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Producing liquid organic fertilizer (LOF) by combining rice straw waste with local microorganisms (MOL) to enhance the growth of rice plants

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Abstract

Rice straw is a byproduct of rice harvesting that is often underutilized or discarded, contributing to agricultural waste. Finding effective ways to utilize rice straw could reduce waste and potentially enhance agricultural productivity. This study investigates the impact of rice straw and Local Microorganisms (MOL) on rice plant growth through liquid organic fertilizer (LOF). Employing a 2 x 2 factorial randomized regular two-level factorial design with three replications and blocks, the study assessed the impact of varying levels of rice straw (50 grams and 100 grams) and MOL application (200 mL and 400 mL) on rice plant height over a 7-day period. Results indicate that the combination of 50 grams of rice straw and 200 mL of MOL yielded the highest average plant height of 4.91 cm. Notably, MOL (B) exerted the most substantial influence on plant height, with the interaction between rice straw (A) and MOL also contributing, albeit to a lesser degree. Optimization analysis identified the optimal combination of 50 grams of rice straw and 266 mL of MOL for maximizing rice plant growth, underscoring the potential of integrating these elements into agricultural practices. This approach not only mitigates agricultural waste but also reduces dependence on chemical fertilizers, aligning with principles of sustainable agriculture. Moreover, the study robust experimental design and statistical analysis using Design Expert Version 13 validate the reliability and applicability of these findings in agricultural settings.

Keywords: liquid organic fertilizer, local microorganisms, rice plants, rice straw, soil amendment

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1. INTRODUCTION

The increasing population growth poses a significant challenge for the agricultural sector, particularly in food crops such as rice. In Indonesia, the availability of rice as a staple food is crucial, and the country boasts 7,463,948 hectares of lowland rice fields (Bps, 2021). Java Island, with its vast expanse of rice fields, particularly dominates land ownership. East Java leads with 1.2 million hectares of LBS, followed by Central Java with 1,049,661 hectares and West Java with 928,218 hectares (Bps,

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2021). While rice harvested area and productivity increased from 2010 to 2017, a decline was noted in 2018 and 2019 due to prolonged dry seasons, rendering some fields unusable or delaying planting. Climate aside, improper cultivation practices, especially in fertilization, also contributed to the drop in rice productivity (Bps, 2021).

Nationwide, rice straw production totals 90.02 million tons annually. Despite this abundance, much rice straw is underutilized, often burned in fields, contributing to global warming, or used minimally as animal feed. The potential of rice straw remains largely untapped. Rice straw compounds such as glucose, cellulose, and hemicellulose of 53.39 %, 63 %, and 37 %, respectively (Ramandani et al., 2023b). The use of inorganic fertilizers has increased, indicating a decline in field productivity. Long-term use of such fertilizers damages soil physical properties, phosphate buildup, soil compaction, erosion, and humus layer erosion, resulting in poor soil microbiology (Mahroof et al., 2024; Rezania et al., 2017). Consequently, soil microorganism activity declines. Continuous chemical fertilizer use could deplete soil quality (Bps, 2021). Chemical fertilizers may lead to soil quality degradation (Kurniastuti & Puspitorini, 2023), and biological ecosystems in the soil may become unbalanced (Sutanto, 2006). Organic fertilizers are essential to maintaining soil fertility in the long term as they do not harm soil physical, chemical, or biological properties (Delgado & Gómez, 2016; Pahalvi et al., 2021; Rezania et al., 2017). Rice straw can be utilized for organic fertilizer to enhance rice plant growth. Several studies have shown that liquid organic fertilizers enhance vegetable production (Sajiwo et al., 2016), rice plant (Ramandani et al., 2023a), and sweet corn (Rahmi & Jumiati, 2007) by activating microorganisms within and around the soil (Yasin, 2016). Liquid organic fertilizers derived from rice straw decompose quickly and are readily absorbed by the soil.

Local Microorganisms (MOL) are essential in organic farming cycles, contributing to high-quality, healthy, and sustainable agricultural products (Amalia & Widiyaningrum, 2016). MOL primarily consists of carbohydrates, glucose, and microorganism sources. Fermented MOL solutions function as decomposers and liquid fertilizers, enhancing soil fertility and providing plant nutrients (Atman & Nurnayetti, 2014). Liquid organic fertilizer application reduces farming costs and improves crop quality. It plays a role in improving soil physical, biological, and chemical properties. Rice straw is utilized in liquid organic fertilizer production along with MOL (Pardosi et al., 2014). MOL acts as a decomposer, activator, and additional nutrient source, facilitating compost, liquid organic fertilizer, and livestock feed production (Suhastyo & Raditya, 2019). Bacteria, fungi, and other organisms decompose during MOL production. Based on the research conducted by Pratiwi (2016) has reported that a 7.9-ton/ha rice yield increase with a 12 L/ha liquid bokashi fertilizer dosage. Liquid organic fertilizer application significantly contributes to N, P, and K in rice fields. Effective application of LOF by farming communities is emphasized due to its abundant and beneficial nutrient content, which enhances rice plant growth. Rice straw, typically burnt or used as livestock feed, can be innovatively transformed into LOF, reducing the dependency on commercially available fertilizers that are becoming increasingly costly (Ramandani et al., 2023a).

This study aims to investigate the efficacy of using rice straw waste and local microorganisms in producing liquid organic fertilizer (LOF) and its impact on the growth of rice (Oryza sativa L.). The primary goal is to facilitate farmers in adopting and applying LOF effectively to enhance soil fertility and ultimately improve rice crop productivity. Additionally, the study seeks to promote sustainable agricultural practices by utilizing agricultural and household waste to produce LOF, thereby supporting environmental conservation efforts and potentially increasing farmers' income.

2. MATERIALS AND METHODS

2.1 Equipment and Materials

The equipment utilized for the experiment included 10 L drums, 2 L aqua bottles (PET), an analytical balance, ruler, and a disk mill. The rice straw used as the raw material was specifically collected from an agricultural plant located in Natar, South Lampung. The local microorganisms (MOL) crucial for the experiment were cultivated using a carefully selected blend of organic materials: rice waste, coconut water, animal manure obtained from Lampung State Polytechnic Farm, banana stems, and brown sugar.

2.2 Experimental Design

This research employed a randomized regular two-level factorial design in a 2 x 2 factorial pattern with 3 replicates and 3 blocks (Ramandani et al., 2023b). The first factor involved 50 g of rice straw with two levels: addition of 200 mL and 400 mL of Local Microorganisms (MOL). The second factor consisted of 100 g of rice straw with similar levels of MOL addition. The experimental design is detailed as shown in **Table 1**.

Table 1. Experimental design matrix

Block	Run	Rice straw (g)	MOL (mL)
1	1	50	200
	2	100	400
	3	100	200
	4	50	400
2	5	50	400
	6	100	400
	7	100	200
	8	50	200
3	9	100	400
	10	100	200
	11	50	200
	12	50	400

In this study, 12 experiments will be conducted using a rice plant growth. The observed parameter will be the height of rice plants after application of the liquid fertilizer composition over a period of 7 days (Ramandani et al., 2023a). The data collected will be analysed using effects, diagnostics, contour plot 3D, and optimize condition in a Randomized two-level factorial design in software Design expert version 13.

2.3. Fermentation MOL to produce liquid organic fertilizer (LOF)

The fermentation process of MOL begins with combining 1 kg of brown sugar, 1 L of coconut water, and 1 L of rice wash water. Additionally, 1 kg of banana stems, 1 kg of animal manure, and 0.8 kg of leftover rice are added to this mixture along with 5 Ls of water (Ramandani et al., 2023b). During fermentation, anaerobic conditions are maintained to foster the growth and activity of indigenous microorganisms. The process begins with the careful mixing of these ingredients in a controlled environment to initiate microbial activity. Throughout the 14-day period, the fermentation progresses as microorganisms metabolize the organic materials, releasing beneficial compounds such as enzymes, organic acids, and nutrients (Ramandani et al., 2023a). The fermentation environment is monitored for factors like temperature, pH levels, and microbial population dynamics to ensure optimal conditions for microbial growth and activity. This method not only enhances the diversity and viability of beneficial microorganisms but also increases the nutrient bioavailability and overall quality of the final product, which can be used effectively in agricultural applications to promote soil health and plant growth. Following fermentation, the process continues by cutting rice straw into 5 cm pieces and mixing it with the MOL solution. This mixture undergoes another round of anaerobic fermentation for 7 days, resulting in the production of LOF. The next step involves sedimentation, where the MOL is blended with finely chopped rice straw. This step is repeated in different combinations: 50 g of rice straw with MOL additions of 200 mL and 400 mL, and 100 g of rice straw with MOL additions of 200 mL and 400 mL, each repeated three times. The mixture is left undisturbed for 7 days under anaerobic conditions until the sedimentation process is complete, yielding LOF ready for direct application as liquid fertilizer for rice plants.

2.4 Statistical analysis

This study was designed to variable independent and dependent using design expert version 13. There are many information and visualizations in this software (i.e., analysis and optimization). Analysis section determined of effect (i.e., half normal plot and pareto chart), diagnostic (i.e., normal plots of residuals, residual vs predicted, residual vs run, residuals vs block, Cook's distance, predicted and actual, DFFITS vs run, and DFBETAS for AB vs run), and model graphs (contour plot 3D). On the other hand, optimization was determined for numerical and all dependent variables of in range were used this study.

3. RESULTS AND DISCUSSION

3.1 Fermentation MOL and Rice Straw to produce LOF

Fermenting rice straw with Fermentation Microorganism Local (MOL) to produce Liquid Organic Fertilizer (LOF) offers a promising approach to enhancing the growth of rice plants sustainably (Ramandani et al., 2023a). Rice straw, a residue from rice cultivation, is rich in carbon and nutrients but often considered a waste product. By utilizing MOL in a fermentation process, this agricultural residue can be transformed into a nutrient-rich fertilizer beneficial for rice cultivation. The process begins with collecting and preparing rice straw, which is then mixed with MOL culture in a fermentation vessel or composting system. MOL, consisting of indigenous microorganisms adapted to local conditions, initiates the breakdown of complex organic compounds in the rice straw. During fermentation, MOL metabolizes these compounds, releasing essential nutrients such as nitrogen, phosphorus, potassium, and micronutrients into a soluble form that is readily available to rice plants. The resulting LOF serves multiple purposes in enhancing rice plant growth. Firstly, it enriches the soil with organic matter, improving soil structure and fertility (An et al., 2022). This enhances soil water retention, nutrient availability, and promotes beneficial microbial activity, which are crucial for supporting robust root development and overall plant health. Additionally, LOF contributes to maintaining soil pH levels conducive to optimal nutrient uptake by rice plants, thereby improving nutrient use efficiency. From an environmental perspective, using LOF derived from rice straw and MOL reduces reliance on chemical fertilizers, thereby minimizing the risk of environmental pollution and nutrient runoff into water bodies (Kumar et al., 2021; Lizcano Toledo, 2022). It supports sustainable agricultural practices by recycling agricultural waste into a valuable resource. Moreover, the organic nature of LOF enhances soil biodiversity and resilience over time, contributing to long-term soil health and productivity. In fact, fermenting rice straw with MOL to produce LOF represents a sustainable and eco-friendly approach to enhancing the growth of rice plants (Mahroof et al., 2024; Rezania et al., 2017). By harnessing local microorganisms and agricultural residues, this method not only improves soil fertility and crop productivity but also supports environmental conservation efforts in agriculture. It stands as a practical solution towards achieving sustainable food production while reducing ecological footprint in rice farming systems.

3.2 Effect of LOF for rice plant growth

The research outcome aims to assess the impact of different combinations of rice straw and MOL on rice growth, conducted at the Teaching Factory of Lampung State Polytechnic. The study involved a 7-day observation period, evaluating the growth of rice under various treatment conditions, as presented in **Table 2**.

Table 2. Experimental results for 7 days observation based on rice plant height (cm)

Rice straw (g)	MOL (mL)	Rice plant growth (cm)							Average (cm)
		1	2	3	4	5	6	7	
Control		4	4	4.1	4.3	4.3	4.5	4.6	4
50	200	4	4.3	4.3	4.4	4.5	4.5	4.7	4.38
100	400	4	4.4	4.5	4.5	4.6	4.7	4.8	4.5
100	200	4	4.5	4.7	5	5.2	5.3	5.4	4.87
50	400	4	4.4	4.4	4.4	4.5	4.7	4.8	4.45
50	400	4	4.3	4.3	4.4	4.6	4.7	4.7	4.42
100	400	4	4.1	4.2	4.3	4.4	4.5	4.6	4.3
100	200	4	4.2	4.3	4.4	4.4	4.5	4.6	4.34
50	200	4	4.1	4.2	4.3	4.4	4.5	4.6	4.91
100	400	4	4.5	4.5	4.6	4.6	4.7	4.7	4.51
100	200	4	4.4	4.6	4.9	5.1	5.2	5.4	4.8
50	200	4	4.2	4.4	4.5	4.6	4.6	4.7	4.42
50	400	4	4.5	4.6	4.8	4.9	5	5.1	4.47

Based on the conducted observations, it is evident that both rice straw and the addition of MOL significantly impact the growth of rice plants. Plants treated with LOF exhibited greater heights compared to those without LOF. This conclusion aligns with our 7-day observation period, where across three repetitions, the average rice plant growth was notably highest at 4.91 cm, 4.87 cm, and 4.8 cm. Particularly, the combination of 50 g of rice straw and 200 mL of MOL consistently demonstrated the most robust growth among all tested combinations. These finding emphasize the effectiveness of using a combination of 50 g of rice straw and 200 mL of MOL to achieve optimal rice growth when applying LOF. This similar with recent study conducted by Ramandani et al. (2023a) has reported that a combination 50 g rice straw and 200 mL MOL was achieved rice plant growth of 5.00 ± 0.42 cm. This fertilization approach is crucial as it compensates for nutrient deficiencies that would otherwise limit the optimal growth of rice plants (Supartha et al., 2012). Furthermore, the application of LOF is essential due to its role in providing essential nutrients necessary for optimal vegetative growth in plants. Nitrogen (N) is critical for chlorophyll and protein synthesis, deficiencies of which can lead to stunted growth and yellowing. Similarly, Phosphorus (P) supports flower, fruit, and seed development, although excessive amounts can hinder overall plant growth (Rezania et al., 2017). Controlled and balanced application of LOF derived from abundant organic sources such as rice straw not only enhances crop productivity but also reduces dependency on commercially available fertilizers, which are often expensive. The strategic use of rice straw and MOL in LOF significantly enhances rice plant growth, as evidenced by both practical field observations and statistical analyses. This approach not only supports sustainable agricultural practices but also ensures optimal crop health and yield for rice farming communities.

To further analysed the effects of different factors on rice plant growth, we can use a half-normal plot and a Pareto chart as shown in **Figure 1**. These visualizations help identify the most significant factors and their contributions to the response variable. Figure 4 illustrates the analysis of the effects of rice straw (A) and MOL (B) on a response variable, likely average height, using a Half-Normal Plot (a) and a Pareto Chart (b). In the Half-Normal Plot, the standardized effects of the factors and their interaction are plotted against a cumulative normal distribution. The green triangles represent error estimates, while the colour red squares indicate the effects of the individual factors and their interaction. A-Rice straw, denoted with an orange square, and B-MOL, denoted with a blue square, are identified along with their interaction AB. The plot reveals that B-MOL is the most significant factor, followed by the AB interaction, while A-Rice straw has the least effect. The Pareto Chart confirms these findings by ranking the factors based on their t-values. The B-MOL bar has the highest t-value, indicating the most significant impact, although none of the effects exceed the Bonferroni limit for high statistical significance.

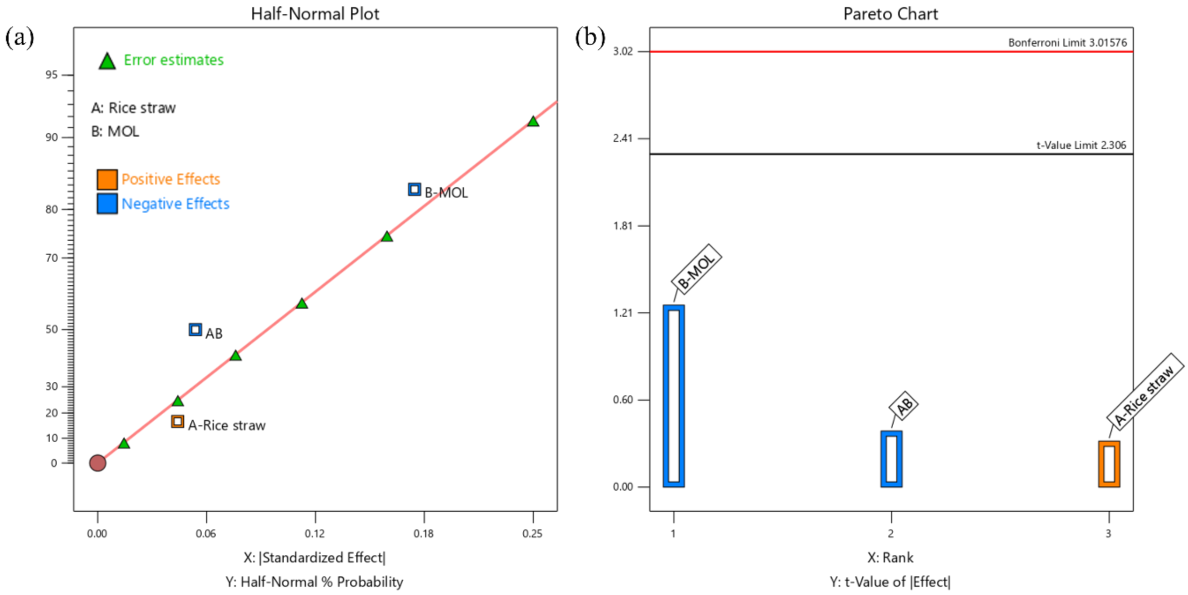

Figure 1. Analysis of significant effects on rice plant growth of (a) half-normal plot and (b) pareto chart

In comparison with other researchers' findings, these results align with studies where MOL (or similar nutrient solutions) often show a more substantial impact on plant growth compared to organic amendments like rice straw. For instance, researchers investigating the effects of different fertilizers on plant growth have frequently found that liquid nutrients can have a more immediate and pronounced effect compared to solid organic matter, which typically acts more slowly as it decomposes. This study's findings are consistent with those of similar studies in agricultural research, reinforcing the significant role of MOL in influencing growth parameters, while also highlighting that interactions between different amendments can play an important role, albeit sometimes less significantly than the primary nutrient source.

3.3 Diagnostics average value of rice plants growth using Design Expert

The diagnostics of the average value of rice plant growth were conducted using Design Expert Version 13. Several diagnostic plots were generated to evaluate the model's assumptions and identify any potential issues with the data or model fit as shown in **Figure 2**. The diagnostic plots for evaluating the average height of rice plants. Plot (a), the Normal Plot of Residuals is used to check if the residuals are normally distributed. In this plot, the internally studentized residuals are compared against a normal probability distribution. The points should ideally lie along the red diagonal line, indicating normal distribution of residuals. The colour gradient from 4.3 to 4.91 represents the average values of the rice plant height. Plot (b), Residuals vs. Predicted, assesses the homoscedasticity and the fit of the model by plotting residuals against the predicted values. Ideally, the residuals should be randomly scattered around the horizontal line at zero without forming any patterns, which would indicate constant variance of residuals (homoscedasticity) and a good model fit. Plot (c), Residuals vs. Run, examines potential trends or patterns related to the order of data collection. This plot displays residuals against the run number, where a random scatter of points suggests no time-related or order effects influencing the residuals. Any noticeable patterns could indicate such effects.

Plot (d), Residuals vs. Block, assesses the effect of blocking within the experiment by showing residuals against different blocks. Random scatter across blocks indicates that blocking has been properly accounted for. A pattern or significant difference in residuals across blocks might suggest block effects. Plot (e), Cook’s Distance, identifies influential observations that significantly impact the model. Cook’s distance measures each observation's influence on the fitted values, with points exceeding the red threshold line indicating highly influential data points. Plot (f), Predicted vs. Actual, evaluates the accuracy of the model’s predictions by comparing predicted values on the x-axis to actual (observed) values on the y-axis. Points should lie close to the 45-degree line (y = x), signifying accurate model predictions. Deviations from this line indicate discrepancies between predicted and actual values. Plot (g), DFFITS vs. Run, identifies observations that significantly influence their own fitted values by plotting DFFITS values against the run number. Points beyond the blue lines suggest influential observations that might affect the model fit. Finally, plot (h), DFBETAS for AB vs. Run, assesses the impact of individual observations on the estimated coefficients for the interaction term AB. This plot shows DFBETAS values for the AB interaction term against the run number, where points beyond the blue lines indicate observations with a substantial impact on the estimation of the AB interaction term.

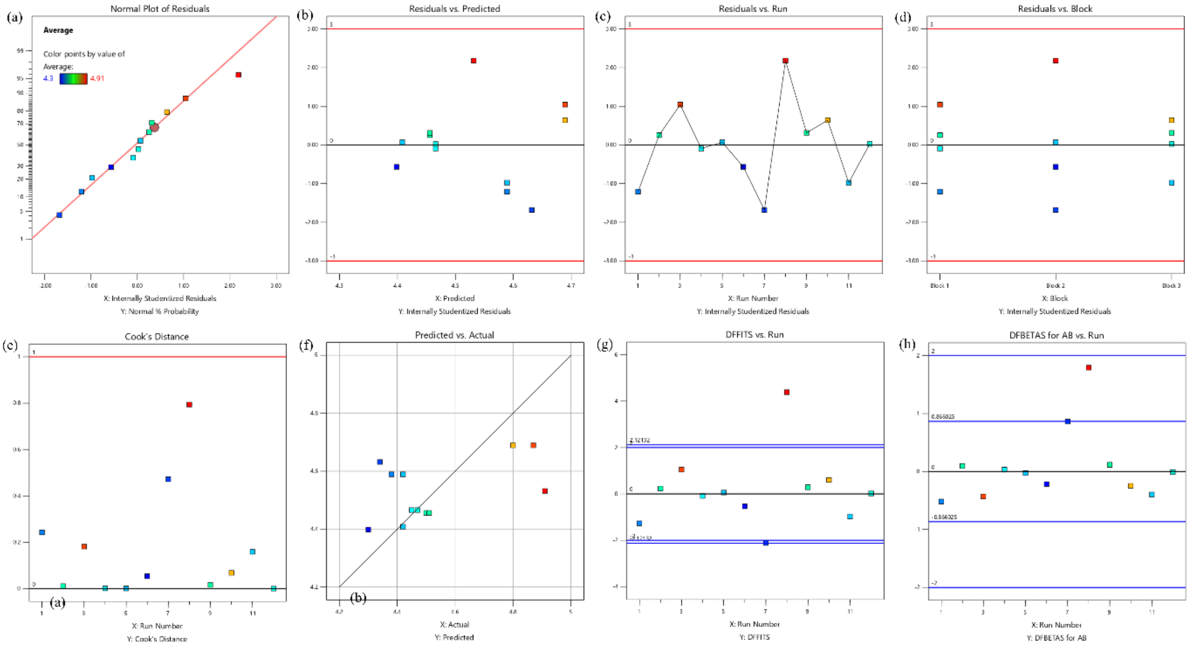

Figure 2. diagnostics average value of rice plants hight (cm) based on (a) normal plots of residuals, (b) residual vs predicted, (c) residual vs run, (d) residuals vs block, (e) Cook’s distance, (f) predicted and actual, (g) DFFITS vs run, and (h) DFBETAS for AB vs run

3.5 Counter plot 3D

A 3D contour plot is an extension where the contour lines are drawn on a 3D surface. This plot allows for visualizing complex surfaces and their variations in three dimensions (x, y, and z axis), as shown in **Figure 3**. The provided 3D contour plot visualizes the relationship between the amounts of rice straw (A) and MOL (B) in grams and mL, respectively, and the resulting average height in cm. The plot includes a color-coded surface where blue and green shades indicate lower values and red represents higher values. Contour lines on the base plane highlight the gradient changes, while design points show specific measured values above and below the surface. These points are marked in red and blue, indicating whether they are above or below the fitted surface. This type of plot is useful for understanding how the two independent variables (rice straw and MOL) interact to influence the dependent variable (average height), aiding in the optimization of the experimental parameters.

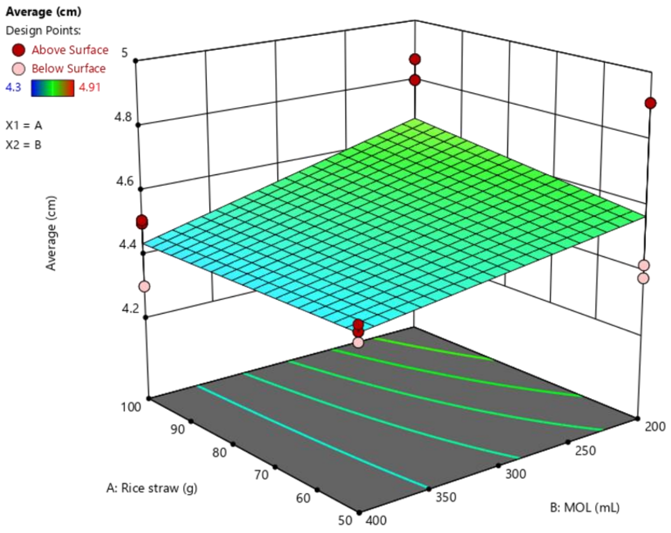

Figure 3. Visualizing complex surfaces and their variations in three dimensional, such as rice straw (x-axis), MOL (y-axis), and average (y-axis)

3.6 Optimization to get best variations for increasing rice plants growth

To determine the optimal conditions for increasing rice plant growth, we used Design Expert Version 13 to analyse the effects of varying amounts of rice straw and MOL on rice plant height (**Table 3**). The goal (in range) is to identify the best combination of these two factors to maximize growth.

Table 3. The effects of varying amounts of rice straw and MOL on rice plant height

Rice straw (g)	MOL (mL)	Rice plant growth (cm)							Average (cm)
		1	2	3	4	5	6	7	
50	266	4	4.325	4.417	4.542	4.650	4.742	4.841	4.530

The optimization process using Design Expert Version 13 successfully identified the best variations for increasing rice plant growth. The optimal combination was found to be 50 g of rice straw with 266 mL of MOL, resulting in an average plant height of approximately 4.841 cm for 7 days. These findings provide valuable insights for agricultural practices aiming to maximize rice plant growth using rice straw and MOL. Further experimental validation is recommended to confirm these results under different conditions.

4. CONCLUSION

In conclusion, the study underscores the efficacy of utilizing fermentation Microorganism Local (MOL) to convert rice straw into Liquid Organic Fertilizer (LOF), thereby enhancing rice plant growth sustainably. The process involves fermenting rice straw with MOL to release essential nutrients that promote soil fertility, improve nutrient uptake efficiency, and support robust rice plant development. The experimental findings from Lampung State Polytechnic demonstrate that combinations of rice straw and MOL significantly influence rice plant height, with the optimal growth observed using 50 g of rice straw and 200 mL of MOL. This approach not only minimizes agricultural waste but also reduces reliance on chemical fertilizers, aligning with principles of sustainable agriculture. The analysis using Design Expert Version 13 further validates the impact of varying rice straw and MOL amounts on rice growth, identifying an optimal combination of 50 g rice straw and 266 mL MOL to achieve peak plant height. Diagnostic plots confirm the model's reliability and suitability for predicting growth outcomes, suggesting robust experimental design and data analysis. Moreover, 3D contours plot visually illustrate the interaction effects between rice straw and MOL, providing insights into how these factors synergistically affect rice plant height. Overall, integrating MOL-driven fermentation of rice straw into agricultural practices offers a promising pathway to enhance crop productivity while mitigating environmental impacts associated with conventional fertilizers. Future research could explore broader applications across different soil types and climatic conditions to further optimize these findings and promote sustainable agricultural solutions globally.

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