Research Article

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Analysis of *Asparagus Africanus* Vigor from Split-Plot Experimental Design

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ABSTRACT

This research performed analysis on a four-year experiment on *Asparagus africanus*. The experimental design layout is a 4^2 split-plot design where both the whole and split plots had a single factor each at four different levels. The experiment was to determine if there is any significant difference in the mean vigor (weight) of *A. africanus* at four different years and cutting dates. The result from the analysis shows that year, cutting dates, and the interaction effect have significant effect on the vigor of harvested *A. africanus* at 5%. A post hoc test was performed using the least significant difference statistic and it was found that *A. africanus* cultivated in 2021 has the largest mean vigor compared to other cultivated years and cutting dates of 1st and 15th June produced the largest mean vigor. Also, it was found that the experiment was well managed and controlled but the split-plot designed experiment was not efficient enough.

KEYWORDS: *Asparagus africanus*; Relative design efficiency; Split-plot design; Plant vigor

INTRODUCTION

Asparagus africanus Lam (Liliaceae) is a plant with many medicinal properties from the leaf and root extracts for treating ailments like malaria, lishmaniansis, bilharziasis, syphilis, and gonorrhoea [1], headache, backache, stomach pain, and for aiding child delivery [2], externally for the relief of pain, rheumatism and chronic gout [3], used as a diuretic, for sore throat and otitis [4]. Its analgesic and anti-inflammatory activities have been studied extensively confirming the plants potential dose-dependent analgesic and anti-inflammatory activities [5]. Many studies have been carried out on *A. africanus* to ascertain its medicinal potentials [6-11]. *Asparagus africanus* can be described as a perennial climbing vertical armed herb that can grow up to five feet tall or between 700 and 3800 m above sea level and it is widely distributed in tropical Africa at 1450m and 2900m altitude range. In Nigeria, it is traditionally called "Shekan bera" in Hausa language and "aluki" in Yoruba language. The objective of this study is to compare the vigor (weight) of harvested *Asparagus Africanus* for a period of four years at four different cutting dates.

MATERIALS AND METHODS

Most field (agronomic) experiments are large and the selection of an appropriate experimental unit may have some scope of resourcefulness. Division of the experimental materials into blocks in such a way that the plots within blocks are as homogeneous as possible, that is, block should remove as many trends in the material as possible is necessary [12]. In this research a 4^2 split-plot experiment with four blocks was designed to measure the vigor of *A. africanus*. The two factors considered in the experiment is plant year and harvested dates. Four different years (2018, 2019, 2020, and 2021) were considered as whole plot (WP) factor and the different cutting dates (1st June 15th June 1st July and 15th July) as subplot (SP) factor.

SPLIT-PLOT DESIGN MODEL

The split-plot design model (SPDM) is a linear additive superimposition of two different experimental design models and it is given below mathematically as follows:

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$$Y_{ijk}=\mu+\gamma_i+A_j+w_{ij}+B_k+(AB)_{jk}+\varepsilon_{ijk} \quad (1)$$

be the linear SPDM with two factors A and B where, Y_{ijk} is the response variable (measured vigor); i = 1, ..., s block; j = 1, ..., a levels of the *WP* factor A (Year); k = 1, ..., b levels of the *SP* factor B (Cutting dates); w_{ij} is the *WP* error, and ε_{ijk} is the *SP* error; and (AB) is the interaction between the *WP* and *SP* factors (Year × Cutting dates). The parameters block, A and B are assumed fixed. Also, the *WP* error and *SP* error are independent identically distributed normal random effects, that is, $w_{ij} \sim^{i.i.d} N(0,\sigma^2_{wp})$ and $\varepsilon_{ijk} \sim^{i.i.d} N(0,\sigma^2_{sp})$. A detailed theory of the SPDM with intrinsically linearity and nonlinearity in parameters can be found in [12-18].

EFFICIENCY AND CONTROL OF THE SPDM FOR *A. AFRICANUS*

Experimenters utilize the SPDM for certain specific reasons like applying one factor to the large area due to lack of optimal control of the experimental factor in smaller area or the inability to randomize one of the factors appropriately in smaller units or plots. Therefore, it is imperative to evaluate the relative efficiency of the SPDM to sub models like the randomized complete block design (RCBD) to ascertain the design gain efficiency. This is done to determine how much information have been gained or lost for all treatment comparisons. The efficiency statistic in [19] is given below as

$$Ef = \frac{(a-1)MS_{w_{ij}}+a(b-1)MS_{\varepsilon_{ijk}}}{ab-1} \quad (2)$$

where, *Ef* is the weighted average of whole plot and subplot mean square errors, $MS_{w_{ijk}}$ is the mean square *WP* error, $MS_{\varepsilon_{ijk}}$ is the mean square *SP* error, a and b are the levels of the WP and SP factors respectively. The information on *WP* treatments from the split-plot experiment relative to RCBD is then $EF/MS_{w_{ij}}$ and it is expected to be less than one. For SP factor and interaction effect from the split-plot experiment relative to RCBD is $EF/MS_{\varepsilon_{ijk}}$ and it is expected to be greater than one. To determine how well the experiment was controlled and managed, the coefficient of variation (CVS) statistic is used, and a value less than 30 is expected from the experiment. The CVS is given as follows.

$$CVS = \frac{\sqrt{MSE}}{GM} \times 100\% \quad (3)$$

where, MSE is the mean square error of the SPDM, and GM is the grand mean from the data.

MEAN *A. AFRICANUS* VIGOR COMPARISON TEST

In this research, the least significant difference (LSD) mean comparison test is applied. However, it is valid if and only if the experimental factors are significant. Suppose following the analysis of variance test and there is a significant effect, it is worth to determine how large the mean vigor of *A. africanus* is at different years, cutting dates and years by cutting dates interaction. Each pair of mean *A. africanus* vigor difference is compared to the corresponding LSD value. The test is given as follows.

H_0: $\mu i = \mu j$ for all $i \neq j$ then reject H_0 if

$$\left|\overline{Y}_{i.} - \overline{Y}_{j.}\right| > (\text{LSD} = t_{(\alpha/2),dfE} \times \text{SED}), \quad (4)$$

where, t is the t-test table value at 5% α significance level, *dfE* is the degree of freedom for error, and SED is the standard error of difference. The SED for the SPDM is given for the WP factor, SP factor and interaction effect as follows.

$$\left.\begin{aligned} SED_A &= \sqrt{\frac{2MSE}{sa}} \\ SED_B &= \sqrt{\frac{2MSE}{sb}} \\ SED_{AB} &= \sqrt{\frac{2MSE}{s}} \end{aligned}\right\} \text{for s, a, and b are as defined in (1). (5)}$$

RESULTS AND DISCUSSION

Table 1: A. *africanus* SPDM ANOVA table.

Source of Variation	DF	Sum of Squares	Mean Square	F-Value	*P*-Value
Blocks	3	30611.05	10203.68	18.04	0.0004
Year (A)	3	519849.55	173283.18	306.29	0.0001
WP error	9	5091.77	565.75		
Cutting Date (B)	3	241570.55	80523.52	81.86	0.0001
A*B	9	48238.02	5359.78	5.45	0.0002
SP error	36	35412.69	983.69		
Total	63	880773.61			
CV_{WP} = 8.19% CV_{SP} = 10.79% *Ef* = 900.102 EF/MS_{wij} = 1.591 EF/MS_{eijk} = 0.915					

The SPDM analysis was performed using SAS 9.4 and MSTATC for the mean comparison analysis. (Table 1) shows the analysis of variance table (ANOVA) for the SPDM with the CVS values. The results indicate that the *WP* factor, year (*A*), SP factor, cutting dates (*B*), and the interaction effect (*A* × *B*) are all significant at 5%. Also, the CVS values obtained for the *WP* and *SP* experimental units indicates that the experiment was well managed and controlled because both values of 8.19% and 10.79% are less than 30%. However, the efficiency statistic (*Ef*) values of 1.591 and 0.915 for the *WP* and *SP* respectively shows that the experiment is not efficient since the *Ef* value for the *WP* is greater than one and less than one for the *SP*. In line with the results obtained it can be said that there is significant difference Among *A. africancus* vigor (weight) in the four different years and at four different cutting

dates. Likewise, there is a significant effect of years by cutting dates on the vigor of *A. africanus*. This result surely supports a post-hoc analysis to determine which year and cutting dates have the largest mean vigor of *A. africanus*. (Table 2,3) presents the mean comparison results and Figure 1 shows the *A. africanus* vigor mean interaction plot.

Table 2: LSD mean rank grouping for year and cutting dates.

Year	Mean Rank	Cutting Dates	Mean Rank 2
2018	179.13^{d}	1st June	356.6^{a}
2019	299.44^{b}	15th June	323.1^{ab}
2020	427.69^{a}	1st July	290.4^{b}
2021	256.06^{c}	15th July	192.2^{c}

Table 3: LSD mean rank grouping for interaction effect.

Cutting Dates	Year			
	2018	2019	2020	2021
1st June	216.25^{ef}	340^{cd}	499^{a}	371.25^{c}
15th June	175.75^{fg}	331.25^{cd}	484.75^{a}	300.5^{d}
1st July	187.25^{efg}	310.25^{d}	433^{b}	231.25^{e}
15th July	137.25^{gh}	216.25^{ef}	294^{d}	121.25^{h}

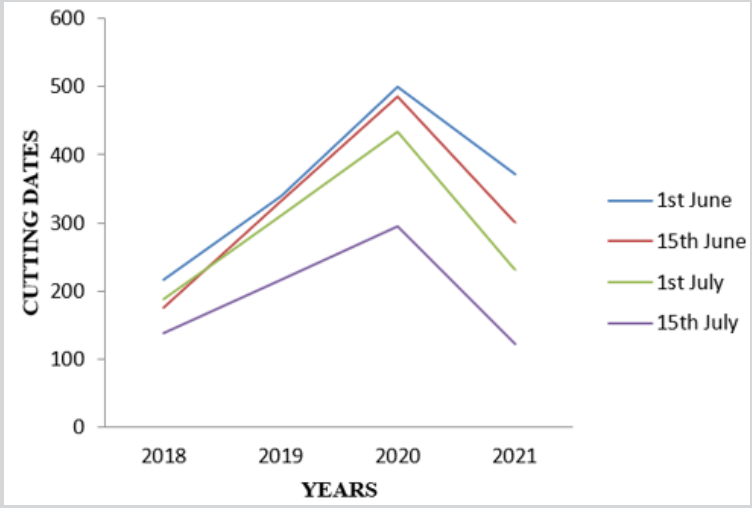

Figure 1: Mean interaction plot for *A. africanus* vigor.

The mean interaction plot in Figure 1 clearly shows that there exists an interaction effect between cutting dates and the four different planting years of *A. africanus* vigor.

Table 2 shows that *A. africanus* mean vigor from year 2020 has a significant larger mean than the means from year 2018, 2019, and 2021, therefore year 2020 has the maximum yield vigor of *A. africanus*. However, for cutting dates, Table 2 shows that 1st June has the largest mean vigor of *A. africanus* but its mean is not significantly larger than *A. africanus* mean vigor at 15th June but the mean vigor at the cutting date of 15th June is not significantly larger than the mean vigor of *A. africanus* at 1st July while the mean vigor of *A. africanus* at the cutting date of 15th July has the lowest mean compared to all other cutting dates.

Table 3 shows that at 1st and 15th June of year 2020 produced the largest means vigor of *A. africanus* of 499 and 484.75 respectively. These two means are not significantly larger than each other (both ranked a) but the two-mean vigor of *A. africanus* at 1st and 15th June cutting dates at year 2020 are significantly larger than all other mean vigor of *A. africanus*. 15th July cutting date for year 2021 has the lowest mean vigor but not significantly different from the mean vigor at year 2018. Hence, it can be concluded that 1st and 15th June cutting dates at year 2020 produced the maximum mean vigor of *A. africanus*.

CONCLUSION

In this research four different year effect and four different cutting dates effect on *Asparagus africanus* from a split-plot experiment was studied. It was found that both the WP and SP factors were significant to *A. africanus* vigor and as well the interaction effect between the plant year and cutting dates. The experiment for measuring the *A. africanus* vigor was found to be well managed and

controlled based on the results from the coefficient of variation but the SPDM for the experiment was found not to be efficient based on the efficiency statistic results. Also, the mean vigor analysis using LSD clearly shows that *A. africanus* planted in 2021 had the highest mean vigor while on 1st June and 15th June cutting dates produced *A. africanus* with the largest mean vigor compared to 1st and 15th July cutting dates.

AUTHORS CONTRIBUTION

Both authors contributed equally towards the drafting of the topic, analysis of the data, and the writing of the manuscript.

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