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Effect of Industrial Coconut Oil Effluent on the Morphological Characteristics of *Corchorus olitorius*

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Abstract There is a growing awareness of the potential health benefit of coconut oil. To that effect, there is also an increase in the amount of production of coconut oil wastewater effluents from the coconut oil producing industries. The shortfall in the pond or canal water condition during the dry season in Nigeria has pushed many local farmers to look for an alternative to use as irrigation water. In this study, different concentrations (0, 20, 40, 60, 80 and 100%) of industrial coconut oil effluents were used to study the morphological characteristics of *Corchorus olitorius.* The experiment was conducted in a greenhouse and arranged in a completely randomized block design. The result obtained was subjected to analysis of variance and the least significant difference test (LSD) at $p < 0.05$ was measured. The results of the study showed a significant decrease ($P < 0.05$) in the morphology characteristics and development of the plant. Seedlings irrigated with 0% (Control) had a higher plant height, stem girth, leaf area, leaf dry weight, root fresh weight and root dry weight but were not significantly different at 20% industrial coconut oil effluent treatment. The 80 and 100% industrial coconut oil effluents treated seedlings could not survive beyond 8 weeks of irrigation. Suggesting that higher concentrations of industrial coconut oil effluents have adverse effects on the survival of the *Corchorus olitorius* plant. A relative decreased in the morphological characteristics observed in plants under a lower concentration of industrial coconut oil effluents, suggest the possibility of less concentrations of toxic compounds present.

Keywords Industrial coconut oil effluent (ICE), Corchorus olitorius, Morphology, Vegetables

1. Introduction

Since its creation, man most important requirements for survival have been food, shelter and clothing and of all the three requirements, food stands out the most needed (Schipper, 2000). Man obtains food from different plant sources. Food obtained from plant sources is in the form of leafy vegetable, fruits, grains, seeds, root stem tubers, spices and nuts (Okafor, 1981; Achinewhu *et al*., 1995). Vegetables stand out as the most popular and valued components of most dishes and diets eaten by man (Schippers, 2000).

Corchorus olitorius L. is a member of the Malvaceae (Olaniyi and Ajibola, 2008). The species was identified as mallow plant which referred to as the leafy edible part (Purseglove, 1968). The species is an annual or short-lived perennial herb, which grows to about 2m tall. The stem is well developed with abundant fibre in the phloem tissues (Chweya and Eyzaguirre, 1999). The leaves are simple, oblong to lanceolate, with a serrated margin, alternately arranged, with setae at the base of the lamina (Edmond, 1990). The flowers are small and yellow, located opposite the leaves and are up to 8-17 mm in diameter. The fruit is a straight or curved capsule that terminates in a beak-like structure, which is the most important taxonomic feature for the identification of the species (Grubben, 1977).

There are many reports on the medicinal potentials of *C. olitorius* (Oboh *et al*., 2009). It had been reported to be useful in preventing constipation (Smith, 1985), treatment of fever and cold (Oboh *et al.,* 2009). It is also used in the treatment of toothache and as an iron supplement (Eifediyi, *et al.*, 2008; Grubben & Denton, 2004; Oyedele *et al.,* 2006). The plant is of significance to the majority of the local rural dweller of the eastern part of Nigeria because of its nutritional and medicinal values. The plant leaves are low-cot compare with other vegetables and are easily grown in the mixed or monocropping farming system (Schippers, 2000).

Increasing population, hunger and couple with the present economic crises, especially in developing nations, is pushing people in the urban cities to look for low-cost vegetables with nutritional and medicinal values (Schippers, 2000). Rural dwellers took advantage to cultivate the plant in

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commercial quantity. The plant is produced in the rainy season when water is abundantly available. In this period, the vegetable is much affordable. During the dry season, most farmers resort to irrigation for the production of the vegetable. In most cases, the water is being supplied by individual water stations (boreholes) dealers (Ubochi *et al.*, 2019). However, the majority of farmers cannot afford to pay for irrigation water. And there is always a shortfall in the pond or canal water after the rainy season this condition has pushed local farmers to seek an alternative to the irrigation water. Therefore, they tend to use industrial effluents which were in most cases wastewater discharged from industries to irrigate the vegetable plantation. The southeastern Nigeria where this study was carried out has many of the coconut oil producing industries (Ubochi *et al*., 2019). The industries are among the major producers of industrial wastewater effluents. Such industries produce coconut oil effluents as wastewater during the production process (Ubochi *et al.*, 2019). Because of the growing recognition of the potential health benefit of coconut oil, the demand is increasing which in turn may increase the amount of production of coconut oil effluents in those areas. Therefore, in this study, the objective was to assess the effect of industrial coconut oil effluent (ICE) on the morphological growth parameters and development of *Corchorus olitorius.*

2. Material and Methods

The study was carried out in the greenhouse of the Botanic Garden, Department of Plant Science and Biotechnology, University of Nigeria, Nsukka (UNN) of 6°51’56’’N latitude and 7°24’22’’E longitude. ICE was collected from a food factory in Nsukka urban. Capsules of *C. olitorius* L. were harvested from a home garden in Danfodio Street, University of Nigeria, Nsukka. Poultry manure was bought from a poultry farm in the Department of Animal Science, University of Nigeria, Nsukka.

Chemical Analysis of Industrial Coconut Oil Effluent

The pH was determined using a battery-operated pH meter (Hanna Model). The biochemical oxygen demand (BOD) was determined following Winkler’s method as described by Horvitz and Latimer (2006). Chemical oxygen demand (COD) was determined by mixing 3.5 ml of sulphuric acid and 1.5 g of potassium dichromate (Carranzo, 2012). Total organic carbon was determined by titration of ferrous ammonium sulphate. While potassium, zinc, nitrogen, and copper, were determined by the process described by Horwitz & Latimer (2006) using a spectrophotometer (Systronic 21D). The presence of mercury was determined using the mixture/solution of 0.002 M potassium iodide (AOAC, 2002). The lead was determined by the sodium sulphide method (AOAC, 2002). Cadmium was determined using xylenol orange indicator (AOAC, 2002).

Field Experiment

Twenty-eight (28) poly pots (25 x 12 cm) filled with 10 kg topsoil and poultry manure (2:1) was used in the nursery. Four weeks after seed germination, uniform seedlings were transplanted into three hundred perforated poly pots. The potted seedlings were divided into five batches of sixty poly pots per batch. The five batches of potted seedlings were treatments with 0, 20, 40, 60, 80 and 100% ICE treatments which were transferred to greenhouse. The experimental design was a completely randomized block design (CRBD).

Data Collection and Analysis

Each treatment was replicated three times and each poly pots contains two seedlings. Data were collected on seedling height, seedling girth, leaf area, and the number of leaves, at two weeks interval for fourteen weeks while lateral root and dry weights of seedlings were evaluated at fourteen weeks. The data obtained were statistically analyzed using IBM SPSS software and subjected to analysis of variance (ANOVA) to test the least significant difference (LSD) between means.

3. Results

Chemical composition of industrial coconut oil effluent (ICE)

Table 1. Chemical analysis of industrial coconut oil effluent and tap water

Properties	ICE	TW	FEPA (1991)
pH	3.8	6.9	6.5-9
Total suspended solids (TSS) (mg/l)	500	NA	NA
Dissolved oxygen (DO) (mg/l)	8.50	22.0	NA
Biochemical oxygen demand (BOD) (mg/l)	429.00	3.70	4.00
Chemical oxygen demand (COD) (mg/l)	520.30	40.50	120
Nitrogen (N) (mg/l)	0.29	0.001	0.10
Calcium (Ca) (mg/l)	26.50	15.00	0.20
Magnesium (mg) (mg/l)	36.40	5.00	0.50
Zinc (Zn) (mg/l)	6.50	0.20	2.00
Iron (Fe) (mg/l)	2.60	0.25	5.00
Cadmium (Cd) (mg/l)	1.14	0.10	0.01
Chromium (Cr) (mg/l)	0.02	0.00	0.10
Lead (Pb) (mg/l)	4.36	0.00	5.00
Phosphate (PO_4) (mg/l)	0.35	0.20	0.02
Mercury (Hg) (mg/l)	2.00	0.00	0.10
Nickel (Ni) (mg/l)	0.14	0.00	0.02
Copper (Cu) (mg/l)	8.20	0.05	0.20
Potassium (K) (mg/l)	4.63	0.45	0.02
Fat and Oil	48.04		NA

Key: ICE= Industrial coconut oil effluent; **TW**= Tap water; **FEPA**= Federal Environmental Protection Agency, **NA**= Not available.

The results of chemical characteristics of industrial coconut oil effluent (ICE) had higher values of most of the water quality indicators (pH, total suspended solids, biochemical oxygen demand, chemical oxygen demand, nitrogen, calcium, magnesium, zinc, iron, cadmium, lead, chromium, mercury, nickel, copper and potassium) compared to the tap water. While the pH was lower than the federal environmental protection agency, other parameters were higher (Table 1).

Morphology of plants under industrial coconut oil effluent (ICE)

Results showed that at the second and fourth week after transplanting (WAT), seedling irrigated with 0-100% ICE treatments did not differ significantly ($p< 0.05$) from one another. Plants at 6 and 8th WAT irrigated with tap water (control) grew significantly taller than those irrigated with 100% ICE treatment The control plants also grew significantly taller than plants from 60-100% ICE treatments. As at the 10th WAT, 80 and 100% ICE irrigated plants, majority showed sign of wilt. But plants that grew under 0-40% ICE treatments are healthier and greenish at the 10th week while no significant difference was observed in the plants height (Table 2).

The results as presented in Table 3 showed that there was a decline in the stem girth in ICE irrigated plants as compared to the control. However, from 2-6th WAT at lower concentrations of 20 and 40% ICE treatment, the plants' girth was not significantly different from the control (0%). But from 8th WAT the decrease in stem girth became significant at ($p< 0.05$) (Table 3). On the other hand, between 10-14th WAT the number of leaves did not vary significantly from the survived plants across treatments (Table 4).

The effect of 14th WAT was significantly different from others except for 8 and 100% ICE treatments which shrivelled, wilted and died at the 10th, 12th and 14th weeks after planting (Table 5). The leaf area of 0% treatment was was not significantly different from 20-60% treatments across the weeks except week 10 to 14. At 10th WAT, 0% ICE treatment had the largest leaf area of 50.67 ± 4.81 cm^2 which was significantly different from the leaves of other plants in the ICE concentrations except for 20% ICE treatment (Table 5).

Table 2. Effect of industrial coconut oil effluent on plant height (cm) of *Corchorus olitorius*

Treatment (%)	Duration (Weeks)						
	2	4	6	8	10	12	14
0	15.8 ± 3.06^{a,3}	32.7± 3.06^{a,23}	43.7 ± 4.67^{a,2}	58.0 ± 5.86^{a,2}	64.7± 15.90^{a,1}	66.3 ± 15.12^{a,1}	68.7± 18.89^{a,1}
20	13.0 ± 10.4^{a,4}	28.7 ± 0.88^{a,3}	37.3 ± 1.45^{ab,23}	45.0 ± 2.89^{ab,2}	57.7± 6.69^{ab,1}	61.0 ± 1.53^{a,1}	69.0± 0.58^{a,1}
40	12.0 ± 1.45^{a,5}	27.0± 0.00^{a,45}	34.0 ± 3.19^{ab,34}	44.0 ± 5.86^{ab,23}	45.0± 7.94^{ab,123}	53.3 ± 13.33^{a,12}	61.0± 10.60^{a,1}
60	11.7 ± 1.67^{a,2}	23.7± 10.04^{a,12}	29.0 ± 11.0^{ab,1}	36.8 ± 14.09^{bc,1}	38.2± 7.23^{b,1}	39.60 ± 8.41^{ab,1}	39.7 ± 6.7^{a,1}
80	11.7 ± 1.67^{a,2}	24.0± 2.65^{a,1}	26.3 ± 5.36^{ab,1}	26.0 ± 5.51^{bc,1}	0.00± 0.00^{c,3}	0.00 ± 0.00^{b,3}	0.00± 0.00^{b,3}
100	10.3 ± 0.8^{a,2}	22.3± 2.03^{a,1}	23.3 ± 2.03^{b,1}	20.7 ± 2.96^{c,1}	0.0 ± 0.00^{c,3}	0.00 ± 0.00^{b,3}	0.00± 0.00^{b,3}

Data are presented as mean ± standard error of the mean. Significant means are separated with different alphabets on the same column for treatments (concentrations) effect while the numbers on the same row are for duration (weeks) effect.

Table 3. Effect of industrial coconut oil effluent on stem girth (cm) of *Corchorus olitorius*

Treatment (%)	Duration (weeks)						
	2	4	6	8	10	12	14
0	3.6 ± 0.46^{a,5}	3.6 ± 0.33^{a,5}	4.3 ± 0.38^{a,4}	5.9 ± 0.78^{a,3}	6.9 ± 0.33^{a,2}	7.0 ± 0.70^{a,12}	7.22 ± 0.43^{a,1}
20	3.3 ± 0.23^{a,2}	3.4 ± 0.38^{a,2}	3.8 ± 0.38^{a,2}	4.2 ± 0.34^{b,2}	5.8 ± 0.07^{b,1}	6.2 ± 0.72^{b,1}	6.8 ± 0.12^{a,1}
40	3.1 ± 0.61^{a,3}	3.3 ± 0.38^{a,23}	3.6 ± 0.47^{a,23}	4.0 ± 0.44^{b,2}	5.4 ± 0.00^{c,1}	5.8 ± 0.57^{b,1}	6.0 ± 0.15^{b,1}
60	2.3 ± 0.32^{b,4}	2.4 ± 0.38^{b,4}	3.6 ± 0.23^{a,3}	3.8 ± 0.38^{b,23}	4.0 ± 0.35^{d,23}	4.6 ± 0.20^{c,12}	5.2 ± 0.60^{c,1}
80	2.3 ± 0.38^{b,1}	2.2 ± 0.19^{b,1}	2.0 ± 0.58^{b,1}	1.9 ± 0.34^{c,1}	0.0 ± 0.00^{e,2}	0.0 ± 0.00^{d,2}	0.0 ± 0.00^{d,2}
100	1.9 ± 0.47^{b,1}	1.6 ± 0.12^{c,1}	1.5 ± 0.41^{b,1}	1.25 ± 0.52^{d,1}	0.0 ± 0.00^{e,2}	0.0 ± 0.00^{d,2}	0.0 ± 0.00^{d,2}

Data are presented as mean ± standard error of the mean. Significant means are separated with different alphabets on the same column for treatments (concentrations) effect while the numbers on the same row are for duration (weeks) effect.

Table 4. Effect of industrial coconut oil effluent concentrations on number of leaves (cm) of *Corchorus olitorius*

Treatment (%)	Duration (weeks)						
	2	4	6	8	10	12	14
0	10 ± 0.33^{a,4}	12 ± 1.15^{ab,34}	18 ± 2.65^{a,3}	34 ± 3.21^{a,2}	30 ± 6.77^{a,2}	36± 10.82^{a,12}	40 ± 6.84^{a,1}
20	8 ± 0.33^{b,2}	12 ± 4.18^{ab,12}	16 ± 2.04^{ab,12}	20 ± 0.18^{b,12}	26 ± 15.34^{ab,12}	28 ± 6.98^{a,12}	32 ± 5.21^{a,1}
40	6 ± 0.67^{c,2}	13 ± 3.84^{a,12}	16 ± 1.20^{ab,12}	20 ± 4.41^{b,12}	24 ± 6.06^{b,12}	26 ± 6.69^{a,12}	30 ± 13.87^{a,1}
60	5 ± 0.33^{d,5}	12 ± 2.00^{ab,4}	18 ± 4.36^{a,3}	21 ± 2.89^{b,3}	26 ± 5.21^{ab,2}	34 ± 7.26^{a,1}	32 ± 1.73^{a,1}
80	5 ± 0.33^{e,12}	6 ± 1.53^{a,1}	8 ± 2.33^{b,1}	8 ± 3.00^{c,1}	0.00 ± 0.00^{c,2}	0.0 ± 0.00^{b,2}	00 ± 0.00^{b,2}
100	4 ± 0.88^{f,1}	4 ± 1.33^{b,1}	6 ± 3.84^{c,1}	6 ± 6.66^{d,1}	0.00 ± 0.00^{c,2}	0.0 ± 0.00^{b,2}	0.00 ± 0.00^{b,2}

Data are presented as mean ± standard error of the mean. Significant means are separated with different alphabets on the same column for treatments (concentrations) effect while the numbers on the same row are for duration (weeks) effect.

Table 5. Effect of industrial coconut oil effluent concentration on leaf area (cm^2) of *Corchorus olitorius*

Treatment (%)	Duration (weeks)						
	2	4	6	8	10	12	14
0	14.33 ± 3.48^{a,6}	41.67 ± 1.67^{a,5}	46.67 ± 7.06^{a,4}	46.67 ± 7.06^{a,4}	50.67 ± 4.81^{a,3}	59.67 ± 2.60^{a,2}	62.33 ± 1.67^{a,1}
20	12.33 ± 1.45^{a,6}	41.67 ± 1.67^{a,5}	45.33 ± 5.55^{a,4}	46.67 ± 1.67^{a,34}	48.33 ± 3.48^{ab,3}	54.67 ± 1.76^{b,2}	60.33 ± 0.67^{ab,1}
40	10.33 ± 1.33^{a,4}	35.00 ± 5.00^{ab,3}	44.33 ± 6.36^{a,2}	46.33 ± 2.96^{a,2}	46.33 ± 2.19^{bc,2}	50.33 ± 6.36^{c,12}	56.00 ± 3.06^{b,1}
60	10.67 ± 1.15^{a,3}	28.33 ± 6.01^{ab,2}	32.00 ± 6.56^{a,12}	38.26 ± 2.60^{a,12}	42.00 ± 6.25^{c,12}	46.67 ± 3.33^{d,1}	47.0 ± 3.33^{c,1}
80	10.0 ± 1.33^{a,12}	18.33 ± 6.01^{b,1}	20.67 ± 9.68^{b,1}	18.67 ± 3.33^{b,1}	0.00 ± 0.00^{d,2}	0.00 ± 0.00^{e,2}	0.00 ± 0.00^{d,2}
100	9.33 ± 1.15^{a,3}	12.67 ± 5.21^{b,2}	14.67 ± 2.60^{c,1}	10.00 ± 4.00^{c,3}	0.00 ± 0.00^{d,4}	0.00 ± 0.00^{e,4}	0.00 ± 0.00^{d,4}

Data are presented as mean ± standard error of the mean. Significant means are separated with different alphabets on the same column for treatments (concentrations) effect while the numbers on the same row are for duration (weeks) effect.

Table 6. Effect of industrial coconut oil effluent concentration on the number of lateral roots of *Corchorus olitorius*

Treatment (%)	Duration (weeks)						
	2	4	6	8	10	12	14
0	8 ± 0.88^{a,3}	12 ± 1.45^{a,3}	16 ± 3.22^{a,2}	18.0 ± 0.58^{b,2}	24.0 ± 10.11^{a,1}	24 ± 2.03^{b,1}	28 ± 13.30^{a,1}
20	8 ± 1.00^{a,4}	13 ± 1.86^{a,34}	16 ± 4.70^{a,23}	16 ± 1.00^{b,23}	18 ± 12.25^{b,12}	21 ± 4.67^{b,1}	24 ± 13.00^{ab,1}
40	7 ± 1.53^{a,5}	12 ± 0.33^{a,4}	18 ± 0.88^{a,3}	25 ± 5.04^{a,12}	26 ± 4.70^{a,1}	28 ± 5.13^{a,1}	29 ± 12.55^{a,1}
60	8 ± 0.88^{a,3}	11 ± 2.19^{a,2}	18 ± 1.16^{a,1}	18 ± 5.69^{b,1}	20 ± 3.48^{ab,1}	20 ± 0.33^{b,1}	20 ± 2.52^{b,1}
80	6 ± 4.58^{a,23}	11 ± 1.53^{a,2}	13 ± 8.08^{b,2}	10 ± 3.51^{c,1}	0 ± 0.00^{c,3}	0 ± 0.00^{c,3}	0 ± 0.00^{c,3}
100	6 ± 1.16^{a,2}	9 ± 8.33^{a,2}	12 ± 8.58^{b,2}	10 ± 2.65^{c,1}	0 ± 0.00^{c,3}	0 ± 0.00^{c,3}	0 ± 0.00^{c,3}

Data are presented as mean ± standard error of the mean. Significant means are separated with different alphabets on the same column for treatments (concentrations) effect while the numbers on the same row are for duration (weeks) effect.

Table 7. Effect of industrial coconut oil effluent concentration on leaf dry weight (g) of *Corchorus olitorius*

Treatment (%)	Duration (weeks)						
	2	4	6	8	10	12	14
0	0.25 ± 0.06^{a,4}	0.26 ± 0.10^{a,4}	0.76 ± 0.15^{a,12}	0.82 ± 0.38^{a,12}	0.88 ±0.48^{a,12}	0.92 ± 0.59^{a,12}	1.60 ± 1.94^{a,1}
20	0.23± 0.05^{a,3}	0.26 ± 0.06^{a,3}	0.64 ± 0.21^{ab,2}	0.68 ± 0.01^{ab,2}	0.74 ± 0.24^{ab,12}	0.80 ± 0.19^{ab,1}	1.25 ± 1.84^{b,1}
40	0.21± 0.05^{a,4}	0.24 ± 0.08^{b,4}	0.40 ± 0.09^{ab,3}	0.48 ± 0.44^{abc,3}	0.60 ± 0.27^{b,12}	0.66 ± 0.67^{ab,12}	0.72 ± 1.04^{c,1}
60	0.20± 0.03^{a,4}	0.22 ± 0.07^{c,34}	0.26 ± 0.19^{b,3}	0.30 ± 0.38^{b,23}	0.34 ± 0.53^{c,2}	0.39 ± 0.71^{b,2}	0.52 ± 1.64^{d,1}
80	0.19± 0.02^{a,1}	0.12 ± 0.13^{d,1}	0.11 ± 0.26^{c,1}	0.09 ± 0.41^{c,2}	0.00 ± 0.00^{d,3}	0.00 ± 0.00^{b,3}	0.00 ± 0.00^{e,3}
100	0.15± 0.17^{a,1}	0.10 ± 0.09^{d,2}	0.10 ± 0.13^{c,2}	0.06 ± 0.10^{c,3}	0.00 ± 0.00^{d,4}	0.00 ± 0.00^{b,4}	0.00 ± 0.00^{e,4}

Data are presented as mean ± standard error of the mean. Significant means are separated with different alphabets on the same column for treatments (concentrations) effect while the numbers on the same row are for duration (weeks) effect.

The results showed no significant difference in the number of lateral roots formed across all treatments at 2nd and 4th WAT. While at 6th and 8th WAT, the number of the root formed in 80 and 100% ICE treatments was significantly reduced compared to the control. At 14 weeks 60% of ICE treatment also showed a significantly reduced number of roots compared to the control (Table 6).

The result presented in Table 7 showed that the dry weight of the leaves was similar at 2nd WAT grew under all the different ICE treatments. However, from the 4th WAT, there was a significant decrease in the dry leaf weight grew under higher concentrations of ICE treatments (40-100%) compared to the control. At the 14th WAT, seedlings irrigated with ICE all recorded significantly lower dry leaf weight as compared to the control.

Similarly, there was a decrease in the stem dry weights of plants irrigated with ICE treatments compared to the control plants (Table 8). While the results showed a significant decrease in stem dry weight with an increase in ICE concentration at the 8th week while there was an increase in the stem dry weight of plants that grew under 20-60% ICE treatments in 2-14th WAP.

As the concentrations of ICE treatments increases, the root dry weight reduced in all the different duration of the experiments. At 2nd WAT, 0% ICE treatment had the highest root dry weight value which differed significantly from 80% and 100% ICE treatments. The 4th and 6th WAT at 0% ICE treatment had the highest mean value that differed significantly from concentrations of 60-100% ICE treatments. At 8th WAT, the mean root dry weight at 0% ICE treatment was significantly higher than the mean value from 40-100% ICE treatments. However, the mean dry root weight values from 10-14th WAT grew under 20 and 40% ICE concentrations have similar mean values (Table 9).

Table 8. Effect of industrial coconut oil effluent concentration on stem dry weight (g) of *Corchorus olitorius*

Treatment (%)	Duration (weeks)						
	2	4	6	8	10	12	14
0	0.46 ± 0.25^{a,2}	0.48± 0.12^{a,2}	0.52± 0.29^{a,2}	0.58± 0.34^{a,12}	0.63± 1.17^{a,1}	0.66± 0.89^{a,1}	0.70± 2.08^{a,1}
20	0.42 ± 0.28^{ab,2}	0.44± 0.10^{ab,23}	0.49± 0.15^{a,123}	0.53± 0.66^{b,12}	0.58± 0.39^{a,1}	0.60± 0.92^{ab,1}	0.62± 1.11^{a,1}
40	0.39± 0.17^{ab,2}	0.41± 0.23^{bc,123}	0.46± 0.09^{ab,12}	0.48± 0.02^{c,1}	0.52± 1.02^{a,1}	0.56± 0.77^{ab,1}	0.56± 1.21^{a,1}
60	0.34± 0.07^{ab,23}	0.36± 0.44^{cd,23}	0.39± 0.44^{b,2}	0.42± 0.03^{d,2}	0.49± 0.41^{a,12}	0.51± 0.55^{b,1}	0.54± 2.46^{a,1}
80	0.20± 0.03^{ab,2}	0.22 ± 0.07^{de,12}	0.28± 0.26^{c,1}	0.26± 0.31^{e,1}	0.00± 0.00^{b,3}	0.00± 0.00^{c,3}	0.00± 0.00^{b,3}
100	0.09± 0.04^{b,2}	0.18 ± 0.10^{e,1}	0.20± 0.17^{c,1}	0.19± 0.12^{f,1}	0.00± 0.00^{b,3}	0.00± 0.00^{c,3}	0.00± 0.00^{b,3}

Data are presented as mean ± standard error of the mean. Significant means are separated with different alphabets on the same column for treatments (concentrations) effect while the numbers on the same row are for duration (weeks) effect.

Table 9. Effect of industrial coconut oil effluent concentrations on root dry weight (g) of *Corchorus olitorius*

Treatment (%)	Duration (weeks)						
	2	4	6	8	10	12	14
0	0.20 ± 0.10^{a,3}	0.23 ± 0.22^{a,3}	0.26± 0.18^{a,23}	0.28 ± 0.23^{a,123}	0.31± 0.15^{a,12}	0.33± 0.53^{a,1}	0.36± 0.31^{a,1}
20	0.18 ± 0.08^{a,3}	0.19± 0.13^{ab,23}	0.22± 0.28^{a,23}	0.24 ± 0.21^{ab,2}	0.26± 0.00^{a,12}	0.28± 0.85^{ab,1}	0.30± .47^{ab,1}
40	0.13 ± 0.12^{a,3}	0.15± 0.16^{a,23}	0.18± 0.05^{ab,2}	0.20 ± 0.14^{b,2}	0.22± 0.29^{ab,12}	0.25± 0.40^{ab,1}	0.26± .63^{ab,1}
60	0.12 ± 0.06^{ab,4}	0.14± 0.04^{b,34}	0.16± 0.04^{b,34}	0.18 ± 0.10^{b,23}	0.21± 0.34^{b,12}	0.22± 0.56^{b,12}	0.25± 0.14^{b,1}
80	0.09 ± 0.07^{b,1}	0.11± 0.15^{bc,1}	0.14± 0.12^{b,1}	0.14± 0.06^{bc,1}	0.00± 0.00^{c,2}	0.00± 0.00^{c,2}	0.00± 0.00^{c,2}
100	0.06 ± 0.19^{b,1}	0.08± 0.09^{c,1}	0.08± 0.22^{c,1}	0.06± 0.07^{c,1}	0.00± 0.00^{c,2}	0.00± 0.00^{c,2}	0.00± 0.00^{c,2}

Data are presented as mean ± standard error of the mean. Significant means are separated with different alphabets on the same column for treatments (concentrations) effect while the numbers on the same row are for duration (weeks) effect.

4. Discussion

The pH of industrial coconut oil effluent (ICE) was above FEPA (1991) standard for use as irrigation water for vegetable. The acidity level of the industrial coconut oil effluent may have been influenced by the presence of organic acid found in the coconut fruit. This could be a potential source of acidity in the soil which will affect the growth and development of the plants (Younger *et al*., 2002; Mbagwu *et al.*, 2003; Nganje *et al*., 2010). In this study, the biochemical oxygen demand (BOD) and chemical oxygen demand (COD) values are higher than that of the fresh tap running water and these are an indication that the high degree of pollutant in ICE treatments may not favour plant growth and development. Okwute and Isu (2007) reported that a high amount of BOD and COD in palm oil mill effluent (POME) have altered environmental parameters, for, example, depletion oxygen in the soil.

Here in this study, the result obtained shows that *Corchorus olitorius* seedling at different concentrations of ICE treatments (0, 20, 40, 60, 80 and 100%) for the different time intervals (2, 4, 6, 8, 10, 12 and 14 weeks), did not generally favour the growth and development performance of the seedlings. For example, the values of the seedlings growth parameters decrease with an increase in ICE concentration and time of exposure. Despite the decrease in the seedling growth parameters, the results showed that after the eight (8) week of irrigation, seedlings irrigated with 80 and 100% ICE treatments, respectively, appeared to be plasmolysed, shrivelled with wilted leaves and eventually died. The seedlings irrigated with 20, 40 and 60% ICE which persisted until the fourteen (14) week lacked vigorous growth performance and had an unpresentable appearance, suggesting to loss of its pecuniary value. Wastewater effluent may not support healthier plant growth and development probably due to the presence of some traces of toxic compounds that are potential phytotoxic (Udom *et al*., 2004).

The plant height of *C. olitorius* was better at low concentrations especially at 0 and 20%. Further results showed a decrease in the morphological characteristics with an increase in concentrations of ICE treatments which may be due to the acidic nature of the effluent. This was also reported by Okwute and Isu (2007) who suggested the acidity of discharged effluents in the soil affect nutrients availability to nearby plant because most plants grow and do better within a pH range of 6.5 - 7.5. The positive effect of the ICE concentration on stem girth was at low concentration and reduced at higher concentration probably due to the accumulation of potentially toxic compounds at a much higher level. This is in agreement with the observed findings of Ammar *et al*. (1997) who demonstrated that industrial effluent had a positive effect on plant stem girth at low concentrations. The decrease in the number of leaves in the plant with increased ICE concentrations was in line with the findings by Orhue *et al*. (2005) who reported that brewery effluent had reduced several leaves at higher concentrations. The reduced number of lateral roots at higher concentrations of ICE may be due to high BOD associated with the high concentrations of ICE treatments. This agrees with the report of Rani *et al*. (1990) using different concentrations of distillery effluents on the root growth of *Pisum sativum*.

They reported the inhibition of root growth of *Pisum sativum* at higher concentration due to the high BOD and excess salt present in distillery effluents. Higher levels of the effluent concentrations were deleterious to leaf area whereas lower concentrations considerably increased leaf area and this agrees with the finding of Gufran (2013) who reported the impact of textile tannery and sewage effluent on *Phaseolus vulgaris* (French bean). The dry weight of *C. olitorius* irrigated with industrial coconut oil effluent (ICE) decreased with increased concentrations of the effluent which may have attributed to the accumulation/deposition of some traces of metals in the plant and consequently reduced their growth (Hussain *et al*., 2010).

5. Conclusions

Industrial coconut oil effluent contains higher physicochemical properties compared with the FEPA required standard for irrigation water. There was a deleterious effect on the seedling growth and development of *Corchorus olitorius* with an increase in the concentration of industrial coconut oil effluent. For, example, seedlings irrigated with 80 and 100% ICE treatments, were observed to be plasmolysed, shrivelled and several wilted leaves. However, the relative effect observed with lower concentrations of ICE treatments suggests that ICE treated water could be used for irrigation. For instance, the results obtained from the different ICE treatments showed no significant differences in the number of lateral roots formed across all ICE treatments during the 2nd and 4th week after planting.

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