Chapter 19
The Utilization of Arbuscular Mycorrhiza to Support Revegetation on Degraded Tropical Peatland of Central Kalimantan

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Abstract Tropical peatland in Indonesia especially in Central Kalimantan has been degraded due to various factors including repeating fires, illegal logging, and conversion into other land use and inappropriate drainage such as the ex-Mega Rice Project. Efforts to revegetate this area have encountered many obstacles due to nutrient poor peat soil characteristic. Arbuscular mycorrhiza is one of potential soil microbes that can be utilized as plant growth-booster in bio-rehabilitation technology particularly in degraded land. However, this bio-rehabilitation-technology has not been utilized intensively to support revegetation of degraded tropical peatland. This paper aimed to summarize the recent progress on the utilization of arbuscular mycorrhiza fungi in supporting the plant's growth of the peatland revegetation efforts. The result showed that arbuscular mycorrhiza application significantly increased plant's growth and survival rates especially in the nursery stage. However, compatibility between arbuscular mycorrhiza fungal species and host plants was an important factor that determines the success of colonization and its contribution to plant's growth performance. Appropriate combination of indigenous mycorrhizal fungal species and native peatland plant species needs to be considered for the success of this bio-rehabilitation technology in revegetating degraded tropical peatland.

Introduction

Eleven percent or approximately 44 million ha of the world's peatland is tropical peatland [1]. The tropical peatland in Indonesia covers an area of 13.43 million ha distributed across four main islands namely Sumatera (5.85 Mha), Kalimantan (4.54 Mha), and Papua (3.01 Mha) and Sulawesi (0.024 Mha) [2]. The tropical

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peatland has ecologically important roles as carbon storage, hydrological control, and habitat of flora fauna and microbes. After 2015, the tropical peatland in South East Asia experienced massive changes and only 6% remains in pristine condition [3]. Fire, logging, drainage, and conversion into other land uses such as agriculture, oil palm plantation, Acacia plantations and smallholdings were causes of those massive changes [4–6]. Two thousand and fifteen fire has burnt 2.6 million ha of Indonesia's tropical peatland and in order to restore it, the government of Indonesia established The Peatland Restoration Agency or Badan Restorasi Gambut in early 2016 [7]. The restoration policy includes rewetting, revegetation, and revitalization of local livelihood, known as the 3R approach. As of the end of 2019, the Peatland Restoration Agency claimed to construct 713 revegetation demonstration plots across various provinces of Indonesia namely Riau, Jambi, South Sumatera, South Kalimantan, and Central Kalimantan. The direct barriers of peatland revegetation includes physical, hidrological and biological constrains [8]. Most of Indonesia's peatland characterised as lowland ombrotrophic meaning that it has low nutrient and acidic conditions [9]. Moreover, according to [8] the dense shrubs and ferns communities has caused the increased competition for nutrients and makes it difficult for indigenous plant species to survive.

Soil microorganisms such as ectomycorrhizal and arbuscular mycorrhiza fungi (AMF) have the potential to be used as growth stimulators and bioremediation agents for degraded or polluted lands; but this potential has not been recognized or utilized until recently. There is a number of benefits potentially obtained from tree-mycorrhizal associations, such as increased seedling and mature plant growth, increased uptake of phosphorus (P) and other nutrients, increased root longevity, increased disease resistance, increased resistance to water stress and increased resistance to toxic elements [10].

A preliminary study to determine the presence of mycorrhizal association in peat swamp forest species found that there were mycorrhizal associations in the roots of peat swamp forest species such as *Shorea balangeran* (Balangeran), *Gonistylus bancanus* (Ramin), *Cratoxylon arborescens* (Gerunggang) and *Calophyllum soulattri* (Kapur Naga) [11, 12]. The effect of *Glomus clarum* and *Gisgasora decipiens* inoculation on *Dyera polyphylla* and *Aquilaria filaria* under green house conditions was investigated [13]. The result showed that plant height, diameter and shoot and root dry weight of *D. polyphylla* and *A. filaria* increased after innoculation. The positive effect of *G. clarum* and *G. aggregatum* on *Ploiariuum alternifolium* and *Calophyllum hosei* was also reported [14].

This paper presented the result of AMF species innoculation research on several local peatland plant species namely *Alstonia pneumatophora*, *Gonistylus bancanus*, *Stemonurus scorpioides*, *Callophylum soulattri*, *Tetramerista glabra* and *Palaquium* sp in the nursery condition and also reporting the growth and survival after being planted in the field. The spores of *Glomus clarum*, *Gigaspora decipiens* and *Enthrophospora* sp. were isolated from degraded tropical peatland in Kalampangan, Central Kalimantan province. The spores were mass-produced by using *Pueraria javanica* as host plant in a pot culture with zeolite as the growth medium. The seedlings media were autoclaved-sterilized (121 °C for 15 min). The seedlings and

cuttings were surfaced-sterilized with H_2O_2 5% for 5 min and rinsed with tap-water before sowing. Ten milligrams of the inoculums were applied. The plants were grown in the nursery for 24 weeks (6 months) and transplanted to the field. The growth performance and survival rate were recorded periodically.

The Growth of Tropical Peatland Plant Species After AMF Innoculation

The growth performance, number of leaves and survival rate of the tropical peatland plant species in the nursery and the field is presented in Table 19.1. The early height and diameter growth of *C. soulattri* increased after inoculated with *G. clarum*, *G. decipiens* and *Enthrophospora* sp. five months after inoculation in the nursery [15]. Moreover, for *A. pneumatophora*, inoculation with *G. clarum* significantly effect the height and diameter growth 6 months after transplanted in the field; while *T. glabra* and *G. bancanus* did not show any significant growth effect after AMF inoculation in the nursery and transplant to the field [16]. The study of [16] showed interesting result for *S. scorpioides* after AMF innoculation. There was no significant different in term of height and diameter growth in the nursery, however ten months after transplant to the field innoculated seedlings were shown better growth. Another study [17] showed a consistent effect of *Gigaspora decipiens* inoculation on *A. pneumatophora* 24 weeks in the nursery and 5 years after transplanted in the field.

Moreover, the study [16] showed that *G clarum* is significantly effect height growth of *C. rotundatus* 9 months after inoculation in the nursery.

The effect of AMF innoculation varied between treatments and control both on the height and diameter. It was considered that the growth response to AMF colonization appeared more than 24 weeks after innoculation because the growth of peat swamp species was slow [13]. The compatibility of AMF to the host plant was also considered. The AMF which was not compatible to the host plant would not result in positive symbiosis. This will lead to limited P-available absorption to the plant root. The height, diameter and survival rate of peat swamp plant species varied in the nursery and the field. The growth response to AMF colonization appeared longer after inoculation because of the slow groath of peat swamp plant species. The compatibility between AMF and its host plant should also be taken into consideration. Indigenous mycorrhiza exploration and field trials of inoculated peat swamp plant species were needed to support the revegetation of degraded peatland especially in Central Kalimantan. It was expected that AMF application increase the growth and survival rate of seedlings in the nursery and the field.

Table 19.1 Height, diameter growth, number of leaves and survival rates of tropical peatland plant species after AMF innoculation

No	Plant species	AMF species	Height (cm)	Diameter (cm)	Leaf number	Survival rate (%)	Age		Reference
							Nursery	Field	
1	*Alstonia pneumatophora* (Pulai Rawa)	Control	40 a	0.7 a		40		6 months	[15]
		Glomus clarum	55 b	1.0 b		40		6 months	
		Gigaspora sp.	45 a	0.9 b		30		6 months	
2	*Callophylum soulattri* (Kapur Naga)	Control	7.5 a	2.0 a		78	5 months		
		Glomus sp.	11 b	5.0 b		100	5 months		
		Gigaspora sp.	10 b	4.0 b		80	5 months		
		Enthrophospora sp.	12.5 b	5.0 b		100	5 months		
3	*Tetramerista glabra* (Punak)	Control	13 a	0.6 a	3.0 a		6 months		
		G. clarum	14 a	0.5 b	5.0 b		6 months		
		Gigaspora decipiens	14 a	0.7 a	4.0 a		6 months		
4	*Gonistylus bancanus* (Ramin)	Control	30 ab	0.4 a	5.0 a	40		2 years	
		G. clarum	25 a	0.4 a	5.0 a	40		2 years	
		G. decipiens	50 b	0.7 b	6.0 a	50		2 years	
5	*Stemonurus scorpioides* (Medang telur)	*Control*	9.0 ab	0.28 ab			24 weeks		[16]
		Glomus clarum	8.5 a	0.28 ab			24 weeks		
		G. decipiens	9.0 ab	0.30 a			24 weeks		
		Enthrophospora sp.	10.0 b	0.30 a			24 weeks		
		Mix	11.0 b	0.25 b			24 weeks		

(continued)

Table 19.1 (continued)

No	Plant species	AMF species	Height (cm)	Diameter (cm)	Leaf number	Survival rate (%)	Age		Reference
							Nursery	Field	
6	*Palaquium sp.* (Nyatoh)	*Control*	7.0 a	0.2 a			24 weeks		
		Glomus clarum	10.0 b	0.2 a			24 weeks		
		G. decipiens	7.0 a	0.2 a			24 weeks		
		Enthrophospora sp.	7.5 a	0.2 a			24 weeks		
		Mix	7.5 a	0.2 a			24 weeks		
7	*T. glabra* (Punak)	*Control*	12.0 a	0.6 a			24 weeks		
		Glomus clarum	12.0 a	0.4 b			24 weeks		
		Gigaspora sp.	12.0 a	0.8 a			24 weeks		
8	*S. scorpioides* (Medang telur)	*Control*	15 a	0.35 ab				10 months	
		Glomus clarum	18 ab	0.32 a				10 months	
		G. decipiens	22 b	0.35 ab				10 months	
		Enthrophospora sp.	22 b	0.40 b				10 months	
		Mix	18 ab	0.40 b				10 months	
9	*Palaquium sp.* (Nyatoh)	*Control*	10.0 a	0.20 a				10 months	
		Glomus clarum	14.0 a	0.20 a				10 months	
		G. decipiens	13.0 a	0.20 a				10 months	
		Enthrophospora sp.	14.0 a	0.20 a				10 months	
		Mix	13.0 a	0.20 a				10 months	
10	*T. glabra* (Punak)	*Control*	25.0 a	0.65 ab				10 months	
		Glomus clarum	20.0 a	0.60 a				10 months	
		Gigaspora sp.	25.0 a	0.80 b				10 months	

(continued)

Table 19.1 (continued)

No	Plant species	AMF species	Height (cm)	Diameter (cm)	Leaf number	Survival rate (%)	Age		Reference
							Nursery	Field	
11	*A. pneumatophore*	*Control*	18.0 a	4.0 a			24 weeks		[17]
		Glomus clarum	25.0 b	6.0 b			24 weeks		
		Gigaspora sp.	25.0 b	6.0 b			24 weeks		
12	*G. bancanus*	*Control*	28.0 a	5.0 a			6 months		
		Glomus clarum	25.0 b	5.0 a			6 months		
		Gigaspora sp.	32.0 a	6.0 b			6 months		
13	*A. pneumatophora*	*Control*	300 a	10.0 a		78		5 years	
		Glomus clarum	300 a	15.0 a		80		5 years	
		Gigaspora sp.	250 b	30.0 b		76		5 years	
14	*G. bancanus*	*Control*	80 a	5.0 a		83		3 years	
		G. clarum	85 ab	5.0 a		80		3 years	
		G. decipiens	85 ab	7.0 b		89		3 years	
		Enthrophospora sp.	120 c	5.5 ab		100		3 years	
		Mix	100 bc	5.5 ab		100		3 years	
15	*Cratoxylon arborescens* (Gerunggang)	*Control*	2.0 a	0.4 a	1.5 a		3 months		[18]
		Glomus sp.1	3.0 ab	0.35 a	2.0 ab		3 months		
		Glomus sp.2	2.0 a	0.35 a	2.0 ab		3 months		
		Glomus sp. 5	4.0 ab	0.4 a	3.5 ab		3 months		
		Gigaspora sp.	5.0 b	0.3 a	4.0 b		3 months		
16	*Combretocarpus rotundatus* (Merapat)	*Control*	20.0 a	0.6 a		60	9 months		[16]
		G. clarum	10.0 b	0.65 a		100	9 months		
		Gigaspora sp.	25.0 a	0.6 a		70	9 months		

The Root Colonization of Tropical Peatland Plant Species After AMF Innoculation

The root colonization after AMF innoculation is presented in Table 19.2. From Table 19.2 we can see that root colonization was higher for inoculated seedlings compared with control. AMF colonization on plant's roots showed variation from negative (parasite endophyte) to positive (mutualistic) [19]. High number of colonization does not always correlate with the benefit obtained by the host plants [20]. The AMF symbiosis is said to be effective when providing positive effect on the host plant and its environment. Those positive reaction is determined by various factors such as AMF species, soil types, the age of host plant and time needed for symbiosis to happen [21]. Inoculums, which could effectively colonize the roots, is potential to be utilized as inoculum source. However, each AMF genus owns different infection characteristics and various sporulation in different environmental condition [21].

Arbuscular mycorrhizal fungi are obligate symbiotic fungi that have been known to have a positive effect on plant growth. Arbuscular Mycorrhiza Fungi has four functional roles [21], namely: (1) as a bioprocessor, able to help the absorption of nutrients and water in plants from locations that are not reached by hair roots; (2) as

Table 19.2 Root colonization of tropical peatland species after AMF innoculation

No	Plant species	AMF species	Root colonization (%)	Age		Reference
				Nursery	Field	
1	*Alstonia pneumatophora* (Pulai Rawa)	Control	5.0 a		6 months	[15]
		Glomus clarum	75 b		6 months	
		Gigaspora sp.	70 b		6 months	
2	*Callophylum soulattri* (Kapur Naga)	Control	0.0 a	5 months		
		Glomus sp.	10.0 a	5 months		
		Gigaspora sp.	2.0 a	5 months		
		Enthrophospora sp.	3.0 a	5 months		
3	*Tetramerista glabra* (Punak)	Control	0.0 a	6 months		
		G. clarum	100 b	6 months		
		Gigaspora decipiens	45 b	6 months		
4	*A. pneumatophore*	*Control*	0.0 a	24 weeks		[17]
		Glomus clarum	80.0 b	24 weeks		
		Gigaspora sp.	80.0 b	24 weeks		
5	*G. bancanus*	*Control*	15.0 a	6 months		
		Glomus clarum	10.0 a	6 months		
		Gigaspora sp.	100.0 b	6 months		

(continued)

Table 19.2 (continued)

No	Plant species	AMF species	Root colonization (%)	Age		Reference
				Nursery	Field	
6	*Cratoxylon arborescens* (Gerunggang)	*Control*	0.0 a	3 months		[18]
		Glomus sp. 1	20.0 a	3 months		
		*Glomus sp. 2*ara>	60.0 b	3 months		
		Glomus sp. 5	65.0 b	3 months		
		Gigaspora sp.	70.0 b	3 months		
7	*Combretocarpus rotundatus* (Merapat)	*Control*	0	9 months		[16]
		G. clarum	29	9 months		
		Gigaspora sp.	65	9 months		

a bioprotector, capable of protecting plants from biotic stresses such as pathogens, pests and weeds as well as biotic stresses such as temperature, soil moisture, soil density and heavy metals; (3) as a bioactivator, able to help increase carbon storage in the rhizosphere so that the activity of microorganisms increases and (4) as a bioaggregator, able to increase soil aggregation.

In the forestry sector, this AMF is widely recommended as a stimulant to accelerate plant growth (biofertilizer) in restoration activities of degraded land [22]. The use of AMF in the forestry sector can be seen from several related studies that have been carried out. AMF inoculation and composting increased the growth of teak seedlings on planting media from limestone ex-mining soil [23]. Provision of compost by inoculation of several doses of AMF on ultisol soil media also affects the increase in stem diameter of Surian seedlings [24]. Local AMF inoculum proved to be quite effective in increasing growth, biomass and nutrient uptake of nail wood seedlings *Pericopsis mooniana* [25].

Conclusion

AMF application in tropical peatland plant species at nursery level showed varying effects on height, diameter growth and survival rate. Field test results showed that the application of mycorrhizae on tropical peatland plants could increase the diameter and number of leaves of the plants. AMF has prospects to be developed in order to support the revegetation of degraded peatlands in Central Kalimantan, but there are still challenges to be faced, namely the suitability of AMF with host plants and plant survival rate which is still low in the field. Further AMF exploration in peat swamp forest needs to be carried out to obtain new isolates that are compatible with the plants to be developed.

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