Smart farming on pepper for fertilizers recommendation in Bangka Belitung

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Abstract. Bangka Belitung, Indonesia was once known for pepper production before farmers switched to tin mining. Pepper plantations are still cultivated by individual farmers and significantly occupying large areas. It is necessary to provide fertilizer recommendations for farmers which is easily to be accessed. In the program of SpiceUp, farmers can simply inform the coordinates of their agricultural land so that farmers can obtain data on soil properties and fertilizer recommendations. Land units were developed and representative soil samples with the depth of 0-30 cm were collected in each land units. By using the soil data and nutrients absorption and put the loss factor of fertilizers the formula for fertilizers recommendation in each points were developed. The final productions were map of N, P, K and other nutrients status and map of fertilizers recommendation for N, P and K. These information were stored in the database centre. By sending the coordinates of their lands, the database centre sends the information for their soils nutrient status and N, P and K fertilizers recommendation. By developing this system, it is expected agriculture 4.0 could be reached by pepper farmers in Bangka Belitung for fertilizers application.

Keywords: Agriculture 4.0, map of N, P and K, nutrient status

1. Introduction
Bangka Belitung is a province in Indonesia that was previously a famous producer of pepper before farmers switched to tin mining. They cultivated pepper as the main crop on their farms. However the area of land cultivated by farmers for pepper is still relatively occupying large areas. Therefore economically, pepper still contributes relatively large to the welfare of farmers in Bangka Belitung. The government and the private sector through various projects are trying to increase pepper production. One of the needs of farmers related to increase the production is information on soil nutrient status and fertilizer recommendation. Pepper in Indonesia, is cultivated in various types of soil ranging from soils with high in clay content to soils with high in sand content [1]. The major soil orders where pepper is cultivated are Ultisols, Inceptisols, Entisols, Alfisols, and Oxisols [2]. In Bangka Belitung, pepper is grown in several different parent materials. The soil texture is generally sandy with different soil chemical properties. Although the spatial characteristics of the soil are different, the amount of fertilizers applied among pepper farmers are not based on the soil characteristics. The pepper farmers in Bangka Belitung apply the fertilizers without knowledges of their soils.
The land suitability criteria issued by the Ministry of Agriculture [3] describe that pepper is an adaptive plant with not many requirements needed especially related to soil nutrient status. High annual rainfall, light soil texture and organic matter content are basic requirements for pepper to grow well. However, in order to achieve production in accordance with the genetic potential of the pepper cultivated, the knowledge of nutrient status and how much fertilizer is applied is important because genetically high yielding pepper requires a good growing environment that supports its genetic potential. Hamza et al. [4] reported that soils of high yielding black pepper plantation have characteristics that the soil texture are sandy to loam, soil pH close to neutral value, exchangeable bases are high, organic carbon is high and micronutrients are sufficient especially zinc.

Current data on the status of soil nutrients in Bangka Belitung and how much nutrients absorption in Bangka Belitung relatively are not yet available. The data of nutrient absorption were published for some countries such as in Kuching, Malaysia [5], [6], India [7] and Brazil [8] and [9]. They revealed that the nutrient absorbed by pepper following the order from high to low were nitrogen (N), potassium (K), phosphorus (P), calcium (Ca) and magnesium (Mg). They also revealed that micronutrients (Fe, Mn, Cu, Zn) were also absorbed by pepper. However the original data of nutrient absorption of pepper in Bangka Belitung were not available. The data of soil nutrients status and nutrients absorption are very necessary to calculate how much fertilizer is needed so that fertilization is done right because it is based on soil nutrients status data and pepper nutrient absorption data.

Farmers in Bangka Belitung have difficulties to access the knowledges or information of their soils nutrient status. This is because they can not send their soil samples easily to the soil laboratory and they do not have any tools to assess their soils. Therefore they need tools which are easily accessed without sending their soil samples to the laboratory.

In Agriculture 4.0, information technology is widely combined to speed up the process and gain the precise data and decision. The signal of smartphone is already receivable widely in many areas including villages in Bangka Belitung. SpiceUp project works to create information system where information can be accessed by pepper farmers using their smartphones. Farmers simply send the coordinates of their agriculture land through their smartphone and this will be responded quickly by the system to deliver the messages of fertilizer recommendation and other information related to the pepper cultivation.

The objective of the research was to provide soil data in Bangka Belitung, nutrients absorption of pepper, maps of nutrients and maps of fertilizers recommendation.

2. Materials and methods

Map of landsystem scale 1:250,000 [10] was used to reveal land units. The study revealed 26 land units. The map showing the land unit in Bangka Belitung and soil samples distribution is presented in Figure 1. Land unit was the land with same characteristic based on slope, soil type, parent material and other soil properties and climate. Representative amount of soil samples points were determined in land units map. Soil samples were collected in 0-30 cm depth in each points compositely. The amount of soil samples collected was 161 samples. Soil samples were analyzed for soil pH, exchangeable Al, the content of total N, the content of available N (nitrate), the content of available P (Bray 1 P), exchangeable basic cations (Ca, Mg, K, Na), and micronutrients namely Fe, Mn, Cu, Zn.

Soil pH (pH H2O) was extracted by distilled water and measured the pH with pH meter. Exchangeable Al was extracted by 1 mol L⁻¹ KCl and then Al were determined by titration method. Nitrate was determined using quick test developed by AKVO combining strip paper test colorimetry and smartphone. Available P was extracted by method developed Bray and Kurtz [11]. The content of P was then determined colorimetry by spectrophotometer. Ca, Mg, K and Na were extracted by 1 mol L⁻¹ NH₄OAc pH 7.0 and the content of Ca and Mg were determined by atomic absorption spectrophotometer (AAS) while K and Na were determined by flame photometer. Fe, Mn, Cu and Zn were extracted by DTPA and their contents were measured by AAS.

Pepper Lampung variety with the age of less than 1 year, 1-3 years and above 3 years were also collected. Biomass of root, stem, leaves and fruit of those pepper were measured. Those samples were
analyzed for the content of N, P, K, Ca, Mg, Fe, Mn, Cu, and Zn. Absorption of certain nutrient in root, stem, leaves, and fruit were determined by multiplying the content and biomass. Total absorption was the sum of absorption of all parts. Except N, the method used was wet destruction using concentrated nitric acid and perchloric acid. N was obtained by Kjeldahl method. The content of N was determined by titration method. P was determined colorimetry by spectrophotometer. Ca, Mg, Fe, Mn, Cu and Zn were measured by AAS and K was measured by flame photometer. Besides the pepper, the supporting tree for pepper, it is *Gliricidia maculate* (gamal) was also measured for the biomass of root, stem and leaves and analysed for N, P and K contents. The N, P and K absorption were determined by multiplying the N, P and K contents by biomass of each parts. The total absorption of N, P and K of gamal was the sum of absorption of all parts.

![Figure 1](image)

*Figure. 1. Map of land units and soil samples distribution in Bangka Belitung*

The results of soil analyses (soil pH, exchangeable Al, available N, P, K, Ca, Mg, Fe, Mn, Cu and Zn) were mapped. Fertilizers recommendation were formulated by taking into account the amount of soil nutrients and nutrients absorbed by pepper and gamal. It also took into account the lost factor of nutrients in the soil.

3. Results and discussion

3.1. The soil characteristics of soil properties

The soil characteristics are presented in Table 1, 2, and 3. The soil pH in general were very acid. Some locations showed the pH close to 6. The organic C of the soils varied from very low to very high. Total N were in general very low and also it was reflected in their low nitrate contents. Available P were in general very low however some locations showed high status of available P. Basic cations (Ca, Mg, K and Na) in general were very low with some locations showed high content of those cations. Cation exchange capacity, base saturation, exchangeable Al and micronutrients showed the similar pattern. They varied from very low to very high status. Soil texture also varied from sand to clay but in general the soil texture were sandy loam where the sand fractions were about 60%. Judging from their physico-chemical properties the soil in Bangka Belitung relatively low in soil fertility. Absolutely the soils should be improved by soil ameliorants and fertilizers.

3.2. The nutrients absorption of pepper and gamal

The nutrients absorption of pepper and gamal are presented in Table 4 and Table 5 respectively. Table 4 showed that N, P and K were the main nutrients absorbed by pepper. N absorption was the highest compared to other nutrients. It was followed by K and P. Ca, Mg are lower absorption than that of K
and P but they were higher compared to micronutrients (Fe, Mn, Cu, Zn). As micronutrients, Fe, Mn, Cu and Zn were absorbed in low amount by pepper. However these micronutrients are essential nutrients for pepper [12]. They could affect the growth pattern of the pepper. Therefore the availability of nutrients not only N, P, K, Ca, Mg should be concerned but also the availability of the micronutrients.

As for gamal, high amount of N, P and K were absorbed. The amount N absorbed by gamal was higher than absorption of K and P while K absorption was higher than absorption of P. The amount of N, P and K absorbed by gamal as supporting tree were more than five times higher that those of pepper. These results suggested that there was competition between pepper and gamal for the nutrients. Therefore the application of N, P and K fertilizers and other fertilizers should fulfilled the nutrients needed by both plants.

| Table 1. The characteristics of soil pH, total, N, nitrate and available P of Bangka Belitung |
|-----------------------------------------------|-----------------|--------|--------|--------|------|
| pH (H₂O)                                      | Organic C       | Total N | Nitrate | Bray 1 P |
| Minimum                                       | 3.49            | 0.08   | 0.03   | 2.06   | 2.00 |
| Maximum                                       | 6.73            | 22.7   | 0.37   | 73.2   | 35.7 |
| Average                                       | 4.48            | 2.50   | 0.15   | 7.86   | 7.28 |
| Standard Deviation                            | 0.39            | 2.13   | 0.05   | 7.83   | 6.71 |

| Table 2. The characteristics of basic cations and cation exchange capacity |
|-----------------------------------------------|-----------------|--------|--------|--------|------|
| Ca                                            | Mg              | K      | Na     | Cation Exchange Capacity |
| Minimum                                       | 0.01            | 0.04   | 0.01   | 0.02   | 0.80 | 0.99 |
| Maximum                                       | 10.9            | 2.31   | 1.68   | 7.80   | 45.6 | 100  |
| Average                                       | 0.71            | 0.30   | 0.14   | 0.18   | 8.06 | 20.9 |
| Standard Deviation                            | 1.19            | 0.32   | 0.15   | 0.66   | 6.34 | 25.4 |

| Table 3. The characteristics of exchangeable Al, micronutrient, sand, silt and clay |
|-----------------------------------------------|-----------------|--------|--------|--------|------|
| exchangeable Al                               | Fe              | Cu     | Zn     | Mn     | sand | silt | clay |
| cmol c kg⁻¹                                   | mg kg⁻¹         | %      |------|------|------|------|------|
| Minimum                                       | 0.00            | 5.60   | 0.05  | 0.34  | 0.05 | 8.16 | 0.71 | 1.01 |
| Maximum                                       | 12.8            | 598    | 2.24  | 15.2  | 10.4 | 95.1 | 57.4 | 74.9 |
| Average                                       | 2.10            | 95.2   | 0.35  | 1.25  | 0.94 | 60.3 | 9.28 | 30.7 |
| Standard Deviation                            | 1.59            | 78.9   | 0.36  | 2.05  | 1.16 | 16.6 | 9.17 | 14.0 |
Table 4. The nutrients absorption of pepper Lampung variety

| Element | Age (year) | < 1 | 1-3 | >3 |
|---------|------------|-----|-----|----|
|         | g plant\(^{-1}\) |     |     |    |
| N       |            | 43.9| 51.7| 153|
| P       |            | 6.30| 8.70| 27.7|
| K       |            | 18.1| 19.9| 93.8|
| Ca      |            | 11.8| 8.85| 42.6|
| Mg      |            | 1.85| 1.36| 5.28|
| Fe      |            | 1.08| 0.34| 1.54|
| Mn      |            | 0.18| 0.13| 0.40|
| Cu      |            | 0.03| 0.03| 0.10|
| Zn      |            | 0.26| 0.04| 0.15|

Table 5. The nutrients absorption of gamal (Gliricidia maculata)

| Element | g plant\(^{-1}\) |
|---------|------------------|
| N       | 747              |
| P       | 41               |
| K       | 311              |

The data of nutrient availability in the soil, pepper nutrients absorption and gamal nutrients absorption were used to calculate fertilizers of N, P, K and other nutrients. The other inputs like compost application and N fixation by gamal were also taken into account [13].

3.3. Formula of fertilizers recommendation

Good Agricultural Practices (GAP) published by Indonesian Spice and Medicinal Crops Research Institute (ISMCRI) explain that fertilizers recommendation was established in g plant\(^{-1}\). Hole dimension for growing pepper was 60cm x 60cm x 60cm. If it was assumed that soil bulk density was 1 g cm\(^{-3}\) therefore the weight of soil was 216,000g. After calculation the difference between nutrients in the soils and their absorption by pepper only N, P and K which should be added by fertilizers while the others were sufficiently fulfilled by the soils and foliar application for some micronutrients. As for Ca and Mg were fulfilled by dolomite application.

Calculation of N fertilizer recommendation considered some inputs. Six month before planting peppers, stem cutting of gamal trees as supporting tree were grown in the field. These stem cuttings have grown well after six month with good growing root. The N absorption of Gamal was 747 g plant\(^{-1}\). Absorbed N of gamal was also from N fixation. 55% of absorbed N was from N fixation so that the absorbed N from soil was 336 g plant\(^{-1}\) [13]. After six month of growing gamal, the hole was dug and added compost 10 kg and then the soil was limed. Lime application was calculated using the amount of dolomite to neutralize 1 cmol kg\(^{-1}\) of exchangeable Al. The dolomite used was dolomite with neutralizing power 85%.

It was assumed that the N content of compost was 0.60%. Therefore the N contribution from compost was 60g plant\(^{-1}\). N absorption of pepper were 43.9 g plant\(^{-1}\) for pepper below 1 year, 51.7 g plant\(^{-1}\) for pepper between 1 to 3 years and 153 g plant\(^{-1}\) for pepper above 3 years. Those data were incorporated into formula for each stage of growth. N contribution from soil was determined as nitrate content and it is written as N-NO\(_3\).

On P recommendation calculation, contribution from compost was not taken into account because the P content in compost was very little and neither form microorganisms contribution. Therefore P
input was only from soil. P absorption of pepper with the age below 1 year was 4.16 g plant\(^{-1}\), 6.07 g plant\(^{-1}\) for pepper with the age 1-3 years and 18.2 g plant\(^{-1}\) for pepper with the age above 3 years. P absorption of gamal was 41 g plant\(^{-1}\). Based on those considerations the formula for P fertilizer recommendation was determined.

As for K recommendation calculation, K contribution from compost was not taken into account because the content of K in compost was also very low. Therefore the K input was only from soil. K absorption of pepper with the age below 1 year was 18.1 g plant\(^{-1}\), 19.9 g plant\(^{-1}\) for pepper with the age 1-3 years and 93.8 g plant\(^{-1}\) for pepper with the age above 3 years. K absorption of gamal was 623 g plant\(^{-1}\). Based on those considerations the formula for K fertilizer recommendation was determined.

The map of exchangeable Al, N-NO\(_3\), P and K were produced in the scale 1:250,000. Maps of exchangeable Al, N, P, and K and the formula for calculations fertilizers recommendation were sent to database center. This database center was called Lizard. Below is the example of K map in Bangka Belitung (Figure 2).

![Figure 2. Map of K in Bangka Belitung](image)

After mapping the nutrients content, Lizard processed the data of exchangeable Al, N-NO\(_3\), P and K by using the formula to produce the lime, N, P and K application recommendations. The lime, N, P and K application recommendation were established spatially on maps. The kind of fertilizers are adjusted to their availability in the market. The users can use single fertilizers or compound fertilizers. Lizard transformed the amount of lime, N, P and K into the amount fertilizers the farmers use. These services can be accessed in smartphone by downloading the application or by opening the website or Lizard can send it directly as short messages. Farmers just send the coordinate of their locations to have these services. As summary the amount of lime (dolomite), N, P and K recommendation for each points are presented in Table 6, 7, 8 and 9. The example of map of KCl as K fertilizer is presented in Figure 3.
Table 6. The range of dolomite with neutralizing power 85%

| Dolomite (DN=85%) (g hole⁻¹) | minimum | maximum | Average | Standard Deviation |
|------------------------------|---------|---------|---------|-------------------|
|                              | 0       | 1,630   | 267     | 202               |

Table 7. The range amount of N recommended for Pepper in Bangka Belitung where Gamal as supporting tree

| Statistic variable | < 1 year | 1-3 year | > 3 years |
|--------------------|----------|----------|-----------|
| minimum            | 365      | 374      | 496       |
| maximum            | 384      | 393      | 515       |
| Average            | 382      | 391      | 513       |
| Standard Deviation | 2.03     | 2.03     | 2.03      |

Table 8. The range amount of P recommended for Pepper in Bangka Belitung where Gamal as supporting tree

| Statistic variable | < 1 year | 1-3 year | > 3 years |
|--------------------|----------|----------|-----------|
| minimum            | 28.0     | 31.6     | 60.1      |
| maximum            | 70.4     | 74.0     | 102       |
| Average            | 68.1     | 71.7     | 100       |
| Standard Deviation | 4.76     | 4.76     | 4.76      |

Table 9. The range amount of K recommended for Pepper in Bangka Belitung where Gamal as supporting tree

| Statistic variable | < 1 year | 1-3 year | > 3 years |
|--------------------|----------|----------|-----------|
| minimum            | 602      | 605      | 693       |
| maximum            | 768      | 770      | 859       |
| Average            | 757      | 759      | 848       |
| Standard Deviation | 17       | 17       | 17        |

At present, the maps of fertilizer recommendation were presented in the scale 1:250.000. In the future, accuracy will be increased by using maps with the scale 1: 50.000. The soil samples will be collected more and more to reach lower standard deviation. By using this system it is expected that pepper farmers in Bangka Belitung can easily obtain the information of fertilizers recommendation.
4. Conclusions
The soil fertility in Bangka Belitung was relatively low with high sand fraction. The N, P and K were the main nutrients should be concerned in pepper due to their high absorption. The increase of pepper production were very possible by addition of soil ameliorant and fertilizers. The knowledges of farmers for their soils were very limited. Mapping of soil nutrients, lime and fertilizers were very promising to help farmers in using the fertilizers. The scale of the maps will be more detail in the future to improve the services.

By collaborating the information technology, farmers just send the coordinates of their land positions to accessed the services of fertilizers recommendation. In the coming years farmers of Bangka Belitung can use the service of on line fertilizers recommendation in SpiceUp application to increase the production of their pepper.

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