Peatland nutrient status and Liberica coffee seedlings growth as a response to biofertilizer

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Abstract. Knowing the nutrient status of growing media is a strategy for precision agriculture. The research aims to study the Liberica coffee seedling response to the nutrient status of peat under the influence of bio-fertilizer. The experiment used a completely randomized design in a factorial treatment arrangement with six replications. 1st factor was peat types; fibric, hemic, and sapric and 2nd factor were inoculated and non-inoculated peat by cellulolytic bacteria. Liberica coffee seedlings were found very responsive to P_2O_5 and Ca deficiencies, so the growth was not optimal on sapric, whereas the seedlings did not seem to respond to the low K status in fibric. The enrichment of cellulolytic bacteria increased the P_2O_5 of sapric from deficiency (6.84 ppm) to high (12.25 ppm), although the effect was not yet significant to improve the seedling growth. By cellulolytic bacteria enrichment, stem diameter, stem height, and leaves numbers of Liberica coffee seedlings on fibric added 2.33 mm, 9.25 cm, 3.75 strands, on hemic added 3.05 mm, 7.75 cm, and 4.25 strands and on sapric added 2.18 mm, 2.25 cm, and 1.25 strands, respectively. This study was the first step to getting more precise fertilizers for Liberica coffee planting on peatlands.

1 Introduction

One aspect justified in precision agricultural technology is soil fertility management, including the relationship between nutrient content such as soil P and K with crop yields [1]. The application of precision agricultural technology, among others, achieves efficient use in land resource inputs. Tips are to match the type and amount of inputs like fertilizers with crop needs, even in small areas [2].

Soil, such as peat, as a principal component in a sustainable agricultural system, must be quantitatively identified before the management. Knowing the balance of nutrients in the soil will be the key to nutrient management, such as the 4 Rs for a precision agricultural technology application, namely the right amount, the right source, the right place, and the right timing [3]. The correct amount of fertilizer application is a product of soil testing and calculations to compensate for the nutrients transferred by crop yields. The right source reflects the type of fertilizer and its use in a balanced way. Meanwhile, the right place is related to the placement and the application method, and the right time is to justify the plant life cycle [4].

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Liberica coffee plants are not widely known to the public. Their existence in the future can compete with Robusta and Arabica coffee because of some advantages, such as better taste and price, especially compared to Robusta coffee [5]. In addition, the development of Liberica coffee has received enough attention because the Liberica coffee plant adapted well to the peatland ecosystem [6-8]. The productivity of Liberica coffee on peatlands has not been optimal, with the average bean production at the farmer level only around 700 kg/ha [6, 9]. The reason for the low productivity is simply management and still conventional, including without the use of inorganic/mineral fertilizers. In increasing the Liberica coffee bean production, it is necessary to use inorganic fertilizers in combination with organic fertilizers, bio-fertilizers, and other ameliorants. Therefore, to use fertilizers and other resource inputs efficiently as proposed in the application of precision agricultural technology, applied fertilizer should be based on an analysis of soil nutrient status [9], including nutrient status in connection with fertilizer requirements for the nursery period. These analysis results help diagnose nutrient deficiency levels in soil/peat and to design fertilizer application management. The research aims to study the Liberica coffee seedling response to the nutrient status of peat under the influence of biofertilizer.

2 Materials and methods

2.1 Experimental site

Chemical properties analysis to determine the nutrient status in some peat types was in the Integrated Laboratory of the Indonesian Industrial and Beverage Crops Research Institute, Sukabumi, west Java. Peat was sampled from a peatland in the Betara sub-district, Tanjung Jabung Barat district, Jambi province. Furthermore, testing the effect of peat soil nutrient status on the growth of Liberica coffee seedlings was carried out in a greenhouse.

2.2 Experimental design

The study was pots experiment with a completely randomized design in a factorial treatment arrangement, repeated six times. The first factor was the type of peat, namely fibric (low weathering), hemic (medium weathering), and sapric (advanced weathering). The second factor was the inoculation of indigenous cellulolytic bacteria and non-inoculation. The indigenous cellulolytic bacteria of *Comamonas testosteroni* strain NBRC 14951 and *Delftia lacustris* strain 332 are collections of the Indonesian Industrial and Beverage Crops Research Institute, isolated from the same peat.

Fibric, hemic, and sapric identified in the field using the squeeze method [10] were sampled compositely and prepared for the pot experiment was fresh peat of 5 kg/pot with a moisture content of about 70%. Next they were enriched by colonies of cellulolytic bacteria as much as 25 ml/pot by a pipette, with a concentration of bacterial colonies 10^6-10^8 CFU/ml.

The enrichment of peat by cellulolytic in the experimental pots was a week before Liberica planting. Next, Liberica coffee seedlings, aged six months, with a diversity of growing, not more than 15%, were planted to the pot with no addition of chemical fertilizers in all treatments. To maintain peat moisture, under each pot was placed a plastic plate. The presence of water was kept every day.

2.3 Plant observation and soil analysis

After planting, the initial growth performance of the seedlings was observed, including stem circumference, stem length, and the number of leaves. Observations of the same parameters

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were also carried out four months after planting. Another parameter observed was the chemical properties of each peat at the beginning and four months after cellulolytic bacteria enrichment. Chemical properties analyzed were pH (a glass electrode method), organic C and ash content by loss on ignition (LOI) method, C/N ratio, total N by the Kjeldahl digestion method, available P by the Bray method, and exchangeable K, Ca and Mg by 1 M NH4OAc extraction at pH 7.

2.4 Data analysis

The data on the seedling growth and the chemical peat properties were subjected to ANOVA (F test) using statistics 22 software.

3 Result and discussions

3.1 The nutrient status in each peat before treated

The chemical properties of each peat (Table 1) showed that the pH of sapric peat (4.2) was higher and significantly different from that of hemic and fibric peat. In fibric, hemic, and sapric peat, N content was 1.5%, 1.2%, and 1.2% each. It was very high status. P availability in fibric (26.3 ppm P_2O_5) and hemic (32.8 ppm P_2O_5) was classified as very high status, while in sapric peat (6.8 ppm P_2O_5) was deficiency status. Exchangeable K in fibric peat (0.3 cmol(+)/kg) was low, and it was significantly different from very high K status in hemic (1.1 cmol(+)/kg) and moderate status in sapric (0.5 cmol(+)/kg). Higher K status in hemic and sapric peat compared to fibric peat was also reported by Arabia et al. [11], as well as exchangeable Ca in fibric peat (9.1 cmol(+)/kg), while in hemic (6.1 cmol(+)/kg) were moderate status, was higher than sapric peat (1.0 cmol(+)/kg) (Table 1), It was also in line with the report of Arabia et al. [11]. The concentration of exchangeable Mg was high in all types of peat, which was in line with the Arabia et al. report [11], which also predominantly found very high-status Mg in fibric, hemic and sapric peat.

Table 1. Chemical properties of fibric, hemic and sapric peat.

Variables	Unit	Peats		
		Fibric	Hemic	Sapric
Ash content	%	9.1	15.3	16.7
pH of H_2O		3,7 b	3,5 b	4,2 a
C	%	52,7	49,1	48,3
Total N	%	1,5	1,2	1,2
C/N		36,1	42,9	39,6
P_2O_5	ppm	26,3 a	32,8 a	6,8 b
Exchangeable K	cmol(+)/kg	0,3 b	1,1 a	0,5 ab
Exchangeable Ca	cmol(+)/kg	9,1 a	6,1 b	1,0 c
Exchangeable Mg	cmol(+)/kg	3,8	4,6	2,6

Numbers in the same row followed by different letters were significantly different at the significance level of 0.05.

The difference in nutrient status between the three types of peat was the impact of peat decomposition. As stated by Drzymulska [12], further weathering causes the peat pH to increase like in sapric peat. In sapric peat, inorganic P will be more bound/fixed by Al or Fe [13]. Therefore, the available P in sapric peat was classified as low status (deficiency), and the opposite in fibric and hemic was very high. The degree of peat decomposition in the two peats was lower [14]. In fibric and hemic, P was more bound by Ca, which is relatively soluble (ease available for plants) [13]. This interpretation is supported by the Ca measured higher in fibric and hemic peat (Table 1). On the other hand, the higher measured K in hemic and sapric peat (Table 1) was comparable to the higher ash content in both types of peat. The higher ash in peat contains more mineral materials like exchangeable K [15].

3.2 The growth of Liberica coffee seedlings on peat

Liberica coffee growth of seedlings after four months of planting showed better on hemic and fibric peat than on sapric peat, both in inoculated and not inoculated peat with indigenous cellulolytic bacteria (Table 2). Data on the increase in stem diameter showed that on fibric, the stem diameter of Liberica coffee seedlings increased on average by 2.33 - 2.85 mm, and on hemic increased by 2.49 - 3.05 mm, while on sapric peat, it increased by 2.04 - 2.18 mm. The height/length of Liberica coffee stems on fibric peat increased by 4.15 – 9.29 cm, hemic increased by 4 – 7.75 cm, while on sapric, it increased by only 1 – 2.25 cm. Similarly, the number of leaves on fibric increased by 3 – 3.75, on hemic increased by 3 – 4.25, while on sapric increased only 1 – 1.25 on average (Table 2). How the Liberica coffee seedlings perform on each peat is as in Figure 1.

The better growth of Liberica coffee seedlings on fibric and hemic peat was in line with the results of peat chemical analysis in which the nutrients N, P_2O_5, and Mg in both types of peat were very high, and Ca was moderate. In sapric peat, although the N and exchangeable Mg content was high and exchangeable K was medium, the P_2O_5 and exchangeable Ca was in deficiency status, had inhibited the growth of the Liberica coffee seedlings. The performance of this growth (Figure 1) showed that Liberica coffee seedlings were indicated to be very responsive to the availability of P_2O_5 and Ca nutrients. The exchangeable K nutrient status in sapric peat, which is better than in fibric peat, has not been able to encourage the growth of Liberica coffee seedlings, although the N status in this peat was also very high.

Table 2. Vegetative growth of Liberica coffee seedlings as the effect of indigenous cellulolytic bacteria enrichment on peats of fibric (FB), hemic (HM), and sapric (SP).

Peat	Cellulolytic bacteria	Increment		
		Stem diameter	Stem height	Leave number
		mm	cm	
Fibric	Inoculated	2.33 ab	9.29 a	3.75 ab
	Non-iniculated	2.85 ab	4.15 b	3.00 b
Hemic	Inoculated	3.05 a	7.75 a	4.25 a
	Non-iniculated	2.49 b	4.00 b	3.00 b
Sapric	Inoculated	2.18 b	2.25 bc	1.25 c
	Non-iniculated	2.04 b	1.00 c	1.00 c
P<0.05		*0.009*	*0.002*	*0.007*

Numbers in the same column followed by different letters were significantly different at the significance level of 0.05.

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Fig. 1. The growth of Liberica coffee seedlings on peat of fibric (FB), hemic (HM), and sapric (SP) enriched by indigenous cellulolytic bacteria (B) in pots in the greenhouse experiment.

The results of this study illustrate that P and Ca deficiency harms the development of seedlings. The growth of Liberica coffee seedlings looks better on peat having high P and Ca status, such as on fibric and hemic peat. In sapric peat, N was high, K was moderate, yet deficient in P had inhibited the growth and development of Liberica coffee seedlings (Figure 1). Phosphorus is essential for plant growth and development [16]. The presence of P in the growing media is crucial for cell propagation and enlargement [17]. Young plants require more P than old plants, which is indicated by prominent deficiency symptoms in seedlings [18]. P and Ca deficiency makes the growth of seedlings stunted, and the leaf surface narrows.

3.3 Nutrients status of peat as the effect of the indigenous cellulolytic bacteria enrichment

Indigenous cellulolytic bacteria enrichment was to improve the nutrient status and growth of Liberica coffee seedlings on peat soil. Analysis of nutrient status is of concern due to the enrichment of cellulolytic bacteria without the application of other fertilizers has succeeded in improving the growth of Liberica coffee seedlings on peat (Table 2). Therefore, it was necessary to see the changes in the nutrient status of peat in response to enrichment with cellulolytic bacteria.

The results of the chemical properties analysis of peats before enrichment and four months after being enriched by cellulolytic bacteria and planted with Liberica coffee seedlings, showed that the pH of the three types of peat changed. The pH of fibric, hemic, and sapric increased from 3.73 to 4.26, from 3.49 to 4.01, and from 4.15 to 4.51, respectively (Fig. 2). Carbon (C) as the main element in peat decreased after four months of cellulolytic bacteria enrichment. C in fibric decreased from 52.70% to 44.66%, and hemic decreased from 49.11% to 47.05. Yet in sapric, it was still at relatively the same concentration. The N was initially very high in all peat, after four months decreased sharply. In fibric, N decreased from 1.5% to 0.35%, hemic from 1.23% to 0.34%, and sapric from 1.22% to 0.36 %. Another essential element, available P, also decreased from the initial 26.31 ppm in fibric and 22.85 ppm in hemic decreased to 20.62 ppm and 13.56 ppm, respectively (Figure 2).

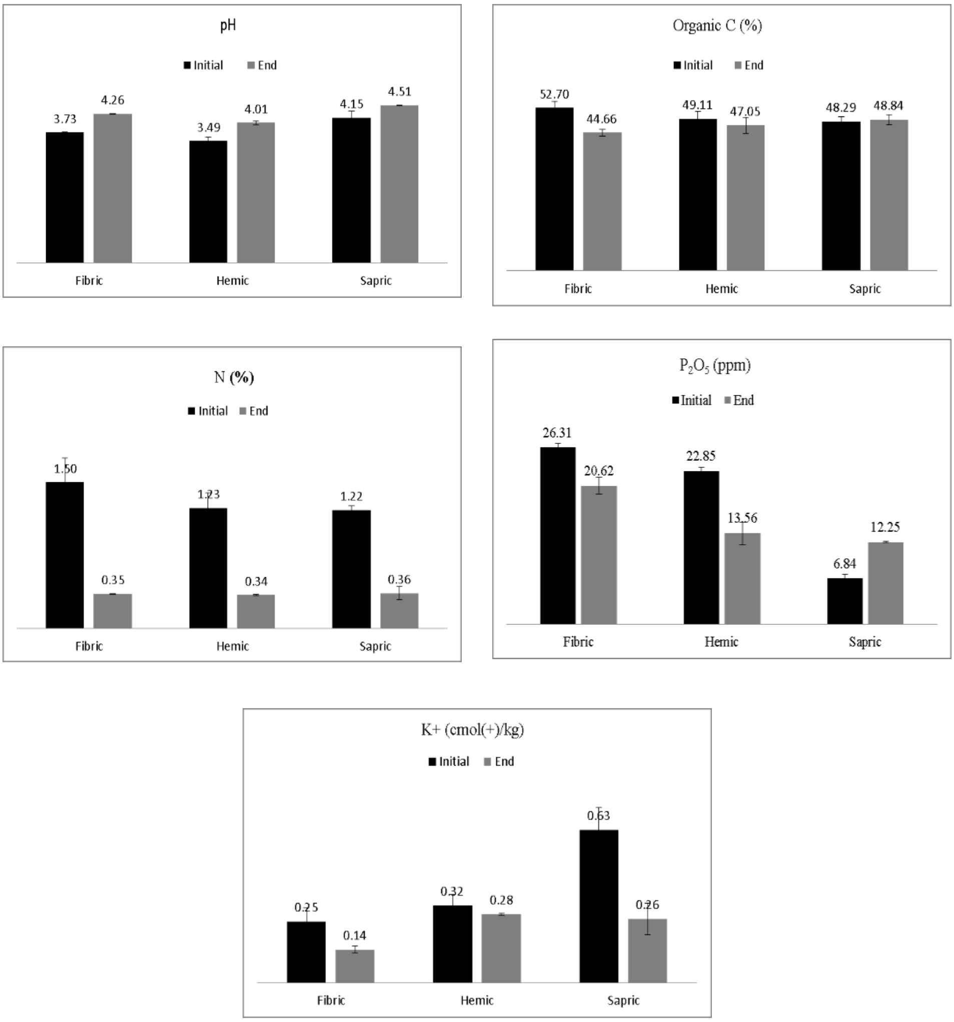

Fig. 2. The change of nutrients status in each peat type under enrichment effect of cellulolytic bacterial *Comamonas testosteroni* and *Delftia lacustris*.

Although the P concentration decreased in fibric and hemic, its status was still very high. On the other hand, available P in sapric was initially deficiency (6.84 ppm), but after four months increased to high status (12.25 ppm). The exchangeable K status of the three types of peat also decreased. In fibric peat, K decreased from 0.25 cmol/kg to 0.14 cmol/kg and in hemic decreased from 0.32 cmol/kg to 0.28 cmol/kg (all still in the low status). Meanwhile, in sapric peat, the concentration of K, which was initially high (0.63 cmol/kg), decreased to 0.26 cmol/kg (low).

Enrichment of cellulolytic bacteria in peat accelerated peat decomposition, indicated by an increase in the pH of the three types of peat [19]. The acceleration of the decomposition process will also increase C loss through CO_2 emissions into the atmosphere [20], especially on peat with low weathering levels, such as fibric and hemic. Meanwhile, in peat that has decayed further, the decomposition process will run more slowly because the peat is more stable [21]. So the loss of C due to oxidative decomposition is slow. The concentration of N rapidly decreases due to the growth of Liberica coffee seedlings need it, and is lost through N2O emissions into the atmosphere by N mineralization and peat decomposition [22].

The high available P in fibric and hemic peat is essential for plant seedlings' development because P is an important nutrient for young plants in cell division and enlargement [17, 18]. Good seedling growth on fibric and hemic peats, which require a lot of phosphorus (P), is the cause of the decreased concentration of available P in both peats. Meanwhile, P, which is heavily bound by humified peat such as sapric [14] so that it is difficult to be available to plants, its concentration can be increased by enrichment of the cellulolytic bacteria such as *Comamonas testosterone* and *Delftia lacustris.*

The bacterium *Comamonas testosterone* could dissolve P and mobilize soil bound-P [24, 25]. Likewise, the bacterium *Delftia lacustris* also could solubilize bound P [25]. Unfortunately, the increase in available P in sapric peat has not fully improved the growth of Liberica coffee seedlings in that medium. Exchangeable K also decreased in all three types of peat, indicating that seedling has used this element for development. The relatively better K status in sapric than in fibric has not yet played a role in the four months of growth and seedling development. It seems that for the development period of seedlings, P was more needed than K.

4 Conclusions

The nutrient status of N, P, Ca, and Mg on fibric and hemic peat from Betara, Tanjung Jabung Barat, Jambi province, was still in the high category. However, the K in fibric peat was deficiency status, in hemic was high-status and in sapric was medium status. The growth of Liberica coffee seedlings on fibric and hemic peat was optimal, while on sapric, the seedling growth tended to be stunted, although the N and Mg status in this peat was very high, and K status was moderate. The seedling growth indicated that the Liberica coffee seedlings were very responsive to the content of P and Ca in the planting medium and did not respond to the K deficiency status, such as in fibric peat. Enrichment of indigenous cellulolytic bacteria in peat improved the Liberica coffee seedlings' growth and increased P content in sapric from deficiency to high status. However, improvement in P status could not improve the Liberica coffee seedlings' growth in 4 months of seedling maintenance on sapric peat.

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