The effect of ameliorant on peat soil properties and shallots productivity in peatlands

Maswar¹, A Firmansyah², U Haryati¹ and Irawan¹

¹Indonesian Soil Research Institute, Bogor, Indonesia
²Central Kalimantan Assessment Institute for Agriculture Technology, Palangkaraya, Indonesia

E-mail: maswar_bhr@yahoo.com

Abstract. Shallot farming on peatland has physical, chemical and biological constraints which does not support crop growth properly. These constraints can usually be treated with amelioration. It is therefore important to understand the effects of applying ameliorant on soil properties and shallots productivity. The study was conducted in Central Kalimantan Province of Indonesia from April to August 2017. In this study, ameliorant such as 10 t ha⁻¹ mineral soil + 4 t ha⁻¹ dolomite + 5 t ha⁻¹ manure has been applied into 0 – 20 cm soil depth. Furthermore, NPK fertilizer, peat fertilizer, bio fertilizer, mulch and or a combination thereof had been added as the treatments. The results showed that application of mineral soil + dolomite + manure was able to improve the physical, and chemical properties of soil on all treatments such as increases in bulk density, mineral content, pH, Ca, Mg, K, base saturation, and P, so that the improved soil condition can support the shallots growth properly. The shallot dry weight production ranged from 9.60 to 15.49 t ha⁻¹. As a comparison, Indonesia's national average shallots productions is 9.31 t ha⁻¹. This finding indicates that shallots farming can be considered as the alternative for peatlands utilization.

1. Introduction

Utilization of peatlands for agriculture has developed quite easily since the limited availability of mineral soils that can be utilized. Peatland use for agricultural land has great potential, because it has high organic matter content. However, peatlands are classified as suboptimal land with low productivity, because they have constraints, including: physical, chemical, and biological characteristics that are not supportive for proper plant growth. Indonesian peatlands utilization for agriculture activity has a long historical foundation. Starting from success of indigenous peoples who looked peatland as a resource to produce traditional food crops, fruits, and other plants [1]. However peatlands carrying capacity for agricultural cultivation is closely related to very specific characteristics such as easily subsidence, irreversible drying, and easily damaged [2].

Shallot farming on peatland has physical, chemical, and biological constraints. Naturally physical properties of peat soils are low in bulk density and bearing capacity [3], affecting their suitability for crop production. Peat with high organic matter and moisture contents is an ideal condition for fungus growth and reproduction. Diseases caused by fungi such as *Fusarium oxysporum*, *Alternaria porii*, and *Colletotricum gloespoodes* are some of the obstacles to shallot farming on peatlands [4]. In general peat chemical properties are low in pH, base saturation, macro nutrient (K, Ca, Mg, and P), and micro nutrient (Cu, Zn, Mn, and B) contents and otherwise high in cation exchangeable capacity (CEC) [3,5]. In addition, the chemical nature of peat is dominated by organic acids, resulted by the
accumulation of plant residue [6,7]. Organic acids produced during the decomposition process are substances that are toxic to plants, thus disrupting the plant's metabolic processes which will have direct impact on productivity [7,8].

To gain best quality and high productivity of crop farming in peat soil it is necessary to modify or improve the natural characteristics of the peat. In general to improve the physical and / or chemical properties of peat soil can be done with ameliorants application. In this regard sources of the ameliorant can be organic or inorganic material. A good ameliorant material is characterized by a high base saturation, capable of increasing peat pH, and having complete nutrient contents [9], so it can also function as fertilizer and have the ability to improve the peat soil structure. The types of ameliorants that have been used are volcanic ash, lime, mineral soil, wood ash / litter from burning, agricultural waste ash and manure [10].

The presence of minerals or ameliorants in peat can protect organic carbon from mineralization through physical protection and / or chemical stabilization. Several studies have shown that cations, especially divalent and trivalent ones, can associate with organic matter, thereby protecting organic carbon from degradation. Besides being able to increase the interaction between minerals and humic materials, the exchangeable cations (such as Al, Ca, Mg, and Fe) are also able to increase the molecular bonds of humic materials so that they are difficult to degrade. In the conditions of the complexes formation between cations and organic acids derived from the decomposition of organic matter, these show that cations can play a role in increasing the buffering capacity of the ecosystem [11].

Therefore, to improve the physical, chemical, and biological properties of peat soils for shallot farming can be done by ameliorant application. The aim of this research was to study the effect of ameliorant application to improve the physical and chemical characteristics of peat soils and shallots productivity.

2. Methodology

2.1. Time and place
The research was conducted in Kereng Bangkirai village, Sebangau sub district, Palangkaraya City, Central Kalimantan Province, from April until August 2017.

2.2. Research approach
The modification of soil properties to improved physical and chemical properties was done in a number of ways including applying 10 t ha⁻¹ mineral soil + 4 t ha⁻¹ lime (dolomite) + 5 t ha⁻¹ manure. To prevent disease caused by fungal attack biological control was carried out by Tricoderma sp application. After peatland is ameliorated with mineral soil + lime + manure, it is followed by seven fertilization treatments on shallot farming, namely:

T1 = Application 1 t fertilizer ha⁻¹
T2 = 1 t peat fertilizer ha⁻¹ + mulch on soil surface
T3 = Application 5 g bio-fertilizer per clump
T4 = Application 5 g bio-fertilizer per clump + mulch on soil surface
T5 = Application 5 g bio-fertilizer per clump + 1 t peat fertilizer ha⁻¹
T6 = Application 5 g bio-fertilizer per clump + 1 t peat fertilizer ha⁻¹+ mulch on soil surface
T7 = Control (application of recommended NPK fertilizer)

For all treatments (T1 to T7), NPK fertilizer application is based on "farmer's management practices" fertilization with NPK compound (16: 16:16) applied gradually. Fertilization starts in the first week (7 days after planting), by firstly dissolving NPK compound fertilizer in water with a dose of: a). 5 kg NPK dissolved in 20 l water for fertilizing in weeks I and II; b). 6 kg NPK dissolved in 20 l water for fertilizing in weeks III and IV; c). 7 kg NPK dissolved in 20 l water for the fifth week of
fertilization, and d) 8 kg NPK dissolved in 20 l water for fertilizing in week VI. For each fertilization time, 0.5 l NPK fertilizer solution is diluted again with 5 l water to be applied to a 10 m$^2$ plot by flushing system.

Peat fertilizer (Pugam) is a compound inorganic fertilizer containing 13.15% P2O5, 25.6% CaO and 10.88 MgO. The content of other important elements is Fe 9.46%, Al 6.29% which is a source of polyvalent cations needed by peat soils to increase its stability and reduce peat degradation and greenhouse gas emissions. The microelements content of Zn, Cu and B are in sufficient amount to supply the needs of plants on peat soil. The mulch from Imperata cyindrica was applied by spreading it evenly on the soil surface. The biological fertilizer contains phosphate solubilizing microbes.

The study was used a Randomized Block Design. Each treatment was repeated 4 times. The plot size for each treatment was 1 m x 20 m. Planting space of shallots is 20 cm between bases x 15 cm in a row.

Undisturb soil samples were collected by a ring sample with 7.6 cm in diameter size and 4 cm high from 0 to 20 cm depth for bulk density, carbon, and ash content analyses. Composit soil samples were collected by hoe from 0 to 20 cm depth for soil chemical properties determination i.e: N, P, K, Ca, Mg, Na, CEC, base saturation (BS). Soil sampling was done 2 times namely: 1) prior to land cultivation to determine initial peat characteristics (before treated), and 2) before shallot harvest.

2.3. Statistical analysis
Analysis of variance (ANOVA) was used to detect any significant differences for each parameter studied. Where significant differences exist, Duncan Multiple Range Test (DMRT) was used to separate them. All statistical analyses were done using SAS for Windows™ release 6.12.

3. Results and discussion
The results of soil physical analysis before and after treated with ameliorant application are presented in table 1.

| Treatments | BD (g cm$^{-3}$) | C-Organic (%) | Ash (%) |
|------------|-----------------|--------------|--------|
| T1         | 0.66            | 9.67         | 81.41  |
| T2         | 0.63            | 10.90        | 79.04  |
| T3         | 0.71            | 8.86         | 82.97  |
| T4         | 0.67            | 10.00        | 80.77  |
| T5         | 0.69            | 8.58         | 83.50  |
| T6         | 0.68            | 8.71         | 83.27  |
| T7         | 0.60            | 11.02        | 78.83  |
| Control (Initial) | 0.16       | 44.81        | 13.87  |

Notes:
T1 = Application 1 t fertilizer ha$^{-1}$.
T2 = 1 t peat fertilizer ha$^{-1}$ + mulch on soil surface.
T3 = Application 5 g bio-fertilizer per clump.
T4 = Application 5 g bio-fertilizer per clump + mulch on soil surface.
T5 = Application 5 g bio-fertilizer per clump + 1 t peat fertilizer ha$^{-1}$.
T6 = Application 5 g bio-fertilizer per clump + 1 t peat fertilizer ha$^{-1}$ + mulch on soil surface.
T7 = Control (application of recommended NPK fertilizer).
When the data of soil physical properties such as bulk density (BD), carbon content (C), and peat ash content of all treatments (T1-T7) compared to initial condition (table 1), it can be seen that bulk density increased from 0.16 g cm$^{-3}$ (initial condition) to 0.6 - 0.7 g cm$^{-3}$ after treated. In other word that after amelioration, BD increased 4 times greater than initial condition. A similar trend occurred in ash content, showing that it was increased from 13.87% at initial codition to 78.83-83.50% after amelioration. Contrary there was a decrease in carbon content. These results showed that amelioration has significantly improve peat physical properties.

Table 2. The average of soil chemical properties before and after ameliorant application for all treatments on shallots farming in peatland.

| Treatments | pH | N (%) | Cation exchange (NH$_4$Acetat 1N, pH7) | Total (Extracted with HNO$_3$) |
|------------|----|-------|--------------------------------------|-------------------------------|
|            | H$_2$O | KCl | Ca | Mg | K | Na | Total | CEC | BS | P | K |
| T1 | 6.60 | 6.24 | 0.27 | 18.12 | 8.28 | 0.51 | 0.09 | 26.99 | 34.34 | 78.44 | 0.11 | 0.07 |
| T2 | 6.59 | 6.18 | 0.28 | 16.00 | 11.06 | 0.36 | 0.06 | 27.48 | 36.18 | 76.22 | 0.10 | 0.06 |
| T3 | 6.60 | 6.17 | 0.23 | 15.76 | 7.68 | 0.46 | 0.07 | 23.97 | 34.92 | 67.23 | 0.12 | 0.08 |
| T4 | 6.47 | 6.11 | 0.21 | 15.50 | 7.63 | 0.29 | 0.05 | 23.46 | 36.49 | 63.99 | 0.10 | 0.06 |
| T5 | 6.68 | 6.23 | 0.20 | 13.23 | 6.78 | 0.43 | 0.08 | 20.52 | 33.12 | 60.73 | 0.10 | 0.05 |
| T6 | 6.76 | 6.38 | 0.22 | 14.94 | 7.51 | 0.31 | 0.08 | 22.84 | 33.03 | 69.41 | 0.12 | 0.03 |
| T7 | 6.93 | 6.49 | 0.21 | 18.09 | 9.78 | 0.47 | 0.08 | 28.42 | 38.53 | 73.62 | 0.11 | 0.04 |
| C (init.) | 3.72 | 2.88 | 0.70 | 2.33 | 1.48 | 0.24 | 0.06 | 4.11 | 65.55 | 6.58 | 0.02 | 0.02 |

Notes:
- T1 = Application 1 t peat fertilizer ha$^{-1}$.
- T2 = 1 t peat fertilizer ha$^{-1}$ + mulch on soil surface.
- T3 = Application 5 g bio-fertilizer per clump.
- T4 = Application 5 g bio-fertilizer per clump + mulch on soil surface.
- T5 = Application 5 g bio-fertilizer per clump + 1 t peat fertilizer ha$^{-1}$.
- T6 = Application 5 g bio-fertilizer per clump + 1 t peat fertilizer ha$^{-1}$ + mulch on soil surface.
- T7 = Control (application of recommended NPK fertilizer).

The results of chemical analysis of peat soil samples from each treatment compared to controls (initial) showed that all treatments (T1 to T7) significantly increased peat pH both pH H$_2$O and pH KCl. Especially the pH of H$_2$O increased by about 77-86% or from 3.72 to 6.59 - 6.93 (or from very acid to neutral reactions). The neutral soil pH conditions are very supportive for plant growth, because almost all nutrients are available in this condition. In general, the land at pH range of 6.5 - 7.5 is suitable for most plants and generally all nutrients become available at this pH range. Improvement of peat soil pH in all treatments (T1 to T7) compared to untreated soil (K) is due to the dolomite application at a dose of 4 t ha$^{-1}$. Similar results in acid mineral soils by Domagoj et al. [12] showed that dolomite application could increase soil pH from 6.36 to 7.32, as well as P and K availabilities. Provision of ameliorant materials such as organic fertilizer, mineral soil, zeolite, dolomite, natural phosphate, manure, agricultural lime, husk ash, rat purun (Eleocharis dulcis) can increase soil pH and soil base saturation [6,13,14]. Masganti [15] and Supriyo [16] stated that amelioration using lime with a dose of 5 to 5.2 t ha$^{-1}$ can increase the pH of sapric peat from 3.34 to 4.5. Besides all the treatments that were tested significantly increased soil pH it was also seen that there was an increase in interchangeable soil cations such as K, Ca, Mg, Na, and P nutrients (table 2). From the analysis of the chemical properties of peat after treatment it can be seen that the application of mineral soil 10 t ha$^{-1}$ + dolomite 4 t ha$^{-1}$ + manure 5 t ha$^{-1}$, was able to improve the chemical properties of peat, so that it can support the growth of shallot plants well. The shallot production in each treatment is presented in table 3.
Table 3. Mean dry weight shallots production of each treatments.

| Treatments | Block I (t ha\(^{-1}\)) | Block II (t ha\(^{-1}\)) | Block III (t ha\(^{-1}\)) | Block IV (t ha\(^{-1}\)) | Mean (t ha\(^{-1}\)) |
|------------|--------------------------|---------------------------|---------------------------|--------------------------|---------------------|
| T.1        | 13.58                    | 14.39                     | 20.90                     | 13.10                    | 15.49 a             |
| T.5        | 11.86                    | 12.02                     | 16.87                     | 14.17                    | 13.73 ab            |
| T.3        | 11.13                    | 12.81                     | 15.90                     | 8.59                     | 12.11 abc           |
| T.6        | 12.08                    | 13.77                     | 13.41                     | 7.49                     | 11.69 bc            |
| T.4        | 11.41                    | 9.13                      | 12.43                     | 7.88                     | 10.21 c             |
| T.7        | 8.89                     | 11.52                     | 9.59                      | 9.17                     | 9.79 c              |
| T.2        | 11.85                    | 8.49                      | 8.96                      | 9.09                     | 9.60 c              |

Notes: Within column, the numbers followed with the same letter are not significantly different at the 5% level of DMRT

T1 = Application 1 t peat fertilizer ha\(^{-1}\).
T2 = 1 t peat fertilizer ha\(^{-1}\) + mulch on soil surface.
T3 = Application 5 g bio-fertilizer per clump.
T4 = Application 5 g bio-fertilizer per clump + mulch on soil surface.
T5 = Application 5 g bio-fertilizer per clump + 1 t peat fertilizer ha\(^{-1}\).
T6 = Application 5 g bio-fertilizer per clump + 1 t peat fertilizer ha\(^{-1}\) + mulch on soil surface.
T7 = Control (application of recommended NPK fertilizer).

The data presented in table 1, 2, and 3, show that the improved physical and chemical soil conditions in all treatments and also show a good effect on the productivity of shallots planted in all treatments. It is seen that the mean dry weight shallots production can reach 15.49 t ha\(^{-1}\). The average yield of shallots in all treatments (especially ameliorant and fertilization) is 9.31 t ha\(^{-1}\) above the national average shallot production [17]. However, it can be seen in the treatments T2, T4, and T6 using mulch (*Imperata cylindrica*) as treatment, shallot production is even lower than the same treatment without mulch (compare T1 to T2, or T3 with T4, or T5 with T6). This shows that the use of Imperata grass as mulch is not suitable for shallot plants. Similiar research results by Mulyono [18] showed that the use of Imperata as mulch on shallot farming also tends to reduce biomass weight, tuber number, and tuber weight per shallot plant clump compared to control treatment. In general, the results of the study found that after improving the chemical and physical properties of peat with the application of ameliorant such as 10 t ha\(^{-1}\) mineral soil + 4 t ha\(^{-1}\) dolomite + 5 t ha\(^{-1}\), manure, followed by NPK fertilization and pugam (peat fertilizer) gives the highest shallot bulbs. Visual observations at harvest time showed that the average tuber diameter was 2.1 cm (figure 1)

![Figure 1. Snapshot of the shallots tuber performance of this study.](image-url)
4. Conclusions
Application of ameliorant in the form of mineral soil + manure + dolomite followed fertilization in peatland significantly improves peat physical properties especially bulk density and mineral content and peat chemical properties such as pH and nutrients i.e K, Ca, Mg, Na, and P availability, so that it becomes very supportive for the shallots growth well.

Improved peat soil properties by ameliorant application and followed by fertilizer application either one or a combination of NPK fertilizer, peat fertilizer (pugam), or bio fertilizer were potential to produce high shallot productivity which is greater than the national average productivity (>9.31 t ha⁻¹). This finding indicate that shallots farming can be considered as the alternative crop for peatlands development.

Acknowledgments
Thanks, are conveyed to the director of ISRI for the budget allocation for the implementation of this research. Thanks also go to Bpk. Arifin Sutekno (Central Kalimantan AIAT Extension), Bpk. Slamet (land owner) for their excellent assistance during the research implementation in the field. The authors also state that the positions of all authors are equal; as main contributors.

References
[1] Osaki M, Nursyamsi D, Noor M, Wahyunto and Segah H 2016 Peatland in Indonesia In Book Tropical Peatland Ecosystems. pp 49 – 58.
[2] Sabiham and Sukarman 2012 Pengelolaan lahan gambut untuk pengembangan kelapa sawit di Indonesia (in Bahasa) Prosiding Seminar Nasional Pengelolaan Lahan Gambut Berkelanjutan Badan Penelitian dan Pengembangan Pertanian Kementrian Pertanian pp 1-16
[3] Hikmatullah and Sukarman 2014 Physical and Chemical Properties of Cultivated Peat Soils in Four Trial Sites of ICCTF in Kalimantan and Sumatra Indonesia. J. Trop. Soils Vol 19 No 3 2014 131-141
[4] Firmansyah M A, Musaddad D, Liana T, Mokhtar M and Yufdi M P 2014 Adaptation Test of Shallots at Peat Land During the Rainy Season in Central Kalimantan J Hort 24 (2) 114-123
[5] Alwi M and Hairani A 2007 Karakteristik kimia lahan gambut dangkal dan potensinya untuk pertanaman cabai dan tomat (in Bahasa) Bul. Agron. 35 36-43
[6] Dohong S 1999 Peningkatan Produktivitas Tanah Gambut yang Disawahkan dengan Pemberian Bahan Amelioran Tanah Mineral Berkadar Besi Tinggi (in Bahasa) Disertasi Institut Pertanian Bogor Bogor 171 halaman
[7] Prasetyo T B 1996 Perilaku asam-asam organik meracun pada tanah gambut yang diberi garam Na dan beberapa unsur mikro dalam kaitannya dengan hasil padi (in Bahasa) Disertasi Program Pascasarjana Institut Pertanian Bogor
[8] Tadano K B, Ambak K, Yonebayashi T, Hara P, Vijarnson C, Nilnond and Kawaguchi S 1990 Nutritional factors limiting crop growth in tropical peat soils In Soil Constrains on Sustainable Plant Production in the Tropics Proc 24th Inter. Symp. Tropical Agric. Res. Kyoto
[9] Attiken W P, Moody P W and Dickson T 1998 Field amelioration of acid soil in South East Queensland. I. Effect of amendments on soil properties. Austr. J. Agric Res 49 627-638
[10] Pramono D S 2004 Transmigration Development in The Peatlands, Its Prospect and Problems Workshop on Assessment Conservation Restoration and Sustainable Use of Tropical Peatland and Peat Swamp Forest Biodiversity in Pontianak 14-16 April 2004
[11] Cruz-Guzman M R et al 2003 Sorption-Desorption of lead (II) and mercury (II) by model association of soil colloids Soil Sci. Soc. Am. J 67 1378-1387
[12] Domagoj R, Vladimir Z and Mirta R 2014 Impacts of liming with dolomite on soil pH and phosphorus and potassium availabilities 13th Alps-Adria Scientific Workshop. Villach, Ossiacher See Austria Pg 193 – 196 DOI 10 12666/Novenyterm 63 2014 Suppl
[13] Mario M D 2002 Increased productivity and peat stability through the provision of mineral soil enriched by the high abundance of iron materials Doctoral Dissertation Bogor Agricultural University Bogor

[14] Subiksa I G M, Nugroho K, Sholeh and Widjaja Adhi I P G 1997 The effect of ameliorants on the chemical properties and productivity of peat soil In: Rieley and Page (Eds) pp 321-326 Biodiversity and Sustainability of Tropical Peatlands Samara Publishing Limited UK

[15] Masganti 2003 Kajian Upaya Meningkatkan Daya Penyediaan Fosfat dalam Gambut Oligotrofik (in Bahasa) Disertasi Program Pascasarjana UGM Yogyakarta p 355

[16] Supriyo A 2006 Inundation impact settings and ameliorant against chemical properties and results rice (Case Study Pangkoh Central Kalimantan)

[17] Kementrian Pertanian 2019 Produktivitas bawang merah menurut provinsi 2015 – 2019 (in Bahasa) https://www.pertanian.go.id/home/?show=page&act=view&id=61

[18] Mulyono 2015 Pengaruh penggunaan mulsa alang-alang, kenikir dan kirinyu terhadap pertumbuhan dan hasil bawang merah di tanah Mediteran pada musim enghujan (in Bahasa) Planta Tropika Journal of Agro Science 3 (2) doi 10.18196/pt.2015.042.73-77