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EFFECT OF TROPICAL VEGETATION COVERS ON VESICULAR-ARBUSCULAR MYCORRHIZA (VAM) PROPAGULE DENSITIES

PENGARUH JENIS TANAMAN PENUTUP TANAH DI DAERAH TROPIS TERHADAP KEPADATAN FUNGI VAM

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ABSTRACT

VAM fungi differ greatly in effectiveness and, thus, it is of interest to have information on the ecological tropical conditions where specific VAM fungi are found. Therefore, it is important to know the distribution of VAM fungi as related to different type vegetative covers in the tropics in order to understand the reasons for specific VAM management to optimize crop productivity. The objectives of this study were to (i) quantify the influence of vegetative land cover on the presence of VAM propagule densities and (ii) define the relationship between the density of VAM fungi to total C, total N and available P. The results suggest that the vegetative cover had a significant effect on all properties, but total N at the depth of 5-15 cm. The inclusion of trees as a land cover has demonstrated clearly their beneficial role in increasing total soil C, N and P especially at the soil surface of 0-5 cm. Data indicate that the greatest changes in soil chemical properties occurred in P level as the vegetative cover change from trees, herbaceous to grass. For VAM fungi propagule, vegetative cover and depth interval were no significant effect but the interaction term of vegetative cover and depth interval was significant. This implied that both vegetative cover and depth effects are important considerations in evaluating the effects of land cover on VAM fungi propagules.The greatest VAM densities were found under herbaceous plants at the depth interval of 0-5 cm, and the lowest occurred in the grass land. The greater value of VAM propagules distribution occurred at the depth interval of 0-5 cm (70%) compare to the depth of 5-15 cm (30%). In this study, VAM fungi ecologically prefers to associate with the herbaceous plants. The close relationship between VAM and other soil parameters suggests that changes of VAM propagule presence as affected by type of vegetative cover in these soils were closely associated with the changes in the magnitude of the soil nutrients, such total C, N and available P.

Key words : Carbon, Forest, Grass, Herbaceous, Nitrogen, Phosphorus, Vesicular-arbuscular mycorrhiza (VAM)

ABSTRAK

Efektivitas fungi VAM di alam bervariasi, sehingga diperlukan informasi tentang faktor ekologi yang mempengaruhi keberadaan VAM secara spesifik. Untuk mendukung hal tersebut, maka pengetahuan mengenai keterkaitan antara fungi VAM dengan tanaman penutup tanah perlu dipahami agar optimalisasi produktivitas tanaman dapat dipertahankan. Penelitian ini bertujuan untuk melakukan kuantifikasi terhadap populasi VAM serta menunjukkan keterkaitan antara kandungan total C,N dan ketersediaan P dengan kepadatan VAM. Hasil penelitian memberikan gambaran bahwa tanaman penutup tanah mempengaruhi secara nyata terhadap semua sifat-sifat tanah, kecuali pada kandungan total N untuk kedalaman 5-15 cm. Data menunjukkan bahwa perubahan terbesar terjadi pada level ketersediaan P dengan kisaran mulai dari pohon, herba dan rerumputan. Sebagai faktor tunggal, tanaman penutup tanah dan kedalaman pengambilan sampel tanah tidak berpengaruh secara nyata terhadap kepadatan VAM, tetapi interaksinya berpengaruh nyata. Kepadatan fungi VAM tertinggi terdapat pada lahan yang ditumbuhi herba untuk kedalaman 0-5 cm dan terendah ditemukan pada lahan rumput. Distribusi propagul VAM tertinggi terdapat pada kedalaman 0-5 cm (70%) dan terendah pada kedalaman 5-15% (30%). Dalam studi ini, fungi VAM secara ekologis lebih memilih berasosiasi dengan herba dibandingkan dengan jenis pohon dan rumput. Keeratan hubungan antara fungi VAM dengan sifat-sifat tanah yang lain memberikan indikasi bahwa keberadaan dan kepadatan VAM erat kaitannya dengan kandungan unsur hara tanah, seperti total C, N dan ketersediaan P.

Kata kunci : Fosfor, Karbon, Nitrogen, Tanaman penutup tanah, Vesicular-arbuscular mycorrhiza,

INTRODUCTION

Vesicular-arbuscular mycorrhizal (VAM) fungi colonize the roots of most plants. Their hyphae function as extensions of the host plant's root system and reach microsites outside the rhizosphere which are not accessible to the root. A voluminous literature has clarified the beneficial and often essential role of VAM fungi in supplying nutrients to the host plants (Harley & Smith, 1983; Powell & Bagyaraj, 1984; Sanders *et al.*, 1975). In contrast, only a few studies have considered the effect of different natural ecosystem on the presence and densities of VAM fungi, especially under tropical environment.

Evans & Miller (1988) reported that mycorrhizal colonization was higher in undisturbed soil due to the greater shoot P absorption for plants grown in undisturbed soil. McGonigle *et al.*(1990) suprisingly found that mycorrhizal colonization did not differ among the soil disturbance, but the disturbance influenced the extraradical mycelium which leads to reduced P absorption. A role of extraradical mycelium in soil disturbance experiments has also been suggested by other studies (Evans & Miller, 1990; Jasper *et al.*, 1989).

The most important biotic factor influences mycorrhizal development under undisturbed environment in the tropics is the role of vegetation as a land cover. Vegetation cover can act as a host to provide and enhance the development of VAM propagules, thus increase the population of VAM fungi in the rhizosphere and bulk soil. There is a good evidence that VAM development is affected by plants (Mulligan *et al.*,1985; Vivekanandan & Fixen, 1991; Sieverding,1991). Mulligan *et al.* (1985) observed a significantly lower mycorrhizal colonization under garden bean of excessive tillage as affected by greater soil compaction. Under low soil P conditions, mycorrhizal colonization of maize was lower under conventional tillage than ridge tillage (Vivekanandan & Fixen, 1991). According to Sieverding (1991) the indigenous VAM propagule concentrations are mainly correlated with the vegetation cover and agronomic practices. The VAM of grasses and herbaceous plants penetrate the cortical cells of roots to form arbuscules and generally improve plant uptake of inorganic P (Jakobsen, 1995). On their study in Somalia, Africa, Michelsen & Rosendahl (1988) reported that degradation of vegetation negatively affects VAM propagule densities because VAM fungi depend on photosynthetic assimilates from the host plants. A reduction in the incidence of mycorrhizae after fallowing has also been reported (Kucey & Paul, 1983; Harinikumar & Bagyaraj, 1988). The fungal partner cannot multiply without living plant roots and the population declines during fallow, resulting in poor root colonization and symbiotic effectiveness with next crop.

Although the ubiquitous occurrence of VAM and its favorable influence on plants has been described, relatively few experiments have been conducted to determine the vegetative cover effect on VAM fungi densities under field tropical conditions. The objectives of this research were to: (i) quantify the influence of vegetative land cover on the presence of VAM propagule densities and (ii) define the relationship between the density of VAM fungi to total C, total N and available P. This information is important to better understand the impact of plant species on VAM development.

METODOLOGY

Study Site

The study site was located in Bengkulu Province in south Sumatra. Average precipitation for the area is about 300 mm per month. Rainy season period is from October to March, whereas dry season period is from April to

September. An average daily temperature is 21 °C – 31 °C with differences between minimum and maximum temperature was about 10 °C. The study site was located on a relatively flat (< 5% slope) area mapped as an Ultisol, one of the predominant soil order in Sumatra, Indonesia.

Three types of vegetation cover, including forest garden, grasses of Imperata cylindrica, and mix herbaceous plants sites were selected in 2001. These sites were adjacent to one another; maximum distance was 1000 m. Forest garden was established in 1966, and the grassland site was initiated in 1996 which is typical tropical grassland during shifting cultivation period. Herbaceous land was initiated in 1991 consisting of mixed *Chromolaena odorata* and *Melastoma malabathricum*.

Sample Collection and Processing

Disturbed soil samples were collected from the depth 0-5 cm and 5-15 cm using three replications for each vegetation cover treatment. Fresh soil samples were sieved using 1.7 mm diameter and analyzed for the presence and density of VAM fungi (Sieverding, 1991). A portion of the sieved, moist soil was dried at 60°C for 48 days then analyzed for soil chemical properties, such as soil pH, total C, total N and available P. Soil pH was measured in water with ratio 1:2.5. Total C was determined by the Walkley-Black method (Anderson & Ingram, 1989), assuming that all plant C was oxidized during digestion. Nitrogen concentration in soil was determined by the Kjedahl method (Anderson & Ingram, 1989). Avalaible P in soil was determined by the method of Ball-Coelho *et al.* (1993).

Data Analysis

Vegetative cover and depth effects for VAM fungi propagule densities were evaluated by analyses of variance with vegetation as the whole-plot factor and depth as the split-plot factor. Because depth cannot be randomized, caution was exercised while interpreting results (Cassel & Nelson, 1985). Comparisons for main and interactive effects were made using least significant differences at $p < 0.05$.

RESULTS AND DISCUSSION

Selected soil chemical properties under three types of vegetative cover for the first two depth intervals are presented in Table 1. Average values of the chemical properties of soils for the three vegetative cover are given in Table 1. The vegetative cover had a significant effect on all properties, but total N at the depth of 5-15 cm (Table 2). The inclusion of trees as a land cover has demonstrated clearly their beneficial role in increasing total soil C, N and P especially at the soil surface of 0-5 cm. However, increased potential for accumulation of residual nitrates in the system could be a drawback of the system. The accumulation of organic anions and nitrites are the main causes of net acid addition to the main agrofrestry and forest garden of Sumatra (Handayani, 2001). This finding is similar to the previous study on the impact of different natural fallow species on the soil nutrient (Handayani *et al.*, 2002). The results suggest that various plants species caused different magnitude of litter fall, thus influenced the level of soil organic matter, total N, inorganic N and P. The research also shows that herbaceous plants significantly increased total C,N and P content in soil compare to grasses. In addition, various plant species (grain crops vs trees vs grass) resulted in differences in the soil capacity to mineralize N and C (Handayani *et al.*, 2001). This eventually would influenced the magnitude of C and N levels in soil. Data indicate that the greatest changes in soil chemical properties occurred in P level as the vegetative cover change from trees, herbaceous to grass.

Tabel 1. Selected soil chemical properties under three types of vegetative cover.

Vegetative cover	Depth (cm)								
	0-5			5-15			0-15		
	C (%)	N (%)	P (ppm)	C (%)	N (%)	P (ppm)	C (%)	N (%)	P (ppm)
Forest garden	4.45	0.28	13.50	2.74	0.20	12.85	3.60	0.24	13.18
Grass	2.44	0.26	1.25	2.29	0.21	0.70	2.38	0.24	0.98
Herbaceous	2.56	0.21	2.53	1.90	0.18	2.23	2.23	0.20	2.38
Means	3.15	0.25	5.76	2.31	0.20	5.26	2.74	0.23	5.51

Table 2. Probability levels for statistical significance for treatment effect on total C, N and available P contents in soil.

Soil Property	Significance (P>F)	
	Depth 0-5 cm	Depth 5-15 cm
Total C	p< 0.05	P<0.05
Total N	p<0.05	p>0.05
Available P	p<0.05	p<0.05

Statistical analysis of VAM fungi involved two levels factors: vegetative cover and depth interval (Table 3). Vegetative cover and depth interval was no significant effect but the interaction term of vegetative cover and depth interval was significant. These results show that both vegetative cover and depth effects are important considerations in evaluating the effects of land cover on VAM fungi propagules.

The greatest VAM densities were found under herbaceous plants at the depth interval of 0-5 cm, and the lowest occurred in the grass land (Table 3). The greater value of VAM propagules distribution occurred at the depth interval of 0-5 cm (70%) compare to the depth of 5-15 cm (30%). This implied that the depth of sampling is an important factor in determining and isolating the VAM propagules. This result is similar to the research reported by Michelsen & Rosendahl (1988). The lowest propagule numbers are found in degraded vegetations which are overgrazed, logged or cleared for shifting cultivation.

Table. 3. Effect of vegetative cover on distribution of VAM fungi propagule densities.

Vegetative Cover	VAM (spora/100 g soil)		
	Depth (cm)		
	0-5	5-15	0-15
Forest garden	3275ab	1956a	2661
Grass	5300b	2233a	3767
Herbaceous	7600c	2773a	5187
Means	5391.67	2320.67	3871.67
Analysis of Variance	*Vegetative Cover (V)*	*Depth (D)*	*V x D*
p> F	0.1139	0.1841	0.044

Number followed by the same letter indicates no sigifinant different at α 5%.

Dehne (1988a) reported that high input inorganic fertilizer under high technology farming in Colombia caused low reproduction of VAM fungi due to that the crop plants were slightly dependent on VAM fungi. This is the reason that VAM fungi propagules were lower in the forest garden, which had the best soil fertility levels compare to grassland and herbaceous land. Thus, in the long run, will result in low VAM populations in forest soils. It is very likely that in these soils the low VAM propagule density limits the growth when an obligate mycotrophic crop is planted, or when a specific abiotic and biotic stress is influencing the crop (Dehne, 1988b). In addition, the facts also show that preferential associations and preferential reproduction of VAM fungi can be expected to be common in tropical ecosystems, because even small agronomic inputs to a system may improve the competitive ability of a fungal species. In this case, VAM fungi in Bengkulu environment prefers to associate with the herbaceous plants. However, preferential associations are additionally influenced by soil properties (chemical, physical and biology) and are dependent on the initial VAM population.

It seems that the vegetative cover of forest and grass tend to decrease the VAM population. There are three mechanisms that could explain this result: (i) VAM fungi may not tolerate the new edaphic conditions, or (ii) VAM fungi are not able to infect the host plant under the condition in forest and grass, or (iii) VAM fungi are not able to compete with other VAM fungal species which had become dominant due to the new growth conditions. Other study by Mosse (1981) indicated that during fallow period generally improves the VAM propagule density in soils. This may be due to the fact that the plant density per ha is increased by cultivation or that crop have high photosynthetic assimilation rates. It is assumed that VAM propagule density in uncropped and cropped soils fluctuated due to the growth stages, seasonal stresses and the intensity of agronomic inputs applied to the ecosystem (Sieverding, 1991).

VAM propagule densities decrease with increasing soil depth (Table 3). This is a correlation between organic matter and depth. The reason is that root growth is generally concentrated in the upper soil horizon because there, due to mineralization of organic matter, nutrients are present and the oxygen content of the soil is higher. Thus, subsoils have very low propagule concentrations. This is important consideration if there is a risk of erosion.

The means of VAM propagule density in the three types of vegetative cover and two depth intervals were linearly regressed with means of the soil parameters of total C, N and available P given in Table 4. The results show that variations in VAM alone could explain rest of the variations in total C, total N and available P. The coefficient of determination associated with the variations of available P was low. Of interest is the fact that negative slopes indicate as the values of total C, N and available P increased then the VAM propagule densities decreased. The close relationship between VAM and other soil parameters suggests that changes of VAM propagule presence as affected by type of vegetative cover in these soils were closely associated with the changes in the magnitude of the soil chemical properties, such as C, N and P.

Table 4. Linear relationships between total C, N and available P and VAM fungi propagule densities of the soil.

Dependent variable	Intercept	Slope	R^2
Total C	159.49	- 30.13	0.77*
Total N	276.67	-886.89	0.79*
Available P	93.94	-2.98	0.59

* indicates a significant relationship at α 5%.

VAM fungal propagule density is correlated with the organic matter in the soil (Sieverding, 1991). The decrease of soil organic matter through plowing may induce an enormous mineralization within a few weeks of this activity. Within 4 weeks of plowing, up to 400 mg N in the form of ammonium were liberated per kg soil when water was not limiting the mineralization. Chambers *et al.* (1980) said that amonium inhibits the VAM formation, hence the negative effect of plowing may be an indirect one. Increasing levels of N may inhibit VAM formation and may negatively affect the VAM population (Hayman, 1987). Ammonium sources were reported inhibit more than nitrate sources (Chambers *et al.*, 1980). However, it is likely that the N effect on VAM formation depends on the crop or plants studied (Sieverding, 1991).

Hayman (1987) reported that high P availability negatively correlated with VAM activity and apparently, the internal P content of plants regulates VAM infection ratings. Higher P levels, such in the forest could decrease cell membrane permeability for carbohydrates, thus VAM fungi may suffer through inhibited photosynthate support from plants.

CONCLUSIONS

The vegetative cover had a significant effect on all properties, but total N at the depth of 5-15 cm. The inclusion of trees as a land cover has demonstrated clearly their beneficial role in increasing total soil C, N and P especially at the soil surface of 0-5 cm. Data indicate that the greatest changes in soil chemical properties occurred in P level as the vegetative cover change from trees, herbaceous to grass. For VAM fungi propagule, vegetative cover and depth interval were no significant effect but the interaction term of vegetative cover and depth interval was significant. These results show that both vegetative cover and depth effects are important considerations in evaluating the effects of land cover on VAM fungi propagules.The greatest VAM densities were found under herbaceous plants at the depth interval of 0-5 cm, and the lowest occurred in the grass land. The greater value of VAM propagules distribution occurred at the depth interval of 0-5 cm (70%) compare to the depth of 5-15 cm (30%). VAM fungi in Bengkulu environment prefers to associate with the herbaceous plants. There are three mechanisms that could explain the lower VAM population under forest and grass land : (i) VAM fungi may not tolerate the new edaphic conditions, or (ii) VAM fungi are not able to infect the host plant under the condition in forest and grass, or (iii) VAM fungi are not able to compete with other VAM fungal species which had become dominant due to the new growth conditions. The close relationship between VAM and other soil parameters suggests that changes of VAM propagule presence as affected by type of vegetative cover in these soils were closely associated with the changes in the magnitude of the soil chemical properties, such total C, N and available P.

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