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Investigating the Effects of Multiple Factors on Sesame Yield Using Strip Split Plot Experiment

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Abstract: *The basic problem of farming is on how to improve crop production to obtain higher yields. To achieve this, commensurate nitrogen quantity and quality needs to be applied to the farmland. In this study, the effects of multiple factors namely variety, Nitrogen sources and Nitrogen levels were investigated on the yield of sesame crop in the Department of Plant Breeding and Seed Science, Joseph Sarwuan Tarka University Makurdi Benue State from August to November 2020. A Strip Split plot design was implemented as the experimental layout. Two varieties namely White and Golden sesame, three Nitrogen sources namely Cow Dung, Poultry Dung and Urea and four Nitrogen level at 12, 24, 36 and 48 were applied during the period. Analysis of Variance (ANOVA), Estimated Marginal Means and POST-HOC were performed using SPSS 25 version. The result of this study showed that Nitrogen level, Nitrogen sources and their interactions were significant at 0.000, 0.044, 0.020 and 0.023 at 5% level of significance. The study also showed an average yield of 588.534 ± 13.40Kg/ha of sesame yield. Nitrogen level showed the highest average yield of 742.226 ± 8.077 Kg/ha at level 36 while Nitrogen sources yielded 605.975 ± 6.95 Kg/ha as the highest yield when UREA was applied for cultivation. The interaction of Nitrogen level and Nitrogen sources was 774.067 ± 13.98 Kg/ha as the highest yield when UREA was applied at 36kg. The impressive Sesame yields recorded from the Strip Split plot experimental layout showed that the application of UREA at 36kg provided highest yield than other nitrogen sources. Sustaining this nitrogen sources and level would have significant yield impact on Sesame yield. Farmers are advised to use UREA at 36kg for optimum yield in sesame production.*
Keywords: Strip-split, ANOVA, design of experiments

INTRODUCTION

Experimental design is a crucial research methodology used across various scientific disciplines to investigate cause-and-effect relationships between variables. It involves systematic planning, designing, and conducting experiments to test hypotheses, evaluate treatments, and make statistical inferences. By carefully controlling variables and minimizing bias, experimental design enhances the validity and reliability of study results, providing a structured framework for researchers to manipulate independent variables, measure dependent variables, and control extraneous factors (Gomez and Gomez 2015). The use of randomization, replication, and control groups in experimental design further aids in establishing causal relationships and drawing valid conclusions (Kirk, 2013). The most unusual and underutilized design in experimental design is the strip plot design. But when the researcher or experimenter has to do specific tests, using strip plot design becomes essential (Kutsanedzie et al., 2015). The Strip-Split Plot design's ability to examine factor interactions is one of its main advantages.

When the amount of one factor affects the influence of another on a response variable, this is known as an interaction. For example, a crop variety's reaction to a given fertilizer dosage may differ based on the irrigation technique employed. Comprehending these interplays is vital in formulating integrated management approaches that maximize productivity, efficacious utilization of resources, and possibly ecological consequences (Gomez and Gomez, 2015).

In the era of increasing human population and the need for food security, there is a need for increased productivity of crops. Sesame is an important seed crop with high nutritional value, providing a source of diversification in diet and enhancing food access. Moreover, its production provides income generation and helps to improve the health of the soil to investigate the Nitrogen levels, Variety, and Nitrogen sources of sesame. Although there are several statistical experimental designs, the strip-split plot design measures accuracy as it enables the efficient use of resources, accommodating multiple factors, and improving accuracy. Importantly, it regulates the experimental area into strips and subplots, thereby reducing experimental errors among others.

The aim of this research work is to investigate the effects of multiple factors on the yield of sesame crop using the strip-split plot experiment with an objective to investigate the significance of the treatment effects and the interaction, by defining the factors and levels to be studied, determining the number of whole plots, sub-plots, and specifying the treatment combinations for each factor. The data consists of 96 values of Yields (Kg/Ha) of Sesame for three factors namely Nitrogen Sources with four levels (level 12, level 24, level 36, and level 48), two Varieties (Variety 1 and Variety 2), and three Nitrogen Sources (Poultry Dung, Cow Dung, and Urea) which were replicated four times during the experiment. A secondary experimental data was collected from the Department of Plant Breeding and Seed Science, Joseph Sarwuan Tarka University Makurdi, Benue State. Therefore, a 423*4 strip plot design approach was used in obtaining the data, while SPSS software version 25 was used for the analysis.

LITERATURE

Karki et al. (2017) determined how tillage, residue, and nutrient management techniques affect the characteristics of the soil and the yield of rice grains. A field experiment was carried out in Rampur, Nepal where three factors were considered namely tillage (with or without), residue (with or without), and nutrient management were each categorized into two levels: farmers doses (FD) at 5 Mt ha of FYM+50:23:0 NPK kg ha and recommended dose (RD) at 100:60:30 NPK kg ha. However, three replications of a strip-split plot design were used to test eight treatments, comprising two levels of tillage (Conventional Tillage, or CT) and No Tillage (NT), two levels of residue management (Residue Kept, or RK), two levels of nutrient management (Farmer's Dose of fertilizer, or FD), and two levels of Residue Management (RD and RR). In comparison to the residue removal plots, the residue retained plots had higher soil organic matter (5.73%). In comparison to conventional tillage (76.77 kg ha), exchangeable potassium was found to be higher in no-till areas (110.52 kg ha). There were more efficient tillers in the no-till area; residue was retained, and required fertilizer dosages were followed. Compared to conventional tillage plots with 2.28 Mt and residue removed, yielding 2.22 Mt ha, grain yield was considerably greater in no-till plots with 3.66 Mt and residue kept at 3.72 Mt ha. RD yielded 4.53 Mt ha, a substantially larger grain yield than FD, which generated 1.41 Mt ha. ANOVA was performed on all the data using the MSTATC statistical software and the results of this study showed that suggested fertilizer dosages and no-till, residue-keeping methods were more effective than other studied treatments at enhancing soil characteristics and rice yield. As a result, it is advised that farmers use conservation agriculture to ensure profitable and sustainable farming throughout the nation. Optimizing nitrogen management goes beyond simply determining the ideal application rate. Some additional practices that play a crucial role include Split application, Controlled-Release Fertilizers, and Soil Testing. Split application involves applying nitrogen fertilizer in multiple installments throughout the growing season instead of a single large dose. This approach helps match nitrogen availability with crop demand, preventing excessive leaching or volatilization losses (Liu et al., 2019). Controlled-Release Fertilizers are designed to release nitrogen gradually over time, minimizing the risk of nutrient loss and optimizing Nitrogen Use Efficiency (NUE) (Chen et al., 2018). Regularly testing soil nitrogen levels allows for informed fertilizer application decisions. By understanding the existing soil nitrogen content, farmers can avoid over-application and tailor nitrogen inputs to meet the specific needs of the crop and soil conditions. By implementing these diverse nitrogen management practices in conjunction with strip-split plot designs, researchers can conduct more robust experiments that not only investigate the impact of nitrogen application rates but also explore how different management strategies interact with crop varieties and environmental factors to influence yield and NUE. This can be calculated by dividing grain yield by the total amount of Nitrogen available to the crop. Experimental design is a fundamental aspect of scientific research that involves the systematic planning, structuring, and implementation of experiments to test hypotheses. The objective is to obtain reliable and valid results that can be used to make sound scientific conclusions. Controlled experiments are essential tools for isolating and analyzing the effects of specific factors on yield. By systematically varying one or more factors while keeping others constant, researchers can determine their individual and interactive effects on crop yield. This scientific approach allows for a better understanding of the underlying mechanisms and helps in developing effective strategies for yield optimization. The key principles of experimental design which are randomization, replication, and control are integral to achieving these objectives (Zubair, 2023).

The split-plot design emerged as an advancement to address specific issues in agricultural experiments where complete randomization was impractical. Introduced in the 1920s and 1930s, the split-plot design allowed for the application of treatments to larger main plots, with sub-treatments applied within these plots. This design provided a way to manage treatments that required different plot sizes or those that were difficult to change frequently, such as irrigation levels or crop varieties (Fisher, 1935; Yates, 1937).The strip-plot design evolved as a refinement of the split-plot design to handle experiments with more complex treatment structures and spatial variability. Unlike the split-plot design, where sub-treatments are nested within main plots, strip-plot designs allocate one factor to strips that run across the entire experimental field. This design allows for the study of interactions between multiple factors by intersecting strips, each representing different levels of the factors under investigation (Gomez and Gomez, 2015).Early applications of strip-plot design in agricultural research demonstrated its effectiveness in studying interactions between multiple treatments and their impact on crop yield. Researchers utilized this design to explore a range of agricultural variables, including fertilizer application rates, irrigation methods, and crop varieties. The ability to control for spatial variability and examine interaction effects made the strip-plot design particularly valuable in agricultural experiments, where environmental factors can vary significantly across the experimental area (Gomez and Gomez, 1984).

In recent years, the strip-plot design has continued to be a valuable tool in agricultural research. Studies have applied this design to investigate a wide range of factors affecting crop yield, including soil amendments, pest control methods, and climate change adaptation strategies. The flexibility and robustness of the strip-plot design make it well-suited for modern agricultural research, where multiple interacting factors need to be studied simultaneously (Montgomery, 2017).

METHODOLOGY

Methods of Data Analysis

Model Specification

The model summary breakdown of the components in a strip-split plot design adapted from (Gomez and Gomez., 1983) is given below.

$$Y_{hijk} = \mu + R_h + N_i + e_{N_i} + V_j + e_{v_{hj}} + NV_{ij} + e_{NV_{hij}} + S_k + NS_{ik} + VS_{jk} + NVS_{ijk} + e_t$$
(1)

ANOVA

Table 1: Analysis of variance

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F
Replicates (r)	$r-1$	SSR	MSR	
Nitrogen Levels (n)	$n-1$	SSN	MSN	$\frac{MSN}{(n-1)}$
Error Nitrogen	$(r-1)(n-1)$	SSE_N	MSE_N	
Variety(v)	$v-1$	SSV	MSV	$\frac{MSV}{(v-1)}$
Error Variety	$(r-1)(n-1)$	SSE_V	MSE_V	
Nitrogen and Variety(nv)	$(n-1)(v-1)$	SS_{NV}	MS_{NV}	$\frac{MS_{NV}}{(n-1)(v-1)}$
Error Sources(s)	$(n-1)(v-1)(r-1)$	SSE_S	MSE_S	

Sources	$(s-1)$	SSS	MSS	$\frac{MSS}{(s-1)}$
Nitrogen versus Sources	$(n-1)(v-1)(r-1)$	SS_{NS}	MS_{NS}	$\frac{MS_{NS}}{(n-1)(v-1)(r-1)}$
Variety versus Sources	$(n-1)(v-1)(r-1)$	SS_{VS}	MS_{VS}	$\frac{MS_{VS}}{(n-1)(v-1)(r-1)}$
Nitrogen versus Variety versus Sources	$(n-1)(v-1)(r-1)$	SS_{NVS}	MS_{NVS}	$\frac{MS_{NVS}}{(n-1)(v-1)(r-1)}$
Total Error (e_t)		SSE_T	MSE_T	

Coefficient of Variation

The coefficient of variation can be utilized in several frameworks for both distribution comparison and single sample analysis (Santos and Dias, 2021).

$$CV = \frac{s}{\bar{y}} \tag{2}$$

Where $\bar{x}$ is mean and s is standard deviation of the observations

$$\bar{y} = \frac{1}{n}\sum_{s=1}^{n} y_s \tag{3}$$

$$s = \sqrt{\frac{1}{n}\sum_{s}^{n}(y_s - \bar{y})^2} \tag{4}$$

Duncan's Multiple Range Test (DMRT)

The DMRT is given by the formula below:

$$D = q_{\alpha,r,N-k}\sqrt{\frac{MSE}{n}} \tag{5}$$

RESULTS AND DISCUSSION

Table 2: Between-Subjects Factors in the Experiment

		Value Label	N
Nitrogen Level	12	12	24
	24	24	24
	36	36	24
	48	48	24
Sesame Variety	1	White Sesame	48
	2	Golden Sesame	48
Nitrogen Sources	1	Cow Dung	32

	2	Poultry Dung	32
	3	Urea	32
Replication	101	101	24
	202	202	24
	303	303	24
	404	404	24

Table 3: Estimated Marginal Means for Nitrogen Level * Sesame Variety

				95% Confidence Interval	
Nitrogen Level	**Sesame Variety**	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
12	White Sesame	399.798	11.422	377.029	422.568
	Golden Sesame	403.825	11.422	381.055	426.595
24	White Sesame	556.069	11.422	533.299	578.838
	Golden Sesame	597.256	11.422	574.486	620.025
36	White Sesame	741.729	11.422	718.959	764.498
	Golden Sesame	742.724	11.422	719.955	765.494
48	White Sesame	632.176	11.422	609.406	654.945
	Golden Sesame	634.709	11.422	611.940	657.479

Table 4: Estimated Marginal Means for Nitrogen Level * Nitrogen Sources

				95% Confidence Interval	
Nitrogen Level	**Nitrogen Sources**	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
12	Cow Dung	380.260	13.989	352.373	408.147
	Poultry Dung	381.796	13.989	353.909	409.683
	Urea	443.379	13.989	415.492	471.266
24	Cow Dung	584.285	13.989	556.398	612.172
	Poultry Dung	569.281	13.989	541.394	597.167
	Urea	576.421	13.989	548.534	604.308
36	Cow Dung	722.217	13.989	694.330	750.104
	Poultry Dung	730.396	13.989	702.509	758.283
	Urea	774.067	13.989	746.180	801.953
48	Cow Dung	630.033	13.989	602.147	657.920
	Poultry Dung	640.261	13.989	612.374	668.148
	Urea	630.033	13.989	602.147	657.920

Table 5: Estimated Marginal Means for Sesame Variety * Nitrogen Sources

				95% Confidence Interval	
Sesame Variety	**Nitrogen Sources**	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
White Sesame	Cow Dung	565.809[a]	9.678	546.512	585.106
	Poultry Dung	571.874[a]	9.678	552.577	591.172
	Urea	609.645[a]	9.678	590.348	628.942
Gold Sesame	Cow Dung	592.588[a]	9.678	573.291	611.885
	Poultry Dung	588.992[a]	9.678	569.695	608.289
	Urea	602.305[a]	9.678	583.008	621.602

Table 6: ANOVA for the factors and interactions

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Rep	Hypothesis	16965.984	3	5655.328	1.336	.386	.514
	Error	16043.817	3.790	4233.209			
Nlevel	Hypothesis	1455648.639	3	485216.213	261.495	.000	.989
	Error	16699.901	9	1855.545			
nlevel * rep	Hypothesis	16699.901	9	1855.545	1.556	.154	.215
	Error	60804.779	51	1192.251			
Nsource	Hypothesis	14584.396	2	7292.198	5.512	.044	.648
	Error	7938.415	6	1323.069			
nsource * rep	Hypothesis	7938.415	6	1323.069	1.110	.370	.115
	Error	60804.779	51	1192.251			
nsource * nlevel	Hypothesis	20037.786	6	3339.631	2.801	.020	.248
	Error	60804.779	51	1192.251			
Variety	Hypothesis	3588.038	1	3588.038	1.043	.382	.258
	Error	10317.290	3	3439.097			
variety * rep	Hypothesis	10317.290	3	3439.097	2.885	.045	.145
	Error	60804.779	51	1192.251			
variety * nlevel	Hypothesis	6736.604	3	2245.535	1.883	.144	.100
	Error	60804.779	51	1192.251			
variety * nsource	Hypothesis	4978.119	2	2489.059	2.088	.134	.076
	Error	60804.779	51	1192.251			
variety * nsource * nlevel	Hypothesis	19388.619	6	3231.437	2.710	.023	.242
	Error	60804.779	51	1192.251			

Table 7: DUNCAN Multiple Range Test (DMRT) for Nitrogen Sources

nsource	N	Subset 1	Subset 2
1.00	32	579.2616	
2.00	32	580.4334	
3.00	32		605.9744
Sig.		.893	1.000

The error term is Mean Square (Error) = 1192.251.

Table 8: DUNCAN Multiple Range Test (DMRT)for Nitrogen Levels

nlevel	N	Subset 1	2	3	4
12.00	24	401.8112			
24.00	24		576.6621		
48.00	24			633.5258	
36.00	24				742.2267
Sig.		1.000	1.000	1.000	1.000

The error term is Mean Square (Error) = 1192.251.

SUMMARY OF DISCUSSION

The result of this study showed that Nitrogen level, Nitrogen sources and their interactions were significant at 0.000, 0.044, 0.020 and 0.023 at 5% level of significance. The study also showed an average yield of 588.534 ± 13.40Kg/ha of sesame yield. Nitrogen level showed the highest average yield of 742.226 ± 8.077 Kg/ha at level 36 while Nitrogen sources yielded 605.975 ± 6.95 Kg/ha as the highest yield when UREA was applied for cultivation. The interaction of Nitrogen level and Nitrogen sources was 774.067 ± 13.98 Kg/ha as the highest yield when UREA was applied at 36kg. The impressive Sesame yields recorded from the Strip Split plot experimental layout showed that the application of UREA at 36kg provided highest yield than other nitrogen sources. Sustaining this nitrogen sources and level would have significant yield impact on Sesame yield. Farmers are advised to use UREA at 36kg for optimum yield in sesame production.

CONCLUSION

The study found the following: i. Generally, an average of 588.53 ± 13.40Kg of sesame yield per hectare. ii. An estimated marginal means of Nitrogen level showed that the highest average yield of 742.226 ± 8.077Kg/ha is attributed to Nitrogen level 36. iii. As Nitrogen level increases the yields also increase but attain maximum at level 36 and thereafter decline in further increase in Nitrogen level. iv. The estimated marginal means for sesame variety showed that the golden sesame produced the highest mean yield of 594.628 ± 5.711Kg/ha. v. The estimated marginal mean yield for Nitrogen sources showed that the application of UREA produced the highest average yield per hectare of 605.975 ± 6.995. vi. The interaction of Nitrogen Level and Sesame variety showed that the higher average yield of 742.724 ± 11.422 Kg/ha is attributed to Nitrogen level 36 and golden sesame. vii. The interaction Nitrogen Level and Nitrogen sources revealed that the highest average yield of 774.067 ± 13.989 Kg/ha is attributed to UREA at level 36. According to the Duncan post-hoc test, the nitrogen levels differ significantly from one another. There are notable differences in yield outcomes between each nitrogen level (12.00, 24.00, 48.00, and 36.00), with level 36.00 yielding the highest. Although there might be slight numerical variations in yield between the nitrogen sources, the Duncan post-hoc test reveals that these variations are not statistically significant at the 0.05 level.

Further research could focus on the impact of atmospheric conditions on the yield of sesame crop and also practicing irrigation to check for better yield. Another promising area for future research is the use of higher frequency data, such as weekly or daily observations, to capture more immediate effects on the yield of sesame crop.

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