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Optimizing the Detection of Soil Nitrogen Levels via Grayscale Conversion: A Full-Factorial Design of Experiment Approach

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Abstract: In smart agriculture, the detection the level of soil macronutrients is essential in soil fertility and productivity that correlates to crop yields and fertilizer recommendations. With the advancement of technology, identification of such levels is easily obtained using devices that capture images. The levels of soil macronutrients from the captured images are affected by two factors, i.e., the tilting angle of the test tube and the lighting condition. The device produces images containing three red, green, and blue values, respectively. Using grayscale conversion, these values are then converted into a single value to analyze appropriately. This study aims to determine the optimal combination of the factors to obtain the correct reading of Nitrogen and Phosphorus using a full-factorial design of experiments with four replications designed by Minitab®. The results are analyzed using Analysis of Variance. The determined factors are the tilting angle and lighting condition. The results depicted that the factors and their interactions are significant. The developed regression model explains 76.43% of variability among factors. The optimal setting for tilting angle is 90°, while the lighting condition should be indoors. Design of Experiment is a valuable statistical tool that promotes optimization and efficient experimentations used by scientists and engineers.

Keywords: Automation, Design of Experiments, Full-Factorial, Grayscale conversion. NPK level, Optimization, RGB values

1. Introduction

From the modern global perspective, soil health and the management of soil nutrients have increased attention and have been the focus of research [1]. It is notably observed that the population of the world continues to increase in number; thus, an urgent concern of each state government of ensuring sustainable and plentiful agricultural products and maintaining and promoting agricultural processes are undoubtedly needed to increase the food supply without compromising the health of the planet [2].

The first of the primary macronutrients is Nitrogen. It is considered an essential component of nucleic acid and protein, which are the building blocks of plant cells. It is vital in the chlorophyll, which is included in photosynthesis, a process by which plants convert sunlight to helpful energy. Without Nitrogen, plants cannot produce necessary organic compounds for survival and growth [3]. Phosphorus is second of the primary macronutrient for plants, necessary for transferring energy within the plant cells. It focuses on the growth and development of seeds and roots. Without Phosphorus, plants may show stunted growth, decreased seed production, and poor root development [4]. Potassium is the last of the primary macronutrients. It focuses on regulating water balance since it maintains turgor pressure in plant cells. It also maintains the shape and prevents wilting. Without Potassium, no activation of vital enzymes will be possible [5].

Monitoring and detecting levels of soil macronutrients (i.e., Nitrogen, Phosphorus, and Potassium) are vital in the practices and guidelines on sustainable farming and implementation [6]. Farmers, agriculturists, and soil enthusiasts can utilize information from the monitoring of levels of soil nutrients in terms of future trends and application of the appropriate amount and type of fertilizers needed to ensure optimal plant growth and increased crop yield. This initiative not only assures increasing in financial aspects as these reduce over and under-application of fertilizer, but this also aids in reducing any risk of environmental damage and degradation in soil fertility and productivity [7].

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Moreover, monitoring and detecting soil macronutrients not only span agricultural production and the improvement of agricultural processes. The maintenance of soil health is interconnected with climate change, biodiversity, and water quality [8]. Excessive application and implementation of nitrogen-based fertilizers expel nitrous oxide into the atmosphere creating possible greenhouse gas that can affect climate change [9]. Any efforts to mitigate the effects of climate change must impart the principles and management of sustainable soil management to decrease greenhouse gas emissions [10].

Furthermore, overuse of fertilizer can cause unnecessary runoff of excessive fertilizer into nearby water sources like rivers or oceans, negatively impacting the aquatic ecosystems [11]. Excessive phosphorous and Nitrogen from fertilizers may cause algal blooms in water bodies that consume oxygen and give dead zones that aquatic living things cannot survive [12].

These soil macronutrients are easily determined through the use of Soil Test Kits. These kits are intended to analyze the given soil's characteristics and properties [13]. The produced information regarding soil quality is generally helpful in planting crops, improving crop yields, and improving plant growth. Based on the colorimetric approach, soil test kits are considered cost-effective and time efficient, making them a convenient tool for farmers, agriculturists, and interested individuals [14]. The colorimetric approach in the Soil Test Kits involves chemical reagents that change color with regard to the concentration and presence of specific soil components. Therefore, the color produced in the chemical process determines the corresponding level of the macronutrients present in the sampled soil [15].

With the recent advancement of technology, the colors produced by the reagents can be easily determined through image processing under computer vision without laboratory analysis, which is considered time-consuming and expensive. The advancement in imaging technology allows us to analyze the nutrient content of the soil in a non-invasive or non-destructive way. Images capturing the colors the reagents produce are the main focus of image processing [16].

These images produced can be affected by several factors leading to an inappropriate reading of the levels of the soil macronutrients. These factors include user error, soil properties, and equipment calibration. However, the two significant factors affecting the reading results are the lighting condition and the tilting angles of the test tube containing the reagents [17].

The primary objective of this study is to determine the optimal lighting condition and tilting angles of the test tube, leading to the correct interpretation of the level of the soil macronutrients via an image produced from the chemical reagents. The achievement of the objective can be employed through the full-factorial design of experiments that leads to streamlining the process and saving time in soil nutrient analysis.

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2. RELATED LITERATURE AND STUDIES

A. On the detection of Soil Macronutrients

The study of Isaak et al. [18] focuses on determining soil macronutrients through soil spectroscopy measurement. The study's product was a device considered low-cost compared to laboratory-grade spectroscopy. The device observes the absorbance spectroscopy on the linear relationship in obtaining Nitrogen, Phosphorus, and Potassium through light-emitting diodes.

Yamin et al. [19] modified the colorimetric process for determining the macronutrients in oil palm plantations using the Soil Test Kit. The method describes the passage of light through an opaque medium utilizing a specified reagent in the soil solution. The study reported an accuracy of 91.7% for Nitrogen, 89.6% for Phosphorus, and 93.8% for Potassium. This research concluded with an Internet-of-Things network data fusion to assess the variation of soil macronutrients and the management of nutrients in oil palm plantations.

Kaushik [20] emphasized that obtaining the soil characteristics, including the level of soil macronutrients, i.e., Nitrogen, Phosphorus, and Potassium, is vital in soil fertility and productivity leading to food security. The study showcases the India-based soil macronutrient classification. Regarding the K-mean clustering method, India was divided into three clusters based on the absolute correlation values of various soil nitrogen, the different soil phosphorus content, and other organic carbon contents.

Patel et al. [21] incorporated hyperspectral remote sensing in determining and identifying soil Nitrogen, Phosphorus, and Potassium soil level instead of laborious, cost-intensive, and time-consuming laboratory analysis. Derivative Analysis for Spectral Unmixing approach was used in the composition of soil macronutrients. The study concluded with the fractional abundance of the soil macronutrients incorporated in situ to estimate soil fertility.

Sadowska, Świątkiewicz, & Żabiński [22] determined the soil macronutrients, i.e., the Nitrogen and Potassium, in the three-year field trial on Peppermint (Mentha piperita L.) sandy soil. This is intended for the appropriate application of Biochar on plants and how it affects their growth. Soil feedback, microbial, and plant were the main influencing factors in the time-dependent responses of soil to Biochar. These were experimented with through a three-factorial design replicated three times.

Shiwakoti et al. [23] observed that residue burning on soil macronutrients has no difference over time after the treatments incorporated in no burn residue incorporation with farmyard manure or pea vines, no burn or spring burn with the application of Nitrogen (0, 45 and 90 kg ha-1) and fall burn wheat residue incorporation. The study concluded reducing the macronutrient decline over time can be attributed to the residue incorporation of farmyard manure at a fertilizer rate of Nitrogen at 90 kg ha-1.

Madhumathi, Arumuganathan, & Shruthi [24] conducted a study that incorporated a wireless sensor network that determines the level of soil pH, macronutrients, moisture, and temperatures that recommends an appropriate amount of fertilizer and water that ensures optimal crop growth and yield. The monitoring indicators are projected on mobile applications from the cloud from wireless sensor networks. This attempts to develop a system that can compete with existing time-consuming and cost-inefficient laboratory analyses.

Burton, Jayachandran & Bhansali [25] reviewed the related in situ soil nutrient monitoring research, including pH and soil macronutrients, i.e., Nitrogen, Phosphorus, and Potassium. The review study concluded that there is more to learn about the soil heterogeneity in several indicators of the electrochemical and optical system performance during in situ. This review study revealed that incorporating several sensors advances Internet-of-Things in agriculture is evident.

Lisuma, Mbega & Ndakidemi [26] studied the effect of Tobacco (Nicotiana tabacum L.) plant in sandy soil, especially on the level of soil macronutrients and micronutrients, i.e., Calcium, Magnesium, and Sulfur at Tabora, Tanzania. Generally, the Tobacco plant is expected in the uptake of soil macronutrients. Several experiments compare the unfertilized and fertilized Tobacco plants. The study concluded that there is a decrease in Potassium, Phosphorus, Sulfur, and Magnesium while there is a notable increase in Calcium and Nitrogen.

Alves et al. [27] developed an acceptable range for several vital macronutrients in plants, specifically the Forage cactus pear (Opuntia ficus-indica Mill), leading to the appropriate nutrient content demands for soil management. The range is achieved using 4×3 × 2 factorial in randomized blocks in three replicates. There were 72 plots that were utilized in the macronutrient contents of dry matter and cladodes. The acceptable range is intended for the improvement of fertilizer recommendations.

B. Maintaining the Integrity of the Specifications

The study of Carvalho et al. [28] utilized the Design of Experiments to optimize collagen-chitosan-fucoidan cryogel manufacturing. The study's parameters or factors are fucoidan concentration, collagen concentration, and temperature. The box-Behnken design was incorporated since it has three levels for three factors. According to the study, through the use of Design of Experiments, the optimal combination for the production of cryogels is 10% fucoidan, 5% of collagen, and 3% of chitosan at -80 C.

Outeiro et al. [29] implored the combination of machine learning and Design of Experiments to investigate the effects of the cutting conditions in the machining of Ti-6Al-4V Titanium Alloy. The study's objective is to optimize the said alloy's machinability while minimizing the residual stress time. The machine learning is intended to predict the residual stress versus the cutting conditions, i.e., cutting speed, uncut chip thickness, tool rake angle, and the cutting-edge radius incorporating linear regression. The results showcased that when there is a 40% increase in the residual stress at the machine surface, the rake angle must increase from negative (-6o) to positive (5o), the cutting edge should be increased by 100% (from 16µm to 30 µm) and the cutting speed must be decreased by 67% (from 60 to 20 m/min).

Dragan & Lelea [30] studied thermal design optimization through area reduction of printed circuit boards via the Design of Experiments under the optimization phase. In the study, it was mentioned that the shape of the printed circuit board is more vital compared to the area and how the said area was reduced in terms of the thermal performance of the experiments. The parameters were the length and width of the printed circuit board using the finite volume method. As the size of the printed circuit board, the housing dimension is reduced, leading to less integration space and cost, having the same thermal performance.

Chong et al. [31] reviewed the concrete mechanical properties prediction in the concrete mix design and the measurement of the concrete performance through the use of Design Experiments. It considered several factors, including different waste materials, dosage and type of chemical additives, and amount and proportion of constituent materials. The paper considered and reviewed several methods of analyzing concrete performance: Artificial Neural Network, Response Surface Methodology, and Taguchi method. It positively criticized the Design of Experiments. It saves time and simplifies work without compromising mechanical performance.

Chandra and Prakash [32] optimized the microchannel heat sink performance using the Taguchi design of experiments considering six factors, i.e., channel diameter, channel number, mass flux, channel length, power, and time. The main objective is to optimize the factors mentioned above while minimizing the surface temperature of experimental results. The optimized flux (150kg/m2s) and the higher number of channel (13) is vital in the heat transfer performance of the microchannel heat sink.

Arcieri, Baragetti & Ž. Božić [33] determined which among the parameters highly influenced the residual stress distribution in an hourglass specimen subjected to the impact of a foreign object damage on 7075-T6 using Design of Experiments. The 7075-T6 is an alloy in the aeronautical industry. The specimen was tested with bending or axial fatigue load and was assessed using finite element analysis. It resulted in incorporating high-impact forces that observe high tensile stresses, unfavorable from a fatigue point of view. Hence, it is wanted to have a low weight and reduce speed.

In the study of Guerra-Zubiaga & Luong [34], the Design of Experiments is used in the energy consumption of industrial robots aligning it to the objectives of Industry 4.0, i.e., reduced energy consumption. Using the linear factorial experiment analysis, the observed factors are temperature, payload, speed, and acceleration. The study observed that the most contributing factors to industrial robots' increased energy consumption are linear speed and acceleration, having a percentage of 95% in the first three joints of a Kawasaki robot.

According to the literature review conducted by Román-Ramírez & Marco [35], in the optimization of the development of lithium-ion batteries, the Design of Experiments played an essential role in observing time-saving initiatives and cost-reduction measures in the production of the batteries as mentioned above. Several factors were considered depending on the objectives of various researchers, including aging electrode formulation, active material synthesis, thermal design, capacity, and charging.

Yarici & Öztürk [36] analyzed the inverted square split ring resonator in terms of its resonance frequencies based on the chosen geometric parameters. The analysis used in the study is the Design of Experiments approach. The distance between the rings, the width of the rings, and the split width of the rings were investigated and considered as the factors, while the interaction in terms of the frequencies produced is the response of the study. The conclusion focused on the most significant parameter, the distance between rings and the width of the rings, while the least significant is the split width of the rings.

Rodriguez et al. [37] simulated the texture geometries in optimizing tribological properties in terms of surface texturing via Design of Experiments- Box Behnken. The study factors are the percentage of the textured area, depth, width, and oil film thickness. Texturing reduced the Coefficient of Friction in the Tribological tests and aided in the consumption of laboratory resources. The study mentioned that all factors are significant, but the lubricant film thickness is the most statistically significant.

C. On the determined factors for the Design of Experiments

Dacay et al. [38] developed a mobile application that determines the Nitrogen, Phosphorus, and Potassium of soil dedicated to corn. The study incorporated an Optical transducer, considered a wavelength detection sensor that needs Light Emitting Diode as a light source. The study results were able to detect the soil macronutrients and were validated by the Department of Agriculture-Soil Laboratory.

Manickam [39] crafted a framework for monitoring the soil condition using Internet-of-Things. The study incorporated several sensors, i.e., pH value, humidity, moisture, temperature, and light. These sensors were attributed to the increase in crop production. The data from the sensors were sent to MCP3204 ADC and from ADC to the cloud via Raspberry Pi.

Golicz et al. [40] investigate for potential employment of a smartphone application alongside Nitrogen and phosphate-sensitive test strips intended to determine the content of plants available found in the soil. The noted errors in determining soil nutrients were attributed to temperature dependency, chemical interferences, and ensuring optimal light conditions.

Lavanya, Rani & GaneshKumar [41] presented a study focusing on the Internet of Things which incorporated Nitrogen, Phosphorus, and Potassium sensor in conjunction with Light Dependent Resistor and Light Emitting Diodes. An optimal light condition is vital in increasing the farmer's yields. After the data are collected, these are sent to the Google cloud database for the fast retrieval system that includes fuzzification of the levels of the soil macronutrients.

Hou et al. [42] studied the additive effect of biochar amendment nitrogen deposition that stimulates plant growth, photosynthesis, and Nitrogen, Phosphorus, and Potassium observance. In determining the photosynthetic gas exchange, one of the criteria in choosing matured fresh leaves is that it is packed under good light conditions for measures.

Budinski & Donlagic [43] incorporated colorimetric chemical sensing into the fluidic flow injection sensor system. The sensor system description of the study mentioned that there must be substantial titling of the fiber end-face; an extreme tilt angle also decreases the amount of returned light signal. The angle between 9° and 10° allowed a back reflection from the microcell's end cap.

Yuan et al. [44] mentioned that the titling angle is vital in the minimum separation time and maximum plasma volume with high purity in developing manual and portable centrifuges for myocardial infarction diagnosis. Upon tilting the angle and tuning the diameter of the blood sample vessel, 99.9% purity plasma was observed in less than 3 min.

Guterstam et al. [45] presented a portion of their study regarding the critical tilt angle affecting the implicit model of other people's visual attention. It was considered an invisible force-carrying beam projecting from the eyes. Several experimentations were held to confirm the claims of the study. The respondents' judgment was highly affected by the image of a face to one side and staring at the object.

Huang et al. [46] studied how to determine the optical rotation of liquid crystal polymer retarders using digital image processing. The study mentioned an optimal optical rotation angle or tilting angle ranging from -90° to 90° for two opposing wedge-shaped dark areas by computation of the titling angle, optimization of the detection speed, and more substantial stability of the mechanical properties of the crystal polymer vortex retarder.

Yukhymenko et al. [47] studied a multistage shelf device using a fluidized bed for heat-mass transfer processes. In the processes mentioned in the study, the optimal angle of the shelve is 25° concerning the horizontal. This means that material particles on the shelf surface have a smaller angle, impeding the material particle's free flow concerning the out loading space.

3. METHODOLOGY

This section discusses the various strategies and techniques for achieving the research objectives. It is a must to outline the series of instructions to be observed to be systematic and thorough in executing the experimental protocols. The essence of establishing the design of the experiment is tantamount to yielding reliable and accurate results, emphasizing suitable statistical tools for analysis leading to the likelihood of producing valuable insights among factors.

A. Procedural Flowchart

Figure 1 showcases the procedural flowchart of the study, composed of six significant steps to fulfill the research objectives. Following the correct soil sampling for the soil test kit is vital in detecting soil macronutrients. The soil sample must be collected, observing the correct

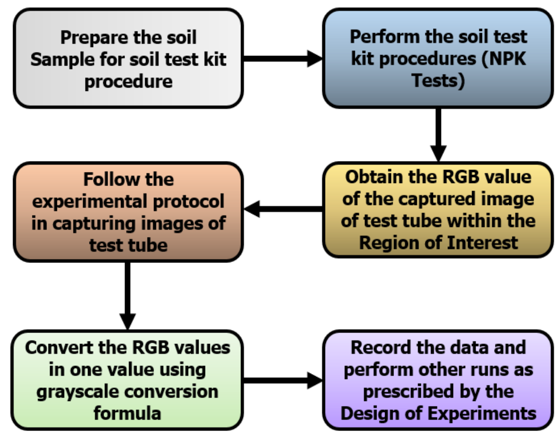

Figure 1. Procedural Flowchart

TABLE 1. FACTORS AND THEIR LEVELS

Factor	Low (-1)	High (+1)
Tilting Angle	45°	90°
Lighting Condition	Indoor	Outdoor

representation of the tested area. After the soil has been successfully sampled, it is ready to be tested in terms of the procedure set by the Soil Test Kit, performing the Nitrogen and Phosphorus Tests.

This produces several test tubes that have reagents that have the corresponding color. The Soil Test Kit observes the colorimetric method pinpointing the level of the soil macronutrients. In this step, it is a must to capture the test tubes, as mentioned above, containing reagents to determine their RGB values that directly link to the level of soil macronutrients being tested at hand. This experimentation observes the full-factorial design of experiments that lessen the number of runs and make gathering necessary data efficient and time-saving; thus, observing the experimental protocol is a must.

B. Selection of Factors

The device that captures the images from the test tube with reagents has set a region of interest, and the corresponding RGB values shall be extracted and analyzed appropriately. It is imperative to convert the necessary three-value factors, i.e., Red Value, Green Value, and Blue Value, into one response, thus using the grayscale conversion formula. Record the necessary response as a prelude to the statistical treatment of the data. As carefully prescribed by the Design of Experiments, the runs must be fulfilled, ensuring consistency and replicability, making the results reliable and accurate.

In the optimization of the system and before the conduct of experiments, it is crucial to determine the factors that affect the system's output. In line with the related literature and studies, the identified factors in detecting soil macronutrients are the tilting angle of test tubes containing the reagents and the lighting condition where the images were captured.

These factors are chosen so that the level is lowest and highest. Table 1 summarizes the factors and their corresponding levels. The tilting angle has two levels, i.e., 45° and 90°, while the lighting condition has two environments, i.e., outdoor and indoor. With the consideration of this experimental protocol, this ensures the reliability and accuracy of the results of the study.

C. Full factorial design of experiments using Minitab®

The implementation of the full factorial design can be done using Minitab®. It is considered a high-performance statistical software package that is significantly used in data analysis, quality control, and especially in using Design of Experiments used by industry practitioners and engineers. Regarding the Design of Experiments, the software offers a wide range of designs, including factorial response surface and mixture designs.

In this study, the design matrix was designed by Minitab®, considering 2^2 full-factorial designs of experiments under four replications. Table 2 summarizes the runs that the research must follow in the experimentation, leading to the time-saving and cost-effective gathering of necessary data. Sixteen runs need to be done for the analysis to be possible. In the Minitab® graphical user interface, the factors can be coded or uncoded depending on the user's appreciation.

D. Grayscale Conversion of RGB Values

The standard color model utilized in digital images is RGB (Red, Green, Blue) values, representing the three primary colors with individual pixel values starting from 0 to 255.

In this study, the device that captures the images of the test tubes contains the chemical reagents that produce an RGB value, which has three individual values for red, green, and blue. In order to have a single value, it is essential to convert these three values to a single value for it to be analyzed in the design of experiments.

Conversion from a three-value data set to a single value makes it a single channel of information, thus making it easier to process and analyze. There are many ways to convert the RGB values into grayscale, and this includes the lightness method, the average method, and the luminosity method [47]-[50]. The formula for the luminosity method is shown in formula (1) below; this converts RGB values to grayscale values:

$$Grayscale = 0.3 \times R + 0.59 \times G + 0.11 \times B \quad (1)$$

Table 2. Response Matrix for Four Replicates

Run	Tilting Angle	Lighting Condition	Grayscale Value
1	45° (-1)	Indoor (-1)	126.11
2	90° (+1)	Indoor (-1)	190.13
3	45° (-1)	Outdoor (+1)	128.07
4	90° (+1)	Outdoor (+1)	89.51
5	45° (-1)	Indoor (-1)	126.81
6	90° (+1)	Indoor (-1)	157.99
7	45° (-1)	Outdoor (+1)	126.18
8	90° (+1)	Outdoor (+1)	126.34
9	45° (-1)	Indoor (-1)	125.31
10	90° (+1)	Indoor (-1)	182.6
11	45° (-1)	Outdoor (+1)	109.9
12	90° (+1)	Outdoor (+1)	93.51
13	45° (-1)	Indoor (-1)	99.20
14	90° (+1)	Indoor (-1)	158.32
15	45° (-1)	Outdoor (+1)	108.17
16	90° (+1)	Outdoor (+1)	106.18

4. RESULTS AND DISCUSSION

This section discusses the study's results after it underwent the processes set forth by the procedural flowchart found in the methodology section. The Design of the Experiment was followed as prescribed by the design matrix. The data collected gathered were analyzed using Minitab®.

A. Data Gathering of Grayscale Values

Table 2 summarizes the results of the 16 runs designed by Minitab® according to a 2^2 full factorial design of experiments with four replicates. The RGB values were initially recorded and computed accordingly using formula (1) to convert the RGB values into grayscale values. Upon having a single value, this was recorded in Table 1 and was ready to be analyzed by Minitab®.

B. Significance of Effects

With α=0.05, the effects' significance can be determined by comparing the effects' computed p-value and its interaction. Using Minitab® as a computer-aided software for statistics, table 3 summarizes the coded coefficients containing valuable values like the computed p-values of tilting angle, lighting condition, and their interaction.

Analyzing Table 3 and as provided by the Pareto chart of the standardized in Figure 2, provides us that all the effects and their interaction are significant since all of them are less than 0.05 with values of 0.020 for tilting angle, 0.000 for lighting condition, and 0.001 for tilting angle*lighting condition.

In Figure 2, the tilting angle, lighting condition, and titling angle*lighting condition crossed the dotted red line, concluding its significance in the model.

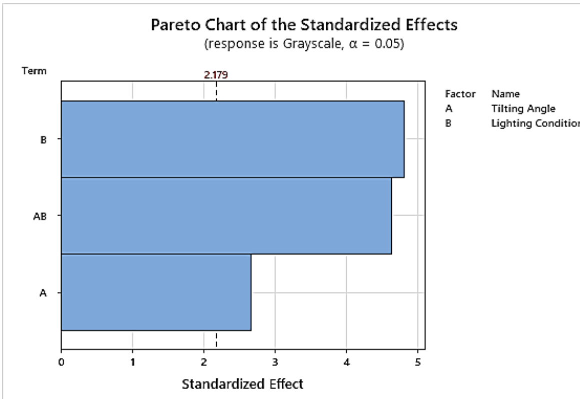

Figure 2. Pareto Chart of the Standard Effects

Table 3 also provides the value for the variance inflation factor (VIF), which primarily concerns the measurement of how much the behavior of the factors is influenced or inflated. This checks for the amount of multicollinearity present in the developed regression model. The factors and their interaction have a VIF of less than 10. Therefore, no multicollinearity is present in the developed regression model.

C. Regression Model

After performing the needed runs and experimentations, they concluded a statistically reliable and helpful model primarily based on Analysis of Variance. The developed model is found in formula (2), calculated by Minitab®.

Since Table 3 concluded that all the factors and their interaction are significant, there is no need to reconstruct the model by omitting insignificant factors or interactions.

$$Grayscale = 99.4 + 0.430\,Tilting\ Angle + 32.9\,Lighting\ Condition - 0.746\,Tilting\ Angle * Lighting\ Condition \quad (2)$$

Table 4 showcases the summary of the developed regression models' characteristics based on the factors and their interaction. The R square explains the proportion of the entire variability of the developed model. The computed R square is 81.15%. However, R square is easily threatened by the increase of factors, even by the increase of insignificant factors.

Thus, the usefulness of the other parameter, R square adjusted since this is adapted to the total model size and thus explains 76.43% variability in the incoming new data.

D. Main Effects and Interaction Plots

The combined main effects plot for the titling angle and lighting condition is found in Figure 3. Comparing the main effects of tilting angle and lighting condition, the light condition has a dominant effect in the regression model compared to the titling. There is an increase in grayscale value as the tilting angle is changed from 45 to 90 degrees, while there is a decrease in grayscale value once the test tube is placed from indoor to outdoor. Since the tilting angle and lighting condition is significant, there is a must to check the interaction of tilting angle and lighting condition.

The interaction of titling angle and lighting condition can be visualized in Figure 4. Since the two lines do not exhibit a similar line behavior, the titling angle and lighting condition have significant interaction. This can be further confirmed by having different slopes, thus indicating an intersection in the lines.

E. Optimizinf the factors

In order to optimize the factors by giving the appropriate RGB values and then converted to a grayscale value, the Minitab® can determine the optimal combination and values of the factors.

Table 5 and Figure 5 summarize and depict the optimal tilting angle and lighting condition values. The optimal tilting angle should be 90 degrees, and the optimal lighting condition should be indoors under a 95% confidence interval between 156.5 and 188.1 and a 95% prediction interval between 137.0 and 207.6.

Table 3. Coded Coefficients

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		128.40	3.62	35.43	0.000	
Tilting Angle	19.35	9.68	3.62	2.67	0.020	1.00
Lighting Condition	-34.83	-17.41	3.62	-4.81	0.000	1.00
Tilting Angle*Lighting Condition	-33.55	-16.77	3.62	-4.63	0.001	1.00

Table 4. Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
14.4954	81.15%	76.43%	66.48%

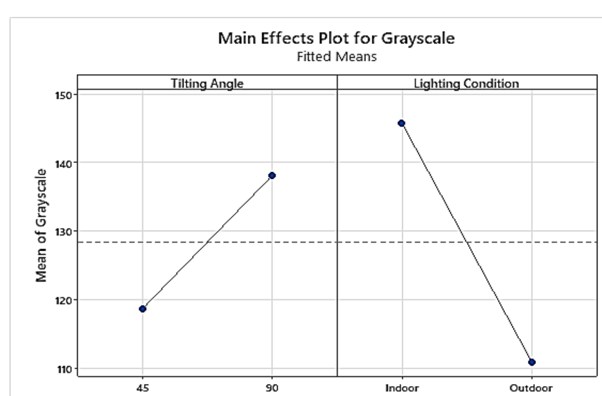

Figure 3. Main Effects Plot for Grayscale with Titling Angle and Lighting Condition as Factors

Table 5. Multiple Response Prediction

Variable	**Setting**			
Tilting Angle	90			
Lighting Condition	Indoor			
Response	**Fit**	**SE Fit**	**95% CI**	**95% PI**
Grayscale	172.26	7.25	(156.5, 188.1)	(137.0, 207.6)

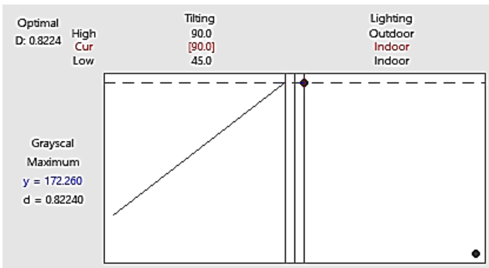

Figure 5. Optimization chart for the Grayscale Values

5. CONCLUSION

The utilization of the Design of Experiments in the optimization of the appropriate determination of the levels of soil nitrogen and phosphorus level is substantially beneficial since it explores the logical combination of factors governed by the titling angle and lighting condition for the grayscale values. The Design of Experiments also allowed the exploration of the interaction of the factors. The optimization process is geared towards enhanced accuracy and precision in the analysis, improved overall quality, and time-saving and cost-efficient experimentation. Furthermore, the success of using the Design of Experiments depends on the appropriateness of the experimental protocol, the data quality, and the accurate interpretation of results. Using Minitab® as computer-aided software allows scientists and engineers to efficiently explore the factors and their corresponding interactions, thus allowing them to determine the optimal conditions and combinations of factors effectively.

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