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Predictive Analysis of the Effect of Tillage System on the Growth and Yield of Rice Plant under Lowland Plantation

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Abstract: Empirical data and analysis of the effect of tillage techniques on the growth and yield of three varieties of rice under lowland farming were undertaken. Soil samples were taken up to a depth of 21 cm to obtain the soil characteristics and textural classification of the experimental site. The experimental data obtained were based on three varieties of rice namely FARO 52, FARO 44 and local rice type under three field preparation methods-no tillage flat field (A), tillage with shanti hydropower power tiller (China technology Model DF-121) (B) and tillage with Sawah eco-technology rice farming (serif) (Indonesian technology Quick G1000 Boxer) (C)). Requisite data gathered during the rice developmental stages such as days to flowering, days to maturity, number of tillers, panicle length, plant height and grain yield were statistically analysed to obtain predictive equations of the effect of the tillage techniques on the growth and yield of the rice varieties investigated. The soil analysis of the experimental site showed a sandy loam using USDA textural classification and the predictive results obtained showed a linear relationship between the investigated parameters. The research outcome can be a viable tool for future prediction of the effect of tillage techniques on the agronomic and yield characteristics of rice under lowland plantation.

Key words: Rice variety, lowland plantation, tillage techniques, developmental characteristics, predictive tools, sandy loam

INTRODUCTION

Rice (*Oriza sativa L.*) is a monocotyledonous cereal crop belonging to the Gramineae group (Ajala and Gana, 2015). Rice is a staple food crop with wide acceptability in Nigeria and many other parts of the world because of the importance attached to it both at the family cycle and social events. The demands for it have been on the increase over the year with demand exceeding the current local production in Nigeria. Importation mostly from Asia of the deficit has been undertaken in order to meet the demand of this essential food materials by the teeming population (Olaye *et al*., 2016; Merem *et al*., 2017). Analysis of the nutritive properties of rice revealed a rich food substance constituting about 23% of human per capita energy and 16% of per capita protein (Kemi, 2018). The government of Nigeria has made significant efforts at making the country self-sufficient in rice production for her populace. There have been the adoption of modern technology in rice farming and the training of personnel in the use of these technologies. The performance of these technologies varies because of factors relating to the weather condition, crop and soil types. An investigation into the effect of this technology on the growth and yield of rice using a predictive approach is necessary for future study and inferences relating to this area of knowledge.

Predictive equations are mathematical representation of conception of a system or a set of equations which represent the behaviour of a system with the purpose of aiding, understanding and improving the performance of the system (Patricia *et al*., 2007). Researchers have used these techniques for predicting crop yields. Problems relating to biology, ecology and environment have been solved using set of mathematical equations. These have helped to predict system output, classify data and

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understand processes (Adekalu and Okunade, 2008; Safa, 2011). The application of simulation models in agriculture is rapidly increasing and gaining acceptability (Adekalu and Okunade, 2008; El-Sharkawy, 2011). Many of these applications have become useful tools that characterize and estimate yield under different levels of available water. Various models are now being used to gain better insight into the design and management of irrigation and drainage systems, irrigation scheduling and water use and the environmental monitoring of pollutants in the soil-water network (Adekalu and Okunade, 2008). Modeling that aid decision making in sustainable agriculture does not necessarily require the description of all elements in fine detail, the approach needs to be tailored for the purpose. Relatively, simple descriptions of specific processes are sufficient if the processes are known to respond to a limited subset of external conditions or if other unmodeled effects can be solved through appropriate adjustments to accommodate errors (Oladapo and Omidiora, 2014). The need to provide a logical procedure for predicting process output in conditions other than those that have been observed is the focus of this research.

Yield crop modeling can also be useful as a means to help scientists define research priorities (Donohue *et al*., 2018). Using a model to estimate the importance and the effect of certain parameters, a researcher can observe which factors should be more investigated in future research, thus, increasing the understanding of the system (Donohue *et al*., 2018). Crop Simulation Models (CSM) are computerized representations of crop growth, development and yield, simulated through mathematical equations as functions of soil conditions, inputs, weather and management practices (Gottschalk *et al*., 2018). These have played important roles in the interpretation of agronomic results and their application as decision support systems for farmers is increasing. The crop growth system, in general is more stochastic than deterministic because many parts of the agro-ecosystem are heterogeneous (Gottschalk *et al*., 2018).

Statistical models can provide many insights into past yields and historical influences and can be used to inform the other kinds of models (Ramirez-Villegas *et al*., 2017; Rowhani *et al*., 2011). Parametric linear models as a form of parametric regression are frequently used to describe the association between the dependent variable and the independent variables. They require the estimation of a finite number of parameters (Meshesha and Abeje, 2018).

MATERIALS AND METHODS

Experimental site description and research procedures: The experimental site is located at the Landmark University teaching and research farm. It is on latitude 8.1239°N and longitude 5.0834° in the North Central Region of Nigeria. The experimental layout is a 3×3 factorial design that was completely randomized. It involved three methods of tillage namely, no-tillage but flat field (A), tillage using Shanti hydropower tiller (B) and Serif technology (C). The field termed no tillage was prepared using hoes and shovel, the hydropower using China made Model DF-121 and the serif technology using Indonesian made Quick G1000 Boxer. Three varieties of paddy rice namely FARO 52, FARO 44 and local rice was raised in the nursery for 4 weeks to produce seedlings for transplanting. Using the two other tillage methods, basin sizes of dimension 3×2 m were created. These were guarded by bunds to control water flow in and out of the basins (Gupta and Kumar, 2001). Each rice variety was transplanted after 4 weeks into the basin which is the plot size for the no-tillage, hydropower (shanti) and serif technology plot. This was replicated 3 times to give a total of 1350 plant stands (Aremu *et al*., 2018).

Collection of soil samples and experimental measurement: Soil samples were taken at random location up to a depth of 20 cm using a hand auger. Soil samples taken were kept in an airtight polythene bag and taken to the laboratory for analysis of the soil physicochemical properties following procedures described by Alhassan *et al*. (2018). Some of the physical and chemical parameters determined were texture, porosity, bulk density, moisture content, pH, electrical conductivity, available phosphorus, available potassium, sodium, Cation Exchange Capacity (CEC), extract iron, copper, manganese and zinc, total nitrogen and carbon, organic matter, calcium, bacterial and fungal count.

Some agronomic characteristics such as days to flowering, days to maturity, number of tillers, panicle length, plant height and grain yield data were counted/measured. Measuring tape, visual counting and weighing scale were used for the data collection. IBM SPSS Statistics 22, Microsoft Excel and Minitab 17 statistical tools were used for the analysis of the collected data.

RESULTS AND DISCUSSION

Soil classification and physicochemical properties: The results of the soil samples taken up to a depth of 20 cm are as presented in Table 1. It revealed the descriptive statistics of obtained field data. The soil textural analysis shows a 4.32-8.32% of clay, 8.56-15.56% of silt and 78.12-86.12% of sand. The experimental site is a sandy loam soil based on USDA textural classification. The

Table 1: Experimental soil analysis results of the research field (Sampling depth: 0-20 cm)

	Minimum		Maximum				
Parameters	Values	Ratings	Values	Ratings	Mean±SD (N = 18)	Grid(s) with the minimum values	Grid(s) with the maximum values
Gravel (%)	25.40	Low	78.9	High	62.6 ±13.0	TR16	TR15
Textural class		Sand		Sandy loam			
Clay (%)	4.32	8.32			5.38±1.11	TR16	TR9
Silt (%)	8.56	15.56			11.06±1.76	TR1, TR9	TR8
Sand (%)	78.12	86.12			83.56±2.04	TR8	TR12
pH (Water)	5.90	Mod. acid	6.67	Neutral	6.30±0.2	TR14	TR12
pH (0.01 M $CaCl_2$)	5.24		6.03		5.70±0.3	TR1	TR15
pH (1 M KCl)	5.19		6.06		5.5 0±0.2	TR2	TR15
Tot. Nitrogen (%)	0.12	Mod. low	0.61	Very high	0.22±0.12	TR3	TR6
Tot. Carbon (%)	1.00	Low	2.21	Very high	1.45±0.38	TR16	TR15
C:N	1.80		11.7		7.60±2.2	TR6	TR10
Avail P (mg P/kg)	8.50	Moderate	36.7	High	15.10±7.0	TR16	TR1
Ca^{2+} (cmol(+)/kg)	1.60	Very low	4.50	Low	2.90±0.7	TR16	TR14, TR15
Mg^{2+} (cmol(+)/kg)	3.80	High	9.20	Very high	5.1±1.2	TR8, TR14	TR15
K^+ (cmol(+)/kg)	0.25	Low	0.30	Low	0.28±0.02	TR8, 10, 12	Rest
Na^+ (cmol(+)/kg)	0.00	Very low	0.10	Very low	0.04±0.01	TR8	TR6
Al+H (cmol(+)/kg)	0.00		0.90		0.34±0.31	TR1,4,6	TR10
CEC (cmol(+)/kg)	7.20	Low	14.80	Moderate	8.60±1.7	TR1	14.8
Base saturation (%)	89.50	Very high	100.00	Very high	96.20±3.3	TR10	TR4, 6, 1
Extract Fe (mg/kg)	9.50		23.40		15.50±4.3	TR14, IRLS	TR16
Extract Cu (mg/kg)	28.10		105.90		72.00±24.0	IRMS	TR9
Extract Mn (mg/kg)	8.00		41.30		22.00±7.8	TR7	TR14
Extract Zn (mg/kg)	3.30		35.40		15.30±0.1	IRLS	TR2

Table 2: Tillage methods and effect on soil characteristics

Soil characteristics	Flat land (Non-tillage)	Tilled (Hydrolic P Tiller)	Tilled (Sawah Eco Techrif)
Soil pH	6.30	5.60	5.90
Organic matter			
OC	1.84	0.50	0.97
OM	3.18	0.87	1.76
Particle clay			
Clay (%)	6.32	4.3	4.95
Silt (%)	16.22	6.72	10.53
Sand (%)	77.46	88.96	91.22
Bulk density(g/cm^3)	1.049	0.64	0.85
Bacteria count	17×10^{-5}	19×10^{-5}	18×10^{-5}
Fungal count	3×10^{-2}	40×10^{-2}	31×10^{-2}

required macro and microelements needed for the proper vegetative growth of the plant were also found to be adequate as analysed.

An investigation into the effect of the tillage technologies on the soil characteristics as studied is as presented in Table 2.

According to Ingle *et al*. (2018), the most suitable pH range is 6.0-8.0 for crop production. The experimental site has a pH range of 5.60-6.30 for the three tillage methods. This shows a favourable environment for activities required for healthy plant growth.

The plot with the non-tillage method had the highest bulk density. This may be due to the inability of the tillage technique to penetrate deep into the soil. It also has the highest quantity of organic matters because the level of soil pulverization and inversion is also small compared to the other two techniques that use mechanical power. The bacteria and fungi count are also the highest in the no-tillage method.

There is also variation in the textural properties of the soil based on the tillage techniques. This has an effect on the soil physicochemical properties as shown in Table 2.

Graphical representation of the effect of investigated parameters on rice agronomical characteristics: The surface and contour plots for the rice variety and the tillage treatment are as shown in Fig. 1. These plots show the interaction of the tillage techniques and plant agronomic characteristics as investigated.

Box plot representation of the effect of tillage techniques on the agronomic properties of rice varieties: Figure 2-7 shows the graphical representation of the effect of tillage systems on the growth and yield of the rice plant. These boxes also show the location of the first, second (median), third and fourth quartile distribution of each tillage systems effect on the various varieties. This location corresponds to the horizontal lines starting from the

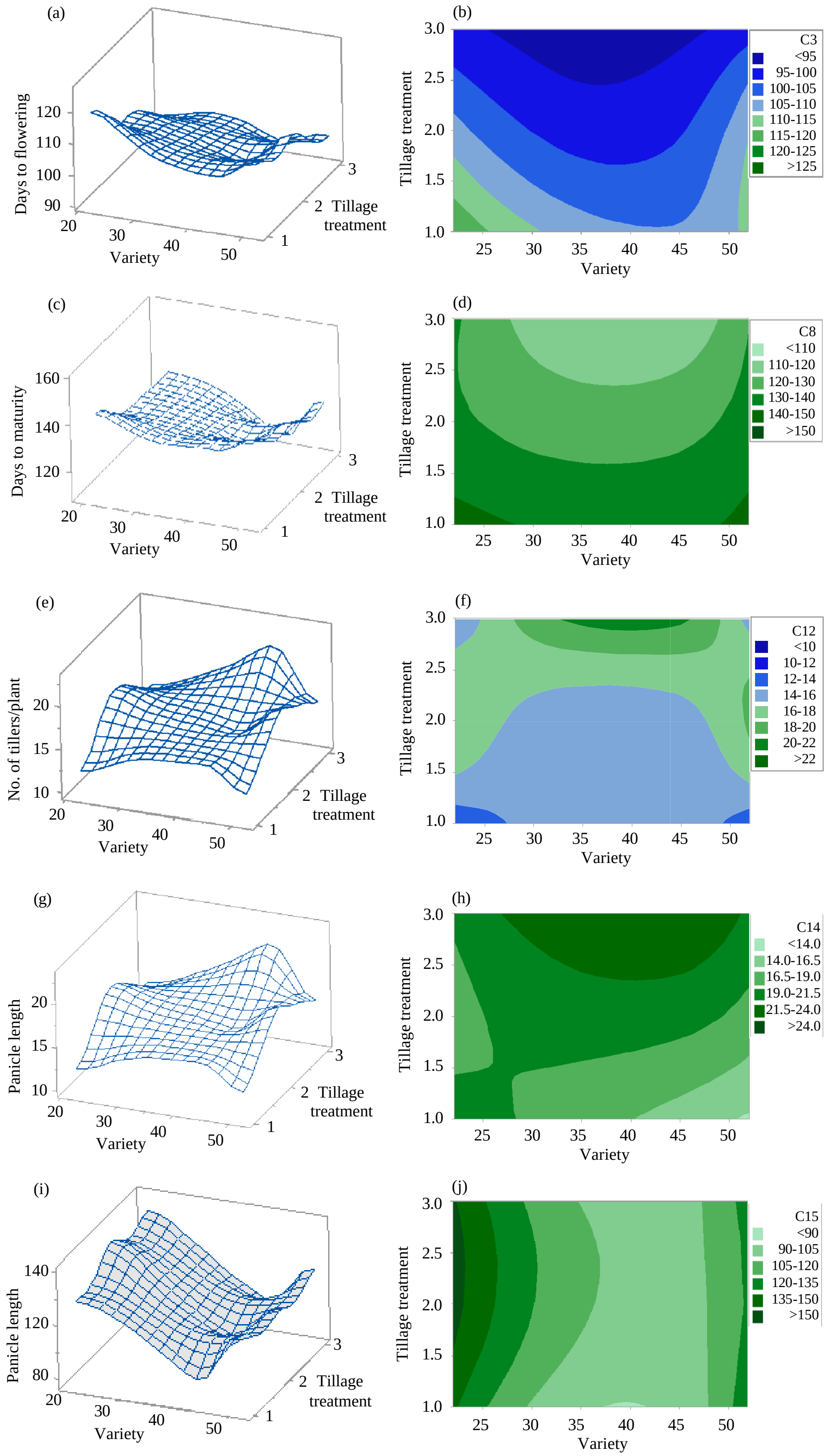

Fig. 1: Continue

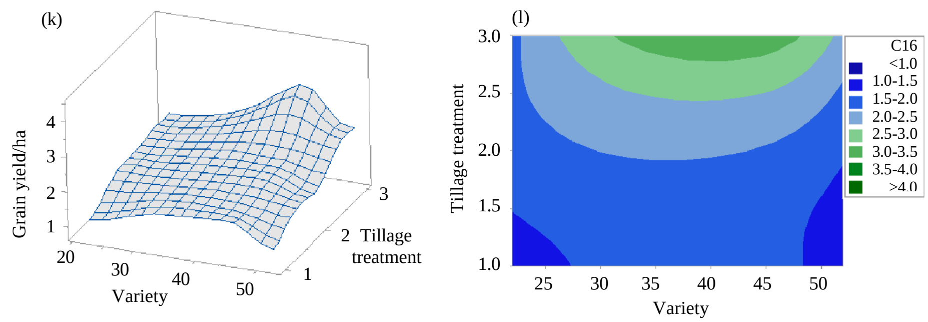

Fig. 1: Relationship between the 3 different rice varieties and tillage treatments on the developmental performance and yield of rice: a) Days to flowering; b) Days to flowering; c) Days to maturity; d) Contour plot of days to maturity; e) Surface plot for No. of tillers per plant; f) Contour plot of No. of tillers per plant; g) Surface plot of panicle length; h) Contour plot of panicle length; i) Surface plot of plant height; j) Contour plot of plant height; k) Surface plot of grain yield and l) Contour plot of grain yield/ha

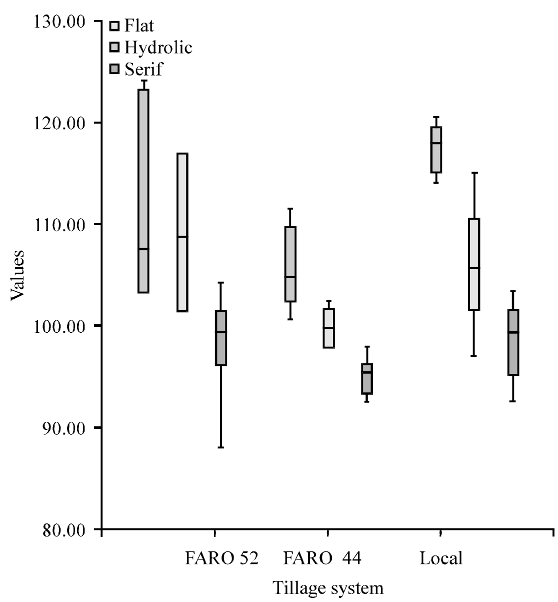

Fig. 2: Box plot of tillage systems effect on the days to flower of the three varieties of rice

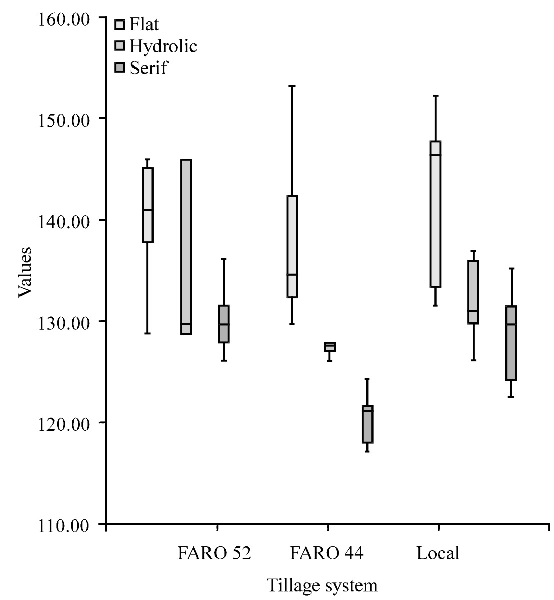

Fig. 3: Box plot of tillage systems effect on the days to mature of the three varieties of rice

baseline of the box to the top whisker with the thick line dividing the box as the second quartile (median). Overlapping boxes reflects a possible relationship between the three tillage techniques, especially, when the median line is almost on the same point on the y-axis.

Regression and correlation analysis of the investigated parameters: Table 3 revealed a linear relationship which is statistically significant between tillage systems and the growth and yield properties of FARO 52 rice except for the height of the rice plant where the model failed to be adequate with a $p>0.05$. It was also observed that the explained variation for FARO 52 rice was too small except for the panicle length that was able to explain 71.5% of the variations in the model.

For FARO 44 as shown in Table 4, a linear relationship which is statistically significant was established between tillage systems, the growth and yield properties. The explained variation for FARO 44 rice was a little high except for plant height where the model is capable of accounting for only 24.7% of the variations.

In Table 5, for the number of tiller and panicle length, a linear relationship which is statistically significant could not be established between tillage systems, the growth

Table 3: Linear relationship between the tillage systems, growth and yield of FARO 52

					Coefficients	
Properties	R	R^2	F-values	Models	α	β
Days to flower	0.602	0.363	0.008	Y = 121-7.417X	0.001	0.008
Days to maturity	0.558	0.312	0.016	Y = 145.668-5.417X	0.001	0.016
No. of tillers	0.635	0.403	0.005	Y = 20.944-1.500X	0.001	0.005
Panicle lenght	0.846	0.715	0.000	Y = 9.556+4.333X	0.001	0.000
Plant height	0.257	0.066	0.304	Y = 114.309+2.969X	0.001	0.304
Grain yield	0.650	0.422	0.004	Y = 1.585+0.207X	0.001	0.004

Table 4: Linear relationship between the tillage systems, growth and yield of FARO 44

					Coefficients	
Properties	R	R^2	F-values	Models	α	β
Days to flower	0.851	0.723	0.000	Y = 111.167-5.833X	0.001	0.000
Days to maturity	0.821	0.675	0.000	Y = 146.889-9.583X	0.001	0.000
No. of tillers	0.746	0.557	0.000	Y = 18.167-1.500X	0.001	0.000
Panicle length	0.842	0.709	0.000	Y = 12.378+3.629X	0.001	0.000
Plant height	0.497	0.247	0.036	Y = 86.226+9.253X	0.001	0.036
Grain yield	0.826	0.682	0.000	Y = 1.724+0.366X	0.001 s	0.000

Table 5: Linear relationship between the tillage systems, growth and yield of local rice

					Coefficients	
Properties	R	R^2	F-values	Models	α	β
Days to flower	0.866	0.751	0.001	Y = 128.389 – 10.500X	0.001	0.001
Days to maturity	0.702	0.492	0.001	Y = 150.000 – 7.833X	0.001	0.001
No. of tillers	0.039	0.001	0.879	Y = 19.278 – 0.083X	0.001	0.879
Panicle length	0.156	0.024	0.536	Y = 20.731 – 0.378X	0.001	0.536
Plant height	0.613	0.376	0.007	Y = 132.288 + 7.363X	0.001	0.007
Grain yield	0.703	0.494	0.001	Y = 1.072 + 0.303X	0.001	0.001

R = Correlation, R^2 = Explained variation, F = p-value for model adequacy, Coefficients = p-values for showing the significance of the model's coefficient

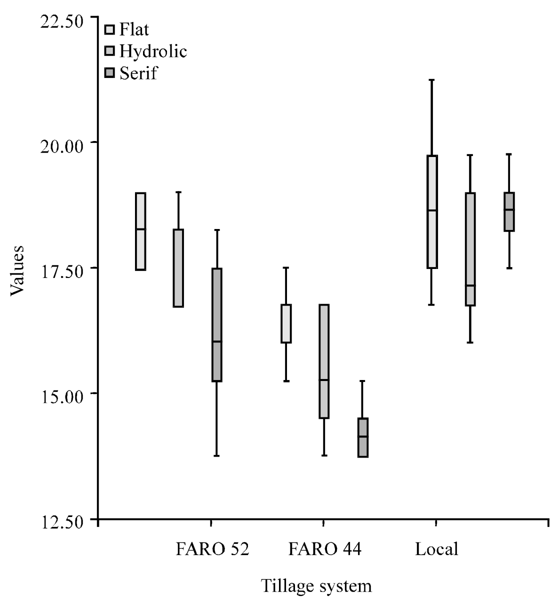

Fig. 4: Box plot of tillage systems effect on the no tillage of the three varieties of rice

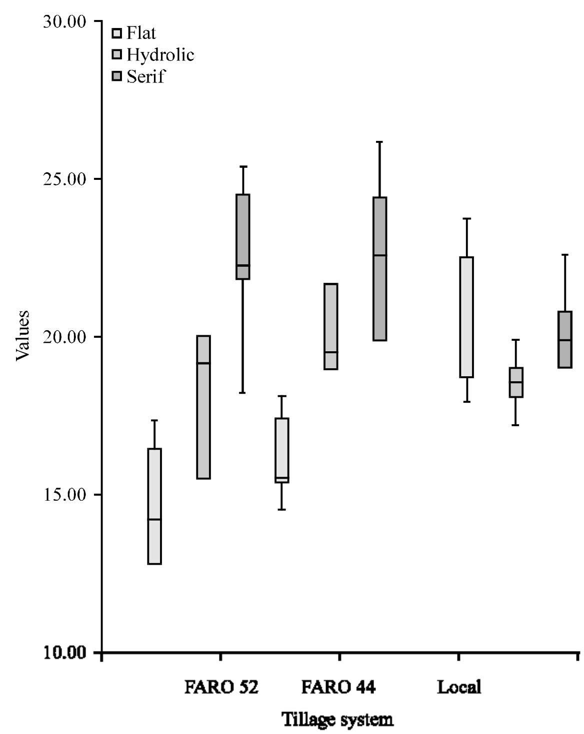

Fig. 5: Box plot of tillage systems effect on the pannicle length of the three varieties of rice

and yield properties of local rice. This is because of the insignificant value of F at $p<0.05$ causing the linear model to be inadequate. This can also be observed from the

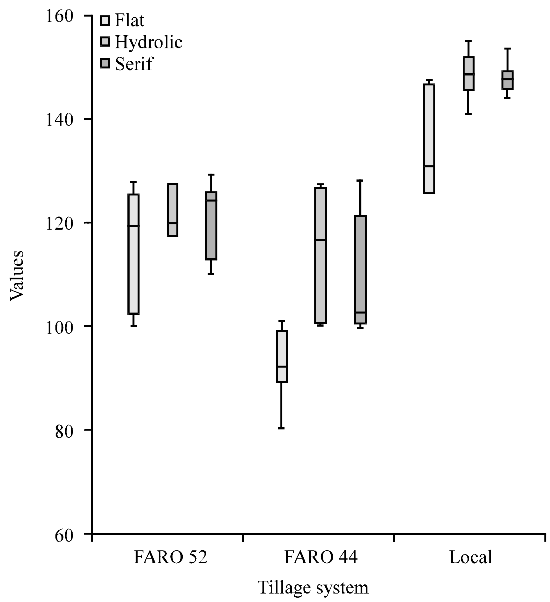

Fig. 6: Box plot of tillage systems effect on the plant height of the three varieties of rice

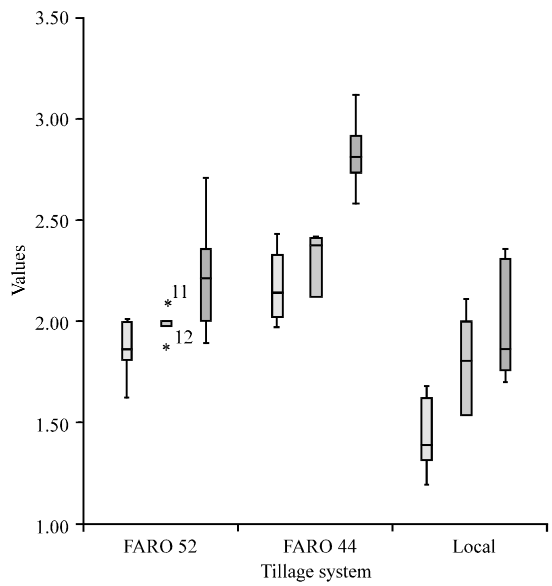

Fig. 7: Box plot of tillage systems effect on the grain yield of the three varieties of rice

insignificant value of β at $p<0.05$. It was also noticed that the explained variation for local rice was too small except for the days to flower where the model was capable of explaining 75.1% of the variations.

CONCLUSION

The research was undertaken to help rice growers and stakeholder in rice farming to appreciate the interaction effect that tillage practice and varieties have on the yield performance and other plants developmental performance and how these are correlated. The knowledge is to guide fabricators of agricultural equipment in precision decisions and planning towards efficient agricultural machinery development. This will make energy and resources to be tailored towards profitable technique for rice production towards a self-sufficient output. Results obtained showed investigated parameters has an effect and linear relationships on the agronomic characteristics of rice varieties under lowland plantation.

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