DETERMINATION OF MACRONUTRIENTS SEQUENCE ON RED CHILI PEPPER (Capsicum annuum L.) BY DRIS METHOD

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Abstract: Most of Indonesian like a spicy food, and they put chili pepper to get a spicy flavor. Due to of that, chili pepper becomes a primary ingredient in every single kitchen in Indonesia. The increasing of chili pepper demand, especially red chili pepper, do not meet their production, so that we need a technology to improve the production. DRIS (diagnosis and recommendation integrated system) is one of the way to identify the nutrient sequence needed by plant. Macronutrients, such us nitrogen (N), phosphorus (P), and potassium (K), are an essential nutrients which influence the plant growth and development. Knowing what the essential nutrients sequence needed by plant can optimize the metabolism system which induce their production. This research was conducted to find out the macronutrients sequence needed by red chilli pepper in Wuluhan, Jember. This area is a center area of chili pepper cultivation in Jember. One area of red chili pepper cultivation field with high productivity was selected, then decided as an indicator. Two red chili pepper fields (Field 1 and Field 2) were selected purposevisely, then samples (soils and leaves) were collected. Samples were analyzed then DRIS diagram were made. The results showed that those fields were K deficiency. Futhur analysis described nutrient sequence in those area tended to be the same, there were K>P>N and K>P≥N in Field 1 and Field 2, respectively. It means those areas should be fertilized first by potassium then phosphorus then nitrogen.

1. Introduction

Chili pepper (Capsicum annuum L.) is one of the most favourite ingredient for Indonesian. Most of them like a spicy food that is way chili pepper always be ready in every single kitchen in Indonesia. Beside giving a spicy flavor, fruit of chili pepper are an excellent source of natural, micronutrient antioxidants (vitamins C and E and carotenoids) which appear to be critically important in preventing or reducing chronic and age-related diseases [1]. Another study conducted by Rachmawati [2] showed that vitamin C contained in chili pepper is about 59.9 mg 100 ml-1.

The requirement of chili pepper in Indonesia is increasing year by year. Based on data from Suwandi [3], chili pepper needs in city populated around one million people is about 800,000 ton year-1 or 66,000 ton month-1. The needs of chili pepper increase up to 10-20% on special day, such us wedding time and celebration of Holiday, compared to normal needs. Generally, it needs around 11,000 ha month-1 for harvesting area, then during special day increases 12,100 - 13,300 ha month-1.

Data from Central Bureau of Statistics [4] declared that red chili pepper production was 1.045 million ton on 2016. East Java especially produced 91,135 and 95,541 ton on 2015 and 2016,
respectively. Its productivity have not meet the chili pepper needed. Increasing of its production by intensification and extensification should be conducted. One of the way to improve its production through intensification is application of fertilizer, mainly fertilizer containing macronutrients such as nitrogen (N), phosphorus (P), and potassium (K). Those macronutrients are an essential nutrients which affect on plant growth and development. However, farmers usually apply the fertilizer just the way they used to do. This inappropriate way cause unmaximalize the red chili pepper plant production.

Understanding the nutritional status of plants could be considered by tissue analysis. It needs a specific part of the plants to conducting the diagnose. That part is leaf tissue. The leaf tissue is considered the most important part of the plant where the physiologic activate happens and this tissue shows easily the nutritional disturb. To use the leaf tissue is necessary to have the chemical analyses. Furthermore, to assess the nutritional status there is the need to have leaf standard to sample, this leaf standard depend on the crop that intend to evaluate, but, nowadays there are many information about the most cultivated commercial crops. The leave diagnose can be a useful tool to assess the nutritional status of plant, but, the procedure to analyse the data must be appropriate. Furthermore, because of natural dynamic of the leaf tissue composition that is strongly influenced by leaf age, maturation stage and interaction among nutrients on uptake and translocation into the plant, if all the damages criteria were not observed the leaf diagnose becomes very difficult to understand and used [5].

The Diagnosis and Recommendation Integrated System (DRIS) was developed by Beaufils in 1973 [6]. If the other method usually use of sufficiency range or critical level to determine the nutrients content, this method focus on relation between a pair of nutrients (N/P, P/N, N/K, K/N, and so on). [5] DRIS enables the evaluation of the nutritional balance of a plant, ranking nutrient levels in relative order, from the most deficient to the most excessive.

According to Baldock & Schulte [7], there are four advantages of DRIS; (1) the scale of interpretation is continuous numeric scale, and easy to use, (2) put the nutrients in order of the most deficiency to the most excessive, (3) identify cases where the yield of plant is been limited by into factor as nutritional status and (4) the Nutritional Balance Index (NBI) give a result of combined effects of nutrients. [5] Nevertheless, the disadvantage of this methodology is that the DRIS index is not independent, because one nutrient concentration can have hard influence on the other DRIS index for one nutrient but this problem can be corrected in parts with a hard selection of the nutrient that will compound the DRIS norms.

Therefore the aim of this study was to indentify the relative sequence of macronutrients in red chili pepper fields in order to minimize inefficiency of fertilizer applied by farmers.

2. Methods

This study was conducted on Mei to August 2018 in Wuluhan, Jember, East Java (ordinat). This location was selected due to a center area of red chili pepper production in Jember.

Top soil was collected (0-20 cm) then soil was mixed and air drying [8]. The air drying of top soil was sieved by 2 and 0.5 mm sieves. Soil texture was analyzed by hydrometer method, and soil pH was measured by pH meter. Organic carbon (C) was analyzed by Walkley Black method. Total soil-N was analyzed by Kjeldahl method. Available P (P2O5) was analyzed by wet oxidation by extracted with HNO3+HClO4 and molybdovanadat, then measured by spectrometry. Available K (K2O) was analyzed by wet oxidation also by extracted with HNO3+HClO4 then measured by Atomic Absorption Spectrophotometer (AAS). Cation exchangeable capacity (CEC) was measured by extracted with NH4OAc 1M pH 7.0.

Plant sampling was collected based on Mahbub [9]. Plant samples was taken at starting of reproduction phase (about 2 months after transplanting) on 10 samples plant representative all of the...
plant in the study site. In the site which had high productivity of red chilli pepper was selected as the standard to arrange DRIS map. The other two sites, Field 1 and Field 2, which produced low yield of red chili pepper were selected as study site to determine macronutrients sequence. Samples were collected at sunny day around 8 – 12 am. The picked leaves were the third leaf from the shoot, clean, and healthy leaves (did not show any indicate of pest and disease attack). Then it was washed and ovened at 65°C during 48 hours. After that, it was grinded and analyzed the N, P, K content, same method as soil analysis conducted.

To be feasible the use of DRIS to assess the nutritional status of plants, the first step was establish the DRIS norms or standard. The DRIS norms consist on average and standard deviation of dual ratio between nutrients (N/P, N/K, P/K) obtained from the crop reference shows high yield [6]. The data bank to compose the DRIS norms was formed by the crop yield and chemical analysis of leaf tissue [10] [11]. The DRIS index was calculated and for each nutrient a DRIS index was determined, which may have positive or negative values, that represent the arithmetic average of functions in which the nutrient is involved, when the result is negative (below zero), this means deficiency and when the positive value indicates excess, as proposed by Beaufils [6]. The formula to determine DRIS index was described below.

\[
\begin{align*}
N \text{ index} &= \frac{f(N/P) + f(N/K)}{2} \\
P \text{ index} &= \frac{-f(N/P) + f(P/K)}{2} \\
K \text{ index} &= \frac{-f(N/K) - f(P/K)}{2}
\end{align*}
\]

Then, to calculate of their function on nutrient comparison, used the following formula.

If \(N/P > \frac{a}{b}\), then \(f(N/P) = \left(\frac{N/P}{a/b} - 1\right) \times \frac{100}{CV}\)

If \(N/P < \frac{a}{b}\), then \(f(N/P) = \left(1 - \frac{N/P}{a/b}\right) \times \frac{100}{CV}\)

Note : \(a/b\) is norms, \(N/P\) is ratio of N and P content, CV is coefficient variation of \(a/b\). Those formulas also used to calculated the other dual ratio of \(N/K\) and \(P/K\).

DRIS map was drawn based on dual ratio between nutrients from high productivity site. In each ratio was calculated mean (X), standard of deviation (SD), and coefficient of variation (CV). Each norms (N/P, N/K, P/K) was drawn of their axis and the intersection among the axis was the value of the norms. The center point was the mean value of dual ratio between nutrients. If the value of dual ratio between nutrients inside the inner (X ± 2/3 SD) circle, between inner and outer (X ± 4/3 SD) circle, and out of outer circle mean sufficient, deficiency-prone or excess-prone, and deficiency or excess, respectively.

3. Result and Discussion

Soil characteristics in the study sites (Field 1 and Field 2) tended to be the same (Table 1). Actual pH (pH H₂O) was categorized in neutral. Foth (1990) described that nitrogen availability is maximum between pH 6 and 8, because this is the most favorable range for soil microbes that mineralize the nitrogen in organic matter. But, the analysis showed the different result, total N was low in both fields. Concentration of soil organic-C, available P and K were very low. It might be caused of an intensive red chili cultivation with low input of organic matter. Soil was classified as loamy sand. This class texture indicated that soil was dominated by sand. Soil CEC was high in both study site.
Table 1 Soil characteristics in study sites

<table>
<thead>
<tr>
<th>Site</th>
<th>pH</th>
<th>H₂O (%)</th>
<th>C-org (%)</th>
<th>Total N (%)</th>
<th>P₂O₅ (%)</th>
<th>K₂O (%)</th>
<th>CEC (cmol/kg)</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field 1</td>
<td>7.0</td>
<td>0.4</td>
<td>0.19</td>
<td>0.22</td>
<td>2.55</td>
<td>32.3</td>
<td>74.4</td>
<td>Sand (%) 10.0, Silt (%) 74.4, Clay (%) 15.6</td>
</tr>
<tr>
<td>Field 2</td>
<td>7.1</td>
<td>0.1</td>
<td>0.15</td>
<td>0.21</td>
<td>1.98</td>
<td>27.6</td>
<td>74.8</td>
<td>Sand (%) 12.0, Silt (%) 74.8, Clay (%) 13.1</td>
</tr>
</tbody>
</table>

Although DRIS standard was obtained from a limited field data, it could be a guideline to determining on nutrient sequence of the most limiting production and sequence of plant nutrient requirements, also, enable to diagnose nutrient imbalances at various stages of plant growth. By DRIS method, nutrient requirement sequence is relatively constant, it means eventhough sample was taken at different stage of plant growth on one period, DRIS index is relatively constant [12].

Qualitative diagnose which describe range of nutrient balancing for each nutrient ratio could be categorized as deficiency, sufficient, and excess [13] [14]. Dual ratio between nutrient was categorized in 5 ranges, i.e. deficiency, deficiency-prone, sufficient, excess-prone, and excess (Table 3). In each dual nutrients ratio had different range of classification depend on the leaf tissue analysis. While DRIS map was made to simplify how to interpret and read the value of dual nutrient ratio, shown in Diagram 1. If the value of nutrient ratio inside the inner circle, it means both nutrient were balance, given → arrow. If the result was away from the center of the diagram, it means those nutrient were slightly balance, given ↗ or ↘ arrows if the nutrient ratio value between inside and outer circle, and imbalance given ↑ and ↓ arrows if the the nutrient ratio value out of outer circle.

DRIS map could predict the dominant nutrient needed by plant, mainly for improving plant growth and development related to the yield target. On suitable condition of the plant, existence of N, P, and K nutrients are the main macronutrient determine the yield production. DRIS map also describe that to achieve a maximum production need a good management nutrient which try to get a nutrient ratio value on the inside of inner circle [15] [16].

Table 2 Nutrient ratio value of norms, standard deviation, and coefficient of variation from red chilli pepper’s leaf

<table>
<thead>
<tr>
<th>Nutrient Ratio</th>
<th>Norms (X)</th>
<th>Standard Deviation (SD)</th>
<th>Coefficient of Variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/P</td>
<td>8.35</td>
<td>0.58</td>
<td>6.99</td>
</tr>
<tr>
<td>N/K</td>
<td>0.98</td>
<td>0.16</td>
<td>16.76</td>
</tr>
<tr>
<td>K/P</td>
<td>8.68</td>
<td>1.44</td>
<td>16.57</td>
</tr>
</tbody>
</table>

Table 3 Nutrient status ratio value of red chilli pepper

<table>
<thead>
<tr>
<th>Nutrient Ratio</th>
<th>Deficiency</th>
<th>Deficiency-prone</th>
<th>Sufficient</th>
<th>Excess-prone</th>
<th>Excess</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/P</td>
<td>&lt; 7.57</td>
<td>7.57 - &lt; 7.96</td>
<td>7.96 - 8.74</td>
<td>&gt; 8.74 - 9.13</td>
<td>&gt; 9.13</td>
</tr>
<tr>
<td>N/K</td>
<td>&lt; 0.76</td>
<td>0.76 - &lt; 0.87</td>
<td>0.87 - 1.09</td>
<td>&gt; 1.09 - 1.20</td>
<td>&gt; 1.20</td>
</tr>
<tr>
<td>K/P</td>
<td>&lt; 6.77</td>
<td>6.77 - &lt; 7.72</td>
<td>7.72 - 9.64</td>
<td>&gt; 9.64 - 10.60</td>
<td>&gt; 10.60</td>
</tr>
</tbody>
</table>

Table 4 and Diagram 1 described that in Field 1 dual ratio between nutrients of N/P and N/K were categorized as excess, while K/P was deficiency. Dual ratio between nutrients of N/P, N/K and K/P in Field 2 were categorized as sufficient, excess, and deficiency, respectively.
Diagram 1 DRIS map to diagnose N, P, K nutrients needed by red chilli pepper in Jember. Values showed in DRIS circle map were getting from Table 2. Arrows showed nutrient status, ↑: excess, ↗: excess-prone, →: sufficient, ↘: deficiency-prone, ↓: deficiency.

Table 4 Nutrient deficiency diagnosis in field 1 and field 2 based on DRIS diagram

<table>
<thead>
<tr>
<th>Sites</th>
<th>Nutrient Content in Leaves</th>
<th>Dual Ratio Between Nutrient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>Field 1</td>
<td>4.66</td>
<td>0.44</td>
</tr>
<tr>
<td>Field 2</td>
<td>4.71</td>
<td>0.54</td>
</tr>
</tbody>
</table>

Table 5 Determination of relative nutrient sequence depend on nutrient index on red chilli pepper

<table>
<thead>
<tr>
<th>Sites</th>
<th>Nutrient Content in Leaves (%)</th>
<th>Nutrient Index</th>
<th>Nutrient Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field 1</td>
<td>4.66 0.44 2.43</td>
<td>46.77 -0.94 -45.83</td>
<td>K&gt;P&gt;N</td>
</tr>
<tr>
<td>Field 2</td>
<td>4.71 0.54 1.18</td>
<td>93.72 87.55 -181.27</td>
<td>K&gt;P≥N</td>
</tr>
</tbody>
</table>

Determination of nutrient index is a quantitative diagnose to describe nutrients sequence priority applied to the field to improve nutrient balance. In this case, leaf tissue analysis is the appropriate way to diagnose the nutrient. The nutrient index is showed in positive and negative values, indicates the nutrient on excess or deficiency level [16]. Based on leaf tissue analysis showed that the relative nutrients sequence tended to be the same (Table 5). In the Field 1, the requirement of K was higher than P, compared to N which on sufficient condition. While in Field 2 the most nutrient requirement was K than other two nutrients.
It is assumed that K⁺ binds to the enzyme surface, changing the enzymic conformation and thus leading to enzyme activation [17]. Increasing of active anzyme leads to a high metabolism activity which induce to plant growth and development. [18] Aldana explained that K rates significantly affected plant growth, increasing height, weight, stem diameter, leaf area, and dry weights of plant sections with increasing rates in nutrient solution. K rates also affected plant yield and some fruit quality variables in tabasco pepper production. Compared to the result of this study, deficiency of K (Tabel 4) in both fields will affect on red chilli pepper yield production and quality. If the value of nutrient index is negative, it means that nutrient at low status compared to other nutrients. In the other words, if the value of nutrient index is negative, it means that nutrient needed by plant, more negative value so strongly needed by plant, due to that nutrient on a deficiency condition to promote plant growth and development. Conversely, if the value of nutrient index is positive, it means that nutrient is relatively sufficient or excess, so it does not need more input added.

4. Conclusion
a. The nutrient sequence on red chili pepper based on DRIS method was K>P>N and K>P ≥N on Field 1 and Field 2, respectively.

b. The most deficiency nutrient on both fields was K.

References

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