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THE EFFECTS OF SOIL MANAGEMENT PRACTICES ON SOIL ORGANIC MATTER CHANGES WITHIN A PRODUCTIVE VINEYARD IN THE NITRA VITICULTURE AREA (SLOVAKIA)

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Since understanding soil organic matter (SOM) content and quality is very important, in the present study we evaluated parameters of SOM including: carbon lability (L_C), lability index (LI), carbon pool index (CPI) and carbon management index (CMI) in the soil as well as in the water-stable aggregates (WSA) under different soil management practices in a commercial vineyard (established on Rendzic Leptosol in the Nitra viticulture area, Slovakia). Soil samples were taken in spring during the years 2008–2015 from the following treatments: G (grass, control), T (tillage and intensive cultivation), T+FYM (tillage + farmyard manure), G+NPK3 (grass + 3rd intensity of fertilisation for vineyards), and G+NPK1 (grass + 1st intensity of fertilisation for vineyards). The highest LI values in soil were found for the G+NPK3 and T+FYM fertilised treatments and the lowest for the unfertilised intensively tilled treatments. The CPI in the soil increased as follows: T < G+NPK3 < T+FYM < G+NPK1. The highest accumulation of carbon as well as decomposable organic matter occurred in G+NPK1 compared to other fertilised treatments, while intensive tillage caused a decrease. On average, the values of LI in WSA increased in the sequence G+NPK1 < T+FYM < G+NPK3 < T. Our results showed that the greatest SOM vulnerability to degradation was observed in the WSA under T treatment, and the greatest values of CPI in WSA were detected as a result of fertiliser application in 3rd intensity for vineyards and farmyard manure application.

Key words: index lability, carbon pool index, carbon management index, fertilisation, soil tillage, vineyard

SOM represents a polyfunctional, uneven-aged, multicomponent continuum of destroyed plant residues, root exudates, microbial biomass, biomolecules, and humic substances. It has lifetimes varying from several hours or days through to millennia (Schepaschenko *et al.* 2013; Semenov *et al.* 2013). SOM content in the soils is influenced by several factors, such as climate, clay content and mineralogy and soil management techniques etc. (Stevenson 1982; Lugato & Berti 2008). Organic carbon content in the soil (SOC) is one of the qualitative parameters of the soil humus regime and long has been recognized as a key component of soil quality (Reeves 1997). SOC can be divided into labile and recalcitrant fractions based on the relative susceptibility to biological decomposition (McLauchlan & Hobbie 2004; Belay-Tedla *et al.* 2009). Labile SOC pools such as water-extractable organic C, hot water-soluble organic C, potassium permanganate oxidizable organic C, and organic C fractions of different oxidizability are considered to respond to agricultural management more rapidly than total organic C (Blair *et al.* 1995; Benbi *et al.* 2012). As such labile fractions of SOM are used as sensitive indicators for soil management and land use induced changes in soil quality (Kolář *et al.* 2011; Benbi

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et al. 2015; Shang *et al.* 2016). Small changes in total SOM are difficult to detect because of its high background levels and natural soil variability. For this reason Blair *et al.* (1995) recommended the use of the carbon lability (L_C), lability index (LI), carbon pool index (CPI) and carbon management index (CMI) for the determination of smaller changes and changes over a short time period. These parameters have been rather quickly adopted and used for the evaluation of SOM changes (Szombathová 1999; 2010). However, data about L_C, LI, CMI and CPI in individual size fractions of water-stable aggregates are very rare.

In this study we evaluated the effect of different soil management practices on L_C, LI, CPI and CMI parameters in (i) the soil and (ii) the water-stable aggregates. Finally, we investigated relationships between these parameters within both the soil and water-stable aggregates.

MATERIAL AND METHODS

The study was conducted at Dražovce (48°21'6.16"N; 18°3'37.33"E), a village located near Nitra city in the west of Slovakia. The area (vineyard) is located under the south-west side of the Tribeč Mountain. In the 11th century, the southern slopes of the Zobor hills were deforested and vineyards were planted. Today the locality is used as a horticulture area and for growing wines. The climate is temperate with a mean annual rainfall of 550 mm and the mean annual temperature ≥ 10°C. The soil was classified as Rendzic Leptosol (WRB 2006) with a sandy loam texture developed on limestone and dolomite. Characteristics of the topsoil (0–30 cm) before the experiment in 2000 are presented in Table 1.

Before vineyard establishment the locality was abandoned. In the year 2000, the vines (*Vitis vinifera* L. cv. Chardonnay) had been planted and up to the year 2003 the vineyard was intensively cultivated in and between rows of the vine (mechanical removal of weeds). In 2003, a variety of grasses in following ratio *Lolium perenne* 50% + *Poa pratensis* 20% + *Festuca rubra commutata* 25% + *Trifolium repens* 5% were sown in and between rows of the vine. In the year 2006, the experimentation of different soil management practices in a productive vineyard was initiated. This experimental design had been previously described by Šimanský & Polláková (2014). Briefly, the treatments consisted of (1). G: as a control (in the rows and between vines rows, a mixture of the grass were sown), (2). T: tillage (in autumn tilth to a depth of 25 cm and intensive cultivation between vine rows during the growing season), (3). T+FYM: tillage + farmyard manure (ploughed farmyard manure at a dose of 40 t/ha in autumn 2005, 2009 and 2012), (4). G+NPK3: doses of NPK fertilisers in 3rd intensity for vineyards, this means 120 kg/ha of N, 55 kg/ha of P and 195 kg/ha of K kg/ha (Fecenko & Ložek 2000). The dose of nutrients was divided: 2/3 applied into the soil in the spring (bud burst) and 1/3 at flowering. The grass was sown in and between the vine rows. (5). G+NPK1: doses of NPK fertilisers in 1st intensity for vineyards, this means 80 kg/ha of N, 35 kg/ha of P and 135 kg/ha of K (Fecenko & Ložek 2000). The dose of nutrients was divided: 1/2 applied into the soil in the spring (bud burst) and 1/2 at flowering. The grass was sown in and between the vine rows.

Sampling was done in the spring throughout the years 2008–2015. Soil samples were collected (0–20 cm layer) from 4 random locations within each treatment of different vineyard soil management practices. Soil samples were then mixed together to form an average sample for each treatment. Samples were air-dried. Then, each of the samples was divided and one half of them were sieved through a 2 mm sieve for chemical analyses and the second half of samples were used for the determination of water-stable aggregates (WSA).

Table 1

Characteristics of a Rendzic Leptosol at Nitra-Dražovce in the year 2000

Soil properties	Means and standard deviation
Rock fragments [%]	8±1.6
Clay [g/kg]	101±12
Silt [g/kg]	330±18
Sand [g/kg]	569±23
Organic carbon [g/kg]	17.0±1.6
Base saturation [%]	99.3±0.01
pH (in 1 mol/dm^3 KCl)	7.18±0.08

Seven aggregate-size fractions (>5, 5–3, 3–2, 2–1, 1–0.5, 0.5–0.25 and <0.25 mm) were separated by the wet-sieving of the soil through the series of six sieves using the Baksheev method. The method for aggregate separation was adopted from Vadjunina and Korchagina (1986). In soil samples as well as in size fractions of WSA, the soil organic carbon (C_{org}) and labile carbon (C_L) contents were determined by Tyurin (Dziadowiec & Gonet 1999) and by Loginow (Loginow *et al.* 1987), respectively. On the base of determined C_{org} and C_L we calculated the following parameters of SOM: carbon lability (L_C), lability index (LI), carbon pool index (CPI) and the carbon management index (CMI), as suggested Blair *et al.* (1995). In this research, the control (G) treatment was the reference and different soil management practices (T, T+FYM, G+NPK3 and G+NPK1) were used as treatments.

Analysis of variance for SOM parameters were performed using Statgraphics Centurion XV.I statistical software (Statpoint Technologies, Inc., USA). The difference between the treatments was examined by one-way analysis of variance (ANOVA) and the *LSD* test ($P < 0.05$) was used for means comparison. Correlation analyses were used to assess the relationship between L_C, LI, CPI and CMI in the soil and the same parameters of SOM in individual size fractions of water-stable aggregates.

RESULTS AND DISCUSSION

SOM in soil

The values of carbon lability (L_C) were not affected by soil management practices, however differences between treatments were observed. The content of L_C increased on average in the following order: G+NPK1 = T < G < T+FYM < G+NPK3. We also evaluated the effect of different soil management practices on changes in SOM parameters such as: LI, CPI and CMI, which are used for determination of smaller changes and changes over a short time period (Blair *et al.* 1995; Szombathová 1999; Vieira *et al.* 2007). Higher values of L_C and LI indicated that SOM was rapidly degradable by micro-organisms, otherwise, lower values of LI indicated SOM had greater stability and resistance to microbial degradation. The highest LI values were found for the G+NPK3, T+FYM and G+NPK1 fertilised treatments and the lowest for the unfertilised, intensively tilled treatments (Table 2). Thus, higher doses of mineral fertilisers as well as organic amendment increased the amount of less stable forms of SOM, mainly by FYM addition, as well as by the promotion of root exudates excretion and the amount of grasses' residues, or through the decay of stable SOM due to high doses of NPK application (G+NPK3). Our findings are in agreement with Fröberg *et al.* (2013), Tong *et al.* (2014), who reported the impacts of mineral fertilisers and effect of manure on mineralization of SOM. Generally,

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Analyses of variance of soil organic matter parameters

Parameters	Soil management				
	G	T	T+FYM	G+NPK3	G+NPK1
L_C	0.150^a	0.149^a	0.166^a	0.176^a	0.149^a
LI	–	0.831^a	1.104^b	1.184^b	1.073^{ab}
CPI	–	0.807^a	1.014^b	0.956^b	1.073^b
CMI	–	70.800^a	113.700^b	116.000^b	116.100^b

G – control; T – tillage; T+FYM – tillage+farmyard manure; G+NPK3 – doses of NPK fertilisers in 3rd intensity for vineyards; G+NPK1 – doses of NPK fertilisers in 1st intensity for vineyards
L_C – carbon lability; LI – lability index; CPI – carbon pool index; CMI – carbon management index
Different letters between columns (a, b) indicate that treatment means are significantly different at $P < 0.05$ according to *LSD* multiple-range test

labile SOM is highly susceptible to mineralization. Our results non-significantly confirmed this fact by low value of CPI in G+NPK3 treatment. Conversely, intensive cultivation (T treatment) was responsible for microbial decomposition of SOM, since aeration caused by cultivation stimulated decomposition and the subsequent mineralization of both labile and also later stable forms of SOM (Prasad *et al.* 2016), which resulted in an overall decrease of SOM quantity. Subsequently we found then that the T treatment contained the lowest stock of C_{org} (13.0 g/kg), and also, significantly, the lowest value of CPI (0.807). When we expressed LI from C_{org} (C_{org} varied in different treatments: G = 17.4 g/kg, T = 13.0 g/kg,

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Analysis of variance of organic and labile carbon contents in size fractions of water-stable aggregates

Parameters	Size fraction of water-stable aggregates in mm		Treatments				
			G	T	T+FYM	G+NPK3	G+NPK1
Lc	WSA_{mi}	<0.25	0.147[a]	0.197[b]	0.176[ab]	0.197[b]	0.154[ab]
	WSA_{ma}	0.25–0.5	0.143[a]	0.183[a]	0.177[a]	0.164[a]	0.164[a]
		0.5–1.0	0.140[a]	0.159[a]	0.151[a]	0.176[a]	0.173[a]
		1.0–2.0	0.130[a]	0.192[b]	0.159[a]	0.149[a]	0.130[a]
		2.0–3.0	0.132[a]	0.166[a]	0.150[a]	0.147[a]	0.146[a]
		3.0–5.0	0.139[ab]	0.159[ab]	0.152[ab]	0.168[b]	0.134[a]
		>5.0	0.128[a]	0.169[b]	0.162[ab]	0.162[ab]	0.133[ab]
LI	WSA_{mi}	<0.25	–	1.372[a]	1.232[a]	1.369[a]	1.077[a]
	WSA_{ma}	0.25–0.5	–	1.295[a]	1.262[a]	1.164[a]	1.124[a]
		0.5–1.0	–	1.155[a]	1.099[a]	1.316[a]	1.254[a]
		1.0–2.0	–	1.556[b]	1.293[ab]	1.178[ab]	1.061[a]
		2.0–3.0	–	1.292[a]	1.159[a]	1.147[a]	1.127[a]
		3.0–5.0	–	1.165[ab]	1.110[a]	1.274[b]	0.989[a]
		>5.0	–	1.453[a]	1.354[a]	1.329[a]	1.109[a]
CPI	WSA_{mi}	<0.25	–	0.824[a]	1.038[b]	1.061[b]	1.053[b]
	WSA_{ma}	0.25–0.5	–	0.915[a]	1.165[b]	1.087[ab]	1.098[ab]
		0.5–1.0	–	0.891[a]	1.127[b]	1.017[ab]	1.035[ab]
		1.0–2.0	–	0.955[a]	1.173[b]	1.056[ab]	1.062[ab]
		2.0–3.0	–	1.019[a]	1.209[b]	1.167[ab]	1.094[ab]
		3.0–5.0	–	1.098[a]	1.334[b]	1.191[ab]	1.126[a]
		>5.0	–	1.087[a]	1.439[b]	1.134[a]	1.030[a]
CMI	WSA_{mi}	<0.25	–	117.2[a]	131.9[a]	143.4[a]	112.8[a]
	WSA_{ma}	0.25–0.5	–	119.7[a]	146.6[a]	126.3[a]	118.8[a]
		0.5–1.0	–	99.6[a]	122.8[a]	132.9[a]	122.6[a]
		1.0–2.0	–	146.6[a]	149.7[a]	121.5[a]	119.1[a]
		2.0–3.0	–	122.9[a]	140.9[a]	133.5[a]	117.2[a]
		3.0–5.0	–	131.2[a]	148.7[a]	152.9[a]	109.7[a]
		>5.0	–	171.9[a]	197.5[a]	151.5[a]	117.0[a]

G – control; T – tillage; T+FYM – tillage+farmyard manure; G+NPK3 – doses of NPK fertilisers in 3rd intensity for vineyards; G+NPK1 – doses of NPK fertilisers in 1st intensity for vineyards
L_C – carbon lability; LI – lability index; CPI – carbon pool index; CMI – carbon management index
WSA_{mi} – water-stable micro-aggregates; WSA_{ma} – water-stable macroaggregates
Different letters between columns (a, b) indicate that treatment means are significantly different at $P < 0.05$ according to *LSD* multiple-range test

T+FYM = 17.4 g/kg, G+NPK3 = 16.8 g/kg, in G+NPK1 = 18.4 g/kg), the most intense mineralization was observed in G+NPK3 < T+FYM < T < G+NPK1. Using Blair *et al.* (1995) and Conteh *et al.* (1999) recommendation of the use of CPI for determination of SOM content, we found the lower the CPI value is, the more soil degradation is intensified in terms of reduction of soil organic matter content. Soil CPI increased in the following order: T < G+NPK3 < T+FYM < G+NPK1. However, CPI was lower in T treatment by 18%, 26% and 33% than in G+NPK3, T+FYM and G+NPK1, respectively. We also calculated the values of CMI in the soil to examine the impact of soil management practices. Usually, lower values of CMI indicate more intensive changes in the content of organic matter due to soil management practices and more carbon released from the soil stock (Blair *et al.* 1995). In our study, when considering CMI indices, the most intense change was caused as a result of intensive cultivation. The highest accumulation of carbon as well as decomposable organic matter occurred in G+NPK1 (Table 2), while intensive tillage caused decreases in not only SOM content, but also the percentage of its labile forms, since these were quickly mineralized due to cultivation.

SOM in water-stable aggregates

Soil management practices in the vineyard had a statistically significant influence on L_C in WSA. The largest values of L_C in water-stable micro-aggregates (WSA_{mi}) were found for the T, G+NPK3, then T+FYM and G+NPK1, whilst the smallest influence was seen for the G. The highest statistically significant difference of the L_C in WSA_{mi} was observed between the control and treatment with added fertilisers in 3rd intensity for vineyards as well as tillage treatment. Carbon lability indices in greater sized (water-stable macro-aggregates) WSA_{ma} (> 3mm) copied this trend as was also seen in L_C in WSA_{mi} of the investigated soil treatments. In size fractions of WSA_{ma} 1–2 mm and >5 mm the highest differences were observed between the control and tilled treatment. In all treatments, except G+NPK1, higher values of L_C were determined in WSA_{mi} than WSA_{ma}, which indicated higher proportions of labile carbon were in micro-aggregates. This means that micro-aggregates were more sensitive to the microbial decomposition than macro-aggregates. This is surprising because previous literature reports the opposite finding. Peth *et al.* (2008) and Kögel-Knabner *et al.* (2008) reported that SOM inside of micro-aggregates is more stabile due to better physical protection and physico-chemical protection. On average, the values of LI in WSA increased in the sequence G+NPK1 (1.11±0.08) < T+FYM (1.22±0.10) < G+NPK3 (1.30±0.11) < T (1.33±0.15). The largest differences (statistically significant) were found between treatments T and G+NPK1 in fractions of WSA_{ma} 1–2 mm and between the G+NPK3 and G+NPK1 in fractions of WSA_{ma} 3–5 mm. Lobe *et al.* (2001) reported that the largest content of total carbon (60–90%) is found in small macro-aggregates and that micro-aggregates up to 40% may decrease carbon supply as a result of cultivation compared with meadows. Our results showed that the greatest vulnerability to degradation of organic matter was observed in the micro-aggregates (the greatest Lc and LI values) and also macro-aggregates (the greatest average L_C and LI values) under intense cultivation of vine rows, which indirectly confirmed the findings of Lobe *et al.* (2001). The highest values of the CPI in WSA_{ma} were detected as a result of farmyard manure application (Table 3). The results point to the fact that SOM is degraded not only in the soil but also in the WSA, especially due to intensive soil cultivation, which confirmed findings of several studies (Khorramdel *et al.* 2013; Abdollahi *et al.* 2014), and also as a result of the application of high doses of fertilisers to the soil (Yang *et al.* 2011). Results obtained in this study showed, that the greatest enrichment in C in WSA occurred in the T+FYM treatment, the depletion in C in T treatments, whereas in G+NPK1 and G+NPK3 treatments the values were almost the same. In T treatment, the average CPI in macro-aggregates was lower than 1, what means a decreasing trend of organic carbon. In T treatment in addition to macro-aggregates, the CPI value was not lower than 1 also in micro-aggregates, which means that the microbial decomposition of organic matter occurred at the level of micro-aggregates, which may gradually result in the collapse of soil structure. Moreover, the lability of organic matter (L_C) was the greatest just in T treatment (Table 3), indicating greater susceptibility of organic matter to decomposition. Although organic matter lability

(L_C) means the biodegradability of labile organic matter forms, the cultivation without organic and mineral fertilisers added, considerably accelerated the decrease of C_{org} – when in control treatment C_{org} was 17.4 g/kg, and in T treatment 13.0 g/kg. Generally, labile (active) forms of organic matter are precursors of the stable (passive, slow) forms of SOM. When soil lacks labile organic matter, soil micro-organisms gradually use as a source of nutrients and energy more stable forms of SOM, and the result is a slow, gradual decrease of organic matter in the soil (Brady & Weil 1999). Surprising finding was revealed that the largest changes in stocks of SOM in all soil management practices occurred in WSA_{mi}

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Correlation between SOM parameters in soil and water-stable aggregates

Soil management	SOM parameters in soil	Size fractions of water-stable aggregates						
		>5	5–3	3–2	2–1	1–0.5	0.5–0.25	<0.25
Together		L_C						
	L_C	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		LI						
	LI	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		CPI						
	CPI	0.398$^+$	n.s.	0.379$^+$	n.s.	0.384$^+$	n.s.	0.358$^+$
		CMI						
	CMI	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		L_C						
G	L_C	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
T		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
T+FYM		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
G+NPK3		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
G+NPK1		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		LI						
T	LI	n.s.	n.s.	n.s.	n.s.	n.s.	0.739$^+$	n.s.
T+FYM		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
G+NPK3		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
G+NPK1		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		CPI						
T	CPI	0.806$^+$	0.750$^+$	n.s.	n.s.	n.s.	n.s.	n.s.
T+FYM		n.s.	0.734$^+$	n.s.	n.s.	n.s.	n.s.	n.s.
G+NPK3		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
G+NPK1		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		CMI						
T	CMI	n.s.	n.s.	n.s.	n.s.	0.717$^+$	n.s.	n.s.
T+FYM		0.723$^+$	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
G+NPK3		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
G+NPK1		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

$^+P \leq 0.05$; n.s. – non-significant
G – control; T – tillage; T+FYM – tillage+farmyard manure; G+NPK3 – doses of NPK fertilisers in 3rd intensity for vineyards; G+NPK1 – doses of NPK fertilisers in 1st intensity for vineyards
L_C – carbon lability; LI – lability index; CPI – carbon pool index; CMI – carbon management index

compared to WSA_{ma}. For example, Six *et al.* (2004) reported that macro-aggregates are less stable due to intensive soil cultivation and therefore break-up into micro-aggregates. Thus, significant changes in the carbon content, particularly in the largest fractions WSA_{ma} recorded by Gale *et al.* (2000), are not consistent with our findings (Table 3). In the WSA we also calculated CMI indices depending on the soil management practices in vineyard. Overall, smaller CMI values, indicating minor changes in the content and quality of organic matter due to land management, were recorded more in WSA_{mi} than WSA_{ma} (except G+NPK3). The lowest value of CMI in WSA_{mi} was determined in G+NPK1 and T treatments (Table 3). One-way ANOVA analysis did not confirm significant differences between treatments in contents of WSA_{ma}. The largest accumulation of SOM was detected in the size fraction of WSA_{ma} > 5 mm due to application of farmyard manure and application of fertilisers in 3rd intensity for vineyards, but also due to intensive cultivation of vine rows. In G+NPK1, the highest accumulation of SOM was observed in size fraction of WSA_{ma} 5–3 mm.

Correlations between SOM parameters in soil and in WSA

Correlation coefficients between SOM parameters in soil and in WSA are shown in Table 4. When the L_C and LI values were assessed together regardless of soil management practices, no correlation was recorded. However, the value of LI in soil positively correlated with LI in WSA_{ma} 0.5–0.25 mm, but only under T treatment. This means that intensive cultivation between vine rows can increase the lability of carbon in smaller macro-aggregates. Statistically significant positive correlations were observed between CPI in soil and CPI in WSA (together), and this effect was stronger in size fractions of 5–3 mm, 2–1 mm and 0.5–0.25 mm. As the CPI values were assessed with relation to soil management practices, we detected a positive significant correlation between CPI in soil and CPI in WSA_{ma} in size fractions of >5 mm and 5–3 mm under intensive cultivated rows of vine, and in fractions of 5–3 mm in treatments with ploughed farmyard manure (Table 4). Statistically significant positive correlation was observed between CMI in soil and CMI in WSA_{ma} 1–0.5 mm, if the CMI values were assessed together, regardless of soil management practices in the vineyard. Evaluating CMI values in relation to soil management practices, we only detected positive significant correlation between CMI in soil and CMI in WSA_{ma} in size fractions of 1–0.5 mm under T treatment and > 5mm in T+FYM treatment (Table 4).

CONCLUSIONS

This study indicates that the highest accumulation of carbon, as well decomposable organic matter in soil, occurred in treatments with the application of fertilisers in 1-st intensity for vineyards compared other fertilised treatment, while intensive tillage caused the decrease not only of total SOM content, but also its labile forms, which were quickly mineralized due to cultivation. Similarly, the greatest vulnerability of organic matter to degradation was observed in the WSA under T treatment, however, the highest accumulation of SOM in WSA were detected as a result of farmyard manure application. Results further showed that between CPI in soil and WSA there were significant relationships if all soil management practices were assessed together. When soil management practices in a vineyard have been assessed separately, there were clear relationships between CPI in soil and higher size fraction of water-stable macro-aggregates.

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