Optimization of AB Fertilizer for Plant Growth in Fertigation Using Central Composite Design

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Abstract. A plant needs to consume sufficient essential nutrients for production speed. This study investigated the optimum condition for water spinach growth using wick technique fertigation. Fertigation is a fertilizer application process in which the drip system mixes fertilizer within the irrigation water. The fertilizer solution is uniformly distributed in the irrigation system. The chosen method is a hydroponic method and suitable in an urban area with no soil for planting. Fertigation is also an easy and cost-effective method. The water spinach height's optimum condition was determined through the central composite design (CCD) as the experiment (DOE) design. The critical factors selected for this study were the concentration of AB fertilizer and wick length. Obtaining an adequate AB fertilizer concentration is crucial because it will affect the growth of water spinach. The statistical analysis based on a CCD showed that 1.5 mL of AB fertilizer concentration (volume/volume) and 12 cm of wick length were the optimum conditions to achieve the best water spinach growth in 21 days. The CCD as a response surface method was proved to help obtain optimum water spinach plant growth conditions.

1. Introduction

In the late year of 2019, the COVID-19 pandemic developed quickly and widely across the globe had profound consequences for food safety and nutrition. The unfolding crisis has impacted food systems and, through multiple factors, disrupted people's access to food. In the aftermath of lockdowns caused by the global health crisis, people worldwide have experienced a massive disturbance to food supply chains and a major global economic recession [1]. The combination of consequences of COVID-19 itself through the long run, such as without a wide scale of concerted action, the corresponding mitigating initiatives, and the growing worldwide recession, could threaten food systems' functioning [2]. In Malaysia, the Ministry of Agriculture and Food Industry started the Urban Agriculture Program to help urban households reduce living costs. This program is seen to be a good program through the self-production of some of the foodstuffs needed [3].

Fertigation is widely used in industry agricultural purposes as dispenser units, making it more convenient and comfortable for general landscape projects [4]. A dosing device for the standard solutions where nutrients are inserted, and good irrigation is needed for fertigation. For an urban area, the hydroponic method is more suitable since no soil is necessary for planting. The soil-less production of plants growing using mineral fertilizer solutions. Nutrients are transmitted directly to the roots in this process [5]. Hydroponic vegetables are usually produced in closed systems techniques. Compared to field farming, this method ensures less water is required [6]. The hydroponics method was reported to
successfully apply to cultivate vegetable crops and other plants [7]. Inorganic fertilizers are usually used in hydroponic systems, whereas organic fertilizers cannot be added. These chemical fertilizers are a significant component of hydroponics. There are two formulated functional solutions for fertilizer: solution A and solution B, representing any hydroponic formula. To expand, all plants require seventeen elements. These contain carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), copper (Cu), iron (Fe), sodium (Na), manganese (Mn), boron (B), molybdenum (Mo), and chlorine (Cl). Most of the materials used in the formulation of hydroponics AB nutrients are obtained through these natural sources of minerals in the soil [5,6]. It is expected the plant growth will affect due to the controlled amount of AB fertilizers concentration. Therefore, obtaining the optimization of chemical fertilizer (AB fertilizers) concentrations is essential.

Irrigation is the direct consumption of liquid fertilizer to plant growth. Irrigation aims to specify ample water for plants to reduce the pressure that can decrease productivity. The amount of water and its frequency rely upon local climatic factors, crop and development phase, and soil-moisture-plant features [4]. There is an approach to examining crop measures such as colour or leaf angle transitions, but the result can become too late to prevent crop yield or quality from decreasing. The faster a plant grows, the more fertilizer and water it will require. Consequently, as watering is increased, so is leaching and nutrient loss [8]. Thus, obtaining the need for irrigation that will not involve analysis of evapotranspiration rates is crucial.

In this study, water spinach growth was explored. Water spinach is a semi-aquatic plant that flourishes with little or no supervision. Water spinach contains a fair amount of vitamins A, B6, and C, along with magnesium and fibre. The plant has been considered medicinal in Asia for hundreds of years for its purge effects. The plant also has been studied for its use in India to treat lead toxicity [9]. This study examined the optimum condition for water spinach growth of wick technique fertigation using Central Composite Design (CCD) as experimental (DOE) design. CCD is the typical design of response surface methodology (RSM) and widely used in various experiments. RSM collects mathematical and statistical techniques for designing experiments, building models, evaluating the effects of factors, and searching for optimum condition factors for desirable responses [10]. The optimization process of this methodology involves four steps. Firstly, the statistically designed combinations' responses are studied, followed by estimating the coefficients and fitting them in a mathematical model that best works the experimental conditions. Then, the response of the fitted model is predicted. CCD advantages are that it allows the experimental designer to know what effect the factors had on response. It also provides high-quality predictions of linear and quadratic interaction effects of parameters affecting the process [11]. In this study, two factors (AB fertilizer's concentration and wick length) were used for the optimum height of water spinach growth.

2. Methodology

The material used was AB fertilizer in liquid form, cocopeat, water spinach seed, aluminium foil 1.5-litre bottle, and water. The stock of AB fertilizer used is complimentary from Jabatan Pertanian Negeri Terengganu. The Nutri-pot method was constructed in this hydroponic study. First of all, the cocopeat has been washed and let it wet about 60% and covered with a wet towel. Then, sprout the seed using the egg board and cocopeat for three days. After three days, transfer them into a bottle that has been cut according to the experiment. Next, add AB fertilizer into the water at the bottom of the bottle and cover the bottom with aluminium foil to prevent algae from growing, as shown in figure 1. The experiment was conducted for 21 days to obtain the complete data of water spinach's length.

The CCD again using a coded factor level for the variable, as shown in table 1. Meanwhile, the high and low levels defined for two independent variables were shown in table 2. The manipulated variables were the concentration of AB fertilizer and wick length from the CCD, while the response variable was the water spinach plant's height. The total volume of water used is 500 mL for all 12 experiments. Design Expert 13 software was used to analyze all the obtained data. By using electrical conductivity (EC) meter concentration of AB fertilizer (volume/volume) for coded level -1, 0 and +1 is 1.0 mS/cm, 2.2 mS/cm and 3.8 mS/cm, respectively.
Figure 1. Example of Nutri-pot for the experiments

Table 1. The concentration of AB Fertilizer and Wick Length using Coded Factor Level in Central Composite Design.

| Run | Fertilizer (Volume/Volume) | Wick Length (cm) |
|-----|--------------------------|------------------|
| 1   | -1                       | -1               |
| 2   | 1                        | -1               |
| 3   | -1                       | 1                |
| 4   | 1                        | 1                |
| 5   | 0                        | 0                |
| 6   | 0                        | 0                |
| 7   | 0                        | 0                |
| 8   | 0                        | 0                |
| 9   | 0                        | 1.414            |
| 10  | 1.414                    | 0                |
| 11  | -1.414                   | 0                |
| 12  | 0                        | -1.414           |

Table 2. Experimental Factor and Level in CCD for Concentration of AB Fertilizer and wick length

| Variables                        | Level                  |
|----------------------------------|------------------------|
| Concentration of AB fertilizer   | -1                     |
| (volume/volume)                  | 0                      |
|                                 | 1                      |
| 0.5 mL A + 0.5 mL B             | 1.0 mL A + 1.0 mL B    | 1.5 mL A + 1.5 mL B |
| Wick length (cm)                 | 6                      |
|                                 | 9                      |
|                                 | 12                     |

3. Results and Discussion
Table 3 shows the water spinach height after 21 days of the experiment according to the run, respectively, with the concentration of AB fertilizer (volume/volume) and wick length (cm) as the factors.
Table 3. Height of Water spinach

| Run | Factor 1                        | Factor 2 | Response Height of Water spinach (cm) |
|-----|--------------------------------|----------|-------------------------------------|
| 1   | 0.5 mL A + 0.5 mL B            | 6.0      | 3.1                                 |
| 2   | 1.5 mL A + 1.5 mL B            | 6.0      | 6.5                                 |
| 3   | 0.5 mL A + 0.5 mL B            | 12.0     | 5.5                                 |
| 4   | 1.5 mL A + 1.5 mL B            | 12.0     | 9                                   |
| 5   | 1.0 mL A + 1.0 mL B            | 9.0      | 11.3                                |
| 6   | 1.0 mL A + 1.0 mL B            | 9.0      | 5.1                                 |
| 7   | 1.0 mL A + 1.0 mL B            | 9.0      | 11.5                                |
| 8   | 1.0 mL A + 1.0 mL B            | 9.0      | 8.1                                 |
| 9   | 1.0 mL A + 1.0 mL B            | 13.2     | 6.0                                 |
| 10  | 1.7 mL A + 1.7 mL B            | 9.0      | 12.3                                |
| 11  | 0.3 mL A + 0.3 mL B            | 9.0      | 9.6                                 |
| 12  | 1.0 mL A + 1.0 mL B            | 4.8      | 7.7                                 |

Based on the results obtained in Table 3, statistical analyses were carried out using Design Expert 13.0 software. The ANOVA results in Table 4 show the reaction condition value for F-value, P-value, and R² value. These three components are related to each other by the performance of the experiment.

Table 4. ANOVA for Response Surface Quadratic Model

| Source                  | Sum of Squares | df | Mean Square | F-value | P-value |
|-------------------------|----------------|----|-------------|---------|---------|
| Model                   | 44.73          | 5  | 8.95        | 1.10    | 0.4376  |
| A-Concentration of AB Fertilizer | 14.36          | 1  | 14.36       | 1.77    | 0.2257  |
| B-Wick length           | 0.7787         | 1  | 0.7787      | 0.0957  | 0.7660  |
| AB                      | 0.0025         | 1  | 0.0025      | 0.0003  | 0.9865  |
| A²                      | 0.0003         | 1  | 0.0003      | 0.0000  | 0.9955  |
| B²                      | 29.06          | 1  | 29.06       | 3.57    | 0.1007  |
| Residual                | 56.95          | 7  | 8.14        |         |         |
| Lack of Fit             | 24.39          | 3  | 8.13        | 0.9987  | 0.4794  |
| Pure Error              | 32.56          | 4  | 8.14        |         |         |
| Cor Total               | 101.67         | 12 |             |         |         |

R² = 0.4399, predicted R² = -1.2061, adjusted R² = 0.0398

F-value is a value on the F distribution that measured the distance between individual distributions. Many statistical tests generate F-value. This value can determine whether the test is statistically significant. It is also used to analyze variance (ANOVA) and calculated by dividing two mean squares. This calculation is to determine the ratio of explained variance to unexplained variance. The F-value must correspond to a p-value where if the F-value is high, the P-value will low, which means that when the F-value goes up, the P-value will go down.
As shown in table 4, the F-value for this model is 1.10. It implies the model is not significant relative to the noise. There is a 43.76% chance that an F-value this large could occur due to noise. Then, the lack of fit F-value of 1.00 implies the lack of fit is not significant relative to the pure error. Therefore, a 47.94% chance of a lack of fit F-value could occur because of noise. The non-significant lack of fit is good [12], and the most important is when the model is fitted.

A p-value is a probability measurement to observe a difference that may occur just by a random chance. Generally, the lower the p-value shows, the greater the statistical significance of the observed difference. The p-value can be used as pre-selected confidence levels for hypothesis testing. The p-value that has less than 0.0500 indicates the model term is significant [13]. If the p-value is more than 0.1000, it tells the model term is not significant. This model's p-value is 0.4376 causing the R-square value to be relatively high, which is 0.4399.

R-squared (R²) is a statistical measurement explaining the percentage of the variance for a dependent variable response by the movement of an independent variable [14]. It shows how well the model fits the data or how much variation was explained by the model. R² explains the extent to which the variance of one variable will be presented to the second variable even though the correlation explains the strength of the relationship between independent and dependent variables. Other than that, the higher the value of R², means the more explanation of variation by the model. If this situation happened for a model, it is undoubtedly the best scenario in that model [15]. Next, if there is a low value of R², the model does not explain much about the data variation. As shown in table 5, the results of the value of R² is 0.4399. It means about 43.99% of the variation of the model was explained within the data. This value is a bit low, but the predictor variable still provides information about the response. Even short R² can have a unique contribution to this study. Next, the adjusted and predicted R² value is 0.0398 and -1.2061, respectively. Adj R-squared is a measure of the variation around the mean explained by the model, adjusted for the model's number of terms. The adjusted R-squared decreases as the number of terms in the model increase if those additional terms don't add value to the model. This statistical model showed that the positive value of R² adj is produced. It is an ordinary model to be chosen because there are no warning issues about the variation explained by the model.

| Source    | Std. Dev. | R²   | Adjusted R² | Predicted R² | PRESS   |
|-----------|-----------|------|-------------|--------------|--------|
| Linear    | 2.94      | 0.1489 | -0.0213 | -0.4677 | 149.22 |
| 2FI       | 3.10      | 0.1489 | -0.1348 | -1.2541 | 229.18 |
| Quadratic | 2.85      | 0.4399 | 0.0398 | -1.2061 | 224.29 | Suggested |
| Cubic     | 3.13      | 0.5172 | -0.1588 | -9.9064 | 1108.88 | Aliased |

Next, Pred R-squared measures the amount of variation in new data explained by the model. Table 5 the R² pred value is not within 0.2 to each other, meaning that the terms in this model are not significant, and the number of design points to the unstable prediction. However, the R² pred value is lower than the R² adj that shows the warning sign, but there is no negative impact on the analysis or the conclusions [15].

Figure 2 indicates the relationship of the result surface plots for the height of water spinach (cm) vs wick length (cm), the concentration of AB fertilizer (mL). The factors influencing the variables on response can be seen according to the figure 2. These graphs are used to comprehend the interaction of two reaction variables. The plot below illustrates how the concentration of AB fertilizers (mL), and wick length (cm), impact the height of water spinach (cm) [16].
Figure 2. Response Contour Plot (2D) and Surface Plot (3D) Display Interactive Effect of The Variables on The Height of Water spinach

Based on the contour plot graph, the darker orange regions have a maximum water spinach height (cm). In this graph, a peak of wick length is ten, and showing the value of the concentration of AB fertilizers is at 0.45 at the contour ranges. This response indicates that the higher water spinach length depends on the wick length and AB fertilizers' concentration. Those plots display the influence of two variables at a time on the response.

Generally, the height of water spinach increases with the increase in AB fertilizer concentration. This result is in line with the outcome reported by previous researchers in canola cultivation [17]. It is because fertilizers are crucial for plant growth as a source of nutrients, and the consistency of liquid fertilizers is determined by their pH and nutrient content [18]. In this experiment, the result explains that the concentration of AB fertilizer and wick lengths is not always necessarily in a tremendous amount to obtain a higher value of water spinach's height. The average rate of wick length and AB fertilizer concentration admitted the height of water spinach to increase. The slope of the water spinach height enhanced by the average wick length rates was found to be under the average amount of AB fertilizer's concentration level than at a lower level. Thus, the water spinach plant is accelerated at the mean value of wick lengths and AB fertilizer concentration, resulting from the higher water spinach height. This result agrees with previous researchers' reported work in optimizing AB-mix fertilizer varieties of hydroponic lettuce (Lactuca sativa L.) [19].

4. Conclusion
The response surface method is useful for optimizing the concentration of AB fertilizers. Statistical analysis was developed as a valuable and efficient tool for creating the optimum AB fertilizer concentration for plant growth. The statistical analysis based on the central composite design showed that containing 1.5 mL of A fertilizer and 1.5 mL of B fertilizer concentration of AB in 500 mL water (volume/volume) and 12.0 cm wick length was the best condition to achieve the optimum water spinach growth. Further studies need to carry out to verify the optimum condition for the plant's growth.

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