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Effect of arbuscular mycorrhizal fungi and poultry manure on growth and nutrients contents of maize in different soil type

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ABSTRACTS

Public concerned about food safety and quality have raised interest in manipulating soil nutrients management strategies that could reduce potential threat on environment and sustain food production. Recently, the application of arbuscular mycorrhizal fungi (AMF)as bio-fertilizer has gained recognition especially, in low-input agriculture. The fungi are known to improve plant nutrition and growth. However, this effect may differ according to soil properties and nutrients concentration. A greenhouse experiment was conducted to investigate the effect of AMF and poultry manure (PM) on growth and nutrients contents in maize compared to chemical fertilizer; and to determine the effect of soil properties on colonization potential of AMF. The experiment consists of 13 treatments combinations in 2 soil types (loam and peat), *viz*; 6 application rates of composted PM in tones (t) ha^{-1} (0, 4, 6, 8, 10 and 12) and 2 levels of AMF; inoculated (+AMF) and un-inoculated (-AMF) plus recommended dose of NPK (RD NPK). Un-inoculated plants showed no symptoms of root colonization and recorded no AMF spore under both soils. Addition of PM stimulated AMF colonization and sporulation, the highest root colonization (RC %) and spore counts were recorded at 8 t PM+AMF under loam and 12 t PM+AMF in peat soils. Shoot dry biomass at 8 and 12 t PM+AMF under loam and peat were comparable to RD NPK. Applying 8 and 12 t PM+AMF in loam and peat recorded the highest N& K comparable to RD NPK. However, P content in shoot were statistically higher at 8,10 & 12 t PM+AMF in loam and at 12 t PM+AMF in peat compared to RD NPK. Application of 10 & 12 t PM+AMF in loam significantly decreased plant growth, lowered AMF RC%, and nutrient content (N & K). There was a strong positive correlation between shoot dry biomass and RC % in loam (R^2= 0.740 P<0.01) and peat (R^2=0.884 P<0.01). From the results of this study, it could be concluded that AMF have increased the efficiency use of PM and their integration have the potential to improve plant growth due to enhanced nutrients uptake and stimulated RC% in both soils. Results also indicated significantly higher shoot dry biomass, nutrients content (N, P, & K), spore counts and RC % in loam soil compared to peat, indicating that soil properties has a significant influence on effectiveness AMF.

Keywords: AMF inoculation; poultry manure (PM); nutrients content; NPK fertilizer; maize growth; soil properties.

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1. INTRODUCTION

For optimum maize growth and yield, high fertilizer application is essential. Fertilizer sources varied from organic, chemical and bio-fertilizers. Of all the fertilizers, chemical fertilizer is the most accepted and widely used by farmers due to fast and direct effect on plant growth. However, consequences from long term usage have degraded soil from its productive quality thereby reducing yield (Loveland and Webb, 2003; Phelan, 2004; Khan et al., 2008) due to poor soil structure, low soil organic matter content (Flieβbach et al., 2007; Ball, 2006; Roldån et al., 2005) and imbalance in soil microbial communities, affecting agro-ecosystem functioning (Griffiths et al., 2001; Gunapala and Scow, 1998). As a result of those negative impacts, huge interest is recently geared towards promoting soil nutrients management techniques that could strengthen sustainable agricultural structure. Application of organic amendments and microbial inoculants (bio-fertilizer) is a good agronomic practice that could maintain fertility status of soil, improve plant nutrients uptake and minimize the use of chemical fertilizer. Applying poultry manure (PM) to agricultural farms has increased recently as best means for its disposal (Erich et al., 2002; McDowell and Sharpley, 2004; Toor et al., 2006). It is the most excellent of all animal manures due to high content of N, P, and K (Ma et al., 2009; Nahm et al., 2003). PM supplies nutrients more readily than other organic source (Garg and Bahla, 2008; Chandrashekara et al., 2000), improves soil fertility (Eriksen, 2005), motivate microbial growth (Suresh et al., 2004), improve soil structure which increases infiltration rate and soil water holding capacity (Deksissa et al., 2008; Belay et al., 2001). Addition of organic amendments to soil enhances microbial community and activities. Important group among the microorganisms are arbuscular mycorrhizal fungi (AMF) which form symbiotic association with majority of higher plants aiding nutrients and water uptake limited for plant growth; in exchange, fungus obtains fixed carbon from plant host. Plants colonized by AMF benefit more from enhanced water and nutrients uptake, especially, N, P, Cu, and Zn. Thus, improve plant growth and yield, ensured plant health (Lingua et al., 2002; Pozo et al., 2002) and resistance to environmental stress (Auge, 2001; Koske and Gemma, 2005) compared to un-colonize plants.

PM and AMF could serve as sustainable nutrient alternative to chemical fertilizer. This is due to the potential of the fungi to utilize unavailable organic nutrients and increase the efficiency use of nutrientsthrough enhanced nutrients uptake (Mamatha et al., 2002; Atimanav and Adholeya, 2002; Joner, 2000), which might improve plant growth and yield (Jackson et al., 2002; Martin and Stutz, 2004; Ortas et al., 2011). Earlier workers have clearly revealed the positive effect of organic amendments in combination with AMF (Caravaca et al., 2003; Douds et al., 2010; Tanwar et al., 2013) on plant growth and improve nutrients uptake. However, excessive application of poultry manure might be undesirable due to risk of soil and water pollution (Sharpley et al., 1999; Herpperly et al., 2009) and most particularly, the high content of P in the manure could affect AMF colonization potential (Jordan et al., 2000; Varga et al., 2004). In this context, it could be interesting to understand the optimum application rate of PM that could enhance maximum benefits from AMF symbiosis. The aim of this research is to determine the optimum application rate of PM that could stimulate AMF-plant symbiosis and provide nutrients for optimum growth of maize compared to chemical fertilizer and to investigate the effect of soil properties on colonization potential of AMF.

2. MATERIALS AND METHODS

Experimental site: The experiment was conducted at the Forestry Research Garden green house (East Campus), University Malaysia Sarawak, Kota Samarahan. Located at 0^{o}50’ and 5^{o} N and 109^{o}36’ and 115^{o}40’E, having average rainfall of 247 days per annum with annual mean precipitation between 2,500 and 5,000, and a monthly minimum rainfall recorded around June or July but exceeded 100 mm (Andriesse, 1968). The temperatures ranges between 23 °C (73 °F) and 33^{o}C (91^{o} F) in the early hours of the morning and during mid-afternoon respectively with heat index reaching 42 ^{o}C (108 ^{o}F) during dry season due to humidity reaching to about 85%.

AMF inoculum: AM inoculum was a mixture of *Gl. mossea*, *Gl. geosporum* and *Gl. etunicatum* from trap cultures of *Cymbopogon citratus*, containing spores, soil with infected root fragments and hyphae.

Source of poultry manure: Composted poultry manure was procured from a commercial poultry farm around Kota Samarahan. Prior to use, the nitrogen, phosphorus and potassium composition of manure were analyzed using Kjeldahl method (A.O.A.C, 1970) and tri-acid mixture for phosphorus and potassium as outlined by Jackson, (1973). Chemical analysis of the manure indicated a pH of 8.3; N, 2.3%; P, 1.3% and K, 1.6%.

Treatments and experimental design: The experiments consist of 6 levels of poultry manure in tones (t) ha^{-1} (0, 4, 6, 8, 10, & 12) × 2 levels of AM fungi, inoculated (+AMF) and un-inoculated (-AMF) + 1 recommended dose of NPK (RD NPK) chemical fertilizer making 13 treatment combinations × 2 (soil types) laid out in a completely randomized block design (CRBD). The following scheme was used for categorizing the treatment combinations;**Un-inoculated (-AMF):** 0 t PM-AMF (Control), 4 t PM-AMF, 6 t PM-AMF, 8 t PM-AMF, 10 t PM-AMF, 12 t PM-AMF; **Inoculated (+AMF):** 0 t PM+AMF (AMF+ only), 4 t PM+AMF, 6 t PM+AMF , 8 t PM+AMF , 10 t PM+AMF, 12 t PM+AMF and RD NPK.

Collection of soil samples and preparation of pots: Composite soil samples at 0-15 cm depth of loam and peat soils were sampled from farms around Universiti Malaysia Sarawak. Prior to experiment, the physical and chemical properties of soils were determined using standard methods. Characteristics of soil are presented in table 1. Soil samples were passed through 4.0 mm sieve and steam sterilized at 121^{o}C for 2 h to kill all indigenous microorganisms including AM fungi. Three kilogram (3 kg) of each soil was weighed into individual plastic pot of 15cm (diameter) x 20cm (height) capacity. Soils were mixed thoroughly with poultry manure according to treatments a week before sowing. Inoculated pots received 10 g pot^{-1} of AM inoculum placed 3 cm below pot surface and 10 g pot^{-1} of sterilized soil for un-inoculated pots. RD NPK at 130kg N, 130kg P, and 67kg K (Department of Agriculture, 2003) was applied to appropriate pots in form of urea, triple super phosphate (TSP) and muriate of potash (MOP) and a control without fertilizer. TSP, MOP and half dose of urea fertilizer were applied as basal nutrient and remaining half of the urea fertilizer was applied three weeks after sowing. Four viable and sterilized maize seeds (Sweet corn) were sown to individual pot. Pots were irrigated regularly and maintained at 60% field capacity. Seedlings were later thinned to one pot^{-1} arranged within six blocks of inoculated and un-inoculated treatments on a greenhouse bench with 12 h photoperiod. The plants were harvested six weeks after sowing (WAS).

Table 1: Initial physical and chemical characteristics of soils used for greenhouse study

Properties	Soil 1	Soil 2
pH (1:5 Soil: H_2O)	4.9	3.4
EC (dS m^{-1})	0.52	0.26
Texture	Loam	Peat
Organic matter %	0.98	38.6
NO_3-N (mg kg^{-1})	6.3	4.8
Available P (mg kg^{-1})	5.2	2.7
Available K (mg kg^{-1})	120.3	78.6

Data collection

Plant growth characteristics: Plant growths parameters *viz*; plant height, root volume, leaf area, shoot and root biomass were assessed.

Plant height(cm): The plant height was measured from plant base to upper tip of the tallest leaf (Fageria et al., 2006) using a meter rule.

Leaf area(cm^2 $plant^{-1}$): Leaf area was measured as described by Saxena and Singh (1965) using the formula: Leaf length (cm) x leaf width (cm) x 0.75

Root volume(cm^3 $plant^{-1}$): Root volume was determined by non-destructive volume displacement analysis as described by Brundette, (1979).

Root and shoot dry biomass(g $plant^{-1}$): Plant dry biomass was determined after oven drying at 80^{o}C until constant weight was attained.

Mycorrhizal assessment

Percent root colonization (%): Root colonization was determined as described by Phillips and Hayman (1970).

$$\% \text{ colonization} = \frac{\text{No. of colonized root}}{\text{Total root No.}} \times 100$$

Soil spore count:AM spores were isolated by wet-sieving and decanting method as outlined by Gerdeman and Nicolson (1963). Isolated spores were counted under stereo binocular microscope using a counter.

Plant shoots nutrients content: The oven dried shoots were ground to fine powder and analyzed for N, P and K. Nitrogen was determined by colorimetric nitrate method using salicylic acid as described by Cataldo *et al*., (1975). Phosphorous and potassium were determined, by acetic acid extraction (Prokopy, 1995) and measured with spectrophotometer and flame photometer as outlined by Johnson and Ulrich, (1959) and Knudsen *et al*., (1982) for P and K respectively.

Data analysis: All data collected were subjected to one-way and two-way analysis of variance (ANOVA) under general linear model (SPSS version 19), to determine the effect of main factors and interactions. To assess the AMF effectiveness between two soil types, mean comparison based on shoot dry biomass andRC%, were regressed. Correlation coefficient between root colonization and shootdry biomass were assessed using Pearson correlations and differences between means were separated using Duncan's LSD P<0.05.

3. RESULTS AND DISCUSSION

Effects of different rates of poultry manure on root colonization and spore counts of AMF: Results on mycorrhizal root colonization of maize and spore density under loam and peat soils indicated no evidence of mycorrhizal colonization in both soils; therefore results were not shown (Table 2). Integration of poultry manure and AMF recorded higher spore density and RC % compared to AMF without amendment (0 t PM**+**AMF) in both soils. Except at the highest application rate (12 t PM+AMF) under loam soil where value did not differ significantly to 0 t PM+AMF. Applying 8 and 12 t PM+AMF recorded the highest spore counts and RC % under loam and peat soils respectively. Enhanced RC % and sporulation due to poultry manure addition as recorded in this study is in agreement with the findings of some workers (Oehl et al., 2004: Verbruggen et al., 2010; Posada and Sieverding, 2014; Gryndler et al., 2006; Vaidya et al., 2008).

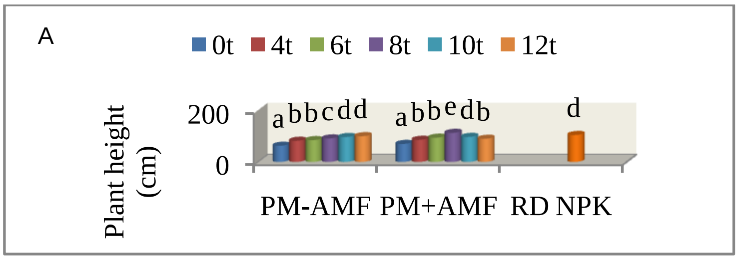
Table 2: Effect of poultry manure application on AMF spore counts and root colonization % in maize six WAS in different soil type.

Treatments	Root colonization (%)		Spore counts (g^{-1} soil)	
	Loam	Peat	Loam	Peat
Inoculated (+AMF)				
0 t PM+AMF (AMF only)	30.67a±3.499	22.83a±2.330	9.33a±0.803	7.67a±0.558
4 t PM+AMF	43.83b±3.027	29.17b±1.352	15.17b±1.302	7.83a±0.946
6 t PM+AMF	47.00b±0.966	34.67c±0.882	16.00b±1.065	10.00c±1.065
8 t PM+AMF	67.17c±1.887	40.00d±0.577	18.17c±0.872	12.33d±1.054
10 t PM+AMF	58.67d±2.060	43.17e±0.601	16.17b±0.703	14.67e±1.406
12 t PM-AMF	33.83a±3.124	46.50ed±0.428	11.00a±0.365	16.67ed±1.022

Values are the mean of replicates with ± SE. Means in the same row followed with different alphabet are significantly different at P<0.05 according to DMRT

They justified the effect of organic amendments to have stimulated AMF community, increase their diversity and colonization potential. Srivastava et al., (2001) observed increased AMF colonization in maize due to application of farmyard manure. As revealed in this study, high application rates of PM (10 and 12 t PM ha^{-1}) under loam soil lowered degree of RC % and spore counts (Table 2), depressed plant growth (Table 3), and N & K content in shoot (Table 4). This could be attributed to the influence of nutrients concentration on AMF symbiosis (Martin et al., 2002; Smith and Read, 2008; Talbot et al., 2008; Cheeke et al., 2011; Johnson et al., 2003). It is suggested that optimum benefit from AMF symbiosis tends to be higher at low and moderate fertilizer input (Tawaraya et al., 2012; Wang et al., 2006; Alguacil et al., 2009) compared to high rates. This was further clarified by Cheeke et al., (2012), who reported high degree of AMF colonization in *Bt* and non-*Bt* maize grown under low or no fertilizer application compared to high fertilizer treatments.On the contrary, peat recorded the highest RC% and spore counts (Table 2) with maximum shoot dry biomass (Table 3) at high application rate of poultry manure (12 t PM ha^{-1}). AMF symbiosis in peat is not clearly understood (Linderman and Davies, 2003). The fact that soil properties impact great influences on AMF colonization has been revealed (Liu and Li, 2000; Linderman and Davies, 2003; Carrenho *et al*., 2007). Soil P concentration, type or origin of peat and microbial composition (Ponton et al., 1990; Calvet et al., 1992; Linderman and Davies, 2004) could have negative (Wang et al., 1993) or positive impact on AMF (Biermann and Linderman, 1983). Similar to the finding of this study, Graham and Timmer (1984) reported lower root colonization by *Glomus intraradices* in *Citrus jambhiri* grown in peat compared to soil. Estaùn et al., (1999) observed lower degree of root colonization of *Prunus* plantlets by AMF after three months growing period in peat (17%) compared to 60% in sandy loam and 45% in peat mixed with compost. Mitysiak and Falkowski, (2010) reported increased trend in RC % due to high application rate of compost in peat.

Effects of different rates of poultry manure and AMF on plant growth: Result on plant growth biometrics *viz*; plant height, leaf area, root volume, shoot, and root dry weight biomass of maize as affected by AM fungi inoculation and PM are presented in table3 and figure1 for loam and peat soils. Plant growth biometrics varied significantly between the treatments in loam and peat soil. Inoculated and RD NPK fertilizer produced taller plants (Figure 1A & B), larger leaf area, higher root volume, shoot and root biomass (Table 3) compared to un-inoculated plants. Plant growth qualities increased with increase in application of PM in un-inoculated and inoculated plants under both soils. However, a gradual decrease at 10 and 12 t PM+AMF were noted for all growth biometrics under loam soil (figure 1A & table 2). Applying 8 t PM+AMF produced the tallest plant (112.50±2.265 cmthat unequalled all the treatmentsin loam. While, applying 10 t PM+AMF produced the tallest plant (92.00±3.706 cm) that did not differ significantly to RD NPK (90.00±2.309 cm) and 12 t PM+AMF (89.83±1.721 cm) in peat soil(figure 1B).



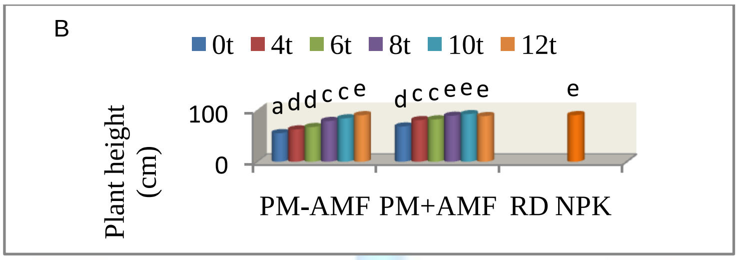


Fig. 1:Effect of AMF and poultry manure on maize plant height six WAS in (A): loam soil (B): peat

Legend: PM-AMF; poultry manure un-inoculated, PM+AMF; poultry manure inoculated; NPK chemical fertilizer

8 t PM+AMF produced shoot and root dry weight (25.33±0.494 & 3.25 g) that were statistically comparable to RD NPK (25.50e±1.232, 3.33c±0.211 g) under loam soil. Highest shoot and root dry weight were recorded in RD NPK (21.00±0.365, 3.50d±0.183 g) that were statistically similar to 12 t PM+AMF (19.55±0.134, 3.33d±0.211 g) under peat soil. Addition of poultry manure has promoted plant growth in inoculated and un-inoculated plants. However, integrating AMF and poultry manure proved to be more effective compared to sole application of either of the fertilizers. This could be attributed to the high nutrients value in PM which increases soil fertility making nutrients available for plant growth (Toor et al., 2006; Guo and Song, 2009; Zhong et al., 2010; Blaise et al., 2006; Utkhede, 2006). On the other hand, AMF inoculated plants could have benefitted more due to enhance nutrients uptake by extraradical mycelium which is lacking in un-inoculated plants (Talbot et al., 2008; Muthukumar and Udaiyan, 2000). Combination of biofertilizer and organic/inorganic fertilizers were proven to be similar or almost superior to exclusive application of recommended dose of inorganic fertilizers (Campos, 2006; Galbiatti et al., 2011; Abdullahi and Sheriff, 2013; El-Kholy and Gomaa, 2000).

Table 3: Effect of AMF and poultry manure on leaf area, root volume, shoot and root dry biomass of maize plant six WAS in different soil type

Treatments	Leaf area (cm^2)		Root vol. (cm^3)		Shoot dry biomass (g)		Root dry biomass (g)	
	Loam	Peat	Loam	Peat	Loam	Peat	Loam	Peat
Un-inoculated (-AMF)								
0 t PM-AMF (control)	120.68a	121.08a	0.94a	1.20a	3.10a	2.33a	1.33a	0.74a
4 t PM-AMF	188.85b	166.50b	1.27a	1.25ab	7.17b	4.42b	1.67a	1.48b
6 t PM-AMF	220.67c	196.88b	1.95b	1.27ab	9.00bc	4.75b	2.00ab	1.43b
8 t PM-AMF	259.92e	197.98b	2.44c	1.92c	9.50bc	8.35cb	2.58ab	1.75b
10 t PM-AMF	262.25e	193.75b	2.75c	2.30d	12.00cd	9.77c	2.33ab	1.98bc
12 t PM-AMF	283.75e	237.02cb	2.71c	2.50c	13.67cd	11.07c	2.50ab	2.00bc
Inoculated (+AMF)								
0 t PM+AMF (AMF only)	120.97a	137.38a	1.13a	1.28ab	7.00b	3.33a	1.67a	1.13a
4 t PM+AMF	211.50b	197.35b	1.78b	1.53b	11.17cd	6.83d	2.00a	1.58b
6 t PM+AMF	242.05f	225.71cb	3.28cd	1.97c	17.67d	9.50c	2.33ab	1.83b
8 t PM+AMF	320.30d	240.42cb	3.50d	2.41d	25.33e	16.33e	3.25c	3.00c
10 t PM+AMF	298.67d	249.17cb	3.09cd	2.70ef	19.33d	17.00e	3.00c	2.83c
12 t PM-AMF	228.67c	252.00cb	2.42c	2.92e	16.58d	19.55f	2.62ab	3.33d
RD NPK	324.63d	255.63cb	3.60d	3.08e	25.50e	21.00f	3.33c	3.50d

Values are the mean of six replicates. Means in the same row followed with different alphabet are significantly different at P<0.05 according to DMRT.

Effects of different rates of poultry manure and AMF on shoot nutrients concentration: Inoculated and RD NPK plants recorded higher shoot nutrients content (N, P, and K) compared to un-inoculated ones. N, P, and K concentration in shoots increases with increase in addition of PM in un-inoculated plants and inoculated plants in both soils. However, a gradual decrease in N and K shoot content were noted at 10 & 12 t PM+AMF (Table 4) under loam soil. N and K concentration at 8 & 12 t PM+AMF were comparable to RD NPK under loam and peat respectively (Table 4). Conversely, significantly higher P shoots contents were recorded at 8, 10 & 12 t PM+AMF in loam and at 12 t PM+AMF in peat compared to all treatments.

Table 4: Effect of AMF and PM on shoot nutrients concentration in maize plant six WAS under different soil type

Treatments	Concentration (%)					
	N		P		K	
	Loam	Peat	Loam	Peat	Loam	Peat
Un-inoculated(-AMF)						
0 t PM-AMF (control)	1.28a	1.06a	0.16a	0.13a	1.14a	1.06a
4 t PM-AMF	1.83b	1.28a	0.24bc	0.20b	1.45b	1.27b
6 t PM-AMF	2.45c	2.83b	0.27c	0.21b	1.78c	1.44c
8 t PM-AMF	2.52c	1.95bc	0.29c	0.25c	1.98d	1.71d
10 t PM-AMF	2.75c	2.30c	0.30c	0.28ab	2.13e	1.80d
12 t PM-AMF	2.93ac	2.73b	0.32cb	0.32cb	2.25cb	2.05e
Inoculated (+AMF)						
0 t PM+AMF (AMF only)	1.72b	1.57d	0.23b	0.24c	1.75c	1.36c
4 t PM+AMF	2.42c	2.12c	0.28c	0.28ab	2.07d	1.73d
6 t PM+AMF	3.23cd	2.50cb	0.34cb	0.29ab	2.57ac	2.18f
8 t PM+AMF	3.45cd	2.85b	0.44de	0.33cb	2.90bc	2.22f
10 t PM+AMF	3.12cd	3.03e	0.49e	0.36e	2.88bc	2.34cb
12 t PM-AMF	2.50c	3.13e	0.55cd	0.38ed	2.85bc	2.84bc
RD NPK	3.43cd	3.18e	0.40d	0.35e	2.87bc	2.81bc

Values are the mean of six replicates. Means in the same row followed with different alphabet are significantly different at $P<0.05$ according to DMRT.

Liu et al., (2002) reported high plant biomass, K, Ca and Mg accumulation in tissue and their uptake by maize due to AMF symbiosis at low soil nutrients concentration. Jadhav and Patil, (1996) and Marshner and Dell, (1994) have demonstrated increased plant dry biomass, grain yield and improved accumulation of N, P and K in several plant species due to AMF symbiosis .Negative effects from high dosages of different organic amendments on AMF were revealed by some researchers (Tanwar et al., 2010; Tanwar and Angarrawal, 2013). It was documented that under high nutrients availability particularly, P, AMF-plant interaction may become C sink leading to reduction in growth of plant host (Graham et al., 1997; Jifon et al., 2002). Beside saturation of soil nutrients (McArthur and Knowles, 1992; Amijee et al., 1989), P concentration in plant tissue could evidently be a critical factor influencing AMF colonization (Ratnayake et al., 1978; Braunberger et al., 1991). Azcón et al., (2003) also reported reduction in uptake of (N, P, K, Mn and Zn) and low degree of AMF colonization when high rate of N and P fertilizer were applied to lettuce plant.

Conclusion: From this study, it could be concluded that, maize responded positively to application of AMF and poultry manure. AMF have increased the efficiency use of PM by providing nutrients which enhanced maize growth over un-inoculated plants. 8 and 12 t PM ha^{-1}+AMF enhanced tissue nutrients concentration and plant growth equivalent to RD NPK in loam and peat soil respectively. Integration of PM and AMF could be considered for maize production, however; applying PM at 10 and 12 t ha^{-1} in combination with AMF should further be investigated due to antagonistic effect on plant growth and development of AMF in loam soil as demonstrated in this study.

REFERENCES

[1] Abdullahi, R. and Sheriff, H. H. 2013. Effect of Arbuscular mycorrhizal fungi and chemical fertilizer on growth and shoot nutrients content of onion under field condition in Northern Sudan Savanna of Nigeria. Journal of Agriculture and Veterinary Science, 3 (5), 85-90.

[2] Alguacil, M.M., Díaz-Pereira, E., Caravaca, F., Fernández, D.A. and Roldán, A. 2009. Increased diversity of arbuscular mycorrhizal fungi in a long-term field experiment via application of organic amendments to semiarid degraded soil. Applied Environmental Microbiology, 75, 13, 4254-4263.

[3] Amijee, F., Tinker, P.B. and Stribley, D.B. 1989. The of endomycorrhizal roots systems.VII. A detailed study of soil phosphorus on colonization. New Phytologist, 111, 435-446.

[4] Andriesse, J.P. 1968. A study of the environment and characteristics of Podzols occurring in the tropical lowland of Sarawak (East Malaysia). In Andriesse, J.P. (ed). Proceedings of the 3rd Malaysian Soil Science Conference, May 1968. Kuching, Sarawak, Malaysia, pp. 17-33.

[5] A.O.A.C. 1970. Official Methods of Analysis. 11th edn, Association of official Agricultural Chemist, Washington, D.C.

[6] Atimanay, G.and Adholeya, A. (2002). AM inoculation of five tropical fodder crops and inoculum production in unfertilized soil amended with organic matter. Biology and Fertility of Soil, 35, 214-218.

[7] Augé, R.M. 2001. Water relations, drought and vesicular-arbuscular mycorhhizal symbiosis. Mycorhhiza, 11, 3-42.

[8] Azcón, R., Ambrosano, E., & Charest, C. 2003. Nutrient acquisition in mycorrhizal lettuce plants under different phosphorus and nitrogen concentration. Plant Science, 165, 1137-1145.

[9] Ball, A.S. 2006. Energy input in soil systems. In: Uphoff, N., Ball, A.S., Fernandes, E., Herren, H., Husson ,O., Laing, M., Palm,C.A., Pretty, J., Sanchez, P.A., Sanginga, N. & Thies, J.(eds.) Biologcal approaches to sustainable soil systems. CRC Taylor and Francis, Boca Raton, 79-91.

[10] Belay, A., Classens, A.S., Wehner, F.C. and DE Beer, J.M. 2001. Influence of residual manure on selected nutrient elements and microbial composition of soil under long-term crop rotation. South African Journal of Plant and Soil, 18,1-6.

[11] Biermann, B.and Linderman, R.G. 1983. Effect of container plant growth medium and fertilizer phosphorus on establishment and host growth response to vesicular-arbuscular mycorrhizae. Journal of American Society and Horticultural Science, 108, 962-972.

[12] Blaise, D., Ravindran, C. D.and Singh, J.V. 2006. Trend and Stability Analysis to Interpret Results of Long-Term Effects of Application of Fertilizers and Manure to Cotton Grown on Rainfed Vertisols. Journal of Agronomy & Crop Science, 192, 319—330.

[13] Braunberger, P.G., Miller, M.H.and Peterson, R.L. 1991. Effect of phosphorus nutrition on morphological characteristics of vesicular-arbuscularmycorrhizal colonization of maize. NewPhythologist, 119, 107-133.

[14] Brundrette, A.N. 1979. A nondestructive method for measuring the volume of intact plant parts. Canadian Journal of Forest Research, 9, 120-122.

[15] Calvet, C., Estaun, V. and Camprubi, A. 1992. Germination, early mycorrhizal growth and infectivity of a vesicular–arbusular mycorrhizal fungus in organic substrates. Symbiosis, 14, 405-411.

[16] Campos, V.S. 2006. Comportamento do maracuj azeiro amarelo em solo com potassio, biofertilizante e cobertura morta. Monografia de gradução do curso em agromia centro de ciéncias agrårias, Universidada Federal da Paraiba, Areja, 70.

[17] Caravaca F., Barea J.M., Palenzuela J., Figueroa D., Alguacil M.M.andRoldán, A.2003. Establishment of shrub species in a degraded semiarid site after inoculation with native or allochthonous arbuscular mycorrhizal fungi. Applied Soil Ecology, 22, 103-111.

[18] Carrenho, R., Trufem, S.F.B., Bononi, V.L.R.and Silva, E.S. 2007. The effect of different soil properties on arbuscular mycorrhizal colonization of peanuts, sorghum and maize. Acta Botanica Brazilica, 21, 723-730.

[19] Cataldo, D.A., Haroon, M., Schrader, L.E. and Young, V.L. 1975. Rapid colometric determination of nitrate in plant tissue by nitration of salicylic acid. Commun.. Soil Science Plant Annals, 6, 71.

[20] Chandrashekara, S.I., Harlapur, S., Muralikrishan, and Girijesh, G.K. 2000. Response of maize to organic manures with inorganic fertilizers. Journal of Agricultural Sciences, 13, 144-146.

[21] Cheeke, T.E., Rosenstiel, T.N. and Cruzan, M.B. 2012. Evidence of reduced arbuscular mycorrhizal fungal colonization in multiple lines of Bt maize. American Journal of Botany, 99, 4700-4707.

[22] Cheeke, T.E., Pace, B.A., Rosenstiel, T.N.and Crunzan, M.B. 2011. The influence of fertilizer level and spore density on arbuscular mycorrhizal colonization of transgenic Bt 11 maize (Zea mays) in experimental microcosms. FEMS Microbiol Ecology, 75, 304-312.

[23] Deksissa, T., Short, I.and Allen, J. 2008. Effect of soil amendment with compost on growth and water use efficiency of Amaranth. In: Proceedings of the UCOWR/NIWR Annual conference International Water Resource Challenges for the 21st Century and Water Resource Education, Durham, NC.

[24] Douds, D.D. Jr., Nagahashi, G.andHepperly, P.R. 2010. On-farm production of inoculum of indigenous arbuscular mycorrhizal fungi and assessment of diluents of compost for inoculum production. Bioresource Technology, 101, 2326–2330.

[25] El-Kholy, M.A. andGomaa, A.M. 2000. Biofertilizers and their impact on forage yield and N-content of millet under low level of mineral fertilizers. Agricultural Science, Moshtohor, 38, (2), 813-822.

[26] Erich, M.S., Fitzgerald, C.B. and Porter, G.A. 2002. The effect of organic amendments on phosphorus chemistry in a potato cropping system. Agricultural Ecosystem and Environment, 88, 79-88.

[27] Eriksen, J. 2005. Gross sulphur mineralization-immobilization turnover in soil amended with plant residues. Soil Biology and Biochemistry, 37, 2216-2224.

[28] Estaùn, V., Calvet, C., Camprubì, A. andPinochet, J. 1999. Long-term effects of nursery starter substrates and AM inoculation of micropropagated peach×almond rootstock GF677. Agronomie, 19, 483-489.

[29] Fageria, N.K., Baligar, V.C. and Clark, R.B. 2006. Root growth parameters and methods of measurement. Root architecture. Physiology of crop production, Food Products Press.

[30] Fließbach, A., Oberholezer, H.R., Gunst, L.andMäder, P. 2007. Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. Agricultural Ecosystems and Environment, 118, 273-284.

[31] Galbiatti, J.A., Silva, F.G., Franco, C.F.andCaramelo, A.D. 2011. Desenvolvimento de fejoeiro sob o uso de biofertilizante e a dubação mineral. Engenharia Agricola, 31, 167.

[32] Garg, S.and Bahla, G.S. 2008. Phosphorus availability to maize as influenced by organic manures and fertilizer Passociated phosphatase activity in soils. Bioresource Technology, 99, 5773-5777.

[33] Graham, J. and Timmer, L.W. 1984. Vesicular-arbuscular mycorrhizal development and growth response of rough lemon in soil andsoilless media: effect of phosphorus source. Journal of American Society of Horticultural Science, 109, 118-121.

[34] Graham, J.H., Duncan, L.W. and Eissenstat, D.M. 1997. Carbohydrate allocation patterns in citrus genotypes as affecated by phosphorus nutrition, mycorrhizal colonization and mycorrhizal dependency. New Phytologist, 135, 335-343.

[35] Griffiths,B.S., Bonkowski, M., Roy.J.and Ritz, k. 2001. Functional stability, substrate utilization and biological indicators of soils following environmental impacts. Applied Soil Ecology, 16, 49-61.

[36] Gryndler , M., Larsen, J., Hršelová, H., Řezáčová, V., Gryndlerová, H. and Kubát, J. 2006. Organic and mineral fertilization ,respectively, increase and decrease the development of external mycelium of arbuscular mycorrhizal fungi in a lond-term field experiment . Mycorrhiza, 16, 159-166.

[37] Gunapala, N. and Scow, K.M. 1998. Dynamics of soil microbial biomass and activity in conventional and organic farming systems. Soil Biology and Biochemistry, 30, 805-816.

[38] Guo, M. and Song, W. 2009. Nutrient value of alum-treated poultry litter for land application. Poultry Science, 88, 1782-1792.

[39] Hepperly, P., Lotter, D., Ulsh, C.Z., Seildel, R. and Reider, C. 2009. Compost, manure and synthetic fertilizer influences crop yields, soil properties, nitrate leaching and crop nutrient content. Compost of Science and Utilization, 17, 117-126.

[40] Jackson, L., Miller, E.D.and Smith, S.E. 2002. Abuscular mychorrhizal colonization and growth of wild and cultivated lettuce in response to nitrogen and phosphorus. Scientia Horticulturae, 94:205-218.

[41] Jadhav, D.N. and Patil, M.S. 1996. Effect of AM inoculation on growth and NPK uptake of groundnut. Acta Agronomica Hungarica, 44, (2), 153-159.

[42] Jifon, J.L., Graham, J.H., Drouillard, D.L. and Syvertsen, J.P. 2002. Growth depression of mycorrhizal Citrus seedlings grown at high phosphorus supply is mitigated by elevated CO2. New Phytologist, 153, 133-142.

[43] Johnson, C. M. and Ulrich, A. 1959. Analytical methods for for use in plant analysis, Bulletin 766. University California, Agricultural Experiment Station, Berkeley. pp. 26-78.

[44] Johnson, N.C., Rowland, D.L., Corkidi, L., Egerton, Warburton, L.M.and Allen, E.B. 2003. Ntrogen enrichment alters mycorrhizal allocation at five mesic to semiarid grasslands. Ecology, 84, (84), 1895-1908.

[45] Joner, E. J. 2000. The effect 0f long time fertilization with organic and inorganic fertilizers on mycorrhiza mediated P uptake in subterranean clover. Biology and fertility of Soil, 32, 435-440.

[46] Jordan, N.R., Zhang, J. and Huerd, S. 2000. Arbuscular-mycorrhizal fungi, potential roles in weed management. Weed Research, 40, 397–410.

[47] Khan, M.S., Shil, N.C.and Noor, S. 2008. Integrated nutrient management for sustainable yield of major vegetable crops in Banglasdesh. Bangladesh Journal of Agriculture and Environment, 4, 81-94.

[48] Knudsen, D., Peterson, G. A.and Pratt, P.F. 1982. Lithium ,sodium and potassium .In: Page AL, Millar RH, Keeney DR (eds) Methods of soil analysis. Part 2, American Society of Agronomy, Madison ,WI, 225-246.

[49] Koske, R.E.and Gemma, J.N. 2005. Mycorrhizae and organic amendment with biostimulants improve growth and salinity tolerance of creeping bentgrass during establishment. Journal Turfgrass Sports Surface Science, 81, 10-25.

[50] Lingua, G.,D' Agostino, G., Massa, N., Antosiano, M.and Berta, G. 2002. Mycorrhiza-induced differential response to a yellows disease in tomato. Mycorrhiza, 12, 191-198.

[51] Linderman, R.G. and Davies, E.A. 2003. Soil amendment with different peatmosses affects mycorrhizae on onion. Horticultural technology, 13, 285-289.

[52] Linderman, R.G. and Davies, E.A. 2004. Varied response of marigold (Tagetesspp.) genotypes to inoculation with different arbuscular mycorrhizal fungi. Science of Horticulture, 99, 67-78.

[53] Liu, R.J., & Li, X.L. (2000). *In*: Arbuscular mycorrhizae application. Science Press, Beijing.

[54] Liu, A., Hamel, C., Elmi, A., Costa, C., Ma, B., & Smith, D.L. 2002. Concentrations of K, Ca and Mg in maize colonized by arbuscular mycorrhizal fungi under field conditions. Canadian Journal of Soil Science, 82: 3, 271-278.

[55] Loveland, P.and Webb, J. 2003. Is there a critical level of organic matter in the agricultural sols of temperate regions: A Review: Soil Tillage and Research, 70, 1-18.

[56] Mamatha , G., Bagyaraj, D.J. and Jaganath, S. 2002. Inoculation of field established mulberry and papaya with AM fungi and a mycorrhiza helper bacterium. Mycorrhiza, 12, 313-316.

[57] Martin, C.A. and Stutz, J.C. 2004. Interactive effects of temperature an arbuscular mycorrhizal fungi on growth ,P upake and root respiration of Capsicum annuum L. Mycorrhiza, 14, (4), 241-244.

[58] Martin, J., Sampedro, I., Garcia-Romera, I., Garacia-Garrido, J.M.and Ocampo, J.A. 2002. Arbuscular mycorrhizal colonization and growth of soybean (Glycine max) and lettuce (Lactuc sativa) and phytotoxic effects of olive mill residues. Soil Biology and Biochemistry, 34, 1769-1775.

[59] Marschner, H.and Dell B. 1994. Nutrient uptake in mycorrhizal symbiosis. Plant and Soil, 159, 89–102.

[60] Matysiak, B.and Falkowski, G. 2010. Response of three ornamental plant species to inoculation with arbuscular mycorrhizal fungi depending on compost addition to peat substrate and the rate of controlled release fertilizer. Journal of Fruit and Ornamental Plant Research, 18,(2), 321-333.

[61] McArthur, D.A.J.and Knowles, N.R. 1992. Resistance response of potato to vesicular-arbuscular mycorrhizal fungi under varying abiotic phosphorus levels. Plant Physiology, 100, 341-351.

[62] McDowell, R.W.and Sharpley, A.N. 2004. Variation of phosphorus leached from Pennsylvanian soils amended with manures, compost or inorganic fertilizer. Agriculture, Ecosystems and Environment, 102: 17-27.

[63] Muthukumar, T. and Udaiyan, K. 2000. Arbuscular mycorrhizas of plants growing in the Western Ghats region, southern India. Mycorrhiza, 9, 297–313.

[64] Nahm, K.H. 2003. Bioavailability of phosphorus in poultry manure. Avian and poultry biology Reviews, 14, 53-62.

[65] Oehl, F., Sieverding ,E., Mäder, P., Dubios, D., Ineichen, K., Boller, T.and Wiemken, A. 2004. Impact of long-term conventional and organic farming on the diversity of arbuscular mycorrhizal fungi. Ecologia, 138,574-583.

[66] Ortas, I., Nebahat, S., Akpinar, C. and Halit, Y. 2011. Screening mycorrhizal species for plant growth, P and Zn uptake in pepper seedling grown under greenhouse conditions. Scientia Horticulturae, 128, 92-98.

[67] Phelan, L.P. 2004. Connecting belowground and aboveground food webs: The role of organic matter in biological buffering. In: Magdoff, F., Weil, R.R.(eds.), Soil organic matter sustainable agriculture. CRC Press: Boca Raton, FL, pp. 199-226.

[68] Phillips, J.M.and Hayman, D.S., 1970. Improved procedures for clearing roots and staining parasitic and vesicular-arbuscular mycorrhizal fungi for rapid assessment of infection. Transactions of the British Mycological society, 55: 158-161.

[69] Ponton, F., Piche, Y., Parent, S. and Caron, M. 1990. The use of vesiculararbuscular mycorrhizae in Boston fern production: I. Effects of peat-based mixes. Horticultural Science, 25, 183–189.

[70] Posada, R.H.and Sieverding, E. 2014. Arbuscular mycorrhiza in Colombian coffee plantations fertilized with coffee pulps as organic manure. Journal of Applied Botany and food quality, 87, 243-248.

[71] Pozo, M. J., Cordier, C., Dumas-Gaudot, E., Gianinazzi, S., Barea, J. M. and Azcon-Aguilar, C. 2002. Localized versus systemic effect of of arbuscular mycorrhizal fungi on defence responses to Phytophthora infection in tomato plants. Journal of Experimental Botany, 53,525-534.

[72] Prokopy, W. R. 1995. Phosphorus in acetic acid extracts. Quik Chem Method 12-115-01-1-C Lachat Instruments, Milwaukee, WI.

[73] Ratnayake, M.R., Leonard, T. and Menge, J.A. 1978. Root exudation in relation to supply of phosphorus and its possible relevance to mycorrhizal formation. New Phytologist, 81, 543–552.

[74] Roldán, A., Salinas-García, J.R., Alguacil, M.M., Díaz, E. and Caravaca, F . 2005. Soil enzyme activities suggest adgantages of conservation tillage practices in sorghum cultivation under subtropical conditions. Geoderma, 129, 178-185.

[75] Saxena, M.C.and Singh, Y. 1965. A note on leaf area estimation of intact maize leaves. Indian Journal of Agronomy, 10, 437-439.

[76] Smith, S.E. andRead, D. J. 2008. Mycorrhizal symbiosis 3rd (edn.), London ,UK: Academic Press.

[77] Suresh, K.D., Sneh, G., Krishn, K.K.and Mool, C.M. 2004. Microbial biomass carbon and microbial activities of soils receiving chemical fertilizers and organic amendments. Archive of Agronomy and Soil Science, 50, 641-647.

[78] Talbot, J.M., Allison, S.D. and Treseder, K.K. 2008. Decomposers in disguise: mycorrhyzal fungi as regulators of soil C dynamics in ecosystems under global change. Functional Ecology, 22, 955-963.

[79] Tanwar, A., Aggarwal, A., Yadav, A.and Parkash, V. 2013. Screening and selection of efficient host and sugarcane bagasse as substrate for mass multiplication of Funneliformismosseae. Biological Agriculture and Horticulture: An International Journal for Sustainable Production Systems, 29, (2), 107–117.

[80] Tanwar, A., Kumar, A., Mangla, C. and Aggarwal, A. 2010. Mass multiplication of Glomus mosseae using different hosts and subtrates. Journal of Mycology and plant pathology, 40,306-308.

[81] Tawaraya, K., Hirose, R. and Wagatsuma, T. 2012. Inoculation of arbuscular mycorrhizal fungi can substantially reduce phosphate fertilizer application to Allium fistulosum L. and achieve marketable yield under field condition. Biology and Fertility of Soils, 48, 839–843

[82] Toor, G.S., Hunger, S., Peak, J.D., Sims, J.T.and Sparks, D.L. 2006. Advances in the characterization of phosphorus in organic wastes: environmental and and agronomic applications. Advances in Agronomy, 89, 1-72.

[83] Utkhede, R. 2006. Increased growth and yield of hydroponically grown greenhouse tomato plants inoculated with arbuscular mycorrhizal fungi and Fusarium oxysporum f. sp. radicis-lycopersici. Biological Control, 51, 393-400.

[84] Validya, G.S., Keshab, S., Khadge, B.R., Johnson, N. C. and Wallander,H. 2008. Organic matter stimulates bacteria and arbuscular mycorrhizal fungi in Bauhinia purpurea and Leucaena diversifolia plantations on eroded slopes in Nepal. Restoration Ecology, 16, 79-87.

[85] Varga, C., Buban, T. and Piskolczi, M. 2004. Effect of organic mulching on the quantity of microorganisms in soils of apple plantation. Journal of Fruit and Ornamental Plant Research, 12, 147-155.

[86] Verbruggen E., Roling, W.F.M., Gamper, H.A., Kowsalchuk, G.A., Verhoef, H.A. and van der Heiden, M.G.A. 2010. Positive effects of organic farming on below-ground mutualists: large-scale comparison of mycorrhizal fungal communities in agricultural soils. The New Phytologist, 186, 968-76.

[87] Wang, F.Y., Lin, X.G., Yin, R.and Wu, L.H. 2006. Effects of arbuscular mycorrhizal inoculation on the growth of Elsholtzia splendens and Zea mays and the activities of phosphatase and urease in a multi-metal-contaminated soil under unsterilized conditions. – Applied Soil Ecology, 31, 110–119.

[88] Zhong, W., Gu, T., Wang, W., Zhang, B., Lin, X., Huang, Q. and Shen, W. 2010. The effects of Mineral fertilizer and organic manure on soil microbial community and diversity. Plant and Soil, 326, 511-522