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Change of Sandy Soil Chemical Properties with *Azolla microphylla* and Quail Manure

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ABSTRACT

Uncontrolled land conversion reduces the available land for plant cultivation. The alternative used for rice cultivation is marginal land, such as sandy soil. However, several constraints led to very low productivity, so it needs proper management, such as adding organic matter. This study aimed to determine changes in the chemical properties of sandy soil treated with *Azolla microphylla* and quail manure. The pot research was carried out in the Greenhouse of the Faculty of Agriculture, Universitas Sebelas Maret, using a factorial Completely Randomized Design (CRD) with two factors. The first factor consisted of four levels of *Azolla microphylla* (AM),i.e., (0, 50,100, and 150 Mg ha^{-1}). The second factor was three-level quail manure (QM), i.e., (0, 20, 40 Mg ha^{-1}). Fresh *Azolla microphylla* and quail manure were incubated for 14 days under anaerobic conditions. The results showed that applying *Azolla microphylla*, with or without quail manure, significantly improved the chemical properties of sandy soil. The addition of *Azolla microphylla* (100 Mg ha^{-1}) with quail manure (40 Mg ha^{-1}) increased organic C, Cation exchange capacity (CEC), available-P, Ammonium, Nitrate, exchangeable-K, Ca, electrical conductivity (EC), and redox potential (Eh).

Keywords: Ammonium, available P, organic carbon, organic matter, soil fertility

INTRODUCTION

The availability of fertile soil for rice cultivation is continuously decreasing (Silalahi et al., 2019) due to land conversion (Prabowo et al., 2020; Sunartomo, 2015), thereby reducing rice production. To meet the increasing demand for rice (Ayunita et al., 2021), extensification to marginal land, such as sandy soils in coastal areas, is an alternative. It is necessary to use marginal land (Gill et al., 2020)

Indonesia has sandy coastal soil, covering an area of around 99.65 million hectares (Nugroho & Caturatmi, 2014). However, not all of them are utilized for agriculture because sandy soil has various constraints, such as low nutrient levels (Roslan et al., 2010; You et al., 2019), organic matter (Šimanský et al., 2014), the capability of holding and storing water (Hossain et al., 2011; Ho et al., 2019), while the infiltration (Regelink et al., 2015) and evaporation rates are high (Ward et al., 2009).

The addition of organic matter is one effort that can be done as stated by Li et al. (2017) that the use of appropriate organic fertilizer increase soil organic carbon, availability of phosphorus (von Wandruszka, 2006), potassium (Ansari & Mahmood, 2017), nitrogen (Wang et al., 2019), increase the productivity of plant biomass (Baba et al., 2021) affect the increase in the amount of rice grain (Metwally, 2015), provided a source for microbes; regulated the inflow of water, and air. It also improves soil structure (Esmaeilzadeh and. It can shrink soil pores and prevent nutrient loss during leaching in sandy soil (Putra et al., 2021), provide micronutrients for plants (Zeidan, 2007), and act as a buffer against unwanted changes in soil pH (Roba, 2018).

Quail manure is one of the organic matter sources that are easy to obtain (El-Dakar et al., 2021). IMg has a high organic C content of 17.61% (Manurung et al., 2019), N 1.32%, P_2O_5 3.10%, and K_2O 1.24% (Danial et al., 2020), making it useful as an organic fertilizer (Novia et al., 2019). However, the use of quail manure as fertilizer in agriculture is still low (Nurhidayat, 2022). In addition, quail manure can reduce the use of inorganic fertilizers, which can damage the environment, and increase the efficiency of phosphate rock use (Widijanto et al., 2011; Triatmoko et al., 2020).

The use of quail manure itself has not provided sufficient nutrient availability for plants, especially nitrogen. Shahein et al. (2015) reported that the nitrogen level in quail manure is the lowest among chicken, turkey, and quail manures. So it needs to be supported by other organic fertilizers. One of them is *Azolla microphylla. Azolla microphylla* is an organic fertilizer (Syamsiyah et al., 2016) in the form of a water fern that can fix nitrogen due to symbiosis with the cyanobacterium *Anabaena azollae* (Setiawati et al., 2018). Giving *Azolla microphylla* can meet plants' nutrient needs, especially nitrogen. *Decomposed Azolla microphylla* can contain up to 5% nitrogen, and its biomass can serve as a carbon source (Setiawati et al., 2020). In addition, *Azolla microphylla* has the advantage of multiplying rapidly (5-6 days) and producing biomass (Jumadi et al., 2014; Bhaskaran & Kannappan, 2017; Kaur et al., 2021). Results from other studies by Taha et al. (2018) showed that *Azolla microphylla* improved the chemical properties of sandy soils, including C, N, P, K, Ca, Mg, and Na. Until now, research on *Azolla microphylla* combined with quali manure on sub-optimal sandy soils is still limited. The research would examine the role of *Azolla microphylla* and quail manure on the chemical properties of sandy soil.

MATERIALS AND METHODS

The pot research was conducted from November 2020 to July 2021 in the Greenhouse of the Faculty of Agriculture at Sebelas Maret University. It used a completely randomized factorial design (CRD) with two factors. There were four levels of *Azolla microphylla* (AM), i.e., (0, 50, 100, and 150 Mg ha^{-1}), and three levels of quail manure (QM), i.e., (0, 20, 40 Mg ha^{-1}). The sandy soil (9.6 kg pot^{-1}) was added to a pot (24 cm pot diameter, 37 cm high). Quail manure was mixed with soil, and *Azolla microphylla* was immersed to a depth of 10 to 15 cm and incubated for 14 days under anaerobic conditions. The *Azolla microphylla* used in the experiment was fresh *Azolla* obtained from pond cultivation. Within 1 week, about 10 kg of fresh Azolla was collected from a pond measuring 2 × 3 m^2. Meanwhile, quail manure is obtained from quail breeders. According to quail breeders, when raising 6500 quails, they need as much as 75 kg of feed per day and produce about 150 kg of wet quail manure. During incubation, water is maintained at 5 cm above the soil surface (Nikiyuluw et al., 2018). During incubation, water was maintained at 5 cm above the soil surface. That level was maintained by adding water every 2 days (Ruhaimah et al., 2009). Soil sampling for analysis of chemical properties was carried out during the ripening phase (95-102 days after incubation) and at rice harvest (120 days after incubation).

The electrical conductivity was measured with a conductivity meter (Putranto dan Alexander, 2017), nitrate with the brucine spectrophotometric method (Ridhosari dan Roosmini, 2011), and ammonium using the phenate method (Azizah & Humairoh, 2015). Redox potential (Eh) using ORP meter (Syahrial et al, 2018), soil pH using the potentiometric method (Ferreira et al., 2015), Organic-C (Walkey and Black method) (Walkley & Black, 1934), Total-N (Kjeldahl method) (Kjeldahl, 1883), base cations and cation exchange capacity (CEC) uses the ammonium acetate extracting method (Schollenberger & Simon, 1945; Hajek et al., 1972), Available-P (Olsen) (Koralage et al., 2015). Data were analyzed using SPSS 25, with an ANOVA at the 95% confidence level, followed by a 5% DMRT and Pearson's correlation tests to determine relationships among variables.

RESULTS AND DISCUSSION

The sandy soil used had low fertility, with low levels of N, P, K, CEC, organic C, ammonium, nitrate, and sodium (Table 1). To improve the condition, adequate management is needed, such as the use of organic matter. *Azolla microphylla* (AM) used had high levels of water, total-N, and organic-C, and quail manure (QM) had high levels of organic-C, total-P, and total-K (Table 1).

The ANOVA results (Table 2) show that single *Azolla microphylla* (AM), quail manure (QM), or their interaction had a significant effect on all chemical parameters observed in the sandy soil. It was because *Azolla microphylla* and quail manure are organic matter that could improve soil chemical properties. Hasibuan (2015) stated that organic matter (OM) can improve the chemical properties of sandy soil.

Organic-C, Nitrogen (N), Phosphorus (P)

An interaction between AM and QM was observed on soil organic C ($p= 0.043$) (Table 3). This is because *AM* and QM are organic matters that can add organic-C to the soil (Liu et al., 2019)and improve soil chemical properties (Anetasia et al., 2013). In line with the statement of Bhuvaneshwari

Table 1. The Characteristics of Sandy Soil, *Azolla Mycophylla (AM)*, and Quail Manure (QM).

No	Parameter		Soil	*AM*	QM
1.	pH H_2O	-	-	6.61	7.09
2.	Total-N	%	0.01	2.31	1.89
3.	Avail-P	$mgkg^{-1}$	1.30	-	-
4.	Avail-K	me $100g^{-1}$	0.08	-	-
5.	Avail-Ca	me $100g^{-1}$	0.30	-	-
6.	Avail-Mg	me $100g^{-1}$	0.18	-	-
7.	Avail-Na	me $100g^{-1}$	0.17	-	-
8.	CEC	me $100g^{-1}$	2.57	-	-
9.	Organic-C	%	0.17	27.72	28.66
10.	Total-P	%	-	0.36	2.98
11.	Total-K	%	-	0.52	1.20
12.	Ammonium	mg kg^{-1}	0.27	-	-
13.	Nitrate	mg kg^{-1}	0.24	-	-

Note: based on the results of the analysis of the Laboratory of Chemistry and Soil Fertility, Faculty of Agriculture, Sebelas Maret University

Table 2. ANOVA Test Results for Sandy Soil Chemical Properties.

No	Parameter	*AM*	QM	AM x QM
1.	Organic-C (%)	0.000**	0.000**	0.043*
2.	Avail-P ($mgkg^{-1}$)	0.000**	0.000**	0.003**
3.	CEC (me $100g^{-1}$)	0.000**	0.000**	0.030*
4.	pH	0.002**	0.013**	0.021**
5.	Total-N (%)	0.000**	0.000**	0.001**
6.	Ammonium (mg kg^{-1})	0.000**	0.000**	0.000**
7.	Nitrate (mg kg^{-1})	0.001**	0.000**	0.000**
8.	Exch-K ($me100g^{-1}$)	0.000**	0.000**	0.000**
9.	Exch-Ca (mg $100g^{-1}$)	0.000**	0.000**	0.000**
10.	Exch-Mg (mg $100g^{-1}$)	0.000**	0.000**	0.000**
11.	Exch-Na (mg $100g^{-1}$)	0.000**	0.000**	0.000**
12.	Electrical Conductivity(mS cm^{-1})	0.000**	0.000**	0.005**
13.	Redox Potential (mV)	0.003**	0.001**	0.008**

Notes: *: significant, **: highly significant, QM: quail manure

and Kumar (2013), *Azolla microphylla* is beneficial in increasing organic matter. As well as the same results were also reported by Triatmoko et al. (2020), stated that the decomposition of quail manure can increase the organic-C.

Using AM or QM alone was able to increase organic-C than from the control. *Azolla microphylla* at dose 50,100 and 150 Mg ha^{-1} with QM 20 Mg ha^{-1} significantly increase organic-C whenthe QM dose is increased up to 40 Mg ha^{-1}, there is no significant difference in organic-C. At QM of 20 Mg, the addition of AM (50, 100, 150 tons ha^{-1}) gives an increase in organic-C significantly, but if the dose QM 40 Mg ha^{-1}, the addition of AM (50, 100, 150) did not show a difference in organic C. *Azolla microphylla* and quail manure are organic matters that can add organic-C to the soil (Liu et al., 2021). Bhuvaneshwari and Kumar (2013) and Syamsiyah et al. (2016) state that *Azolla microphylla* could increase organic matter. It has an organic-C of 27.72%,whereas QM has 28.66% organic C (Table 1). Castellano et al. (2015) state that OM that has high quality can affect the C content in the soil

Giving *AM* with QM significantly affects total N, ammonium, and nitrate in sandy soil (Table 4). Nitrogen total with QM without *AM,was* not

Table 3. Effect of *Azolla Mycophil*a and Quail Manure on Organic-C.

Treatment	C Organik (%)		
	Quil Manure (QM) ($Mg\ ha^{-1}$)		
Azolla Microphilla (AM) ($Mg\ ha^{-1}$)	0	20	40
0	0.38 a	0.61 bc	0.75 cd
50	0.58 b	0.82 de	0.86 def
100	0.62 bc	0.92 efg	0.84 def
150	0.97 efg	1.02 g	0.99 fg

Notes: The number which was followed by the same letter showed results that were not significantly different (P<0.05; Duncan Test 5%), *: significant, **: highly significant.

Table 4. Effect of *Azolla microphylla* and Quail Manure on Total-N (%), Ammonium ($mg\ kg^{-1}$), and Nitrate ($mg\ kg^{-1}$).

Treatment	Total-N (%)			Ammonium ($mg\ kg^{-1}$)			Nitrate ($mg\ kg^{-1}$)		
	-------------------- Quil Manure (QM) (Mg ha-1) --------------------								
Azolla Mycrophilla (AM) ($Mg\ ha^{-1}$)	0	20	40	0	20	40	0	20	40
0	0.08 a	0.09 a	0.17 b	0.07 a	0.19 def	0.24 f	0.11 a	0.21 d	0.17 b
50	0.17 b	0.3 d	0.23 c	0.13 efg	0.13 bc	0.25 g	0.18 cd	0.19 bcd	0.23 e
100	0.25 cd	0.27 cd	0.26 cd	0.15 bcd	0.17 cde	0.26 g	0.17 b	0.20 cd	0.18 bc
150	0.38 e	0.41 e	0.39 e	0.11 ab	0.21 efg	0.14 abc	0.19 bcd	0.17 b	0.19 bcd

Notes: The number which was followed by the same letter showed results that were not significantly different (P<0.05; Duncan Test 5%), *: significant, **: highly significant.

different between 20 and 40 $Mg\ ha^{-1}$, but the application of *AM*, 50, 100, and 150 tons ha^{-1} without QM had given a significant increase compared to the control. For *AM* 100 $Mg\ ha^{-1}$ or 150 $Mg\ ha^{-1}$, the addition of 20 or 40 $Mg\ ha^{-1}$ of manure did not significantly increase total N compared to no QM. *Azolla microphilla* is a sousce of N for plant because it can fix N up to 1.1 $Mg\ ha^{-1}$ in one year (Kollah et al., 2016). In addition, the increase in soil N is associated with an increase in organic C (r=0.809**). Carbon in OM serves as the primary energy source for the development and activity of soil microbes. These microbes gradually decompose OM (Chaari et al., 2014), thereby increasing the availability of various nutrients (Chavarría et al., 2016).

On the other hand, QM has quite a high N level (Utami et al., 2021). So at 20 $Mg\ ha^{-1}$, iMg has the same effect as a dose of 40 $Mg\ ha^{-1.}$ A similar result was reported by Febrianna et al. (2018) and Hayadi et al. (2014): decomposed OM produces amino acids, which then decompose into ammonium or nitrate, the most significant contributors of N total in the soil. The other studies also found that soil with high OM increases N availability (Elisabeth et al., 2013; Valentiah et al., 2015).

A single application of *AM* or QM increases ammonium and nitrate levels in sandy soil. At the rates of *AM* 50 and 100 $Mg\ ha^{-1}$, the application of 40 $Mg\ ha^{-1}$ QM resulted in significantly higher ammonium and nitrate levels than no quail manure. At the AM dose of 150 $Mg\ ha^{-1}$, the application of QM at 20 and 40 $Mg\ ha^{-1}$ does not significantly increase ammonium or nitrate levels compared with *AM* alone. The results of this study also show that there is no significant correlation between total N and ammonium or nitrate. It means that the ammonification and nitrification processes do not run simultaneously.

Available-P on sandy soil is significantly affected by the application of *AM* with QM together (p=0.003) (Table 5). It is because the OM is mineralized, leading to greater P in the soil solution (Arifin et al., 2018; Garg & Bahl, 2008). The available P in sandy soil ranges from 4.5 to 26.3 $mg\ kg^{-1}$. The single application of *AM* or QM significantly increases the available P in sandy soils. At *AM* 50, 100, or 150 $Mg\ ha^{-1}$, the application of

Table 5. Effect of *Azolla Mycophylla* and Quail Manure on Available-P (mg kg^{-1}).

Treatment	Available-P (mg kg^{-1})		
	Quil Manure (QM) (Mg ha^{-1})		
Azolla Mycrophilla (AM) (Mg ha^{-1})	0	20	40
0	4.5 a	13.36 c	20.88 e
50	7.71 b	15.12 d	24.11 f
100	8.29 b	16.13 d	26.3 g
150	12.19 c	16.32 d	25.3 fg

Notes: The number which was followed by the same letter showed results that were not significantly different (P<0.05; Duncan Test 5%), *: significant, **: highly significant.

20 or 40 Mg ha^{-1} QM shows significantly higher available P than without QM. At QM 20 or 40 Mg ha^{-1}, increasing the AM dose from 50 to 150 Mg ha^{-1} do not increase available P, although it is significantly higher than without *AM*. Quail manure has a relatively high P content of 2.98% (Table 1), and it will add P to the soil after mineralization. The result is in line with Rosemarin et al. (2021), who find that phosphorus availability increases with the application of poultry fertilizer, leading to a lack of digestive enzymes to degrade phytate and resulting in relatively high P. *Azolla mycophylla,* on the other hand, also provides P. These results are in line with those of Syamsiyah et al. (2016) and Setiawati et al. (2018), state that using *Azolla mycophila* could increase soil P availability.

Azolla mycophila and quail manure are used to produce organic C as an energy source for microorganisms to decompose organic compounds from OM and produce nutrients, including P. This can be seen in the very significant positive correlation between organic C and available P (r=0.629**). These results are consistent with Alvernia et al. (2017), who found that organic-C has a positive correlation with available-P, suggesting that an increase would follow an increase in organic carbon in available-P.

Base Cations (K, Ca, Mg, Na)

There is interaction between QM and *AM* affected exchangeable -K (p=0.000), Ca (p=0.012), Mg (p=0.000), and Na (p=0.000) (Table 6). The application of OM reduces soil acidity by retaining alkaline cations (Comte et al., 2013). Subowo (2010) stated that during decomposition, OM will release nutrients, including base cations. The single application of *AM* or QM significantly increased exch-K and Mg, but was not significant in Exch-Ca and Na. Using 20 Mg ha^{-1} QM, with *AM* 50, 100, and 150 Mg ha^{-1} showed exch- K, Ca, Mg, and Na, which were not different, but at a dose of 40 Mg ha^{-1} QM, there was a significant increase in exch-K, Mg, and Na, but no difference for exch-Ca.

At *Azolla microphylla* dose of 50 Mg ha^{-1}, an increase in quail manure from 20 to 40 Mg ha^{-1} significantly increased exch- Ca and Na, but not exch- K and Mg. Whereas at 100 Mg ha^{-1} *AM,* the addition of QM at 20 and 40 Mg ha^{-1} markedly increased exch-K, Ca, and Mg. At 150 Mg ha^{-1} AM, however, the addition of QM at 20 and 40 Mg ha^{-1} showed no difference in exch-K, Ca, or Na. This result is in line with Lestari and Muryanto (2018), who found that decomposed *AM* would release base cations (exch-K, Ca, Mg, and Na). Another researcher concludes that when Azolla microphylla has decomposed, it can provide potassium for the soil, and it is available for rice plants (Sadeghi et al., 2013)

Quail manure application can improve exch-K. According to Sharma et al. (2008), the availability of K increases with increased OM addition to the soil. Another study found that the application of QM is able to significantly increase K^+ levels in the soil in the range of 83-110 mg dm^{-3} (Carmo et al., 2016). In general, poultry manure releases a lot of K into the soil (Najafi-Ghiri et al., 2018)

Organic-C has a positive correlation with base cations. According to Azri (2015), the addition of OM increases the organic-C level and also the base cations produced when the OM is decomposed. Pasang et al. (2019) reported that applying 5 Mg ha^{-1} compost and 10 Mg ha^{-1} poultry manure increase the availability of base cations. Zhang et al. (2016) found that adding organic matter from QM increases soil Na due to the release of mineral salts during organic matter decomposition.

Table 6. Effect of *Azolla microphylla* and Quail Manure on Base Cations (Exchangeable of KCa, Avail-Mg, Avail-Na, and Avail-K) in Sandy Soil

Treatment	Exch- Ca (me100 g^{-1})			Exch--Mg (me100 g^{-1})			Exch-K (me100 g^{-1})			AExch-Na (me100g^{-1})		
	---------------------- Quil Manure (QM) (Mg ha^{-1}) ----------------------											
	0	20	40	0	20	40	0	20	40	0	20	40
Azolla Mycrophilla (AM) (Mg ha^{-1})												
0	0.34ab	0.21a	0.34ab	0.25a	0.25a	0.31b	0.1a	0.33b	0.39cd	9.39abc	7.04ab	7.44 ab
50	0.22a	0.46b	0.63c	0.24a	0.33bc	0.34bcd	0.37c	0.41def	0.42ef	6.15a	9.33abc	12.42d
100	0.32ab	0.66cd	0.86e	0.31b	0.36cd	0.45f	0.38c	0.39cde	0.43f	7.42ab	9.68abc	11.9 c
150	0.64c	0.78de	0.91e	0.39e	0.37de	0.50g	0.39cd	0.4cdef	0.42ef	10.01abc	10.47bc	10.6 bc

Notes: The number which was followed by the same letter showed results that were not significantly different ($P<0.05$; Duncan Test 5%), *: significant, **: highly significant.

Cations Exchange Capacity (CEC), Soil pH, Electrical Conductivity (EC), and Redox Potential (Eh)

The results of the ANOVA showed that the application of *AM* and QM significantly affected the CEC of sandy soil (p=0.030) (Table 2). Cation Exchange Capacity (CEC) of sandy soils ranged from 2.8 me 100 g^{-1} to 5.13 me 100 g^{-1}, and QM is an OM that is one of the factors that determine CEC (Hamawi et al., 2020). This result is in line with Kweon et al. (2013), who found that soil rich in organic matter has a high CEC. The results of this study also showed a positive correlation between organic C and CEC (r = 0.827**). Organic carbon increases the soil's negative charge, thereby increasing the soil CEC (Lumbanraja et al., 2019). In addition, an increase in pH caused by the addition of *AM* with QM can increase the negative charge and CEC (Khair et al., 2021).

Table 7 shows that AM influenced the CEC of sandy soil with QM ($p<0.05$). The single effect of *AM* or QM increases CEC significantly. Quail Manure 20 and 40 Mg ha^{-1}, accompanied by *Azolla mycophylla* 50, 100, and 150 Mg ha^{-1}, significantly increased soil CEC. Likewise, at *AM,* 50ts ha^{-1}, the addition of QM (40 Mg ha^{-1}) resulted in a higher CEC than at 20 Mg ha^{-1}. The same results were found in the *AM* 100ts ha^{-1}. However, the CEC at *AM* 150 Mg ha^{-1} with QM 20 Mg ha^{-1} was not different from that with QM 40 Mg ha^{-1}.

According to Sudadi and Sumarno (2011), *Azolla mycophila* can increase CEC. According to Revell et al. (2012), another study found that the consistent addition of poultry manure increased soil CEC.

There was a significant interaction between *AM* and QM on soil pH (p=0.021) (Table 2). The result aligns with Citak and Sonmez (2011): the application of organic fertilizers positively affects soil pH. The pH of the sandy soil ranged from 7.41 to 7.47.

The single application of *AM* and QM did not give a significant change in soil pH. At a dose of 20 or 40 Mg ha^{-1}, QM, accompanied by various doses of AM, showed no difference in soil pH. Whereas at *AM* 50, 100, or 150 Mg ha^{-1}, with a QM of 20 Mg ha^{-1}, it gives a soil pH almost the same as QM 40 Mg ha^{-1}

It was consistent with the findings of Paler and Alcantara (2021), who reported that adding *Azolla myriophylla* increased soil pH. The same results were reported by Adekiya et al. (2019): quail manure increased soil pH, due to the presence of alkaline cations. According to Yuniarti et al. (2020), organic fertilizers applied to the soil undergo decomposition, releasing alkaline cations that increase the concentration of OH^- ions and, in turn, the soil pH. This statement was consistent with the results of a positive correlation between soil pH and Ca (r=0.847**) and Mg (r=0.851**). Other research also reported that the pH of the soil solution increased due to the alkaline adsorption of Ca^{2+} and Mg^{2+} Ions into complex colloids that replaced H^+ and Al^{3+} ions, and the acid saturation decreased (Emiru & Gebrekidan, 2013). In addition to the exchanged bases, soil pH also positively affected

Table 7. Effects of *Azolla Mycophila* and Quail Manure on CEC, pH, Electrical Conductivity, and Redox Potential in Sandy Soil.

Treatment	CEC (me100g^{-1})			Soil pH			Electrical conductivity (mS cm^{-1})			Redox Potential (mV)		
	------------------- Quil Manure (QM) (Mg ha^{-1}) -------------------											
Azolla Mycrophilla (AM) (Mg ha^{-1})	0	20	40	0	20	40	0	20	40	0	20	40
0	2.8a	3.67b	3.75bc	7.44abcd	7.41a	7.43abc	0.8ab	0.75a	1.36e	155.33c	82.33ab	40.33a
50	3.7bc	3.96c	4.45d	7.41a	7.45bcde	7.45bcde	0.8ab	0.81ab	1.34e	44.33a	61.33ab	40.67 a
100	3.79bc	4.41d	4.93e	7.42ab	7.45bcde	7.47de	0.86ab	1 cd	1.63g	55 ab	59.67ab	39 a
150	4.38d	4.9e	5.13e	7.46cde	7.44bcde	7.47e	1.07d	0.91bc	1.52 f	91b	50.33ab	47 ab

Notes: The number which was followed by the same letter showed results that were not significantly different ($P<0.05$; Duncan Test 5%), *: significant, **: highly significant.

soil CEC (r = 0.522**). According to Tomasic et al. (2013), if soil pH increases, the negative charge on the colloid and the CEC will increase as well. Oksana et al. (2012) also note that the increase in pH is caused by CEC, which is influenced by the negative charge of organic matter.

The application of *AM* and QM significantly affects the EC ($p<0.005$) (Table 2). Mineralization of OM from *AM* and QM will produce salts (Gigliotti et al., 2012) and result in water loss by evaporation due to higher temperatures during OM oxidation. It will determine the value of EC (Zhang et al., 2016)—soil EC value in the range of 0.75 to 1.63 mS cm^{-1} (Table 5). At 50, 100, and 150 Mg ha^{-1} *AM*, adding QM 40 Mg ha^{-1} gives a higher EC than 20 Mg ha^{-1}. Whereas at QM 20 Mg ha^{-1}, an increase in *AM* from 50 to 150 Mg ha^{-1} tends to increase EC. Increasing the QM will significantly increase EC. The high EC values in the *AM* and QM are due to elevated levels of various nutrients and other properties. The results showed that EC was positively correlated with pH (r= 0.548**), organic C (r = 0.450**), available P (r= 0.859**), exch-K (r = 0.436**), CEC (r = 0.622**), exch- Ca (r = 0.586**) and exch- Mg (r = 0.578**) and exch-Na (r=0.414*), according to Peralta and Costa (2013). Soil with high nutrient and salt content, as an illustration of soil fertility, will affect EC. Khairunnas and Gusman (2018) state that the more dissolved salts that can be ionized, the higher the EC.

The application of *AM* with QM significantly affected soil Eh (p=0.000) (Table 2). The application of OM from *AM* and QM will decrease in soil Eh (Husson et al., 2018). It is because, during the decomposition of organic matter, microorganisms consume large amounts of oxygen to form organic compounds and reduce oxygen (Husson, 2013). Another factor affecting soil Eh is flooding (Yao et al., 2022), and flooding reduces Eh by decreasing oxygen (Qiu et al., 2018).

The use of QM alone significantly reduces Eh. However, the single-use *AM* is not always followed by a decrease in Eh. Application QM 20 Mg ha^{-1}, accompanied by *AM* 50, 100, and 150, significantly reduced Eh, but at QM 40 Mg ha^{-1} showed no difference in Eh. At QM, 20 Mg ha^{-1}, accompanied by *AM* 50, 100, and 150 Mg ha^{-1}, significantly reduced Eh, but at QM, 40 Mg ha^{-1} showed no difference in Eh. In the application of *AM* at 50, 100, and 150 Mg ha^{-1}, accompanied by QM at 20 and 40 Mg ha^{-1}, there was a decrease in Eh, although the difference was not significant. This study found a very significant negative correlation between Eh and organic C (r = -0.456**). This result is in line with Husson et al. (2018). There was also a negative correlation between Eh and available-K (r = -0.766**). It was supported by Mulyadi et al. (2021), who reported that flooding decreased Eh, producing Mn^{2+} and Fe^{2+}, which could replace adsorbed K, releasing it into the soil solution and making it available to plants.

CONCLUSIONS

Azolla microphylla and quail manure improved the chemical properties of sandy soil. The addition of *Azolla microphylla* (100 Mg ha^{-1}) with quail manure (40 Mg ha^{-1}) significantly increased organic-C, Cation exchange capacity (CEC), available-P, Ammonium, Nitrate, exchangeable and Ca, electrical conductivity (EC), and redox potential (Eh).

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