Fertilizer recommendation for pepper based on soil properties and nutrient uptake

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Abstract. Generally, pepper fertilizer’s application is based on the old recommendation decided by related institutions. Fertilizer application in the SpiceUp project is based on current soil properties and nutrient uptake. This study aimed to compare leaf chlorophyll content and plant growth with fertilization treatment based on soil and nutrient uptake (recommendation) and fertilization treatment based on the old recommendation (conventional). The treatments tested on two varieties of pepper, namely Petaling 1 and Nyelungkup. Measurements of leaf chlorophyll content and plant growth parameters were in a demonstration plot located in Namang District, Central Bangka Regency, Bangka Belitung Islands, from December 2020 to March 2021. The leaf chlorophyll content was expressed by the chlorophyll content index, and plant growth parameters were represented by the number of leaves, number of internodes, number of climbing vines, number of fruit stalks, and plant height. The results showed that the leaf chlorophyll content and plant growth parameters with the recommendation treatment were higher than conventional treatments, in the Petaling 1 and Nyelungkup varieties. The results suggested that recommended treatment of the SpiceUp provided more optimum nutrients for pepper.

Keywords: Bangka, chlorophyll content Index, plant growth, SpiceUp

1. Introduction

Indonesia is one of the largest pepper supplying countries in the international market. However, statistical data showed that productivity per hectare in Indonesia is generally low [1]. This can cause Indonesia's position in the global pepper community to weaken gradually. The obstacle in pepper production is agriculture practices that are still conventional and not carried out optimally. According to the research [2], many pepper plantations owned by farmers have not been cared for well. These are indicated by many symptoms of abnormal plant growth, as well as low production. Symptoms of plant nutrient deficiency with complex causes were also common to find there.

One of the agriculture practices that must be considered is fertilization to provide nutrients for pepper. However, fertilization by farmers is still relatively not optimal, even though pepper is classified as a high nutrient demanding crop [3]. It is based on the results of surveys and interviews, farmers generally provide minimal fertilizer and often do not comply with the recommended dose [4]. In the case of Bangka Island, farmers generally fertilize pepper with relatively low doses of fertilizer, varying from 0.2 to 1.0 kg compound fertilizer (NPK) 15:15:15 plant⁻¹ year⁻¹ [2].
Fertilizers application by farmers is carried out in uniform dose without considering variations in soil characteristics between land units. Furthermore, fertilizers application is also carried out without considering the variation in nutrient requirements of each variety used. Therefore, fertilization research on pepper needs to be done by compiling more specific fertilization guidelines. Soil properties information can explain the availability of soil nutrients in a location. This information is better completed with the nutrient uptake information to have information on plant nutrient requirements of a variety of pepper.

Institutions related to the pepper development published fertilizer recommendations for pepper in Bangka Belitung, but the recommendation has been long not corrected. Some soil properties are dynamically changing from time to time, especially nitrogen (N), phosphorus (P), and potassium (K). The new fertilizer recommendation for pepper is developed based on soil properties and nutrients uptake. The new fertilizer recommendation is expected to provide a balanced the dose of fertilizer to increase the growth and production of pepper.

The objective of the study was to compare leaf chlorophyll content index and plant growth parameters in plots where dose of fertilizers is based on soil properties and nutrient uptake and plots where the dose of fertilizers is based on old fertilizer recommendation.

2. Materials and Methods
This study was conducted in a demonstration plot (demo plot) located in Namang District, Central Bangka Regency, Bangka Belitung Islands, from June 2019 to March 2021. This period is from determining the dose of fertilization, the treatment (fertilization) until observation. The pepper was planted on June 2019 and the gamal was planted two months before. The plant spacing was 2 m x 2 m. Soil and plant analysis were conducted in the Laboratory of Soil Chemistry and Fertility, Department of Soil Science and Land Resource, Faculty of Agriculture, IPB University, Bogor.

![Figure 1. Experimental block in demo plot.](image-url)

The study on fertilizer recommendation for pepper based on soil properties and nutrient uptake was carried out as shown in Figure 1. The treatment of N, P, and K doses consisted of 2 treatments, namely old recommendation (conventional) and recommendation based on soil properties and nutrients uptake.
(recommendation). Block 1 for recommendation treatment with Nyelungkup variety, block 2 for conventional treatment with Nyelungkup variety, block 3 for recommendation treatment with Petaling 1 variety and block 4 for conventional treatment with Petaling 1 variety. The treatment was given in a dose of NPKMg compound fertilizer 12-12-17-2. For the recommendation treatment, NPKMg 12-12-17-2 compound fertilizer was combined with Urea and KCl single fertilizer. The description of each experimental block is described in Table 1.

**Table 1.** Description of experimental block in demo plot.

| Block     | Treatment     | Variety     | Number of Plants |
|-----------|---------------|-------------|------------------|
| Block 1   | Recommendation| Nyelungkup  | 571              |
| Block 2   | Conventional  | Nyelungkup  | 624              |
| Block 3   | Recommendation| Petaling 1  | 605              |
| Block 4   | Conventional  | Petaling 1  | 533              |

Determination of dose for recommendation treatments were made based on the soil properties and plant nutrients uptake analysis. The data for N, P and K fertilizers recommendation were extracted from average values of soil samples collected in the depth of 0-18 cm, 18-33 cm, and 33-60 cm. Available N in the form of nitrate was determined using the quick test method developed by AKVO. Available P was determined using Bray-1 method and the content of P was measured by spectrophotometer. As for available K was extracted using 1 mol L⁻¹ NH₄OAc pH 7.0 and the K content was measured by flame photometer. The N, P, and K uptake by pepper plant as the main crop and *Gliricidia maculate* (gamal) as climbing pole were analyzed. Plant parts, namely leave and plagiotropic branch (fruit stalk), climbing vine, root, and fruit of pepper aging <1 year, 1-3 years, and >3 years were collected and analyzed for total N, P, and K. As for gamal, leave, stem, and root aging >3 years were collected and also analyzed for total N, P, and K. The total uptake of N, P, and K of pepper and gamal respectively were obtained by summing its all plant parts. The ashing method was used to obtain their total, N, P, and K.

Nutrient requirements in this study were determined based on pepper nutrient uptake, gamal nutrient uptake, available soil nutrient, and available organic matter nutrient. The formula for determining nutrient requirements is explained as in equation (1).

\[ NR = (Pepper NU + Gamal NU) - (Soil NA + OM NA) \]  

(1)

*NR* was the amount of nutrients given to meet pepper nutrients need (g plant⁻¹ year⁻¹), *Pepper NU* was pepper nutrient uptake (g plant⁻¹ year⁻¹) resulted of summation of all plant parts, *Gamal NU* was gamal nutrient uptake (g plant⁻¹ year⁻¹), *Soil NA* was the amount of available soil nutrients in planting holes measuring 60×60×60 cm (g planting hole⁻¹), and *OM NA* was the amount of available nutrients from given organic matter (g plant⁻¹ year⁻¹) in the form of manure. The amount of manure given to each plant was 5 kg year⁻¹.

**Table 2.** Pepper nutrient uptake on Petaling 1 and Nyelungkup varieties and nutrient uptake on gamal.

| Plant Type | Plant Age (year) | Nutrient Uptake (g plant⁻¹ year⁻¹) |
|------------|------------------|-----------------------------------|
|            |                  | N       | P       | K       |
| Pepper     | <1               | 43.9    | 6.30    | 18.2    |
| Petaling 1 | 1-3              | 51.7    | 8.70    | 19.9    |
|            | >3               | 153.0   | 27.7    | 93.8    |
| Pepper     | <1               | 28.3    | 4.20    | 13.2    |
| Nyelungkup | 1-3              | 29.7    | 6.10    | 15.0    |
|            | >3               | 139.0   | 18.2    | 55.2    |
| Gamal      | >3               | 96.0    | 11.7    | 178.0   |
Table 3. Availability of soil N, P, and K nutrients in planting hole measuring 60×60×60 cm at the demo plot (BD = 1 g cm⁻³).

| Soil Nutrient | Soil Nutrient Availability (mg kg⁻¹) | Soil Nutrient Availability (g planting hole⁻¹) |
|---------------|-------------------------------------|---------------------------------------------|
| N             | 1.37                                | 0.30                                        |
| P             | 2.71                                | 0.59                                        |
| K             | 17.6                                | 3.80                                        |

Table 2 shows the information on the nutrient uptake of pepper and gamal, and Table 3 shows the information on the availability of soil N, P, and K nutrients in the planting hole. The amount of N in manure was taken into account in the calculation of nutrient need, while P and K in manure were not included because the amount of P and K contained in manure was relatively very low. The total nutrient requirements of pepper plant for Petaling 1 and Nyelungkup varieties with gamal as climbing pole plant based on soil and plant analysis results is shown in Table 4.

Table 4. The nutrient requirements for Petaling 1 and Nyelungkup varieties of pepper with gamal as climbing pole.

| Plant Age (year) | Nutrient Requirements (g plant⁻¹ year⁻¹) |
|-----------------|----------------------------------------|
|                 | Petaling 1 | Nyelungkup |
|                 | N  | P  | K  | N  | P  | K  |
| <1              | 180 | 68.0 | 348 | 154 | 59 | 340 |
| 1-3             | 192 | 77.0 | 352 | 156 | 67.0 | 343 |
| >3              | 358 | 151 | 485 | 336 | 114 | 415 |

The formula for determining the fertilizer dose is explained as in equation (2).

\[
FD = \frac{1}{FNC} \times (NR + LF) \tag{2}
\]

FD was the amount of fertilizer given to meet plant nutrient needs (g plant year⁻¹), FNC was the fertilizer nutrient content (%), NR was the amount of nutrient given to meet plant nutrient needs (g plant⁻¹ year⁻¹), and LF was the amount of fertilizer that was not available or lost so that it cannot be absorbed by plants, which was 64% of NR for N fertilizer, 70% of NR for P fertilizer, and 50% of NR for K fertilizer. The fertilizer applied was compound fertilizer NPKMg 12-12-17-2. Determination of the amount of compound fertilizer given referred to the P nutrient requirements pepper. Nutrient needs of N and K plants that were not met from the application of compound fertilizers were given with the addition of single fertilizers Urea and KCl. The dose of conventional treatment is also shown in Table 5. The application of fertilizers were split evenly three times in a year. Twenty plant samples were observed in each treatments.

The variables observed in this study were leaf chlorophyll content and plant growth. Leaf chlorophyll content was expressed by the chlorophyll content index (CCI), while plant growth parameters were expressed by the number of leaves, the number of internodes, the number of climbing vines (orthotropic branches), the number of fruit stalks (plagiotropic branches), and plant height. The CCI values were measured using the Chlorophyll Content Meter Model CCM-200 Plus, while all plant growth parameters were counted or measured directly on plants. All parameters were counted or measured in a time range of 1-4 months after pruning (MAP) of 2 year old plants. The CCI was measured at 2 MAP, the number
of leaves was counted at 1 MAP, the number of internodes was counted at 2-4 MAP, the number of climbing vines (orthotropic branches) was counted at 1-4 MAP, the number of fruit stalks was counted at 1-4, and plant height was measured at 2-4 MAP. Analyses of variance of completely randomized design followed by a least significant difference (LSD)’s test was applied to evaluate the effect of the treatments to the parameters.

Table 5. Fertilizer dose treatment.

| Variety      | Plant Age (year) | Recommendation Treatment (g plant⁻¹ year⁻¹) | Conventional Treatment (g plant⁻¹ year⁻¹) |
|--------------|------------------|---------------------------------------------|------------------------------------------|
|              |                  | NPKMg | Urea | KCI | NPKMg |
| Petaling 1   | <1               | 564   | 248  | 420 | 300   |
|              | 1-3              | 644   | 256  | 404 | 600   |
|              | >3               | 1,260 | 460  | 452 | 2,400 |
| Nyelungkup   | <1               | 496   | 212  | 424 | 300   |
|              | 1-3              | 556   | 200  | 412 | 600   |
|              | >3               | 952   | 492  | 424 | 2,400 |

Numbers followed by the different letter at the column are significantly different according to LSD test at 5% level.

3. Results and Discussion

3.1. Chlorophyll Content Index (CCI)
The average value CCI on young leaves and old leaves of pepper applied with the conventional and recommended dose of fertilizer is presented in Table 6. The average CCI value on the pepper plant’s young leaves and old leaves with recommendation treatment was higher than conventional treatment, both in Petaling 1 and Nyelungkup varieties. This is in line with the research that the amount of CCI increased with the increasing dose of N fertilizer [5]. The other study also reported a significant correlation between CCI values and N content [6]. These results indicated that the dose of fertilizer given in the recommendation treatment provided more optimal N for pepper. Based on variety, the average CCI value for Nyelungkup variety was higher than Petaling 1, both for young leaves and old leaves. This difference might be related to the morphological characteristic of the varieties.

Table 6. The average value CCI on young leaves and old leaves of pepper applied with the conventional and recommended dose of fertilizer.

| Treatment         | Petaling 1 | Nyelungkup |
|-------------------|------------|------------|
|                   | Young Leaves | Old Leaves | Young Leaves | Old Leaves |
| Conventional      | 48.1 a       | 50.6 a       | 65.3      | 78.9      |
| Recommendation    | 50.8 b       | 70.6 b       | 68.5   | 80.0   |

3.2. Number of Leaves
The average number of leaf on the pepper applied the conventional and recommended dose of fertilizer is presented in Table 7. The number of leaves is strongly influenced by the availability of nutrients, especially P. The increasing P supply led to an increase in the number of leaves because it enhanced the rate of primordial leaf initiation in the stem apex [7]. The results showed that the average number of leaves of the pepper plant with the recommended treatment was higher than that of the conventional treatment, both in the Petaling 1 and Nyelungkup varieties.
Table 7. The average number of leaf on the pepper applied the conventional and recommended dose of fertilizer.

| Treatment       | Petaling 1 | Nyelungkup |
|-----------------|------------|------------|
| Conventional    | 335        | 313        |
| Recommendation  | 421        | 332        |

3.3. Number of Internodes

The average number of internode on the pepper applied the conventional and recommended dose of fertilizer at 2, 3, and 4 MAP is presented in Figure 2 and Table 8.

![Graph of internode growth](image)

(a) (b)

Figure 2. The average number of internodes of Petaling 1 (a) and Nyelungkup (b) varieties at 2, 3, and 4 MAP.

Table 8. The average number of internode on the pepper applied the conventional and recommended dose of fertilizer at 2, 3, and 4 MAP.

| Treatment       | 2 MAP  | 3 MAP  | 4 MAP  |
|-----------------|--------|--------|--------|
|                 | Pt     | Ny     | Pt     | Ny     | Pt     | Ny     |
| Conventional    | 14     | 14 a   | 20     | 20     | 25     | 25     |
| Recommendation  | 15     | 16 b   | 21     | 21     | 26     | 25     |

Numbers followed by the different letter at the column are significantly different according to LSD test at 5% level. Pt = Petaling 1; Ny = Nyelungkup.

The average number of internodes of the pepper plant with the recommended treatment was higher than that of the conventional treatment, both in the Petaling 1 and Nyelungkup varieties. The number of internodes is influenced by the rate of N and P fertilizer. The other research observed an increase in the internode growth with higher P fertilizer dose than lower doses [8]. The other research reported that the response of the number of internodes to the dose of urea was significant, with the optimum rate of urea fertilizer of 1 year old pepper being at 315 g plant$^{-1}$ year$^{-1}$ (145 g N plant$^{-1}$ year$^{-1}$) [9]. The recommendations in this study when the plants were 1 year old were 180 g N plant$^{-1}$ year$^{-1}$, and 154 g N plant$^{-1}$ year$^{-1}$, respectively for the Petaling 1 and Nyelungkup varieties. These results indicated that recommended treatment was able to meet the N and P requirements of the pepper plant.
3.4. Number of Climbing Vines

The average number of climbing vines on the pepper applied the conventional and recommended dose of fertilizer at 1, 2, 3, and 4 MAP is presented in Figure 3 and Table 9.

![Figure 3. The average number of climbing vines of Petaling 1 (a) and Nyelungkup (b) varieties at 1, 2, 3, and 4 MAP.](image)

| Treatment  | 1 MAP | 2 MAP | 3 MAP | 4 MAP |
|-----------|-------|-------|-------|-------|
| Pt Ny     | Pt Ny | Pt Ny | Pt Ny | Pt Ny |
| Conventional | 5 9 11 a 11 9 13 10 a 13 | | | |
| Recommendation | 6 7 15 b 11 12 14 12 b 14 | | | |

Numbers followed by the different letter at the column are significantly different according to LSD test at 5% level. Pt = Petaling 1; Ny = Nyelungkup.

The primary role of N for plants is to stimulate overall growth, including branches [10]. Based on the results, climbing vines were part of the plant that responds quickly to fertilization. The increase in the number of climbing vines (orthotropic branches) at 1-2 MAP was very fast, while it started to slow down at 2-4 MAP. Generally, the average number of climbing vines of the pepper plant with the recommended treatment was higher than that of the conventional treatment, both in the Petaling 1 and Nyelungkup varieties. The other study reported that the number of climbing vines of the pepper plant was influenced by the rate of N fertilizer [9]. This is in line with the result of the research on the coffee plant, that the orthotropic branch is one of the parts of the plant that contained the greatest amounts of N from fertilizer [11]. These results indicated that fertilization with the recommended treatment was able to meet the N requirements of the pepper plant.
3.5. Number of Fruit Stalks

The number of fruit stalks on the pepper applied the conventional and recommended dose of fertilizer at 1, 2, 3, and 4 MAP is presented in Figure 4 and Table 10. The pepper plant’s average number of fruit stalks (plagiotropic branches) with recommendation treatment was higher than that of conventional treatment, both in Petaling 1 and Nyelungkup varieties. At 3-4 MAP, the rate of increase in the number of fruit stalks with conventional treatment slowed down. This result indicated that the supply of nutrients during this period had decreased to an amount below the optimum plant nutrient requirements to support its growth. The other study reported that an adequate N supply provides increased branching of plagiotropic branches of the plant [12]. It was also stated that K affected the levels of sclerenchyma on the stem (orthotropic branches), which increased the formation of buds on the plant stem [13]. The buds then grew into plagiotropic branches. These results indicated that the dose of fertilizer given in the recommendation treatment provided more optimal N and K for pepper.

![Figure 4](image)

**Figure 4.** The average number of fruit stalks of Petaling 1 (a) and Nyelungkup (b) varieties at 1, 2, 3, and 4 MAP.

**Table 10.** The average number of fruit stalk on the pepper applied the conventional and recommended dose of fertilizer at 2, 3, and 4 MAP.

| Treatment    | 1 MAP | 2 MAP | 3 MAP | 4 MAP |
|--------------|-------|-------|-------|-------|
|              | Pt    | Ny    | Pt    | Ny    | Pt    | Ny    | Pt    | Ny    |
| Conventional | 25    | 23    | 36    | 32    | 73    | 75    | 88 a  | 91    |
| Recommendation | 26    | 25    | 44    | 34    | 81    | 81    | 113 b | 106    |

Numbers followed by the different letter at the column are significantly different according to LSD test at 5% level. Pt = Petaling 1; Ny = Nyelungkup

3.6. Plant Height

The average plant height on the pepper applied the conventional and recommended dose of fertilizer at 2, 3 and 4 MAP is presented in Figure 5 and Table 11. Several studies reported that pepper plant height was affected by balanced N, P, and K fertilization [14, 15]. The average plant height of pepper plants with recommendation treatment was higher than that of conventional treatment, both in Petaling 1 and Nyelungkup varieties. These results indicated that the dose of fertilizer given in the recommendation
treatment provided more optimal nutrients for pepper. A similar result was found that the balance N, P, and K fertilization caused the pepper plant height to be higher than the control treatment [16].

![Graphs showing plant height over time for Petaling 1 and Nyelungkup varieties](image)

**Figure 5.** The average plant height of Petaling 1 (a) and Nyelungkup (b) varieties at 2, 3, and 4 MAP.

**Table 11.** The average plant height on the pepper applied the conventional and recommended dose of fertilizer at 2, 3, and 4 MAP

| Treatment          | 2 MAP (cm) | 3 MAP (cm) | 4 MAP (cm) |
|--------------------|------------|------------|------------|
|                    | Pt  | Ny | Pt  | Ny | Pt  | Ny | Pt  | Ny |
| Conventional       | 99.0 | 86.6| 144 | 133 | 175 | 146 |
| Recommendation     | 104  | 103 | 152 | 143 | 184 | 178 |

Numbers followed by the different letter at the column are significantly different according to LSD test at 5% level. Pt = Petaling 1; Ny = Nyelungkup.

**4. Conclusions**
The fertilizer recommendation based on soil properties and nutrient uptake can provide more precise information on pepper nutrient requirements. This was shown by the higher values of leaf chlorophyll content and plant growth parameters of the recommendation treatment than the conventional treatment, both in Petaling 1 and Nyelungkup varieties. The results indicated that the recommendation treatment of SpiceUp provided more optimum nutrients for pepper.

**Acknowledgment**
The authors would like to thank the Netherland Space Office for funding the SpiceUp project. The authors also would like to thank the ICCO, PT. CAN, AKVO and IPB University soil team for cooperation and helps in the field and laboratory.
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