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The effect of bio-humus on Cardinal grape yield (*Vitis vinifera* L.) and nutrient contents of dark brown soil using drip irrigation systems under the open field conditions

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Abstract

The aim of this study was to investigate impact of bio-humus on Cardinal grape yield (*Vitis vinifera* L.) and nutrient contents of dark brown soil using drip irrigation systems under the open field conditions in the vineyard region of Azerbaijan. A field experiment was conducted in a Cardinal Vineyard farm located in Shamakhi district, Azerbaijan between May and October 2021. An experiment with one dose of bio-humus treatment (5 $t.ha^{-1}$) and three replications, with a plot size of 1 ha treatment was used. There were performed drip irrigation, starting from May 15 up to September 15, every 15 days. The soil sampling and measurements carried out after harvest the application of bio-humus in soil and the soil samples were collected from depth of 20 cm. The results showed that addition of bio-humus increased fresh berryweight yield, contents of organic matter, total N, available P, and available micronurtient (Fe, Cu, Zn and Mn) in soil compared with control plots. The soils treated with bio-humus had significantly more EC in comparison to unamended plots. The addition of bio-humus in soil resulted in increase of soil pH.

Keywords: Bio-humus, grape yield, soil nutrients, vermicompost.

Introduction

The continuous decomposition of organic matter in cultivated soils of arid and semiarid regions may lead to soil degradation with a consequence of inability to ensure a sustainable production (Aggelides and Londra, 2000). The application of organic materials could be a way of solving two problems, the materials disposal and the correction of the low organic matter content of many agricultural soils. While chemical fertilizers are important input to enhance crop productivity, over reliance on chemical fertilizers is associated with decline in some soil properties and crop yields over time (Hepperly et al., 2009). Hence, integrated use of chemical fertilizers with organic materials is a sustainable approach for efficient nutrient usage which enhances efficiency of the chemical fertilizers while reducing nutrient losses (Candemir and Gülser, 2010; Schoebitz and Vidal, 2016). Organic material treatments could contribute significantly to the improvement of the soil organic matter content in the long term (Barral et al., 2009) and hence to the physicochemical and biological quality of the soil (Ozores-Hampton et al., 2011; Gülser et al., 2015, 2017; Cercioğlu, 2019; Yakupoğlu et al., 2021). Conventional organic materials such as farmyard manure and compost are widely used for these purposes (Ferreras et al., 2006; Herencia et al., 2007). However, in recent years, vermicompost, in many countries of the former Soviet Union such as Azerbaijan, Kazakhstan and Russian Federation, vermicompost is called bio-humus, has been emerged as an alternative to conventional organic fertilizers due to its additional benefits.

Bio-humus has been the subject of several studies related to its utilization in agriculture. The main objectives in majority of these studies have been its effect on plant growth and yield (Arancon et al., 2003; Kalantari et al., 2011; Kızılkaya et al., 2012). There are also some studies focusing on the relationship between bio-humus

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and some soil properties under various soil conditions (Arancon et al., 2006; Gopinath et al., 2011; Doan et al., 2013; Lazcano et al., 2013). However, most of these studies were under controlled conditions in greenhouse or incubator. Therefore, in terms of soil parameters, how Bio-humus performs in field conditions is open to speculation due to lack of information. This is especially important for vineyard region in Azerbaijan whose soils are typically dark brown soil. Even though there are some studies investigating potential of bio-humus for plant growth and yield in the region (Umetov and Xudaybergenov, 2017), to our knowledge, there is no detailed study focusing on the effect of bio-humus on grape yield and nutrient contents of soil in this region.

Therefore, the aim of this study was to investigate effect of bio-humus on grape yield and nutrient contents of dark brown soil using drip irrigation systems under the open field conditions in the vineyard region of Azerbaijan.

Material and Methods

Site Description

The field experiment was located in one of the agricultural districts, Shamakhi, Azerbaijan (Figure 1). The study area is vineyard region in Azerbaijan. This region is located between 40°37′49″N and 48°38′29″E. Total areas of individual wine growing districts are much smaller than the areas of the subregions such as Avakhil and Pirgulu. Conversely, areas under vineyards are far smaller than the distribution of each wine growing district, as well as areas that have the potential for wine growing production. These areas have been increasing in recent years. The climate in study site is clasified as classified as continental climate, with a daily average air temperature of 17 °C and an annual precipitation of 600 mm (Figure 2). The eye altitude of the study site is 8.96 km.

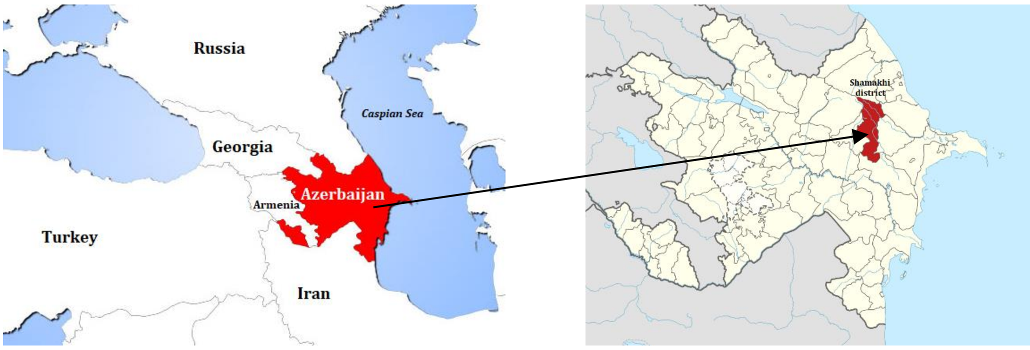

Figure 1. Study area

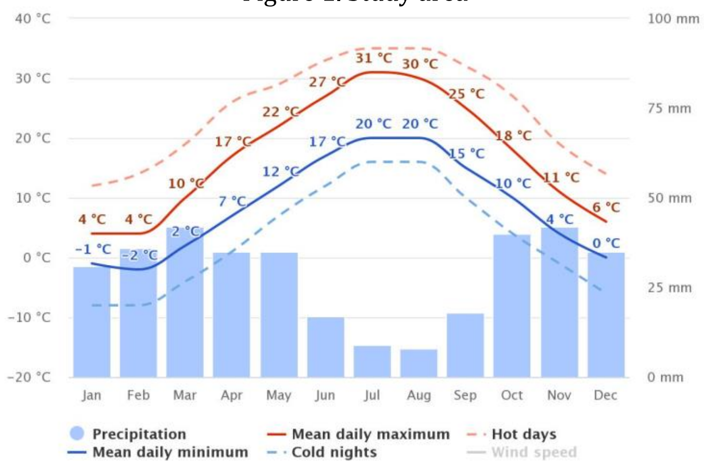

Figure 2. Monthly average temperature (^{0}C) and distribution of precipitation (mm) of the experimental area.

Bio-humus (Cattle manure vermicompost)

Bio humus was obtained from cattle manure by worm composting in a container way using earthworms 'Eisenia Fetida'. Vermicomposting duration – 2,5 months. Aqueous extract of bio humus was prepared in 6 m^3 tanks, mixing it with water at a rate of 6:10 and using a compressor for drip irrigation. The filtered aqueous extract was a dark brown odorless liquid with neutral to slightly alkaline medium reaction. The properties of the bio-humus were expressed on a dry weight basis and were analyzed by standard procedures as given in Ryan et al. (2001) and Jones et al. (1991).

Vineyard

Although it has a wide range of grape varieties in Shamakhi district, Azerbaijan, it is mostly well-known for its table grape varieties used in production of high quality. The most widespread table vineyard varieties are “Prima”, “Cardinal”, “Alfonz Lavelle” and “Danuta”. In this study we selected “Cardinal” grape variety (*Vitis vinifera* L.) . Cardinal is certainly one of the most popular vineyard varieties of table grapes and one of the best and most proven red table grapes early due to its appearance and flavour, as well as its hardiness in withstanding handling and shipping. This grape used as a typical table grape for eating and making raisins. Grains of grapes Cardinal are large, oval-shaped and slightly raised longitudinal ribs. The skin is dark violet, medium thick, fragile. The flesh is crunchy and palatable with a mild muscat flavor (with good ripening). The grains are uneven in size. With low value variations and viral diseased vines often uneven coloring of the skin of the nipple, a tendency to strongly bunch stem necrosis and millerandage.

Irrigation

Many irrigation systems such as flood, sprinkler and drip are suitable for vineyard use. In study site in Shamakhi district, climate is continental climate and water management is a key issue for agriculture. So, in present study we selected drip irrigation system. The big reason why drip irrigation is so common among these vineyards is due to that fact that drip irrigation has a high irrigation efficiency. Drip irrigation puts the water directly where the irrigator wants it, and does not lose much water to evaporation. Drip systems are typically the most efficient and save a lot of water that other systems might lose to inefficacies. In this research, subsurface drip irrigation with two drip line positioned equidistantly between adjacent vine rows and at 35 cm deep. The drip line was mechanically installed before vineyard establishment, deep enough to prevent damage by tillage, but sufficiently shallow to supply water to the root zone without wetting the soil surface.

Experimental Procedure

A field experiment was conducted in a Cardinal Vineyard farm located in Shamakhi district, Azerbaijan between May and September 2021. The soil at the site is classified as dark brown soil. Basic soil physico-chemical properties were determined according to the Rowell (1996). The experimental plot was situated in a uniform flat land with 3-4° sloping gradient, 636 m elevation, and a planting density of 1000 vine bushes ha^{-1}. Vines were trained according to Tent system with 2 m height. Drip irrigation system was constructed since 2021. An experiment with one dose of bio-humus treatment (5 $t.ha^{-1}$) and three replications, with a plot size of 1 ha treatment was used. There were performed drip irrigation, starting from May 15 up to September 15, every 15 days. The other cultural practices were the same as for the other part of the vineyard.

Soil sampling and analyses

After harvest in September 15, the soil samples collected from depth of 20 cm were naturally air-dried, milled and passed through 2.0 mm sieve. Soil pH and EC (Electrical Conductivity) value was determined by the potentiometric method in a 1:1 suspension of soil in dH_2O using a pH meter and EC meter, respectively according to Jackson (1973) and Rhoades (1996).Soil organic matter was determined by modified Walkley-Black method (Walkley and Black, 1934). Total Nitrogen (N) by the modified Kjeldahl method (Bremner, 1965), available Phosphorus was determined by the 0.5M $NaHCO3$ extraction method (Olsen and Sommers, 1982), available micronutrients (Fe, Cu, Zn and Mn) content were determined by the DTPA+TEA+$CaCl_2$ extraction method (Lindsay and Norvell, 1978).

Grape yield

Data are reported from the 2021 vegetative season during harvest, the productive grape yield as a fresh berryweight and green bush density were gravimetrically determined.

Results and Discussion

Soil Properties

The experimental site is characterized by a dark brown soil with an slightly acidic soil reaction. These soils have equal amounts of silt, sand and clay particles giving them a loamy texture. As there is space between the soil particles for air and water to pass through it, this means that dark brown soils are well drained making them very fertile and ideal for agricultural practices. The soils of study are has 29.22% sand, 34.44% silt and 36.34%% clay fraction and soil textural class was named as loamy. Also, soil properties in experimental field are given in Table 1. The soil were medium in organic matter content (1.71-3%), low in electrical conductivity (<0.98 dS m−1), medium in total N (0.15-0.25%), high in available P (>18 $mg.kg^{-1}$). The soil were medium in available Fe (2.5–4.5 $mg.kg^{-1}$), high in available Cu (>0.2 $mg.kg^{-1}$), medium in available Zn (0.7–2.4 $mg.kg^{-1}$) and medium in available Mn (14–50 $mg.kg^{-1}$).

Table 1. Soil properties in experimental field

Properties		Value
Texture	Sand, %	29.22
	Silt, %	34.44
	Clay, %	36.34
	Texture class	Loamy
pH (1:1)		6.70
EC (1:1), dSm^{-1}		0.86
Organic matter, %		2,01
Total N, %		0.23
Available P, $mg.kg^{-1}$		21.56
Available micronutrients	Fe, $mg.kg^{-1}$	3.99
	Cu, $mg.kg^{-1}$	4.02
	Zn, $mg.kg^{-1}$	1.04
	Mn, $mg.kg^{-1}$	16.09

Bio-humus properties

The bio-humus contained high levels of macro- (N, P, K, Ca and Mg) and micronutrients (Fe, Cu, Zn and Mn), and organic matter (Table 3). However, it also had high levels of Na (1045 mg kg^{-1}) with slightly high EC value (1675 $\mu mhos.cm^{-1}$) and pH values of 7.10 (Table 2), indicating that is a non-saline organic product of neutral reaction. These values are in the expected range in stabilized and mature compost. It is important to state that the chemical properties of bio-humus are variable depending on the type and state of decomposition and storage time of the subproducts used for its elaboration.

The organic matter had values of 48.1%, which was in the range considered as adequate in this type of compost. The C/N ratio was 5.1, indicating that is a bio-humus (vermicompost) stable and mature, since according to some authors (Ndegwa and Thompson, 2000; Majlessi et al., 2012) it meets the established value for this characteristic (C/N = 15 or less). This is a direct estimation of the biological degradable fractions of C and N in the organic substrates (Jiménez and García, 1992), plus it is an index for celerity of substrate decomposition and later mineralization of their components. Similar to previous studies (Padmavathiamma et al., 2008; Fornes et al., 2012), the vermicompost or bio-humus has many favorable properties including high content of organic matter, and macro- and micronutrients, in spite of the high EC value due to its high contents of Na. This suggests that a high application rate as soil amendment is not recommended because of the salinity stress it might cause. Even after harvesting, soil bio-humus amendments had high contents of nutrient and organic matter. The results indicate that bio-humus could be used to improve soil fertility as a soil amendment.

Table 2. Chemical characteristics of Bio-humus (cattle manure vermicompost)

Properties	Value
pH (1:10)	7.1
EC (1:10), $\mu mhos\cdot cm^{-1}$	1675.0
Organic matter, %	48.1
C/N	5.1
Total N, %	5.6
Total P, $mg.kg^{-1}$	675.0
Total Fe, $mg.kg^{-1}$	4543.0
Total Cu, $mg.kg^{-1}$	4.7
Total Zn, $mg.kg^{-1}$	156.0
Total Mn, $mg.kg^{-1}$	180.0

Changes in pH, EC and organic matter in soil

Bio-humus treatments increased pH values of soil. The pH of soil was 6.70 in control treatment and the value increased to 7.30 (Figure 3a). This trend may be the result of the high base content in the compost and its large capacity to absorb free protons (H^+) in the soils, this result is similar to that reported by Cox et al. (2001). Romaniuk et al. (2011) reported that in low pH soils, 20 Mg ha^{-1} vermicompost treatment increased soil pH from 6,06 to 6,45. Such an increase was attributed to greater pH of vermicompost than the soil. The study conducted by Mabuhay et al (2006) agreed with these results; they found that soil pH increased when organic and chemical fertilizers were applied to agricultural lands. Nastri et al (2009) observed very slight soil pH response to addition of either organic or inorganic fertilizers. Giannakis et al (2014) reported that compost application increased soil pH from 7.80 to 8.10 and 8.20 in the 50 and100 t ha^{-1} application rates, respectively, at the 0-15 cm soil layer.

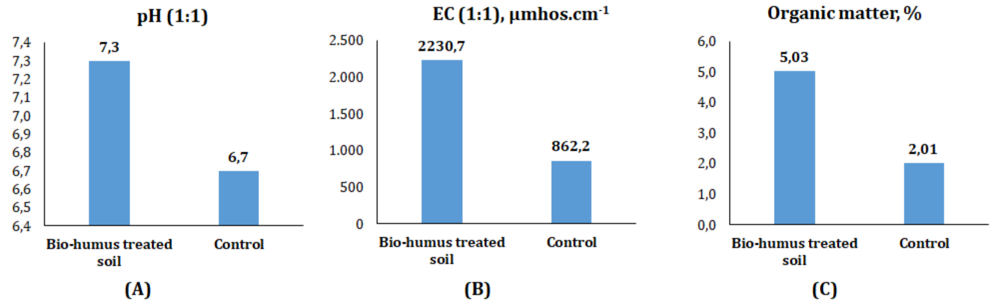

Figure 3. Changes in pH (A), EC (B) and organic matter content (C) in soil

The electrical conductivity (EC) in bio-humus was 1.6 dSm^{-1}. The soils amended with bio-humus had significantly higher EC than the untreated control soils (Figure 3b); this trend may be due to the high amount of nutrients in the applied compost. The soil EC increased with vermicompost in soil as reported by Atiyeh et al. (2001) with pig manure vermicompost substituted into Metro-Mix 360. The EC of vermicompost depends on the raw materials used for vermicomposting and their ion concentration (Atiyeh et al., 2002). Several researchers reported that addition of organic manure and compost to the soils significantly increased electrical conductivity (Candemir and Gulser, 2010; Morugán-Coronado et al., 2011; Cercioglu et al 2012; Mahmoud and Ibrahim, 2012).

Experimental bio-humus had an organic matter content of about 48%. The soils amended with bio-humus had significantly higher organic matter in soil than the untreated control soils (Figure 3c). The soil organic matter content was increased because of high organic matter content of bio-humus.. The increase in the levels of soil organic matter was expected, since, organic sources have the ability of increasing soil organic matter content. Many researchers reported that addition of organic matters on soil also increased organic matter content in soil (Cercioglu et al., 2012; Kızılkaya et al., 2012, 2020).

Changes in Nitrogen and Phosphorus content in soil

The results showed that the total N and available P concentration in soil was significantly affected by bio-humus treatments (Figure 4a). These effects may have been caused by the high content of these elements in the bio-humus (Table 2). The soils treated with bio-humus at the rate of 5 t ha^{-1} had more total N compared to soils without bio-humus treatment. Bio-humus might have produced more residual N in soil than those in control plots.

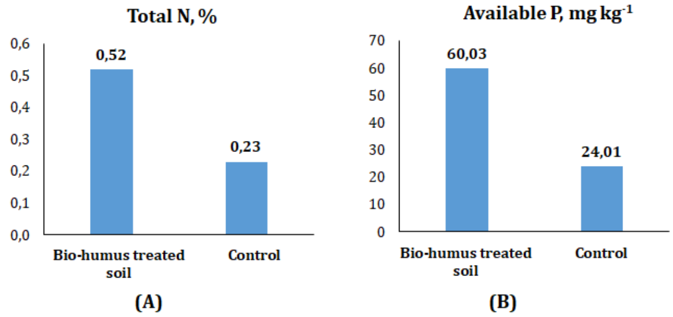

Figure 4. Changes in Total N (A) and available P (B) content in soil

Soils treated with bio-humus had significantly more available P as compared to control plots (Figure 4b). This implied that the continuous inputs of P to the soil were probably from slow release from bio-humus and release of P was due largely to the activity of soil microorganisms (Arancon et al., 2006). Marinari et al. (2000) showed similar increases in soil P after application of organic amendments such as vermicompost and/ or bio-humus. The enhancement of phosphatase activity and physical breakdown of material resulted in greater mineralization (Sharpley and Syres, 1977). In this experiment the more available P probably could have contributed to decrease of soil pH caused from application of bio-humus.

Changes in available micronutrients in soil

The data on effect of bio-humus treatment on available micronutrients (Fe, Cu, Zn and Mn) in soil are presented in Figure 5a,b,c,d. The results showed that the available micronutrients concentration in soil was significantly affected by bio-humus treatments. The total Zn content, pH and organic matter addition on soil affect the Zn availability (Alloway, 1993; Karaca et al., 2010). The application of bio-humus increased the available micronutrient concentration, almost 2.5 times as compared with the control. Bio-humus contain micronutrients (Table 2) due to the supplements in animal feeds, which could increase soil Fe, Cu, Zn and Mn contents. When organic materials are applied to soils to improve organic matter status, they also supply soils with nutrients including macro- and micronutrient concentrations in soil (Tiwari et al., 2004; Kızılkaya, 2004; Zakir et al., 2012). Our data are in agreement with this fact. On the other hand, these findings contradict some previous reports suggesting that especially nutrients in vermicompost is released more gradually in available form in soil (Nethra et al., 1999; Lazcano et al., 2008).

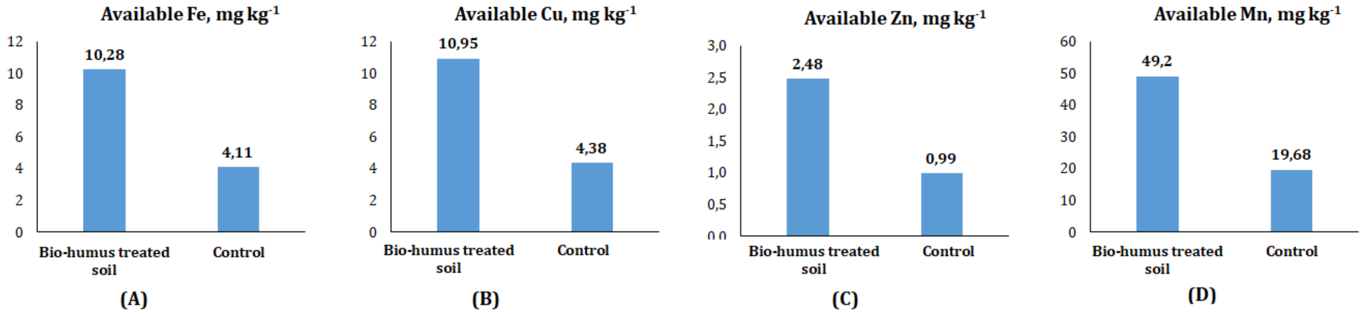

Figure 5. Changes in available Fe (A), available Cu (B), available Zn (C) and available Mn (D) content in soil

Changes in Grape yield

Results indicated that application of bio-humus showed a significant effect on the fresh berryweight yield, green bush density and tield duration (Figure 6a,b,c). All changing in soil properties show itself in grape yield, too. Fresh berryweight yield values significantly varied between 11.86 and 26.25 t ha^{-1} with an increase of 221% over the control. Green bush density became 41% more than before being fertilized and yield duration lasts 6 month that is twice more than the initial duration. Before fertilizing productivity increased in early autumn. Higher Fresh berryweight and green bush density were found after the treatments bio-humus, which is consistent with previous research showing that crop plants had increased height after vermicompost was applied (Atik and Yılmaz, 2014). This result could be due to the higher macro- and micronutrient content in soil caused by applying bio-humus in this experiment. And also, different types of phytohormones have been found in vermicomposts (bio-humus) (Zhang et al., 2014; Scaglia et al., 2016), and these phytohormones can significantly improve fruit quality. The use of organic fertilizer was shown to increase soil organic carbon and soil fertility, consequently resulting in a larger yield trend compared to a balanced chemical fertilizer (Gong et al., 2011).

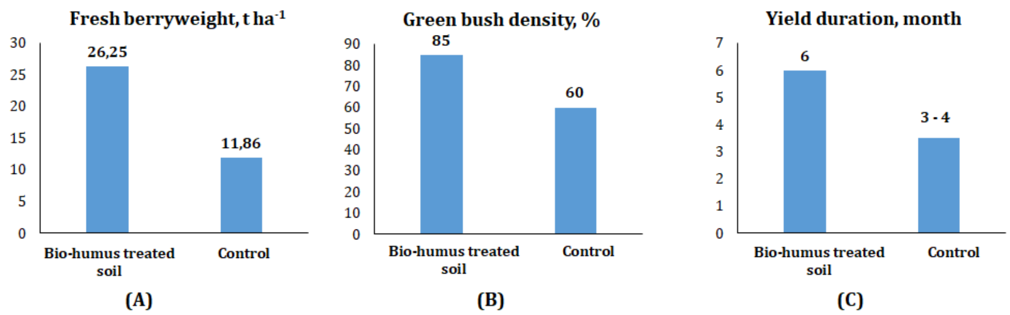

Figure 6. Changes in fresh berryweight yield (A), green bush density (B) and tield duration (C)

Conclusion

In conclusion, our results suggest that bio-humus improved organic matter and available nutrient contents of soil, thereby increasing fresh berry weight yield, and yield quality compared with control. Moreover, considering the higher electrical conductivity (EC) and pH achieved by applying bio-humus could be a better recommendation for dark brown soil using drip irrigation systems. However, more field studies are still needed to confirm our results. These studies should be designed to elucidate the long-term effects of bio-humus on nutrient contents and cycling on different soil types, to increase grape yields under sustainable production systems. The final goal is to optimize its application rates in the field to maximize yields and quality.

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