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A Study of the Effect of Site, Variety and Fertilizer Application on Growth and Yield Component of Rice: Using Univariate Analysis of Variance (Anova) Techniques

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Abstract

This study evaluates the separate effects of site, variety, and fertilizer application on three key rice performance indicators plant height, tiller height, and grain yield using univariate analysis of variance (ANOVA). A field experiment was conducted across three sites in National Cereals Research Institute Baddegi Niger state, Nigeria, using four rice varieties and three fertilizer treatments. Data were analyzed using Type III ANOVA to isolate the main effects and interactions on each dependent variable. The results for plant heights, significant main effect were observed for site and variety, indicating that both environmental factors and genetic difference among rice varieties influence plant height. Additionally the interaction between site and variety was significant suggesting that the performance of rice varieties in terms of plant height was site dependent. However, fertilizer has no significant effect and no interactions between fertilizer and the other factors significantly influence plant height. Regarding tiller height, significant main effect were found for site and fertilizer, indicating that all three factors independently contribute to variations in the tiller height. The findings suggest that site and genetic factors predominantly influence vegetative growth, whereas yield outcomes may depend on more complex or longer-term factors. This study emphasizes the utility of univariate models for targeted agronomic trait analysis and field-level decision-making.

Key words: Title, Author, Abstract, Introduction.

Introduction

Modern crop productivity depends heavily on empirical evidence derived from field trials assessing the influence of various agronomic factors. Among the commonly analyzed parameters in rice cultivation are plant height, tiller number, and grain yield. While multivariate analyses allow for the simultaneous evaluation of these parameters, univariate ANOVA remains a powerful method for isolating and comparing the direct effects of each factor on individual traits.In Nigeria's quest for rice self-sufficiency, agronomic research must be fine-tuned to provide practical recommendations at the field level. This includes understanding which traits are most responsive to which factors and how specific management decisions affect rice performance. By disaggregating the statistical model and analyzing each dependent variable separately, researchers can offer clearer guidance to farmers and policymaker.

In most statistical experiments here we work on more than one dependent variables as these are often correlated with one another. In these situations, a single overall statistical test that assesses the effects of the independent variables on all of the response variables simultaneously is desired and univariate analysis of variance (ANOVA) test often mostly preferred to performing individuals (univariate) test. There is also a strong need to explore how the independent variables influence some patterning of response on the dependent variables. This can only be achieved by the use of univariate analysis of variance. This work therefore evaluates the effects of planting site, variety, and fertilizer on rice plant height, tiller height and yield using ANOVA technique. Priya and Singh (2024), who studied the market dynamics and potential for organic agriculture in the global South. Despite these valuable contributions, there remains a significant gap in the literature regarding comprehensive investigations into the economic incentives and government support systems, including certifications and subsidies, that are instrumental in scaling up organic agriculture within the global South. There is a noticeable gap in studies that have comprehensively explored if, and which economic incentives and government support systems, including certifications and subsidies, can be instrumental scaling up organic agriculture within the global South. Verburg *et al.* (2022) studied the case of organic dairy farming in the Netherland sand reported that government subsidies bolstered the economic feasibility of organic farming by offering financial support for organic certification fees, organic inputs, and infrastructure development. According to their findings, these subsidies reduce the financial barriers that farmers may face when considering expanding.

According to Zhou *et al.* (2022), organic fertilization practices can yield multiple benefits for rice crop production and soil quality. Such practices have enhanced soil fertility, structure, and nutrient availability while increasing the organic carbon content and providing a nutrient-rich food source for micro-organisms. Dollison (2023). Carried out analysis of inorganic and organic fertilizers application/hectare of rice production particular quantity unit cost, based on the results of the study, it can be

concluded that the growth performance tested was not significantly affected by the kind and amount of inorganic and organic fertilizer application. Furthermore, the kind and amount of inorganic and organic fertilizer application did not yield significant results in all observed yield characteristics. These findings suggest that the use of organic fertilizer, specifically vermicast or vermicompost, may be more economical than inorganic fertilizer for agricultural purposes.

Andriatmoko (2020) analyzed the effect of the use of organic rice and inorganic rice production factors in Sambirejo sub-district, Sragen Regency, analyzed the level of efficiency in organic and inorganic rice farming production and compared the level of production benefits between organic and paddy rice inorganic in the study area.

The results obtained in the study were the area of land, seeds, and fertilizer together had a positive effect on the amount of organic rice and inorganic rice production which significantly affected the production including the area of land and fertilizer

A study by Cheng *et al.* (2014) found that organic fertilizers significantly increased soil organic carbon, microbial biomass, and nutrient cycling in rice fields. The improvement in soil health was attributed to the slow release of nutrients and enhanced microbial activity, which supported long-term productivity. In a study by Kumar *et al.* (2015), organic fertilizer (compost) was found to increase rice yield by approximately 20% compared to the control group. However, the yield from organic fertilizers was lower than that from inorganic fertilizers, which showed a higher immediate impact on growth. Liu *et al.* (2017) conducted a study comparing organic and inorganic fertilizers and found that organic fertilizers had a significantly lower environmental impact, particularly in reducing nutrient leaching and greenhouse gas emissions. Organic fertilizers, such as compost and manure, promoted better soil structure and minimized the risk of water contamination compared to synthetic fertilizers. Sahoo *et al.* (2024) reported that while organic fertilizers led to lower immediate yields compared to inorganic fertilizers, they contributed to the sustainability of rice farming by improving long-term soil fertility and microbial activity.

Zhang *et al.* (2016) highlighted the long-term negative impacts of excessive inorganic fertilizer use on soil health. Their study found that over-reliance on inorganic fertilizers led to soil acidification, reduced microbial biodiversity, and an overall decline in soil organic matter. This can result in diminished soil fertility over time and increased vulnerability to soil erosion. Molla *et al.* (2015) investigated nutrient runoff and leaching from rice fields treated with inorganic fertilizers. Their findings showed that high application rates of nitrogen fertilizers led to significant nitrogen leaching into groundwater, contributing to water pollution and eutrophication. This study emphasized the environmental risks associated with the overuse of inorganic fertilizers.

Control groups in fertilizer experiments serve as the baseline, receiving no fertilizer or a placebo treatment. The purpose of including a control group is to determine how much fertilizer improves rice yield and growth compared to natural or unaltered conditions.

Yadav *et al.* (2019) was used to compare the effects of organic and inorganic fertilizers on soil health. Their study indicated that, without fertilizer application, soil nutrients such as nitrogen, phosphorus, and potassium were much lower than in treated plots. This demonstrated that the control group experienced nutrient depletion and showed less soil microbial activity. This approach offers a comprehensive analysis, revealing hidden interactions and providing empirical evidence for improved resource allocation in rice farming. The aim of these research is to asses the effect of planting site, variety and fertilizer on growth and yield component of rice and the objective of the research is to evaluate the effect of planting site, variety and fertilizer on rice plant height, tiller height, and grain yield using ANOVA technique

Impact of Fertilizer on Soil Microbial Diversity in Rice Fields

Soil microbial diversity plays a crucial role in nutrient cycling, organic matter decomposition, and disease suppression. Organic fertilizers, unlike synthetic ones, provide a rich supply of carbon and nutrients that stimulate microbial activity and diversity. Zhou et al. (2023) found that long-term application of compost and green manure significantly increased microbial biomass and diversity in paddy fields. "Organic amendments enriched soil microbial communities, especially beneficial bacteria like Pseudomonas and Actinobacteria, which enhance nutrient availability and plant health. "Increased microbial diversity not only improves soil structure and nutrient cycling but also fosters plant resilience against abiotic stress, contributing indirectly to improved rice yield.

Role of Organic Fertilizer in Rice Plant Nutrient

Organic fertilizers influence nutrient uptake dynamics by slowly releasing nutrients in sync with plant demand while improving root zone conditions. This gradual nutrient release minimizes leaching and promotes physiological efficiency in rice plants. Nguyen et al. (2022) demonstrated that rice plants grown with compost and vermicomposting had significantly higher chlorophyll content, root biomass, and spikelet fertility compared to control treatments. "Organic inputs enhanced plant physiological functions, particularly nitrogen uptake efficiency and photosynthetic rate, leading to increased grain filling and productivity. "This indicates that beyond soil health, organic fertilizers directly influence plant physiological responses that are critical for yield formation.

Effects of Organic Fertilizer on Greenhouse Gas Emissions in Paddy Fields

Paddy fields are major sources of methane emissions due to anaerobic decomposition. The use of organic matter in such environments can either increase or reduce greenhouse gas (GHG) emissions depending on decomposition pathways. Sun et al. (2021) found that while raw manure increased methane emissions, composted organic matter reduced it by promoting aerobic decomposition and reducing labile carbon availability. Composted organic fertilizers reduced methane emissions by 28% compared to raw manure, due to enhanced aerobic microbial activity and reduced methanogenesis. Thus, the type and treatment of organic

fertilizer significantly influence its environmental footprint, particularly in flooded rice systems.

Economic Viability of Organic Fertilizer Use in Smallholder Rice Farming

The cost-effectiveness of organic fertilizers is a vital consideration for smallholder farmers. While initial labor and input costs may be higher, long-term benefits such as improved soil health, reduced dependence on external inputs, and premium market prices for organic rice can offset these costs. Ali et al. (2024) conducted a cost-benefit analysis in Southeast Asia and found that integrated organic systems yielded a 15–20% higher net return over 5 years compared to conventional systems. "Though initial adoption costs were high, organic and integrated systems outperformed chemical-based systems in terms of net profit, particularly when premium organic rice prices were considered. The study suggests that with proper market access and government support, organic fertilizer use can be economically sustainable for smallholders.

Methodology

This chapter focusses on the source of data used and the methods used for the analysis. To assess the effects of site, variety, and fertilizer application on crop performance, a multivariate analysis of variance (MANOVA) was conducted. The following steps outline the methodology:

Experimental Location and Design

The research was conducted at the research unit of National Cereal Research Institute (NCRI) Badeggi, in Niger state during the 2022-2023 farming season. The experimental field was plowed with a chisel plow and basins were prepared. Each plot size was $16m^2$ and was separated from each other by 1m space. The soils at Badeggi site are sandy loam with bulk density of $1.489gm^3$. The relative humidity at dry and raining season ranges between 75 – 85%. Annual rainfall at the site ranges between 1,200 – 1,400mm and mean temperature of between 23^{0c} – $33^{0c.}$.These research was conducted in a Randomize Block Design with three replication and 36- level of rice, the plant height was measured in 4, 6, 8 and 10 weeks, and the tillering height was also measured at 4,6,8 and 10 weeks.

Variables and Treatments

Independent variables: Site: 3 agro-ecological zones,
Variety: FARO 49, FARO 55, FARO 57, NERICA 7,
Fertilizer: Inorganic (NPK), Organic (poultry manure), Control (no fertilizer).
Dependent variables (analyzed separately):
Plant Height (PH)
Tiller Height (TH)
Grain Yield (Y)

Data Collection

Growth parameters were measured at four different growth stages (4, 6, 8, and 10 weeks), while grain yield was collected post-harvest. Each measurement was averaged across 10 plants per plot.

Measurements were taken at 4, 6, 8, and 10 weeks for growth parameters. Grain yield was measured at harvest. Plant height and tiller height were averaged across ten plants per plot.

The data for this study was a secondary data obtain from an experiment conducted by the research unit of the National Cereal Research Institute badeggi in Niger state. Data on plant height is collected by measuring the distance from the base of the plant to the tip of the main head (panicle).Taking an average height of 10 plants. Data on growth parameters of rice were collected from Randomize complete block design (RCBD) with three replication. Several agronomic traits were measured for each treatment combination, including but not limited to: plant height, Tiller height, and final yield. The data was collected at various growth stages to capture the temporal variation in response to the treatments.

The measurements were recorded for each variety, at each site, and under each fertilizer treatment.

The following hypotheses are tested in this work.

H_{o1}: there is no significant effect of planting site on rice plant height, tiller height and grain yield.

H_{o2}: there is no significant effect of variety on rice plant height, tiller height and grain yield.

H_{o3}: there is no significant effect of fertilizer type on rice plant height, tiller height and grain yield.

H_{o4}: there is no significant effect of each of *site x variety*, *site x fertilizer type*, and *variety x fertilizer type* interactions on rice plant height, tiller height and grain yield.

H_{o5}: there is no significant effect of *site x variety x fertilizer type* interaction on rice plant height, tiller height and grain yield.

Statistical Analysis

Data were analyzed using one-way and factorial ANOVA in STATA. Each dependent variable was evaluated independently to detect significant differences attributable to main effects and interactions. The significance threshold was set at $\alpha = 0.05$. R^2 values and adjusted R^2 were reported to assess model fit.

The 3-way ANOVA model below is used to describe the collected data used in this work.

$$y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\beta\gamma)_{jk} + (\alpha\beta\gamma)_{ijk} + \epsilon_{ijkl} \qquad (2.1)$$

where

y_{ijkl} denotes the observed value of the response variable for ith level of site factor (factor A), jth level of variety factor (factor B), kth level of fertilizer factor (factor C) in the lth replicate.

μ is the overall mean.

α_i is the effect of the ith level of the site factor.
β_j is the effect of the jth level of the variety factor.
γ_k is the effect of the kth level of the fertilizer factor.
$(\alpha\beta)_{ij}, (\alpha\gamma)_{ik}, (\beta\gamma)_{jk}$ and $(\alpha\beta\gamma)_{ijk}$ are the respective interaction terms.
ϵ_{ijkl} is the random error term.

Results

From the univariate ANOVA (Table 3.2a and 3.2b):

Table 3.2a: Tests of between subject effects

Source	Dep Var	Type III Sum of Squares	df	Means Square	F	Sig.
Corrected Model						
	Plant ht	22014.496[a]	35	628.986	2.544	0.000
	Tiller ht	2001.373[b]	35	57.182	4.124	0.000
	Grain yld	79.533[c]	35	2.272	1.178	0.275
Intercept						
	Plant ht	810462	1	810461.768	3278.216	0.000
	Tiller ht	30852.6	1	30852.64	2224.891	0.000
	Grain yld	2106.49	1	2106.494	1092.28	0.0000
Site						
	Plant ht	1964.77	2	982.387	3.974	0.023
	Tiller ht	804.351	2	402.176	29.002	0.0000
	Grain yld	8.797	2	4.398	2.281	0.11
Variety						
	Plant ht	11092.7	3	3697.574	14.956	0.0000
	Tiller ht	435.609	3	145.203	10.471	0.0000
	Grain yld	10.566	3	3.522	1.826	0.15
Fertilizer						
	Plant ht	388.844	2	194.422	0.786	0.459
	Tiller ht	232.151	2	116.076	8.371	0.001
	Grain yld	0.126	2	0.063	0.033	0.968
Site*fertilizer						
	Plant ht	631.827	4	157.957	0.639	0.636
	Tiller ht	8.83	4	2.208	0.159	0.958
	Grain yld	4.999	4	1.25	0.648	0.63

Table 3.2b: Tests of between subject effects

Source	Dep Var	Type III Sum of Squares	df	Means Square	F	Sig.
Variety*fertilizer						
	Plant ht	721.477	6	120.246	0.486	0.816
	Tiller ht	89.879	6	14.98	1.08	0.382
	Grain yld	25.626	6	4.271	2.215	0.051
Site*variety						
	Plant ht	6399.13	6	1066.521	4.314	0.001
	Tiller ht	146.224	6	24.371	1.757	0.12
	Grain yld	15.027	6	2.504	1.299	0.269
Site*variety*fertilizer						
	Plant ht	815.724	12	67.977	0.275	0.991
	Tiller ht	284.328	12	23.694	1.709	0.083
	Grain yld	14.392	12	1.199	0.622	0.817

Source	Dep Var	Type III Sum of Squares	df	Means Square	F	Sig.
Error						
	Plant ht	17800.3	72	247.227		
	Tiller ht	998.427	72	13.867		
	Grain yld	138.854	72	1.929		
Total						
	Plant ht	850277	108			
	Tiller ht	33852.4	108			
	Grain yld	2324.88	108			
Corrected Total						
	Plant ht	39814.8	107			
	Tiller ht	2999.8	107			
	Grain yld	218.387	107			

a. R Squared = .553 (Adjusted R Squared = .336)
b. R Square = .667 (Adjusted R Squared = .505)
c. R Square = .364 (Adjusted R Squared = .055)

Plant Height:
Site: Significant ($F = 3.974$, $p = 0.023$)
Variety: Highly significant ($F = 14.956$, $p < 0.001$)
Fertilizer: Not significant ($p = 0.459$)
Tiller Height:
All main effects significant: Site ($p < 0.001$), Variety ($p < 0.001$), Fertilizer ($p = 0.001$)
Grain Yield:
No main effect significant (Site: $p = 0.11$; Variety: $p = 0.15$; Fertilizer: $p = 0.968$)
Variety × Fertilizer interaction: borderline ($p = 0.051$)

Discussion

The Univariate Analysis of Variance (ANOVA) was conducted to assess the impact of Site, Variety, and Fertilizer application, along with their interactions, on the growth and yield components of rice—specifically, Plant Height, Tiller Height, and Grain Yield. For plant height, significant main effects were observed for Site ($F = 3.974$, $p = 0.023$) and Variety ($F = 14.956$, $p < 0.001$), indicating that both environmental factors and genetic differences among rice varieties influenced plant height. Additionally, the interaction between Site and Variety was significant ($F = 4.314$, $p = 0.001$), suggesting that the performance of rice varieties in terms of plant height was site-dependent. However, Fertilizer had no significant effect ($p = 0.459$), and no interactions between Fertilizer and the other factors significantly influenced plant height ($p > 0.05$). Regarding tiller height, significant main effects were found for Site ($F = 29.002$, $p < 0.001$), Variety ($F = 10.471$, $p < 0.001$), and Fertilizer ($F = 8.371$, $p = 0.001$), indicating that all three factors independently contributed to variations in tiller height. However, none of the interaction effects were significant ($p > 0.05$), suggesting that the factors influenced tiller height independently. For grain yield, no significant main effects were found for Site ($p = 0.110$), Variety ($p = 0.150$), or Fertilizer ($p = 0.968$), and most interaction effects

were also not significant ($p > 0.05$). Nevertheless, the interaction between Variety and Fertilizer approached significance ($F = 2.215$, $p = 0.051$), indicating a possible trend where the effect of fertilizer application on grain yield might vary by rice variety. Although not significant at the 5% level, this interaction warrants further investigation in future studies. Most existing studies have employed univariate methods, focusing on one response variable at a time, which may overlook the complex interrelationships among variables such as plant height, tiller number, and grain yield. Furthermore, the influence of site-specific conditions and varietal responses under different fertilizer regimes remains underexplored in a multivariate context.These observations echo the findings of Hasanuzzaman et al. (2010) and Molla et al. (2015), who also noted that yield determinants are not solely dependent on vegetative vigor.

Conclusion

The univariate ANOVA results demonstrated that plant and tiller height are strongly influenced by site and variety, while grain yield was not significantly affected by any individual factor. The findings indicate that although fertilizer improved tiller height, it did not translate into increased yield under the study conditions. These results highlight the need for a more nuanced understanding of the physiological and environmental factors that drive yield formation beyond vegetative performance.

Recommendations

Farmers should focus on selecting appropriate rice varieties for their specific agro-ecological zones, especially where vegetative vigor is a concern.

Fertilizer management practices should be linked to reproductive-phase requirements, not just vegetative growth.

Yield improvement strategies should integrate non-agronomic factors such as water availability, pest control, and planting date.

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