ISSN: 1394-7990
Malaysian Journal of Soil Science Vol. 25 : 107-122 (2021) Malaysian Society of Soil Science

Effects of Arbuscular Mycorrhiza and Organic Wastes on Soil Carbon Mineralisation, Actinomycete sand Nutrient Content in Maize Plants (*Zea Mays* L.)

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ABSTRACT

Arbuscular mycorrhizal fungi are a fundamental contributor to soil carbon mineralisation and nutrient cycling in saline soils. This study aimed to evaluate the interactions between arbuscular mycorrhizal fungi (*Glomus mosseae*) (G), tea residue (T), macroalgae biomass (M) and its subsequent effects on carbon mineralisation, actinomycetes counts,nutrients content, chlorophyll content, and corn growth (*Zea mays* L.).T wenty four pots with eight treatments,control (C), macroalgae (M), tea residue (T), *Glomus mosseae* (G), *Glomus mosseae* + macroalgae (G+M), *Glomus mosseae* + tea residue (G+T), macroalgae+ tea residue (M+T) and *Glomus mosseae* + tea residue+ macroalgae (G+T+M) were randomly distributed in the field using randomised complete design (RCD). Results showed that only treatment T had the highest value of carbon mineralisation (0.216 mg C g^{-1} soil day), while it was lower (0.177 mg C g^{-1} soil day) in the G+T treatments. Additionally, the highest values of actinomycetes, chlorophyll, phosphorous content and roots weight were 4.2 10^{-6} CFU g^{-1}, 35 SPAD, 0.4 % and 55 g, respectively in G+T treatments. In contrast, the addition of T, M and G alone did not increase phosphorous content as compared to the control. In conclusion,the combination of tea residue and macroalgae biomass with *Glomous mossea* affected carbon decomposition and increased the number of actinomycetesas as well as nutrients content. This can be beneficial to ecosystems through facilitating carbon conservation and microbial diversity in arid saline soils..

Keyword: Mycorrhizae, carbon mineralisation, actinomycetes, roots, chlorophyll content, nutrients content.

INTRODUCTION

Arid and semi-arid zones cover nearly 40% of the land surface (IPCC 2008). The shortage of rainfall under arid and semi-arid regions could lead to the accumulation of salts in soil (Rengasamy 2006) (Rengasamy 2006) resulting in high quantities of sodium and soil alkalinity problems (Dierickx 2009) (Dierickx 2009). Arid-region soils have concurrently suffered from the loss of soil fertility and soil degradation (Su *et al*. 2004). The loss of organic carbon and vegetation

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in arid soils can lead to a deteriorated soil structure (Al-Maliki *et al*. 2014;Turgut and Kose 2016; Al-Maliki 2016; Al-Maliki *et al.* 2018)

Arbuscular mycorrhizal (AM) fungi play an important role in litter decomposition and soil aggregate formation (Al-Maliki and Scullion 2013; Al-Maliki and Bresam, (2020); Rillig 2004; Al-Zabee and Al-Maliki 2019). AM fungi have been reported to produce excretions which have a vital function for microbial activity and organic matter degradation. These fungi have been found to increase organic carbon and glomalin in soil (Wilson *et al*. 2009). More importantly, Mukerji *et al.* (2012) noted that AM fungi participated in the decomposition process by releasing enzymes such as pectinases, cellulases, and hemicelluloses. However, its role in the decomposition process is still in debate. Leifheit *et al*. (2015) claimed that AM fungi minimised the process of decomposition in woody substances. Likewise, Zhang *et al.* (2016) stated that the release of CO_2 was depressed after inoculation of AM fungi, leading to less depletion of carbon in the semi-arid soils. AM fungi are an important part of soil biota that largely engage in crop productivity and are capable of creating symbiotic relationships with some 80% of the various plant roots. Such a phenomena not only enhances the growth of plants through uptake of nutrients but improve schlorophyll content in the plant. AM fungi symbiosis is believed to enhance photosynthesis rate (Auge *et al.* 2016). It hasbeen reported that the amount of chlorophyll in the inoculated plants of mycorrhizal fungi was far more pronounced than in non mycorrhizal plants (Arya and Buch 2013).

Mycorrhizal fungi are not the only beneficial microbes in soil; actinomycetes are predominant microbes in soil that areengaged in many decomposition processes. They are resistant against undesirable soil conditions and have an ability to stimulate plant growth (Hamdali *et al*. 2008) and also may also participate in P solubilisation (Ghorbani-Nasrabadi *et al*. 2012).

Tea residue is one of the most important wastes in the global world and can play a critical role in agriculture. The Ministry of Commerce reports that the amount of imported tea is up about 150,000 tons annually. This tea was teneeds to be exploited to improve physical, chemical and biological properties of soil as they contain nutrients, carbon, vitamins and amino acids (Feng *et al*. 2018) which can enhance plant growth. Tea waste has been shown to increase soil aggregate stability of degraded lands (Turgut and Kose 2016). In addition, tea waste can improve saline soils by modifying soil electric conductivity (Abdul ghani 2012). Likewise, compost tea has been cited as an optimal option to enhance crop fertility, microbial activity and soil nutrient retention (Merrill and McKeon 2001).

Algal biomass is another waste which also maybe used as an important agent in increasing soil organic matter and nutrients leading to improved CO_2 release by stimulating microbes in soil (Gougoulias *et al.* 2018; Al-Maliki *et al.*, 2019). The experimental hypothesis is that the applied mycorrhizal fungi, tea residue and macroalgae biomass have a tendency to improve carbon mineralisation, actinomycetes counts, roots density and growth of the plant. Therefore, the current study has focussed on the interaction between mycorrhizalfungi, tea residues and

macroalgal dried biomass and their effect oncarbon mineralisation, actinomycetes, roots weight, and chlorophyll, nutrients content and maize growth.

MATERIALS AND METHODS

Experimental Site

This experiment was conducted in the city of Babylon (32°30'02.8"N, 44°19'49.7"E). The study area of the study is considered anarid zone (Köppen 1928) (Köppen and Geiger, 1928) as it has suffered from the impact of salinity for years. The high temperature, low rainfall and low humidity are the most current climatic characteristics of the Babylon area. A field area of 2500 m^2 with the wheat plant (*Triticumae stivum*. L) being the most dominant cultivated plant was used in this study. The electrical conductivity for the field was 7.8 dSm^{-1}. Soil samples were taken from 0.30 m depth, air-dried and then sieved using a 4-mm diameter sieve. Pots of 50kg were placed at the greenhouse. Eight treatments were selected for this study:control (C);macroalgae (M); tea residue (T);*Glomus mosseae* (G);*Glomus mosseae* + macroalgae (G+M);*Glomus mosseae* + tea residue (G+T); macroalgae + tea residue (M+T); and *Glomus mosseae* + tea residue + macroalgae (G+T+M). These treatments were replicated three times to obtain 24 pots. Using randomised complete design (RCD), pots were randomly distributed in the greenhouse which was covered with a plastic nylon. Five seeds of the maize plant (*Zea mays* L.) were sown to a depth of 3 cm. Soil moisture content in pots was maintained close to field capacity (25%) (Al-Maliki *et al*. 2017). Soil samples were collected at the end of the experiment when the plant had a maximum growth (90 days) from the rhizospheric habitat which was located about 2 mm distance from the roots. The analysis of plant tissue was measured based on Harborne (1998). The percentages of nitrogen, phosphorus and potassium in tea waste were 1.5 %, 0.02 % and 1.1 % respectively while in algae, they were 1.6%, 0.33 % and 1.45% respectively. Moreover, the total carbohydrates and polyphenols were 1.3% and 20% in tea waste respectively, whereas it was 0.7 % and 0.8% in algae respectively. Soil properties were measured as described by Black (1962) (Black 1965). Soil texture was sandy clay (clay 46, silt 7, sand 47) g/kg^{-1}. The spores of mycorrhiza fungi (*Glomus mosseae*) were examined using a wet sieving and decanting method (Gerdemann and Nicolson 1963). Mycorrhizalspore density was 42 per one gram of soil. The top soil was mixed with 200 g of mycorrhizal fungal inoculums.Tea residue was air-dried and crunched to 1mm in diameter and 350 g of tea residue were mixed at a depth of 30 cm for each pot. Macroalgal biomass was added at a rate of 250 g per pot.

Analysis

Carbon mineralisation analyses were performed based on Carter and Gregorich (2007) using three replicates for each sample. The measurements were carried out at 2, 4, 8, 12 and 30 days for the tea waste, algae, mycorrhizal fungi and their combinations. Hundred grams of fresh soil of 25% water content was put in a flask. The released CO_2 was trapped in 5 ml of NaOH (1 M) and then titrated with

1 M HCl, following the addition of 2 ml of $BaCl_2$ solution (30%) to precipitate the $BaCO_3$ (AL-Maliki 2012; Abvien *et al.* 2007).The following equations were created to predicate the amounts of CO_2.

meq CO_2 = meqNaOH - meqHCl(1)
CO_2 mg = meq CO_2 x equivalent weight CO_2(2)
Where the equivalent weight of CO_2 is 22
meq= volume (ml)× molarity (3)

Subsequently, the carbon mineralisation rate wasestimated by dividing the quantity of CO_2 released in samples to soil mass (g) and the incubation period (days) according to the equation below:
C mineralisation rate = CO_2 released in samples / (soil mass in g × incubation time (days) (4)

Actinomycetes were enumerated using the serial dilution-spread plate technique. Ten grams of fresh soil were thrown into a flask containing 90 mL of distilled water, which was then vibrated for 30 min. One mL of the created culture was put into 10 mL tubes with 9 mL of water resulting in 10^{-1} dilution. One mL of 10^{-1} dilution was taken for dilution of 10^{-2}. The dilution process was maintained until dilution 10^{-8} was achieved. For the actinomycetes, 1mL of the 10^{-6} diluted solution was poured onto glycerol-arginin-agar medium (Porter *et al*. 1960) and then incubated for 5 days at 30°C. The colony-forming units (CFU) were estimated based on Equation 5and the velvety colonies were regarded as actinomycetes.

Σcolony mL^{-1} = Σcolonies x dilution factor (5)

The Kjeldahl method was used to analyse total N and P utilising an automated colorimetry with a Technicon auto-analyzer Technicon Instruments Corp (Parkinson and Allen 1975). The chlorophyll percentage in corn leaf was measured using a chlorophyll meter (SPAD-504) (Dwyer *et al*. 1991). Using a portable chlorophyll meter, 10 readings of the leaf were obtained for each pot.

Statistical Analysis
Two-way analysis of variance (ANOVA) was used to analyse carbon mineralisation that included two factors (treatments and time), eight treatments (control (C), macroalgae (M), tea residue (T), *Glomus mosseae* (G), *Glomus mosseae* + macroalgae (G+M), *Glomus mosseae* + tea residue (G+T), macroalgae + tea residue (M+T) and *Glomus mosseae* + tea residue + macroalgae (G+T+M) and five incubation periods (0, 4, 8, 12, 30 days). Results for the actinomycetes counts, chlorophyll percentage, roots density, plant weight and nutrients were analysed by one-way ANOVA. Means differences were noted using Tukey'shonestly significance difference (HSD) test with a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

Effect of Treatments on Carbon Mineralisation Rate

The carbon mineralisation rate for the eight treatments was evidently different (Figure1). Tea residue and macroalgal biomass recorded the highest increases in carbon mineralisation but decomposed rapidly during the first 4 days (0.546 mg C g^{-1} soil day) and 0.592 (mg C g^{-1} soil day) but more slowly at day 30 (0.024 mg C g^{-1} soil day and 0.022 mg C g^{-1} soil day) for the tea residue and macroalgal biomass respectively. It appears that the lower C/N of tea residue and macroalgal biomass degraded quickly causing an increase in carbon mineralisation. In addition, tea residue decomposed faster than macroalgal dried biomass and this could be attributed to the enormous quantity of carbohydrates and nutrients in tea residue which might increase soil microbial activity leading to rapid carbon mineralisation. It is hypothesised that tea residue, macroalgal biomass and *Glomous mossea* were able to enhance carbon mineralisation as they not only provided a substrate but also exudates to the microbial community. A study of Gougoulias *et al.* (2018) has shown that the mineralisation of soil organic carbon increases after application of macroalgal biomass in the soil. Our findings suggest that the algae and tea residue has ten soil organic matter decomposition resulting in improved nutrient availability in the soil.

To the best of our knowledge, our study is the first to investigate carbon mineralisation in a combination of *Glomous mossea* and tea residue or macroalgal biomass. We expected the inoculation of *Glomous mossea* to increase carbon mineralisation to a greater extent in tea residue and macroalgal dried biomass due to the production of several enzymes like cellulase which converts the more difficult materials of cellulose to a simple sugar which in turn promotes microbial activity to release more CO_2. Contrary to our expectations, the inoculation of *Glomous mossea* significantly reduced carbon mineralisation (0.173 mg C g^{-1} soil day) overall compared with tea residue (0.216 mg C g^{-1} soil day) and macroalgal biomass (0.202 mg C g^{-1} soil day) treatments. These results can be justified by the possibility of improved soil aggregate formation when *Glomous mossea* was incorporated into the soil leading to an ultimate protection of organic carbon. The well-formed stable aggregates have a priority to protect organic matter from the decomposition process. Six *et al*. (2004) found that soil structure retained organic carbon from the decomposition process. Likewise, Zhang *et al.* (2016) outlined that the inoculation of AM fungi in soil lowered CO_2 release and its consequences on a slower organic matter decomposition. Our results suggest that *Glomous mossea* might improve carbon sequestration and benefitclimate change. (Al-Maliki and Bresam, (2020); reference to support this statement???) Additionally, at day 2, the combination of *Glomous mossea* with tea residue showed a significant increase in carbon mineralisation (0.483 mg C g^{-1} soil day) compared to the single addition of *Glomous mossea* (0.456 mg C g^{-1} soil day). Moreover, the same scenario happened at day 8 which revealed a consistent increase in carbon mineralisation (0.108 mg C g^{-1} soil day) where AM fungi combined with tea residues compared to *Glomous mossea* alone (0.100 mg C g^{-1} soil day). The possible reason could be

that the availability of substrates from the tea residue to the microbial community might have served as energy sources to has ten mineralised carbon. Based on the results of this study, it is suggested that the combination of *Glomous mossea* with tea residue raised carbon mineralisation compared to the single addition of *Glomous mossea* and its consequences for nutrient availability. Vierheilig *et al.* (2000) noted that the mycorrhizal fungal mycelium produced enzymes such as cellulase and pectinase which increased organic matter decomposition in the soil.

Effect of Treatments on ActinomycetesColony

There were clear significant differences in actinomycetescounts between treatments. All treatments maximised actinomycetes significantly compared to control. It is known that the application of organic material sources has an important role in rising microbial community (Al-Maliki *et al.* 2018; Al-Maliki 2016) due to their rolein providing the fertile platform for preferential growth of actinomycetes. Jedidi *et al*. (2004) and Bouzaiane *et al*. (2007) revealed that microbial biomass increased following the addition of organic residue.The highest increase in actinomycetes was after incorporation of *Glomous mossea* with tea residue and the probable reason is that *Glomous mossea* can produce exudates like sugars and organic acids (Toljander *et al*. 2008) which might have contributed to an increase in soil actinomycetes. Furthermore, tea residue contains several nutrients

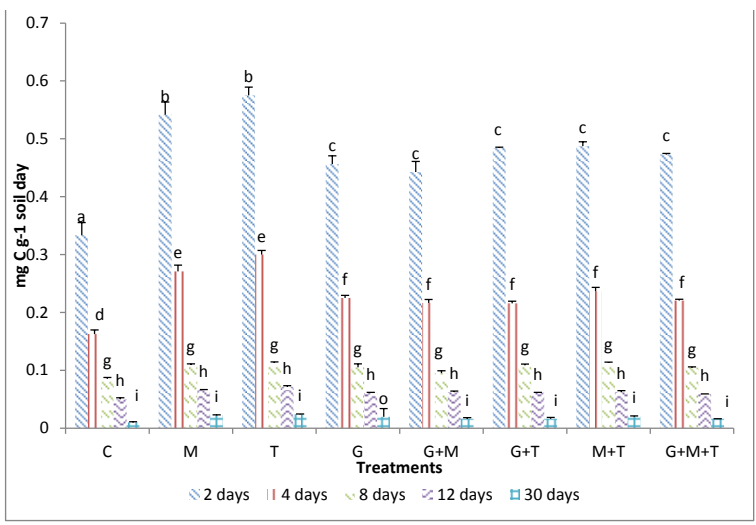

Figure 1.Carbon mineralisation rate (mg C g^{-1} soil day) in saline soil under different treatments:control (C);macroalgae (M);tea residue (T);Glomus mosseae(G);Glomus mosseae +macroalgae (G+M);Glomus mosseae + tea residue (G+T);macroalgae + tea residue (M+T); and Glomus mosseae + tea residue+ macroalgae (G+T+M), over anincubation period of 2 days, 4 days, 8 days, 12 days, and 30 days. The vertical bars represent standard errors. Means with different superscript letters represent statistically significant differences at $p<0.05$

and polyphenol components, the impact of which might have ameliorated the habitat of microbes resulting in increased actinomycetes. Interestingly, we found higher roots biomass in these treatments inferring that roots exudates played a vital role in developing actinomycetes in soil.

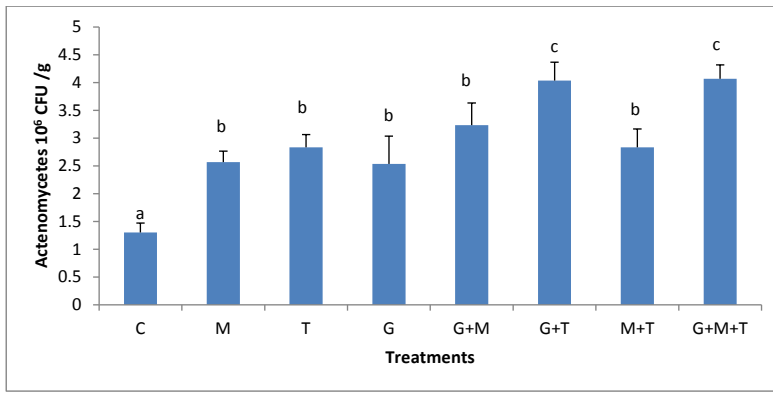

Figure 2. Soil actinomycetes colony counts under different treatments:control (C) ;macroalgae (M);tea residue (T);Glomus mosseae(G);Glomus mosseae +macroalgae (G+M);Glomus mosseae + tea residue (G+T), macroalgae + tea residue (M+T); and Glomus mosseae + tea residue+ macroalgae (G+T+M). Bars represent standard errors. Different superscript letters represent statistical difference (p< 0.05).

Chlorophyll Content

Chlorophyll content varied significantly across treatments (Figure 3). The highest value of chlorophyll content was 35 SPAD in G+T treatment, though not significantly different from G+M and M+T treatments. First, it is well known that the decomposition of tea residue in saline soil raises nutrients level in soil resulting in the promotion of root density and plant growth leading to higher chlorophyll content (Figures 4 and 5). Second,it is also well known that *Glomous mossea* has a major role in absorbing nutrients which can boostchlorophyll content. These suppositions are supported by finding a higher carbon mineralisation in G+T or T treatments, indicating the importance of the carbon mineralisation outcomes in improving plant growth and chlorophyll content. In addition, *Glomous mossea* might have increased photosynthetic efficiency of maize plant in saline soil. This efficiency might be increased to a greater extent when *Glomous mossea* was incorporated with tea residue resulting in a more greenish plant. In contrast, the rate of photosynthesis was lowest in control plants which had leaves that turned yellow. A previous study has confirmed that the chlorophyll rate in mycorrhizal plants ishigher than in non- mycorrhizal plants (Gemma *et al*.,1997) (Gemma 1997 in ref list???)

It is noted that treatments with the inoculation of only *Glomous mossea* significantly increased chlorophyll content compared with control. Nevertheless, this increase was significantly lower than in G+T and G+M treatments. The

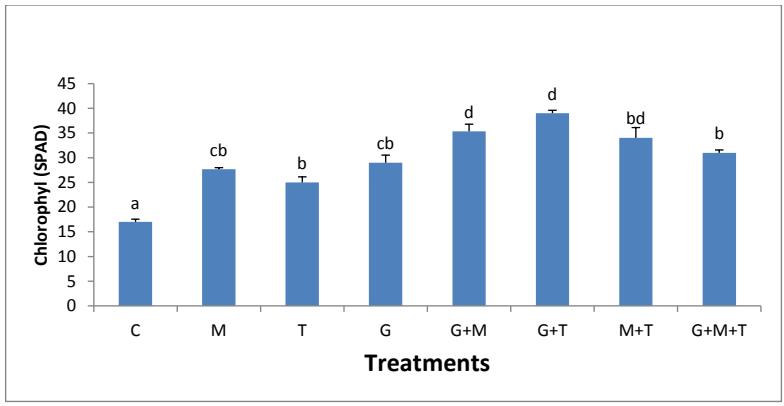

Figure 3. Chlorophyll (SPAD) content in plant leaves under different treatments:control (C);macroalgae (M);tea residue (T);Glomus mosseae (G); Glomus mosseae +macroalgae (G+M);Glomus mosseae + tea residue (G+T);macroalgae + tea residue (M+T); and Glomus mosseae + tea residue+ macroalgae (G+T+M). Vertical bars represent standard errors. Different superscript letters represent the statistical difference (p< 0.05).

application of tea residue and macoalgal biomass in soil was found to increase chlorophyll content significantly in comparison to the control treatment. As mentioned earlier, this increase might be due to improvements in carbon mineralisation and soil structure besides the increase in soil phosphorus content after root colonisation by *Glomous mossea* which can contribute to an increase in the chlorophyll content. Phosphorus is one of the most important constitutes of chlorophyll. A higher uptake of nitrogen, phosphorus, and potassium by AM fungi can maximise plant tolerance to salinity stress and has a consequence on the production of greater leaves and leaf area, causing higher chlorophyll content. Such a relationship between plant and *Glomous mossea* can affect stomatal status and photosynthesis of host leaves. More over, these symbiotic relationships might increase transpirational and photosynthetic rates as well as chlorophyll content (Devi and Reddy 2004).

Nutrients Content (Is it Nitrogen or NutrientsContent???)

Nitrogen content was significantly different in the soil after the incorporation of treatments (Figure. 4) (Should it be Figure 4????). The significant increase in nitrogen content was at G treatment despite it not being significantly different from G+T, G+M and T treatments.(Figure 4 should have been mentioned somewhere here and placed here????)

Undoubtedly Glomous mossea, tea residue and macroalgal biomass have a role in soil fertilityas they can decrease pH and increase nutrient availability (N, K, P and Ca), and organic matter amount. *Glomous mossea* induced tea residues and macroalgal biomass decomposition by stimulating the bacterial population (Al-Maliki and Al-Masoudi 2018) which could have allowed the bacterial community to participate in nitrogen fixation. This explainsan increase in nitrogen content

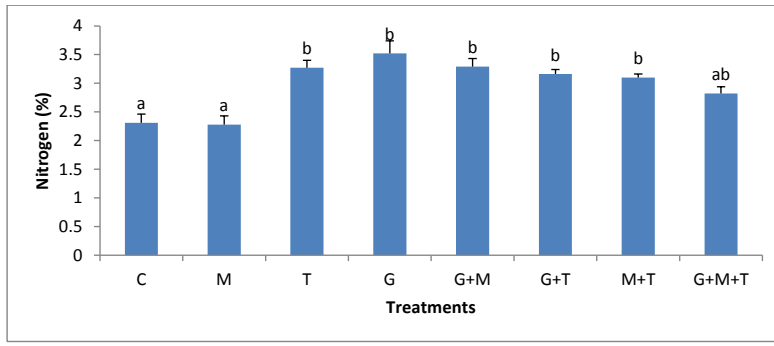

Figure 4. Nitrogen content (%)in the soil under different treatments: (control (C);macroalgae (M);tea residue (T); Glomus mosseae (G);Glomus mosseae +macroalgae (G+M);Glomus mosseae + tea residue (G+T);macroalgae + tea residue (M+T); and Glomus mosseae + tea residue+ macroalgae (G+T+M). Vertical bars represent standard errors. Different superscript letters represent the statistical difference (p< 0.05).

recorded after incorporating the *Glomous mossea* into the soil. *Glomous mossea* can supply energy for the microbial community by degrading cellulose into sugars (Radford *et al*. 1996). Moreover, a lower C/N ratio of tea residue and macroalgal biomass might have allowed for rapid decomposition which in turninduced carbon mineralisation, thus enriching the saline soil through nutrient availability. Contrary to our belief, the application of macroalgal biomass alone did not significantly increase nitrogen content in soil; it was when *Glomous mossea* was incorporated into the soil with macroalgal biomass, that a significant increase in nitrogen content was detected compared with control treatment. This suggests that the incorporation of macroalgal biomass alone does not contribute to nitrogen content and it is deduced that it could be that the lower C/N of macroalgal biomass was accessed rapidly by microbes leading to a quick depletion of soil nitrogen.

It was observed that phosphorous content in soil was significantly higher in G+T treatment, although it was not significantly different from G+M, M+T and G+M+T (Figure 5). This observation could be linked to the increase in actinomycetes population which might solubilise organic phosphates and enhance the decomposition process. Actinomycetes have been reported else where tohydrolyse organic P in soils (Ghorbani-Nasrabadi *et al*. 2013) (not in ref list???). It appears that actinomycetesare able to survive under high salinity, thus phosphorous increases are closely linked to the higher number of actinomycetes. Moreover, improvements in carbon mineralisation might increase the available nutrients in soil. In general, the microbial community can use the energy produced from the decomposition of carbon compounds to release phosphorous (Arcand and Schneider 2006). These effects become even more important with *Glomous mossea* which aids nutrients uptake. For instance, *Glomous mossea* combined with tea residueor macroalgal biomass might encourage the bacterial community to solubilise phosphate by producing lactic acid, oxalic acid and glycolic acid,

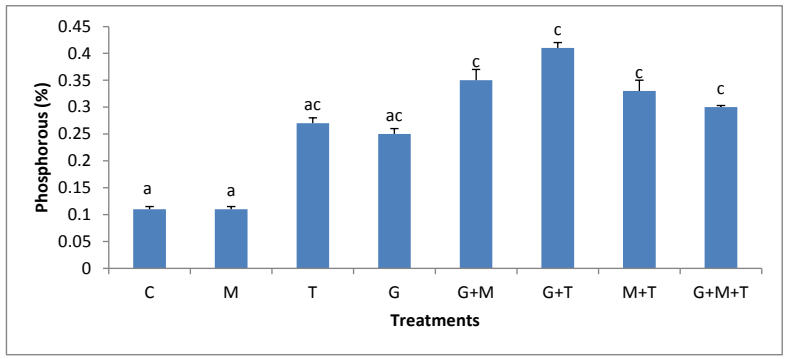

Figure 5. Phosphorouscontent (%) in the plant leaves under different treatments: (control (C);macroalgae (M);tea residue (T);Glomus mosseae (G);Glomus mosseae +macroalgae (G+M);Glomus mosseae + tea residue (G+T);macroalgae + tea residue (M+T); and Glomus mosseae + tea residue+ macroalgae (G+T+M). Vertical bars represent standard errors. Different superscript letters represent the statistical difference (p< 0.05)

or by forming HCO_3 acid which has an important role in maintaining PH and solubilising phosphate in the soil. Toljander *et al*. (2008) outlined that AM fungal hyphal exudates such assugars and organic acids increase soil bacteria which have a robust role in organic matter decomposition and nutrient availability. More importantly, *Glomous mossea* has a cementing role in protecting soil enzymes like phosphatase enzyme and soil organic matter (Qian *et al*. 2012). The aim of phosphatase enzyme is to remove phosphate molecules from organic compounds leading to more phosphorous content in the soil. The application of tea residue, macroalgal biomass and *Glomous mossea* alone did not significantly increase phosphorous content compared with control. This could be dueto the lower amounts of phosphorus in tea residue and macroalgal dried biomass.

Plant Growth

Roots weight was highly ameliorated by treatments. Roots weight increased significantly in all treatments compared with control. (Figure 6 should be mentioned here???) The highest raise in root weight was in a response to acombination of *Glomous mossea* with tea residue compared toall treatments except for G+M+T treatment which confirmed non-significant differences with G+T. The increase in root weight when *Glomous mossea* was combined with tea residue was supported by enhancements in nitrogen and phosphorous contents which are considered very important macro-elements in developing root weight. Niu *et al*. (2012) reported that the availability of phosphorous in the soil can benefit root architecture, root length, branching, and root hair progress. Thus, the increase in root weight can also be expected due tothe rise in carbon mineralisation from organic matter decomposition, leading to increased nutrient availability. The increase in root growth when AM fungi was inoculated in maize is consistent with those reported by Dickson *et al.* (1999).

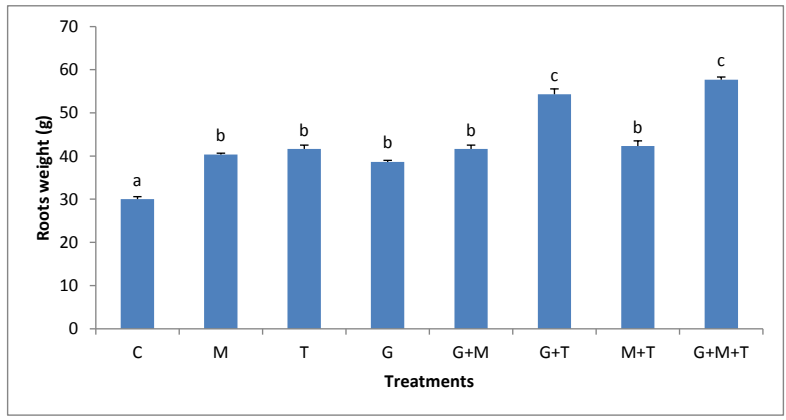

Figure 6. Root weight (g) in the plant leaves under different treatments: (control (C); macroalgae (M);tea residue (T);Glomus mosseae (G);Glomus mosseae +macroalgae (G+M);Glomus mosseae + tea residue (G+T);macroalgae + tea residue (M+T); and Glomus mosseae + tea residue+ macroalgae (G+T+M). Vertical bars represent standard errors. Different superscript letters represent the statistical difference (p< 0.05).

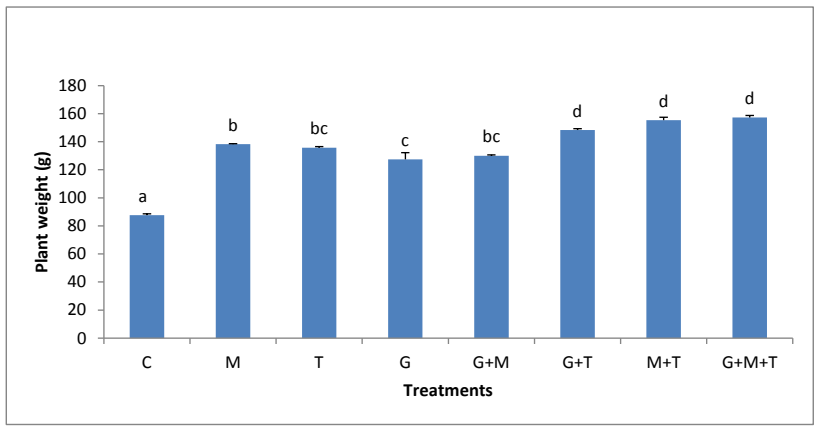

Figure 7. Plant weight (g) in the plant leaves under different treatments: (control (C);macroalgae (M);tea residue (T);Glomus mosseae (G);Glomus mosseae +macroalgae (G+M);Glomus mosseae + tea residue (G+T);macroalgae + tea residue (M+T); and Glomus mosseae + tea residue+ macroalgae (G+T+M). Vertical bars represent standard errors. Different superscript letters represent the statistical difference (p < 0.05).

There were clear significant differences in plant weight among treatments (Figure 6)(or Figure 7). The highest value in plant weight was in G+M+T but this was not significantly different from G+T and M+ T treatments. It was noted that plant weight in tea residue alone was significantly lower than in G+T. The increase in plant weight isa response to acombination of *Glomous mossea* with tea residue and can be mainly attributed to the development in soil structure and root weight which play an important role in absorbing nutrients leading to successful

plant growth. Increases in plant growth in response to *Glomous mossea* have also been shown in other cereal crops (Wahid *et al.* 2016).

Conclusion

This study showed that the carbon mineralisation is influenced by tea residue, macroalgae and *Glomous mossea*. Undoubtedly, carbon decomposition increased rapidly in T and M. In contrast, *Glomous mossea* in combination with T and M mitigated carbon release compared with T and M treatments suggesting an important role for *Glomous mossea* in minimising carbon release and constraining carbon degradation. The G+T treatment increased to a greater extent chlorophyll content, actinomycetes, root weight and phosphorous content. These findings present new insights into the impacts of *Glomous mossea* with tea residue on carbon decomposition and organic carbon stabilisation in arid saline soils.

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