

A Search for Suitable Growing Environment for Sesame Production in Nigeria

**A. Hussaini^{1*}, M. Usman², J. Y. Falgore², S. S. Sani³, Y. Zakari²
and H. D. Muktar¹**

¹*Department of Mathematics and Statistics Federal Polytechnic, Kazaure, Nigeria.*

²*Department of Statistics, Ahmadu Bello University, Zaria, Nigeria.*

³*Department of Agronomy, Ahmadu Bello University, Zaria, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. Author AH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JYF and MU managed the type setting and corrections. Authors SSS, YZ and HDM managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAEES/2020/v38i830383

Editor(s):

(1) Dr. Tulus T. H. Tambunan, University of Trisakti, Indonesia.

Reviewers:

(1) M. Shanmuganathan, Tamil Nadu Agricultural University, India.

(2) Swapnil Pandey, Punjab Agricultural University, India.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/59307>

Original Research Article

Received 14 May 2020
Accepted 20 July 2020
Published 01 August 2020

ABSTRACT

The economic relevance of farm management practices to the production of sesame crops in Nigeria includes preventing and combatting food crises, actualization and realization of national food security as well as enhancing gross domestic product. This research seeks to examine the edaphology of some soil types in relation to the productivity of sesame crops in Nigeria. The experiment was conducted in statistical farm of Hussaini Adamu Federal Polytechnic, Kazaure, Jigawa State, Nigeria during 2019 growing season. The experimental design was Completely Randomized Design with one hundred replications. There were three types of soils investigated; Clay, Sandy, and Loamy were compared with one another. The soils were made free of any nuisance factors effects. The chlorophyll content of the plants was read using Konica Minolta chlorophyll meter SPAD-502 plus, and the data analyzed using one-way ANOVA and the Statistical Package for Social Sciences (SPSS) version 20. The result of the analysis indicates a higher significant effect of Sandy soil ($M = 11.20$, $SD = 2.37$) on the yield of sesame crops in this region as

compared to the effects of the Clay ($M = 3.60$, $SD = 0.89$), and Loamy ($M = 6.86$, $SD = 3.39$) soils. The overall ANOVA test indicates that growing environment does have effect on sesame production, $F(2, 27) = 6.70$, $p = 0.00$. However, the result indicates insignificant chlorophyll mean difference between Clay and Loamy soils. It is therefore evident from these results and the reviewed literatures that the suitable growing environment for sesame production in Nigeria is fertile Sandy soil that is deep, light textured, well-drained and that is exposed to an average temperature of 25°C to 37°C. The crop is also tolerant to draught, but not at the germination and seedling stages, water logging, and excessive rain fall while it requires 90–120 frost-free days to achieve optimal yields in cold regions. The challenges which stand in the way of increasing the productivity and quality of sesame crops need to be overcome. As with other crops, which is a major export crop in many countries, these crops should be given more research attention.

Keywords: ANOVA; growing environment; sesame; Konica Minolta chlorophyll meter SPAD-502 plus; Nigeria.

1. INTRODUCTION

Sesame is the oldest oil crop known to humanity [1] which has spread into many climatically different regions in the world. It has been documented to originate in north-eastern Africa [2,3,4]. Reference [5] describes the sesame plant as one that has short harvest cycle of 90 –140 days, measuring 60 to 120 cm tall, whitish to brown or black seeds depending on the variety with a high oil content of 44-60%, deep rooting. In Nigeria, the crop has remained a popular cash crop among farmers due to its good local and international markets potentials even though its production volume is fluctuating in recent years.

Achieving global food security remains a key challenge for the future, particularly given continued population increases, dietary shifts, and global climate change [6]. The key cause of food insecurity is inadequate food production which is at times owing to mismanagement of farms including inappropriate crop growing practices which lead to non-realization of green revolution in the affected area.

Despite the increasing demand and price of sesame in the world market, its productivity is declining from 8 to 3 q/ha in most parts of Ethiopia. The major reasons are the lack of knowledge and skill in land preparation and agronomic practices [7], which is the pillar to achieving bumper harvest, and consequently addressing food crisis and food insecurity.

Other reports indicate that the sesame production is increasing from year to year mainly driven by high current market demand and suitability of environmental factors. For instance, the recent five years data indicated that the production is growing at the rate of about 54% in

parallel with an increased area coverage of about 45% during the same years indicating a yield gain from extensive farming system [7]. In comparison, Japan is the world's largest importer of sesame because of the fact that sesame oil is an important component in Japanese food, followed by China, which is the world's second largest importer of sesame, although it is one of the largest producers of sesame seed. In addition, there are several other large importing countries such as the United States, The Turkey, Netherlands, Canada and France. Sesame is cultivated over an area of more than 7 million ha in the world with an annual production of 4 million tonnes and yield of 535 kg ha by Status paper on oil seeds, 2014 as cited in [8]. Sesame production at world level is estimated at 3.15 million tonnes per year in 2016 having risen from 1.4 million tonnes in the early 1960s with Asia and Africa producing 70 and 26% of this estimation respectively [9]. In Nigeria, sesame is becoming an important component of Nigeria's agricultural exports given its current rate of cultivation. At global level, exports in year 2000 were put at 657,000 tonnes having risen from 427,000 tonnes in 1988 [10]. References [10] and [11] valued annual exports from Nigeria at about US\$20 million.

Global cultivated area of sesame crops in 2017 amounted to around 10,245,246 ha, producing 5.90 million metric tons, which increased production by 1.6 million cubic meters compared to yield output in 2013 [12]. The leading countries in the world for the development of sesame crops in 2013 were Myanmar, India and China, followed by Sudan, Ethiopia, the United Republic of Tanzania (Tanzania), Uganda and Nigeria. Though the largest producers of sesame seed in 2017 were Tanzania where production grew compared to 2013, Myanmar retreated to fourth

after becoming the world's leading producers of sesame in 2013 followed by India, Nigeria and Sudan [13].

About 24% of the Sesame produced in the world is exported from the regions where it is produced while, in Africa, 44% of the produce is exported [12]. In 2001, Nigeria became Japan's largest supplier of Sesame [5]. Asia imports over twice as much Sesame as it produces, because the seeds are consumed as tahini or crushed into toasted oil. Reference [14] observed that Nigeria earned an estimated US\$20 million from sesame export.

Exporting about 209 tons, Sudan was the world's leading exporter, followed by India (173 tons) while China was the leading importer (153 tons) [15]. As per the same source, the market for Sesame in Asia and Europe has been growing at a very high rate, over the last decade, because the products from Sesame meet the health requirements for food in the developed world and the popular cuisine in the oriental world.

Sesame yields are much higher in developing countries than in developed countries, where sesame production in Asia and Africa accounted for more than 93 percent of global output as Asia produces half of the world's sesame crop production, followed by Africa with an average yield of about 43 percent [16]. Among European countries the average yield of sesame per hectare is the most productive. Italy, for instance, produces 7.2 metric tons per hectare. In comparison, some African and Asian countries have a relatively low yield of sesame, such as Kenya, which produces about 0.4 metric tons, and Pakistan, which produces approximately 1.2 metric tons of sesame seed per hectare [16], suggesting poor farm management practices.

As indicated in this section of the paper, several studies have indicated the need to improve in farm management as one of the measures to contribute to a sustained agricultural development in Nigeria, Africa, and the world at large. The use of appropriate crop growing practices is an important strategy recommended for improving farm hygiene, which in turn enhances farm yield [17].

Consequently, identifying the information needed for sesame farming could help research activities at solving its production problems and ensure optimal utilization of farm lands. This will build competency, improve yield, profit, and living

standard and ensure improved sustainable production among sesame farmers. It may as well incite Africa to step up her production, to benefit from the ever-increasing demand for the crop, especially in Asia.

This paper therefore aimed at investigating the suitable environment for sesame production that may help in improving the productivity of Nigeria's farm lands, improving food security of Nigerians and actualization and realization of the much-awaited green revolution in Nigeria and Africa at large, and the improvement of small-scale farmers' livelihood in Nigeria. The specific objectives include:

1. To determine the suitable growing environment for sesame production in Nigeria.
2. To determine which among Sandy, loamy, and clay soil types contributes most to the yield of sesame in Nigeria.

The research questions to be addressed in accomplishing the aforementioned research objectives are:

1. Which environment is suitable for sesame production in Nigeria?
2. Which among Sandy, loamy, and clay soil types contributes most to the yield of sesame in Nigeria?

In order to accomplish the set objectives of the study which were formulated in the form of research questions, Consequent upon which the following hypotheses are posed and tested:

1. Soil type is not significant in the yield of sesame in Nigeria.
2. Sandy soil contributes more to the yield of sesame in Nigeria as compared to loamy and, clay soils.
3. Loamy soil contributes more to the yield of sesame in Nigeria as compared to sandy, and clay soils.
4. Clay soil contributes more to the yield of sesame in Nigeria as compared to Sandy, and loamy soils.

Many articles have reported different features of the suitable environment for sesame production across the world. Reference [5] described sesame as the seed that is well adapted to withstand dry conditions, poor soils and climates that are generally unsuitable for other crops. This same source maintained that sesame thrives

around the dry tropics between the latitudes of 40° N and S. Sesame is adaptable to many soil types but it thrives best on well-drained and light-textured fertile soil with 5 to 8 soil pH in Ethiopia [18]. The same article opined that that the best soil for sesame growth in Ethiopia is light alluvial and chromic Vertosols. It does not grow well on heavy clay, salty and waterlogged soils. The article also warned farmers not to plant sesame on heavy clay soils especially on low spots where water cannot be drained off, as the plant is extremely susceptible to even short periods of water logging at any stage of growth.

Another article maintained that even though sesame grows on almost any moderately, and well drained fertile soil, it grows reasonably well on poor soil (sandy loamy) that is light textured with a pH in the range of 5.5-8.0 [19]. Reference [20] also confirmed that sesame efficiently uses resource-poor land. The plant was also considered by [21] as one of the resilient crops best-suited to the arid climate capable of being cultivated in marginal lands and inclement areas under frequent droughts and/or high heat. Their position was supported by [16] by saying that the crop has a high ability to adapt to tropical and semi-tropical regions.

The optimum temperature reported for sesame production ranges from 25°C to 27°C, while it requires 90–120 frost-free days to achieve optimal yields in cold regions [16]. It requires minimum rainfall of 43 - 44mm and day time temperature of 35°C-37°C for optimum growth [22].

Sesame requires hot conditions during growth to produce maximum yields. For optimum development and yield, sesame requires 25°C to 37°C temperature throughout its growth period. A temperature of 25°C to 27°C encourages [18] rapid germination, initial growth, and flower formation. Temperature below 20°C for any length of time inhibits germination or delay, and a temperature of less than 18°C after emergence will severely retard growth of seedlings. The seeds will not germinate at all at temperature below 11°C.

Sesame grows best on well-drained soils of moderate fertility as per [23]. The article stated further that the optimum pH for growth ranges from 5.4 to 6.7 and that good drainage is crucial, as sesame is very susceptible to short periods of waterlogging. The source also pointed out that sesame is intolerant of very acidic or saline soils.

The response of sesame to both temperature and daylength indicates that it is well adapted to wet season production in the tropics, or summer production in the warmer temperate areas. This same source explained that while there is some variation between cultivars, the base temperature for germination is about 16°C. The optimum temperature for growth varies with cultivar in the range 27–35°C. Periods of high temperature above 40°C during flowering reduce capsule and seed development

It may be noted from the heated arguments seen in this section of the paper that much of sesame production is in semi-arid regions, where rainfall is relatively low, which confirms sesame as a drought-tolerant crop that is cultivatable in many areas including those in which most grain crops cannot survive. These and many other economic reasons highlighted earlier on indicate the need to discuss extensively, on the environment that best suits sesame production in Nigeria.

2. METHODOLOGY

The study was carried out at the experimental farm of Department of Mathematics and Statistics Hussaini Adamu Federal Polytechnic in Kazaure Local Government Area of Jigawa State, Nigeria. The Local Government Area is located in the Sahel savannah with semi-arid conditions. Kazaure covers a land area of 1780 km² and with a population of 161,494 (NPC, 2006). The climatic condition is characterized by two distinct seasons; dry and wet seasons. The atmospheric temperature ranges between 32°C and 42°C with average annual rainfall of 1000 mm 1500 mm.

The paper focuses on determination of best soil type for growing sesame crops. The data collected were experimental, obtained by growing the sesame crops on the three-well-treated soil types. The soils were washed and made free of any nuisance factor effect. The variety of soils learnt to be competitively, commonly used in growing sesame crops are sandy, clay, and loamy soils. The assignment of the treatments to each of the three hundred experimental units was randomly done. The germinated sesame seedlings were well studied, monitored over a period of one month, and their chlorophyll content read using Konica Minolta chlorophyll meter SPAD-502 plus. The data were collected, and presented accordingly. The analyses were carried out by means of One-Way

ANOVA, and Statistical Packages for Social Sciences (SPSS) version 20.

The research designs used was experimental research designs. The estimation technique used in this study was One-Way Analysis of Variance (ANOVA). The concepts of the chosen estimation technique were discussed under the following subheadings.

2.1 Concepts of One-way ANOVA

The concept of analysis of variance (ANOVA) has attracted the attention of many researchers in several fields of study. It is one of the most important statistical tools which are extensively used in almost all sciences. It is one of the most efficient methods available for the analysis of experimental data [24]. The origin of ANOVA goes back to the famous British Geneticist and Statistician Sir R. A. Fisher. The technique was formally published in his book titled “statistical methods for workers” in 1925. ANOVA is a hypothesis testing procedure that tests whether two or more means are significantly different [25]. The concept poses null hypothesis that measurements across some number of groups are all derived from a common distribution. Upon rejection of the null hypothesis of this test, one would conduct multiple pairwise comparisons for mean difference. The required measures for these comparisons include the methods of Fisher, Tukey's, Scheffé's, Bonferroni's adaptation, and DunnŠidák etc. ANOVA has restrictive assumptions about the group distributions under scrutiny: the groups must have equal variances, and the tests must be continuous and normally distributed variables within each group.

However, references [26,27,28] concluded that, the fixed-effects ANOVA F-test is robust with respect to heterogeneous variances when *n*'s are equal. References [29,30,31,32] also indicated that two-tailed F-test is less affected by skewness. In support of this, [33] opined that ANOVA test is robust to violations of normality but needs homogeneous variances. On the other hand, some tests of homogeneity of variance often give fanciful results when the data are skewed. Thus, it is highly recommended to normalize the data as well as possible even though ANOVA itself does not require it. Such tests of normality are: the descriptive, graphical and inferential measures. The inferential measures include Shapiro Wilk (SW), Kolmogorov-Smirnov (KS), Anderson-Darling

(AD) and Lilliefors (LF) tests e.t.c. These procedures involve testing hypothesis that particular data follow a normal distribution. Skewness and kurtosis constitute the descriptive measures while the graphical measures include Box plot, quantile-quantile (Q-Q) plot, probability-probability (P-P) plot, histogram, and Stem-and-leaf plot.

Levene, Hartley, Bartlett, Cochran and Brown and Forsythe tests are on the other hand the most commonly used tests of homogeneity of variance. Alternative to these parametric homogeneity of variance tests are: Ansari-Bradley's test, Mood's test, Siegel-Tukey's test, Capon's test and Klotz's test.

According to [34], one-way variance test analysis is used only for numerical response data and is implemented when the data are divided into at least three classes (factor levels) according to a single factor. Let $y_{11}, y_{12}, y_{13}, \dots, y_{1n_1}, y_{21}, y_{22}, y_{23}, \dots, y_{2n_2}, \dots, y_{m1}, y_{m2}, y_{m3}, \dots, y_{mn_m}$ be *m* independent samples each of size *n*. let Y_{ij} be a random variable corresponding to *j*th row and *i*th level. A basic problem in ANOVA is to determine whether the *m* populations have a common mean.

The model of the concept is given as

$$Y_{ij} = \mu_i + \varepsilon_{ij}, i = 1, 2, m, j = 1, 2, n, \quad (1)$$

Where

$$m \geq 2, n \geq 2, \text{ and } \mu_i \text{ is the mean of the } i^{\text{th}} \text{ group.}$$

Note that, the model given in (1) assumes normality of the observations Y_{ij} and the random variable ε_{ij} , equivalently written as in (2) and (3)

$$Y_{ij} \sim N(\mu_i, \sigma^2) \quad (2)$$

$$\varepsilon_{ij} \sim N(0, \sigma^2) \quad (3)$$

The technique of One-way ANOVA test tests the null hypothesis

$$H_0: \mu_1 = \mu_2 = \dots = \mu_j \quad (4)$$

against the alternative hypothesis

$$H_1: \text{not all the means are equal} \quad (5)$$

Let define

$$\mu_i = \bar{Y}_i, \bar{Y}_{..} = \frac{1}{nm} \sum_{i=1}^m \sum_{j=1}^n Y_{ij} \text{ and}$$

$$\sigma^2 = \frac{1}{nm} \sum_{i=1}^m \sum_{j=1}^n (Y_{ij} - \bar{Y}_i)^2, i = 1, 2, \dots, m, j = 1, 2, \dots, n$$

Where

$$\bar{Y}_i = \frac{1}{n} \sum_{j=1}^n Y_{ij}$$

Let further define

$$SST = \sum_{i=1}^m \sum_{j=1}^n (Y_{ij} - \bar{Y}_i)^2 \tag{6}$$

$$SSE = \sum_{i=1}^m \sum_{j=1}^n (Y_{ij} - \bar{Y}_i)^2 \tag{7}$$

and

$$SSB = \sum_{i=1}^m n_i (\bar{Y}_i - \bar{Y}_{..})^2 \tag{8}$$

Here SST is the total sum of square, SSE is the sum of square error and SSB is the between group sum of square.

From (6), (7) and (8), we obtain another set of quantities: the mean square total (SST), the mean square error (MSE) and the mean square treatment (MSB) respectively given by:

$$MST = \frac{SST}{df(SST)} = \frac{SST}{N-1} \tag{9}$$

$$MSE = \frac{SSE}{df(SSE)} = \frac{SSE}{N-m} \tag{10}$$

$$MSSB = \frac{MSB}{df(SSB)} = \frac{SSB}{N-m} \tag{11}$$

Assuming the test conditions are satisfied, one-way ANOVA test uses the following test statistic

$$F = \frac{SSB/(m-1)}{SSE/(N-m)} = \frac{MSC}{MSE} \tag{12}$$

Under H_0 , this statistic has Fisher's distribution $F(m-1, N-m)$. In case it holds for the test criteria.

The null hypothesis H_0 is rejected at level of significance α when

$$F > F_{\alpha(m-1, N-m)} \tag{13}$$

where $F_{1-\alpha, m-1, N-m}$ is $(1 - \alpha)$ quantile of F distribution with $m - 1$ and $N - m$ degrees of freedom

2.1.1 Test of normality

Though ANOVA F test has once been reported to be robust to violation of normality assumption by [30,31,32], it sometimes affects the validity of

the test. Thus, ANOVA test first confirms the validity of this assumption before proceeding with any relevant procedures. Basically, there are three common methods of checking normality assumption namely graphical, descriptive, and inferential methods. These methods are discussed in next three subheadings.

2.1.1.1 Graphical measures of normality

The most common graphical methods for detecting normality are histogram, Q-Q plot, P-P plot, stem-and-leaf plot and Box plot. Kurtosis and Skewness constitute the two descriptive measures of normality.

An informal approach to testing normality is to compare a histogram of the sample data to a normal probability curve. The empirical distribution of the data (the histogram) should be bell-shaped and resemble the normal distribution [35].

In a situation where the sample is small, the appropriate graphical method for checking the normality assumption is normal (Q-Q plot). "A normal quantile plot of a data set Y_1, Y_2, \dots, Y_n is a graph of the points $(Z_i, Y_{(i)})$, where $Y_{(i)}$ is the i^{th} order statistic of the data and Z_i is the $i/(n+1)100th$ percentile of the standard normal distribution. Significant departures from linearity indicate that the data is probably not a random sample from a normal distribution [36].

However, a preferable graphical method of checking the normality assumption when the data set is large is stem-and-leaf plot [37]. Similar to a histogram, stem-and-leaf plot is obtained by tabulating the frequency of occurrence of values of the data and graphing the frequencies in a histogram. If the diagram is bell-shaped, then the data set is said to come from a normal distribution [37].

Box-and-whisker plot, another graphical approach for detecting normality that uses the median, the first and third quartiles of the sample, consists of a box whose upper and lower boundaries are respectively the third and first quartile. These quartiles are divided by a line segment (whisker) at the position of the sample median together with a line segment protruding from both the top and bottom of the box. If the line segment (the median) appears at the middle of the box, the sample is considered to have been drawn from a normal population.

The P-P plot plots the cumulative probability of a variable against the cumulative probability of a normal distribution. After data are ranked and sorted, the corresponding z-score is calculated for each rank as follows: $z = \frac{Y - \bar{Y}}{S}$. This is the expected value that the score should have in a normal distribution. The scores are then converted to z-scores. The actual z-scores are plotted against the expected z-scores. If the data are normally distributed, the result would be a straight diagonal line [36].

2.1.1.2 Descriptive measures of normality

Kim HY. [38] suggested that the sample estimates of $\sqrt{B_1}$ and B_2 could be used to describe normal distribution for sample size n, Y_1, \dots, Y_n . The sample estimates of preceding statistics are respectively given as:

$$\sqrt{b_1} = \frac{M_3}{M_2^{3/2}} \tag{14}$$

and

$$b_2 = \frac{M_4}{M_2^2} \tag{15}$$

Where

$$M_k = \sum_{i=1}^n (Y_i - \bar{Y})^k / n$$

and

$$\bar{Y} = \sum_{i=1}^n Y_i / n.$$

The values of $\sqrt{b_1}$ and b_2 close to 0 and 3, respectively, indicate normality. More precisely, the expected values of $\sqrt{b_1}$ and b_2 are 0 and $3(n-1)/(n+1)$, respectively.

2.1.1.3 Inferential measures of normality

The inferential measures of normality are supplementary to the graphical assessment of normality. The commonly used tests for the assessment of normality are Kolmogorov-Smirnov (KS) test, Lilliefors (LF) test, Lilliefors corrected (LFC) test, Shapiro-Wilk 1965 (SW) test, Anderson-Darling (AD) test, Cramer-von Mises (CVM) test, D’Agostino skewness (DS) test, D’Agostino Kurtosis (DK) test, D’Agostino-Pearson omnibus 1973 (DPO) test, Kuiper (K) test, Watson (W) test, Chi-square test, and the Jarque-Bera 1987 (JB) test. These procedures are categorized as empirical distribution function (EDF) such as KS, AD, CVM, and LF tests and

non-EDF tests such as SW, Chi-square test, DS test, DK test, DPO test, and JB test. EDF tests compare the scores in the sample to a normally distributed set of scores with the same mean and standard deviation. The null hypothesis is that “sample distribution is normal.” If the test is significant, the distribution is non-normal [39].

SW is the most powerful of all the formal tests of normality. The test is dependent on sample size n and independent of sample mean (\bar{y}) and sample variance (S^2). LF test appears to be more preferable to KS test [37]. AD test differs from the CVM test in such a way that it gives more weight to the tails of the distribution. The test is a modification of the CVM. Unlike SW and KS, DPO and JB tests can be applied even when the sample size is large ($n \geq 300$) [38].

EDF tests compare a given specified distribution function with their analogue empirical distribution [40]. These tests are applied to n ordered data points $y_1 < y_2 < \dots < y_n$.

The tests statistic for Shapiro Wilk test is given as:

$$W = \frac{(\sum_{i=1}^n a_i y_i)^2}{\sum_{i=1}^n (y_i - \bar{y})^2} \tag{16}$$

Where y_i is the i^{th} order statistic, \bar{y} is the sample mean, $a_i = (a_1, \dots, a_n) = \frac{m^i v^{-1}}{(m^i v^{-1} v^{-1} m)^{1/2}}$ and $m = (m_1, \dots, m_n)'$ are the expected values of the order statistics of independent and identically distributed random variables sampled from the standard normal distribution and V is the covariance matrix of those order statistics [37]. The null hypothesis H_0 : the sample comes from a distribution $F(x)$ is rejected at level of significance α if W exceeds the significant percentage point found in [41].

Lilliefors uses the test statistics:

$$D_n = \text{Max}_y |F^* - S_n(y)| \tag{17}$$

where $S_n(y)$ is the sample cumulative distribution function and F^* is the cumulative normal distribution function with \bar{Y} , the sample mean, and $\sigma^2 = S^2$, the sample variance, defined with denominator $n - 1$. If the value of D_n exceeds the critical value, one rejects the hypothesis that the observations are from a normal population [42].

The Cramer-von Mises test statistic is given by:

$$W^2 = \frac{1}{12n} + \sum_{i=1}^n \left[Z_i - \frac{2i-1}{2n} \right]^2 \quad (18)$$

where, Z_i is the cumulative probability of a standard normal distribution and n is the sample size. The null hypothesis H_0 : the sample comes from a distribution $F(x)$ is rejected at level of significance α if W^{2*} , the modified version of W^2 exceeds the significant point of W^{2*} found in [43].

Anderson Derling has the test statistics:

$$A^2 = -n - \frac{1}{n} \sum_{i=1}^n (2i-1) \left(\ln(Z_i) + \ln(1 - (Z_{n+1-i})) \right) \quad (19)$$

where Z_i is the cumulative probability of a standard normal distribution and n is the sample size. The null hypothesis H_0 : the sample comes from a distribution $F(x)$ is rejected at level of significance α if A^{2*} , the modified version of A^2 , exceeds the significant point of A^{2*} found in [43].

The Kolmogorov Smirnov test statistic is given by:

$$\begin{aligned} D^+ &= \max_{1 \leq i \leq n} \left(\frac{i}{n} - Z_i \right) \\ D^- &= \max_{1 \leq i \leq n} \left(Z_i - \frac{(i-1)}{n} \right) \\ D &= \max(D^+, D^-) \end{aligned} \quad (20)$$

where Z_i is the cumulative probability of a standard normal distribution and n is the sample size. The null hypothesis H_0 : the sample comes from a distribution $F(x)$ is rejected at level of significance α if D^* , the modified version of D , exceeds the significant point of D^* found in [43].

or

$$D = \text{Sup}_y |F^* - F_n(y)| \quad (21)$$

where Sup_y stands for the supremum, the greatest, $F_n(y)$ is the sample cumulative distribution function and F^* is the cumulative normal distribution function with \bar{Y} , the sample mean, and $\sigma^2 = S^2$, the sample variance, defined with denominator $n-1$. If the value of D exceeds the critical value, one rejects the hypothesis that the observations are from a normal population [42].

Watson has the following test statistic:

$$U^2 = W^2 - n \left(\bar{Z} - \frac{1}{2} \right)^2 \quad (22)$$

where $\bar{Z} = \sum_{i=1}^n Z_i/n$, Z_i is the cumulative probability of a standard normal distribution, W^2 is Cramer-von Mises statistic and n is the sample size. The null hypothesis H_0 : the sample comes from a distribution $F(x)$ is rejected at level of significance α if D^* , the modified version of D exceeds the significant point of D^* found in [43].

Kuiper statistic is given as:

$$V = D^+ + D^- \quad (23)$$

where D^+ and D^- are the quantities in (24). The null hypothesis H_0 : the sample comes from a distribution $F(x)$ is rejected at level of significance α if V^* , the modified version of V exceeds the significant point of V^* found in [43].

Chi square goodness of fit test uses the test statistic:

$$X^2 = \frac{\sum_{i=1}^r (\gamma_i - n\hat{p}_{i0})^2}{n\hat{p}_{i0}} \quad (24)$$

where, n is the sample size, r is the number of mutually exclusive categories, γ_i is the observed frequency in category i , P is the number of parameters of the fitted distribution and \hat{p}_{i0} is the estimated value of the category i probability given by $P_{i0} = P[X \in C_i]$, if H_0 is true. The hypothesis H_0 that the population is normally distributed is rejected at significance level α when,

$$X^2 > X^2(r-1-p) \quad (25)$$

D'Agostino kurtosis test has the test statistic:

$$\begin{aligned} Z(b_2) &= \\ &= \left(\left(1 - \frac{2}{9A} \right) - \left[\frac{1-2/A}{1+x\sqrt{2/(A-4)}} \right]^{1/3} \right) / \sqrt{2/(9A)} \end{aligned} \quad (26)$$

where $x = (b_2 - E(b_2)) / \sqrt{\text{var}(b_2)}$ is the standardized version of the sample kurtosis b_2 , $E(b_2) = 3(n-1)/n+1$ is the mean of the kurtosis,

$(b_2) = \frac{24n(n-2)(n-3)}{(n+1)^2(n+3)(n+5)}$ is the variance of the kurtosis, $A = 6 + \frac{8}{\sqrt{\beta_1(b_2)}} \left[\frac{2}{\sqrt{\beta_1(b_2)}} + \sqrt{\left(1 + \frac{4}{\beta_1(b_2)}\right)} \right]$ and

$\beta_1(b_2) = \frac{6(n^2-5n+2)}{(n+2)(n+9)} \sqrt{\frac{6(n+3)(n+5)}{n(n-2)(n-3)}}$ is the third standardized moment of the kurtosis.

The null hypothesis H_0 : normality ($B_2 = 3$) versus alternatives H_1 : non normality ($B_2 \neq 3$) two-sided test or ($B_2 > 3$ or $B_2 < 3$) one-sided test is rejected at significance level α when B_2 is greater than the critical value of kurtosis found in [44].

D'Agostino skewness test uses the statistic:

$$Z(\sqrt{b_1}) = \sigma \ln \left(\gamma/\alpha + \{(\gamma/\alpha)^2 + 1\}^{1/2} \right) \quad (27)$$

where $= \sqrt{b_1} \left\{ \frac{(n+1)(n+3)}{6(n-2)} \right\}^{1/2}$,

$\sqrt{b_1} =$ is the sample skewness,

$$\alpha = \left\{ 2/(W^2 - 1) \right\}^{1/2},$$

$$W^2 = -1 + \left\{ 2(\beta_2(\sqrt{b_1}) - 1) \right\}^{1/2},$$

$$\sigma = 1/\sqrt{\ln W}$$

and

$$\beta_2(\sqrt{b_1}) = \frac{3(n^2 + 27n - 70)(n + 1)(n + 3)}{(n - 2)(n + 5)(n + 7)(n + 9)}$$

The null hypothesis H_0 : normality ($\sqrt{B_1} = 0$) versus alternatives H_1 : non normality ($\sqrt{B_1} \neq 0$) two-sided test or ($\sqrt{B_1} > 0$ or $\sqrt{B_1} < 0$) one-sided test is rejected on significance level α when $\sqrt{B_1}$ is greater than the critical value of skewness found in [45].

D'Agostino Omnibus test uses the statistic:

$$K^2 = Z_1(g_1)^2 + Z_2(g_2)^2 \quad (28)$$

Jarque-Bera (1987) has the test statistic:

$$JB = n \left[\frac{(\sqrt{b_1})^2}{6} + \frac{(b_2-3)^2}{24} \right] \quad (29)$$

where n is the number of observations, $\sqrt{b_1}$ is the sample skewness, b_2 is the sample kurtosis, $Z_1(g_1)^2$ and $Z_2(g_2)^2$ are transformed sample skewness and kurtosis respectively.

2.1.2 Test of homogeneity of variance

The second step in carrying out one-way ANOVA test is to check for homogeneity (equality) of variance. The variance equality test is used to determine if the assumption of group (level) equal variances is correct. The null hypothesis for this test is that the sample groups under consideration come from populations with the same variance. The alternative hypothesis is that the populations have different variances [46]. These two hypotheses are symbolically expressed as:

$$H_0: \sigma_1^2 = \sigma_2^2 = \dots = \sigma_m^2 \quad (30)$$

And

$$H_1: \exists 1 \leq i, l \leq m: \sigma_i^2 \neq \sigma_l^2 \quad (31)$$

There are several statistical tests that can be used to test the aforementioned hypotheses; these tests include: Hartley's (1940, 1950), Cochran's (1941), Levene's (1960), Bartlett's (1973), Z-variance, Modified Levene's and Fisher's tests Brown and Forsythe (1974) tests among other. The Bartlett, Hartley and Cochran are technically tests of homogeneity. The Levene's and Brown and Forsythe methods actually transform the data and then test for equality of means.

Note that Cochran's and Hartley's test assumes that there are equal numbers of participants in each group.

The tests of Bartlett, Cochran, Hartley and Levene's may be applied for number of samples $m > 2$. In such situation, the power of these tests turns out to be different. When the assumption of the normal distribution is true for $m > 2$ these tests may be ranked by power decrease as follows: Cochran, Bartlett, Hartley and Levene's. This preference order also holds in case when the normality assumption is disturbed [47]. Unless samples are from heavy-tailed or skewed distributions, this preference order remains the same.

Bartlett's test has the following test statistic:

$$B = C^{-1}[(N - k) \cdot \ln S^2 - \sum_{i=1}^m (n_i - 1) \cdot \ln S_i^2] \quad (32)$$

where constant $C = 1 + \frac{1}{3(m-1)} \cdot \left(\sum_{i=1}^m \frac{1}{n_i-1} - \frac{1}{N-m} \right)$, S_i^2 is the unbiased estimate of variance for i^{th} group, S^2 is the pooled variance and n_i is sample size of the i^{th} group. The hypothesis H_0 is rejected at significance level α , when

$$B > X^2_{1-\alpha, m-1} \tag{33}$$

where $X^2_{1-\alpha, m-1}$ is the critical value of the *chi-square* distribution with $m - 1$ degrees of freedom.

Cochran's test is one of the best methods for detecting cases where the variance of one of the groups is much larger than that of the other groups. This test uses the following test statistic:

$$C = \frac{\max S_i^2}{\sum_{i=1}^k S_i^2} \tag{34}$$

The hypothesis H_0 is rejected at significance level α , when

$$C > C_{\alpha, m, n-1} \tag{35}$$

where critical value $C_{\alpha, k, n-1}$ is in special statistical tables.

Z-variance test uses the following statistics:

$$V = \frac{\sum_{i=1}^m Z_i^2}{m-1} \tag{36}$$

where $Z_i = \sqrt{\frac{c_i(n_i-1)S_i^2}{MSE} - \sqrt{c_i(n_i-1) - \frac{c_i}{2}}}$, $MSE = \frac{\sum_{i=1}^m \sum_{j=1}^{n_i} (y_{ij} - \bar{y}_i)^2}{m}$, m is the number of groups, $c_i = 2 + \frac{1}{n_i}$, n_i is the sample size for i^{th} group, S_i^2 is the unbiased estimate of variance, y_{ij} is the j^{th} observation in the i^{th} group, \bar{y}_i is the mean of the i^{th} group and $N = \sum_{i=1}^m n_i$ is the total sample size. The test has approximately $F(m - 1, \infty)$ distribution.

The hypothesis H_0 is rejected at significance level α , when,

$$V > F(m - 1, \infty) \tag{37}$$

Hartley's test uses the following test statistic:

$$H = \frac{\max S_i^2}{\min S_i^2} \tag{38}$$

where $\max S_i^2 = \max(S_1^2, \dots, S_m^2)$, $\min S_i^2 = \min(S_1^2, \dots, S_m^2)$, S_i^2 is the unbiased estimate of

variance for i^{th} group and m is the number of groups.

The hypothesis H_0 is rejected at significance level α , when

$$H > H_{\alpha, m, n-1}, \tag{39}$$

where critical value $H_{\alpha, k, n-1}$ is in special statistical tables.

Levene's test has the following test statistic:

$$L = \frac{(N-m) \sum_{i=1}^m n_i (Z_i - \bar{Z})^2}{(m-1) \sum_{i=1}^m \sum_{j=1}^{n_i} (Z_{ij} - \bar{Z}_i)^2} \tag{40}$$

where, m is the number of samples, n_i is the sample size of the i^{th} group, $N = \sum_{i=1}^m n_i$ is the total sample size, $Z_{ij} = |y_{ij} - \bar{y}_i|$, \bar{y}_i is the mean of i^{th} group, y_{ij} is the j^{th} observation in the i^{th} group, \bar{Z}_i is mean of Z_{ij} for i^{th} group and \bar{Z} is the overall mean of Z_{ij} .

If the groups sample sizes are greater than or equal to 40, the test has $F_{m-1, N-m}$ distribution. Where the critical value $F(m - 1, N - m)$ is in *F table*. The hypothesis H_0 is rejected at significance level α , when,

$$L > F(m - 1, N - m) \tag{41}$$

Modified Levene's test differs from Levene's test only in the fact that Z_{ij} is defined using the sample median instead of the mean \bar{y}_i . The rejection criterion of this test is the same as that of Levene's test.

Fisher's test is used to test the hypothesis of homogeneity of variance of two samples. The test uses the following statistic:

$$F = \frac{S_1^2}{S_2^2} \tag{42}$$

where S_1^2 and S_2^2 are the unbiased sample variances. The test statistic has $F(n_1 - 1, n_2 - 1)$ distribution. The hypothesis H_0 is rejected at significance level α , when,

$$F > F(n_1 - 1, n_2 - 1) \tag{43}$$

2.1.3 Post hoc comparison procedures

The last important step in ANOVA test is to detect by means of statistical technique namely post hoc comparison, the pair of group means

(μ_i and μ_j) that differ significantly. At first, the technique requires that an overall ANOVA is computed and null hypothesis (H_0) rejected. In pairwise multiple comparisons problem, the entire simultaneous estimation of the class of $m^* = m(m - 1)/2$ pair wise comparisons $\mu_i - \mu_j$ of m means μ_1, \dots, μ_m of the model given in (2.1) is made [48] and [49]. An alternative approach to make pair wise multiple comparisons is the confidence interval (CI) method. Confidence interval is usually taken to mean the range of values that encompass the population or 'true' value estimated by a certain statistic with a given probability [50]. This technique comprises Hochberg's method, Grabriel's method, Spjotvoll-Stoline's method, Fisher's method, Tukey's method, Scheffé's method, Bonferroni's adjustment method, DunnŠidák's method among others. Fisher's method and Tukey's method require equal sample sizes of groups, while Tukey's method, Scheffé's method, Bonferroni's adjustment method, and DunnŠidák's method do not. Recent work spearheaded by [51] leads to the conclusion that the Tukey-Kramer's method (popularly known as "Kramer's Method") is the recommended multiple comparisons procedure for the simultaneous estimation of all pairwise differences of means in an imbalanced one-way ANOVA design with homogeneous variances. The Sidák-Bonferroni's procedure seems a reasonable approach for smaller sets of comparisons. Tukey's HSD (Tukey-Kramer) or the Fisher-Hayter procedure seems to be reasonable for simple pairwise comparisons [52]. However, the choice of the method to follow-up the rejection of the null hypothesis hinges on the type of experimental design and the comparison of interest to the analyst.

The general formula for $100(1 - \alpha)$ percent confidence interval of the point estimate of the difference of two group means ($\mu_i - \mu_j$) is given as:

$$\text{Point estimate} \pm \text{Margin of} \tag{44}$$

where Point estimate is the difference of the two groups means (μ_i and μ_j) being compared, and Margin of error reflects the accuracy of the guess based on the data.

The method tests the null hypothesis,

$$H_0: \mu_i = \mu_j \tag{45}$$

against its alternative,

$$H_1: \mu_i \neq \mu_j \tag{46}$$

The computational formulae for the construction of $100(1 - \alpha)$ percent CI of ($\mu_i - \mu_j$) for the aforementioned pairwise multiple comparison procedures are given as reference [48]:

$$\bar{Y}_I - \bar{Y}_J \pm \sqrt{(m - 1)S^2 \left(\frac{1}{n_i} + \frac{1}{n_j} \right) \cdot F_{1-\alpha, m-1, N-m}} \tag{47}$$

By Scheffé method.

$$\bar{Y}_I - \bar{Y}_J \pm t_{1-\frac{\alpha^*}{2}, N-m} \sqrt{S^2 \left(\frac{1}{n_i} + \frac{1}{n_j} \right)} \tag{48}$$

where $\alpha^* = 1 - (1 - \alpha)^{1/C}$ and $C = \binom{m}{2}$, by DunnŠidák method.

$$\bar{Y}_I - \bar{Y}_J \pm t_{\alpha^*, v} \left(\frac{1}{n_i} + \frac{1}{n_j} \right)^{1/2} \tag{49}$$

where $\alpha^* = \alpha, N - m$ is the quantile of the Student's t probability distribution, by Fisher method (LSD - Least Significant Difference);

$$\bar{Y}_I - \bar{Y}_J \pm q_{\alpha, m, N-m} \cdot \sqrt{\frac{S^2}{2} \left(\frac{1}{n_i} + \frac{1}{n_j} \right)} \tag{50}$$

where $q_{\alpha, m, N-m}$ represents the quantile for the Studentized range probability distribution, by Tukey Kramer method (HSD - Honestly Significant Difference);

$$\bar{Y}_I - \bar{Y}_J \pm t_{1-\frac{\alpha^*}{2}, N-m} \sqrt{S^2 \left(\frac{1}{n_i} + \frac{1}{n_j} \right)} \tag{51}$$

where $\alpha^* = \frac{\alpha}{2}, C = \binom{m}{2}$, C is the number of pairwise comparisons in the family, by Bonferonni method.

$$\bar{Y}_I - \bar{Y}_J \pm (q' \alpha, m, v) \sqrt{S^2 / \left(\frac{1}{n_i} + \frac{1}{n_j} \right)} \tag{52}$$

where $q' \alpha, m, v$ is the upper point of the studentized augmented range distribution with parameter k and v df. $q' \alpha, m, v$ is found in reference [49], by Spjotvoll-Stoline method.

$$\bar{Y}_I - \bar{Y}_J \pm (m_{\alpha}, m, v) \sqrt{S^2 / \left(\frac{1}{n_i} + \frac{1}{n_j} \right)} \tag{53}$$

where m_{α}, m, v is the upper α point of studentized maximum modulus distribution with parameter k and v df. The tabulation of the upper α points of the maximum modulus distribution is found in reference [49], by Hochberg.

$$\bar{Y}_i - \bar{Y}_j \pm (m_{\alpha}, m, v)S \left(\frac{1}{(2n_i)^{1/2}} + \frac{1}{(2n_j)^{1/2}} \right) \quad (54)$$

where m_{α}, m, v is the upper α point of studentized maximum modulus distribution with parameter k and v df. The tabulation of the upper α points of the maximum modulus distribution is found in reference [49], by Grabiell's method.

In each of the above cases, the null hypothesis is rejected if the confidence interval for the point estimate $(\mu_i - \mu_j)$ does not contain zero.

3. RESULTS AND DISCUSSION

The empirical data on the effect of soil type on the yield of sesame seedlings in terms of chlorophyll content were analyzed under this section. Four statistical tests were conducted and their results reported in the next tables and figure. Thereafter comes the conclusion of the study based on the results herein and those results from other relevant literatures.

3.1 Results

The statistical tests conducted were Box plot, Shapiro-Wilk test, Levene's test, and Tukey HSD post hoc comparison test

3.1.1 One-way analysis of variance (ANOVA) test indicating the overall effect of soil type on the yield of sesame

One-way ANOVA was conducted to compare the effect of type of soil on the yield of sesame seedling in sandy, clay, and loamy soils conditions. The test indicates that there was a statistically significant effect of the type of soil on the yield of sesame seedling, $F(2, 297) = 6.70, p = 0.00, p < .05$ level for the three conditions.

Table 1. Represents the one-way ANOVA test for the effect of type of soil on the yield of sesame seedlings

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	99.111	2	49.555	6.695	.004
Within Groups	199.844	297	7.402		
Total	298.955	299			

3.1.2 Normality tests indicating the normality of the collected data

Under this section, two statistical tests for detecting departures from normality, Box plot and Shapiro Wilk test, were conducted and their results presented in Fig. 1 and Table 2, respectively.

A Box plot was plotted to assess the normality of the data. The Box plot indicates normality of the data under sandy soil level and clay soil level, while the data under clay soil level departed from normality.

Table 2. Shapiro-wilk tests of normality indicating the distribution of the collected data

	Type of soil	Shapiro-Wilk		
		Statistic	df	Sig.
Chlorophyll Content	Sandy	.972	11	.901
	Clay	.682	9	.001
	Loamy	.976	10	.938

A Shapiro-Wilk normality tests was conducted to assess the normality of the data. The test indicates that sandy soil and loamy soil conditions were normally distributed, $SW(301) = 0.97, p = 0.90$ and $SW(300) = 0.98, p = 0.94$ respectively. However, the test indicates non normality of the clay soil condition $SW(299) = 0.68, P = 0.01$

3.1.3 Homogeneity of variance test indicating the validity of the equal variance assumption

A Levene's test was conducted to assess the homogeneity of the data. The test indicates that the assumption of homogeneity of variance was tenable, $L(2, 297) = 1.04, p = 0.37$.

Table 3. Represents test of homogeneity of variances

Levene Statistic	df1	df2	Sig.
1.044	2	297	.366

3.1.4 Post hoc comparison test indicating the pair of group means that significantly differ from each other

A Tukey post hoc test revealed that the effect of soil on the yield of sesame seedlings was statistically significantly higher in sandy soil ($M = 11.20, SD = 2.37$) than in loamy soil ($M = 6.86, SD = 3.39$) and clay soil ($M = 3.60, SD = 0.89$).

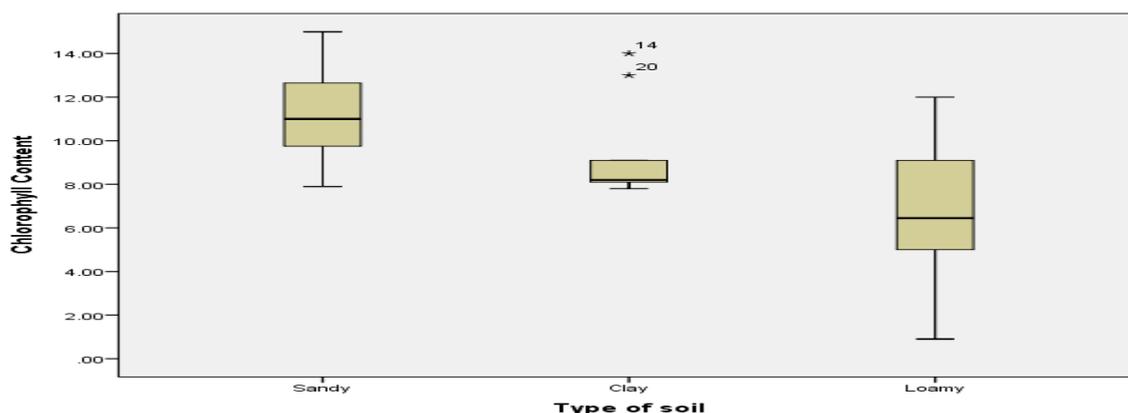


Fig. 1. Represents box plot for detecting departures from normality

Table 4. Represents tukey post hoc comparison test

(I) Type of soil	(J) Type of soil	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Sandy	Clay	1.80000*	1.22282	.320	-1.2319	4.8319
	Loamy	4.34000*	1.18871	.003	1.3927	7.2873
Clay	Sandy	-1.80000*	1.22282	.320	-4.8319	1.2319
	Loamy	2.54000	1.25003	.124	-.5593	5.6393
Loamy	Sandy	-4.34000*	1.18871	.003	-7.2873	-1.3927
	Clay	-2.54000	1.25003	.124	-5.6393	.5593

There was no statistically significant difference between the loamy soil and clay soil conditions.

3.2 Discussion of Results

A Shapiro-Wilk (SW) normality tests was conducted to assess the normality of the data. The test indicates normal distribution of the sandy soil, and loamy soil conditions, $SW(301) = 0.97, p = 0.90$ and $SW(30) = 0.98, p = 0.94$, respectively. However, the clay soil condition did not follow a normal distribution, $SW(299) = 0.68, P = 0.01$. A Levene's (L) test was conducted to assess the homogeneity of variance of the data. The test indicates that the assumption of homogeneity of variance was tenable, $L(2, 297) = 1.04, p = 0.37$. A one-way ANOVA between subjects was conducted to compare the effect of soil, in terms of chlorophyll content, on the yield of sesame seedling in sandy soil, clay soil, and loamy soil conditions. There was a statistically significant effect of type of soil on the yield of sesame seedling, in terms of chlorophyll content, at the $p < .05$ level for the three conditions, $[F(2, 297) = 4.94, p = 0.027]$. This result is in line with that in the reference [53] which reported that sesame productivity depends on the cultivars and the soil structure. Post hoc comparisons using the Tukey HSD test indicates that the

effect of the type of soil on the yield of sesame seedlings was statistically significantly higher in the in sandy soil condition, ($M = 11.20, SD = 2.37$) as compared to loamy soil condition, ($M = 6.86, SD = 3.39$) and clay soil condition, ($M = 3.60, SD = 0.89$). However, the clay soil condition, ($M = 3.60, SD = 0.89$) did not significantly differ from the loamy soil conditions. This find was supported by that in reference [54] that established that the crop grows reasonably well on poor soil (sandy loamy) that is light textured with a pH in the range of 5.5-8.0. Taken together, these results suggest that type of soil really do have effect on the productivity of sesame. Specifically, our results suggest that sesame seedling yields more harvest when grown on sandy soil.

4. CONCLUSION

Sesame seeds are an oily, notable for being palatable and odorless. This is also a healthy source of protein for man as well as for livestock. With the current global climate change and drought conditions in many parts of the world, especially in Africa, there is demand for growing drought-resistant crops including sesame. There is also a rising demand for sesame on the international market as it enters many healthy

foods as a major component and is also a step in the right direction towards ensuring food security with increasing income generation, especially because sesame represents an significant export crop in many countries with the possibility of creating numerous jobs, particularly in the developing world.

This study and several other have indicated the need for an improved farm management practices as it has direct impact on achieving sustainable agricultural development in Nigeria, actualization of green revolution, and combating global food crisis and food insecurity through improved yield of sesame produce.

This therefore instigates the need of an investigational research such as this. The study thus settles on a Sandy soil that is rich in organic matter, light textured, well-drained and deep, and that is exposed to an average temperature of 25°C to 37°C as the suitable growing environment for sesame production in Nigeria and most parts of the world. Though it came to a conclusion of being this crop tolerant to draught, and that It takes 90–120 frost-free days to achieve maximum yields in cold regions, the study shows frostiness of crops at germination and seedling levels, water logging and excessive rainfall.

COMPETING INTERESTS

Authors have declared that no competing of interests exist.

REFERENCES

- Nayar NM, Mehra KL. Sesame: its uses, botany, cytogenetics, and origin. *Economic Botany*. 1970;20-31.
- Vavilov NI. The origin, variation, immunity and breeding of cultivated plants. 1951; 72(6):482.
- Salzano FM, Neel JV, Maybury-Lewis DI. Demographic data on two additional villages: Genetic structure of the tribe. *American Journal of Human Genetics*. 1967;19(4):463.
- Purseglove JW. Tropical crops. Dicotyledons 1 and 2. *Tropical crops. Dicotyledons 1 and 2*; 1968.
- Chemonics Overview of the Nigerian Sesame Industry. Washington DC: Chemonics International Inc; 2003.
- Waha K, Van Wijk MT, Fritz S, See L, Thornton PK, Wichern J, Herrero M. Agricultural diversification as an important strategy for achieving food security in Africa. *Global change biology*. 2018;24(8): 3390-3400.
- Zerihun J. "Sesame (*Sesame indicum* L.) crop production in Ethiopia: Trends, challenges and future prospects." *Science, Technology and Arts Research Journal*. 2012;1(3):01-07.
- Sasson A. Food security for Africa: an urgent global challenge. *Agriculture & Food Security*. 2012;1(1),1-16.
- Chauhan JS, Prasad SR, Pal S, Choudhury PR, Bhaskar KU. Seed production of field crops in India: Quality assurance, status, impact and way forward. *Indian Journal Agricultural Sciences*. 2016;86(5):563-79.
- USAID. Overview of the Nigerian Sesame Industry Nigeria: United States Agency for International Development (USAID); 2002.
- OLAM. Improved Package of Practices for Sesame Production Out-Grower (Training Manual). Lagos: OLAM Nigeria Limited; 2005.
- Sharaby N, Butovchenko A. Cultivation technology of sesame seeds and its production in the world and in Egypt. In *IOP Conference Series: Earth and Environmental Science*. 2019;403(1): 012093. IOP Publishing.
- Girmay AB. Sesame production, challenges and opportunities in Ethiopia. *Agricultural Research & Technology: Open Access Journal*. 2018; 15(5):555972.
- Olowe VIO, Adeyemo YA, Adeniregun OO. "Sesame: the underexploited organic oilseed crop " *Journal of Science and Sustainable Development* 2.1. 2009;29-32.
- Ikwuakam OT, Iyela A, Sangotegbe NS. Information needs of sesame farming households in selected agricultural zones of katsina state, Nigeria. *Mediterranean Journal of Social Sciences*. 2016;7(1-1): 204-204.
- Olowe VIO, Adeyemo YA, Adeniregun OO. Sesame: the underexploited organic oilseed crop. *Journal of Science and Sustainable Development*. 2009;2(1):29-32.
- Sharaby N, Butovchenko A. Cultivation technology of sesame seeds and its production in the world and in Egypt. *IOP Conference Series: Earth and*

- Environmental Science, IOP Publishing; 2019
18. Verma V. Textbook of economic botany. Ane Books Pvt Ltd; 2009.
 19. Teklewold A, Amde T, Baye TM. 18 Sesame Cultivation and Use in Ethiopia. *Sesame: The genus Sesamum*. 2010;297.
 20. Yingzhong Z. 17 Sesame Cultivation and Use in China. *Sesame: The genus Sesamum*. 2010;283.
 21. Dossa K, et al. "Enhancing sesame production in West Africa's Sahel: a comprehensive insight into the cultivation of this untapped crop in Senegal and Mali." *Agriculture & food security*. 2017;6(1):68.
 22. Langham DR. Growth and development of sesame. *Sesaco Corp*. 2008;329.
 23. Bennett M. Sesame seed. *Handbook for Farmers and Investors*; 1998.
 24. Armstrong RA, et al. "The application of analysis of variance (ANOVA) to different experimental designs in optometry." *Ophthalmic and Physiological Optics*. 2002; 22(3):248-256.
 25. Stockburger, D. *Introductory statistics: Concepts, models, and applications*, Atomic Dog Pub; 2001.
 26. Glass GV, et al. "Consequences of failure to meet assumptions underlying the fixed effects analyses of variance and covariance." *Review of educational research*. 1972;42(3):237-288.
 27. Liu H. "Comparing Welch's ANOVA, a Kruskal-Wallis test and traditional ANOVA in case of Heterogeneity of Variance."; 2015.
 28. Rogan JC, Keselman H. "Is the ANOVA F-test robust to variance heterogeneity when sample sizes are equal?: An investigation via a coefficient of variation." *American Educational Research Journal*. 1977;14(4): 493-498.
 29. Cochran WG. "Some consequences when the assumptions for the analysis of variance are not satisfied." *Biometrics*. 1947;3(1):22-38.
 30. Rider PR. "On the distribution of the ratio of mean to standard deviation in small samples from non-normal universes." *Biometrika*. 1929;124-143. Press.
 31. Pearson ES, Adyanthāya N. "The distribution of frequency constants in small samples from non-normal symmetrical and skew populations." *Biometrika* 1929; 21(1/4):259-286.
 32. Pearson ES. "The analysis of variance in cases of non-normal variation." *Biometrika* 1931;23(1/2):114-133.
 33. Legendre P, Borcard D. "Statistical comparison of univariate tests of homogeneity of variances." *Journal of Statistical Computation and Simulation*. 2008;514.
 34. Gosset W. "Test of statistics." *Fundamentals of mathematical statistics*. New Delhi (India): Sultan Chand and Sons. 1908;12-38.
 35. Razali NM, Wah YB, "Power comparisons of shapiro-wilk, kolmogorov-smirnov, lilliefors and anderson-darling tests." *Journal of statistical modeling and analytics*. 2011;2(1):21-33.
 36. Ghasemi A, Zahediasl S. "Normality tests for statistical analysis: a guide for non-statisticians." *International Journal of Endocrinology and Metabolism*. 2012; 10(2): 486.
 37. Hastings KJ. *Probability and Statistics*. United States of America: Addison Wesley Longman, Inc; 1997.
 38. Kim HY. "Statistical notes for clinical researchers: assessing normal distribution (2) using skewness; 2013.
 39. Pearson K. "Contributions to the mathematical theory of evolution. II. Skew variation in homogeneous material." *Philosophical Transactions of the Royal Society of London*. 1895;186(I):343-424.
 40. Anderson TW, Darling DA. "A test of goodness of fit." *Journal of the American statistical Association*. 1954;49(268):765-769
 41. Shapiro SS, Wilk MB. "An analysis of variance test for normality (complete samples)." *Biometrika*. 1965;52(3/4):591-611.
 42. Lilliefors HW. "On the Kolmogorov-Smirnov test for normality with mean and variance unknown." *Journal of the American statistical Association*. 1967;62(318):399-402.
 43. Stephens MA. "EDF statistics for goodness of fit and some comparisons." *Journal of the American statistical Association*. 1974; 69(347):730-737.
 44. D'Agostino RB, Stephens MA. *Goodness of Fit Techniques*, Marcel Dekker, New York; 1986.
 45. D'Agostino RB. "Transformation to normality of the null distribution of g_1 ." *Biometrika*. 1970;679-681.

46. Abdi H. "O'Brien test for homogeneity of variance." Encyclopedia of measurement and statistics. 2007;2:701-704.
47. Gorbunova AA, Lemeshko BY. Application of variance homogeneity tests under violation of normality assumption. Proceedings of the International Workshop "Applied Methods of Statistical Analysis. Simulations and Statistical Inference"–AMSA; 2011.
48. Stoline MR. "The status of multiple comparisons: simultaneous estimation of all pairwise comparisons in one-way ANOVA designs." The American Statistician. 1981;35(3): 134-141.
49. Stoline MR, Ury HK. "Tables of the studentized maximum modulus distribution and an application to multiple comparisons among means." Technometrics. 1979; 21(1):87-93.
50. Quinn GP, Keough MJ. Experimental design and data analysis for biologists, Cambridge University kurtosis." Restorative dentistry & endodontics. 2002;38(1):52-54.
51. Dunnett CW. "Pairwise multiple comparisons in the homogeneous variance, unequal sample size case." Journal of the American statistical Association. 1980;75(372):789-795
52. Keppel G, Wickens T. "Simultaneous comparisons and the control of type I errors." Design and analysis: A researcher's handbook. 4th ed. Upper Saddle River (NJ): Pearson Prentice Hall. 2004;111-130.
53. Terefe G, Wakjira A, Berhe M, Tadesse H. Sesame production manual. Ethiopia: Ethiopian Institute of Agricultural Research Embassy of the Kingdom of the Netherlands; 2012.
54. Teklewold A, Amde T, Baye TM. 18 Sesame Cultivation and Use in Ethiopia. Sesame: The genus Sesamum. 2010;297.

© 2020 Hussaini et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:
<http://www.sdiarticle4.com/review-history/59307>