EXPERIMENTAL STUDY ON THE SURVIVAL OF *Eichhornia crassipes* EXPOSED TO CRUDE OIL

BY

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DEPARTMENT OF PLANT BIOLOGY AND BIOTECHNOLOGY
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MAY, 2021.

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A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF PLANT BIOLOGY AND BIOTECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF SCIENCE (HONOURS) IN PLANT BIOLOGY AND BIOTECHNOLOGY IN THE UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA.

MAY, 2021.

CERTIFICATION

We hereby certify that this project work was carried out by **Miracle Oluebube NWAFOR (Miss)** with matriculation number **LSC1605815** of the Department of Plant Biology and Biotechnology, Faculty of Life Science, University of Benin, Benin City, Edo State.

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Prof. (Mrs) F.I. Okungbowa **Date**

Head of Department

DEDICATION

This work is dedicated to the Almighty God, Jehovah Overdo and to my parents: Mr. Clement Nwafor and Mrs. Salome Nwafor for their personal care and supports.

ACKNOWLEDGEMENT

My profound gratitude to God Almighty whom in his infinite mercy saw me through this research. I am greatly indebted to my supervisor Mr. Otasowie Micheal Eguagie for his constant supervision, encouragement, moral support and concern all through my research.

Special thanks goes to my Head of Department Prof. (Mrs.) F. I. Okungbowa and the role of the lecturers and staff of the Department of Plant and Biotechnology, University of Benin, Benin City who gave me permission to use all required machinery and necessary materials to complete this project and thank you for the displinary support all through my course of study.

My unreserved appreciation to my parents Mr. Clement Nwafor and Mrs. Salome Nwafor for their constant prayers, financial support and advice and for my welfare, your efforts cannot be undermined.

I would also like to acknowledge the role of late Miss Lydia Nebechi Anin, Mr. Ikechukwu Okombah for financially, spiritually and mentally supporting me throughout the years of my studies in this great citadel of knowledge.

Many thanks to my colleague, it has been a very tough journey for the guest of knowledge and I am thankful we made it thus far together, I sincerely wish each and every one of you nothing but the best.

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ABSTRACT

This research was conducted with sole aim of investigating the effect of crude oil on the group, morphology and plant based compound of *Eichornia crassipes*. Samples of the macrophyte were obtained from Ologbo pond in Edo State and transported to the Department of Plant Biology and Biotechnology, where they were used for the experiment conducted in the screen house. The experimental treatments consisted of 0 (control), 0.2, 0.4, 0.6 and 0.8 % v/v. Using a randomized complete block design (RCBD) and three replicates per treatments, the plants were exposed to the treatments for 8 days. *E. crassipes* samples grown in crude oil showed significant decrease ($p<0.01$) in all morphological parameters observed. When compared with the control. Wilting, chlorosis and necrosis were observed in some of the plants treated with 0.8 % v/v and 0.6 % v/v. The plants showed remarkable increase in the accumulation of heavy metals with concentration being more in the roots than in the shoots. Observations obtained in this study revealed that crude oil impact macrophyte parameters at higher concentration levels. The study has shown that *E. crassipes* can be employed as a tool for biomonitoring of crude oil in fresh water habitats. The study further suggests the need for more intensive research to fully understand the impacts of crude oil pollution on aquatic plants.

CHAPTER ONE

INTRODUCTION

1.2 Background of Study

1.1.1 Crude Oil

Crude oil is a naturally occurring, yellowish-black liquid found in geological formations beneath the Earth's surface. It is commonly refined into various types of fuels (Boudet *et al.,* 2014). Components of petroleum are separated using a technique called fractional distillation, i.e. separation of a liquid mixture into fractions differing in boiling point by means of distillation, typically using a fractionating column. It consists of naturally occurring hydrocarbons of various molecular weights and may contain miscellaneous organic compounds (Rebeiro *et al.*, 2000).

Oil spillage and chemical leakage frequently occur during extraction, transportation, transfer and storage. They cause a loss of energy source and have a major negative effect on natural flora and fauna and on human health (Zhu *et al.*, 2011;). Petroliferous regions are under the constant risk of accidents, as much during the process of extraction, as during the transport of crude oil (Val and Almeida-Val, 1999; Keramitsoglou *et al.*, 2003).

1.1.2 Crude oil Exploration in Nigeria

Crude oil exploration in the Niger delta has lead to unprecedented release of crude oil, polluting the land and water sources. Also, illegal tampering of well heads, flow lines, pipelines, manifolds and flow stations have contributed to the total amount of crude oil entering the environment. With these frequent reports of oil spillages in Niger Delta, there is need to seek for a cost effective method for remediation of crude oil contaminated soil (Udeh *et al.*, 2013). Crude oil when spilled on land affects the physicochemical properties of the soil such as temperature, structure, nutrient status and pH (Rebeiro *et al.*, 2000). Since crude oil is a complex mixture of thousands of hydrocarbons and non-hydrocarbon compounds, the chemical compositions can have diverse effects on different micro-organisms within the same ecosystem. Crude oil destroys soil microorganisms causing reductions in biomass. The damaging effects are due to suffocation and toxicity of the crude oil (Udeh *et al.,* 2013).

1.1.3 Impact of Crude oil on Vegetation and Aquatic environment

The impact of crude oil on the environment depends on the specific characteristics of both the crude oil and the environment. Light oils are easily absorbed and, since they act at the cellular level, are immediately toxic to the plants. Heavy oils cover the plants causing asphyxia and hindering gaseous exchange (Pezeshki *et al.*, 2000). When oil spills occur in a terrestrial environment, it directly affects the ecosystem through soil contamination; however, in aquatic environments, the floating oil on the water surface is dispersed through the action of wind and waves in the littoral region, thus affecting the terrestrial environment and vegetation (Pezeshki *et al.*, 2000). The entrance of petroleum into the aquatic-terrestrial system results in a series of alterations, such as the substantial increase of organic material as a result of the death and decomposition of plants (Akinluyi and Odeyemi, 1987), alterations in pH of the soil and the introduction of heavy metals, such as nickel and mercury (Ekundayo and Obuekwe, 2000). These alterations, coupled with the differentiated sensitivity of each species of plant, result in modifications in the composition of the community of aquatic plants (Pezeshki *et al.*, 2000). The difference in sensitivity among aquatic plants allows the use of several species to detect contamination (Mohan and Hosetti, 1999).

1.2 Water hyacinth (*Eichhornia crassipes*)

The free-floating *Eichhornia crassipes*, is one of the most important herbaceous species colonizing most basins around the world. Due to its high tolerance to many pollutants, *Eichhornia crassipes* is one of the most studied floating aquatic plants, being a promising species for decontamination of polluted areas since the species has high capacity to absorb and tolerate elevated levels of heavy metal ions (Roshon *et al.*, 1999). Therefore, evaluating the impact oil on this plant species is paramount to understand the oil impact on the ecosystem (Lewis, 1995).

Eichhornia crassipes is often considered a highly problematic invasive species outside its native range. Water hyacinth (*Eichhornia crassipes*) is an invasive species that has changed the functioning of the ecosystem (Tobias *et al.*, 2019). Reports by so many scientists indicated that water hyacinth alters water quality. In tidal systems, such as the Delta, water moves back and forth through the water hyacinth patch so water quality directly outside the patch in either direction is likely to be impacted. The intricate and distinctive characteristics of water hyacinth make it one of the most ecologically resilient aquatic plants enabling it to invade major water systems (Chapungu *et al.*, 2018). The *Eichhornia crassipes* was introduced into the Nigerian coastal waters in September 1984 from Port Novo creek (Benin Republic) and has continued to flourish (Inyang *et al.*, 2015). The plant has subsequently invaded and established itself on the waterways of Niger Delta oil rich region of Nigeria (Akinyemiju, 1987). Also, several successful researches have been carried out to determine the potentials of *Eichhornia crassipes* to clean-up crude oil contaminated sites (Ochekwu and Madagwa, 2013; Udeh *et al.*, 2013). Its phytoremediation potential therefore cannot be overemphasized.

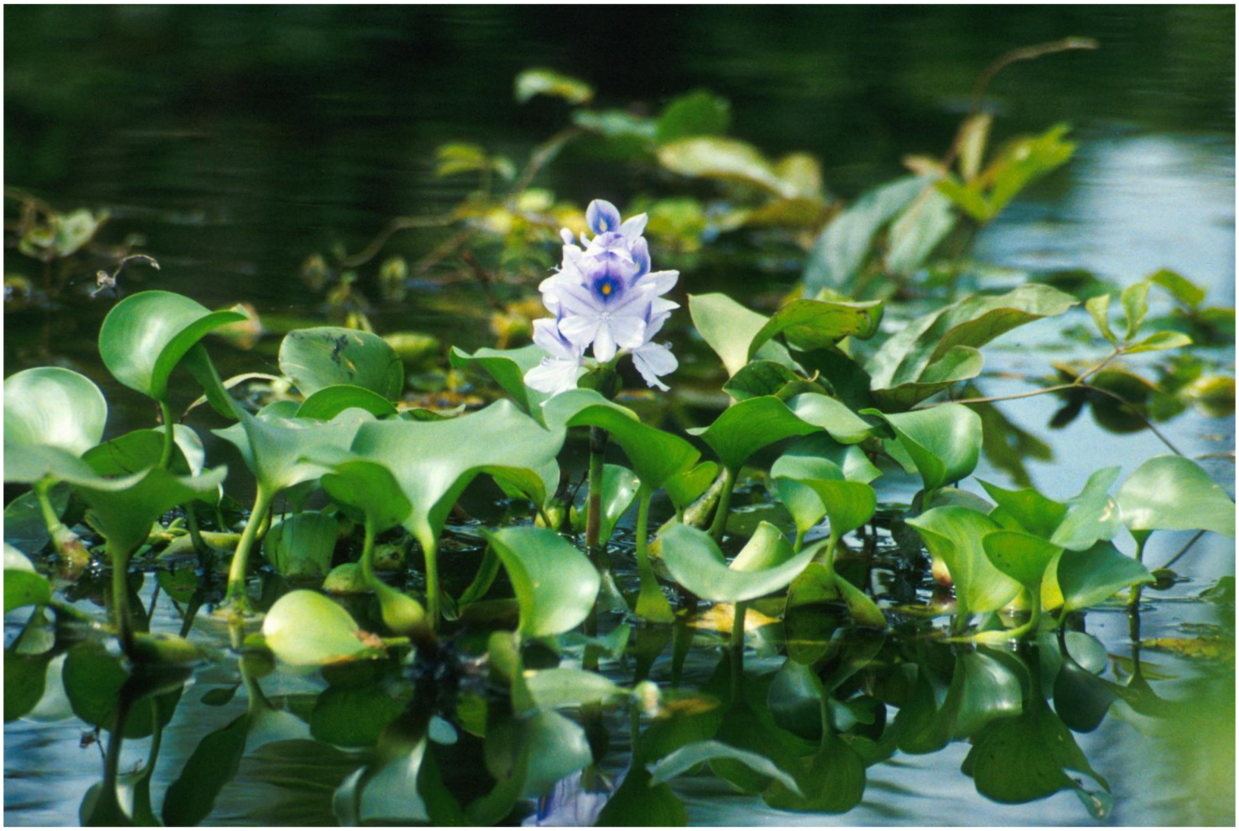

Plate 1: Water hyacinth (*Eichhornia crassipes*)

Table 1.1: Scientific classification of water hyacinth

Kingdom	**Plantae**
Subkingdom	Tracheobionta
Division	Magnoliophyta
Class	Liliopsida
Order	Liliales
Family	Pontederiaceae
Genus	Eichhornia
Species	Crassipes
Scientific name	*Eichhornia crassipes* (Mart.) Solms

Source: Samuels (2009)

1.2.1 Biology of Water Hyacinth

Description The family Pontederiaceae has nine genera including *Eichhornia*, which has eight species of freshwater aquatics including water hyacinth (*Eichhornia crassipes*) (Barrett, 1988). Only *Eichhornia crassipes* is regarded as a pan-tropical aquatic weed (OEPP/EPPO, 2008). The name water hyacinth refers to its aquatic habitat and the similarity of the flower colour to that of the garden hyacinth (Parsons and Cuthbertson, 2001). Water hyacinth, a free-floating macrophyte, live at the air-water interface and form two distinct canopies: leaf canopies comprising above-water structures and root canopies comprising below water structures (Downing-Kunz and Stacey, 2012). The English common names of the plant are waterhyacinth, water hyacinth, and water-hyacinth.

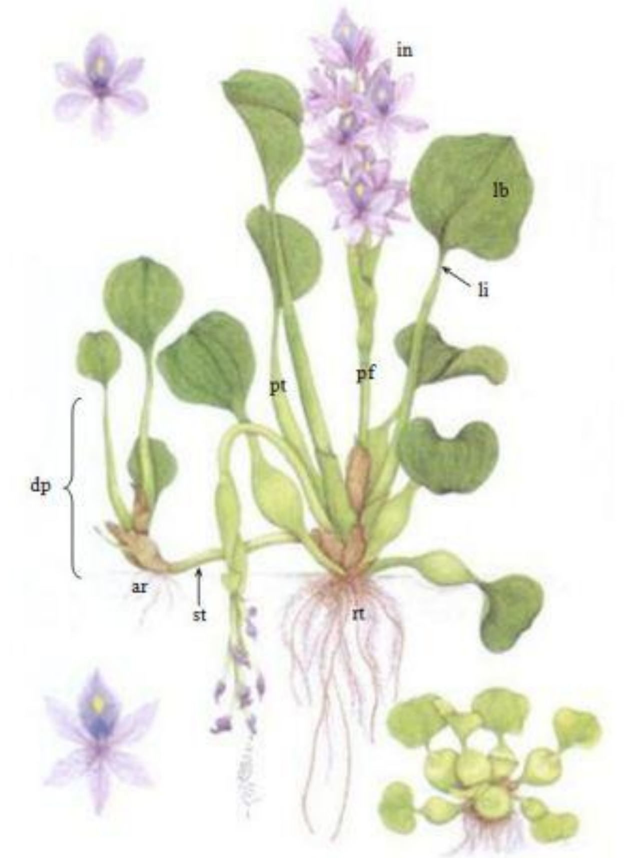

Figure 1.1: Morphology of water hyacinth plants with stolons. ar: adventitious root; dp: daughter plant; in: inflorescence; lb: leaf blade; li: leaf isthmus; pf: peduncle of flower spike; pt: petiole; rt: root; st: stolon. Source: Parsons and Cuthbertson (2001)

Petioles

Water hyacinth petioles are either erect (up to 60 cm long and bearing flowers) or horizontal (stolons), about 10 cm long and producing new plants from terminal buds (Parsons and Cuthbertson, 2001).

Leaves

There are two types of leaves. Some are up to 60 cm long, narrow and stand erect; others are almost round, up to 30 cm diameter and curved upwards with edges somewhat undulate. Both are smooth, glabrous, glossy and with semi- parallel veins following the curvature of the leaf. Leaf stalks can be 50 cm long with bladder-like swellings, either bulbous or elongated, consisting of large air cells enabling the plant to float on water (Parsons and Cuthbertson, 2001).

Flowers

Water hyacinth flowers are attractive mauve with six lobes or petals. The uppermost petal has a yellow dot in the centre surrounded by darker purple. Each spike consists of about 8 (range from 3 to 35) flowers and individual flowers last only a few days. New plants flower when only 3 or 4 weeks old (Parsons and Cuthbertson, 2001). Under favourable conditions, water hyacinth may flower repeatedly throughout the year; although the intensity of flowering may vary with seasonal variation in growth rate (Malik, 2007).

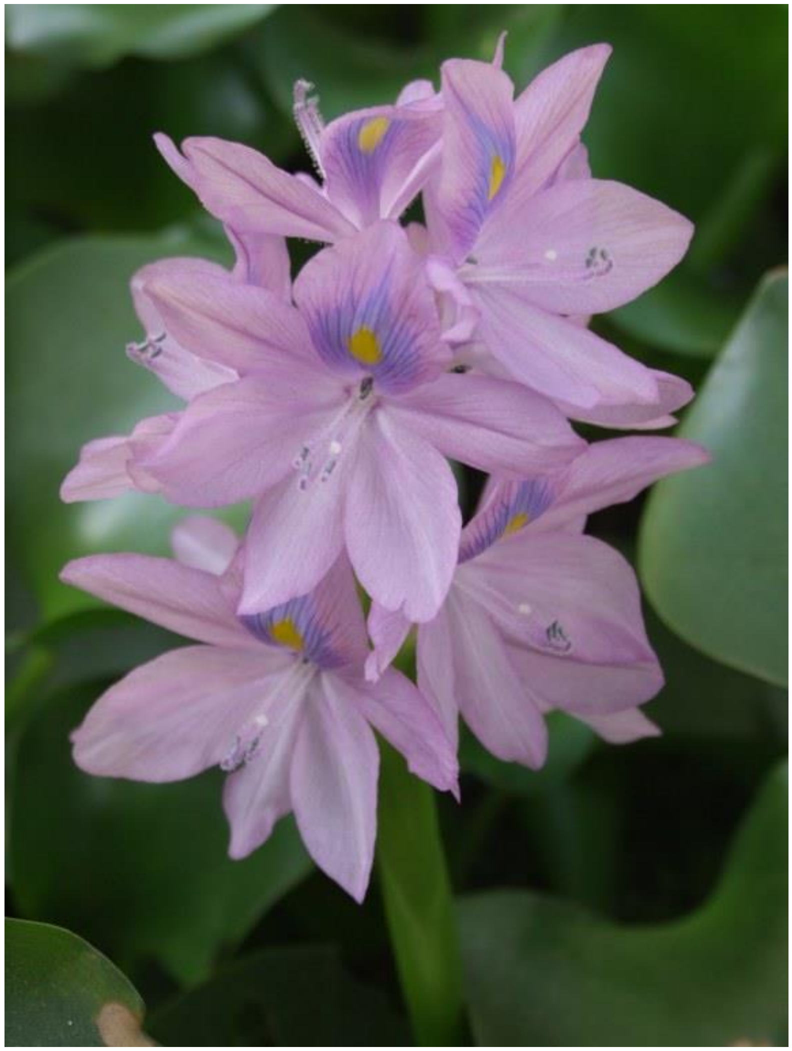

Plate 2: Flower of Water hyacinth

Roots

The root morphology is highly plastic, fibrous and has one single main root with many laterals, forming colossal root system. Because each lateral root has a root tip, water hyacinth may exploit nutrient in a low-nutrient water body (Xie and Yu, 2003). Lateral roots are generally longer and denser at low phosphorus levels than at high phosphorus levels (Xie and Yu, 2003). In shallow water, the roots may become attached to the bottom for several weeks when the water level drops (Parsons and Cuthbertson, 2001). The biomass ratio varies inversely with nutrient level, particularly with respect to nitrogen. Purple roots are characteristic of plants when nutrient levels are low in the water (Xie and Yu, 2003).

1.2.2 Habitat

Water hyacinth rapidly colonises still or slow moving water, resulting in thick extensive mats. It occurs in estuarine habitats, lakes, urban areas, water courses, and wetlands (Gopal, 1987). It prefers nutrient-enriched waters and can tolerate considerable variation in nutrients, temperature, pH levels and toxic substances (Gopal, 1987). Growth occurs in a wide range of temperature from 1 to 40°C, but is most favourable under warm condition with a maximum growth at 25 to 27.5°C (Wilson *et al.*, 2005). Plants tolerate acidity levels as low as pH 3 (DiTomaso and Healy, 2003) but optimum pH for growth is 6 to 8 (Wilson *et al.*, 2005). However, water hyacinth does not tolerate salinity above 1.6% (DiTomaso and Healy, 2003) and there is no evidence to indicate that this fresh water plant can adjust to saline water (Penfound and Earle, 1948).

1.3 Use of water hyacinth

Water hyacinth has received much attention in recent years due to its potential benefits as animal fodder, aquafeed, water purification, fertilizer, biogas production, even food for human and other products (Ogle *et al.*, 2001) (Figure 2). Due to the extreme scarcity of forages in Vietnam, water hyacinth has become more interesting for the improvement of ruminant production. Therefore, attention has gradually shifted from control to the utilization of water hyacinth as a valuable resource (Gopal, 1998).

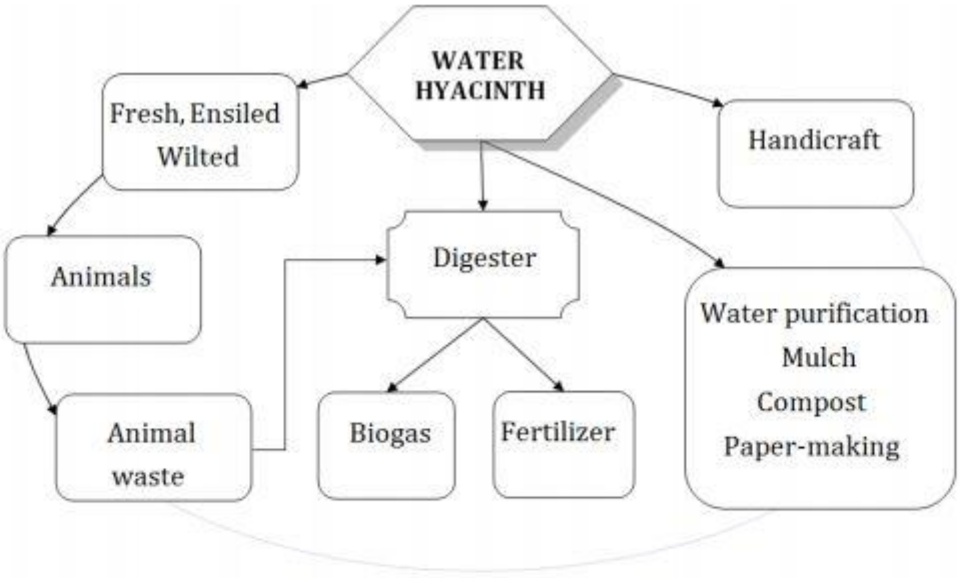

Figure 1.2: A diagram of possible uses of water hyacinth.

1.3.1 Animal feed

In Nigeria, water hyacinth can be used fresh, ensiled or wilted to animals. Whole plants, chopped or ground can used as feedstuffs for both ruminants and monogastrics. Ruminants Water hyacinth contains high levels of cellulose and hemicellulose, which could serve as energy sources for ruminants (Mukherjee and Nandi, 2004). Fresh water hyacinth has been utilised as partial replacement of para grass (*Brachiaria mutica*) in diets to cattle (Thu, 2011), and has given better growth than after wilting when fed to goats (Aregheore and Cawa, 2000).

Pigs: In Vietnam, a replacement of concentrates in pig diets by cooked or fresh water hyacinth reduced organic matter digestibility and digestible energy content without affecting feed intake and performance but the use of concentrates were reduced up to 6% in pig diets (Manh *et al.*, 2002; Son and Trung, 2002).

Rabbits: The University of Florida successfully fed pelleted water hyacinth to rabbits. Waste water grown water hyacinth completely or partially replaced alfalfa without effects on growth rate and reproductive parameters (Moreland *et al.*, 1991).

Fish: Water hyacinth has been recommended as a feed source for herbivorous/omnivorous fresh water fish (Hertrampf and Piedad-Pascual, 2000). El-Sayed (2003) has evaluated on the effects of ensilaged water hyacinth for Nile tilapia fingerlings using 5% sugar cane molasses as an additive. The results indicate that the silage gave better performance than fresh water hyacinth as a replacement of wheat bran at a substitution level of 10 to 20%.

1.3.2 Water purification

A beneficial aspect of water hyacinth is its capacity to remove contaminants from polluted bodies of water (Chen *et al.*, 1989). Various contaminants such as total suspended solids, dissolved solids, nitrogen, phosphorous, heavy metals, etc. as well as biochemical oxygen demand (BOD), have been minimised using water hyacinth (Guptal *et al.*, 2012). Nitrogen and phosphorus removal capacity from dairy waste water was found to be fastest in water hyacinth, followed by *Lemna minor* and *Azolla pinnata* (Tripathi and Upadhyay, 2003). Nitrogen removal by water hyacinth, *Lemna minor* and *Azolla pinnata* were 72, 63 and 60%, respectively, while 63, 59 and 56% of phosphorus were removed by these macrophytes. When water hyacinth growing in wetlands receiving domestic and industrial wastewaters, concentrations of Cu, Cd, Ni, Pb and Zn in the roots were 3 to 15 times higher than those in the shoots (Liao and Chang, 2004). This indicates that roots may act as a natural biosorbent (Low *et al.*, 1994).

1.3.3 Other uses

Water hyacinth has been used as mulch and compost and for paper-making and biogas generation. The fibres from the petioles can be used to make rope, baskets, carpet, etc. (Malik, 2007). Water hyacinth seems to be a good source of organic carbon and has been used as an organic fertilizer (Oroka, 2012).

1.4 Control methods

Mechanical, chemical and biological control methods are commonly used to control water hyacinth, but no one method is suitable for all situations (Julien *et al.*, 2001).

1.4.1 Mechanical

Mechanical control includes harvesting by hand or machine (Villamagna and Murphy, 2010). The use of machinery to remove water hyacinth from water bodies is the most effective non-polluting control method, especially in critical areas such as hydro-electric dams and ports. The main advantage to the use of mechanical harvesting is the simultaneous removal of nutrients and pollutants from the water body, and may therefore act as a means of slowing or even reversing eutrophication (Wittenberg and Cock, 2001).

1.4.2 Chemical

Chemical herbicides are the principal means of control when an immediate solution to a water hyacinth problem is needed (Charudattan, 1986). Glyphosate and 2,4- D [(2,4-dichlorophenoxy) acetic acid] have been the most widely used herbicides and considered as effective and safe herbicides to control water hyacinth (Chen *et al.*, 1989).

1.4.3 Biological

When chemical control is economically unfeasible or harmful to the environment, biological control is recognized as a cost effective, permanent and environmentally friendly control method. Using natural enemies from their original ecosystem is a prime target for biological control (De Groote *et al.*, 2003). The principal drawback with biological control of water hyacinth is the time required to achieve control. In tropical environments, this is usually 2 to 4 years and is influenced by the extent of the infestation, climate, water nutrient status, and other control options (Wittenberg and Cock, 2001).

1.5 Aim and Objectives of the Study

The aimed of this study is to investigate the survival potentials of *Eichhornia crassipes* when treated and exposed to crude oil.

Specific objectives of this study are to evaluated the effect of Crude oil treatment on;

(i) leaf diameter of the plant

(ii) root length of the plant

(iii) stem girth of the plant

(iv) plant chlorophyll content

(v) number of leaves per day in plant

(vi) fresh and dry weight of leaves, stem and root of the test plant

CHAPTER TWO

MATERIALS AND METHODS

2.1 Study site/Location

This study was carried out in the screen house located at the Department of Plant Biology and Biotechnology, Faculty of Life Sciences, University of Benin, Benin City, Edo State.

2.2 Duration of Study

The study was conducted for a period of eight (8) days.

2.3 Collection of Samples

Macrophyte: Samples of *Eichhornia crassipes* popularly known as water hyacinth was obtained from Ologbo pond, Edo State, Nigeria. They were carefully hand picked from the surface of the water to avoid root damage. The plant was then placed in plastic buckets and the roots were covered with pond water to prevent dehydration before getting to the screen house.

Crude oil: the crude oil was obtained from Okporhuru oil well, owned by Seplat Petroleum Development company, located in Sapele, Delta state.

2.4 Experimental Setup

Different treatments of 0%, 0.2%, 0.4%, 0.6%, 0.8% (v/v) were used for the study. The test *Eichhornia crassipes* was thoroughly rinsed with tap water to wash off any particles attached to the leaf surfaces and roots. It was then transferred to the 15 bowls. The bowls were categorised into five places as follows:

(i) 0% v/v containing 100ml distilled water as control

(ii) 0.2% containing 998ml distilled water and 2ml crude oil

(iii)0.4% containing 996ml distilled water and 4ml crude oil

(iv)0.6% containing 994ml distilled water and 6ml crude oil

(v) 0.8% containing 992ml distilled water and 8ml crude oil

There were three replicates of each which were labeled accordingly. The experimental setup prepared and experiment was conducted for eight days. In the course of the experiment readings were taken daily. All experimental materials were placed under the same environmental conditions so as to ensure accuracy of data and completeness.

2.5 Data Readings

Morphological observations of the plants were made to observe changes in leaf diameter, root length, stem girth, chlorophyll content, plant height and number of leaves. The following data were recorded during the experiment.

2.5.1 Leaf diameter measurement: This was evaluated using a metre rule.

2.5.2 Root length: The root length was measured using metre rule before it was introduced into the treatment medium and also measured at the end of the experiment.

2.5.3 Stem girth: It was measured using a digital vernier caliper. This was estimated on day 1 and after termination of the experiment.

2.5.4 Chlorophyll content index: This parameter was measured using Apogee chlorophyll content meter. It was measured by holding the arm of the chlorophyll content meter in contact with the leaf until it made a beep and displayed the result on the screen of the device and was recorded before treatment (day 1) and after treatment (day 8).

2.5.5 Determination of number of leaves: On daily basis, the number of leaves were counted and recorded.

2.5.6 Fresh and dry weight of determination: The fresh and dry weights were determined after eight (8) days of treatment. All observations were recorded at day 8. The plants were separated into leaves, stem and root. Newspaper were used to package the various portions of the plant and thereafter labeled accordingly. The fresh weight was obtained after weighing using an electronic sensitive balance. The dry weight was obtained by drying the plant parts packaged in the newspaper in a ventilated oven at 70^oC for 24 hrs after which the dry weight was determined using electronic sensitive balance.

2.6 Phytochemical analysis of plants

Heavy metals: plant parts were air dried for seven (7) days. They were thereafter oven dried at 60^oC temperature to a constant weight before grinding to powder. One gram of the ground powder was then weighed into a 250ml conical flask. Ten millimeters of mixture of perchloric acid, nitric acid and sulphuric acid in the ration 1:2:2 was added to the flask containing the ground powder and placed in the fume chamber. The mixture was heated for twenty minutes on a hot plate until white fumes were noticed. The digestion was stopped and the mixture cooled, before 20ml of distilled water was added and boiled gently to bring the metals into solution. The solution is aspirated and analyzed with atomic absorption spectrophotometer (AAS). (APHA, 1998).

2.7 Statistical analysis

The results were represented as means ± Standard errors of the three independent replicates. All obtained data were subjected to statistical analysis using statistical package for social sciences (SPSS) version 20.0. Analysis of variance (ANOVA) using Duncan Multiple range test was performed on the experimental data obtained.

Plate 3: Taking fresh and dry weight measurements of *Eichhornia crassipes*

Plate 4: Measuring distilled water for experimental setup

Plate 5: Water hyacinth treated with different crude oil concentration at day 2

Plate 6: Water hyacinth treated with different crude oil concentration at day 5

Plate 7: Water hyacinth treated with different crude oil concentration at day 8

Plant 8: Plant parts separated for fresh and dry weight biomass

CHAPTER THREE

RESULTS

Experimental results obtained in the course of this study has been represented in this section. Results have been presented in table 1 to table 10.

Table 3.1 shows the result obtained for the plant height analysis of water hyacinth (*Eichhornia crassipes*). Water hyacinth specimens were individually measured using a metre rule to obtain plant height and means were obtained for the various replicates for the various treatments with crude oil.

Results revealed increase in plant height of control samples of *Eichhornia crassipes* from 56.33±2.19cm to 61.73±2.43cm. All other test plant which received crude oil treatment showed decrease in plant height indicating negative impact of crude oil on the plant height of *Eichhornia crassipes*. Plant height of samples of *Eichhornia crassipes* treated with 0.2% v/v, 0.4%v/v, 0.6% v/v and 0.8% v/v crude oil decreased from 45.00±5.77cm to 36.67±6.01cm, 41.33±7.88cm to 35.00±3.46cm, 44.00±2.65cm to 42.33±1.76 and 59.67±2.73cm to 45.67±5.17cm respectively. As concentration of crude oil increased the plant height decreased also.

One-Way ANOVA test of plant height of *Eichhornia crassipes* revealed significant ($p<0.05$) in values obtained before and after treatment with crude oil.

Table 3.1: Effect of Crude Oil on Plant height of Water Hyacinth (*Eichhornia crassipes*)

Treatment % (v/v)	Before treatment (cm)		After treatment (cm)	
	Mean	±S.E	Mean	±S.E
0	56.33	$\pm 2.19^{ab}$	61.73	$\pm 2.43^{b}$
0.2	45.00	$\pm 5.77^{ab}$	36.67	$\pm 6.01^{a}$
0.4	41.33	$\pm 7.88^{a}$	35.00	$\pm 3.46^{a}$
0.6	44.00	$\pm 2.65^{ab}$	42.33	$\pm 1.76^{a}$
0.8	59.67	$\pm 2.73^{b}$	45.67	$\pm 5.17^{a}$
	*		*	

N.B: N.S = Non significant (P > 0.05)   * = Significant (P < 0.05)

Data values are shown as means ± standard errors of the 3 replicates used. Means in the column with similar superscript are not significantly different (P > 0.05). Means in the column sharing dissimilar superscript alphabets are significantly different (P< 0.05).

The stem girth of the water hyacinth (*Eichhornia crassipes*) samples were also estimated in the course of the experimental study. Stem girth was measured for each water hyacinth specimen with aid of a vernier caliper before and after treatment with crude oil. Stem girth results are shown in table 3.2.

There was observed increase in stem girth for control samples of *Eichhornia crassipes* from 56.33±2.19cm to 61.73±2.43cm. Plant samples that received crude oil treatment has decreased stem girth values. It was observed that stem girth of *Eichhornia crassipes* treated with 0.2% v/v, 0.4%v/v, 0.6% v/v and 0.8% v/v crude oil decreased from 7.11±0.95cm to 5.77±0.35cm, 5.59±0.04cm to 5.50±0.01cm, 6.91±1.04cm to 5.95±0.29cm and 7.52±0.69cm to 6.50±0.31cm respectively.

No significant difference ($p>0.05$) was obtained in stem girth values of *Eichornia crassipes* before treatment with crude oil. On the other hand, stem girth values of *Eichornia crassipes* revealed significant difference ($p<0.05$) after crude oil treatment.

Table 3.2: Effect of Crude Oil on stem girth of Water Hyacinth (*Eichhornia crassipes*)

Treatment % (v/v)	Before treatment (cm)		After treatment (cm)	
	Mean	±S.E	Mean	±S.E
0	7.05	±0.02[a]	7.07	±0.01[c]
0.2	7.11	±0.95[a]	5.77	±0.35[ab]
0.4	5.59	±0.04[a]	5.50	±0.01[a]
0.6	6.91	±1.04[a]	5.95	±0.29[ab]
0.8	7.52	±0.69[a]	6.50	±0.31[bc]
	NS		*	

N.B: N.S = Non significant (P > 0.05) * = Significant (P < 0.05)

Data values are shown as means ± standard errors of the 3 replicates used. Means in the column with similar superscript are not significantly different (P > 0.05). Means in the column sharing dissimilar superscript alphabets are significantly different (P< 0.05).

To better understand the impact of crude oil treatments on water hyacinth (*Eichhornia crassipes*) samples, the number of leaves were visually counted in the course of the experimental study. Results obtained for the number of leaves is shown in Table 3.

Increase in mean number of leaves was obtained in control samples of *Eichhornia crassipes* which mean number of leaves increasing from 8.33±0.88cm to 9.00±0.58. It was observed that mean number of leaves decreased in number for plant samples which received crude oil treatment contrary to observations made in control samples. The mean number of leaves of *Eichhornia crassipes* treated with 0.2% v/v, 0.4%v/v, 0.6% v/v and 0.8% v/v crude oil decreased 8.00±0.58 to 2.67±1.45, 9.33±0.88 to 4.67±1.20, 10.00±0.58 to 3.67±1.86 and 11.33±0.88 to 7.67±1.20 respectively.

Significant difference ($p<0.05$) was obtained in the mean number of leaves of *Eichhornia crassipes* before and after treatment with crude oil.

Table 3.3: Effect of Crude Oil on Number of leaves of Water Hyacinth (*Eichhornia crassipes*)

Treatment % (v/v)	Before treatment (cm)		After treatment (cm)	
	Mean	±S.E	Mean	±S.E
0	8.33	$\pm 0.88^{a}$	9.00	$\pm 0.58^{c}$
0.2	8.00	$\pm 0.58^{a}$	2.67	$\pm 1.45^{a}$
0.4	9.33	$\pm 0.88^{ab}$	4.67	$\pm 1.20^{abc}$
0.6	10.00	$\pm 0.58^{ab}$	3.67	$\pm 1.86^{ab}$
0.8	11.33	$\pm 0.88^{b}$	7.67	$\pm 1.20^{bc}$
	*		*	

N.B: N.S = Non significant (P > 0.05) * = Significant (P < 0.05)

Data values are shown as means ± standard errors of the 3 replicates used. Means in the column with similar superscript are not significantly different (P > 0.05). Means in the column sharing dissimilar superscript alphabets are significantly different (P< 0.05).

Observations of leaf diameter data obtained revealed increase in values for control samples of *Eichhornia crassipes* (Table 3.4). The highest (8.50±0.17cm) and lowest (7.20±0.15) leaf diameter for control samples occurred at day 8 and day 1 respectively. In the case of water hyacinth samples that received crude oil treatments, there was generally a gradual decline in leaf diameter between day 1 and day 8. For water hyacinth samples treated with 0.2% v/v crude concentration, leaf diameter was observed to decrease exponentially from 6.63±0.03cm on day 1 to 2.60±1.30cm at day 8. Water hyacinth samples treated with 0.4% v/v crude concentration, leaf diameter was observed to decrease exponentially from 7.20±0.15cm at day 1 to 4.37±0.12cm at day 8. Also water hyacinth samples treated with 0.6% v/v crude concentration, leaf diameter was observed to decrease exponentially from 6.27±0.17cm at day 1 to 2.00±1.00cm at day 8. Final treatments of water hyacinth with 0.8% v/v crude concentration, revealed leaf diameter decreased exponentially from 7.53±0.12cm at day 1 to 3.50±0.50cm at day 8.

Significant difference ($p<0.05$) was observed in leaf diameter of *Eichhornia crassipes* at day 1, day 2, day 3, day 4, day 5, day 7 and day 8. No significant difference ($p>0.05$) was observed in leaf diameter of *Eichhornia crassipes* at day 6,

Table 3.4: Effect of Crude Oil on Leaf diameter of Water Hyacinth (*Eichhornia crassipes*)

Treatment % (v/v)	Days after treatment (cm)							
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
0	7.20 ±0.15^{b}	7.17 ±0.09^{c}	7.27 ±0.09^{c}	7.20 ±0.12^{b}	7.23 ±0.15^{b}	7.53 ±0.09^{a}	8.27 ±0.12^{b}	8.50 ±0.17^{b}
0.2	6.63 ±0.03^{a}	6.40 ±0.06^{b}	6.03 ±0.09^{a}	5.97 ±0.09^{a}	5.97 ±0.09^{a}	3.80 ±1.90^{a}	3.17 ±1.58^{a}	2.60 ±1.30^{a}
0.4	7.20 ±0.15^{b}	7.07 ±0.12^{c}	6.70 ±0.21^{b}	6.20 ±0.23^{a}	6.20 ±0.23^{a}	5.87 ±0.22^{a}	5.47 ±0.18^{ab}	4.37 ±0.12^{a}
0.6	6.27 ±0.17^{a}	5.97 ±0.15^{a}	5.70 ±0.23^{a}	5.97 ±0.18^{a}	5.97 ±0.18^{a}	3.67 ±1.83^{a}	3.10 ±1.55^{a}	2.00 ±1.00^{a}
0.8	7.53 ±0.12^{b}	7.27 ±0.12^{c}	7.43 ±0.15^{c}	6.87 ±0.09^{b}	6.87 ±0.09^{b}	6.73 ±0.07^{a}	4.40 ±0.26^{a}	3.50 ±0.50^{a}
	*	*	*	*	*	NS	*	*

N.B: N.S = Non significant (P > 0.05) * = Significant (P < 0.05)

Data values are shown as means ± standard errors of the 3 replicates used. Means in the column with similar superscript are not significantly different (P > 0.05). Means in the column sharing dissimilar superscript alphabets are significantly different (P< 0.05).

Results obtained for the effect of crude oil treatments on stem length of water hyacinth (*Eichornia crassipes*) samples is shown in table 3.5.

Stem length readings obtained in the study revealed an increase in stem length values for only control samples (0% v/v crude oil) from 34.10±0.91cm to 36.47±0.70cm. It was observed that there was decrease mean values of stem length of *Eichhornia crassipes* treated with crude oil. Stem length of *Eichhornia crassipes* specimens treated with 0.2% v/v, 0.4% v/v, 0.6%v/v and 0.8%v/v crude oil concentrations decreased from 32.23±1.76cm to 27.17±3.92cm, 12.70±1.67cm to 10.30±1.41cm, 20.50±2.26cm to 16.70±1.68cm and 31.77±3.68cm to 31.13±1.40cm respectively.

Statistical analysis using One-Way ANOVA technique revealed significant ($p<0.05$) in stem length values of *Eichhornia crassipes* obtained before and after treatment with crude oil.

Table 3.5: Effect of Crude Oil on Stem length of Water Hyacinth (*Eichhornia crassipes*)

Treatment % (v/v)	Before treatment (cm)		After treatment (cm)	
	Mean	S.E	Mean	S.E
0	34.10	$\pm 0.91^{c}$	36.47	$\pm 0.70^{c}$
0.2	32.23	$\pm 1.76^{c}$	27.17	$\pm 3.92^{b}$
0.4	12.70	$\pm 1.67^{a}$	10.30	$\pm 1.41^{a}$
0.6	20.50	$\pm 2.26^{b}$	16.70	$\pm 1.68^{a}$
0.8	31.77	$\pm 3.68^{c}$	31.13	$\pm 1.40^{bc}$
	*		*	

N.B: N.S = Non significant (P > 0.05)   * = Significant (P < 0.05)

Data values are shown as means ± standard errors of the 3 replicates used. Means in the column with similar superscript are not significantly different (P > 0.05). Means in the column sharing dissimilar superscript alphabets are significantly different (P< 0.05).

Table 3.6 shows results obtained for root length of water hyacinth (*Eichhornia crassipes*) before and after treatment with crude oil.

Root length obtained in the study after treatment of water hyacinth with crude oil revealed an increase in root length values for only control samples (0% v/v) from 23.50±3.77cm to 26.75±2.84cm. There was observed decline in mean root length values for *Eichhornia crassipes* treated with crude oil. Root length of *Eichhornia crassipes* specimens treated with 0.2% v/v, 0.4% v/v, 0.6%v/v and 0.8%v/v crude oil concentrations decreased from 16.67±4.06cm to 13.33±2.91cm, 17.33±3.84cm to 14.33±3.48cm, 25.50±3.50cm to 20.50±1.50cm and 25.67±4.98cm to 20.67±5.21cm respectively.

No significant ($p>0.05$) was observed in mean root length values of *Eichhornia crassipes* before treatment with crude oil while significant ($p<0.05$) was observed in mean root length values of *Eichhornia crassipes* after treatment with crude oil.

Table 3.6: Effect of Crude Oil on Root length of Water Hyacinth (*Eichhornia crassipes*)

Treatment % (v/v)	Before treatment (cm)		After treatment (cm)	
	Mean	S.E	Mean	S.E
0	23.50	±3.77[a]	26.75	±2.84[b]
0.2	16.67	±4.06[a]	13.33	±2.91[a]
0.4	17.33	±3.84[a]	14.33	±3.48[ab]
0.6	25.50	±3.50[a]	20.50	±1.50[ab]
0.8	25.67	±4.98[a]	20.67	±5.21[ab]
	NS		*	

N.B: N.S = Non significant ($P > 0.05$), * = Significant ($P < 0.05$)

Data values are shown as means ± standard errors of the 3 replicates used. Means in the column with similar superscript are not significantly different ($P > 0.05$). Means in the column sharing dissimilar superscript alphabets are significantly different ($P< 0.05$).

Figure 3.1 shows the results obtained for fresh and dry weight of stem of water hyacinth (*Eichhornia crassipes*) after treatment with crude oil.

The highest stem fresh weight (14.15±2.46g) occurred in control samples which received no crude oil treatment. The lowest stem fresh weight (9.00±0.58g) occurred in water hyacinth samples treated with 0.2% v/v crude oil concentration. No significant difference was observed in fresh weight of stem of water hyacinth.

The highest mean value of stem dry weight (3.08±1.20g) occurred in control samples which received no crude oil treatment. The lowest mean value of stem dry weight (1.91±0.75g) occurred in water hyacinth samples treated with 0.6% v/v crude oil concentration. No significant difference was observed in dry weight of stem of water hyacinth.

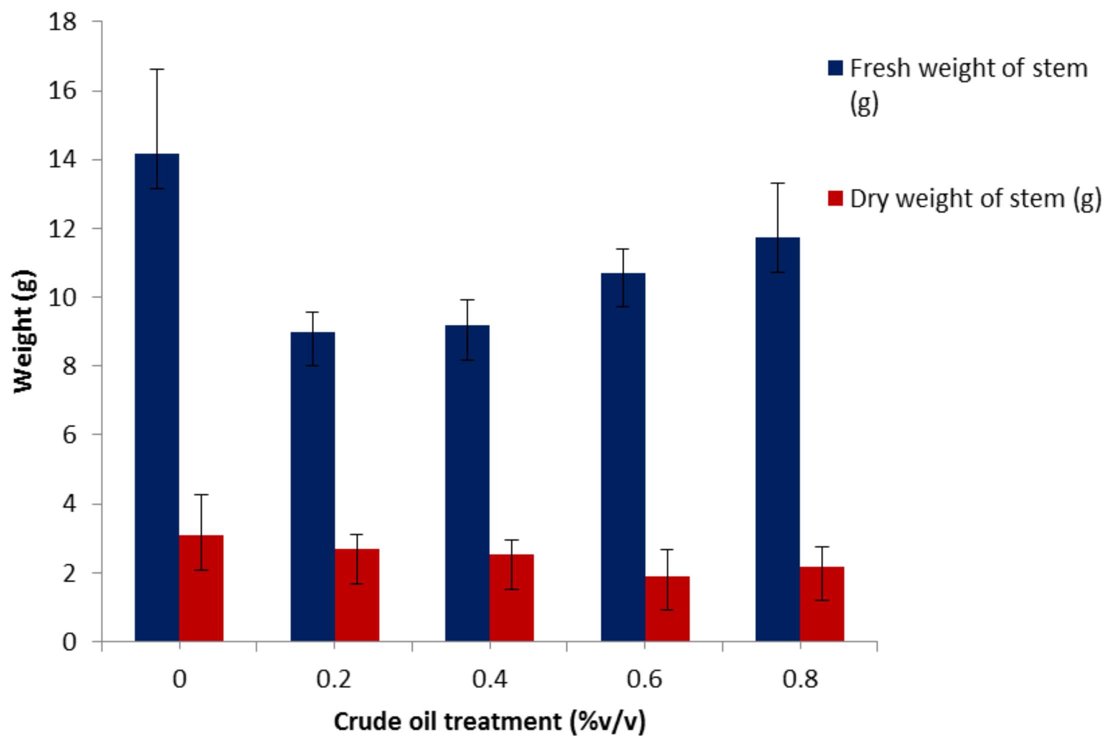

Figure 3.1: Effect of Crude Oil on Fresh and dry weight of stem of Water Hyacinth (*Eichhornia crassipes*)

Figure 3.2 shows the results obtained for fresh and dry weight of root of water hyacinth (*Eichhornia crassipes*) after treatment with crude oil.

The highest root fresh weight (19.34±2.96g) occurred in control samples which received no crude oil treatment. The lowest root fresh weight (12.22±0.89g) occurred in water hyacinth samples treated with 0.2% v/v crude oil concentration. No significant difference was observed in fresh weight of root of water hyacinth.

The highest root dry weight (3.06±1.19g) occurred in control samples which received no crude oil treatment. The lowest root dry weight (1.91±0.75g) occurred in water hyacinth samples treated with 0.6% v/v crude oil concentration. No significant difference was observed in dry weight of root of water hyacinth.

No significance difference (p>0.05) was observed in fresh and dry weight of root of *Eichhornia crassipesi* after treatment with crude oil.

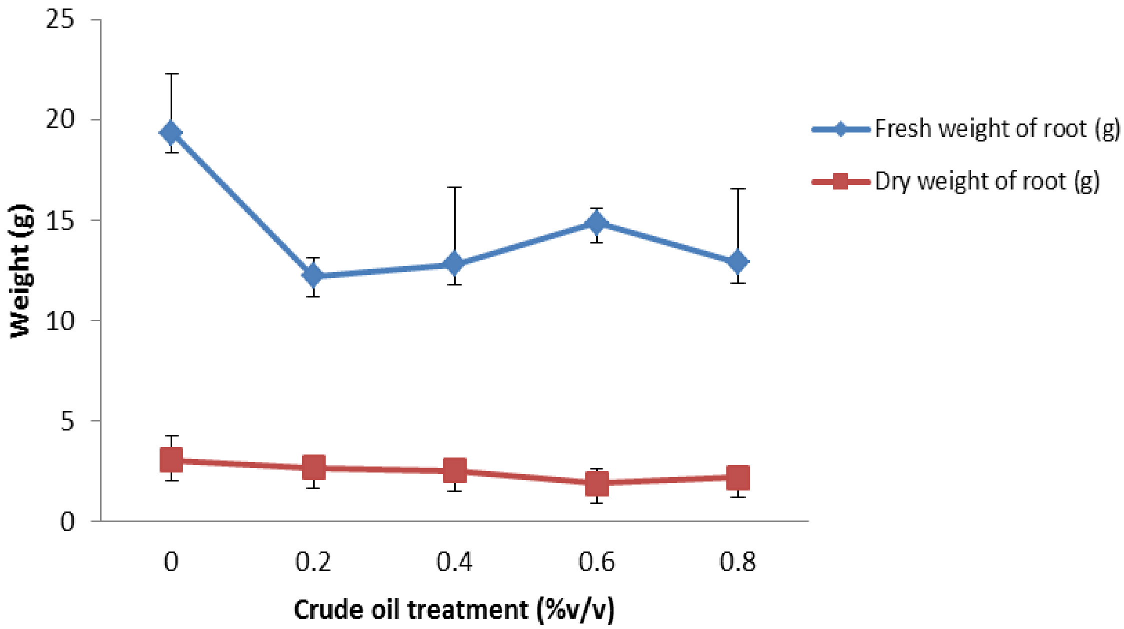

Figure 3.2: Effect of Crude Oil on Fresh and dry weight of root of Water Hyacinth (*Eichhornia crassipes*)

Figure 3.3 reveals the results obtained for fresh and dry weight of leaves of water hyacinth (*Eichhornia crassipes*) after treatment with crude oil.

The highest leaves fresh weight with a mean value of 3.76±1.24g occurred in *Eichhornia crassipes* samples treated with 0.2% v/v crude oil treatment. The lowest leaves fresh weight (2.69±0.36g) occurred in water hyacinth samples treated with 0.8% v/v crude oil concentration. No significant difference was observed in fresh weight of leaves of water hyacinth.

The highest mean value of leaves dry weight (1.95±0.60g) occurred in *Eichhornia crassipes* samples treated with 0.2% v/v crude oil treatment. The lowest mean value of leaves dry weight (1.17±0.27g) occurred in water hyacinth samples treated with 0.6% v/v crude oil concentration. No significant difference was observed in dry weight of leaves of water hyacinth.

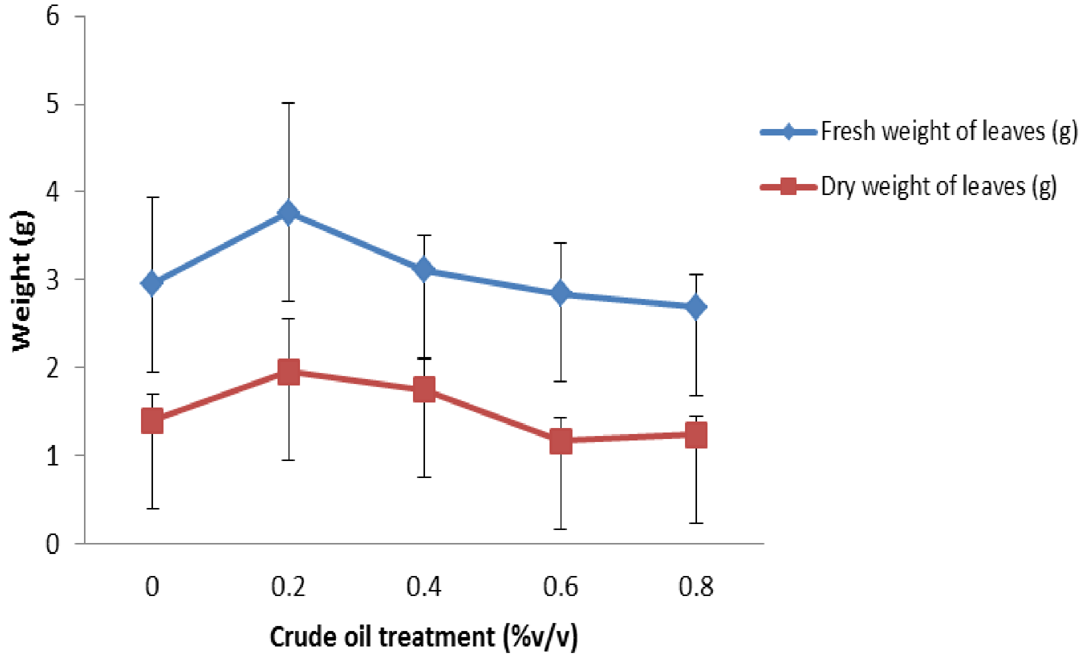

Figure 3.3: Effect of Crude Oil on Fresh and dry weight of Leaves of Water Hyacinth (*Eichhornia crassipes*)

Figure 3.4 reveals results for chlorophyll content of water hyacinth (*Eichhornia crassipes*) before and after treatment with crude oil

The chlorophyll content index (CCI) obtained before treatment with crude oil revealed highest mean values of chlorophyll content index (CCI) (35.93±0.80) occurred in control samples of *Eichhornia crassipes.* The lowest mean value of chlorophyll content index (CCI) (26.80±2.50) obtained before treatment with crude oil occurred in *Eichhornia crassipes* samples treated with 0.6% v/v crude oil. The chlorophyll content index (CCI) obtained after treatment with crude oil revealed highest CCI value (36.90±0.93) occurred in control samples of *Eichhornia crassipes*. The lowest mean chlorophyll content index (CCI) (10.77±5.49) obtained after treatment with crude oil occurred in *Eichhornia crassipes* samples treated with 0.6% v/v crude oil

Significant difference ($p>0.05$) was obtained in chlorophyll content index of *Eichhornia crassipes* before and after treatment with crude oil.

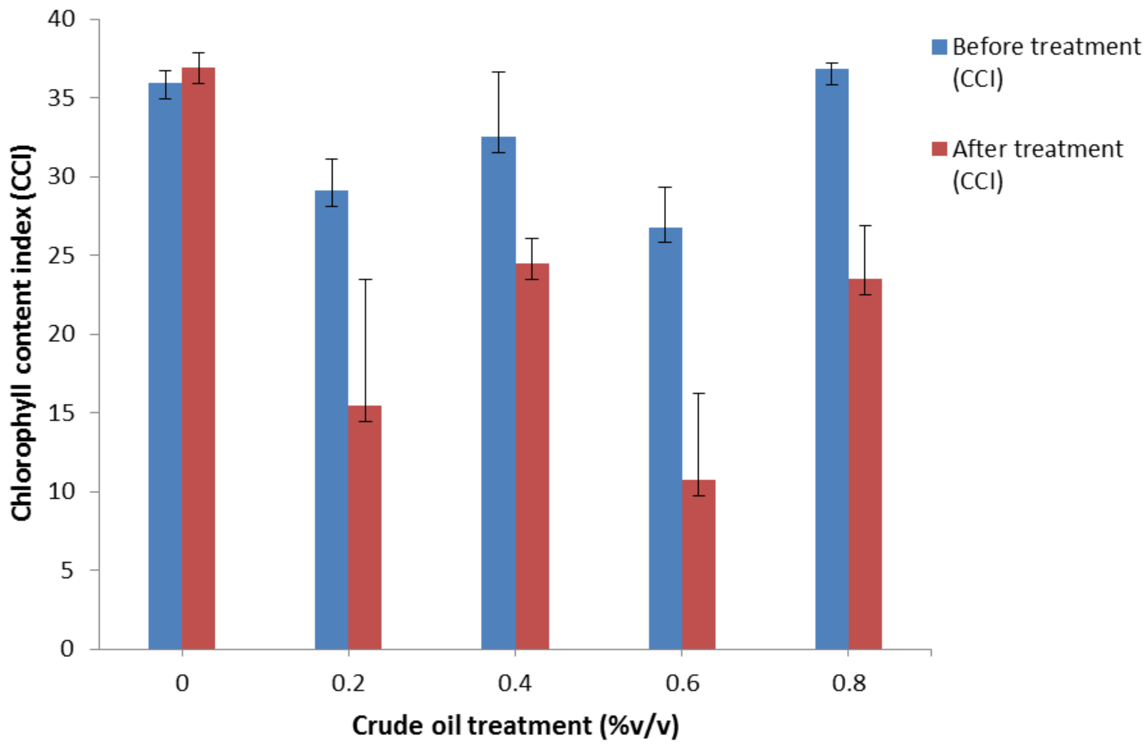

Figure 3.4: Effect of Crude Oil on Chlorophyll content (CCI) of Water Hyacinth (*Eichhornia crassipes*)

The heavy metal analysis of *Pistia stratoites* exposed to different concentrations of crude oil is shown in Table 3.7. The concentration of Iron in shoot and root of *P. stratoites* ranged from 1.79±0.90-55.26±5.06 mg/kg and 0.80±0.29-46.11±2.69 mg/kg respectively.

The concentration of Manganese in shoot and root of *P. stratoites* ranged from 0.41±0.02-6.31±0.33 mg/kg and 1.05±0.11-19.55±0.76 mg/kg respectively.

The concentration of Zinc in shoot and root of *P. stratoites* ranged from 0.18±0.08-25.76±2.17 mg/kg and 0.16±0.06-30.21±1.09 mg/kg respectively

The concentration of Copper in shoot and root of *P. stratoites* ranged from 0.15±0.01-2.99±0.75 mg/kg and 0.50±0.02-4.52±0.56 mg/kg respectively

The concentration of Cadmium in shoot and root of *P. stratoites* ranged from 0.09±0.01-1.91±0.25 mg/kg and 0.09±0.01-2.51±0.51 mg/kg respectively

The concentration of Lead in shoot and root of *P. stratoites* ranged from 0.15±0.02-3.77±0.66 mg/kg and 0.17±0.01-3.93±0.20 mg/kg respectively

Table 3.7: Heavy metal concentration (mg/kg) in *Pistia stratiotes* exposed to different crude oil treatments.

Heavy Metal	Plant Organ	Concentration of treatment (%)				
		0	0.2	0.4	0.6	0.8
Fe	shoot	1.79 ± 0.90^{a}	3.86 ± 1.24^{b}	78.86 ± 4.77^{cd}	55.26 ± 5.06^{d}	37.21 ± 3.33^{c}
	Root	0.80 ± 0.29^{a}	16.19 ± 2.02^{b}	13.62 ± 2.31^{c}	46.11 ± 2.69^{d}	14.76 ± 1.37^{c}
Mn	shoot	0.41 ± 0.02^{a}	4.19 ± 0.22^{b}	6.31 ± 0.33^{d}	4.68 ± 3.41^{e}	3.27 ± 0.37^{c}
	Root	1.05 ± 0.11^{a}	3.59 ± 0.14^{b}	7.88 ± 0.55^{c}	19.55 ± 0.76^{d}	7.70 ± 0.60^{e}
Zn	shoot	0.18 ± 0.08^{a}	13.95 ± 0.53^{b}	25.22 ± 1.11^{c}	25.51 ± 2.02^{d}	25.76 ± 2.17^{c}
	Root	0.16 ± 0.06^{a}	21.11 ± 0.69^{b}	26.17 ± 1.31^{c}	23.19 ± 1.25^{d}	30.21 ± 1.09^{bc}
Cu	Shoot	0.15 ± 0.01^{a}	0.61 ± 0.09^{b}	2.97 ± 1.09^{e}	2.99 ± 0.75^{ab}	2.99 ± 0.75^{d}
	Root	0.50 ± 0.02^{a}	1.15 ± 1.01^{b}	3.51 ± 1.23^{c}	3.81 ± 0.63^{c}	4.52 ± 0.56^{c}
Cd	shoot	0.09 ± 0.01^{a}	0.50 ± 0.11^{b}	1.11 ± 0.21^{d}	1.27 ± 0.15^{e}	1.91 ± 0.25^{c}
	Root	0.09 ± 0.01^{a}	0.83 ± 0.03^{ab}	2.51 ± 0.51^{d}	1.61 ± 0.06^{b}	1.69 ± 0.53^{b}
Pb	shoot	0.15 ± 0.02^{a}	2.09 ± 0.10^{b}	3.77 ± 0.66^{c}	2.26 ± 0.23^{d}	3.09 ± 0.39^{cd}
	Root	0.17 ± 0.01^{a}	1.92 ± 0.11^{b}	3.93 ± 0.20^{d}	3.00 ± 0.16^{d}	3.50 ± 0.19^{c}

*Means with similar alphabets along each row are not significantly different from each other ($p > 0.05$)

The morphological changes observed in *Eichhornia crassipes* after treatment with different concentrations of crude oil is shown in Table 3.8. Chlorosis or yellowing of leaves were observed to occur in *E. crassipes* samples treated with crude oil. Necrotic lesions were observed in plant samples treated with 0.8% v/v crude oil concentration. Health plant features were observed basically in the control plant samples.

Table 3.8: Morphological changes observed in *Eichhornia crassipes* in different crude oil concentrations

Concentration	Observations
Control	Plant growth remain healthy, plant remain green in colour
0.2% v/v	Change in colour but plant had good growth. Older leaves show signs of chlorosis
0.4% v/v	Detachment of some leaves and chlorotic lesions were noticed on the adaxial surface of leaves
0.6% v/v	Chlorosis intensified
0.8% v/v	Colour change observed at the leave margin and weakness at the leave margin intensified. Necrotic lesions were also noticed

Plate 9: Adaxial surface of test plant showing necrotic lesions.

CHAPTER FOUR

DISCUSSION AND CONCLUSION

4.1 Discussion

This study was conducted with the purpose of evaluating the impact of crude oil treatments on growth of water hyacinth. For plant height of water hyacinth, it was observed that values decreased after treatment with various crude oil treatments. The highest plant height was observed in control samples of water hyacinth. There was observed decrease in plant height of water hyacinth samples treated with 0.8% (v/v) crude oil. The lowest plant height was obtained in water hyacinth samples treated with 0.4% (v/v) crude oil.

Stem girth analysis in macrophyte which received crude oil treatment recorded highest decrease stem girth in 0.8% (v/v) crude oil while lowest stem girth values was recorded in macrophyte samples which received 5.50% (v/v) crude oil treatments.

Crude oil impact on number of leaves of water hyacinth were also evaluated. Results obtained revealed that as crude oil treatments increased this lead to decrease in number of leaves of the macrophyte. Number of leaves extended for water hyacinth revealed that values began to decrease from day 3 after crude oil treatments. Crude oil was thus found to impact number of leaves extended. Crude oil treatments were also observed to impact on the stem length. Similar study conducted Ochekwu and Madagwa, (2013) revealed results of the effect of different concentrations of crude oil on the number of leaf of *E. crassipes* showed that the control plant gave the highest number of leaves as 17.00±1.414 after eight (8) weeks of growth while plants treated with 10.0% of crude oil gave the least number of leaves as 2.00±0.002 after four (4) weeks of growth.

Results revealed that macrophytes which received crude oil treatments had highest stem length decrease for samples which received 0.8% (v/v) crude oil treatment while lowest stem length decrease was obtained in macrophyte samples which received 0.4% (v/v).

Also results obtained for root length of the various macrophytes which received crude oil treatments revealed had highest root length decrease for samples which received 0.8% (v/v) crude oil treatment while lowest root length decrease was obtained in macrophyte samples which received 0.2% (v/v).

Highest fresh and dry weight of stem of the macrophytes occurred in control samples, while lowest fresh and dry weight of stem of the macrophytes occurred in 0.2% (v/v) and 0.6% (v/v) crude oil treatment. Highest fresh and dry weight of root of the macrophytes occurred in control samples respectively, while lowest fresh and dry weight of root of the macrophytes occurred in 0.2% (v/v) and 0.6% (v/v) crude oil treatment. Also the highest fresh and dry weight of leaves of the macrophytes occurred in 0.2% (v/v) crude oil treatment respectively, while the lowest fresh and dry weight leaves of the macrophytes occurred in 0.8% (v/v) and 0.6% (v/v) crude oil treatment respectively.

Ochekwu and Madagwa (2013) in their study showed that results of the effect of different concentrations of crude oil on the fresh weight of *Eichhornia crassipes* showed that the control plants gave the highest fresh weight from initial weight of 14.22±0.003g to 62.43±0.009g in week 8 while 10.0% concentration gave the least fresh weight increase from 17.19±0.002g initial weight to 16.28±0.011g in week 4. There was death of *Eichhornia crassipes* in 7.5% and 10.0% concentration of crude oil by the 6 th week of growth. Also their study revealed that the dry weight of *Eichhornia crassipes* of the control plant was the highest with a value 9.62±0.002g after 4 weeks of growth while crude oil treatment, 10%, gave 3.46±0.006g dry weight after 4 weeks of growth. Thereafter, plants treated with 7.5% and 10% died.

Chlorophyll content decreased in macrophyte samples which received crude oil treatment. This revealed that the increased crude oil concentration lead to decrease in photosynthetic activities in the macrophyte samples. Morphological parameters of the macrophyte samples were impacted especially due to loss of chlorophyll and clear chlorosis immediately following crude oil pollution. This conforms with study of Brooks and Robinson (1998) who worked on aquatic phytoremediation by accumulator plants.

Contrary to results obtained in this study Ochekwu and Madagwa (2013) reported a significant increase in the morphological parameters (plant height, number of leaves and leaf area) of *Eichhornia crassipes* after 2 weeks treatment with crude oil treatments and further increase were observed at 4 weeks. A decrease in the afformentioned parameters was only obtained at 8weeks and 12 weeks when the experiment ended and the growth rate reduced greatly.

Observations made in this study revealed response of *Eichhornia crassipes* to crude oil contamination indicated a reduced plant height, leaf area, number of leaves, fresh weight and dry weight as the concentration (treatment) increased. These results are in line with the report of Bailey and McGill (1999) who stated that plants tolerate increased exposure to crude oil with minimal growth rate. Crude oil spills affect plants adversely by creating conditions that make essential nutrients like nitrogen and oxygen needed for plant growth unavailable to them (Wright *et al*., 1997). According to Erute *et al.* (2009), oil contamination causes slow rate of germination in plants. Adam and Duncan (1999) reported that this effect could be due to the oil which acts as a physical barrier (hydrophobic layer), preventing or reducing access of the seeds to water and oxygen.

Morphological distortions in the plant's form and functional parts have been reported and this varies with the pollutant present and its concentration. Reproductive integrity has also been reported to be impaired and also biochemical and physiological distortions (Mearns *et al*., 2020).

When the concentrations of pollutants, for example heavy metals, become excessive, the plant may be at risks of heavy metal toxicity both directly and indirectly. High concentrations of heavy metals in plant may interfere with metabolic functions, including physiological and biochemical processes such as oxidative stress from production of reactive oxygen species (ROS), inhibition of photosynthesis, and respiration and degeneration of main cell organelles, even leading to death of plants (Zhang *et al*., 2017). Other specific effects include growth reduction (especially the origin and main part of system is more affected), chlorosis and leaf necrosis followed by traces of senescence and abscission, which changes lead to lower nutrient uptake and interfere with the biomass acquired (Isiuku and Enyoh, 2019).

This study also indicates the trend of accumulation of heavy metals in the shoots and roots of the plants. Generally, heavy metals were present in trace amounts in the control plants; with the concentration of Iron (Fe) ranging from 1.79±0.90-55.26±5.06 mg/kg in the shoots and 0.80±0.29-46.11±2.69 mg/kg in the roots, manganese (Mn) concentration ranged from 0.41±0.02-6.31±0.33 mg/kg in the shoots and 1.05±0.11-19.55±0.76 mg/kg in the roots, zinc (Zn) concentration ranging from 0.18±0.08-25.76±2.17 mg/kg in the shoots and 0.16±0.06-30.21±1.09 mg/kg in the roots. Copper concentration ranged from 0.15±0.01-2.99±0.75 mg/kg in the shoots and 0.50±0.02-4.52±0.56 mg/kg in the roots. Cadmium (Cd) concentration ranged from .09±0.01-1.91±0.25 mg/kg in the shoots and 0.09±0.01-2.51±0.51 mg/kg in the roots. Lead concentration ranged from 0.15±0.02-3.77±0.66 mg/kg in the shoots and 0.17±0.01-3.93±0.20 mg/kg in the roots. It was observed that treatment with crude oil resulted in the buildup of manganese and lead in all parts of the plants, however, the heavy metals were bioaccumulated more in the roots than in the shoots. Jayaweera *et al.,* (2008); Maine *et al.,* (2004); Das and Maiti (2008) and Qian *et al.,* (1999) also reported similar results from their various studies. This is probably due to the fact that metals are adsorbed to the surface of the root tissues and that some metals show poor mobility from the roots upwards towards the shoots. (Kouame *et al.,* 2016; Yabanli *et al.,* 2014 and Lu *et al.,* 2011). Such observation including the eventual translocation in plant tissues has been observed earlier by Vwioko *et al*. (2006). Considering the trend of accumulation of lead and manganese, this study is in line with the work of Beauford *et al*. (1977). They had observed that heavy metals such as mercury are accumulated more in the roots of plants, and they associated the observation to the fact that the roots are in direct contact with the metals in the soil environment. The accumulation of cadmium by the test plants was relatively low at all concentrations of crude oil, it was highest in the shoots at 0.4% treatment as 3.93±0.20 mg/kg and least in the control plant as 0.15±0.02; in the roots. This supports the work of Akapo *et al* (2011), in their study to determine the morphological and anatomical effects of crude oil on *P. stratiotes*, they showed that cadmium accumulation was relatively not observed except for the little dosage that was analyzed in the leaves of the plant. The result of this study shows that water lettuce (*Pistia stratiotes*) could be regarded as a good accumulator of lead. This agrees with the work of Salim *et al.* (1993). It also agrees with the work of Odjeigba and Fasidi (2004), in their study on the implications of accumulation of trace elements by water lettuce (*Pistia stratiotes*) for the purpose of phytoremediation. They had shown that *P. stratiotes* moderately accumulated zinc, chromium, copper, lead, silver, and cadmium to a high concentration. Akapo *et al*, (2011) also demonstrated that *P. stratiotes* bioaccumulated lead and manganese when exposed to crude oil.

4.2 Conclusion

Fresh water plants perform a lot of crucial roles in the ecosystem, including phytoremediation of minute amounts of oil and being used as bioindicators for oil pollution. The result of this study shows that crude oil is detrimental to the survival of *P. stratiotes* and the effects were dependent on the concentration of the crude oil. *P. stratiotes* is a very sensitive species, because its leaves inevitably come into contact with the oil, and are not resistant to high concentrations of oil. Therefore, adequate measures should be put in place to avoid pollution of the environment with crude oil. It is the responsibility of oil companies to ensure that adequate measures are put in place to reduce the incidences of oil spillage by engaging in exploration and drilling best practices. Early response should be ensured in the case of an oil spillage in order to reduce the duration of exposure of ecosystems to oil pollution. The government should also embrace its responsibilities in monitoring the activities of oil companies.

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