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Multiple Regressions Analysis to investigate the optimal yield of Guava fruits at different level of NPK Fertilizers in south west Nigeria

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Abstract

Purpose: *This study investigates the effect of fertilizers (Nitrogen, Phosphorus & Potassium) on Guava; examines which of the three elements of NPK contribute most to the weight of guava seed. It thus further determines at what proportion each of the three elements is to be applied for optimum yield.*

Subjects and Methods: *A 3 x 3 factorial experiments were adopted in the data analysis; further tests were conducted using different Post Hoc test approaches and a multiple regression analysis was derived to investigate at what proportion the elements are to be applied for optimum yield.*

Results: *The results of the analysis of variance (ANOVA) showed that only Phosphorus and Potassium contribute to the growth and weight yield of guava. The Post-Hoc Tests showed that there was a significant difference between the mean pair of P0 & P20 and P0 & P40 with a p-value of 0.000 and 0.000 respectively. Also, there was a significant difference between the mean pair of K0 & K50 and K0 & P100 with a p-value of 0.004 and 0.008 respectively which is less than the significant level at 0.05. Furthermore, the overall multiple regression models for the weight yield of guava fruits were obtained as: (Y)=5.646+0.0556N-0.3611P+1.5694K+1.7167NP+1.1333NK+1.0361PK.*

Conclusion: *Thus, to obtain an optimal yield of 12- 20t/ha of guava fruits, phosphorus and potassium are to be applied at 40k.g and 50kg respectively with spacing of 6 x 6m accommodating 277.7 plants per hectare.*

1. Introduction

Guava (Psidium guajava L.) is one of the important fruit crops. It belongs to the family Myrtaceae and is native to Tropical America stretching from Mexico to Peru, to Africa and indeed to Nigeria. Guava is a very popular fruit mostly used as a dessert fruit for its delicious taste and nutritive values. Presently, Brazil is the world's top producer of red guava. The Paluma cultivar is highly marketable in Brazil, featuring fine characteristics for both *natural* consumption and fruit industrialization. Furthermore, Paluma has adapted well to intensive production (which uses pruning, irrigation, and adjusted nutritional management). This allows production cycles of approximately eight months, well-suited for scheduling of fruit output. Guava is highly responsive to fertilization (Arova and Sngh, 1970) , (Natale et.al., 1994, 2002), (Anjaneyulu and Raghupuhi, 2009). A whole array of tools is used to provide nutritional support, such as tissue and soil analyses (leaf analysis being the most reliable for assessing the nutritional status of perennial plants) grounded on adequate sampling methods

and correct interpretation of analytical data (Bould et.al., 1960). These plants access nutrients at deeper depths than it would be possible to determine through standard soil analysis procedures. In evaluating plant nutritional status, standard nutrient contents are often criticized for not taking into due account interactions among elements (Bates, 1971). In natural systems, a *ceteris paribus* assumption (interactions between nutrients, in which all other factors remain constant) has its constraints, as double or multiple relations have been well-documented in plant nutrition studies (Fageria, 2001), (Malavolta, 2006). The effects of modifying nutrient proportions due to interactions among the nutrients were first illustrated by Lagatu and Maume (1935). Plant tissue data convey relative information, as they are intrinsically multivariate, i.e., no one component can be interpreted in isolation; it must be related to other components (Tolosana and Vanden, 2011). Hence, for compositional data (as in plant tissue nutrients), tools should be used that allow the analysis of inter-component interactions for the sake of better understanding of plant nutritional status. Compositional data analysis proposed by Aitchison (1982) has sparked wide-ranging discussion, given the practical importance of this new methodology, albeit some reluctance to its use remains to this day (Pawlowsky and Egozcue, 2001). Occasionally, this technique requires interpretation of results in terms of ratios and logarithmic proportions, which are harder to interpret than real vectors in statistical analysis. For the sake of simplifying analysis, components can be ordered to cluster them into two or more subsets, which are somehow easier to interpret (Egozcue and Pawlowski, 2005).

To avoid numerical bias in compositional analyses, Egozcue and Pawlowski-Glahn (2005) proposed using Isometric Log Ratios (*ilr*) based on the principle of orthogonality (D-1 degrees of freedom) to analyze compositional data. Isometric Log Ratios (*ilr*) coordinates can be projected onto Euclidian space, a geometric structure allowing analyses free from numerical bias (Egozcue and Pawlowski, 2011). An *ilr* transformation is a special log-transformation case that preserves the information contained in the new variable, allowing studies of relations among nutrients (Parent et. al., 2012). The *ilr* method is a three-stage method, namely: data represented in *ilr* coordinates; analysis of variance of the coordinates as real random variables; and interpretation of results in terms of balances (Egozcue and Pawlowski, 2011); they cannot, however, be transformed back into their initial values. Unlike conventional methodology, based on the contents of each nutrient, this tool is quite promising for the study of plant nutritional status in view of its sturdiness, and as it assesses nutrients taking into accounts the relations among them through nutrient balances. Hence, it is a more adequate instrument for this type of analysis. This concept has been successfully used in plant nutritional studies (Parent, 2011), (Hernandes et.al, 2012), as well as in soil aggregation (Parent et.al, 2012). Presuming that compositional data analysis is a robust tool to the interpretation of leaf analysis because it takes in consideration the relationship between nutrients.

The study aimed to improve the nutritional diagnosis of Paluma guava, evaluating rates of nitrogen and potassium fertilization in an irrigated commercial area for five consecutive cycles, with careful observation of the influence of fertilizers and the climate, using isometric log-ratios. The nutrient requirement of guava differs from region to region due to soil support system, which imparts desired changes in growth and flushing in a set of climatic conditions. Guava crop is very responsive to the application of inorganic fertilizers. A balanced dose of NPK should be applied to the guava plants for normal growth and production (Mallick and Singh, 1960), (Singh and Singh, 2007). Nigeria lies between longitudes 2°49' E – 14°37'E and

latitudes 4°16'N-13° 52' N and is in the humid tropics. It has a land area of 923, 850 km^2. In Nigeria, over 70 percent of the country's population is engaged in agriculture as their primary occupation and means of livelihood (Onwutube, 2019), (Shiru et.al, 2018), (Nkechi et.al, 2016), (Federal Ministry of Environment, 2014). Agricultural produce in Nigeria is mostly rain-fed. Unpredictable rainfall variation makes it difficult for farmers to plan their operations (Anabaraonye et al. 2019), (Chavez and Torres. 2012).

Fertilizers and Guava

The dispensable use of chemical fertilizers has widened soil imbalance in terms of NPK ratio and the overall decline in production capacity of the soil. Integration of organic substrates with chemical fertilizers can have a significant effect on the physical, microbiological and chemical properties of soil, which are responsible for supporting plant growth. The use of organic manures along with bio-fertilizers and crop residues is considered as a cheap source of available nutrients to plants which have beneficial effects on the growth, yield and quality of various fruit crops. Considering economy, energy and environment, plant nutrients should be caused effectively by adopting a proper nutrient management system to ensure high yield and to sustain the availability in the soil at an optimum level for getting higher yield and quality fruit production for which nutrient management is necessary. Scanty information is available on the effect of chemical fertilizers on the fruits yield of guava, hence the research work investigates the effect of fertilizers (Nitrogen, Phosphorus & Potassium) on Guava; examines which of the three elements of NPK contribute most to the weight of guava seed. It thus further determines at what proportion each of the three elements is to be applied for optimum yield. Fertigation is commonly used for growing guavas in São Francisco Valley, due to it's a proven tool efficiency for uniform and balanced nutrient distribution since it provides water and nutrient availability in the higher root activity area of the plant canopy, especially if localized irrigation is used [28]. One of the nutrients applied through fertigation is nitrogen (N) which is the second nutrient more required by guava tree and it is essential for plant growth and development, as an essential constituent of amino acids, enzymes, nucleic acids, and chlorophyll (Marschner, 2012).

A negative feature of N fertigation is possible groundwater contamination and N loss to the atmosphere, since plants are not able to absorb all N of the fertilizer. One possibility to mitigate N fertilizer excess is partial or total replacement by organic fertilizers such as bovine bio-fertilizer, which is an organic matter source able (or not) to supply N plant demand, it can also be supplied through fertigation, it is decomposed faster than solid fertilizers, has low-cost distribution and fast organic matter decomposition (Gross et al., 2009). Biofertilizer has positive effect soil physical and chemical characteristics (Pires et al., 2008) and consequently on plant growth and development, and, fruit production and quality. Especially for fruit quality it is registered in the scientific literature the biofertilizer effect on improving or maintaining fruit quality of yellow passion fruit custard apple (Leonel et al., 2015) and banana (Santos et al., 2014).

For guava compared organic and conventional production systems partially replaced by bio-fertilizer applied through fertigation and reported that bio-fertilizer was better than other treatments. Additionally, Batista et al. (2015) concluded that organic inputs use for growing

guavas beyond synthetic inputs provides high fruit yield and fruit quality compatible to market demands for soluble solids, pH, titra-table acidity, pulp firmness and soluble solids/titra table acidity ratio.

2. Methodology and Procedures

In practice, the response of biological organism to the factor of interest is expected to differ under different levels of other factors. For example the yield of wheat varieties may differ under different rates of fertilizers application, spacing and irrigation schedules. Thus when the effect of several factors is investigated simultaneously in a single experiment, such an experiment is known as a factorial experiment. The factorial experiment is an extension of the one-way ANOVA in that it involves the analysis of two or more independent variables. It is used in experimental designs in which every level of every factor is paired with every level of every other factor. It allows the researcher to assess the effects of each independent variable separately, as well as the joint effect or interaction of variables. Factorial designs are labeled either by the *number of factor* involved or in terms of the *number of levels* of each factor. Thus, a factorial design with two independent variables (e.g., gender and ethnicity) and with two levels for each independent variable (male/female; Australian/Chinese) is called either a two-way factorial or a 2 × 2 factorial.

In this experiment, there are three factors to be considered (Nitrogen, Phosphorus and Potassium) each at three levels of application at two replication i.e . The NPK fertilizers comprise of three elements namely Nitrogen, Phosphorus and Potassium with three levels: Nitrogen (0, 1, 2), Phosphorus (0, 1, 2) and Potassium (0, 1, 2) Hence, a 3 x 3 factorial experiments were adopted. Various levels of the (NPK) fertilizer component in (kg): N=20.40, 60; P = 0, 20, 40; and K = 0,50,100.

A 3 X 3 Factorial Fixed effect Model:

$$Y_{ijk} = \mu + \tau_i + \beta_j + \gamma_k + (\tau\beta)_{ij} + (\tau\gamma)_{ik} + (\beta\gamma)_{jk} + (\tau\beta\gamma)_{ijk} + \varepsilon_{ijkl} \begin{cases} \mathrm{i} = 1,2,\dots,\mathrm{a} \\ \mathrm{j} = 1,2,\dots,\mathrm{b} \\ \mathrm{k} = 1,2,\dots,\mathrm{c} \\ \mathrm{l} = 1,2,\dots,\mathrm{n} \end{cases} \quad (3.3.1)$$

Where :

μ = is the overall mean

τ_i = is the effect of the ith level of Nitrogen

β_j = is the effect of the jth level of Phosphorous

γ_k = is the effect of the kth level of Potassium

$(\tau\beta)_{ij}$ = is the effect of the interaction between

$(\tau\gamma)_{ik}$ = is the effect of the interaction between Nitrogen and Potassium

$(\beta\gamma)_{jk}$ = is the effect of the interaction between Phosphorous and Potassium

$(\tau\beta\gamma)_{ijk}$ = is the effect of the interaction between Nitrogen, Phosphorous and Potassium

ε_{ijkl}= is the random error component

Table 2.1: The Theoretical Analysis of Variance Table for Three-Factor Fixed Effects Model

Source of Variance	Sum of Square	Degree of Freedom	Mean Square	Expected Mean Square	F_0
A	SS_A	a-1	MS_A	$\sigma^2 + \frac{bcn\sum\tau_i^2}{a-1}$	$F_0 = \frac{MS_A}{MS_E}$
B	SS_B	b-1	MS_B	$\sigma^2 + \frac{acn\sum\beta_j^2}{b-1}$	$F_0 = \frac{MS_B}{MS_E}$
C	SS_C	c-1	MS_C	$\sigma^2 + \frac{abn\sum\gamma_i^2}{b-1}$	$F_0 = \frac{MS_C}{MS_E}$
AB	SS_{AB}	(a-1)(b-1)	MS_{AB}	$\sigma^2 + \frac{cn\sum\sum(\tau\beta)_{ij}^2}{(a-1)(b-1)}$	$F_0 = \frac{MS_{AB}}{MS_E}$
AC	SS_{AC}	(a-1)(c-1)	MS_{AC}	$\sigma^2 + \frac{bn\sum\sum(\tau\gamma)_{ik}^2}{(a-1)(c-1)}$	$F_0 = \frac{MS_{AC}}{MS_E}$
BC	SS_{BC}	(b-1)(c-1)	MS_{BC}	$\sigma^2 + \frac{an\sum\sum(\beta\gamma)_{jk}^2}{(b-1)(c-1)}$	$F_0 = \frac{MS_{BC}}{MS_E}$
Error	SS_E	$abc(n-1)$	MS_E	σ^2	
Total	SS_T	$abcn-1$			

Post Hoc Tests

Post hoc tests are designed for situations in which the researcher has already obtained a significant omnibus F- test with a factor that consists of three or more means and additional exploration of the differences among means is needed to provide specific information on which means are significantly different from each other.

Tukey`s HSD Test

Tukey`s Honest Significance Difference (HSD) Test was designed for a situation with an equal sample size (the simplest adaptation uses the harmonic mean of n-sizes). Tukey`s test procedure makes use of the distribution of the standardized range statistic

$$q = \frac{\bar{y}_{\max} - \bar{y}_{\min}}{\sqrt{\frac{MSE}{n}}}$$

Where $y_{\max}$ and $y_{\min}$ are the largest and smallest sample means respectively out of the group of p sample means The formula for Tukey`s HSD equal sample is

$$HSD = \sqrt[q]{\frac{MSE}{N}}$$

Where q = the relevant critical value of the standardized range statistic and n is the number of scores used in calculating the group mean interest.

3. Results and Discussion

Table 3. 1. Summary of Data

Statistic	Minimum	1st Quarter	Median	Mean	3rd Quarter	Maximum
Value	4.000	6.325	7.550	7.359	8.350	10.100

Table 3.1 above shows the general summary of the data. It shows that the minimum value is 4.0 and the maximum value is 10.100. The mean value is 7.359 while the median is 7.550. This implies that the data is negatively skewed, since the median value is greater than the mean value.

Table 3.2: Differences between Means between Groups of the Three Elements

Elements		Sum of Squares	df	Mean Square	F	Sig.
Nitrogen	Between Groups	1.843	2	.921	.477	.623
	Within Groups	98.428	51	1.930		
Phosphorus	Between Groups	32.591	2	16.295	12.279	.000
	Within Groups	67.680	51	1.327		
Potassium	Between Groups	14.205	2	7.102	4.209	.020
	Within Groups	86.066	51	1.688		
	Total	100.270	53			

The table 3.2 above shows the mean difference between groups of three element of the fertilizer. It shows that there is significant difference between means of Phosphorus and Potassium across the three levels with their p-value of 0.000 and 0.020 respectively which is less than the pre-determine level of significance of 0.05 while there is no significant difference between the mean level of Nitrogen with a p-value of 0.623 which is greater than the pre-determined level of significance of 0.05.

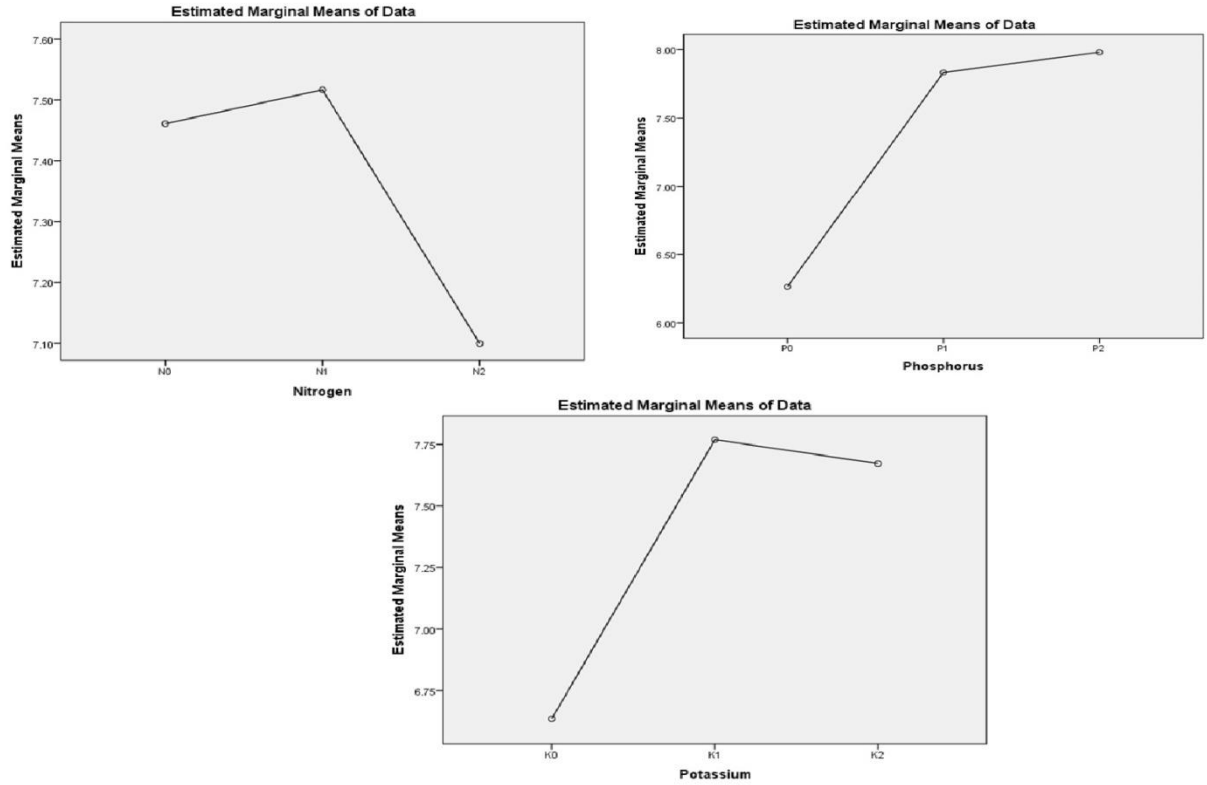

Figure 3.1. The graphical plot of the mean levels of the three elements of NPK fertilizers.

Table 3.3: The Result of ANOVA

Source	Sum of Squares	df	Mean Square	F	Sig.	Remark
Corrected Model	67.983[a]	26	2.615	2.187	.024	Sig.
Intercept	2924.570	1	2924.570	2445.633	.000	Sig.
Nitrogen	1.843	2	.921	.770	.473	N.Sig.
Phosphorus	32.591	2	16.295	13.627	.000	Sig.
Potassium	14.205	2	7.102	5.939	.007	Sig.
Nitrogen * Phosphorus	1.150	4	.287	.240	.913	N.Sig.
Nitrogen * Potassium	5.181	4	1.295	1.083	.384	N.Sig.
Phosphorus * Potassium	5.502	4	1.375	1.150	.354	N.Sig.
Nitrogen * Phosphorus * Potassium	7.513	8	.939	.785	.620	N.Sig.
Error	32.288	27	1.196			
Total	3024.840	54				
Corrected Total	100.270	53				

R Squared = .678 (Adjusted R Squared = .368)

Table 3.3 above shows the result of ANOVA of Factorial Design of the effect of fertilizer on the weight of Guava Seed. From the table, it could be observed that the p-value for the model 0.024 is less than the pre-determined level of significance (0.05) which implies that the model is adequately fit the data. Also, the intercept is highly significant with p-value 0.000. Furthermore, there are significant differences between the mean level of Phosphorus and Potassium with their p-value of 0.000 and 0.007 respectively which is less than 0.05, this

implies that at least one pair of mean level is significant. Also, from the table above, it can be deduced that there is no significant difference in the mean level of Nitrogen as it p-value (0.473) is greater than the level of significance (0.05). In the same vein, it can be observed that there is no significant difference in the mean level of any of the interaction as their p-values are greater than the pre-determined level of significance of 0.05. This implies that applying Nitrogen and any of the possible combination will not influence the weight of Guava seed. The R-square gives 0.678 which implies that about 67.8% of the total variation in the observed variable can be accounted for by the ANOVA model.

Table 4 Post-Hoc Test for Phosphorus

(I) Phosphorus	(J) Phosphorus	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
P0	P20	-1.569*	.365	.000	-2.317	-.822
	P40	-1.717*	.365	.000	-2.465	-.969
P20	P0	1.569*	.365	.000	.822	2.317
	P40	-.147	.365	.689	-.895	.601
P40	P0	1.717*	.365	.000	.969	2.465
	P20	.147	.365	.689	-.601	.895

Table 3.4 above shows the post hoc test between the mean levels of Phosphorus. It can be deduced there is a significant difference between the mean pair of P0 & P20 and P0 & P40 with p-value of 0.000 and 0.000 respectively which is less than significant level 0.05. Also, it can be observed that there is no significant difference between the mean levels of P20 & P40 as its p-value 0.689 is less than 0.05.

Table 3.5: Post-Hoc Test for Potassium

(I) Potassium	(J) Potassium	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
K0	K50	-1.133*	.365	.004	-1.881	-.385
	K100	-1.036*	.365	.008	-1.784	-.288
K50	K0	1.133*	.365	.004	.385	1.881
	K100	.097	.365	.792	-.651	.845
K100	K0	1.036*	.365	.008	.288	1.784
	K50	-.097	.365	.792	-.845	.651

Table 3.5 above shows the post hoc test between the mean levels of Potassium. It can be deduced there is significance different between the mean pair of K0 & K50 and K0 & P100 with p-value of 0.004 and 0.008 respectively which is less than significant level 0.05. Also, it can be observed that there is no significance difference between the mean levels of K100 & K50 as its p-value 0.792 is less than 0.05.

3.1.Optimization of the application of NPK: Using Multiply Regression

To obtain the optimal application of Phosphorous and Potassium the study employed the application of multiple regressions to determine the appropriate levels of the application of Phosphorous and Potassium for the fruit yield of Guava.

General Multiple Regression Model:

$$Y = \beta_0 + \beta_1 Ni + \beta_2 P_i + \beta_3 K_i + e_i \quad (3.1)$$

Where Y is the dependent variable, $Y =$ Guava fruit yield

N_i, P_i and K_i are independent variables; β_1, β_2, β_3 and β_4 are partially regression coefficients

β_o is the intercept (mean effect of variable excluded from the model) and e_i is the stochastic disturbance term.

Table 3.6: Summary of Model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate		Change Statistics					Durbin-Watson
						R Square Change	F Change	df1	df2	Sig. F Change	
1	.610[a]	.373	.335	1.12172		.373	9.897	3	50	.000	2.015

Table 3.6 above shows the summary of the model of the data. The p-value gives 0.000 which implies that the model is significant and adequately fit the data. The R-square gives 0.610 indicates that 61.0% of the total variation can be explained by the model leaving about 39.0% to be explained by other factors. The Dubbin Watson gives 2.015 which falls between 1.5 and 2.5 indicate that the data is not auto correlated.

Table 3.7.: Regression Model of the Data

	Estimate	Std. Error	t value	Pr(>|t|)	Remark
(Intercept)	5.64259	0.375	14.952	0.000	Sig
N	0.05556	0.469	0.159	0.874	N.Sig
P	-0.36111	0.337	-1.034	0.307	Sig
K	1.56944	0.343	4.492	0.000	Sig
N*P	1.71667	0.847	4.914	0.000	N. Sig
N*K	1.13333	0.497	3.244	0.002	N. Sig
P*K	1.03611	0.411	2.966	0.005	Sig

The table 3.7 above shows the regression model of the weight of guava seed. The model is given as:

$$Weight\ of\ Guava\ seed\ (Y) = 5.646 + 0.0556N - 0.3611P + 1.5694K + 1.7167NP + 1.1333NK + 1.0361PK$$

This implies that only Phosphorus and Potassium have a positive impact on the fruit of yield of guava. The combination of Potassium and Phosphorus contribute more to the model than any element. Also, it can be observed that only Nitrogen was not significant to the model with their p-value greater than 0.05.

4. Conclusion and Suggestion

The results of various data analyses showed that: Phosphorus and Potassium contribute to the growth and weight yield of guava. Turkey's HSD test showed that there was a significant

difference between the mean pairs of P_0 & P_{20} and P_0 & P_{40} with p-value of 0.000 and 0.000 respectively. Also, there was a significant difference between the mean pair of K_0 & K_{50} and K_0 & P_{100} with a p-value of 0.004 and 0.008 respectively which is less than the significant level at 0.05. Furthermore, the overall multiple regression models for the weight yield of guava fruits were obtained as: $(Y) = 5.646 + 0.0556N - 0.3611P + 1.5694K + 1.7167NP + 1.1333NK + 1.0361PK$. Thus, to obtain an optimal yield of guava weight and fruit, phosphorus and potassium are to be applied at 40k.g and 50kg per hectare respectively.

Conflict of Interest

None declared.

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Data and Materials Availability

All data associated with this study are presented in this paper.

Peer-review

External peer-review was done through double blind method.

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