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USE OF VERMICOMPOST TO IMPROVE SOIL PROPERTIES AND SPINACH GROWTH IN THE SOIL AFFECTED BY WIND EROSION

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Abstract: Limited nutrient availability and poor soil structure are the major constraints to plant production in the calcareous soils affected by wind erosion. Short-term (90 days) incubation study was carried out to evaluate the impacts of vermicompost on improving crop yield and soil properties in the calcareous soil exposed to wind erosion. Vermicompost was applied at the rate of 0, 1, 2 and 4% (w/w). Significant ($P<0.05$) differences in the selected physico-chemical properties were observed when the treatments with vermicompost and no vermicompost were compared; except for soil pH and lime content. Soil properties were improved substantially in parallel with the application rates. When compared to the control, vermicompost application significantly increased the yield, fresh leaf biomass (FLB), fresh root biomass (FRB), dry leaf biomass (DLB), dry root biomass (DRB), leaf number (LN) and leaf chlorophyll content (LCC) values of the spinach plant grown under greenhouse conditions. Conclusively, applying vermicompost improves soil properties and crop performance; however, field study is recommended in order to validate the findings of this study prior to adopting vermicompost as soil management practices in the calcareous soils exposed to wind erosion.

Key words: Soil properties, spinach, vermicompost, wind erosion

1. INTRODUCTION

Improved fertility of agricultural lands is the key to producing high-yield crops. Land degradation is the principal barrier to maintaining a high quality of soil and environment for a sustainable crop production (FAO, 2015; IPCC, 2019). Irrational soil management practices are the rationale behind land degradation which is a major constraint to crop performance. Lack of soil organic matter (OM), which leads to poor soil structure, deteriorates the soil properties of agricultural lands, resulting in poor crop growth (Golchin et al., 1995). It is a universally acknowledged fact that soil erosion deteriorates soil quality, fertility and water quality (Lal, 2005). Decreasing OM correlates with a decrease in soil structure, which is known to make soils susceptible to soil erosion. Soil erosion, by disrupting the soil aggregate structure, reducing infiltration and water retention, and covering the surface of fertile soils with sediment, causes a decrease in the fertility potential of the soil and the quality of agricultural products (Kılıc, 2021). Particularly in semi-arid and arid regions, soil degradation is a pressing problem where anthropogenic activities, long periods of dry season, intense and irregular rainfalls are all integrated (Hueso-González et al. 2014). One of the most significant factors for a sustainable soil fertility is building up soil organic matter. Şeker & Manirakiza, 2020; Negiş et al., 2020; Manirakiza et al., 2021 reported that applying organic amendments is very important to elevate soil organic matter. Furthermore, applying organic amendments with low-input agriculture is needed for an improved soil structure and crop development (Bertol et al., 2010; Mafakhery et al., 2012; Pasha et al., 2020), thus, addressing low fertility of degraded agricultural lands. Organic and inorganic amendments improved soil hydrophysical properties and prevented pollutants from penetrating into groundwater (Demir, 2021).

Additionally, applying composted organic amendments - such as domestic waste, animal manures and sewage sludge - protects organic matters from going extinct. Use of organic wastes as soil conditioner has become a cutting-edge method for a sustainable agricultural production. Waste of worms, also known as “vermiculture”, is one of the organic wastes that are known to have a high-quality and short-term production process (Erşahin, 2007). Vermicompost, which is synonymous with the waste of earthworms, has recently become popular in most agricultural settings and is derived from converting organic materials into humus via earthworms (Garg et al., 2010). It is obtained when organic wastes - such as manure and crop residues - are decomposed by earthworms and soil microorganisms, resulting in a product with a high degree of maturity and microbial activity (Romaniuk et al., 2011; Doan et al., 2013). A wide range of studies showcased the potential of vermicompost in improving soil quality and crop yield. For instance, vermicompost application enhances many soil functions including soil aggregation, structure, water-holding capacity (Zink & Allen, 1998; Azarmi et al., 2008; Manivannan et al. 2009), and soil chemical fertility (Azarmi et al., 2008; Tejada et al., 2009). However, applying vermicompost, which has not been studied in the sandy and calcareous soils affected by wind erosion, is recommended especially in dry lands characterized by water deficiency and limited fertility since it could be useful for providing adequate water for plants and making up for the loss of soil nutrients because of erosion (Pasha et al., 2020). We hypothesized that dryland soils - which are known to be susceptible to soil erosion, loss of fertility, salinity, and desertification and have low OM, and water scarcity- (Reynolds et al., 2007) could be improved with vermicompost applications. To test our hypothesis, we observed the effects of vermicompost application on physico-chemical properties and spinach (*Spinacia oleracea*) growth in the calcareous soils exposed to wind erosion under controlled conditions.

2. MATERIAL AND METHODS

2.1. Study area

The soil sample used for our study is taken from a wind erosion affected region located in the Konya-Karapınar, Turkey. In this area, a wind erosion control study had been carried out approximately 60 years ago, and wheat, barley, corn etc. have been rotated since the last two decades. The soil was classified as Xeric Haplogypsid (Akça, 2001) and was randomly collected at a depth of 0-20 cm from a public field of Karapinar Research Institute of Soil, Water and Combating Deserfication (37.72° N latitude and 33.55° E longitude) located in the Konya province, Turkey. The climate is semi-arid, with an annual precipitation of 279.5 mm and annual mean temperature of 10.9°C (MGM, 2020).

2.2. Methods

The experiment was carried out in laboratory conditions (21-23°C ± 3) in the form of a pot experiment with triplicate according to the randomized plot design. The soil samples taken at the surface (0-20 cm) were air-dried, ground and sieved at 2-mm sieve, and thereafter mixed homogeneously. Each pots with dimensions of 12.5 cm x 16 cm were used during the experiment and packed with 2000 g of soil for each, and then vermicompost (V) (control (0), 1(V1), 2(V2) and 4(V3) % by weight) were added and thereafter homogenously mixed and incubated for 90 days. During the incubation period, the soil moisture level in the pots was maintained at field capacity. Vermicompost (trade name Rivo) was obtained from a company called Rivo-Riverm, Tekirdağ. The properties of the soil and Vermicompost (V) used in the study are presented in Tables 1 and 2. The soil was characterized by a sandy clay loam texture, an alkaline soil pH (8.43) and organic matter and $CaCO_3$ contents of 0.98 % and 70 %, respectively.

After the incubation, 1 kg-soil was sampled from every pot and potted in a 2 litre pots, which were subsequently placed in the greenhouse. Spinach (*Spinacia oleracea*) plant was used as the test plant.

Table 2. Properties of the vermicompost

Properties	V
pH (H_2O, 1:2.5)	6.7
EC (H_2O, 1:2.5) dS m^{-1}	5
Organic matter (%)	46.7
Total N (%)	2.64

Table 1. Properties of the soil used in the experiment.

Soil properties	Values	Soil properties	Values
Sand (2-0.05 mm)(%)	68.50	Field capacity (%)	12.91
Silt (0.05-0.002 mm)(%)	8.00	Permanent wilting point (%)	9.76
Clay (<0.002 mm)(%)	23.50	Aggregate stability (%)	22.42
Textural class	SCL		
pH (H_2O, 1:2.5)	8.43		
EC (H_2O, 1:2.5) dS m^{-1}	0.393		
Organic matter (%)	0.98		
Carbonates (%)	70		

Ten seeds were planted in each pot, then thinning was done and the number of plants in each pot was reduced to two and spinach plant was grown within the period of 2 months, and irrigation was frequently performed. Initially, all pots were watered to field capacity water content. Then, the mini evaporation cap losses were measured weekly in the greenhouse and occurred cumulative pan evaporation losses was converted to the pot's surface area and irrigation was weekly performed by replenishing water losses in every pot using a distilled water.

2.3. Analysis

Particle-size distribution was doneby the hydrometer method (Gee & Bauder, 1986). The moisture contents at field capacity and permanent wilting point were analyzed using pressure plate apparatus (Cassel & Nielsen, 1986). Soil pH and EC values were measured using a glass-calomel electrode in a 1:2.5 mixture (w/v) of soil and water (Thomas, 1996; Rhoades et al., 1996). Soil organic matter was determined using the Smith-Weldon method (Smith & Weldon, 1941). Total N was determined by using the TruSpec CN Carbon/Nitrogen Determinator (LECO Corporation 2006). Aggregate stability was determined by immersing the sieves containing the aggregate samples (between 1-2 mm size) in a distilled water with up and down oscillation on screens through 55 mm at 30 strokes min^{-1} for 5 min (Kemper & Rosenau, 1986). Extractable cations (Ca, Mg, K and Na) were determined using 1N ammonium acetate extraction method buffered at pH 7 (Thomas 1982). Available micronutrients (Fe, Cu, Mn and Zn) were determined using DTPA extraction method (Lindsay & Norvell 1978).

Leaf chlorophyll content (LCC) was measured through a portable chlorophyll meter (SPAD-502, Konica-Minolta, Japan). Fresh leaf biomass (FLB), fresh root biomass (FRB), dry leaf biomass (DLB) and dry root biomass (DRB) were measured using a balance. Thereafter, FLB and FRB were oven dried at 60° C for 48 hrs for determining DLB and DRB respectively.

2.4. Statistical data analysis

Soil-plant data were statistically subjected to one-way ANOVA analysis using Minitab 16 software to detect the impacts of amendments and the difference between the means was deemed statistically significant with Tukey test at $P < 0.05$ (Minitab, 1991).

3. RESULT AND DISCUSSION

3.1. Impact of vermicompost on soil physico-chemical properties

Responses of soil pH and EC to V applications are given in Figure 1a and Figure 1b. Pursuant to the results of a 90-day trial, V had insignificant effects on pH in the control group (P<0.05). All V doses significantly (P<0.05) increased the EC values in the control group. Increase in the EC values is due to the chemical properties of V (Table 1). Our results are similar with the results of (Wahid et al., 1998). Similar results were observed when EC showed a linear increase as the rate of V applied to the soil increased (Atiyeh et al., 2002; González et al., 2010; Manirakiza & Şeker, 2020). V application exhibited a statistically significant increase in soil OM (P<0.05) when compared to the control and OM increased as V application increased (Figure 1c). Our findings are in line with another study where OM increased after V application (Ouda & Mahadeen, 2008; Mahmoud & Ibrahim, 2012; Tavalı et al., 2014; Demir, 2019; Aktaş & Yüksel, 2020). Soil OM is one of the premier quality criteria for maintaining soil fertility (Arthur et al., 2011; Gümüş & Şeker, 2017; Yazdanpanah et al., 2016), indicating how V improves the properties and fertility of experimental soil. A statistically significant (p<0.05) increase in AS compared to the control after V application was detected (Fig. 1d). Increase in AS (aggregate stability) could be attributed to the increase in OM (Figure 1c). It is ubiquitous that soil OM is the binding agent that takes part in soil aggregation (Tarchitzky et al., 1993). In addition to OM being a cementing agent, OM also forms and stabilizes soil aggregates (Cerdà, 1998; Bronick & Lal, 2005). Our results corroborate the findings of different researchers where increase in aggregate stability after vermicompost addition was reported (Zhu et al., 2017; Aksakal et al., 2016; Aktaş & Yüksel, 2020).

While vermicompost application significantly increased FC and PWP, an insignificant increase in AWC (available water content) was detected (Figure 1 e, f, g). The effect of an organic regulator on soils is multifaceted as it enhances soil properties. Organic substances facilitate the movement of water and air into the soil by having a binding effect on soil aggregates and reducing the formation of crusting layer on the surface, thus, facilitating root development and enabling the plant to efficiently utilize water and nutrients. They also reduce soil erosion and increase the sustainable use of soil (Barus, 2016; Omondi et al., 2016). Increasing water retention in the soil in our study was due to the high OM content found in V, which is consistent with the literature (Abadi et al., 2012; Alaboz et al., 2017).

Figure 1h presents the effects of V on TN (Total nitrogen). The effects were significant (P<0.05). There was a positive correlation between TN and V applications. Our results are analogous with a previous study which reported that increase in TN after organic amendments were added to soil resulted from the nitrogen content in vermicompost (Angelova et al., 2013). Similarly, the upsurge in N, P and K availability is correlated with the addition of organic materials (Germida & Siciliano, 2000; Tiwari et al., 2004; Zakir et al., 2012). The presence of nitrogen-fixing bacteria in the soil is the rationale behind the increasing nitrogen content in the soil after vermicompost application (Ansari, 2010).

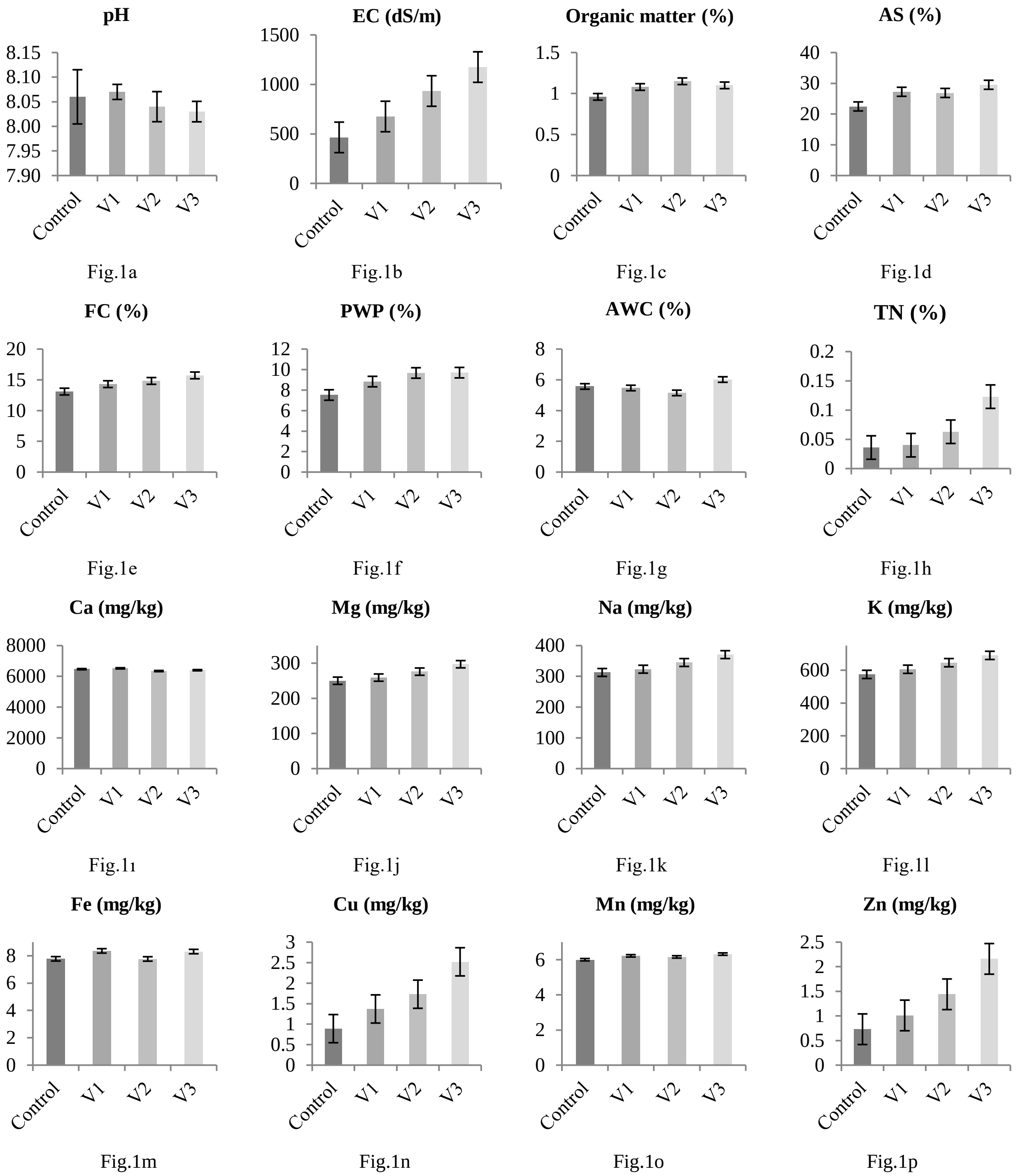

Figure 1. The effects of V aplications on soil physicochemical properties. Bars illustrated with distinct letters show statistically significant difference according toTukey's range test at the 5% probability level.
Control; V1: vermicompost 1%; V2: vermicompost 2%; V3: vermikompost 4%, AS: Aggregate stability; FC: Field capacity; PWP: Permanent wilting point; AWC: Available water content; TN: Total nitrogen

The results indicated that statistically Fe and Mn contents were affected insignificantly while Cu and Zn contents were affected significantly by vermicompost treatments (P<0.05) (Fig. 1 m, n, o, p). Although vermicompost applications increased Fe and Mn contents, their effects were limited. Increasing Cu and Zn concentrations were observed when V dose increased. Gallardo-Lara & Nogales (1987) reported that oxidation of high OM contents found in V increased the availability of Fe, Mn, Zn and Cu in the soil systems. Our results are in line with the study of (Tavalı et al., 2014; Hashemimajd et al. 2004; Azarmi et al. 2008; Suthar 2009).

The results showed that Ca content in the soil was affected insignificantly while Mg, Na and K contents were affected significantly by vermicompost treatments (P<0.05) (Figure 1 ı, j, k, l). The concentration of these nutrients increased as the application rate increased. In many studies, it has been reported that organic material additions increase the contents of Ca, Mg, Na and K in the soil (Asri et al., 2013; Gülser et al., 2015; Namlı et al., 2017, Tarakçıoğlu et al., 2019). Increase in K, P, and N is due to their release into the soil once the organic amendments are decomposed (Zakir et al., 2012). Vermicompost as an organic amendment contains some macronutrients - such as soluble K, phosphate, exchangeable Mg and Ca - that are in plant-available forms (Asciutto et al. 2006). The addition of organic amendments, vermicompost and earthworm casts induces the increase of the bioavailability of macronutrients (Germida & Siciliano, 2000, Angelova et al., 2013). Feeding earthworms with substances rich in organic matters and enzymes has a great impact on the fine soil particles (Angelova, 2013) during aggregation.

3.2. Effects of vermikompost on the spinach growth

During our greenhouse experiment, when compared to the control, all vermicompost treatments significantly increased yield, FLB, FRB, DLB, DRB, LN (leaf number), N and LCC (P<0.05) (Figure 2 a, b, c, d, e, f, g, h). All V applications, especially V3, increasingly promoted spinach development as shown by yield, FLB, FRB, DLB, DRB, LN, N and LCC. This increase could be attributed to the enhanced soil fertility, nutrient release from V and synergistic effect among plant nutrients (Mader et al., 2002) and increased nutrient retention (Sohi et al., 2009, Şeker & Manirakiza, 2020). Recent studies showed that the increasing effect of V on plant development could be attributed to high humic acid

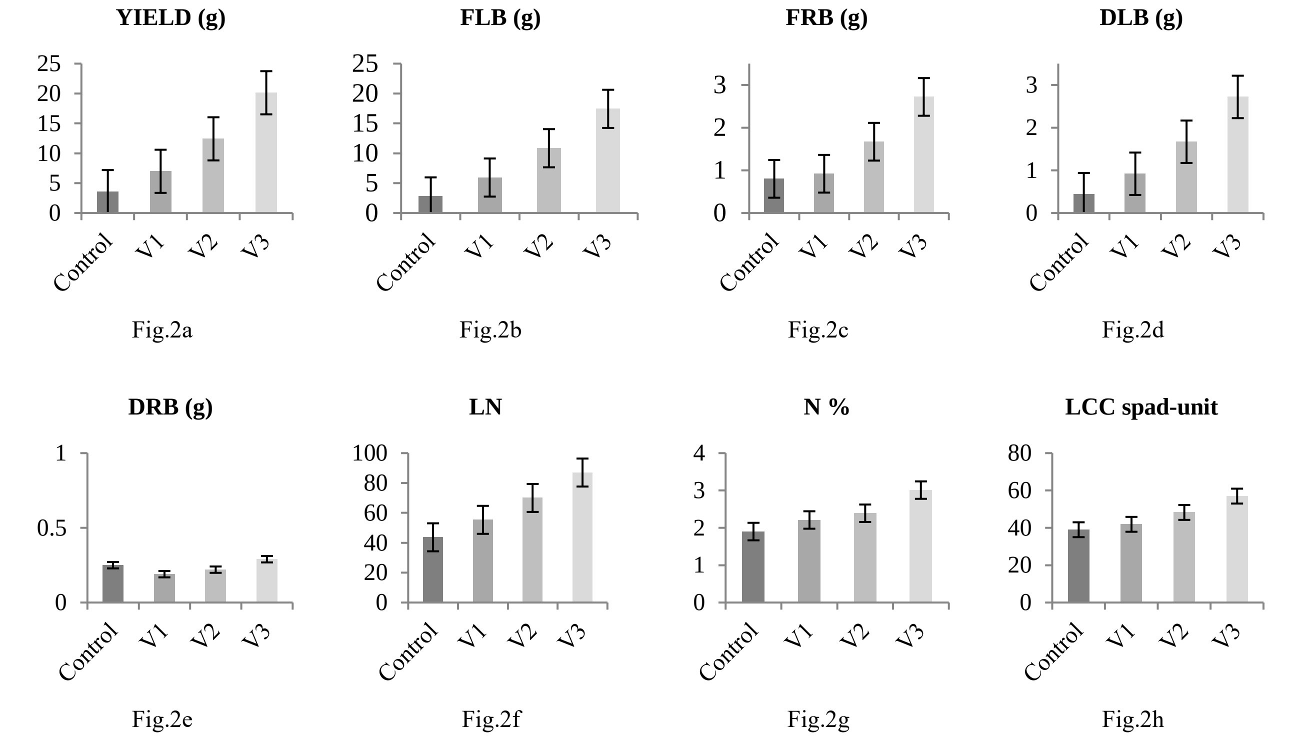

Figure 2. The effects of V applications on spinach growth. Bars illustrated with distinct letters show statistically significant difference according to Tukey's range test at the 5% probability level.
Control; V1: vermicompost 1%; V2: vermicompost 2%; V3: vermikompost 4%. FLB: Fresh leaf biomass; FRB: Fresh root biomass; DLB: Dry leaf biomass; DRB: Dry root biomass; LN: Leaf number; LCC: Leaf chlorophyll content

contents (Atiyeh et al., 2000a; 2000b). Supplementation of soil with V stimulates plant development by scaling up the amount of humic acid and subsequently increasing plant's growth hormones and other beneficial microorganisms involved in a symbiotic relationship. In addition, vermicompost increases nutrient availability, soil structure and microbial activity, thereby plant development and yield increase (Arancon et al, 2004; Edwards et al., 2006). The LCC indicates how crops respond to nitrogen fertilization and other soil nutrients (Minotta & Pinzauti 1996). Peyvast et al., (2008) also indicated that the spinach grown in a soil amended with 10% of V had a high leaf number, area, and fresh weight. Mogle (2013) showed that organic manure amplified fresh weight, dry weight, nitrogen, protein and chlorophyll content of vegetables, thus, addressing the problem caused by vitamin deficiency.

Protecting the organic carbon content of soils and increasing it with various organic amendments; can contribute to the improvement of the structural properties of the soil, increase organic matter content and productivity, reduce atmospheric carbon, and prevent global warming by preventing the infiltration of pollutants into groundwater and their accumulation in plants (Avkopashvili et al., 2022; Paltineanu et al., 2022; Sedrati, 2022).

A previous study conducted under greenhouse conditions reported an increase in mustard number of branches, leaves, flowers pods, root and shoot lengths after V application (Srivastava et al., 2011). Positive impacts on the growth and yield of peppers, tomatoes, strawberries, spinach and lettuce after V applications were obtained from field studies (Arancon et al., 2003, 2004, 2005; Xu & Mou, 2016, Durak et al., 2017).

4. CONCLUSION

Conclusively, the findings of this incubation and greenhouse experiment showed that vermicompost can actually enhance soil's physico-chemical properties and improve the growth of spinach plant in the calcareous soils subjected to wind erosion. Physico-chemical properties of AS, FC, PWP, EC, OM, total N, Mg, Na, K, Cu and Zn contents were improved after vermicompost amendments, which also proves our hypothesis. Additionally, the impacts of vermicompost applications on the yield, FLB, FRB, DLB, DRB, LN, N and LCC values of the spinach plant were significant. It has been verified in this study that vermicompost can effectively enhance plant performance by improving soil properties of the calcareous soils affected by wind erosion, however; field study is recommended in order to validate the findings of this study prior to adopting vermicompost as soil management practices in the calcareous soils exposed to wind erosion.

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