**Effect of Crude Oil Pollution of Soil on the Reproductive Growth of Plantain (*Musa paradisiaca* L.)**


## Abstract

Soil polluted by crude oil is detrimental to the survival of plants and microbes. Plantain (*Musa paradisiaca* L.) is a major important food crop, showing tolerance to abiotic and biotic stress. This study investigated the impact of soil polluted with Bonny Light crude oil (BLCO) on the reproductive growth of two plantain cultivars. Crude oil was added to agricultural soil on which plantain suckers were planted. Reproductive growth was then periodically assessed. The number of suckers was significantly higher in French plantain plants grown on polluted soil in comparison with control. False Horn plantain plants on unpolluted soil produced more suckers in comparison to the plants on polluted soil. Also, the time between planting to flower bud appearance and flower bud appearance to bud opening reduced in plants on polluted soil in both cultivars in comparison with the control. Statistically, there was an insignificant decrease in the fruit size of False Horn plantain on polluted soil compared with the control while there was an appreciable increase with a significant effect in fruits size of French plantain on polluted soil compared with the control. Generally, French plantain tolerated the stress induced by crude oil pollution of soil in its reproductive growth more than False Horn. The reproductive growth of False Horn and French plantain cultivars show that there could be varied response to crude oil polluted soil.



**Keywords:** Crude oil; *Musa paradisiaca*; reproductive growth; and soil pollution.

## 1. INTRODUCTION

Polluted soils may pose threat to all biotic components. This is as a result of the changes in physical and chemical composition of the soil [1, 2]. Soil polluted by crude oil may adversely affect plant life due to reduction in the amount of water and oxygen available [3], decreased soil fertility, and shortage of essential nutrients that are needed by plants [4, 5]. Investigations on the effect of crude oil and its derivatives on plants showed a reduction in the growth and yield of *Zea mays* and *Triticum aestivum* [6, 7, 8, 9]. Reports also indicate significant reduction of plants vegetative and reproductive growth and or complete mortality of some other plant species [10]. According to AI-Jawhari et al. [11], soils polluted by crude oil resulted into inhibition of seed germination, growth, and productivity of soybean and maize. Ahmadu and Egbodion [12] reported that crude oil spillage had a significant impact on the yield of cassava. Ismail et al. [1] reported that control cowpea plants produced flowers, pods and seeds while plants grown on contaminated soil showed no sign of flower appearance, pods or seeds at all levels of contamination tested. Kekere et al. [13] also reported there was no crop yield in cowpea grown on contaminated soil at 8% v/w and 16% v/w oil concentration due to plant mortality. In Nigeria, after cassava and yam, plantain is the third most important starchy staple food grown [14]. It is one of the major plant species identified to survive in Niger Delta region of Nigeria where there is constant oil spillage.

Plantain (*Musa paradisiaca* L.) is a tropical herbaceous perennial monocotyledonous plant. There are various cultivars of plantain. These include: French plantain, French Horn plantain,

False Horn plantain and Horn plantain [15]. The underground component is formed of a bulb or true stem that develops many adventitious roots, allowing for sucker generation. *Musa spp.* develops in two distinct phases: a vegetative phase marked by the appearance of leaves, and a reproductive phase marked by the emergence of the inflorescence to fruiting [16]. The fruiting stage, which occurs after the flowering phase, can range from 60 - 90 days. Plantain life cycles generally last between 10 to 18 months from planting, depending on the environment and cultivar [17]. The flower is a terminal spike made up of an arrangement of nodes of flower clusters. The flower bud appear purple in colour and grows long enough to drop down in a bell form between the leaves after emerging from the centre of the trunk-like pseudostem. Flower buds open in succession. They appear reddish purple when opening before being shed from base to tip as the fruits develop. The male bud of False Horn plantain detaches shortly afterward while French plantain has a male bud at the end of the flower bunch. Temperature, photoperiod, and water content of the soil are the main elements that affect plantain and banana development from planting to flowering [18].

False Horn plantains have an incomplete bunch that lacks a male bud when mature. The bunch is made up of walls of double rows of fruit called hands as well as individual fruit called fingers. False Horn plantain produce few fruits spaced out over one to five hands [15]. The hands are composed of huge fingers followed by a few neutral flowers. False Horn plantain produce between 15 and 31 fruits (fingers) [15, 19]. According to Tenkouano et al. [20], False Horn plantain cultivar can take up to 365 days to produce a mature bunch after planting. French plantain bunch is complete with the male bud at maturity. The bunch is made up of many fingers, followed by the bunch axis covered in neutral and male flowers. Neutral flowers, also known as hermaphrodites or intermediate flowers do not produce fruit because their ovaries are unable to

expand in order to produce pulp. The purple bud at the end of the bunch is known as the male bud and is made up of bracts that cover groups of male flowers. The bunch of French plantain can carry as many as 5 - 8 hands [15, 19]. The total number of fruits ranges between 70 and 93. French plantain can also take up to 365 days to produce a mature bunch after planting [20]. Both French and False Horn cultivars have curved fingers.

Plantain is however vulnerable to the adverse effects of soil pollutants [21]. It requires a healthy soil for rapid reproductive growth. Balogun et al. [22] reported that False Horn and French plantain cultivars grew vegetatively on crude oil polluted soil, indicating their tolerance of the stress caused by soil pollution. Stunted growth, reduced sucker formation and late flowering have been linked to inadequate soil fertility [23]. Soil pollutants can interfere with plant hormone production in plantain, disrupting various physiological processes crucial for reproductive growth [24]. Ndubueze-Ogaraku et al. [25], reported that plantain fruit grown in crude oil polluted communities had smaller fruit size compared with non-crude oil drilling communities. There is little information on the species' reproductive ability on crude oil-polluted soil. The purpose of this study was to assess the reproductive growth of False Horn and French plantains on crude oil polluted soil.

## 2. MATERIALS AND METHODS

False Horn and French plantain suckers planted on crude oil polluted and unpolluted field were observed for reproductive parameters. The experiment was arranged in a completely randomised design (CRD). Each sucker's soil base was treated with 1 litre of Bonny light crude (BLCO) oil via ring application at eight week intervals until fruiting, while the control soil received no crude oil.

### 2.1 Study of Reproductive Parameters

Number of suckers produced per plantain stand was estimated by counting. Time to flower bud appearance from planting and time to bud opening from flower bud appearance were determined by noting the intervals (days). Fruit dimensions were determined using a tape rule. Fruit area was obtained by multiplying length and circumference and expressed in $cm^2$. The length of the fruit was measured along the outer curvature while the circumference was measured halfway along the length of the fruit [26]. Fruit dimensions were measured at 50, 60, 70, 80, 90, 100 days from bud opening. All data were subjected to t-test at $\alpha = 0.05$.

## 3. RESULTS AND DISCUSSION

Initially, False Horn plantain on unpolluted soil had more suckers than plants on polluted soils but 20 weeks later, plants on polluted soil had produced more suckers than the control. The increase in numbers of suckers attached to plants on polluted soil continued till the $30^{th}$ week. Again by the $40^{th}$ week the control had produced more suckers than plants on polluted soil (Fig. 1). For French plantain, the plants on polluted soil produced more suckers than those on unpolluted soil throughout the period of observation. (Fig. 2).

The greater number of suckers attached to French plantain on polluted soil may have been because the plantain cultivar had a higher tolerance for the hydrocarbon present in the crude oil for the production of suckers thereby showing evidence of the accumulation of hydrocarbons. This could also be due to the difference in the time to attain maturity by French plantain on polluted compared with plants on unpolluted soil [27]. Baiyeri et al. [28] reported that *Musa paradisiaca* showed a tolerance to abiotic and biotic stress during reproductive and vegetative growth. However, on polluted soil, False Horn plantain produced fewer suckers compared with

the control. This effect may be due to the poor adaptation of False Horn plantain cultivar on polluted environment. It is evident parent plant's development promotes suckering, but the amount of suckers produced may be affected by environmental factors. Changes in environmental factors such as, low soil pH [29], availability of water, temperature variations and light intensity [30], which may result from soil contamination have been reported to affect sucker production as well as root and overall growth. According to Beeds et al. [31], there is a positive association between parent plant and production of suckers with faster-growing parents producing more developed suckers across most plantain genotypes. Mensah et al. [27], found that False Horn plantain planted on suitable, enhanced soil produced a greater number of suckers. When comparing False Horn and French plantain, the reduced number of False Horn plantain suckers on polluted soil could be attributed to differences in tolerance and acclimation capacity between both cultivars [32]. Additionally, this could be attributed to the regeneration capacity and genotypes resulting in variances in their ability to generate suckers [33]. Another effect could be decreased aeration, nutrient supply and infiltration of water into the soil due to crude oil pollution, affecting sucker production. Also, other researchers have indicated that production of suckers may be affected by a range of factors, phase of plant growth [34], nutrient supply, site elevation and genotype [35]. Result of this study suggest that the differential difference in sucker production may be attributable to the genotype.

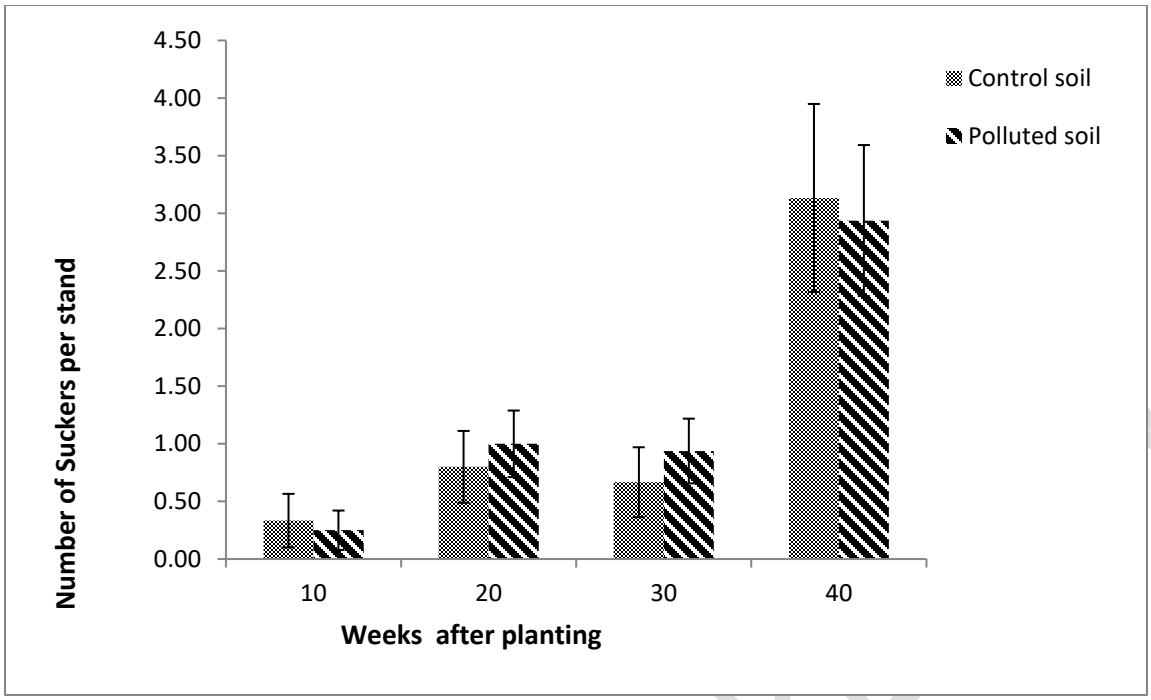


**Fig. 1:** Mean number of suckers produced per stand of False Horn plantain on crude oil polluted soil.

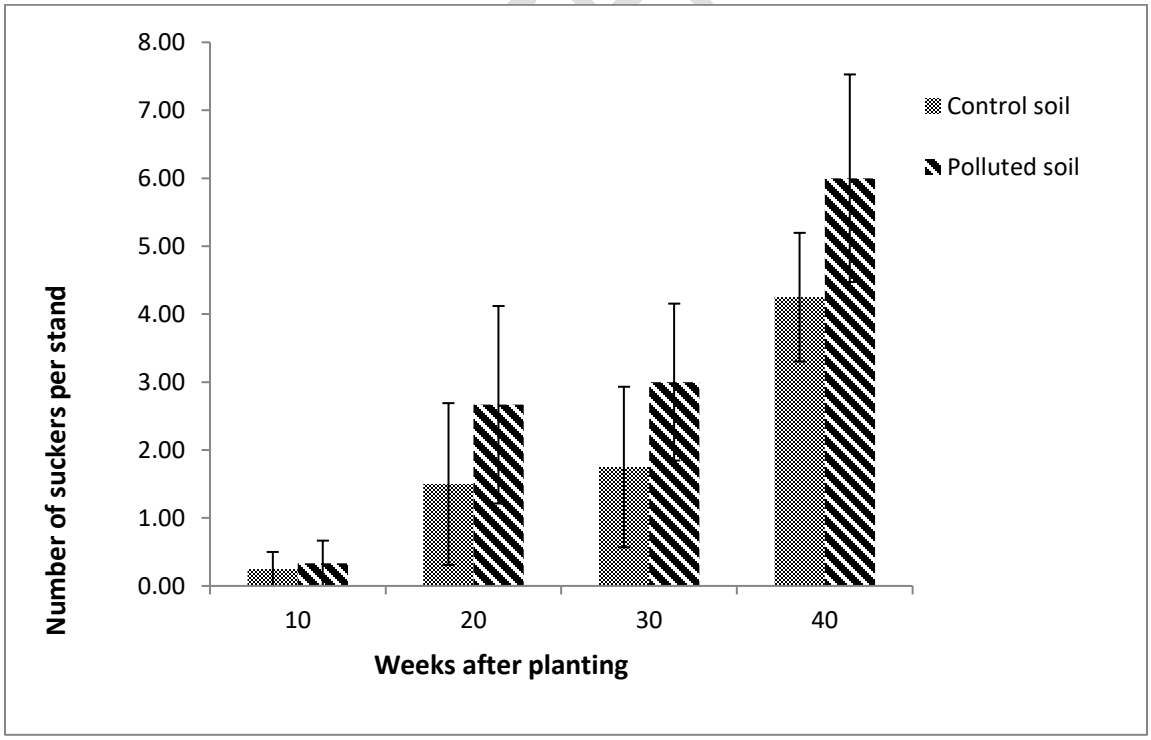


**Fig. 2:** Mean number of suckers produced per stand of French plantain on crude oil polluted soil.

The number of days to flower bud appearance for False Horn plantain was significantly less in plants on polluted soil compared to plants on unpolluted soil with a mean value of 397.33 and 411.17 respectively. For French plantain, the same trend as False Horn plantain was observed. Days to flower bud appearance on polluted soil reduced compared to the control were 351.67 and 385 respectively (Fig. 3).

The number of days to bud opening in False Horn plantain on polluted soil was less compared with the control. The means were 3.08 and 3.50 respectively. French plantain followed a similar trend as False Horn plantain. Plants on polluted soil had mean of 2.75 showing reduction in number of days to bud opening compared with the control which was 3.00 (Fig.4).

The appearance of flowers and flower bud development is crucial to sexual reproductive growth. Soil polluted by crude oil had effect on early flowering and bud opening in both False Horn and French plantain plants. The hydrophobic nature of oil may have caused the blockage of vascular tissues leading to water stress on the plant [36, 37]. Monserrat-Marti et al. [38], reported that water stress alters bud formation. Both cultivars however did not show any severe water stress effect on appearance of flower bud and bud opening in this study. Therefore, there could be a mechanism that allows the cultivars to preserve part of their available water for essential living tissues including buds [39]. Furthermore, it could also be as a result of the hormonal influence in both cultivars [4]. According to Seymour et al. [40] and Mariotti [41], plant hormones such as auxins (AU), cytokinins (CK) and gibberellins (GA) associated with flowering and fruit development are produced more under favourable conditions. These phytohormones responsible for fruit development are also produced in biotic and abiotic stress response [42, 43]. Probably, bioaccumulation of crude oil by the plants caused the early production of such hormones which may be responsible for the early flowering and bud opening in the plants on polluted soil. In

crude oil contaminated soil, plant growth is frequently reported inconsistently because concentrations that are meant to have negative impacts occasionally promote plant growth as presently observed in the two plantain cultivars tested. This agrees with the findings of Vwioko and Fashemi [44] who reported that *Ricinus communis* L. (Castor Oil) grown on 1% w/w soil contaminated by oil, flowered earlier than the control. However, the result of this study contradicts the findings of Osawaru et al. [45] who reported that there was a delay in the number of days from sowing to appearance of first flowers in two Okra cultivars grown on polluted soil,.

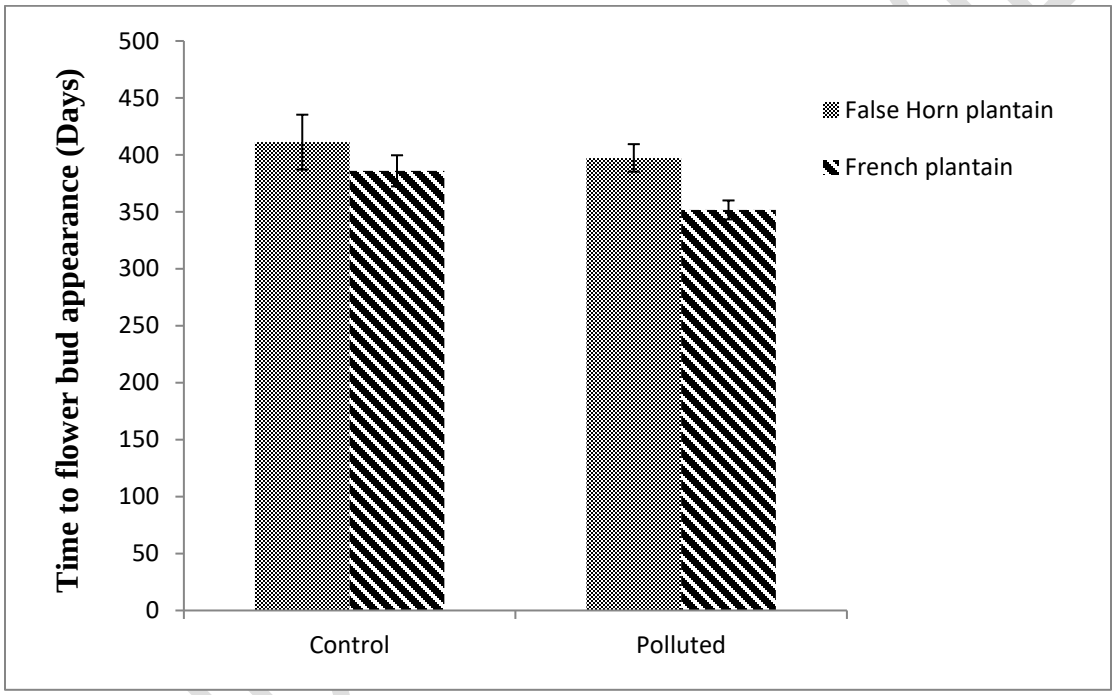


**Fig. 3:** Days to flower bud opening in False Horn Plantain on crude oil polluted soil.

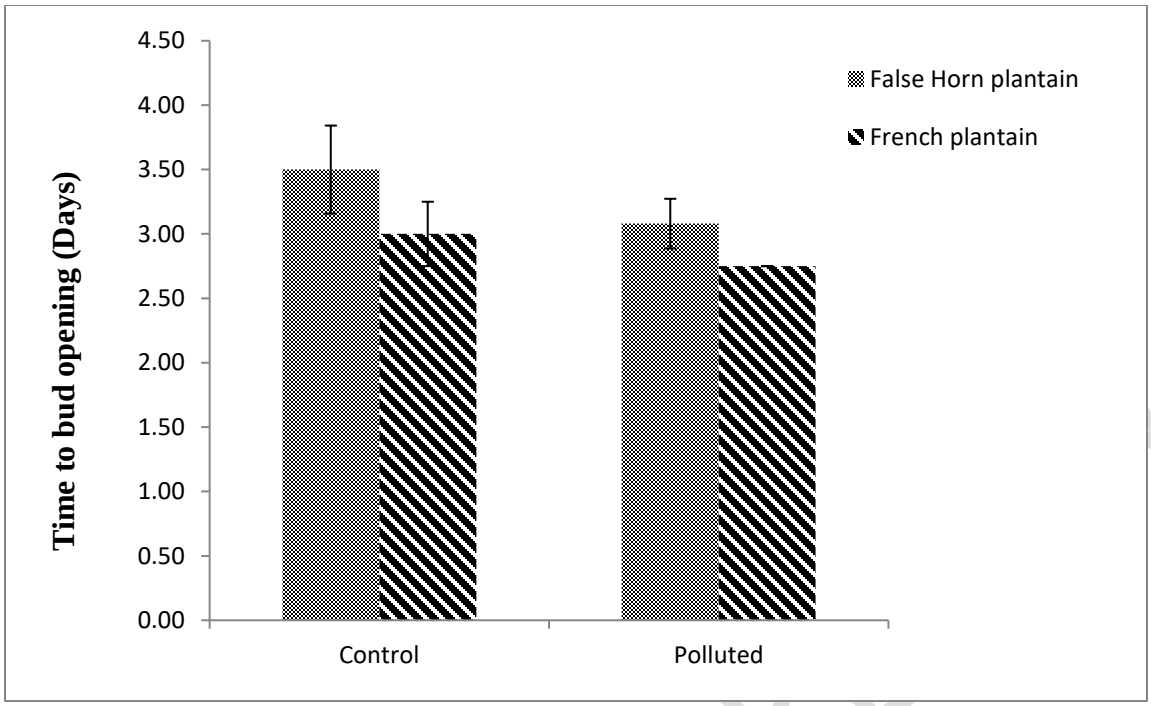


**Fig. 4:** Interval between flower appearance and bud opening in plantain grown on soil polluted by crude oil.

False Horn plantain fruit size on polluted soil was smaller than that of the control in all the days measured, although there was no statistically significant difference between the control and plants on polluted soil (Table 1). For French plantain on polluted soil, the fruits were bigger than the control. Statistically, there was significant difference between the plants on polluted soil and the control (Table 2).

The smaller fruit size of False Horn on polluted soil might be due to the reduced leaf area [22]. Plantain is susceptible to deficiencies in soil water, with expanding tissues such as emerging leaves and increase in fruit size are usually among the most likely to be affected [16]. The number of leaves present during flowering-fruiting is a critical physiological feature for effective fruit-filling considering the fact that no new leaves are produced after this stage [46]. The

inability to properly photosynthesize as a result of the reduced photosynthetic area possibly caused low carbohydrate content leading to reduction in fruit size. This corroborate the findings of Ndubueze-Ogaraku et al. [25], who reported that plantain fruit grown in crude oil polluted communities had smaller fruit size and were sold at lower prices compared with non-crude oil drilling communities. Also, heavy metal such as cadmium which is present in soil polluted by crude oil has been reported to reduce mineral uptake and photosynthesis in plants [47]. The observed disparities in fruit size could also be attributed to the considerable amount of crude oil in the soil, making it difficult for the roots to absorb ions and other nutrients including water needed for reproductive growth [48, 49]. Early stomatal closure due to reduced root water absorption caused by crude oil pollution of soil could have contributed to the decrease in fruit size observed in False Horn plantain planted on polluted soil. However, French plantain grown in crude oil polluted soil which produced bigger fruits may be as a result of earlier flower bud opening compared to control plants. Furthermore, Balogun et al. [22] reported that French plantain on polluted soil had broader leaves than plants on unpolluted soil. This could also indicate the reason for greater fruit size, as the functional leaves enable more photosynthesis compared to the control. The reproductive behavior of the two presently studied cultivars shows that there could be varied response to soil pollution by crude oil.

**Table 1:** Effect of crude oil pollution of soil on fruit size (area $cm^2$) of False Horn plantain.

| Days after flower bud opening | Control Soil | Polluted Soil |
|---|---|---|
| **50** | 6823.32±304.97 | 6733.16±594.39 |
| **60** | 7331.17±381.46 | 7132.03±622.87 |
| **70** | 7666.11±405.84 | 7413.41±629.64 |
| **80** | 8075.15±401.99 | 7844.90±670.65 |
| **90** | 8531.70±427.44 | 8228.81±701.31 |
| **100** | 8914.76±464.27 | 8632.39±739.42 |

Means on the same row with * are significantly different at $P = .05$ based on Student's t-test ± standard error of the mean.

**Table 2:** Effect of crude oil pollution of soil on fruit size (area $cm^2$) of French plantain.

| Days after flower bud opening | Control Soil | Polluted Soil |
|---|---|---|
| **50** | 4726.69±411.63 | 5535.75±539.40* |
| **60** | 4909.02±415.23 | 5882.11±554.20* |
| **70** | 5213.58±446.06 | 6228.04±528.47* |
| **80** | 5431.52±488.98 | 6471.77±557.96* |
| **90** | 5709.32±545.43 | 6824.45±580.20* |
| **100** | 6091.90±683.31 | 7020.28±574.91* |

Means in the same row with * are significantly different at $P = .05$ based on Student's t-test ± standard error of the mean.

## CONCLUSION

This study shows that the two plantain cultivars tolerated the stress of soil polluted by crude oil throughout reproductive growth life. French plantain on polluted soil had the greater number of suckers compared to False Horn plantain. On crude oil-contaminated soil, both plantain cultivars took a lesser number of days than controls from planting to flower bud appearance and opening. False Horn plantain produced smaller fruits on polluted soil while French plantain on polluted soil produced bigger fruit than the control. However, the increase number of suckers on polluted soil by both cultivars indicate bioaccumulation potential of the plants. These findings provide basis for further investigation on phytoremediation potential of the two cultivars on crude oil contaminated soils.

### Ethics approval and consent to participate

Not applicable



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