International Journal of Agricultural Technology 2020 Vol. 16(5):1145-1152
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Arbuscular mycorrhizal fungi related to soil phosphorous, organic matter and pH in cassava field

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Nabhadalung, N. (2020). Arbuscular mycorrhizal fungi related to soil phosphorous, organic matter and pH in cassava field. International Journal of Agricultural Technology 16(5):1145-1152.

Abstract The result showed that cassava can be planted in acidic to alkaline soil (pH 3.0-8.5) in Thailand. Soil phophorous (soil P) in cassava field was 0.05- 91.91 mg kg^{-1}, and organic matter (OM) was 0.22-4.49%. The spores of arbuscular mycorrhizal fungi (AMF) in cassava field was varied in between 25-1,880 spores 100 g^{-1} soil which identified into eighteen species. *Glomus* sp. and *Acaulospora* sp. were mostly found in cassava field. AMF spore number was negatively related to soil P ($r^2 = 0.07$, $p < 0.01$, n = 295). AMF spore number in cassava field was not related to soil OM ($r^2 = 0.003$, $p > 0.05$, n = 295) and AMF spore number in cassava field was not related to soil pH ($r^2 = 0.001$, $p > 0.05$, n = 295). Fifteen AMF species that colonized in cassava root might be possibility to improve cassava growth.

Keywords: AMF, Cassava, Soil P, Organic matter, pH

Introduction

In Thailand, cassava (*Manihot esculenta* Crantz) is considered as one of the most important economic crops with annual production of around 25 million tons (Piyachomkwan and Tanticharoen, 2011). Arbuscular mycorrhizal fungi (AMF) promote many plant life, in particular improved nutrition, better growth, stress tolerance, and disease resistance. In addition, the hyphal networks of AMF improve soil characters such as soil particle aggregation, improving the resistance of soil erosion by wind and water. AMF are also decreased nutrient leaching from the soil, thereby contributing to the retention of nutrients in the soil, and decreasing the risks of contamination of ground water (Chen *et al.*, 2018). AMF diversity in Thailand has been studied and reported in different plant community, In the forest restoration area of Doi Suthep-Pui National Park, northern Thailand, twenty-one AMF species, were founded and identified into *Acaulospora* (6 species), *Glomus* (12 species) and

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Scutellospora (3 species). AMF belonging to the *Glomus* and *Acaulospora* were found to be dominant. Abundant species presented as *Acaulospora elegans, Glomus multicaule* and *Scutellospora pellucida* (Nandakwang *et al.,* 2008). The composition of AMF communities associated with rubber tree roots in Northeast Thailand differed between cassava and rubber tree plantations and was influenced by soil texture and nutrient content (K, P, Ca). AMF community composition gradually shifted with the age of the trees (Herrmann *et al.,* 2016). Twenty-two species of AMF were found associated with tangerine in orchads of Chiang Mai province. AMF colonization and spore density in rhizoshere significantly depressed when available P more than 500 mg P kg^{-1} soil. (Youpensuk *et al.,* 2008). Sarr *et al.* (2019) studied the composition of AMF community in cassava field soils in two agro-ecologies of Cameroon using Illumina MiSeq of the ITS2 region. Fifteen AMF species were identified from the 27 OTU, and they were dominated by *Glomus sinuosum* and *Paraglomus occultum* in both sites. However, AMF species associated cassava field in Thailand have been never reported. The research finding was focused on AMF spore number in the cassava field which related to soil chemical properties, and possibility of the native AMF to improve cassava growth.

Materials and methods

Two-hundreds and ninety-five soil samples were collected from cassava fields across all region of Thailand from fourty-one provinces. Five kilograms of each soil sample was collected in root zone of cassava plant, air dried, grinded through 2 mm sieve. AMF spores from each soil sample was separated from 100 g air-dried soil using wet sieving and decanting method (Gerdeman and Nicolson, 1963) through 250 and 45 μm followed by sucrose centrification (Danial and Skipper, 1982). The AMF spores was counted and identified according to morphological characteristics by international culture collection of the vesicular arbuscular mycorrhizal fungi which species guide and manual for identification of AMF (Schenck and Perez, 1988). The frequency of each AMF spore characteristic was calculated by the percentage of the number of samples in which the genus was observed. Each AMF spore characteristic was established in pot cultures to study AMF colonization in cassava roots. Each soil sample was determined for soil pH using a pH meter, available phosphorus in soil (soil P) was done by Bray II method (Bray and Kurtz, 1945) and ammonium molybdate-ascorbic acid method (Watanabe and Olsen, 1965), soil organic matter (soil OM) was followed the method of Walkley& Black method (Walkley and Black, 1934). The pearson's correlation coefficient was calculated for relation between AMF spore number and soil pH, relation between AMF spore number and soil P, and relation between AMF spore number and soil OM.

Results

Soil samples from cassava field in Thailand was very strongly acid to moderately alkaline soil (soil pH = 3.0-8.5). They contained 0.05 - 91.91 mg kg^{-1} of available P in soil and 0.22-4.49% of soil OM. The spore number of AMF in cassava field was in between 25–1,880 spores 100 g^{-1} soil (Table 1). Eighteen AMF species was found and identified as *Gigaspora, Scutellospora*, *Glomus*, *Acaulospora*, and *Entrophospora*. *Glomus* sp. and *Acaulospora* sp. were high frequency found under cassava field. In pot culture, fifteen AMF species showed colonization in cassava roots (Table 2). The AMF spore number was negatively related to soil P ($r^2 = 0.07$, $p < 0.01$, n = 295). AMF spore number in cassava field was not related to soil OM ($r^2 = 0.003$, $p > 0.05$, n = 295) and AMF spore number in cassava field was not related to soil pH ($r^2 = 0.001$, $p > 0.05$, n = 295). However, AMF spore number trended to increase with increased in soil OM whereas AMF spore number trended to decrease with increased soil pH (Figure 1). The AMF species that showed colonization in cassava roots might be possibility of AMF to improve cassava growth in the field.

Table 1. Ranged and averaged of soil pH, soil P, soil OM and AMF spore number in soil from cassava fields

Regions of Thailand	No. of soil samples	soil pH	soil P (mg g^{-1})	soil OM (%)	AMF spore number (spore 100g^{-1} soil)
1. Northeast	153	4.5-8.0 (6.1)	0.16-81.57(21.9)	0.22-4.49 (1.3)	60-1,880 (334.5)
2. Central	89	3.0-8.5 (6.6)	0.05-91.91(24.2)	0.43-4.23 (1.8)	40-1,220 (315.9)
3. North	53	4.8-7.5 (6.7)	0.84-91.91(24.2)	0.43-3.37 (1.6)	25-1,320 (359.9)
Total	295	3.0-8.5 (6.4)	0.05-91.91 (22.5)	0.22-4.49 (1.5)	25-1,880 (333.4)

Table 2. Characteristic of AMF spores, identification, frequency and root colonization of AMF founded in root zone of cassava

	Characteristic of AMF spores founded in root zone of cassava	**Identification by spore morphology**	**Frequency in field (%)**	**Root colonization (%)**
1	Globose shape with hypha, 150-200 µm, shiny brown color.	*Glomus* sp.1	91	√
2	Globose, 80-100 µm, white to cream color, single chlamydospore with hypha.	*Glomus* sp.2	98	√
3	Globose, 80-115 µm, white to cream color, single chlamydospore with hypha and content in spore present.	*Glomus* sp.3	92	√
4	Sporocarp formation without peridium, sub globose chlamydospore 60-90 µm, grey color.	*Glomus* sp.4	48	√
5	Sporocarp formation with peridium, subglobose chlamydospore, dark brown color.	*Glomus* sp.5	15	×
6	Globose shape with hypha, 220-250 µm, dark orange and grey color.	*Glomus* sp.6	78	×
7	Globose shape with hypha, 200-240 µm, shiny white to green color.	*Glomus* sp.7	66	√
8	Subglobose, 80-90 µm, pale yellow to green color, single chlamydospore with hypha.	*Glomus* sp.8	59	√
9	Globose shape, 75-130 µm, shiny yellow to green color to orange color.	*Acaulospora* sp.1	98	√
10	Globose shape, 70-110 µm, green to grey color.	*Acaulospora* sp.2	80	√
11	Globose shape, 90-120 µm, shiny white to orange color, content in spore present.	*Acaulospora* sp.3	99	√
12	Globose shape, 100-120 µm, shiny creamy to orange to grey color.	*Acaulospora* sp.4	87	√
13	Subglobose, 60-90 µm, dark orange color, single chlamydospore.	*Acaulospora* sp.5	74	√
14	Globose to subglobose shape, 250-280 µm, dark orange color.	*Acaulospora* sp.6	94	×
15	Globose shape with suspensor, 220-250 µm, dark orange color.	*Gigaspora*sp.2	45	√
16	Globose shape with suspensor, 220-250 µm, white to cream color.	*Scutellospora* sp.	33	√
17	Globose shape, 150-200 µm, orange to dark orange brown, and hyaline, subglobose sporiferous succule and thick spines present.	*Entrophospora* sp.1	41	×
18	Globose, 75-90 µm, white color, single chlamydospore	*Entrophospora* sp.2	84	√

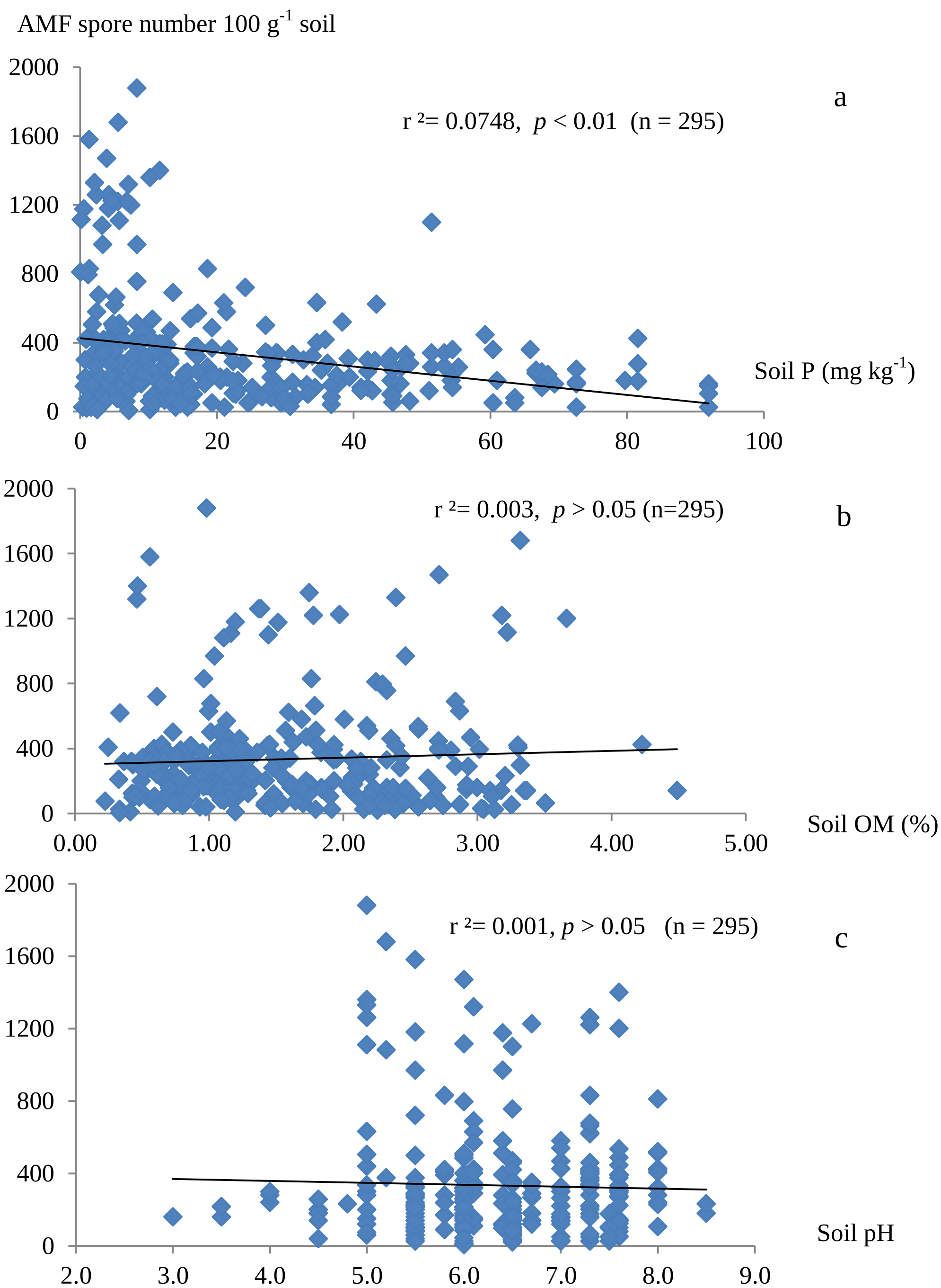

Figure 1. Relationship between AMF spore number 100 g^{-1} soil and soil P (a) between soil OM (b) and between soil pH (c)

Discussion

The result indicated that cassava could be grown in the range of soil pH for 3.0-8.5. The spore number of AMF in cassava field was about 25–1,880 spores 100 g^{-1} soil. The pH of the soil in cassava field with high AMF spore number ranged from 5 to 8. Isobe *et al*. (2007) found that high spore density of AMF in the samples with soil pH ranged from 6 to 8, and soil samples with a pH lower than 6 and higher than 8, the spore density was lower than 5 spores g^{-1} soil. Thus, in the acid or alkaline soil, the sporogenesis of AM fungi is suppressed. Youpensuk *et al*. (2008) studied AMF colonization in upland rice and *Macaranga denticulate* in soil pH at 4.5, 5.9 and 7.8. They found the highest AMF colonization percentage at 5.9 of soil pH. Althought, AMF spore number in cassava field was not related to soil OM but AMF spore number trended to increase with increasing of soil OM supported by Vaidya *et al.*, (2007) found that organic matter addition can improve AMF biomas and spores as well as plant survival. The negative relation between AMF spore number and soil P were found in this study. According to AM fungi colonization and spore number had negative effects by phosphorus fertilization (Jasper *et al*., 1979; NaBhadalung *et al*., 2005). In ecology in Cameroon which had less available P showed a higher AMF diversity and contained 10 site-specific species, compared to ecology in which more than available P where only 2 site-specific species were found (Sarr *et al.*, 2019). Many reports showed negative relation between AMF spore number and soil P**,** as Khakpour and Jalil (2012) stated that the relationship between soil physical and chemical factors and number of mycorrhizal spores were related to these factors and percentage root colonization. Furthermore, there was negative correlation between number of spores with phosphorus content and electric conductivity of soil and positive correlation between number of spores and root colonization. However, some research showed positive relation between numbers of AMF spore and available P in soil. Effendy and Wijayani (2011) found a linear corelation between numbers of AMF spore and available P in soil, and the greater the AMF spore number, the higher the available P in soil. Ong *et al.,* (2012) found soil P in forest rehabilitation was positively related to the spore count ($r > 0.68$, $p < 0.001$) while the most probable number (MPN) was negatively influenced by soil K ($r = -0.632$, $p < 0.01$). In this study, soil chemical properties, especially available soil P confirmed a direct negative effect on the abundance of AMF spores in the root zone of cassava, and also AMF produced spores in strongly acid soil to slightly alkaline soil and soil OM trended to increase the AMF spores.

Acknowledgements

The author would like to particular thanks to Thailand Research Fund (TRF) for granting. The author is also grateful to thank Prof. Dr. Amnat Suwanarit and Prof. Dr. Bernard Dell for supporting. And finally the special thanks goes to all of friend for thier helpful.

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(Received: 26 August 2019, accepted: 30 August 2020)