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Soil physicochemical properties and its relationship with AMF spore density under two cropping systems

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Abstract

The objective of the study was to determine the soil physicochemical properties and its relationship with AMF spore population associated with upland rice grown under mixed and mono cropping systems. The rhizosphere soil of upland rice from the two cropping systems were collected for analysis of soil moisture content, soil temperature, pH, organic carbon, total nitrogen, available phosphorus, exchangeable potassium and AMF spore population. For isolation and enumeration of AMF spores, wet sieving and decanting method was followed. Mixed cropping harboured higher AMF spore population relative to mono cropping. Soil moisture content, total nitrogen and organic carbon was higher in mixed cropping system, whereas soil temperature, pH, available phosphorus and exchangeable potassium were higher in mono cropping system. Among the soil properties analysed, significant negative relationship of spore density with soil pH, available phosphorus and exchangeable potassium was observed in both the cropping systems and a significant positive relationship of spore density with moisture content and organic carbon was observed only in mixed cropping system. The present study suggests that cropping systems and its associate soil physicochemical properties influenced the spore population of AMF in the rhizosphere soil of upland rice.

Key words – arbuscular mycorrhizal fungi – mixed cropping – mono cropping – soil properties – upland rice

Introduction

Soil is a fundamental component of agro-ecosystem, it act as biological entities with complex biochemical reaction (Dick 1994, Kizilkaya & Dengiz 2010). It is said to be fertile, when all conditions – physical, chemical and biological properties are favourable to crop development. Absence of any of these, acts as limiting factor and the crop as a whole suffers (Dutta 1986). Physical conditions determined the environments in which biological processes take place (de Vos et al. 1994), while chemical characteristics determined maximum quality of a particular soil (Hassink 1997). Different crops remove different amounts of mineral nutrients from the soil (Tulu 2002). In this regard, the practices of mixed cropping, mono cropping, crop rotation, among others, deplete the soil essential plant nutrients in varying quantities depending on the nutrient demand of crops and the type of cropping system. Studies on mixed versus mono cropping plant species revealed that plant mixtures can produce greater plant biomass (Forrester et al. 2004), improve

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nutrient cycling and soil fertility (Montagnini 2000). The increase in plant biomass in mixed cropped may have strong effects on soil microbial community.

Analysis of soil is important for enumeration of microbial population, function and activities of soil microorganisms which are potential early indicator of soil health and quality (Schnurerer et al. 1985, Dick 1994). Arbuscular mycorrhizal fungi (AMF) are important components of rhizosphere microbial communities in agricultural ecosystems. It is a beneficial microbe fundamental for soil fertility that helps in increasing resistance to environmental stresses, enhancing plant nutrient acquisition, water relations, disease resistance, efficient recycling of nutrients and thus to long term stability and stabilization of the soil (Smith & Read 2008). AMF are known to be sensitive to changes in soil physicochemical properties alter by land use and land management practices in agricultural system. It has been widely reported that edaphic and climatic factors markedly influence AMF populations, rapid changes in soil nutrients may affect AMF association and spore counts (Abbot & Robson 1991).

In order to exploit the biofertilizers potential of AMF for sustainable crop production, it is essential to understand the different factors influencing population of AMF. Meagre work has been done on the relationship between edaphic factors and AMF spore population in different cropping system particularly in upland rice growing region of Meghalaya, India. Therefore the present study aims to determine the soil physicochemical characteristics and AMF spore population associated with upland rice grown under mixed and mono cropping system and to find out the relationship of the various soil parameters and AMF spore density in each cropping systems.

Materials & Methods

Site description and Field sampling

Samples were collected from farmers' fields of upland rice mixed and mono cropping systems of Ri-Bhoi District, Meghalaya India. The indigenous upland rice variety *Kba Saw* was selected which are widely grown by the local farmers. Under mixed cropping upland rice were grown with other secondary crops like rice bean (*Vigna umbellate*) and maize (*Zea mays*). Rhizosphere soils of upland rice was collected from each cropping system at monthly intervals (April to November 2012) with ten replicates per site with sampling points approximately 5 m apart for analyses of AMF spore density and various soil physico chemical properties viz., soil temperature, soil moisture, pH, organic carbon, total nitrogen, available phosphorus and exchangeable potassium. Samples collected were mixed, kept in sterile plastic bags and transported to the laboratory for analysis. AMF spores isolation and enumeration was done by wet-sieving and decanting method of Gerdemann & Nicolson (1963). Suspension of 25g soil sample in water was passed through a series of 710 to 37µm sieves. The residues in the sieves were washed into beaker and the sievates were dispersed in water and filtered through filter papers. These filter papers were spread in a Petriplates and intact spores were counted using a dissection microscope at 40X magnification. Sporocarps and spore clusters were considered as one unit. The AMF spores and sporocarps were picked up from the filter papers using a laboratory needle and mounted in polyvinyl alcohol-lactoglycerol (PVLG) with or without Meltzer's reagent on a glass slide and identified based on the online species descriptions published by Morton (http://invam.caf.wvu.edu/Myc_Info/Taxonomy/species.htm), AMF phylogeny (http://www.amf-phylogeny.com), Oehl & Sieverding (2004) and Goto et al. (2008).Spore density was expressed as number of AMF spores in 25g soil samples. Soil temperature was recorded using a digital soil thermometer at the time of sampling. Soil moisture content was determined by drying 10g of freshly collected soil sample at 105˚C for 24 hrs in a hot air-oven. Soil pH was measured in 1:5 soil-water suspensions using digital pH meter. Organic carbon was determined using colorimetric method and total nitrogen was determined following Kjeldahl method as outlined in Anderson & Ingram (1993). Soil exchangeable potassium was estimated using flame photometer method of Jackson (1973). Available phosphorus was estimated by molybdenum blue method of Allen et al. (1974).

Statistical analysis

Data were statistically analysed using one-way ANOVA. Pearson correlation coefficient was employed to determine the relationships between AMF spore density and soil physico-chemical properties. Standard errors of means were calculated for all the parameters studied.

Results & Discussion

Different cropping practices causes variation in soil physicochemical properties and AMF spore population in the rhizosphere soils of upland rice. The mean values of soil physicochemical properties and AMF spore density are presented in (Table 1). The spore count of AMF was significantly higher in mixed cropping system relative to mono cropping. The average spore count in rice mixed and mono cropping were 704.3 and 467.9 per 25 g soil respectively. Changes in cropping pattern may modify the sporulation and population of AMF in agriculture due to changes in soil nutrients, microbial activity and vegetation (Abbot & Robson 1991, Jansa et al. 2002). Highest spore density of AMF was observed in rice mixed cropping where the soil had high levels of moisture content, organic carbon and nitrogen content and low levels of temperature, pH, phosphorus and potassium. Pearson's correlation of soil physicochemical properties and AMF spore density is given in (Table 2).

Table 1 Mean (±SE) values and one way analysis of variance (ANOVA) of soil physicochemical properties and AMF spore density in mixed cropping and mono cropping.

Cropping systems	MC (%)	Temp (˚C)	pH	OC (%)	TN (%)	P (%)	K (%)	Spore density/25g soil
Mixed cropping	22.23±0.56	28.3±1.17	5.79±0.01	2.20±0.05	0.37±0.008	0.0043±0.0002	0.13±0.001	704.3±116.7
Mono cropping	19.65±0.65	30.1±1.18	5.84±0.02	2.07±0.03	0.30±0.009	0.0057±0.0001	0.17±0.001	467.9±95.3
ANOVA results								
Cropping systems	F = 5.68; $p = 0.032$	_	_	F =13.24; $p = 0.003$	F = 10.96; $p = 0.005$	F = 4.853; $p = 0.045$	_	F = 4.90; $p = 0.04$

Note: Values are the means of eight months of sampling; MC = Moisture content; Temp = Temperature; OC = Organic carbon; TN = Total Nitrogen; P = Available phosphorus; K = Exchangeable potassium. Values are significant at $p \leq 0.05$; insignificant values are marked with '–'.

Table 2 Pearson correlation coefficient analysis of various soil physicochemical properties with AMF spore density under each cropping systems.

Variables	Correlation coefficient (*r*)	
	Mixed cropping	**Mono cropping**
Moisture content (%)	0.72*	0.09
Temperature (˚C)	-0.52	-0.29
pH	-0.90**	-0.87**
Organic carbon (%)	0.93**	0.08
Total nitrogen (%)	0.67	0.45
Available phosphorus (%)	-0.89**	-0.98**
Exchangeable potassium (%)	-0.97**	-0.91**

***-** Significant at P< 0.01
- Significant at P< 0.05

The rhizospheric soil of upland rice in both the cropping systems was moderately acidic with mean pH of 5.79 in mixed cropping and 5.84 in mono cropping. Soil pH is an important factor influencing AMF development (Wang et al. 1993). The response of AMF to soil pH is highly variable and seems to be dependent primarily on the AMF species. Some AMF species occur either in acid or in alkaline soils and others occurs in both (Young et al. 1985, Robson & Abbott 1989). Wang et al. (1993) and Friberg (2001) reported that AMF responds the most at pH value ranging from 5.5 to 7.1. A significant negative relationship between soil pH and AMF spore density was observed in both the cropping systems. Although the pH values across the two cropping systems do not show significant variations, slightly higher soil pH was recorded in mono cropping compared to mixed cropping system. The differences between soils in AMF spores germination appeared to be negatively correlated with the differences in soil pH (Hepper 1984). High soil moisture content and low soil temperature was recorded in rice mixed cropping system. The average soil moisture content was 22.23% in mixed cropping and 19.65% in mono cropping; soil temperature was 28.3 ˚C and 30.1 ˚C in mixed and mono cropping respectively. Soil moisture retention is important because upland rice depends primarily on rainwater. Presence of deep-rooted plant species along with dense foliage and greater accumulation of litter in mixed cropping system might have reduced surface runoff water and provide optimum surface coverage that checked evaporation losses. Similarly Ghanbari et al. (2010) reported that intercropping maize-cowpea has higher soil moisture content and lower temperature as compared to sole crops. Mono cultural agroecosystem associate to weakened soil structure by increased susceptibility to compaction, reduced water infiltration and increased erosion (Arshad et al. 2011). Significant positive correlation observed between soil moisture content and AMF spore population is in accordance with Khanam et al. (2006) and Kumar et al. (2010). Soil moisture content has been reported to have profound influence on AMF spore population and the optimum moisture for plant growth is suitable for AMF sporulation (Redhead 1975). In the present study mixed cropping may facilitate a more favourable soil moisture condition for AMF to sporulate profusely and increased their numbers. The mean soil organic carbon content was 2.20 % and 2.07% in mixed and mono cropping respectively. Higher soil organic carbon in mixed compared to mono cropping is in accordance to Verma et al. (2014), who also noted higher organic carbon in Geranium mixed cropping with cereals, pulses, fodder and vegetables compared to Geranium sole cropping. Various factors such as plant species composition, plant biomass input, quantity and quality of root exudates could lead to the variation in soil organic carbon between the cropping systems. Nelson & Mele (2006) stated that the amount and quality of plant residues and exudates can influence the composition of soil microbial community as well as the dynamic of carbon and nutrient release in soil. A significant positive relationship between AMF spore density and soil organic carbon was observed in mixed cropping suggesting that increase in organic carbon content of soil is followed by an increase in spore counts. Similar results were reported by Johnson et al. (1991) and Mohammad et al. (2003) who found that spore density increased with soil organic carbon. Mycorrhizal scavenge nutrients from soils and transfer a portion of these nutrients to their host plant in return for labile plant C. This exchange also has important consequences for soil C balance, in that; mycorrhizal fungi can promote belowground storage of plant C.

Higher nitrogen content in mixed cropping with a mean percentage of 0.37 was recorded as compared to mono cropping with a mean percentage of 0.30. The increase in total nitrogen in mixed cropping could be attributed to biological nitrogen fixation by the leguminous plant rice-bean (*Vigna umbellate).* Improvement in soil nitrogen as a result of legumes inclusion in rice cropping has also been reported by Jat et al. (2012).Statistically insignificant correlation was obtained between AMF spore density and total nitrogen. Soil available phosphorus and exchangeable potassium was low in mixed cropping compared to mono cropping. The decreased in soil P and K may be due to greater uptake of these nutrients by different plant species in mixed cropping as compared to mono cropping. Li et al. (2004) and Wang et al. (2014) also reported reduction of soil P and K in crop mixtures, due to the combined demand of intercrops for these nutrients. Statistically significant negative relationship of AMF spore population with available P and exchangeable K was observed in both the cropping systems, thereby corroborating previously reported results (Oliveira & Oliveira 2010, Panwar et al. 2011). Generally AMF spore are reported to increase in soil where phosphorus concentrations is low (Galvez et al. 2001). Lower concentration of phosphorus in rice mixed cropping might have contributed to higher population of AMF spore. Phosphorus deficiency in the soils may results in the release of large amount of amino acids and sugars in the rhizosphere which are utilised by AMF for their growth (Jefwa et al. 2010).

Soil potassium is usually reported to have a stimulatory effect on AMF variables and minimum soil potassium has been suggested to be a prerequisite for AMF development (Quimet et al. 1996).

Thus the present investigation implies that cropping systems and its associate soil physicochemical properties influence the AMF spore population in the rhizosphere soil of upland rice. Maintaining the population of AMF as an essential link between plant and soil is important for sustainable management of cropping systems. Edaphic characteristic including soil pH, soil moisture, temperature, soil nutrient content and cropping pattern have been reported to influence AMF population (Abbott & Robson 1991, Jansa et al. 2002). Consequently the relationship between AMF spore densities with different soil characteristics is a result of the interactions between all of these factors.

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References

Abbott LK, Robson AD. 1991 – Factors influencing the occurrence of vesicular-arbuscular mycorrhizas. Agriculture, Ecosystems & Environment 35,121–150.

Allen SE, Grimshaw HM, Parkinson JA, Quaramby C. 1974 – Chemical analysis of ecological materials. Blackwell Scientific Publications, Oxford.

Anderson JM, Ingram JSI. 1993 – Tropical soil biology and fertility: A handbook of methods. CAB International, Oxford.

Arshad MA, Soon YK, Ripmeester JA. 2011 – Quality of soil organic matter and C storage as influenced by cropping systems in northwestern Alberta, Canada. Nutrient Cycling In Agroecosystems 89, 71–79.

De Vos JA, Raats PAC, Vos EC. 1994 – Microscopic soil physical processes considered within an agronomical and a soil biological context. Agriculture, Ecosystems and Environment 5, 43–73.

Dick RP. 1994 – Soil enzymes activities as indicators of soil quality. In: Doran JW, Coleman DC, Bezdicek DF, Steward BA. (Eds). Defining soil quality for a sustainable environment. Soil Science society of America. Madison, Wis 107–124.

Dutta AC. 1986 – Botany for degree students 2nd revised edition. Indian press.

Forrester DI, Bauhus J, Khanna PK. 2004 – Growth dynamics in a mixed-species plantation of *Eucalyptus globulus* and *Acacia mearnsii*. Forest Ecology and Management 193, 81–95.

Friberg S. 2001 – Distribution and diversity of arbuscular mycorrhizal fungi in traditional agriculture on the Niger inland delta, Mali, West Africa. CBM:s Skriftserie 3, 53–80.

Galvez L, Doudds DD, Wagoner P. 2001 – Tillage and farming system affect AM fungus populations, mycorrhizal formation, and nutrient uptake by winter wheat in a high-P soil. American Journal Of Alternative Agriculture 16,152–160.

Gerdemann JW, Nicolson TH. 1963 – Spores of mycorrhizal Endogone species extracted from soil by wet sieving and decanting. Transactions of the British Mycological Society 46, 235–255.

Ghanbari A, Dahmardeh M, Siahsar BA, Ramroudi M. 2010 – Effect of maize (*Zea mays* L.) - cowpea (*Vigna unguiculata* L.) intercropping on light distribution, soil temperature and soil moisture in arid environment. Journal of Food, Agriculture & Environment 8 (1), 102–108.

Goto BT, Maia LC, Oehl F. 2008 – *Ambispora brasiliensis*, a new ornamented species in the arbuscular mycorrhiza forming Glomero-mycetes. Mycotaxon 105, 11–18.

Hassink J. 1997 – The capacity of soils to preserve C and N by their association with clay and silt particles. Plant and soil 191, 77–87.

Hepper CM. 1984 – Regulation of spore germination of the vesicular-arbuscular mycorrhizal fungus *Acaulospora laevis* by soil pH. Transactions of the British Mycological Society 83,154–156.
Jackson ML. 1973 – Soil chemical analysis. Prentice Hall of India, Private Limited, New Delhi, pp 496.
Jansa J, Mozafar A, Anken T, Ruh R, Sanders IR, Frossard E. 2002 – Diversity and structure of AMF communities as affected by tillage in a temperate soil. Mycorrhiza 12, 225–234.
Jat RA, Dungrani RA, Arvadia MK, Sahrawat KL. 2012 – Diversification of rice (*Oryza sativa* L.)-based cropping systems for higher productivity, resource use efficiency and economic returns in south Gujarat, India. Archives of Agronomy and Soil Science 58(6), 561–572.
Jefwa J, Vanlauwe B, Coyne D, Van Asten P, Gaidashova S, Mwashasha M, Elsen A. 2010 – Benefits and Potential Use of Arbuscular Mycorrhizal Fungi (AMF) in Banana and Plantain (*Musa* spp.) Systems in Africa. Proc. IC on Banana & Plantain in Africa Eds: T. Dubois et al. Acta Horticulturae 879, 479–486.
Johnson NC, Zak DK, Tilman D, Pfleger FL. 1991 – Dynamics of vesicular-arbuscular mycorrhizae during old field succession. Oecologia 86 (3), 349–358.
Khanam D, Mridha MAU, Solaiman ARM, Hossain T. 2006 – Effect of edaphic factors on root colonization and spore population of arbuscular mycorrhizal fungi. Bulletin of the Institute of Tropical Agriculture, Kyushu University 29, 97–104.
Kizilkaya R, Dengiz O. 2010 – Variation of land use and land cover effects on some soil physic-chemical characteristics and soil enzyme activity. Zemdirbyste-agriculture 97(2), 15–24.
Kumar A, Mangla C, Aggarwal A, Parkash V. 2010 – Arbuscular mycorrhizal fungal dynamics in the rhizospheric soil of five medicinal plant species. Middle- East journal of scientific research 6(3), 281–288.
Li S, Li L, Zhang FS, Tang C. 2004 – Acid phosphatase role in chickpea/maize intercropping. Annals of Botany 94, 297–303.
Mohammad MJ, Hamad SR, Malkawi HI. 2003 – Population of arbuscular mycorrhizal fungi in semi-arid environment of Jordan as influenced by biotic and abiotic factors. Journal of Arid Environment 53, 409–417.
Montagnini F. 2000 – Accumulation in above-ground biomass and soil storage of mineral nutrients in pure and mixed plantations in a humid tropical lowland. Forest Ecology and Management 134, 257–270.
Nelson DR, Mele PM. 2006 – The impact of crop residue amendments and lime on microbial community structure and nitrogen-fixing bacteria in the wheat rhizosphere. Australian Journal of Soil Research 44, 319–329.
Oehl F, Sieverding E. 2004 – Pacispora, a new vesicular arbuscular mycorrhizal fungal genus in the Glomeromycetes. Journal of Applied Botany 78, 72–82.
Oliveira AN, Oliveira LA. 2010 – Influence of edaphic-climatic factors on the sporulation and colonization of arbuscular mycorrhizal fungi in two Amazonian native fruit species. Brazilian Archives Of Biology and Technology 53, 653–661.
Panwar V, Meghvansi MK, Sazada S. 2011 – Short-term temporal variation in sporulation dynamics of arbuscular mycorrhizal (AM) fungi and physico-chemical edaphic properties of wheat rhizosphere. Saudi Journal of Biological Sciences 18, 247–254.
Quimet R, Camir EC, Furlan V. 1996 – Effect of soil K, Ca and Mg saturation and endomycorrhization on growth and nutrient uptake of sugar maple seedlings. Plant and Soil 179, 207–216.
Redhead JF. 1975 – Endotrophic mycorrhiza in Nigeria: Some aspects of the ecology of the endotrophic mycorrhizal association of *Khaya grandiflora* C.D.C. In: Endomycorrhizas. F.E. Sanders; B. Mosse and P.B. Tinker. (eds). New York Academic Press, pp 447– 460.
Robson AD, Abbot LK. 1989 – The effect of soil acidity on microbial activity in soils. *In*: Soil Acidity and Plant Growth. A.D. Robson. (ed.). Sydney Academic Press, pp 139–65.

Schnurer J, Claholm M, Rosswell T. 1985 – Microbial biomass and activity in an agriculture soil with different organic matter contents. Soil Biology & Biochemistry 17, 611–618.
Smith SE, Read DJ. 2008 – Mycorrhizal symbiosis, 3rd edn. Academic Press: Amsterdam, the Netherlands and Boston, MA, USA.
Tulu T. 2002 – Soil and water conservation for sustainable agriculture. Mega publication enterprise, Addis Ababa, Ethiopia.
Verma RK, Yadav A, Rahman L-U, Kalra A, Patra DD. 2014 – Influence the status of soil chemical and biological properties by intercropping. International Journal of Recycling of Organic Waste in Agriculture 3, 46.
Wang GM, Stribley DP, Tinker PB, Walker C. 1993 – Effects of pH on arbuscular mycorrhiza I. Field observations on the long-term liming experiments at Rothamsted and Woburn. New Phytologist 124, 465–472.
Wang Z-G, Jin X, Bao X-G, Li X-F, Zhao J-H. et al. 2014 – Intercropping Enhances Productivity and Maintains the Most Soil Fertility Properties Relative to Sole Cropping. PLoS ONE 9(12), e113984.
Young JL, Davis EA, Rose SL. 1985 – Endomycorrhizal fungi in breeder wheats and Triticale cultivars field grown on a fertile soil. Agronomy Journal 77, 219–224.