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Effects of Coconut Oil Effluent (ICE) Irrigation Practice on Some Soil Chemical Properties and Nutrients Composition of *Talinum fruticosum* L.

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ABSTRACT

The recognition of the positive health impacts of coconut oils is growing stronger and the demand on a steady increase. This will no doubt increase the production and discharge of industrial coconut oil effluent (ICE) into the environment. The present study aimed at investigating the effect of ICE irrigation on some soil chemical properties and nutrients composition of *Talinum fruticosum* L. The study was conducted in the Botanic Garden of the University of Nigeria, where plants were subjected to irrigation with 0%, 20%, 40%, 60%, 80% and 100% concentrations of ICE in a completely randomized experimental design (CRD). The soil and plant analyses for nitrogen, phosphorus and exchangeable cations (K, Ca and Mg) were conducted following standard methods. Soil chemical properties significantly ($P < 0.05$) increased with the ICE concentration, and the nutrients content of the plant drastically reduced as the concentration treatments increased. The industrial coconut oil effluent (ICE) contains nutrients that are necessary for the growth of *T. fruticosum* that can also be applicable to other plants. However, the positive effects of these nutrients were not reflected on *T. fruticosum* as indicated by the evaluation of nutrients contentin the plants. There is strong evidence that if ICE is properly treated and managed, it would improve the soil fertility and eventually promote healthy growth of vegetables.

Key Words: Coconut Oil; Nutrient Accumulation; Soil Management; Soil Pollution; Vegetable Crop

INTRODUCTION

The consumption of vegetables in Nigeria has been on the increase in the past decade and it is presently estimated to be above 22 - 47.58 kg per person per year (Hart et al. 2005). As recorded in the reports of Ibeawuchi et al. (2007),-the leaves and young shoots are used to thicken sauce and it is consumed in large quantities in Nigeria specifically the southern part. *T. fruticosum* commonly known as water leaf is one of the most profitable vegetables in Southern Nigeria. It serves as a source of income for small scale farmers during the dry season (Udoh 2015).

T. fruticosum requires well-drained soil rich in nitrogen, phosphorus and potassium and performs better in non-acidic conditions. Water leaf is relatively tolerant to drought and grows best under humid conditions at a temperature of about 30 ºC. Growth is very fast in the wet season but slows down considerably through the dry season. It grows well under shade and in cloudy weather. High temperature (>35 ºC) and drought negatively affect the number of leaves, leaf area, stem size and number of branches (Fontem and Schippers 2004). Therefore, most farmers use irrigation systems in order to meet the high demand of leafy vegetables.

In many areas, the few fresh water supply stations (boreholes) are owned by individuals and the water is sold to others who cannot afford to set up one. Moreover, the shortage of pond or canal water for irrigation compels some poor farmers to resort to cheaper alternatives of irrigation water. Hence, they use industrial effluents.

Wastes from vegetable oil industries, especially the liquid wastes (effluents) are the main industrial pollutants containing organic and inorganic compounds, suspended solids, toxic chemicals, oil and greases. They are discharged into the nearby water bodies making them toxic and unsuitable for drinking and irrigation of plant crops and in some instances, on adjacent land to the company. It has been found that growth and yield of crops and soil health get reduced when the farmers use the effluents for irrigation of the cultivated land (Nandy and Kaul, 1994). Processing of crude vegetable oils generates large amounts of liquid waste. When the wastewaters are diluted, the agricultural reuse of the treated effluents serve goals, such as promoting sustainable agriculture and conservation of the scarce water resources, while untreated effluents cause many plants growth related problems (Arjun et al. 2013).

Industrial coconut oil effluents (ICE) are wastes generated by the Coconut oil industry during the process of oil production. The use of effluent has been promoted by urban farmers due to the belief that wastewaters contain nutrients that can speed the growth of their crops and in return reduce the cost of fertilizer acquisition (Ahmad et al. 2006). It has been reported by different researchers that treated/controlled application of industrial wastewater increases soil minerals such as calcium, magnesium, phosphorus and potassium (Osaigbovo and Orhue 2011, Ak35wute and Isu 2007, Onyia et al. 2001). The recognition of the positive health impacts of coconut oils is growing stronger by the day, therefore demand will become on a steady increase. The overview and a detailed review on coconut oil had been presented by numerous researchers such as Shankar et al. (2013) and Kappally et al. (2016). Therefore, this study was aimed at assessing the effect of ICE on some soil chemical properties and nutrient composition (uptake) in *T. fruticosum.*

STUDY LOCATION

The planting was carried out in the Botanic Garden at the University of Nigeria, Nsukka in Enugu State, Nigeria. Nsukka is both commercial and agrarian town producing varieties of vegetable crops including *T. fruticosum.* The soil and plant samples were analyzed in the Department of Soil Science, and the Department of Crop Science respectively, of the University of Nigeria, Nsukka.

METHODS

Collection of Materials

Viable seeds of *T. fruticosum* were obtained from the Botanic Garden of the Department of Plant Science and Biotechnology, University of Nigeria, Nsukka. Coconut oil effluent was collected from a coconut oil producing company in Nsukka. The top soil and sandy soil were collected from the Botanic Garden of the Department of Plant Science and Biotechnology, University of Nigeria, Nsukka. The poultry droppings were collected from the poultry farm of the Department of Animal Science, University of Nigeria, Nsukka.

Preparation of Soil Samples

The top soil, poultry manure and sandy soil were mixed in the ratio of 3:2:1 following the procedures of Abu and Odo (2017) and Ojua et al. (2019). This is referred to as the amended soil. Two kilogram aliquots of amended garden soil were weighed using an electronic digital weighing balance (Furi, model: FEJ-600) and put into180 polythene bags.

Preparation of Effluent

The coconut oil effluent used for the irrigation experiments was diluted as follows: 0% (100 mL tap water), 20% (20 mL effluent + 80 mL tap water), 40% (40 mL effluent + 60 mL tap water), 60% (60 mL effluent + 40 mL tap water), 80% (80 mL effluent + 20 mL tap water), and 100% (100 mL effluent).

Nursery Development

The seeds were nursed in nursery baskets filled with amended soil samples and watered daily till the plants were ready for transplanting.

Transplanting

The seedlings were transplanted four weeks after germination into 180 polythene bags each containing 2 kg of amended soil. Transplanting was done in the evening to avoid excessive effect of transpiration on the seedlings. The plants were watered with tap water at an interval of two days for two weeks for the seedlings to stabilize before application of effluent. One hundred milliliters of the effluent concentrations were applied on the seedlings after 4 weeks of transplanting at the concentrations of 0%, 20%, 40%, 60%, 80% and 100%. Irrigation was done at an interval of two days for 12 weeks.

Experimental Design

The experiment was carried out in a Completely Randomized Design (CRD) comprising of six treatments. Each treatment was replicated eighteen times given a total of 180 experimental units.

Soil and Plant Analysis

Some selected soil chemical properties such as nitrogen, phosphorus and exchangeable cations (K, Ca and Mg) were determined by leaching method (AOAC, 2002). The pH of the samples was measured with a glass electrode in 1:2 sample-water ratio suspensions using digital pH meter (Metrohm, Model: 872 Labo-maga symbol). The plant nutrients were determined based on the procedure of APHA (1998) using an atomic absorption spectrophotometer (Analyst 200 Perkin Elmer).

Statistical Analysis

The data from each treatment were subjected to analysis of variance (ANOVA) and means were separated using Duncan's Multiple Range Test (DMRT) at $p < 0.05$ level of significance using Statistical Package for Social Sciences (IBM SPSS) version 20.

RESULT AND DISCUSSION

The values of water quality indicators of industrial coconut oil effluent (ICE) as presented in Table 1 revealed that the chemical properties of ICE such as nitrogen, phosphorus, potassium, calcium and magnesium (N, P, K, Ca and Mg) were above FEPA accepted standards for effluent limitation in Nigeria. The pH was acidic, Fats and oils contents were quite high and all the minerals were far above the recommended standard for discharge on land (Table 1).

Soil Chemical Properties

The soil chemical properties before and after the treatments with various concentrations of ICE are presented in Figures 1 to 6 respectively. The results showed significant ($P < 0.05$) increase in soil pH, N, P, K, Ca and Mg in all treatments when compared with the 0% Treatment (control).

Table 1. Analyses of Industrial Coconut Oil Effluent

Properties	ICE	FEPA (1999) Limit
pH	4.0	6.5-9.0
Fats and oil	20.34	10
Nitrogen (mg L^{-1})	9.5	0.1
Phosphate (mg L^{-1})	5.35	0.02
Potassium (mg L^{-1})	4.63	0.2
Magnesium (mg L^{-1})	33.4	0.5
Calcium (mg L^{-1})	26.5	0.2

The pH before the experiment was 6.1, while that of the soil irrigated with water only after the experiment was 6.2. The results showed a concentration dependent increase in pH ranging from 6.4 in 20% to 7.1 in 100% treatment, indicating a progression from moderate acidic to a neutral condition (Figure 1). This gradual increase in soil pH after the experiment could probably be due to the activity of biodegrading bacteria present in the effluent. These biodegrading activities might have increased the various soluble salts in the effluent. The results tend to corroborate with the reports of Okwute and Isu (2007) and Rana et al. (2010).

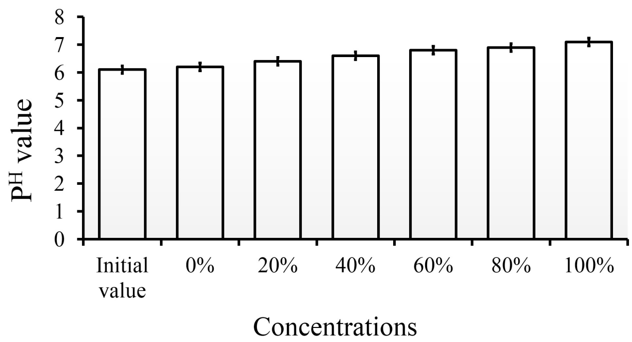

Figure 1. Soil pH levels before (Initial value) and at 12 weeks of irrigation with various concentrations of industrial coconut effluent (ICE)

Soil N, P, K, Ca and Mg significantly ($P<0.05$) increased as treatments concentration increased (Figures

2-6). The highest level of soil minerals level was obtained by treatment 100% while the control treatment recorded the lowest value. It was generally observed that the initial mineral content of the soil was higher than the control values after the experiment across the nutrients evaluated except for magnesium content. This could be a pointer towards the mineral uptake level of the plants during the experiment, indicating that these minerals were not readily available for absorption. This is most likely because in alkaline conditions, nitrogen is less available while calcium and magnesium precipitate out of the soil solution as reported by Patterson (1999).The study also revealed significant increase in soil mineral (N, P, K, Mg, and Ca) as the concentrations of the effluent increased. This could also be probably due to the constant application of ICE because as reported in Table 1, ICE contains high amount of these minerals. Similar reports had also been recorded by Osaigbovo and Orhue (2011) and Nwoko et al. (2010).

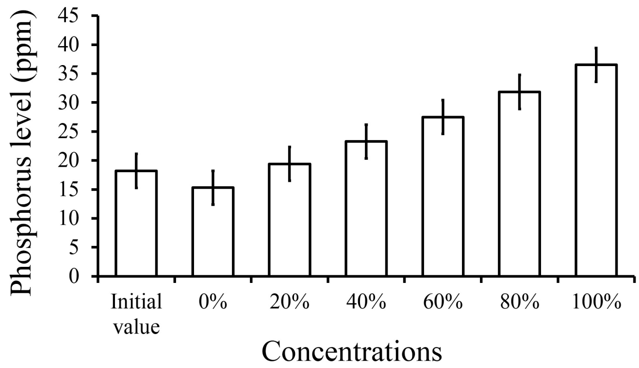

Figure 2. Soil Phosphorus levels before (Initial value) and at 12 weeks of irrigation with various concentrations of industrial coconut effluent (ICE)

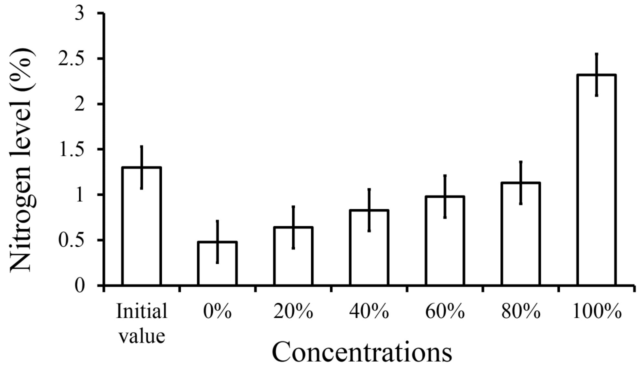

Figure 3. Soil Nitrogen levels before (Initial value) and after 12 weeks of irrigation with various concentrations of industrial coconut effluent (ICE)

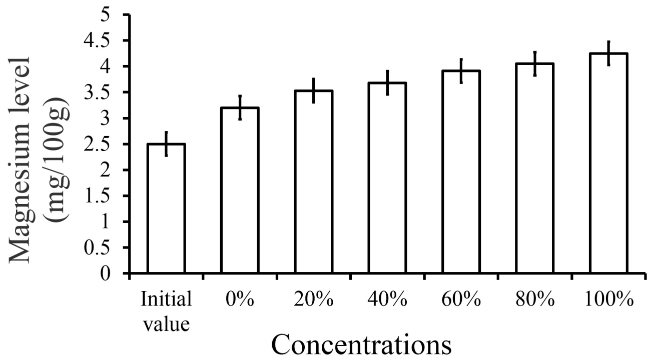

Figure 4. Soil Magnesium levels before (Initial value) and at 12 weeks of irrigation with various concentrations of industrial coconut

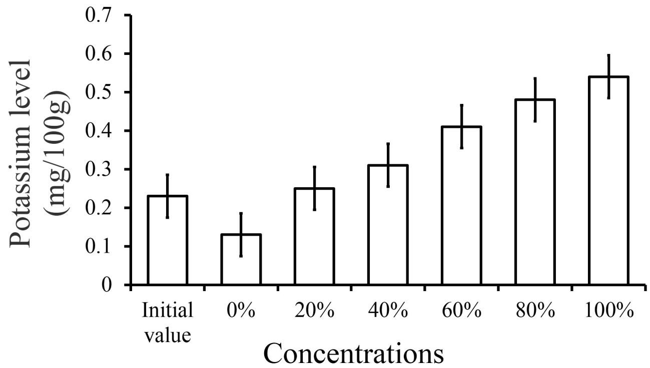

Figure 5. Soil Potassium levels before (Initial value) and after (12 weeks) of irrigation with various concentrations of industrial coconut effluent (ICE)

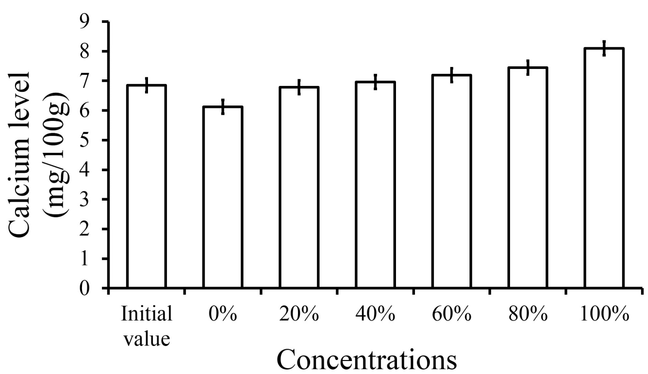

Figure 6. Soil Calcium levels before (Initial value) and at 12 weeks of irrigation with various concentrations of industrial coconut effluent (ICE)

Table 2. Accumulation of nitrate in the leaves of *T. fruticosum* (mg L^{-1}) treated with various concentrations of industrial coconut effluent (ICE).

ICE Concentration	WEEKS AFTER TRANSPLANTING (WAT) 2	4	6	8	10	12
0%	0.103 ± 0.003^{a}	0.117 ± 0.009^{a}	0.130 ± 0.006^{a}	0.147 ± 0.003^{a}	0.157 ± 0.003^{a}	0.167 ± 0.003^{a}
20%	0.120 ± 0.012^{a}	0.100 ± 0.006^{b}	0.090 ± 0.006^{b}	0.080 ± 0.006^{b}	0.070 ± 0.006^{b}	0.060 ± 0.006^{b}
40%	0.100 ± 0.006^{a}	0.080 ± 0.006^{c}	0.070 ± 0.006^{c}	0.060 ± 0.006^{c}	0.050 ± 0.006^{c}	0.040 ± 0.006^{c}
60%	0.100 ± 0.006^{a}	0.060 ± 0.006^{d}	0.060 ± 0.006^{c}	0.050 ± 0.006^{cd}	0.040 ± 0.006^{cd}	0.030 ± 0.006^{c,d}
80%	0.100 ± 0.006^{a}	0.050 ± 0.006^{d}	0.050 ± 0.006^{d}	0.040 ± 0.006^{d}	0.030 ± 0.006^{d}	0.020 ± 0.006^{d,e}
100%	0.100 ± 0.006^{a}	0.040 ± 0.006^{d}	0.030 ± 0.006^{e}	0.020 ± 0.006^{e}	0.013 ± 0.003^{e}	0.013 ± 0.003^{e}

Means with different alphabets on the same column are significantly different using DNMRT at $P < 0.05$.

Table 3. Accumulation of Phosphate in the leaves of *T. fruticosum* (mg L^{-1}) treated with various concentrations of industrial coconut effluent (ICE).

ICE Concentration	WEEKS AFTER TRANSPLANTING (WAT) 2	4	6	8	10	12
0%	0.040 ± 0.006^{a}	0.060 ± 0.006^{a}	0.080 ± 0.012^{a}	0.100 ± 0.006^{a}	0.1200.0 ± 06^{a}	0.140 ± 0.006^{a}
20%	0.030 ± 0.006^{ab}	0.020 ± 0.006^{b}	0.020 ± 0.006^{b}	0.013 ± 0.003^{b}	0.013 ± 0.003^{b}	0.013 ± 0.003^{b}
40%	0.030 ± 0.006^{ab}	0.020 ± 0.006^{b}	0.020 ± 0.006^{b}	0.008 ± 0.001^{bc}	0.008 ± 0.001^{b}	0.003 ± 0.001^{c}
60%	0.020 ± 0.006^{b}	0.006 ± 0.001^{bc}	0.006 ± 0.001^{b}	0.007 ± 0.000^{bc}	0.007 ± 0.000^{b}	0.002 ± 0.001^{c}
80%	0.020 ± 0.006^{b}	0.007 ± 0.001^{c}	0.005 ±0.001^{b}	0.005 ± 0.001^{bc}	0.006 ± 0.001^{b}	0.001 ± 0.000^{c}
100%	0.020 ± 0.006^{b}	0.006 ± 0.001^{c}	0.003 ± 0.000^{b}	0.004 ± 0.001^{c}	0.005 ± 0.000^{b}	0.001 ± 0.000^{c}

Means with different alphabets on the same column are significantly different using DNMRT at $P < 0.05$.

Table 4. Accumulation of potassium in the leaves of *T. fruticosum* (mg L^{-1}) treated with various concentrations of industrial coconut effluent (ICE).

ICE Concentration	WEEKS AFTER TRANSPLANTING (WAT) 2	4	6	8	10	12
0%	0.14 ± 0.006^{a}	0.17 ± 0.006^{a}	0.25 ± 0.012^{a}	0.31 ± 0.006^{a}	0.36 ± 0.003^{a}	0.38 ± 0.006^{a}
20%	0.13 ± 0.006^{ab}	0.10 ± 0.006^{b}	0.06 ± 0.025^{b}	0.06 ± 0.006^{b}	0.04 ± 0.006^{b}	0.02 ± 0.006^{b}
40%	0.12 ± 0.006^{bc}	0.07 ± 0.003^{c}	0.07 ± 0.006^{b}	0.05 ± 0.006^{bc}	0.03 ± 0.006^{bc}	0.01 ± 0.003^{bc}
60%	0.12 ± 0.006^{b,c}	0.07 ± 0.007^{c}	0.06 ± 0.006^{b}	0.04 ± 0.006^{cd}	0.02 ± 0.006^{cd}	0.01 ± 0.001^{c}
80%	0.12 ± 0.006^{b,c}	0.06 ± 0.006^{c}	0.05 ± 0.006^{b}	0.03 ± 0.006^{de}	0.01 ± 0.001^{de}	0.01 ± 0.001^{c}
100%	0.11 ± 0.003^{c}	0.04 ± 0.006^{d}	0.04 ± 0.006^{b}	0.02 ± 0.006^{e}	0.01 ± 0.001^{e}	0.00 ± 0.001^{c}

Means with different alphabets on the same column are significantly different using DNMRT at $P < 0.05$.

Table 5. Accumulation of Calcium in the leaves of *T. fruticosum* (mg L^{-1})treated with various concentrations of industrial coconut effluent (ICE).

ICE Concentration	WEEKS AFTER TRANSPLANTING (WAT) 2	4	6	8	10	12
0%	0.040 ± 0.006[a]	0.050 ± 0.012[a]	0.050 ± 0.006[a]	0.060 ± 0.006[a]	0.070 ± 0.006[a]	0.070 ± 0.006[a]
20%	0.030 ± 0.006[a]	0.020 ± 0.006[b]	0.020 ± 0.006[b]	0.020 ± 0.006[b]	0.013 ± 0.004[b]	0.013 ± 0.004[b]
40%	0.033 ± 0.007[a]	0.020 ± 0.006[b]	0.020 ± 0.006[b]	0.020 ± 0 ± 006[b]	0.013 ± 0.004[b]	0.013 ± 0.004[b]
60%	0.020 ± 0.006[a]	0.023 ± 0.003[b]	0.020 ± 0.006[b]	0.020 ± 0.006[b]	0.013 ± 0.004[b]	0.013 ± 0.004[b]
80%	0.020 ± 0.006[a]	0.013 ± 0.003[b]	0.013 ± 0.004[b]	0.013 ± 0.004[b]	0.008 ± 0.001[b]	0.007 ± 0.001[b]
100%	0.020 ± 0.006[a]	0.010 ± 0.000[b]	0.013 ± 0.004[b]	0.013 ± 0.004[b]	0.008 ± 0.001[b]	0.008 ± 0.001[b]

Means with different alphabets on the same column are significantly different using DNMRT at $P < 0.05$.

Table 6. Accumulation of Magnesium in the leaves of *T. fruticosum* (mg L^{-1}) treated with various concentrations of industrial coconut effluent (ICE).

ICE Concentration	WEEKS AFTER TRANSPLANTING (WAT) 2	4	6	8	10	12
0%	0.100 ± 0.006[a]	0.150 ± 0.006[a]	0.220 ± 0.006[a]	0.330 ± 0.006[a]	0.407 ± 0.003[a]	0.500 ± 0.012[a]
20%	0.090 ± 0.006[ab]	0.080 ± 0.006[b]	0.060 ± 0.006[b]	0.060 ± 0.006[b]	0.050 ± 0.006[b]	0.047 ± 0.007[b]
40%	0.090 ± 0.006[ab]	0.060 ± 0.006[bc]	0.040 ± 0.006[c]	0.040 ± 0.006[c]	0.030 ± 0.006[c]	0.020 ± 0.006[c]
60%	0.090 ± 0.006[ab]	0.040 ± 0.012[cd]	0.020 ± 0.006[d]	0.020 ± 0.006[d]	0.013 ± 0.003[d]	0.010 ± 0.000[c]
80%	0.080 ± 0.006[b]	0.020 ± 0.006[d]	0.013 ± 0.003[d]	0.010 ± 0.000[d]	0.008 ± 0.001[d]	0.006 ± 0.001[c]
100%	0.080 ± 0.006[b]	0.020 ± 0.006[d]	0.010 ± 0.000[d]	0.010 ± 0.000[d]	0.006 ± 0.001[d]	0.005 ± 0.000[c]

Means with different alphabets on the same column are significantly different using DNMRT at $P < 0.05$.

Nutrient Composition in the Leaves

The nutrient compositions in the leaves were evaluated to decipher the nutrient uptake capacity of the plants irrigated with ICE. It was generally observed that there was a decline in nutrient across all treatments except the control as presented in Tables 2 to 6. These nutrients (N, P, K, Ca and Mg) decreased as the concentration of effluent increased. At 100% treatment, the nutrient concentrations in the leaves were greatly reduced when compared with the 0% (control) treatment.

The accumulation of nitrogen in the plants increased in a steady mode as the duration increased. The control had an increase of 0.103 mg L^{-1} at two weeks after transplanting to 0.167 mg L^{-1} at 12 weeks after planting (Table 2). But the accumulation rate was in a reversed order across all the plants irrigated with the effluent. There was rather a decrease in nitrogen accumulation as the duration increased. Across the treatments, there were significant differences in nitrogen accumulation. The reduction in nitrogen content was dose dependent as 100% treatment recorded the least nitrogen accumulated in the leaves of the plant. This observation further explained why nitrogen was higher in the soil irrigated with the higher concentrations. It could be reasonable to think that, although the effluent had sufficient amount of nitrogen, the nitrogen was not readily available for absorption by the plants. The probable reason for this as stated earlier might be due to the increase in the alkalinity of the soil as confirmed by the pH level.

Similar situations were also observed in the accumulation of P, K, Ca and Mg is of case of N. The accumulation of phosphate in the plants increased steadily as the duration increased. The control had an increase of 0.040 mg L^{-1} at two weeks after transplanting to 0.140 mg L^{-1} at 12 weeks after planting (Table 3). But the accumulation rate was in an opposite order across all the plants irrigated with the effluent. There was rather a decrease in mineral accumulation as the duration increased. Generally, the decrease observed in nutrients uptake may be due to oil content of the effluent and high heavy metals dose. Further, the reduction of nutrients uptake could be due to strong absorption in the soil as earlier reported by Osaigbovo and Orhue (2011) that worked on the effect of palm oil mill effluent on maize, and discovered that the mineral nutrients uptake was reduced with increasing effluent application. Mary and Dolor (2007) opined that effluents from oil industries discharged on soil depress and inhibit plant growth.

In conclusion, water scarce countries will require the reuse of effluents for irrigation of various vegetables as an effective method to meet the demand of adequate water and food supply. Within the scope of this study, it was observed that the industrial coconut oil effluent (ICE) contains nutrients that are necessary for the growth of *T. fruticosum* which can also be applicable to other plants. However, the positive effects of these nutrients were not reflected on *T. fruticosum* as indicated by the evaluation of nutrients content in these plants. This shows that ICE inhibited nutrients uptake with increasing effluent application. Therefore, it is obvious that if ICE is properly managed and treated, it would improve the soil fertility and eventually promote healthy growth of vegetables. Suggestively, from the observations made, diluting ICE to 20% (20 ICE : 80 water v/v) before discarding will help reduce its adverse effect on the soil. Studies should be carried out of possible ways of treating 100% ICE either through bio-augmenting with fat and oil degrading microorganisms. This would help maintain the nutritional qualities of ICE and improve soil nutrients that would be readily available

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We declare no conflict of interest.

Data Availability: The data that supports the findings of this study are openly available in Mendeley Data (www.data.mendeley.com) with DOI: http://dx.doi.org/10.17632/cpjhsm2vm6.1 and reference number: #file-122ec5fe-d81b-4c9d-bc49-69ac897bad71

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