Assessments of Nutrients Content in Soil and Leaves of Harumanis Mangoes and Its Relationship with the Yield

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Abstract. Crop yield can determine the health of a tree based on the nutrient content applied by the farmers. Soil nutrients are essential for plant production. This research aims to study the relationship between the yields of Harumanis mango and the nutrient content in soil and leaves. Three (3) primary objectives are highlighted, namely: (1) to study the distribution of nutrients content in the soil; (2) to determine the relationship between the yields of Harumanis mango and nutrient content in soil and leaves; and (3) to identify the significant factors affecting the yields of Harumanis mango. The study area is in the UiTM Perlis branch. Overall, 25 samples have been collected with information on the coordinate position, crop yield and nutrient content; nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca). The Kriging method interpolated the distribution of nutrient content in the soil. Pearson correlation and multiple linear regression analysis were used to study the relationship between yield and nutrient content in soil and leaves to determine which nutrients influenced the yield of Harumanis mango. The result shows only K and Ca in the leaves significantly contribute to the yield of Harumanis mango. The multiple linear regression model for the predicted yield of Harumanis mango is 347.974 – 51.426 (N% in leaves) – 550.225 (K% in leaves) + 86.672 (Ca% in leaves).

1. Introduction
Soil nutrients are crucial, especially for plant production and good fruit quality. Even though the climate affects the plant, the nutrient content of the soil also benefits the plant, making it suitable for planting mango. Mango (Mangifera indica) orchards are famous in Asia, including in Malaysia. There are various mango species, but in Perlis, the smallest state in northern Malaysia, the Harumanis (MA 128) has become the most popular mango to cultivate. It is one of the mango cultivars with high market value due to its excellent quality, attractive colour, great aroma, delicious taste, and high nutritional values. This plant is special and has high demand, especially during its season [5].

Previous studies established various nutrient factors affecting mango production, such as nitrogen (N), phosphorus (P), potassium (K) [1,9,11,12], sulphur (S) [9], magnesium (Mg) and calcium (Ca) [17]. Insufficient nutrient content leads to low crop yields since the plants do not get enough minerals and applying enough nutrient content considerably increases the crop yields due to the appropriate minerals.
Other than that, some studies highlighted the use of Geographic Information System (GIS) especially Geostatistical analysis in soil nutrient prediction and mapping [11,1,7].

Thus, the aim of this research is to study the relationship between nutrient content in soil and leaves with the yield of Harumanis. There are three (3) objectives to achieve the aim which are (1) to study the distribution of nutrients content in the soil; (2) to determine the relationship between the yields of Harumanis mango and nutrient content in soil and leaves; and (3) to identify the significant factors affecting the yields of Harumanis mango. The sample of soil and leaves were obtained from previous study and it has been collected at the Harumanis mango orchard in UiTM Perlis.

This research used GIS technology and statistical method to map and analyze the data. The nutrient information in soil sample was mapped spatially using GIS software - ArcGIS version 10.8. The map is significant for researcher and farmer to visualize the distribution of nutrients in the soil. While, statistical method helps in identifying the relationship between the yields of Harumanis mango and the nutrients, and the nutrients that most affecting the yields of Harumanis mango.

This study obtained data analysis on the relationship between nutrient content in soil and leaves. Soil fertility is essential for the great productivity of plants, implying that Harumanis requires the correct amount of soil minerals with an appropriate balance of N, P, K, Ca, Mg, and S. Climate conditions that influence the amount of moisture, light, and warmth required for growth should also be considered. These primary minerals are vital to plants. A significant lack of these minerals might diminish the efficiency of the plant itself [7]. However, this research only studies four (4) nutrients, namely N, P, K, and Ca.

2. Study Area
The chosen study area was the Harumanis mango plot at UiTM Perlis Branch, Perlis, Malaysia. Perlis is the smallest state in northern Malaysia. The appropriate climate and environment in this state have the potential for Harumanis mangoes to be available abundantly. The study was conducted in the Harumanis mango orchard at coordinates 6° 27' 18'' N and 100° 17' 2'' E. The selected area only covers small part of Harumanis mango plot which is around 0.18 ha acreage. Figure 1 shows the study area in the UiTM Perlis farm.

![Figure 1. The image of mango plot located in UiTM Perlis](image-url)
3. Materials & Method

This research employed a chain of data processing to obtain a relationship between the Harumanis mango yields and the nutrient contents of N, P, K, and Ca in soil and mango leaves. The research was performed based on the methodological structure shown in Figure 2.

![Figure 2. Methodology](image)

Figure 2 shows the four phases of the research methodology, namely planning, data acquisition, data processing, and data analysis. The first phase involved the selection of the study area and software. The study was conducted at the Harumanis mango farm at UiTM Perlis using ArcGIS ver. 10.8 and IBM SPSS Statistics ver. 28 software. Data acquisition in the second phase collected the nutrient content (N, P, K, and Ca) and crop yield. The third phase, data processing, determines the distribution of nutrient content in the soil. The Ordinary Kriging interpolation method was used to create the distribution of nutrient content. Then, Pearson correlation obtained the relationship between the Harumanis mango yield and nutrient content. After that, a multiple linear regression method identified which nutrient content significantly affected the Harumanis mango yield and created the prediction model based on it. The detailed processing part is explained in the data processing.

3.1. Data Acquisition

3.1.1. Soil Sampling and Analyses. Systematic sampling scheme was adopted to collect a total of 25 geo-referenced top soil samples in the Harumanis mango plot. Soil samples were taken 1m away from the main trunk using a stainless steel auger. A handheld GPS receiver (GPSMAP® 62sc, Garmin Ltd., KS) was used to record the latitude and longitude of each sampling point.

Soil samples were air-dried until it is completely dry, ground, and sieved to pass through 2.0 mm mesh stainless steel sieve. Samples were then used for determination of nutrients such as P, K, and Ca. Besides, a small portion of the samples were sieved using 250μm mesh size for determination of N. Soil N content was determined using dry combustion method [3] through CNS analyzer (LECO Trumac CNS-2000, St. Joseph, Michigan). P content in the soil was extracted using the Bray No. 2 extractant (0.03 N NH₄F + 0.1 N HCl) at a solid:liquid ratio of 1:7 (w/v) [2] and was subsequently determined by the flow injection analyzer (Lachat QuickChem FIA+, Zellweger Analytics, Milwaukee, WI). Meanwhile, K and Ca content were obtained by 1 N NH₄OAc buffered at pH 7 [14], followed by their determination using atomic absorption spectrophotometer (Perkin Elmer Analyst 400, USA).

3.1.2. Leaf Sampling and Analyses. Leaf samples were collected by adopting method from [16] where the fourth leaflet from the tip of the leaf terminal of the mango tree was taken around the tree canopy. A total of 10 leaf samples were taken from each of the mango tree. The leaf samples were oven dried at
60°C until it reaches a constant weight, and ground using heavy-duty plant grinder and sieved to pass through 1.0mm sieve. Leaf samples were then subjected to nutrient analyses (N, P, K, and Ca). Leaf N content was determined using dry combustion method [3] and analyzed using CNS analyzer (LECO Trumac CNS-2000, St. Joseph, Michigan). Meanwhile, dry ashing method [6] was adopted to determine P, K, and Ca content in the leaf. P content was determined using the flow injection analyzer (Lachat QuickChem FIA+, Zellweger Analytics, Milwaukee, WI) whereby K and Ca were determined by atomic absorption spectrophotometer (Perkin Elmer Analyst 400, USA).

3.1.3. Yield. Yield parameters of Harumanis mango were measured which include number and weight of harvested fruit per tree. Number of harvested fruit per tree refers to the quantity of fruits from the first to the last harvesting period for a season. Weight of harvested fruit per tree was measured in kilogram by weighing all of the harvested fruits.

3.2. Software
There were two (2) main software packages used for this research:
 i- ArcGIS version 10.8: creates the distribution of nutrient content using the Geostatistical Analyst Tool.
 ii- IBM SPSS Statistic version 28: determines the relationship between the Harumanis mango yield and nutrient content and identifies significantly affected nutrient content toward the yield.

3.3. Data Processing
3.3.1. Ordinary Kriging Interpolation. This research utilised geostatistical techniques to study the distribution of nutrient content (N, P, K, and Ca) in soil from the sample data. It is a widely-used and practical component of GIS applications. Furthermore, geostatistics analyses and estimates values from the existing variable values dispersed in time and location. There are various geostatistical techniques, such as Inverse Distance Weighted (IDW), Kriging, Spline, etc. [15,4] stated that ordinary kriging and IDW has been the most frequently used geostatistical techniques to predict soil properties. Thus, the Ordinary Kriging interpolation method has been selected in this research. It is known as one of the best and most widely-known methods used in spatial-linear predictions.

The Ordinary Kriging interpolation method was conducted to create the prediction distribution of nutrients in soil around the study area. The input data were the 25 soil samples consisting N, P, K, Ca nutrients. The important parameters highlighted in this process were, namely: (1) selecting an appropriate transformation; (2) a possible detrending surface; (3) covariance/ semivariogram models; and (5) search neighborhood. The Ordinary Kriging model was selected as Kriging/ Cokriging in Geostatistical Wizard on the Geostatistical analyst toolbar in ArcGIS version 10.8.

The Ordinary Kriging formula is as follows:

\[ Z(S_0) = \sum_{i=1}^{N} \lambda_i Z(S_i) \]  \hspace{1cm} (1)

Where:
\[ Z(S_i) \] = the measured value at the location (i-th)
\[ \lambda_i \] = the unknown weight for the measured value at the location (i-th), and
\[ S_0 \] = the estimated location

3.3.2. Correlation Test. Correlation is a statistical method that measures the strength and direction of a linear relationship between variables. It is aim to calculate and understand the impact of a linear relationship between continuous variables [13]. It varies between -1 and +1, where a positive value shows a positive relationship and vice versa. A value near 1 indicates a strong linear relationship, while a value near 0 means a weak linear relationship or no relationship. There are three (3) types of correlation, namely Pearson, Spearman, and Kendall’s Tau. This research used Pearson correlation to
determine the relationship between the Harumanis mango yield and nutrient content in the soil and leaves. The Pearson correlation produces a sample correlation coefficient, \( r \), which is used to measure the strength and direction of linear relationship between continuous variables.

Pearson correlation coefficient formula:

\[
\hat{r} = \frac{\sum_{i}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i}(x_i - \bar{x})^2 \sum_{i}(y_i - \bar{y})^2}}
\]

Where:
- \( r \) = correlation coefficient
- \( x_i \) = values of the x-variable in a sample
- \( \bar{x} \) = mean of the value of the x-variable
- \( y_i \) = values of the y-variable in a sample
- \( \bar{y} \) = mean of the value of the y-variable

In order to use Pearson correlation, some requirements need to be met such as involving two or more continuous variables, must not have missing values on both variables, consist linear relationship between the variables, must be independent cases (i.e. independence of observations), bivariate normality, random sample of data and no outliers.

The bivariate Pearson correlation analysis was performed using IBM SPSS Statistics version 28 software by using variables of soil and leaves nutrient content (N, P, K, Ca) with the yield of Harumanis mango. The output was display the correlations in a table, labelled Correlations.

### 3.3.3. Regression Analysis

Regression analysis analyses the relationship between a dependent and independent variable(s) and formulates it into a mathematical equation. It has the same function as correlation analysis, which identifies the relationship between a dependent and independent variable(s) while also providing the influence of the independent variable(s) on the dependent variable. The mathematical equation from the regression analysis can predict the dependent variable values based on the independent variable(s) values. Before the regression analysis, it is necessary to perform correlation first.

Simple linear regression, multiple linear regression, logistic regression, and Poisson or Binomial regression are the four (4) different types of regression analysis. This research used multiple linear regression since the dependent and independent variables met the requirements of one dependent variable and at least one independent variable. Therefore, the dependent variable is the Harumanis mango yield, while the independent variables are the nutrient content N, P, K, and Ca in soil and leaves.

The regression analysis was done using IBM SPSS Statistics version 28 software.

The mathematical model created from multiple linear regression is similar to the following:

\[
y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \varepsilon
\]

Where:
- \( y \) = dependent variable
- \( \beta_0 \) = independent variable 1
- \( \beta_2 x_2 \) = independent variable 2
- \( \beta_k x_k \) = k-th independent variable
- \( \varepsilon \) = error

Three crucial values need to be checked when performing the multiple linear regression analysis:

1. R-squared (coefficient of determination)
   - This value determines whether the regression model is good or not. The higher the value, the better the model, i.e., 80% and above is considered good.
ii- F-test (in ANOVA table)
   • This value tests the model fit. A good fit means the p-value is smaller than the significance level.

iii- t-test (in coefficient table)
   • This value tests the independent variables individually. The independent variable influences the dependent variable if the p-value is smaller than the significance level.

4. Results and Discussion
The result of this study will show the distribution of nutrient content of N, P, K and Ca in soil using interpolation method and the yield of each tree. Then, the result of relationship between yield of harumanis mango and nutrients content (N, P, K, and Ca) in soil and leaves shows in table using regression method.

4.1. Distribution of Nutrients Content in Soil
Figure shows the interpolation value of nutrient content of N, P, K and Ca in soil of the Harumanis mango farm and the yield of each tree. As mention in 3.1, the 25 data samples were collected based on the location of each tree. Thus, the yield also represent the point location of sample data.

Figure 3(a). Distribution of Nitrogen (%) content in the soil and Harumanis mango yield

Figure 3(a) shows the interpolation value of N using ordinary kringing method. The value of N were classify into five (5) level of percentage. The lowest value is 0.12%, and the highest value is 0.18%, indicating the soil contains a low N value (< 0.5%). According to [1], inadequate N affected the growth rate, protein content, and yield as N is crucial for plant cell division. Hence, more N should be added to the soil to meet the desired amount of N applied to the mango plant of 100g/tree/year. Lack of N decreases plant productivity and fruit quality. However, excessive N contributes to water source contamination through volatilization, denitrification, and leaching.
Meanwhile, P content was classified into two (2) classes. The Harumanis mango orchard contain the nutrient of P between 6.84 mg/kg to 24.01 mg/kg. Figure 3(b) showing that the soil contains sufficient P nutrients. [1] claimed high P (> 30 mg/kg) demonstrated adequate phosphorus for Harumanis plants. P is a constituent of plant cells and is vital for cell division and the leaves’ development. The lack of P restricts the growth of roots and tree, eventually retarding the plant’s growth.

The K content in soil shown in Figure 3(c) ranges from low (0.5 cmol./kg) to very high (2.57 cmol./kg). According to [1], the high K content in topsoil is due to the decay of organic matter, including K content in the soil. K was stable in that layer compared to another subsoil layer. It is a vital nutrient for photosynthesis, respiration, and growth in the expansion and development of cells in plants. It also
improves the water-holding capacity of soils and the structural stability of sandy soils in particular. Potassium deficiency results in starch accumulation, whereas sugar accumulation is frequent in K-deficient leaves.

![Figure 3(d). Distribution of Calcium (cmol/kg) content in the soil and Harumanis mango yield](image)

Figure 3(d) shows the distribution of Ca in the soil, ranging from 1.82 cmol/kg to 14.54 cmol/kg. Plants need 17 essential nutrients to complete their life cycle including Ca. Ca is required by the plants as a secondary macronutrient, which amounts to 0.5 cmol/kg. It is essential for the growth of shoots and root tips. Inadequate Ca leads to scalloping of young leaves, abnormally green leaves, and premature shedding of fruit and buds.

In summary, the soil of Harumanis mango farm at UiTM Perlis has sufficient P, K, and Ca but insufficient N content. These may affect plant productivity and fruit quality. The soil requires an optimum amount of N to support healthy plant growth. On the other hand, the results show inconsistencies between the yield and nutrient content in the soil. Therefore, it is more reliable to see the relationship and influence of each nutrient content on the Harumanis mango yield using correlation and multiple regression analysis.

4.2. Relationship between Yield of Harumanis Mango and Nutrients Content (N, P, K, and Ca) in Soil and Leaves

Table 1 shows the correlation analysis of the Harumanis mango yield and nutrient content (N, P, K, and Ca) in soil and leaves. The correlation range is between +1 to -1. A positive value means the variables have a positive relationship, while a negative value means the variables have a negative relationship. A value near 1 shows a strong linear relationship, while a value near 0 shows a weak or no relationship. Table 1 states that N in soil has no relationship (r = 0.086), while P, Ca, and K in soil have a weak positive relationship (r < 0.5) to the Harumanis mango yield.

Regarding the nutrient content in leaves, K has a strong linear negative relationship (r = -0.723), Ca has a strong linear relationship (r = 0.685), N has a weak linear relationship (r = -0.444), and P has no relationship (r = 0.001) to the Harumanis mango yield.

As a result, the N, P, K, and Ca in the soil and the P in leaves do not relate to or contribute to the Harumanis mango yield, making it unable to predict. Thus, only N, K, and Ca in leaves were used as the independent variables to determine which variable influences the yield.
### Table 1. Correlation Analysis of the Harumanis Mango Yield and Nutrient Content (N, P, K, and Ca) in Soil and Leaves

| Tissue / Leaves | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----------------|---|---|---|---|---|---|---|---|---|
| 1. Yield of Harumanis Mango | - |   |   |   |   |   |   |   |   |
| 2. Nitrogen (N) | -0.444* | - |   |   |   |   |   |   |   |
| 3. Phosphorus (P) | -0.001 | 0.297 | - |   |   |   |   |   |   |
| 4. Potassium (K) | -0.723** | 0.353 | 0.217 | - |   |   |   |   |   |
| 5. Calcium (Ca) | 0.685** | -0.485* | 0.006 | -0.470* | - |   |   |   |   |
| 6. Nitrogen (N) | 0.086 | 0.134 | -0.219 | 0.002 | 0.131 | - |   |   |   |
| 7. Phosphorus (P) | 0.178 | -0.252 | -0.382 | -0.116 | 0.208 | 0.489* | - |   |   |
| 8. Potassium (K) | 0.332 | 0.275 | 0.271 | -0.153 | -0.074 | -0.272 | -0.417* | - |   |
| 9. Calcium (Ca) | 0.114 | 0.085 | 0.068 | 0.036 | -0.078 | -0.123 | -0.288 | 0.330 | - |

* Correlation is significant at the 0.05 level (2-tailed).
* Correlation is significant at the 0.01 level (2-tailed).

### Table 4. Coefficients Table of Multiple Regression Analysis

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. |
|-------|-----------------------------|---------------------------|---|------|
| 1     | B       | Std. Error | Beta |   |     |
|       |         |            |      |   |     |
| (Constant) | 347.974 | 235.592 | - | 1.477 | 0.155 |
| Tissue/Leaves_Nitrogen (N) | -51.426 | 114.346 | -0.065 | -0.45 | 0.658 |
| Tissue/Leaves_Potassium (P) | -550.225 | 155.196 | -0.504 | -3.545 | 0.002 |
| Tissue/Leaves_Calcium (Ca) | 86.672 | 31.671 | 0.416 | 2.737 | 0.012 |

a. Dependent Variable: Yield of Harumanis Mango

### 4.3. The Influence of Nutrients Content (N, K, and Ca) in Leaves on the Harumanis Mango Yield

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---|----------|-------------------|---------------------------|
| 1     | .823* | 0.678 | 0.632 | 51.941 |

a Predictors: (Constant), Tissue/Leaves_Calcium (Ca), Tissue/Leaves_Potassium (K), Tissue/Leaves_Nitrogen (N)
b Dependent Variable: Yield of Harumanis Mango
The multiple linear regression analysis predicts the yield of Harumanis mango based on the N, K, and Ca content in the leaves. This result also identifies the nutrient content that influences the yield. The $R^2$ (coefficient of determination), F-Test (in ANOVA table), and t-test (in coefficient table) are three (3) crucial values to consider when performing a multiple linear regression analysis. The $R^2$ checks whether the regression model is good, with a higher $R^2$ value indicating a better model. A good $R^2$ value should be > 80%. As shown in Table 2, the $R^2$ is 67.8%. However, in multiple linear regression analysis, the value that requires attention is the adjusted $R^2$, which is 63.2%. The F-Test indicates a good fit model; $p$-value (Sig) < significance level (0.5). Table 3 shows a good fit model since $p < 0.001$. Finally, the t-test checks the individual influence of independent variables on the dependent variable. In this case, the test determines the effect of the N, K, and Ca content in leaves on the Harumanis mango yield. The independent variables influence the dependent variable if the $p$-value (Sig) < significance level (0.5).

Table 4 shows that only Ca and K affect the yield since the $p$-value is 0.012 and 0.002, respectively. The N in leaves does not contribute to the multiple linear regression model.

A significant regression equation was found ($F (3,21) = 14.740, p < .001$), with an adjusted $R^2$ of 0.632. The yield of Harumanis mango is predicted to be $347.974 – 51.426 (N) – 550.225 (K) + 86.672 (Ca)$, where N, K, and Ca are measured in % of leaves. The increment of N in leaves by 1% decreases the Harumanis mango yield by 51.426. Likewise, the increase of 1% K in leaves decreases the yield by 550.225, and the increase of 1% Ca in leaves increases the yield by 86.672. Only K and Ca are significant predictors of the yield, while N does not contribute to the model.

5. Conclusion

One of the important aspects in ensuring healthy plant and good fruit quality and productivity is by monitoring the nutrient content in the plant's soil and leaves. This research focuses on assessing the relationship between the yields of Harumanis mango and the nutrient content in soil and leaves. There are four nutrients observed – N, P, K and Ca. The Ordinary Kriging interpolation was used to map the prediction distribution of soil nutrients content (N,P,K and Ca), while Pearson correlation and multiple linear regression were used to analyze the relationship between the yield of Harumanis mango and nutrients content in soil and leaves (N,P,K and Ca).

As for the conclusion, the N, P, K, and Ca in soil and the P in leaves have a weak or no relationship to the Harumanis mango yield. Based on the result, only K and Ca in the leaves are significant predictors or contributors to the yield. The result of multiple linear regression model for predicting the Harumanis mango yield is:

Harumanis mango yield (predicted) = $347.974 – 51.426 (N) – 550.225 (K) + 86.672 (Ca)$

However, this result was based on 25 samples collected from Harumanis mango plot and trees. It is recommended to use more sample data to obtain more accurate and reliable output. As mentioned by [7], the more quantity of sample taken in determining the soil nutrients needed by Harumanis mango, the better the result for applying correct quantities of soil nutrients.

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