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Yield Modeling of Okra (*Abelmoschus esculentus L. moench*) in Bituminous Soils of Southern Ondo State, Nigeria

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Abstract**—** *This study investigated the growth and yield response of okra (Abelmoschus esculentus L. Moench) in bituminous soils of selected communities (Loda, Lofo and Legbogbo) in Irele, southern Ondo State for two consecutive growing seasons (2020 and 2021). The Legbogbo site, which of very low bitumen, serves as the control. The textural class is sandy loam and the soil is acidic. Some samples of soil were collected from three dug soil profile pit at depths 0-100 cm at an interval of 10 cm and moved to the soil laboratory for the analysis of the chemical concentrations of macro and trace elements. The highest value of the heavy metal was recorded at Loda. More so, the least amount of the bitumen concentration was recorded at Legbogbo site (control) and in some cases at Lofo site. Result from the study showed that there is significant difference ($P < 0.05$) in the values of the heavy metals among the location at all depths. The results from various locations also showed that the soil depth and location were significant ($P < 0.05$) in their main effects on the soil heavy metals. It was observed that the heavy metal concentration of soil was lower than the permissible limit, an indication that the concentration of heavy metals of the study areas may not have negatively influenced the growth and yield of okra. All agronomic parameters in all locations during the two seasons of experiment were in the way of Legbogbo>Lofo>Loda. Okra had 0 kg.ha^{-1} pod yield at the Loda site at both 2020 and 2021 growing seasons, while Legbogbo had the greatest fruit yield for both seasons. Okra yield prediction model was developed using the stepwise regression model and it was observed that Okra yield significantly correlated to potassium ($r^2 = 0.95$) at $P < 0.05$ and phosphorus ($r^2 = 0.99$) ($P < 0.01$).*

Keyword**— *Bitumen deposit, bituminous soil, Heavy metal, Okra, Yield***

I. INTRODUCTION

Bitumen is a generic term used to cover a wide range of high molecular weight hydrocarbons (Ojovan and Lee, 2014), it can act as a hydrophobic water shield. Three main types of hydrocarbons occur in bituminous materials and they are asphaltenes, resins and oils (alphatic hydrocarbons), (Ojovan and Lee, 2005). One of the properties of bitumen is that, it is visco-elastic. Bitumen is primarily composed of polycyclic aromatic hydrocarbons (New World encyclopedia, 2016). Examples of composition of Bitumen in terms of minerals are nickel, vanadium, lead, chromium, mercury etc.

Bitumen can be described as thick, sticky, tar-like form of petroleum which cannot flow unless it is heated or diluted. At room temperature, bitumen is looks like cold molasses (Government of Alberta, 2008). Bitumen can be described as any hydrocarbon deposit that possess a gas- free viscosity above 10,000 centipoises (cp) measured to original reservoir condition. Bitumen is around 95% hydrogen, and up to 5% Sulphur, 1% oxygen and 200ppm metals (Tom, 2009). Bitumen possesses some properties like, waterproof, adhesive, durability and resistance to heavy loads which make it an ideal material that can be used in all environments (Muritala and Adewole, 2016). Nigeria has about the third largest deposits of bitumen all over the world. This bitumen deposits in Nigeria is mainly located within the southern axis of Ondo State, Nigeria, where inhabitants are predominantly farmers. Surface and sub-surface intrusions of this very important economic resource has made it almost impossible for inhabitants to freely practice their farming operations due to low productivity and/or poor yield.

The heavy metals that infiltrate or through seepage enters the ecosystem may lead to varieties of accumulation in the soil and plant thereby creating negative influence on plant growth. The accumulated toxic heavy metals in soils and plants brings negative influence on the activities of plants such as photosynthesis, gaseous exchange and nutrient absorption in the plants and these helps in determining the reductions in plant growth, accumulated dry matter and crop yield (Suciu *et al*., 2008). Bitumen deposits normally have negative effects on water and soil used for agricultural practices especially in areas that are covered with bitumen deposits, and the deposits will have adverse effect on agricultural soils in such areas. Bitumen deposits are generally harmful to the soil due to its toxicity (Agarry and Oghenejoboh, 2014). There is always occurrence of environmental effects that can bring threat to any area where there are bitumen deposits (Akinmosin *et al*., 2009).

Atojunere and Ogedengbe (2019) reported that lead was found in leaf vegetables and some fruits samples collected from some markets in Lagos, Nigeria. Heavy metal gets into plants through adsorption which refers to binding of materials onto the surface or absorption which implies penetration of metals into the inner matrix where both adsorption and absorption can also take place (Lokeshwary and Chandrappa, 2006). Bitumen deposit in small concentration in a soil cannot confirm the toxicity of the heavy metals in the plants or animals but there are some heavy metals like lead, cadmium and mercury which are very toxic even when their concentration is low (De Vries *et al*., 2007).

Elements which are of different forms and composition can be deposited in the soil in different proportions. Akintola *et al.* (2011) reported that the heavy metals in the soil are associated with biological and chemical properties and the influence by anthropogenic activities (Ubah *et al*., 2009). The degree of pollution or contamination in the soil can be attributed to the effect of the heavy metals embedded in bitumen deposit soil, the environmental impact and their origin (Ramirez et al., 2005, Akintola et al., 2011). Large numbers of toxic heavy metals which are dangerous and have certain effect on man and his environment are released into the environment through various means (Dembitsky, 2003).

Okra (*Abelmoschus esculentus* L. *moench*) or Lady's finger is one of the important vegetables grown throughout the tropics and subtropics. Okra is one of those crops that is largely produced and consumed in the study area due to its nutritional and health benefits (Habtamu *et al*., 2014). Okra when consumed is very rich in vitamins, folic acid, carbohydrates, phosphorus, magnesium, calcium, potassium and other minerals. Despite this importance, okra production is either rendered impossible or marginally possible due to various reasons, which until this present research cannot be confirmed. This research therefore was aimed at investigating the yield response of Okra to soils of different communities around bituminous areas of southern Ondo State, Nigeria.

II. METHODOLOGY

1.1 Site Description

The research was conducted during the cropping seasons of 2020 and 2021 in three different communities (Loda, Lofo and Legbogbo), all located within the bituminous areas of Southern Ondo State, Nigeria. The site was located within latitudes $6^0 16^1$N to $6^0 47^1$ N and longitudes $4^0 45^1$ E to 5^0 10^1 E, and at elevation of about 405 m above the mean sea level. The climate of the study site is humid subtropical, with an annual rainfall of about 1800 mm and the mean temperature is 25°C (Imoukhuede *et al.*, 2023). The economic mainstay of the inhabitants of the three communities is farming and fishing, but the deposits of bitumen (an important economic resource) that was explored but not exploited has turned a huge disadvantage to farming and fishing operations of the people living in the area. More often, there are free surface flow of molten bitumen on soils, which eventually flow further to nearby streams and rivers and the impact of the adverse environmental impact of it had brought untold hardship on the human, plant, animals, water and soil of communities with overlay and underlay of bitumen in Irele, Ondo State, Nigeria (Ogedengbe and Akinbile, 2009; Fagbote and Olanipelun, 2010; Imoukhuede *et al.*, 2023).

2.2 Treatments and Experimental Design

The experimental site consisted of three locations. The first experimental site was at Loda, the second site was at Lofo and the third site, which served as the control experiment was located at Legbogbo, a non-bituminous soil, all in Irele local government area of Ondo State, Nigeria. Land area of about 15 m x 15 m was cleared manually in each of the three selected communities for the experiment. The cleared land were thereafter ploughed using Tractor (Marsey Fegusson) (3.82 tons) attached with a disc plough implement. The ploughed plots were harrowed to further pulverize the soil and loosen all clods before the formation of ridges using local technique that is widely adopted in the three selected communities. Okra seeds were planted in 15 rows of local ridges with ten stands per row (replicates) following a split plot design and at a spacing of 0.5 m by 0.5 m to make a total of 150 plants per experimental sites. The total number of okra stands was 450 in the three different sites (Legbogbo, Loda, and Lofo). This experiment was replicated the second year (2021) to give a clear confirmation how the severity/concentration of the concentration of heavy metal in a bituminous soil can affect crop yield in the study areas.

2.3 Statistical Analysis

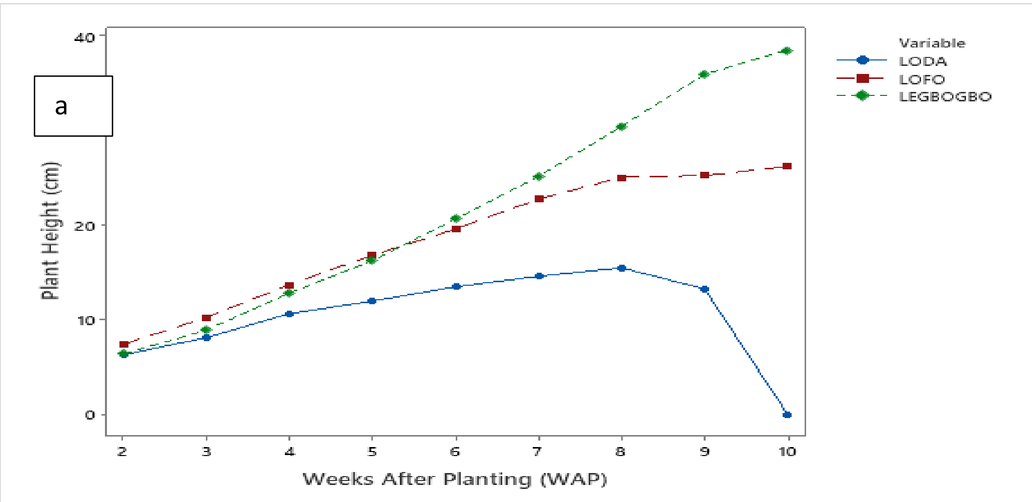
Yield components of okra were subjected to statistical analysis such as mean and standard deviation. Analysis of variance (ANOVA) was conducted to determine the difference in means of the yield parameters at the 5% and 1% level of significance. Linear and non-linear regression analysis was used to develop yield models for okra based on soil and crop data obtained from the field. Models predicting the okra yield were developed using the four important soil factor: organic matter content (OMC), percentage nitrogen (N), moisture content (MC), and three important crop factors: fresh pod yield (FPY), pod length (PL) and biomass yield (BY). Minitab uses normalization to enable data to conform more to ideal random or Gaussian distribution.

III. RESULTS AND DISCUSSION

3.1 Okra Growth Parameters on function of Weeks After Planting (WAP)

The mean of the plant height, number of leaves and stem girth from all the treatment (locations) taken up to 10 weeks after planting (WAP) are presented in Figures 1 - 2. Mean okra height was highest (38.53 ± 11.14)) at Legbogbo and least (0.00 ± 0.00)) in okra planted at Loda. The relationship between the mean heights with respect to days after planting among the locations showed that there were no rapid increase in the mean height of the leaf during the emergence and there was rapid increase at about 3 WAP. At 7 Weeks After Panting and beyond, the plant height reduced sharply in okra planted at LODA until it reached the zero level. However, the height of the crop, number of leaves and stem girth in Legbogbo site increased steadily till the crop reached maturity, before it started to decline.

There was pronounced variability in the plant heights among the locations. At 2 WAP, significant difference ($P < 0.05$) in the average plant heights was recorded among the locations. There was also significant difference ($P < 0.05$) in plant heights at 6 and 10 WAP. The number of leaves increased up to 8 WAP before it started experiencing decline in the number of count. Similar observation was recorded in okra planted during the second season. The decrease in the number of leaves may be due to the dropping of the plant leaves to the ground, which characterized the late season (Allen *et al.*, 1998). Similar trend was observed for the stem girth at both growing seasons. The increasing trend for the agronomic measurement in all locations and seasons were in the trend of LEGBOGBO > LOFO > LODA in most cases with respect to weeks after planting (WAP).



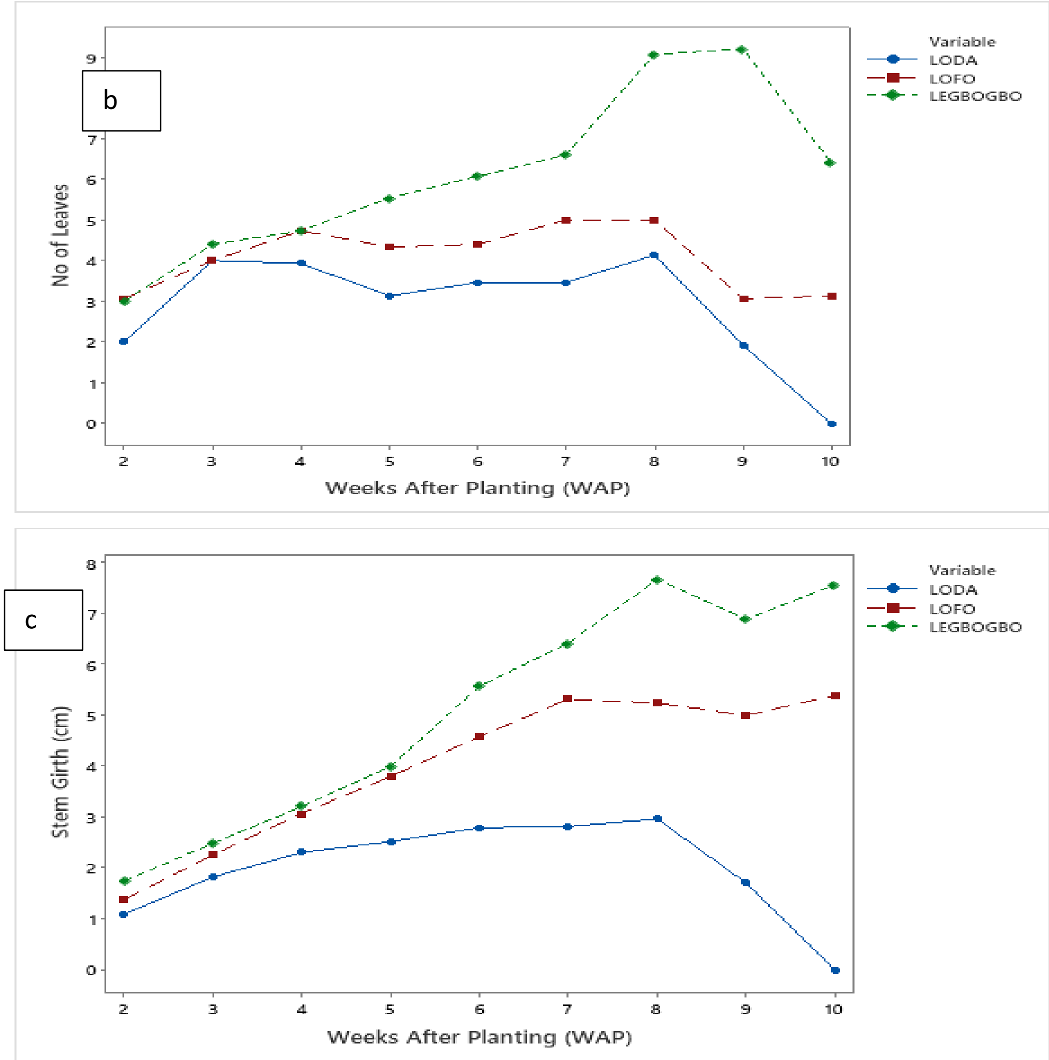
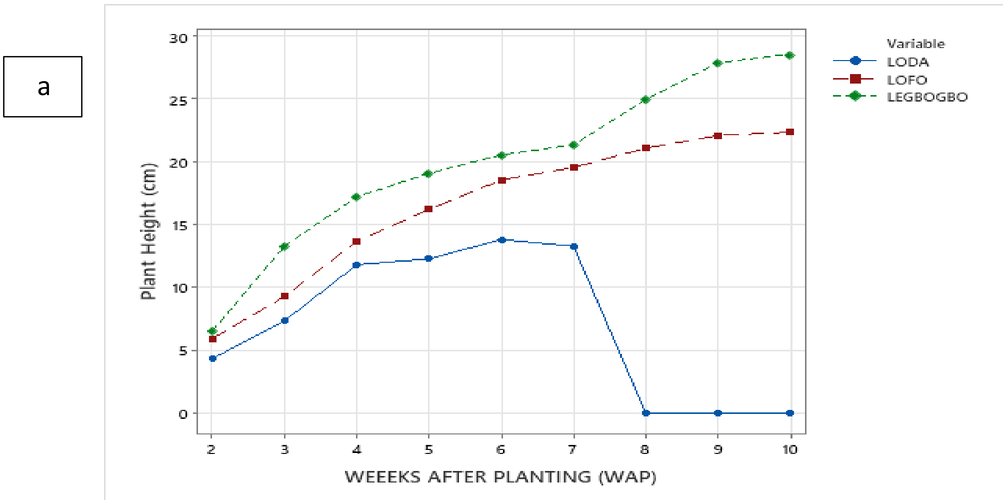


Fig.1: (a) Plant height (b) Number of leaves (c) Stem girth of Okra, as influenced by bitumen content in each of the locations (Loda, Lofo and Legbogbo) in the first year of planting.



b

c

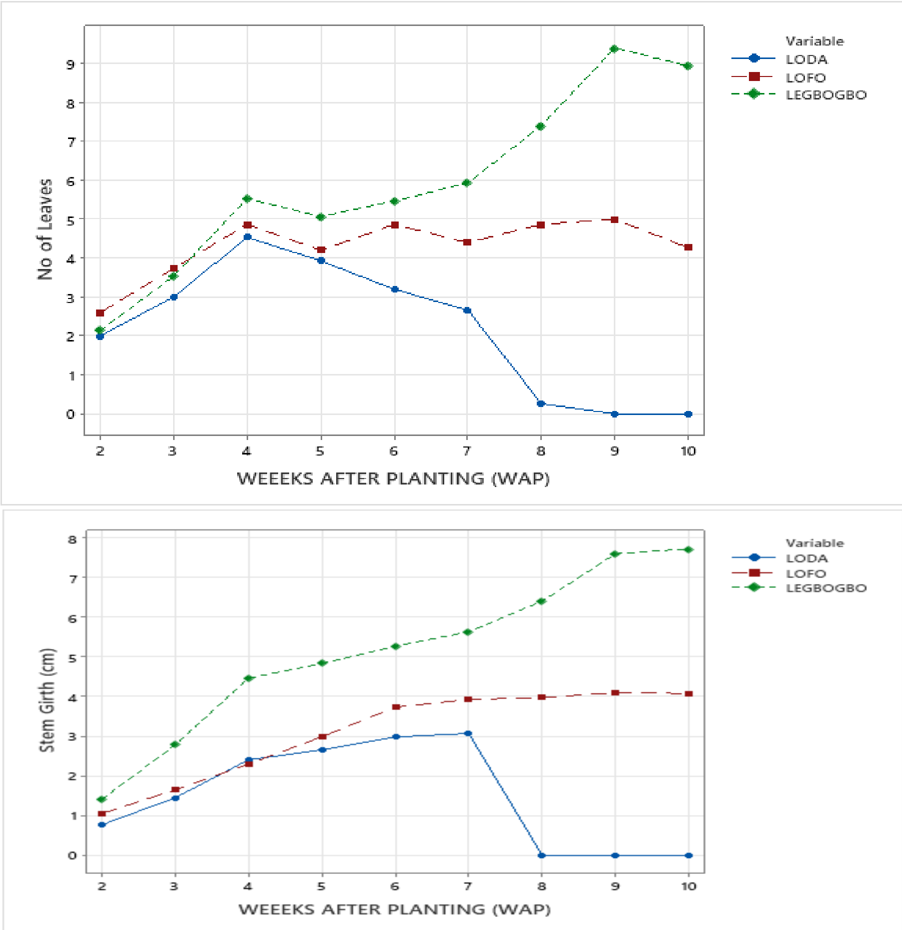


Fig.2: (a) Plant height (b) Number of leaves (c) Stem girth of Okra, as influenced by bitumen content in each of the locations (Loda, Lofo and Legbogbo) in the second year of planting.

3.2 Effects of Bitumen Deposits on Growth of Crops

The growth parameter of okra as affected by the bitumen content in soil at the different locations (Loda, Lofo and Legbogbo) is presented in Tables 1. The Tables showed the average plant heights of the three crops at different location with varying bitumen contents at 2, 6 and 10 weeks after planting (WAP). There was pronounced variability in the heights of the plants at the locations. At 2 WAP, significant difference ($P < 0.05$) in the average plant heights was recorded among the locations. There was also significant difference ($P < 0.05$) in plant heights at 6 and 10 WAP. Tables 4.9 and 4.10 also showed the average stem girth of the three crops (Maize, Groundnut and Okra) grown at different locations (Loda, Lofo and Legbogbo) at 2, 6 and 10 weeks after planting. At 2, 6 and 10 WAP, there was significant difference ($P < 0.05$) in the average stem girth in both seasons of growth. At 2, 6 and 10 WAP, there was significant difference ($P < 0.05$) in number of leaves among the locations (LODA, LOFO and LEGBOGBO) where the crops were planted in both seasons. Highest values of plant height, stem girth and number of leaves was recorded in most cases at the Legbogbo location, which is the control site, while the lowest value was recorded at the LODA site, which is characterized by some large amount of bitumen contents. Despite the lowest rainfall values of 592 mm recorded at LEGBOGBO during the first growing season, highest values of growth parameters were measured. The LOFO site rainfall value of 618 mm with corresponding values of growth parameters is lower, when it is compared with the LEGBOGBO site. LODA site was a bit lower in rainfall value (616 mm) comparatively with the LOFO site but had the lowest plant growth parameters. The growth parameters obtained at the LEGBOGBO site had the highest value which can be explained by moisture availability to crop due to free percolation of water into soil. However, lower values of values of growth parameters recorded at the LOFO and LODA sites may have been caused by the surface seal caused by bitumen deposits, and may also be due to enhanced runoff of surface flow after rainfall, thus affecting water availability at the tap root in the soil for metabolism and cell division (Ndakidemi and Dakora, 2007).

Table 1: Effects of Bitumen Deposits on Okra Growth Parameters of Crops (Season 1)

Location	WAP	LODA	LOFO	LEGBOGBO
Plant height	2	6.33b (± 1.13)	7.43a (± 0.84)	6.40b (± 0.91)
	6	13.50a (± 1.59)	19.60a (± 2.71)	20.67a (± 3.32)
	10	0.00c (± 0.00)	26.20b (± 5.39)	38.53a (± 11.14)
Stem girth	2	1.09b (± 0.16)	1.40ab (± 0.43)	1.74a (± 0.55)
	6	2.84c (± 0.44)	4.58b (± 0.88)	5.56a (± 1.58)
	10	0.00c (± 0.00)	5.39b (± 1.16)	7.55a (± 2.80)
Number of leaves	2	2.00b (± 0.00)	3.07a (± 0.26)	3.00a (± 0.00)
	6	3.47b (± 0.83)	4.40b (± 0.82)	6.07a (± 1.58)
	10	0.00c (± 0.00)	3.13b (± 0.52)	6.40a (± 2.95)

Means that do not share same letter are significantly different (p = 0.05)

3.3 Effects of Bitumen Deposits on the Yield of Crops

The yield response of okra planted at the three sites is shown in Table 2. Planting the crops at the different locations had significant effect ($p < 0.05$) on the pods, length of pod, weight of pod and pod breadth per plants. Okra has no fruit yield (pod) at LODA site during the two growing seasons. The higher values of the yield component recorded at the LEGBOGBO site can be explained by the free inflow of water and air into soil for plant use and uptake of nutrients. Water that would have been available for crop use at the LODA and LOFO sites were intercepted by bituminous materials, thus disallowing percolation to the root zone. This affected largely moisture uptake by plant for nutrient translocation into shoots, which ultimately led to poor growth and zero yield of okra at the sites.

The enhanced nutrient transportation at the LEGBOGBO site could have resulted to the significant ($P < 0.05$) increase in crop yield parameters (number of pods, length of pod, breadth of pod, and pod weight). The above explained the mechanism for the higher values of yield components at the LEGBOGBO, in accordance with the findings of Abd El Lateef *et al*. (2018) and Chemutai (2018). The zero (0) pod weight reported for the vegetable crop (Okra) at the LODA site can be explained by inability of the Okra crop to take up soil nutrient. Macro-nutrients like Nitrogen, Phosphorus and Potassium are essential elements and important determinant of the growth, yield and development of vegetables. Likewise, adequate supply of phosphorous early in plant life is important in laying down the primordial for plant growth (Chemutai, 2018; Chemutai *et al*., 2018). The fact that the yields from the LOFO and LEGBOGBO were generally much greater than from LODA on its own indicates that the nutrients satisfied the growth and yield parameters of okra. Presumably, this can be related to the functionality of soil and contents of the organic matter and macro nutrients (Abd El Lateef *et al*., 2018). The presence of organic matter in soils is very important in the tropical region for sustainable yield of crops (Sangakkara, 1993). Organic matter improves soil tilth, infiltration rate and soil water holding capacity; contributes nutrient to the crop, and it is an important source of raw or partially decomposed organic matter (Bill, 2001).

Table 4.11: Effects of Bitumen Deposits on Yield of Okra

Location	LODA	LOFO	LEGBOGBO
	Season 1		
Number of pod per stand	0.00c (± 0.00)	2.27b (± 1.44)	6.07a (± 1.53)
Weight of pod (g)	0.00b (± 0.00)	19.80b (± 13.91)	123.20a (± 65.10)
Length of pod (mm)	0.00c (± 0.00)	41.04b (± 16.74)	76.68a (± 11.81)
Pod breadth (mm)	0.00c (± 0.00)	18.97b (± 6.23)	26.26a (± 3.11)
	Season 2		
Number of pod per stand	0.00b (± 0.00)	1.00b (± 0.83)	9.00a (± 3.83)

Weight of pod (g)	0.00b (± 0.00)	16.40b (± 9.58)	104.40a (± 40.20)
Length of pod (mm)	0.00b (± 0.00)	23.11b (± 10.72)	68.59a (± 12.54)
Pod breadth (mm)	0.00c (± 0.00)	17.28b (± 3.62)	28.50a (± 5.44)

Regression models between Soil Properties and Okra yield

Finally, for the Okra yield prediction, the stepwise regression model was developed as shown in equations 4.5 and 4.6 below. Equation 4.5 and 4.6 represent yield models for seasons 1 and 2, respectively.

Yield = 3169 - 16995 K * r^2 = 95.5 (1)

Yield = -1978.9 + 246.08 P** r^2 = 99.9 (2)

Note: * significance at 0.05, ** significance at 0.01

The result indicated that Okra yield significantly correlated to potassium and phosphorus ($P < 0.05$). The r^2 values of 0.95 and 0.99 obtained from the model indicated that about 95.5 and 99.9 % variability in the response could be explained by the model, which contained potassium and phosphorus as the predictors. The model validation of the model is presented in Figure 5, which showed a strong relationship between the predicted yield and measured yield for Okra, with r^2 value equal to 0.99.

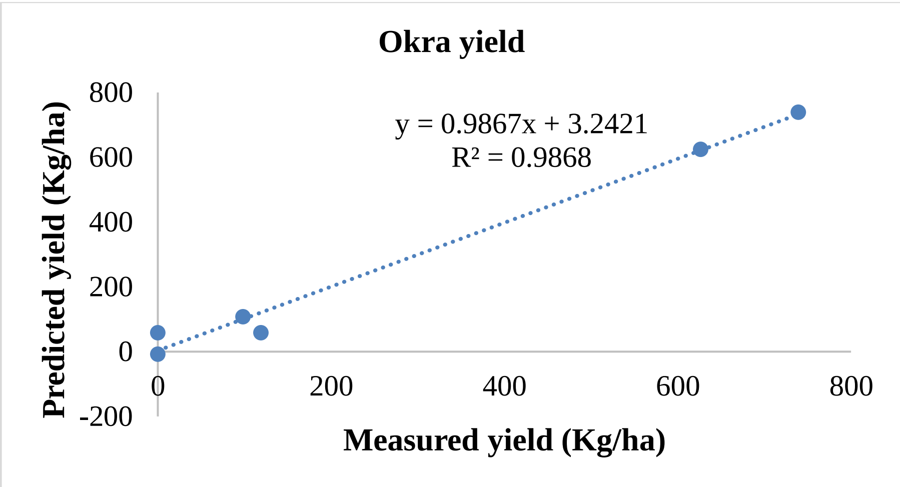


Fig.5. Predicted versus Measured yield of okra (Abelmoschus esculentus, L. moench)

IV. CONCLUSION

The growth and yield response of okra planted in three different locations around the bituminous area of Irele, Southern Ondo State, Nigeria has been investigated in this research. It was observed that the LEGBOGBO site (control site) without bitumen deposit had the highest growth and yield parameters, followed by the LOFO, which had traces of bitumen deposits that gave rise to yield reduction of okra. However, the LODA site that was characterized with surface and undergound layers of bitumen had the least growth parameters and okra yield. Soil amendments and remediation would have to be carried out to reclaim the usefulness of LODA soils for agricultural purposes.

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