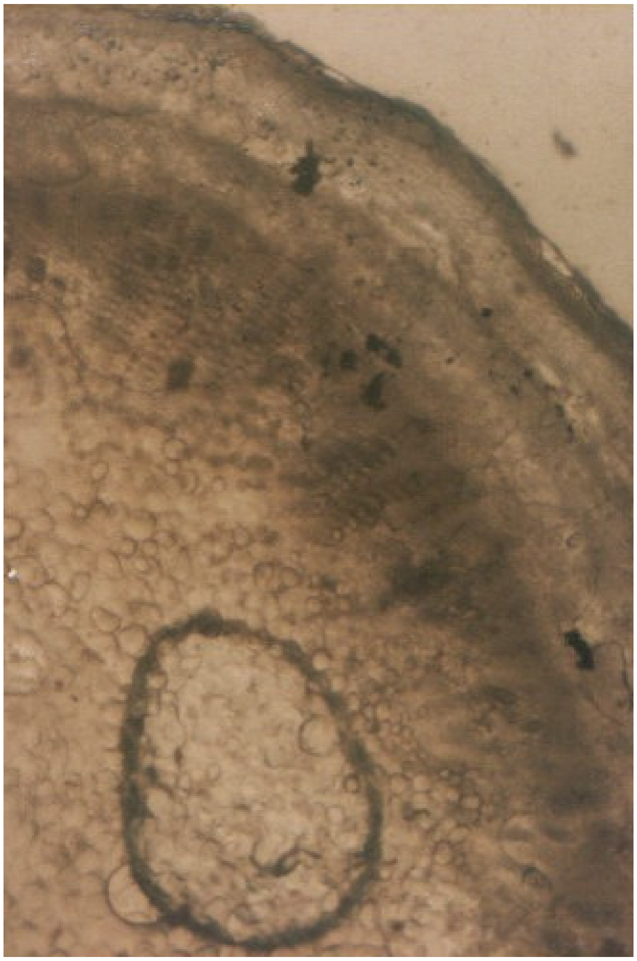

Figure 2. Cross section of *A. esculentus* grown on detergent and bar (DB) effluents showing pathological death of the phloem and xylem tissues, which appear decayed in the vascular matrix. Most of the parenchyma cells in the pith had also become morbid.

Figure 3. Cross section of *A. esculentus* grown on toiletries effluent. The phloem and xylem tissues appear to have lost their structural integrity making it difficult to recognize each tissue distinctly. Both bundles appeared to have become morbid.

Toiletries: Studies of the cross-section of the plant grown with this effluent showed the xylem and phloem to have lost their integrity making it increasingly difficult to observe them, although the basement upon which they are arranged could be seen faintly. Again the pith cells looked muddled up (Figure 3).

Plastic: Studies of cross-sections from plants grown in this effluent revealed that xylem and phloem though arranged appear to have distorted growth as against what was observed in the control (Figure 1). The xylem tissues appeared shortened and the width of the phloem tissues narrowed in the vascular pattern. The parenchyma cells of the pith cannot be seen (Figure 4)

Paint: Observation of a cross-section of plant grown with this effluent shows pathological death of the parenchyma of the pith cells. Although the xylem and phloem were well formedthey showed pathology along their length towards the pith. The phloem and xylem are easily discernible (Figure 5).

Control: Cross-sections of the tissues of okra grown under controlled condition revealed well formed xylem and phloem as well as pith tissues. The cork cells are also well formed. No pathological cells were seen in any of the tissues from the cross-section made.

Statistical analyses of average length of stem, leaf length and width determined for every 10 days throughout the period of observation

Measurement of the above parameters was for the period the growth lasted that is, measurement was stopped as soon as fruits were observed emerging. Values obtained are as shown in Tables 2, 3 and 4.

Figure 4. Cross-section of *Abelmoschus esculentus* grown on plastic effluent. Growth in the vascular matrix appears stunted for both xylem and phloem tissues. The pith parenchyma appears morbid.

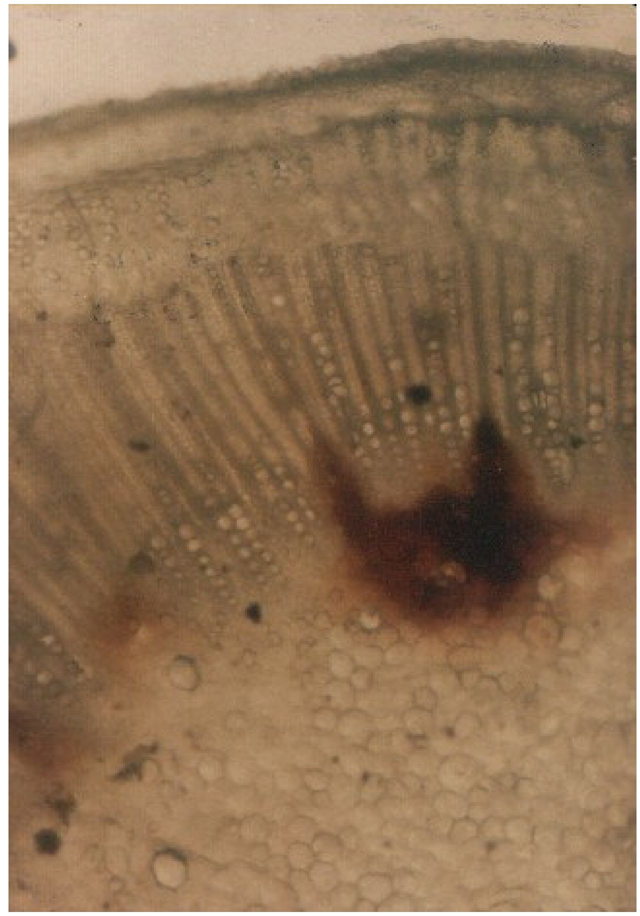

Figure 5. Cross section of A. esculentus grown on paint effluent shows pathological death of some of the pith parenchyma cells. Although the xylem and phloem were well formed, they showed pathology towards the pith.

The parameters analysed in all the effluents used were total dissolved solids, (TDS), chemical oxygen demand (COD), biological oxygen demand (BOD), colour, pH, conductivity, and oil level. The values obtained for each of the parameters analysed in the effluents were not consistent.

However, the COD value (43.2) was higher for plastic effluent than the rest effluents. The value for conductivity was higher for main drain (1961) than the rest effluents. The total dissolved solid (TDS) was also higher for main drain (977) than for the remaining effluents (Table 5). Similar results were obtained by Ramasubramanian (1993) during the analyses of industrial effluents. The period of fruiting of okra for all the effluents was different as can be seen from Table 1. The control fruited at the expected period of time for the species of okra under study (2 months 10 days). Contrariwise, all the okra grown with all the industrial effluents experienced delayed fruiting. The effect was more pronounced on okra grown with effluent from toiletries, which started fruiting after 3 months, 2 weeks and 10 days of planting (Table 1). This was closely followed by okra planted with plastic effluent (3 months, 2 weeks and 7 days. More fruits were produced by okra grown in the control than all okra grown on effluents, producing an average number of 9 fruits, while MD, DB and paint effluents yielded an average number of 4 fruits each. Toiletries and plastic effluents had the least number of fruits (3) (Table 6). The mean weight of fruits obtained show that fruits from effluent grown okra were less in weight relative to the control (30 g). This value was closely followed by okra grown on paint effluent (24.3g) and MD (20.7 g) (Table 7). The mean lengths of stem of okra grown on effluent were less than the control (38.94 cm) (Figure 6).

This value was followed with DB (34.96), MD (32.94 cm), toiletries (32.43 cm), plastic (29.43) and paint (28.61 cm) (Table 2). The mean leaf length obtained was higher for the control (12.1 cm), which was closely followed by MD (12.029 cm), DB (12.0 cm), plastic (11.986 cm), paint (11.1 cm) and toiletries (10.743) (Figure 7). Hence, the leaf length was more affected by the effluent from toiletries (Table 3). The mean leaf width of the control (16.477) was higher in value compared with the values obtained

Table 2. Mean value, standard deviation and pulled stem length per effluent.

Effluent	Stem length reading per effluent							Total	Mean	Std. deviation
MD	8.3	15.5	22.6	29.7	31.9	55.6	67.0	230.6	32.94286	21.22630892
DB	8.9	14.7	22.7	31.1	37.6	59.0	70.7	244.7	34.95714	22.79267844
Toiletries	6.9	13.3	19.4	25.5	35.3	50.9	75.3	227.0	32.42857	23.81349157
Plastic	9.9	14.6	19.5	24.1	31.2	49.1	57.7	206.0	29.42857	17.89559669
Paint	9.5	15.8	20.4	24.7	29.6	45.9	54.4	200.3	28.61429	16.21228223
Control	7.3	16.0	24.5	31.6	51.7	63.6	77.3	272.6	38.94286	25.80225166

Table 3. Mean, standard deviation and pulled leaf length per effluent.

Effluent	Leaf length reading per effluent							Total	Mean	Std. deviation
MD	3.5	8.3	11.7	13.5	15.1	17.1	15.0	82.2	12.02857	4.706277469
DB	3.6	9.4	12.8	13.1	14.1	15.9	15.1	84.0	12.0	4.250490168
Toiletries	3.6	7.7	10.8	12.5	13.5	13.5	13.6	75.2	10.74286	3.802129729
Plastic	3.4	9.0	12.1	13.6	15.2	15.7	14.9	83.9	11.98571	4.432241183
Paint	3.2	7.4	11.9	12.6	13.8	13.9	15.9	77.7	11.1	4.381019668
Control	3.2	8.0	12.4	12.7	16.1	16.8	16.4	85.0	12.14286	5.044421719

Table 4. Mean value, standard deviation and pulled leaf width per effluent.

Effluent	Leaf width reading per effluent							Total	Mean	Std.deviation
MD	3.3	8.6	13.5	16.3	16.9	17.0	17.8	93.4	13.34286	5.446973821
DB	3.7	10.9	14.6	15.3	18.2	20.2	22.5	105.4	15.05714	6.301549318
Toiletries	3.4	8.4	11.8	15.7	16.1	16.9	18.5	90.8	12.97143	5.433143438
Plastic	3.4	10.4	14.6	17.2	19.0	19.0	21.1	104.7	14.95714	6.190276554
Paint	2.9	8.0	12.3	16.0	16.5	17.7	22.9	96.3	13.75714	6.643758259
Control	3.6	9.4	15.9	19.2	20.3	22.14	24.8	115.34	16.47714	7.523362977

Table 5. Analysis of effluents before use.

Effluent	Source	pH	Conductivity (µs)	TDS (mg/g)	COD	BOD	Oil level
Main drain	Greyish	10.43	1961	977	31.32	4.30	0.072
Detergent bar	Bluish green	9.21	11.39	568	12.93	4.31	0.001
Toiletries	Cloudy	2.75	1210	604	8.96	3.15	0.121
Plastic	Almost clear	5.12	456	229	43.2	2.7	0.001
Paint	Brownish black	4.87	389	198	31.3	3.5	0.0002

µs, Microsemien; TDS, total dissolved solid; COD, chemical oxygen demand; BOD, biological oxygen demand.

for all the effluent grown okra (Figure 8). This was closely followed by DB (15.057), plastic (14.957), paint (13.757), MD (13.34286) and toiletries (12.971). Effluent from toiletries has more deleterious effect on the leaf width (Table 4).

DISCUSSION

The issue of the discharge of raw effluents and their effect on the ecology has been discussed extensively by several workers (Agrawal and Agrawal, 1991; Ajmal, 1984; Malabika, 1987; Nennah and Kebia, 1983; Ramasubramanian, 1993). Effluent from different sources were analysed for total dissolved solid (TDS), chemical oxygen demand (COD) and biochemical oxygen demand (BOD) and other parameters like colour, pH, conductivity and oil level.

Results obtained showed that for COD, plastic 43.2> MD 31.32> paint 31.3> DB 12.93> toiletries 8.96. These

Table 6. Average number of fruits on a stem in each of the effluent bags.

Effluent	Number of fruits
Main drain	4
Detergent bar	4
Toiletries	3
Paint	4
Plastic	3
Control	9

Table 7. Average weight of fruits

Effluent	Weight of fruits (g)
Main drain	20.7
Detergent Bar	17.5
Toiletries	17.4
Plastic	19.0
Paint	24.3
Control	26.0

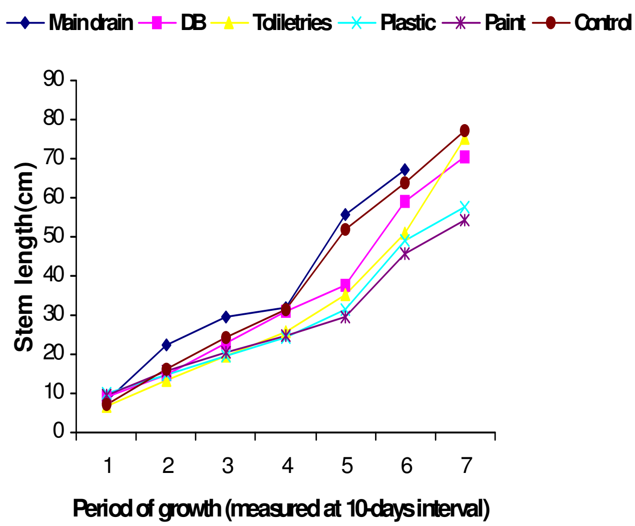

Figure 6. Growth curves of mean stem length of *A. esculentus* in different effluents (cm).

values are far higher than the standard value recommended by FEPA (1991). This result shows that the level of concentration of chemical substances decreases in the order presented. Vijayerengan and Lakshmanachary (1993) had discussed the effect that low and high concentrations of effluents have on total chlorophyll and carotenoid contents of green grain seedlings. However, the BOD values for these effluents were a reverse of those recorded for COD.

When okra was grown in the different effluents and control, various effects were noticed on the time of

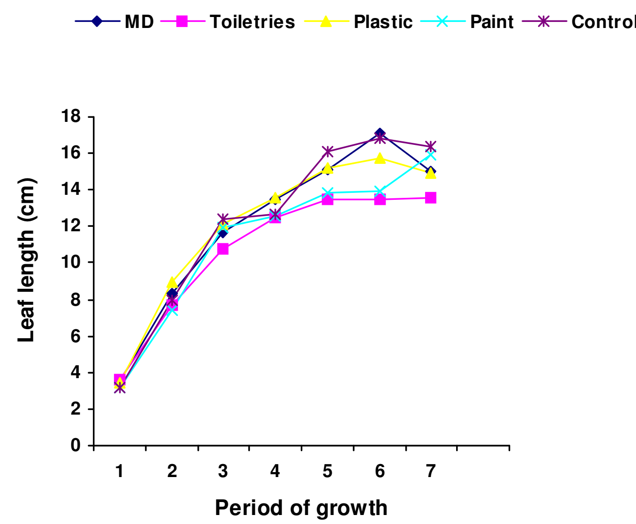

Figure 7. Curves of mean of leaf Length of *A. esculentus* grown in different industrial effluents.

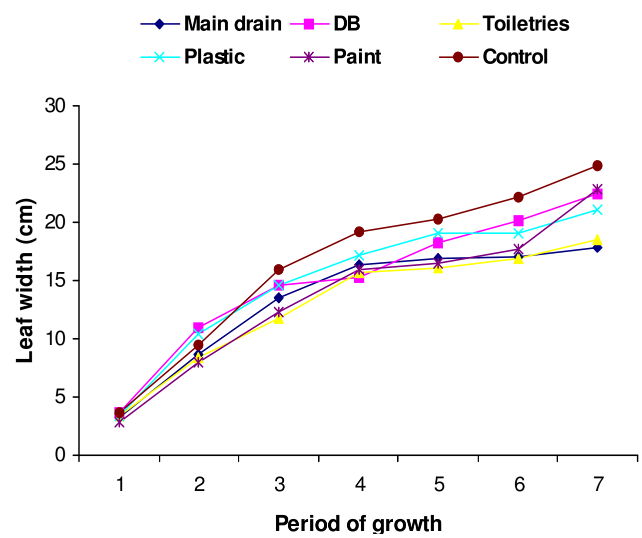

Figure 8. Curves of mean leaf width of *A. esculentus* in different industrial effluents (cm).

flowering, fruit formation, number of fruits and weight of the resulting fruits (Tables 1, 6 and 7). The different results obtained for okra grown in the different effluents is in line with the findings of Malabika (1987) that toxic materials in effluents are capable of affecting the metabolism of plants. Furthermore it is not inconceivable that the constituents of the effluents may have affected the chlorophyll molecules as well as the carotenoids and physiological processes of the okra plant as observed by Ramasu-bramanian (1993). Srivastava (1991) on his study on the effect of paper mill effluent on seed germination and early growth performance of raddish and onion noted stunted growth and poor development of the two plant species.

Figure 9. Cross section of *A. esculentus* grown on main drain effluent showing cytological death of parenchyma tissues accompanied with increasing morbidity at the tip of the vascular bundle.

We decided to study a cross-section of the stems of okra grown on the different effluents to ascertain if there was any pathological damage to the vascular tissues. A critical observation of the cross-section of the stem of okra grown on MD effluent reveals cytological death/or malformation of some of the tissues (parenchyma) in the pith. The space occupied by the xylem and phloem were tremendously reduced when compared with the control (Figure 9).

In the case of okro plants grown on effluents from detergents and bars, the xylem and phloem were no longer arranged on the ring but scattered within the matrix. It is difficult to identify the boundary between the xylem and phloem (Figure 2). For okro plant grown with effluent from toiletries, the normal arrangement of the vascular bundles was distorted although the basement upon which the bundles were arranged can be seen clearly (Figure 3).

For plastic effluents, the cross-sections made showed the vascular bundles were arranged on the basement with minor distortions compared to the control. However, the xylem appeared shortened and the width of the phloem tissues narrowed in the vascular bundles (Figure 4).

For sections of plants grown on paint effluent, we observed obvious morbidity of the parenchyma tissues of the pith and are scattered within the matrix (Figure 5). The prepared sections from plant grown on control revealed properly formed xylem and phloem and pith tissues; there were no pathological death observed for all the tissues (Figure 1). These findings are supported by Malabika (1987) in their study of industrial wastewaters on root meristem cell of *Allium sativum*. They observed that the effluents caused cytological abnormalities, which differ markedly indicating that the constituent component of effluents affected the metabolic pathway in different ways.

The length of stem, leaf and width of okro measured over the period of cultivation for each effluent were subjected to statistical analyses (SPSS, SSP and MS excel) using ANOVA and t-test. It was observed that there were no significant differences between the mean lengths of stem readings of the various effluents as $F_{tab} > F_{cal}$ at $\alpha = 0.05$ (2.90 > 0.21524). Likewise, there was no significant difference between the means of length of leaf readings ($\alpha = 0.05$) as $F_{tab} > F_{cal}$ (2.90 > 0.123) of the various effluents. There was also no significant differences between the means of leaf width readings of the various effluents ($\alpha = 0.05$) as $F_{tab} > F_{cal}$ (2.90 > 0.3044).

When the mean of stem length of readings of plastic effluent were analysed against those of the mean of stem length of reading of the control, t-test showed that there was a significant difference between the two readings as $t_{cal} > t_{tab}$ ($\alpha = 0.05$) (2.850739041 > 2.447). For paint effluent, t-test showed that there is a significant difference between the mean stem length of readings of paint as an effluent and those of the mean stem length readings of the control as $t_{cal} > t_{tab}$ (2.632839298 > 2.447). When the mean stem length of readings of the effluent from toiletries grown okro were analysed against those of the control, t-test showed that there was a significant difference between them as $t_{cal} > t_{tab}$ (2.926767394 > 2.447). These findings indicate that the various effluents exerted their effects in varying degrees on leaf length, leaf width and stem length of the okra. However, when the mean stem length of okro plant grown on the effluents were compared with those grown on the control, tremendous differences were observed as the stem of okro grown on the control were longer than those grown on the effluents. This observation is in line with the findings of Srivastara (1991) and Malabika (1987) on their work on raddish and onion seeds and *A. sativum* respectively. Talukdar et al. (2008) in their study on the effect of pulp and paper mill effluents on seed germination and seedling growth of mustard, pea and rice seeds noted varying degrees of symptoms on these plants and that the more concentrated the industrial effluent, the more pronounced the symptoms observed. Meaning there could be a threshold concentration of the effluent that could be debilitating to the growth and development of these plants.

It follows that the differences in values obtained for leaf and stem length as well as leaf width may have resulted from the effect exerted by different chemical species pre sent in the various effluents. This factor may also have accounted for the number of fruit yield from the okro plant grown in the different effluents (Table 6). Since plant productivity is a function of photosynthesis, it is not implausible that the constituent of the different effluent may have affected the chloroplast, chlorophyll and therefore productivity (Ramasubramanian, 1993). The effluent also affected time of flowering and fruiting differently (Table 1); the control fruiting before all effluent grown plants in 2 months 10 days which is the expected period of fruiting for the variety (NHAe 47) of *A. esculentus* used in this study. Hence each of the effluent caused delay in fruiting of the plant.

The various results obtained in this study confirm the effect untreated effluent could have when discharged on land, natural bodies of water and when used to cultivate plants. The fact that all the effluents have cytological effect on the anatomy of the plant goes further to indicate that a stringent policy on appropriate effluent management by industry should be rigorously pursued. In addition, to maximize the contribution of okro to national diet rather than diseases (Oyofu, 1989), it is imperative that the activities of gardeners who use effluents from these industries as means of irrigation for their crops be checked. They should be educated to acknowledge that the use of such effluents will not only reduce yield but also cause death to consumers. Above all, they should also be educated on the health implication of crops cultivated using such effluents.

Conclusion

In the course of this study we observed that all the effluents from the 5 different industrial concern affected *A. esculentus* in different ways. These effects were seen in time of flowering and fruiting, number of fruits, weight of fruits, and effect on vascular bundles.It was also observed that industrial effluents could also delay the time of flowering and hence fruiting. The various cytological conditions observed in the cross-section of the stems showed the potential danger that industrial effluents pose to plants. Despite the ruggedness and ability of *A. esculenttus* to withstand harsh environmental conditions, it was susceptible to the effect of the effluents.

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REFERENCES

Acutis M (1993). Growth analysis of Rice (*Oryza sativa*, L) exposed to irrigation water of different temperature. Comparism between Indica and Japonica cultivars. Rivista di Agronomia, 27: 504-508.

Agamalian H (1981). Weed competition and its effect on vegetables: In 33rd Proceedings of California Weed Conference Monetary California. pp. 25-26.

Agrawal R, Agrawal SK (1991). Pollution effect of sugar factory effluents on seed germination and seedling growth of *Cyampsis tetragonoloba*. Indian J. Appl. Pure Biol. 6: 13-16.

Ajmal M (1984). Effect of Industrial Dairy processing effluent on soil and crop plants. Environ. Poll. Series, A33: 97-106.

Cargill SM, Jeffries RL (1984). Nutrient Limitation of primary production in a sub-artic salt marsh. J. Appl. Ecol. 21: 657-668.

Crowe AU, Plant AL, Kermonde AR (2002). Effects of an industrial effluent on plant colonization and on the germination and post-germinative growth of seeds of terrestrial and aquatic plant species. Environ. Poll. 117: 179-189.

Evans GC (1972). The Quality Analysis of Plant Growth. Black Well Scientific Publication, Oxford England. p. 734.

FEPA (1991). Guidelines and Standards for Environmental pollution control in Nigeria. Federal Environmental Protection Agency, Lagos, Nigeria. p. 238.

Healer PK, Wayney RO (1985). Calcium and Plant Development. Plant Physiol. 36: 387-439.

Malabika R (1987). Effect of Industrial Wastewaters on Root meristem cells of *Allium sativum.* Phytomorphology, 37: 359-364.

Nennah MG, Kebbia TE (1983). Redistribution of liquid water effluents by irrigation to Orchards and Farms. Environ. Poll. 5: 241-254.

NEST (1991). Nigeria's Threatened Environment: A National Profile, pp. 76-85.

Okigbo BN (1975). Farming Systems for the production of fruits and vegetables. 1st National Seminar on fruits and vegetables, Ibadan, Nigeria. pp. 48-62.

Oyolu C (1980). Maximizing the contribution of okro to the National Diet. Paper Presented to 3rd Conference Horticultural Science of Nigeria at the University of Ife, Ile-Ife, Nigeria.

Parday DK (1994). Distillery Effluent a Potential Resource for Irrigating Forest Seed beds. Abio 23(4-5): 267-268.

Ramasubramanian S (1993). Analysis of Industrial Effluent and their impact on the Growth and Metabolism of *Phaseola mungo L.* Communication in Soil Science and Plant Analysis, 24(17-18): 2241-2249.

Srivastava RK (1991). Effect of Paper Mill Effluent on Seed Germination and Early Growth Performance of Radish and Onions. J. Ecotoxicol. Environ. Monitoring, 1(1): 13-18.

Steentoft M (1988). Flowering Plants in West Africa. Cambridge University Press, England. p. 344.

Vijayarengan P, Lakshmanachary AS (1993). Effect of Textile Mill Effluent on Growth and Development of Green gram Seedlings Adv. Plant Sci. 6(2): 359-365.

Wang W, Gorsuch JW, Lower WR, Lewis MA (1991). Higher Plants (Common Duckweed Lettuce and Rice) for Effluent Toxicity Assessment; 2nd Symposium on use of plants for Toxicity Assessment, San Francisco, California, USA. 23-24. April 1990.