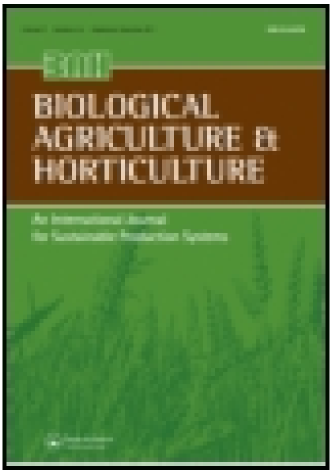

Biological Agriculture & Horticulture: An International Journal for Sustainable Production Systems
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tbah20

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Published online: 11 May 2015.

To cite this article: N. Okur, H.H. Kayikcioglu, F. Ates & B. Yagmur (2015): A comparison of soil quality and yield parameters under organic and conventional vineyard systems in Mediterranean conditions (West Turkey), Biological Agriculture & Horticulture: An International Journal for Sustainable Production Systems, DOI: 10.1080/01448765.2015.1033645

To link to this article: http://dx.doi.org/10.1080/01448765.2015.1033645

Biological Agriculture & Horticulture, 2015
http://dx.doi.org/10.1080/01448765.2015.1033645

A comparison of soil quality and yield parameters under organic and conventional vineyard systems in Mediterranean conditions (West Turkey)

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(*Received 11 September 2014; accepted 21 March 2015*)

Soil chemical and microbial parameters are commonly used as soil quality indicators to evaluate sustainable land management in agroecosystems. The objective of this research was to evaluate the impact of organic and conventional management strategies on biological, chemical and yield parameters in vineyards (*Vitis vinifera* cv. Sultani seedless). Organic plots received a mixture of barley, vetch and broad bean (25 + 35 + 75 kg seed ha^{-1}) as green manure, and farmyard manure (15 t ha^{-1}) every year. Inorganic fertilizers (NPK) and pesticides were used in the conventional managed vineyards. Conventional and mulch tillage methods were used in conventional and organic plots, respectively. Microbiological and chemical soil properties were determined in the soil samples which were taken four times in 2004, 2005, 2006 and 2007. In addition, the yield and some quality parameters of vineyards were also determined. Soil microbial biomass, and dehydrogenase, β-glucosidase and alkaline phosphatase activity were significantly higher in organic management than in conventional management. Higher C_{mic}/C_{org} and lower qCO_2 values were found with the organic management. The response of the chemical indicators (C_{org}, N_t and available nutrient content) of the soils to different management systems appeared after a longer time than with the biological indicators. In the transition zone between continental and Mediterranean climates of West Turkey, soil quality of organically managed vineyards improved after 2 years of the transition period prescribed for organic certification. However, soil quality improvements in organic plots did not result in higher yield.

Keywords: available plant nutrient; enzyme activity; microbial biomass; organic farming

Introduction

Sustainable land management reduces the ecological footprint of agricultural production and limits the loss of biological diversity. One of the challenges in land management is to conserve soil quality and concomitant ecosystem services while optimizing agricultural yields (Kibblewhite et al. 2008). Soil quality is defined as the potential of a soil to function within ecosystem boundaries to maintain biological productivity, sustain environmental quality and promote plant health (Doran & Parkin 1994). Both chemical and microbiological parameters could be used as soil quality indicators (Benintende et al. 2008). In general, most soil chemical parameters respond slowly to changes in land use, and long years are required to obtain a significant difference between treatments (Lagomarsino et al. 2009). The biologically active components of soil, including organic matter, soil microbial biomass and energy sources such as organic C and N, are sensitive indicators of

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changes in soil management (Kennedy & Smith 1995). Soil microorganisms play a major role in organic matter decomposition and plant nutrient cycling. Marinari et al. (2006) measured chemical and microbiological parameters as indicators of soil quality after 7 years of organic certified and conventional management systems and determined large differences between the microbiological parameters of two soils. Bell and Raczkowski (2008) found that soil biological, chemical and physical quality indicators were able to reveal rapid changes in soil conditions that occur because of soil management. Qin et al. (2010) suggested that GMea (the geometric mean of the assayed enzymes), MBC (microbial biomass C), MBN (microbial biomass N) and β-glucosidase were the most effective indicators for monitoring soil quality in a silt loam Haplic Cambisol.

There are limited studies comparing the effect of management on soil properties as indicators of soil quality in viticulture. Some authors suggest that organic farming under different crop management results in higher soil quality than conventional farming due to enhanced soil biodiversity (Oehl et al. 2004), improved soil structure formation (Pulleman et al. 2003), increased soil organic C, microbial biomass and enzyme activity (Tu et al. 2006; Okur et al. 2009). Organic vineyard management systems are characterized by avoiding synthetic pesticides and the use of organic fertilizers, green manure and, often, reduced, shallow tillage. Several authors studied vineyard soil characteristics after applications of different organic amendments (Morlat & Chaussod 2008; Mugnai et al. 2012) and under different grass management practices (Monteiro & Lopes 2007; Virto et al. 2012). Probst et al. (2008) sought an answer to the question whether organic vineyard management positively affects the soil microbiological indices. Coll et al. (2011) measured the long-term effect of organic viticulture by physical, chemical and biological indicators. There is a great need to determine the most suitable soil quality indicator for vineyard ecosystems.

To the authors' knowledge, there are no studies that evaluated soil chemical, biological and yield quality indicators to give a complete overview of soil quality of vineyards. In this work, the impact of organically versus conventionally managed vineyards on soil quality under semi-arid Mediterranean climate conditions of Western Turkey were studied by measuring a number of soil biological, chemical and yield quality indicators.

Material and methods

Study site and soil sampling

This study was conducted from 2004 to 2007 in conventionally and organically managed vineyards in Alaşehir Viticulture Research Centre, located 113 km southeast of the city of Manisa in Western Turkey. The vineyards were established in 1992 with *Vitis vinifera* cv. Sultani seedless. Although it is a variety for drying, sultanas are also processed as table grapes through a series of culture procedures. The climate of this region shows a transition towards a continental climate from a Mediterranean climate. The annual average temperature and rainfall are 16.3°C and 598 mm, respectively. The summer months, including the harvest period, are quite hot with mean temperatures of 30°C. The experiment included a 2-year transition period (2004 and 2005) followed by 2 years of organic production (2006 and 2007). A mixture of barley, vetch and broad bean (25 + 35 + 75 kg seed ha^{-1}) was used for the nutrition of organic vineyards. The green manure cover crop was sown in the month of November and incorporated when the plants began to flower in early May. At the point of incorporation, the green manure had an above-ground biomass of 2.5 kg^{-1} m^2 as fresh weight. In addition, 15 t ha^{-1} of farmyard manure was applied in November every year at the time of seed sowing. Mature and dried farmyard manure (3 year old) was incorporated by ploughing to a depth of 30 cm. The crop was irrigated at a rate of 300 mm year^{-1} based on a predetermined tension value and the physiological growth of grapes. Amounts of organic C, total N and P added to soil by organic treatments during 4 years and some chemical properties of farmyard and green manure are given in Tables 1 and 2, respectively. No pesticides were used and the plots were managed according to the IFOAM Organic Guarantee System (IFOAM 2003). Inorganic fertilizers (ammonium sulphate, 300 kg ha^{-1}; triple super phosphate, 150 kg ha^{-1}; potassium sulphate, 200 kg ha^{-1}) and pesticides were used in the conventionally managed vineyards. In the conventionally managed vineyard, plough + disk harrow with two phases as soil tillage was used. In organically managed vineyard, the same tillage was applied but spring tillage was not performed. Instead, planted mulch material was chopped and laid in the row. Then, mulch was incorporated in the soil with moldboard plough to a depth of 20 cm.

Three replicates per treatment were established. Each plot was 86.4 m long and 3 m wide. Vine spacing was 3.3 m between rows and 2.4 m within rows. Surface soil samples (0–20 cm soil depth) were collected four times between 2004 and 2007 (during May month every year). In each vineyard row, 10 soil samples were taken, half of them between rows and the others within rows. Microbiological properties of soils were measured from the fresh samples. Physicochemical properties of soils were determined with the air-dried samples and given in Table 3.

Physicochemical, microbiological and yield analyses

Physicochemical analyses

Soil texture analysis was performed by the hydrometer method (Bouyoucos 1962). Total salt, organic C (C_{org}) and pH were determined according to MacLean (1982), Nelson and Sommers (1982) and Rhoades (1982), respectively. Total N and available P were determined by the Kjeldahl method (Bremner & Mulvaney 1982) and molybdenum blue method (Bingham 1962), respectively. Available K and Ca were measured by flame

Table 1. Carbon, nitrogen and phosphorus inputs from green manure and farmyard manure (mean values for years 2004, 2005, 2006, and 2007).

Treatments	C input (kg ha^{-1})	N input (kg ha^{-1})	P input (kg ha^{-1})
GM	6125 ± 75	585 ± 10	88 ± 7
FYM	4260 ± 70	280 ± 8	74 ± 5

Note: GM, mixture of barley, vetch, and broad bean (25 + 35 + 75 kg seed ha^{-1}); FYM, farmyard manure (15 t ha^{-1}).

Table 2. Contents of carbon, nitrogen, and phosphorus and C/N ratios of green manure and farmyard manure (mean values for years 2004, 2005, 2006, and 2007).

Organic fertilizers	Total C (%)	Total N (%)	Total P (%)	C/N
GM	24.5 ± 0.3	2.34 ± 0.04	0.35 ± 0.03	10.5 ± 0.3
FYM	28.4 ± 0.5	1.89 ± 0.07	0.49 ± 0.02	15.0 ± 0.6

Note: GM, mixture of barley, vetch, and broad bean (25 + 35 + 75 kg seed ha^{-1}); FYM, farmyard manure (15 t ha^{-1}).

Table 3. General soil properties of the experiment field.

Sand (%)	68.40
Loam (%)	24.00
Clay (%)	7.60
Texture	Sandy loam
Soil taxonomy	Typic Xerofluvent
pH (H_20)	7.60
Total salt (%)	0.025
Organic C (%)	0.88
Total N (%)	0.060
P-available (mg kg^{-1})	3.32

photometer after 1 mol l^{-1} $CH_3CO_2NH_4$ neutral extraction (Knudsen et al. 1996). Available Fe, Mn, Cu and Zn in DTPA extracts and Mg in 1 mol l^{-1} $CH_3CO_2NH_4$ extract were detected by atomic absorption spectroscopy (Lindsay & Norwell 1978).

Microbiological analyses

Microbial biomass C (C_{mic}) was determined by the substrate-induced respiration method (Anderson & Domsch 1978). Soil samples (100 g) were amended with glucose (400 mg) and the pattern of respiration response was recorded for 4 h. Values were converted to mg biomass-C by means of a conversion factor. One milligram CO_2 100 g^{-1} dm h^{-1} corresponds to 20.6 mg biomass-C 100 g^{-1}dm (Schinner et al. 1995).

Basal soil respiration (CO_2-C) was measured by the titration method (Isermeyer 1952). Soil samples were incubated in a closed vessel at 25°C for 24 h. The CO_2 produced was absorbed in NaOH and quantified by titration. The metabolic quotient (qCO_2) was calculated as the ratio of soil respiration to microbial biomass C (Anderson & Domsch 1990).

Dehydrogenase activity (DHA) was assayed using the modified method of Thalmann (1968). Soil samples were suspended in a triphenyltetrazolium chloride solution and incubated for 16 h at 25°C. The triphenylformazan (TPF) produced was extracted with acetone and measured photometrically at 546 nm.

β-glucosidase activity (β-GLU) was measured using the method of Hoffmann and Dedekan (1966). After the addition of β-glucosido-saligenin (salicin) as substrate, soil samples were incubated for 3 h at 37°C and saligenin released from the substrate was determined colorimetrically at 578 nm after colouring with 2,6-dibromchinon-4-chlorimide.

Alkaline phosphatases activity (ALKPA) was assayed using the method of Eivazi and Tabatabai (1977). After the addition of a buffered *p*-nitro phenyl phosphate solution (pH: 11), soil samples were incubated for 1 h at 37°C. The *p*-nitro phenol released by phosphomonoesterase activity was extracted and coloured with sodium hydroxide and assigned photometrically at 400 nm.

N-mineralization (N_{min}) was assayed according to the method of Keeney (1982). This method involves the incubation of a sample under waterlogged conditions at 50°C. At the end of 7 days, NH_4-N released from the soil was determined by modified Bertholet reaction.

Yield and quality parameters

Fresh grape yield (kg $vine^{-1}$) was calculated by weighing all the fruit from the vines in each plot and dividing it by the number of vines. Weights (g) of 100 berries were calculated by dividing the total weight by the number of berries collected in each plot by the Amerine and Cruess (1960) method.

Brix (total soluble solid substance) (%) was determined by squeezing the grapes (berries) collected from the vines using the Amerine and Cruess (1960) method and the level of total soluble solids (Brix) was measured in these berries using a hand refractometer. Titratable acidity (g l^{-1}) was assigned by diluting 10 ml of the juice with 10-ml distilled water and titrating it with 0.1 N NaOH, using phenolphthalein as an indicator. The results were expressed as grams of tartaric acid per 1000 ml (Weaver & Winkler 1952).

Statistical analysis

All statistical analyses were carried out with the programme TARIST (Acikgoz et al. 2004). All values are expressed as average values. The significance was tested between treatments for each sampling, as well as between samplings for each treatment to see changes over time and between treatments by the Duncan's test at $p < 0.01$.

Results

Soil microbial biomass C (C_{mic}) and basal soil respiration (CO_2-C) were significantly higher in the organic vineyard soils than in those of the conventional vineyard soils in all years (Table 4). C_{mic} increased with time in organic soils, but it did not change in conventionally managed soils during last 3 years. Higher C_{mic}/C_{org} and lower qCO_2 values were observed in the organically managed than in the conventionally managed soils in organic period (2006 and 2007). Similarly significantly higher amounts of DHA, β-GLU and ALKPA were found in soils under organic than under conventional management in the years of 2006 and 2007. The N_{min} values regularly increased from 2004 to 2007, but significantly higher N_{min} values were determined in organically managed soils than in the conventionally managed soils in organic period (2006 and 2007).

The response of the chemical indicators of soils to the different management systems appeared after a longer time when compared with the biological indicators (Table 5). The amounts of C_{org}, N_t, and available K, Ca, Fe, Cu and Zn were higher in organically managed soils than those in conventional managed in the last year (2007). But the amounts of available P and Mn were higher in the organically managed than in the conventionally managed soils in all the years. The effect of different soil management systems on the yield and some quality parameters of grape was not significant (Table 6).

Discussion

Typically, organic management of vineyards in Turkey involves the incorporation of farmyard and green manures, minimum tillage and use of biofertilizers. These practices strongly affect the microbial activity and biomass in soil. Moreover, the response of these biological indicators to changes in soil management practices can be observed over short time scales. As one of the most important biological indicators of soil, microbial biomass is part of the labile fraction of soil organic matter, functioning both as an agent for cycling organic matter and supplying plant nutrients within the soil (Tripathi et al. 2007). Microbial biomass C (C_{mic}) in the organically managed soils regularly increased during the transition period (2004 and 2005) but stabilized during the last 2 years (organic production period). These findings match those of Castillo and Joergensen (2001) who showed that biomass C is significantly improved by ecological management. Moreover increases in ergoesterol in their study implied a shift in microbial community composition towards fungal components.

Table 4. Biological indicators of organically and conventionally managed vineyard soils during 4 years.

	2004				2005				2006				2007			
Indicators	Organic		Conventional		Organic		Conventional		Organic		Conventional		Organic		Conventional	
C_{mic} (μg g^{-1})	321	aC[a]	205	bB	572	aB	254	bA	663	aA	260	bA	652	aA	261	bA
C_{mic}/C_{org}	0.28	aC	0.25	aB	0.46	aB	0.35	aA	0.51	aAB	0.36	bA	0.62	aA	0.38	bA
CO_2^-C (mg C g^{-1} 24 h^{-1})	38.84	aB	26.24	bA	58.34	aA	33.27	bA	57.68	aA	35.88	bA	55.42	aA	35.54	bA
qCO_2 (mg CO_2^-C g^{-1} C_{mic})	121	aA	128	aA	102	aAB	131	aA	87	bB	138	aA	85	bB	140	aA
DHA (μg TPF g^{-1})	73.0	aC	52.6	aB	102.8	aB	83.1	aA	105.3	aB	40.0	bC	127.3	aA	84.2	bA
β-GLU (μg saligenin g^{-1} $3h^{-1}$)	63.6	aB	57.9	aA	82.4	aA	59.5	aA	95.2	aA	65.1	bA	95.5	aA	57.9	bA
ALKPA (μg p^-NP g^{-1} h^{-1})	412.6	aBC	376.4	aA	445.7	aAB	384.7	aA	476.0	aA	377.6	bA	387.0	aC	296.6	bB
N_{min} (μg NH^{4-}N g^{-1} d^{-1})	4.03	aB	3.10	aB	4.53	aAB	3.82	aAB	4.99	aAB	3.96	bAB	5.38	aA	4.24	bA

[a]Data followed by same lower case letters in the same row (different treatments in each year) and same upper case letters in the same row (different sampling time in each treatment) do not differ by adjusted Duncan's test ($p < 0.01$).

Table 5. Chemical indicators of organically and conventionally managed vineyard soils during 4 years.

Indicators		2004 Organic		2004 Conventional		2005 Organic		2005 Conventional		2006 Organic		2006 Conventional		2007 Organic		2007 Conventional	
	C_{org} (%)	0.85	aB[a]	0.85	aAB	0.95	aB	0.90	aA	1.22	aA	0.87	aA	1.38	aA	0.69	bB
	N_t (%)	0.050	aC	0.045	aA	0.055	aBC	0.048	aA	0.061	aB	0.044	aA	0.117	aA	0.068	bA
Available (μg g^{-1})	PP	4.62	aB	2.95	bB	4.73	aB	3.05	bB	4.84	aB	3.00	bB	5.89	aA	3.65	bA
	KK	145	aC	110	aA	163	aBC	112	aA	201	aAB	114	aA	244	aA	138	bA
	Ca	2026	aB	1975	aB	2045	aB	1970	aB	2070	aB	1960	aB	2520	aA	2143	bA
	Mg	750	aB	745	aB	805	aB	783	aB	845	aAB	827	aAB	1029	aA	1007	aA
	Fe	8.15	aB	8.12	aA	8.18	aB	8.12	aA	8.21	aAB	8.20	aA	9.99	aA	7.98	bA
	Cu	5.06	aC	4.52	aA	5.75	aBC	4.63	aA	6.95	aAB	4.72	aA	8.46	aA	5.75	bA
	Zn	0.64	aC	0.56	aA	0.66	aBC	0.58	aA	0.80	aAB	0.61	aA	0.98	aA	0.68	bA
	Mn	6.52	aC	4.02	bB	7.02	aC	4.65	bB	9.54	aB	4.66	bAB	11.62	aA	5.68	bA

[a]Data followed by same lower case letters in the same row (different treatments in each year) and same upper case letters in the same row (different sampling time in each treatment) do not differ by adjusted Duncan's test ($p < 0.01$).

Table 6. Yield and some quality parameters of organically and conventionally managed vineyards during 4 years.

Parameters	2004 Organic		2004 Conventional		2005 Organic		2005 Conventional		2006 Organic		2006 Conventional		2007 Organic		2007 Conventional	
Fresh grape yield (kg $vine^{-1}$)	9.55	aA[a]	10.00	aB	10.57	aA	11.40	aB	17.07	aA	25.42	aA	10.48	aA	15.0	aAB
Berry weight (g)	132.0	aA	138.6	aA	138.3	aA	146.1	aA	144.6	aA	162.1	aA	107.0	aA	162.1	aA
Brix (%)	22.2	aA	21.5	aA	23.1	aA	22.3	aA	21.5	aA	21.2	aA	22.9	aA	22.4	aA
Titratable acidity (g l^{-1})	5.98	aAB	6.84	aAB	6.31	aA	7.35	aA	5.51	aB	5.65	aC	6.25	aA	6.42	aB

[a]Data followed by same lower case letters in the same row (different treatments in each year) and same upper case letters in the same row (different sampling time in each treatment) do not differ by adjusted Duncan's test ($p < 0.01$).

The relationship between C_{mic} and soil organic carbon can provide important insights into the biological and chemical changes that occur under different management systems. Anderson and Domsch (1989) proposed that the C_{mic}/C_{org} ratio is an indicator of the availability of soil organic matter to microorganisms. The C_{mic}/C_{org} ratio of both management systems was similar during the transition period (2004 and 2005). But, in the following years (2006 and 2007) of the experiment, the C_{mic}/C_{org} ratio of the organically managed soils was significantly higher than that of the conventionally managed soils. This finding is congruous with a greater active carbon pool in the organic vineyard probably because of the introduction of organic material (green manure + farmyard).

The results of this study support the idea that soil respiration can be used to discriminate between different soil management practices (Pankhurst et al. 1995) and showed that soil respiration was greater in organic than conventional management. Higher values for soil respiration in soils under organic management agree with the increase in soil organic matter and soil microbial biomass C. Higher values measured in organically managed soils also indicate that its microbial community consumed more energy.

Another important soil quality indicator is the metabolic quotient, qCO_2. It is considered a measure of physiological stress in the microbial community (Anderson & Domsch 1993) and has been promoted as a specific indicator that discriminates between organic and conventional management (Anderson & Domsch 1993; Mäder et al. 2002). In this study, qCO_2 decreased during the transition to organic and appeared to stabilize during the organic phase of the experiment possibly indicating a new equilibrium. Mäder et al. (1995) suggested that organic soil management better conserves soil organic carbon, as indicated by a higher C_{mic}/C_{org} ratio and lower qCO_2 level, which can also be seen in this study.

Soil enzyme activities are both early and sensitive indicators of different management practices because of their essential role in plant nutrient cycle in soil (Melero et al. 2006). Enzymatic activities were significantly higher in organically than conventionally managed soils during the organic period (2006 and 2007). Organic amendments such as green manures (Melero et al. 2006), composts (Melero et al. 2007), composted poultry manure/green manure combinations (Marinari et al. 2006) and farmyard manure/green manure combinations (Okur et al. 2009) significantly increased the activity of a number of soil enzymes compared with unamended soil. The increase in the enzymatic activity of organically managed soils is likely to be due to the stimulation of microbial activity rather than the direct addition of enzymes from organic sources (Martens et al. 1992). N-mineralization increased by 33% within 4 years in organically managed soils and was 1.3 times greater than in the conventionally management system in the last year of the experiment. High N-mineralization suggested that organic N in mulch material (barley + vetch + broad bean) and soil microbial biomass N easily decomposed and contributed to the ammonium pool of soil. Steenwerth and Belina (2008) determined two to three times higher NH_4-N in vineyards in which cover crops were managed by mowing with residue left on top of the soil than with vineyard treatments in which soils were disked every 2 months.

The content of soil organic carbon (C_{org}) and soil nutrient availability significantly increased in organic production period (2006 and 2007). This result agrees with the findings from several other studies (Bending et al. 2000; Liu et al. 2007). Although C_{org} remained almost the same in the years between 2004 and 2006, it decreased in 2007 under the conventional management system. The increase in C_{org} in organically managed soils can be explained by the high amount of mulch materials left on the field plots complementing the farmyard amendment.

At the end of the trial, the amounts of total organic nitrogen (Nt) and available P in organically managed soils were 1.7- and 1.6-fold greater than in conventionally managed soils, respectively. Similar increases changing between 1.2- and 1.8-fold were also obtained for the other plant nutrients. These results showed that organic management systems using green and farmyard manure can stimulate biological activity related to plant nutrient cycling in soil and thus support soil fertility.

Fresh grape yield and studied quality parameters were not statistically different between conventionally and organically managed vineyards. The yield obtained in the organic farming systems is generally the same or lower than those of conventional farming systems (Martini et al. 2004). Two major factors account for the actual and potential benefits of organic farming: somewhat lower yield and improvements in soil and plant quality that enhance plant health (Benbrook 2009). In conclusion, organic management in vineyards affects microbiological and chemical properties of soil by increasing microbial biomass and enzymatic activity, and available nutrient content. Soil microbiological properties including enzymatic activity proved to be early sensitive indicators of soil quality changes. In the climatic transition zone between continental and Mediterranean of West Turkey, soil quality of organically managed vineyards improved after 2 years of the transition period prescribed for organic certification. But soil quality improvements in organic plots did not result in higher yield. Initially lower yield on organic farms have been attributed to the negative effects of preceding conventional practices on the soil microorganisms that mineralize soil organic matter, or that control soil-borne pests (MacRae et al. 1990). Gradual changes in microbial community structure and improvements in soil quality may eventually increase yield. Another explanation for the lower yields can be the accelerated decomposition of organic amendments under the hot climatic conditions during the growing season, decoupling nutrient supply and plant demand. Longer-term studies with different types and amounts of organic sources will improve knowledge of the effect of organic management on the yield and grape quality.

Acknowledgements

This work was supported by the TAGEM [Grant number 111.05.2.001].

Disclosure statement

No potential conflict of interest was reported by the authors.

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