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The decomposition of standardised organic materials in loam and clay loam arable soils during a non-vegetation period

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Abstract: The decomposition of plant organic materials in the soil during the non-vegetation period in a cool temperate climate is associated with nutrient loss and asynchrony in nutrient supply for subsequent crops. Therefore, it is important to select sustainable management tools to regulate the decomposition rate of organic material during the non-vegetation period. The aim of the present study was to assess the influence of soil type (loam vs. clay loam), green manuring (wheat straw vs. wheat straw + red clover), and incorporation depth of organic materials (4–7 vs. 14–17 cm) on mass loss, decomposition rate and stabilization of standardised organic material in the organically managed arable soils. A Tea Bag Index method was used in the field experiments with standardised organic plant materials of green and rooibos tea. In addition, litter-bags of locally grown red clover were investigated. The findings of this study suggested that of the three management factors investigated soil type had a significant and longest effect. The mass loss and decomposition rate of the standardised organic materials were significantly ($P < 0.5$) higher and stabilization significantly lower in the loam soil than in the clay loam soil. During the non-vegetation period, green tea lost 46.3% of its initial mass, rooibos tea lost 19.7% and red clover lost 66%. The study showed that decomposition of fast-decomposing materials could be slowed down during the non-vegetation period by choosing soils with a higher clay content, shallow organic material incorporation depth and manuring soil with N-rich plant residues.

Keywords: organic agriculture; red clover; soil texture; tea bag index (TBI); tea bag method

Decomposition is the fundamental biological process, where organic material is decomposed to its mineral components and partly transformed into enduring humus forms. The rate of plant material decomposition is one of the main factors that qualifies the sustainability of nutrient cycles in agricultural ecosystems, especially in organic farming. Research studies have reported the rate of plant material decomposition in different biomes; however, most of them focus on natural ecosystems (Cleveland et al. 2014; Alsafran et al. 2017; Gao et al. 2019) and those in agricultural systems focus on a yearly basis (Cornwell

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et al. 2008; Kriauciuniene et al. 2012; Didion et al. 2016) or only on crop growing season (Buchholz et al. 2017; Helsen et al. 2018; Mueller et al. 2018) and often are done in greenhouse and pot experiments (Frøseth & Bleken 2014; Van Hoesel et al. 2015). As a result, it is important to study the decomposition of organic material during the non-vegetation period in an agricultural ecosystem.

Temperate biome in Europe is characterised by seasonal vegetation and during the cool season crop cultivation is limited by low temperatures and short daylight. Incorporation of green matter into the soil, instead of its removal after the crop growing period, has been suggested as one of the options to increase soil organic carbon (SOC) stocks (Liu et al. 2015), but this could lead to nutrient loss due to leaching (Masauskas et al. 2006) and gas emissions from the soil maintained without a cover. Therefore, it is important to investigate the time and potential rate of decomposition, because organic material has potential to enhance nutrient loss during the non-vegetation period, which lasts for 4–5 months.

On a global scale, the variability of decomposition rates among biomes depends on the regional climate and litter quality (Parton et al. 2007; Cornwell et al. 2008; Zhang et al. 2008; Cleveland et al. 2014). However, climate sets similar conditions for organic matter decomposition within biomes (Parton et al. 2007; Zhang et al. 2008 Alsafran et al. 2017). Decomposition rate of plant litter in a specific location is determined by environmental factors such as temperature (Raich et al. 2006; Mikola et al. 2018) and precipitation (Salamanca et al. 2003; Vilkiene et al. 2016), biological factors such as composition of the decomposer organisms (Cleveland et al. 2014; Gao et al. 2019) and physicochemical factors such as soil texture and fertility (Zhang et al. 2008; Miatto & Batalha 2016;), as well as C : N, labile and recalcitrant fractions of litter (Køgel-Knabner 2002; Kriauciuniene et al. 2012; Keuskamp et al. 2013).

The pronounced variation within biome among arable sites can be due to different management tools, contributing to soil fertility, carbon and nutrient content, physical features of the litter (Cornwell et al. 2008; Bradford et al. 2016). A significant correlation was found between soil clay content and decomposition rate (Poeplau et al. 2015). Some research suggests that various soil types, characterised by different texture and chemical composition, significantly differ in decomposition rates (Buchholz et al. 2017; Toth et al. 2017, 2018). But there is no consensus among researchers on the quantitative effect of soil type and texture on decomposition.

To conduct a quantitative and qualitative investigation of the decomposition of organic matter in specific sites and soils, the Tea Bag Index (TBI) method was developed by Keuskamp et al. (2013). This approach uses a standardised plant matter – fast-decomposing green tea and more recalcitrant rooibos tea, as representative organic material to measure decomposition and stabilization rates at the local, regional or global scales. The method facilitates data comparison between biomes, ecosystems and fields (Didion et al. 2016; Alsafran et al. 2017; Helsen et al. 2018). Its application alongside field decomposition experiments enables global comparison of decomposition efficiency in different soil types (Buchholz et al. 2017).

The objective of this study was to assess and compare the decomposition rates of the standardised organic materials during the non-vegetation period in a cool temperate climate biome as influenced by soil type, incorporation depth and green manuring.

MATERIAL AND METHODS

Experimental site and conditions. Field experiments were conducted during the non-vegetation seasons of 2015 and 2016 at the Lithuanian Institute of Agriculture in two locations of Lithuania – SiteL (55°23'49''N, 23°51'40''E) on a loam soil and SiteCL (56°03'69''N, 24°16'44''E) on a clay loam soil (Table 1). The soil horizons of the experimental sites were defined as O-Ap-E-Bt-B-Ck in SiteL (Žydelis et al. 2018) and O-Ahp-AEl-Btk-Btkg-2Ckg in SiteCL (Volungevičius et al. 2018). In the upper soil layer 0–10 cm, the concentrations of mobile humus substances (MHS) and mobile humic acids (MHA) were 0.294% and 0.138% in SiteL and 0.186% and 0.076% in SiteCL, respectively. In the lower soil layer 10–25 cm, the concentrations of MHS and MHA were 0.288% and 0.155% in SiteL and 0.197% and 0.0.082% in SiteCL, respectively. The colony-forming units (CFUs) of soil microorganisms in appropriate dilutions of the samples with soil bacteria were determined on Plate Count Agar (Oxoid, Thermo Scientific) at the beginning of the experiment. The CFUs in the soil varied in a range of 6.9–7.1 × 10^6 cfu/g in SiteL and in a range of 11.5–13.7 × 10^6 cfu/g in SiteCL. The experiments were conducted in a temperate climate zone, where the growing season lasts for 169–202 days. The non-vegetation period starts in October–December and

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Table 1. The main characteristics of the experimental soils at the 0–25 cm depth

Experimental site	Soil texture (%)		Soil type (WRB 2014)	Soil chemical composition				
				pH	humus content (%)	N_{tot} (mg/kg)	P_2O_5 (mg/kg)	K_2O (mg/kg)
SiteL	clay silt sand	19.3 28.9 51.8	Loam; Endocalcaric Epigleyic Cambisol (Drainic, Loamic) *CM-can.glp-dr.lo*	7.5	2.7	117	51	68
SiteCL	clay silt sand	28.5 50.9 18.8	Clay loam; Endocalcaric Endogleyic Cambisol (Clayic, Drainic) *CM-can.gln-dr.cl*	6.4	2.3	185	68	74

SiteL – site with loam soil; SiteCL – site with clay loam soil

lasts until March–May, depending on the weather conditions and development of crop species. The mean annual air temperature is 6.5 °C, the sum of active temperatures (ΣT > 10 °C) is 2 100–2 200 °C, and the annual precipitation is 500–600 mm. In 2015 and 2016, the average temperature of the non-vegetation period was higher than the long term average of 1980–2010, with no significant shortage of moisture (Figure 1).

Experimental design and methods. The effects of three factors on the decomposition rate were studied in this research: (*i*) two types of soil – loam and clay loam, (*ii*) two depths of organic material incorporation – 4–7 and 14–17 cm, (*iii*) two types of green manuring – wheat straw (WS) and wheat straw supplemented with red clover (WS + RC). Decomposition rate was measured by using the standard Tea Bag Index method (Keuskamp et al. 2013). The method involved two types of commercially available teas – green tea consisting of 89% green tea, and rooibos tea consisting of 93% rooibos incorporated into the soil. Green tea had 12.2 C : N ratio, 4.0% N, 0.49 g/g of water soluble fraction, 0.84 g/g of hydrolysable fraction and weighed 2.019 ± 0.026 g. Rooibos tea had 42.9 C : N ratio, 1.1% N, 0.22 g/g of water soluble fraction, 0.55 g/g of hydrolysable fraction and weighed 2.152 ± 0.013 g. The tea was packed in tetrahedron-shaped synthetic (polypropylene) tea bags with a mesh size of 0.25 mm. Green and rooibos tea bags were buried in 5 replications in each plot. The bags were recovered after 30, 60, 90 and 120 days. Adherent soil was removed and tea bags were dried at 60 °C in a stove for 48 h. The initial and final mass of each tea bag was measured. In order to take into account the error due to soil in the teabag, the content of each bag was ignited for four hours at 600 °C. The content of ash was measured in the tea before decomposition and after it. The decomposed

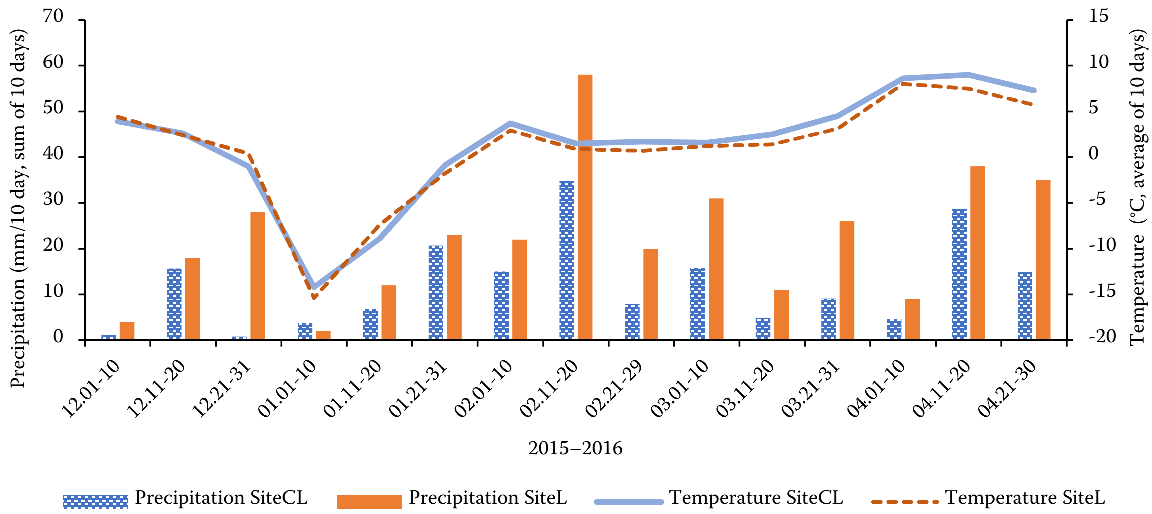

Figure 1. Meteorological conditions during the non-vegetation period in the experimental sites in 2015 and 2016
SiteL – site with loam soil; SiteCL – site with clay loam soil

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weight of tea was adjusted according to the initial and final weight of ashes.

Data calculations and analysis. The Tea Bag Index, consisting of two parameters, decomposition rate (k) and litter stabilization factor (s), was calculated. After measuring the initial and final mass of each bag, the decomposition rate constant (k) was calculated using a modified version (Keuskamp et al. 2013) of the classical decomposition equation of Wieder and Lang (1982):

$$W(t) = ae^{-kt} + (1 - a) \quad (1)$$

where:

$W(t)$ – the mass of the substrate after incubation time t;
a – the labile (hydrolysable);
$1 - a$ – the recalcitrant fraction of the litter.

k from Equation (1) is calculated as: $k = \ln (a_r/(W(t) - (1 - a_r))/t)$. $W(t)$ is calculated as the proportion of final and initial mass of rooibos tea after incubation time t.

The decomposable fraction of rooibos tea (a_r) is calculated from the hydrolysable fraction of rooibos tea (H_r) and the stabilization factor s:

$$a_r = H_r(1 - s) \quad (2)$$

The stabilization factor s is calculated from a_g which is the decomposable fraction of green tea and H_g – which is the hydrolysable fraction of green tea:

$$s = 1 - a_g/H_g \quad (3)$$

Decomposable fraction of green tea was calculated as the proportion of initial and remaining weight of tea after 90 days' incubation period.

The mean temperature and precipitation data were obtained from the weather stations situated in close vicinity to the incubation sites. The soil chemical composition was determined by the following methods: C_{tot} (g/kg) – Diameter method (automatic Vario EL Analyzer; Elementar Analysensysteme, Germany); N_{tot} (g/kg) – Kjeldahl method using a final photometric determination (UV/Vis Cary 50 Conc; Varian Inc., USA); P_{tot} (g/kg) – final photometric determination (UV/Vis Cary 50 Conc; Varian Inc., USA); and K_{tot} (g/kg) – atomic absorption method (ANALYST 200 atomic absorption spectrophotometer; Perkin Elmer, USA).

Statistical analysis was performed using the SAS software (Ver. 9.4). A combined analysis of the interactions of factors was performed. Means for significant effects were separated using Duncan's multiple range tests at the 5% probability level ($P < 0.05$).

RESULTS AND DISCUSSION

Decomposition of the two types of standardised materials. The standardised organic material – green and rooibos tea decomposed differently in loam soil in the non-vegetation period. Decomposition of these materials differed in time, depending on the management factors – green manuring type and depth of tea incorporation (Figure 2). According to the results, the mass of the organic matter degraded the fastest within the first 30 days. Mass loss of green tea ranged from 18.5% to 25.3%, while mass loss of rooibos tea was 4.7–6.7%. After 120 days' long non-vegetation period, when the soil was not disturbed mechanically, green tea lost about 46.3% of its mass, while rooibos lost 19.7%. The proportion of non-soluble compounds and C : N ratio are the main factors which define decomposition rate of different organic materials in the soil (Didion et al. 2016). Readily degradable labile fractions of organic compounds in plant material start to decompose first. Green tea has 0.493 g/g of water soluble fractions and 0.842 g/g of hydrolysable fractions of initial weight, while rooibos tea – 0.215 and 0.552 g/g, respectively (Keuskamp et al. 2013). Opheusden et al. (2012) indicate that organic matter with a high C : N ratio and high mineralization rate leads to a significant increase in mineral N content in the soil over the course of the year. During the non-vegetation period the process of N release is difficult to control (Gaudin et al. 2013; Frøseth & Bleken 2014), therefore specific management of organic materials should be used to prevent N losses and to synchronise the nutrient supply (Tripolskaja & Šidlauskas 2010; De Notaris et al. 2018). The use of organic material with medium or low mineralization inhibits immobilisation (Chatterjee & Acharya 2019) and elongates organic matter mineralisation over time (Opheusden et al. 2012).

Timing of effect. The results showed that decomposition of rooibos tea was significantly affected only within the first 30 days' period by both management tools, green manuring and incorporation depth, because of low mass loss, induced by small amount of labile fraction and woody texture (Figure 2). Green tea mass loss responded more sensitively to the management tools than rooibos and was coherent with faster decomposition. Decomposition of more labile green tea was affected by soil type, green manuring

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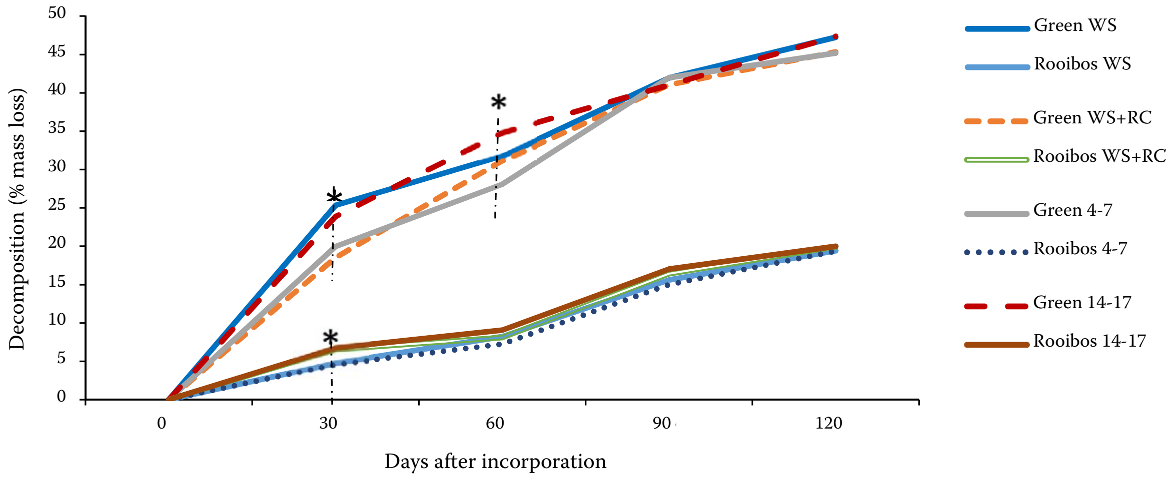

Figure 2. The effect of management factors on the decomposition of standardised organic materials, green and rooibos tea, (% mass loss) during 120 days of non-vegetation period in loam soil

Green – green tea material; Rooibos – rooibos tea material; WS – wheat straw incorporated after vegetation period; WS + RC – wheat straw and red clover mass mixture incorporated after vegetation period; 4–7 – tea incorporated at 4–7 cm depth; 14–17 – tea incorporated at 14–17 cm depth; *significant at $P = 0.05$

and incorporation depth, but the effect was uneven in all 120 days of non-vegetation period (Table 2). The effect of soil type was significant ($P < 0.05$) for three months, depth of tea incorporation for two months, the type of green manure for one month. During the first month, the interaction between soil type and green manure, also between green manure and tea incorporation depth was observed. During the 60 days' period, the interaction only between green manuring and incorporation depth was determined.

In high latitudes, the period of potential greatest risk of N loss occurs during a non-vegetation period following a legume plough down or crop harvest (Jensen 1994). It was shown that incorporation of fast-decomposing materials in the autumn is related with N losses during the so called „asynchrony window" (Tripolskaja & Šidlauskas 2010; Valkama et al. 2015; De Notaris et al. 2018) Other researchers suggest that the time of decomposition could be manipulated and reduced for fast-decomposing materials, while preserving more of the nutrients in the matter until crop growing period (Sorensen & Thorup-Kristensen 2011; Brock et al. 2013; Möller 2018).

Table 2. Significant effects of soil type, green manure, incorporation depth and their interaction on the decomposition of green tea material

Treatments	Period of decomposition (days)			
	30	60	90	120
Soil type (S)	*	*	*	ns
Green manure (M)	**	ns	ns	ns
Depth (D)	**	**	ns	ns
S × M	**	ns	ns	ns
S × D	ns	ns	ns	ns
M × D	*	**	ns	ns
S × M × D	ns	ns	ns	ns

*, **significant at $P = 0.05$, 0.01 level; ns – not significant

Effect of site, manure and depth. The decomposed mass of green tea was 9% lower in the loam soil than in the clay loam soil only in the first month, under the interaction with WS and WS + RC manure types (Table 3). However, when the weather conditions got colder and wetter, lost mass was 10% and 9% higher in differently fertilized loam soil than in clay loam during 60 and 90 days' periods, respectively. The soil texture was often observed to affect decomposition process of organic materials in different ecosystems (Froseth & Bleken 2014). Sandy, loam and clay soils differ by physical protection of organic material leading to higher degree of decomposition in sandy soils and decreasing with clay content in the soil (Hassink et al. 1993).

Also, we expected that WS + RC will increase the decomposition rate of tea because of favourable conditions and therefore increased functional diversity of the decomposers. Previous researches demonstrated that N, P, K and micronutrients enhance plant litter decomposition in soils with multiple nutrient limita-

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tions (Kaspari et al. 2008). However, WS promoted decomposition more than WS + RC under the interaction of both soils and incorporation depths in the first month. In agreement with our results, Toth et al. (2017) have reported no significant effect of agricultural management practices on decomposition rate among 149 arable sites throughout Hungary. Contrarily, in the tropical forest ecosystem it was shown that in the soil covered with litter of higher nitrogen concentration, a lower decomposition rate occurs (Miatto & Batalha 2016).

Decomposition rate and stabilization. The decomposition rate (k) and stabilization (s) were calculated after 90 days of rooibos and green tea incorporation in the soil (Table 4). Significant differences were found in the decomposition rate of green tea matter ($P < 0.05$) and rooibos tea matter ($P < 0.01$) between the two experimental sites. Green manure type or tea incorporation depth did not affect mass losses of both teas and therefore did not impact on decomposition rate and stabilization of organic matter in the soil. In addition, no significant interactions were observed.

The decomposition rate significantly ranged from 0.008 6 in loam soil to 0.010 9 in clay loam soil (Figure 3). The opposite was observed for stabilization; in loam soil it was 0.509, while in clay loam it was 0.548. Higher organic matter mass loss is related to lower stabilization values and higher decomposition rate values. Increased decomposition, associated with lesser residue physical protection, decreases soil organic matter (OM) stabilization (Shahbaz et al. 2017). The differences in OM stabilization value in the soil could be conceptually explained by three processes – (1) selective preservation of recalcitrant compounds, (2) spatial inaccessibility to decomposer organisms, and (3) interactions of OM with minerals and metal ions (Lützow et al. 2008). Spatial inaccessibility is more abundant in clay loam soil than in loam soil due to the occlusion of OM in clay microstructures and due to the formation of hydrophobic surfaces stabilizing OM in the passive pool (Lützow et al. 2008). Hydrophobicity is particularly more relevant in a slightly acid clay loam soil than in a slightly alkaline loam soil in our investigated sites. In addition, long-term experiments in Sweden showed that humification coefficient for straw and thus the stabilization of straw-derived carbon increases significantly with clay content in the soil (Poeplau et al. 2015).

Stabilization of organic matter was insignificantly higher in the soil fertilized with WS, compared with WS + RC, decomposition rates in these treatments were similar (Figure 3). Mueller et al. (2018) documented that nutrient enrichment can decrease s by 72% when usual s values are high without fertilizing, but does not reduce s in the systems where it is already relatively low. In contrast, decomposition rate was not responsive to the nutrient enrichment. However, these trends are more likely to occur in N limited sites, where N addition stimulates early OM decomposition and thus reduces stabilization.

Table 3. Decomposition (mass loss %) of green tea as affected by soil type, green manuring, tea incorporation depth and their interaction during 120 days of non-vegetation period

Treatments	Period of decomposition (days)			
	30	60	90	120
Soil type (S)				
SiteL	21.91^b	31.46^a	41.49^a	46.28
SiteCL	24.10^a	28.02^b	37.83^b	46.71
Manuring (M)				
WS	24.98^a	31.19	38.59	46.68
WS + RC	21.03^b	28.29	40.4	46.31
Depth (D)				
4–7	21.57^a	26.72^b	40.48	45.62
14–17	24.44^b	32.76^a	38.84	47.37
S × M				
SiteL + WS	25.31^b	31.78	41.95	47.23
SiteL + WS + RC	18.50^a	31.15	41.04	45.33
SiteCL + WS	24.65^b	30.61	35.22	46.14
SiteCL + WS + RC	23.55^b	25.43	40.43	47.28
S × D				
SiteL + 4–7	19.95	28.09	41.98	45.19
SiteL + 14–17	23.86	34.84	41.01	47.36
SiteCL + 4–7	23.18	25.35	38.99	46.04
SiteCL + 14–17	25.02	30.69	36.67	47.38
M × D				
WS + 4–7	24.88^b	30.91^b	39.98	44.74
WS + 14-17	25.08^b	31.48^b	37.19	48.63
WS+RC + 4-7	18.25^a	22.54^a	40.98	46.50
WS+RC + 14-17	23.81^b	34.04^b	40.49	46.11
Critical range	1.77	3.33	3.54	2.90

WS – wheat straw incorporated after vegetation period; WS + RC – wheat straw and red clover mass mixture incorporated after vegetation period; 4–7 – tea incorporated at 4–7 cm depth; 14–17 – tea incorporated at 14–17 cm depth; SiteL – site with loam soil; SiteCL – site with clay loam soil; ^{a,b}significant differences at $P = 0.05$

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Table 4. Significant effects of soil type, manure, tea incorporation depth and their interactions on the mass loss of green and rooibos tea, decomposition rate and stabilization, after standardised 90 days' long non-vegetation period

Significance	Mass loss of green tea	Stabilisation	Mass loss of rooibos tea	Decomposition rate
Soil type (S)	*	*	**	*
Manure (M)	ns	ns	ns	ns
Depth (D)	ns	ns	ns	ns
S × M	ns	ns	ns	ns
S × D	ns	ns	ns	ns
M × D	ns	ns	ns	ns
S × M × D	ns	ns	ns	ns

*,**significant at $P = 0.05$, 0.01 level; ns – not significant

In our organically managed sites, where organic material is not limited, stabilization differs but not significantly and no differences were observed for decomposition rate.

Furthermore, management affects the key stabilization mechanisms. The importance of organo-mineral interactions for OM stabilization in the passive pool is well-known and increases with soil depth (Lützow et al. 2008). In the horizons with high microbial activity and C turnover, organo-mineral interactions can contribute to OM stabilization in the intermediate pool. This was demonstrated in our research, where higher stabilization and decomposition rate values were observed at 14–17 cm depth than in the upper layer of 4–7 cm. Nevertheless, decomposition environment did not change sufficiently in these depths to cause significant differences among decomposition rates or stabilization.

Decomposition of red clover. Although tea bag materials are not native to cold temperate climate agroecosystems, they could be compared with local organic materials with similar fractional content. One of the most popular plants, which is ploughed down in the autumn to enhance soil fertility is red clover (Sarunaite et al. 2013; McKenna et al. 2018). Organic matter quality explains up to 64% of the variation in decomposition rates (Cleveland et al. 2014). Red clover green manure has higher amount of labile fractions, similar as green tea, and also a C : N ratio of 15, while green tea – 12, rooibos – 43.

In the same experimental sites we buried litter-bags of red clover and the results were similar to those of

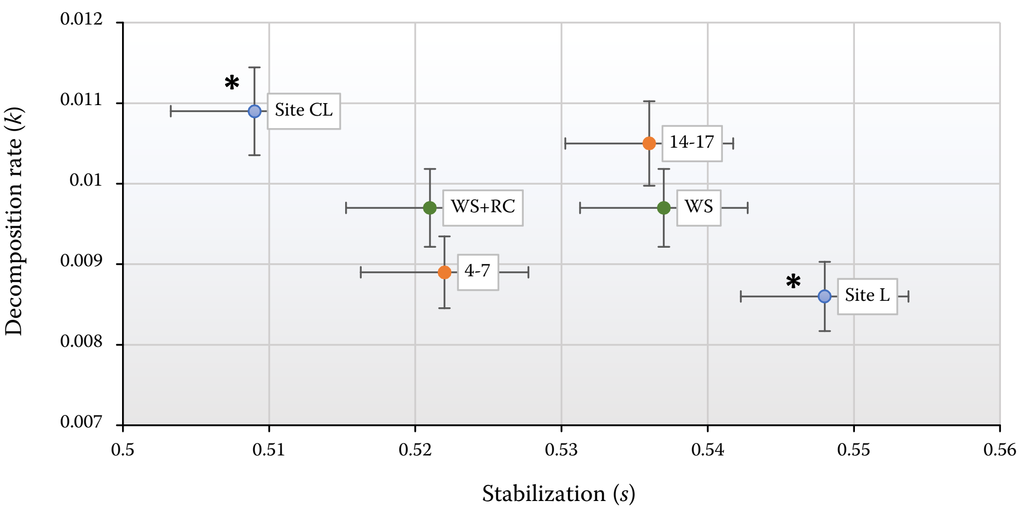

Figure 3. The effect of management factors on the decomposition rate and stabilization of organic materials after standardised 90 days' long non-vegetation period

WS – wheat straw incorporated after vegetation period; WS + RC – wheat straw and red clover mass mixture incorporated after vegetation period; 4–7 – tea incorporated at 4–7 cm depth; 14–17 – tea incorporated at 14–17 cm depth; *significant at $P = 0.05$

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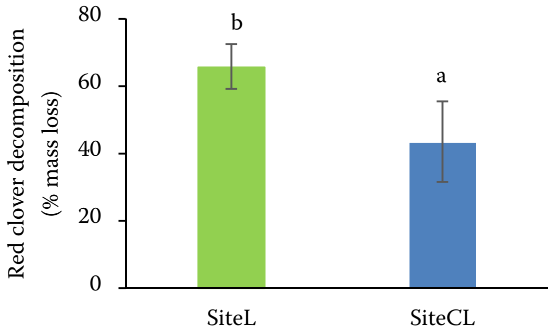

Chemical composition of red clover mass (kg/t DM)				
C	N	P	K	C : N : P : K
520	33.4	2.6	28.6	15 : 200 : 18

Figure 4. The decomposition of red clover material in loam and clay loam soils during non-vegetation period

tea bags. Red clover lost 65.6% of its initial mass in the loam soil, while in the clay loam soil only 43.2% (Figure 4). Red clover decomposed faster in the loam soil than in the clay loam during the non-vegetation period in the cold temperate biome in Europe. In agreement with our results, Frøseth and Bleken (2014) showed that decomposition of red clover leaves was 22–24% higher in the sandy soil than in the clay soil of Norway. The same research found that low temperatures of non-vegetation period 0–4 °C maintain the same decomposition patterns as in 8.5–15 °C. For a large proportion of the non-vegetation period, green tea and red clover mass reached its stable, further slowly degradable value, while the labile fraction of rooibos tea was still actively decomposing (Didion et al. 2016). During the non-vegetation period, fresh red clover mass lost high amount (65.6%) of DM of its initial mass and 37.6 kg/ha of nitrogen. This led to 90% increased mineral N amounts in the soil deeper layer of 30–60 cm, indicating the leaching process in this treatment. However, our study showed that decomposition rate could be reduced by incorporating the matter in a shallow layer (4–7 cm) compared with 14–17 cm, stabilization could be reduced by using high C : N green manure. Decomposition rate also depends on soil type and significantly decreases with higher clay content.

CONCLUSIONS

During the non-vegetation period in the cool temperate climate, faster-decomposing standardised green tea material lost 46.3%, woody rooibos tea 19.7%, locally prevalent red clover 66% of their initial mass. The decomposition depended on the chemical composition, amount of hydrolysable compounds and C : N ratio of the organic material. The mass loss and decomposition rate of the standardised organic materials were significantly higher, the stabilization significantly lower in the loam soil than in the clay loam soil. Faster-decomposing green tea material responded more sensitively to the management tools during the different periods of decomposition. Our study showed that decomposition rate of fast-decomposing material could be reduced by incorporating it in a shallow layer (4–7 cm), by using green manures with a low C : N ratio and by choosing soils with higher clay content. Significant effect of green manuring on organic matter decomposition lasted for 30 days, of incorporation depth for 60 days and of soil type for 90 days.

REFERENCES

Alsafran M.H.S.A., Sarneel J., Alatalo J.M. (2017): Variation in plant litter decomposition rates across extreme dry environments in Qatar. The Arab World Geographer, 20: 252–260.

Bradford M.A., Berg B., Maynard D.S., Wieder W.R., Wood S.A. (2016): Understanding the dominant controls on litter decomposition. Journal of Ecology, 104: 229–238.

Brock C., Franko U., Oberholzer H.-R., Kuka K., Leithold G., Kolbe H., Reinhold J. (2013): Humus balancing in Central Europe concepts, state of the art, and perspectives. Review article. Journal of Plant Nutrition and Soil Science, 176: 3–11.

Buchholz J., Querner P., Paredes D., Bauer T., Strauss P., Guernion M., Scimia J., Cluzeau D., Burel F., Kratschmer S., Winter S., Potthoff M., Zaller J.G. (2017). Soil biota in vineyards are more influenced by plants and soil quality than by tillage intensity or the surrounding landscape. Scientific Reports, 7: 1–12.

Chatterjee A., Acharya U. (2019): Controls of carbon and nitrogen releases during crops' residue decomposition in the Red River Valley, USA. Archives of Agronomy and Soil Science, doi.org/10.1080/03650340.2019.1630732

Cleveland C.C., Reed S.C., Keller A.B., Nemergut D.R., O'Neill S.P., Ostertag R., Vitousek P.M. (2014): Litter quality versus soil microbial community controls over decomposition: a quantitative analysis. Ecosystem Ecology, 174: 283–294.

Cornwell W.K., Cornelissen J.H.C., Amatangelo K., Dorrepaal E., Eviner V.T., Godoy O. (2008): Plant species traits are the predominant control on litter decomposi-

https://doi.org/10.17221/31/2019-SWR

tion rates within biomes worldwide. Ecology Letters, 11: 1065–1071.

De Notaris C., Rasmussen J., Sørensen P., Olesen J.E. (2018): Nitrogen leaching: a crop rotation perspective on the effect of N surplus, field management and use of catch crops. Agriculture, Ecosystems and Environment, 255: 1–11.

Didion M., Repo A., Liski J., Forsius M., Bierbaumer M., Djukic I. (2016): Towards harmonizing leaf litter decomposition studies using standard tea bags – a field study and model application. Forests, 7: 1–12.

Frøseth R.B., Bleken M.A. (2014): Effect of low temperature and soil type on the decomposition rate of soil organic carbon and clover leaves, and related priming effect. Soil Biology and Biochemistry, 80: 156–166.

Gaudin A.C.M., Westra S., Loucks C.E.S., Janovicek K., Martin R.C., Deen W. (2013): Improving resilience of northern field crop systems using inter-seeded red clover: a review. Agronomy, 3: 148–180.

Gao J., Han H., Kang F. (2019): Factors controlling decomposition rates of needle litter across a chronosequence of Chinese pine (*Pinus tabuliformis* Carr.) forests. Polish Journal of Environmental Studies, 28: 91–102.

Hassink J., Bouwman L.A., Zwart K.B., Bloem J., Brussaard L. (1993): Relationships between soil texture, physical protection of organic matter, soil biota, and C and N mineralization in grassland soils. Geoderma, 57: 105–128.

Helsen K., Smith S.W., Brunet J., Cousins S.A.O., Frenne P.D., Kimberley A., Kolb A., Lenoir J., Ma S., Michaelis J., Plue J., Verheyen K., Speed J.D.M., Graae B.J. (2018): Impact of an invasive alien plant on litter decomposition along a latitudinal gradient. Ecosphere, 9: 1–15.

Jensen E.S. (1994): Mineralization-immobilization of nitrogen in soil amended with low C:N ratio plant residues with different particle sizes. Soil Biology and Biochemistry, 26: 519–521.

Kaspari M., Garcia M.N., Harms K.E., Santana M., Wright S.J., Yavitt J.B. (2008). Multiple nutrients limit litterfall and decomposition in a tropical forest. Ecology Letters, 11: 35–43.

Keuskamp J.A., Dingemans B.J.J., Lehtinen T., Sarneel J.M., Hefting M.M. (2013): Tea Bag Index: a novel approach to collect uniform decomposition data across ecosystems. Methods in Ecology and Evolution, 4: 1070–1075.

Køgel-Knabner I. (2002): The macromolecular organic composition of plant and microbial residues as inputs to soil organic matter. Soil Biology & Biochemistry, 34: 139–162.

Kriauciuniene Z., Velicka R., Raudonius S. (2012): The influence of crop residues type on their decomposition rate in the soil: a litterbag study. Zemdirbyste (Agriculture), 99: 227–236.

Liu G., Cornwell W.K., Pan X., Ye D., Liu F., Huang Z., Dong M., Cornelissen J.H. (2015): Decomposition of 51 semidesert species from wide ranging phylogeny is faster in standing and sand-buried than in surface leaf litters: implications for carbon and nutrient dynamics. Plant and Soil, 396: 175–187.

Lützow M., Køgel-Knabner I., Ludwig B., Matzner E., Flessa H., Ekschmitt K., Guggenberger G., Marschner B., Kalbitz K. (2008): Stabilization mechanisms of organic matter in four temperate soils: Development and application of a conceptual model. Journal of Plant Nutrition of Soil Science, 171: 111–124.

Masauskas V., Antanaitis S., Lazauskas S., Masauskiene A. (2006): Content of nitrates in drainage and groundwater from permanent pasture, grassland and arable crop rotation soil. Ekologija, 4: 83–88.

McKenna P., Cannon N., Conway J., Dooley J. (2018): The use of red clover (*Trifolium pratense*) in soil fertility-building: a review. Field Crops Research, 221: 38–49.

Miatto R.C., Batalha M.A. (2016): Leaf chemistry of woody species in the Brazilian cerrado and seasonal forest: response to soil and taxonomy and effects on decomposition rates. Plant Ecology, 217: 1467–1479.

Mikola J., Virtanen T., Linkosalmi M., Vaha E., Nyman E., Postanogova O., Rasanen A., Kotze D.J., Laurila T., Juutinen S., Kondratyev V., Aurela M. (2018): Spatial variation and linkages of soil and vegetation in the Siberian Arctic tundra – coupling field observations with remote sensing data. Biogeosciences, 15: 2781–2801.

Möller K. (2018): Soil fertility status and nutrient input–output flows of specialised organic cropping systems: a review. Nutrient Cycling of Agroecosystems, 112: 147–164.

Mueller P., Schile-Beers L.M., Mozdzer T.J., Chmura G.L., Dinter T., Kuzyakov Y. (2018): Global-change effects on early-stage decomposition processes in tidal wetlands – implications from a global survey using standardized litter. Biogeosciences, 15: 3189–3202.

Opheusden A.H.M., Burgt G.J.H. M., Rietberg P.I. (2012): Decomposition Rate of Organic Fertilizers: Effect on Yield, Nitrogen Availability and Nitrogen Stock in the Soil. Driebergen, Louis Bolk Institute.

Parton W., Silver W.L., Burke I.C., Grassens L., Harmon M.E., Currie W.S., King J.Y., Adair E.C., Brandt L.A., Hart S.C. (2007): Global scale similarities in nitrogen release patterns during long-term decomposition. Science, 315: 361–364.

Poeplau Ch., Katterer Th., Bolinder M.A., Borjesson G., Berti A., Lugato E. (2015): Low stabilization of aboveground crop residue carbon in sandy soils of Swedish long-term experiments. Geoderma, 237: 246–255.

Raich J.W., Russell A.E., Kitayama K., Parton W.J., Vitousek P.M. (2006). Temperature influences carbon accumulation in moist tropical forests. Ecology, 87: 76–87.

https://doi.org/10.17221/31/2019-SWR

Salamanca E.F., Kaneko N., Katagiri Sh. (2003): Rainfall manipulation effects on litter decomposition and the microbial biomass of the forest floor. Applied Soil Ecology, 22: 271–281.

Sarunaite L., Kadziuliene Z., Deveikyte I., Kadziulis L. (2013): Effect of legume biological nitrogen on cereals grain yield and soil nitrogen budget in double-cropping system. Journal of Food, Agriculture & Environment, 11: 528–533.

Shahbaz M., Kuzyakov Y., Heitkamp F. (2017): Decrease of soil organic matter stabilization with increasing inputs: Mechanisms and controls. Geoderma, 304: 76–82.

Sorensen J.N., Thorup-Kristensen K. (2011): Plant-based fertilizers for organic vegetable production. Journal of Plant Nutrition and Soil Science, 174: 321–332.

Toth Z., Hornung E., Dombos M. (2017): Tea bag method: a new possibility to assess impacts of agri-environmental measures on soil functioning. Hungarian Agricultural Research, 2: 1–26.

Toth Z., Hornung E., Baldi A. (2018): Effects of set-aside management on certain elements of soil biota and early stage organic matter decomposition in a High Nature Value Area, Hungary. Nature Conservation, 29: 1–26.

Tripolskaja L., Šidlauskas G. (2010): The influence of catch crops for green manure and straw on the infiltration of atmospheric precipitation and nitrogen leaching. Zemdirbyste (Agriculture), 97: 83–92.

Valkama E., Lemola R., Kankanen H., Turtola E. (2015): Meta-analysis of the effects of undersown catch crops on nitrogen leaching loss and grain yields in the Nordic countries. Agriculture Ecosystems and Environment, 203: 93–101.

Van Hoesel W., Tiefenbacher A., König N., Dorn V.M., Hagenguth J.F., Prah U., Widhalm T., Wiklicky V., Bonkowski M., Lagerlöf J., Ratzenböck A., Zaller J.G. (2015): Single and combined effects of pesticide dressings and herbicides on earthworms, soil microorganisms, and litter decomposition. Frontiers in Plant Science, 8: 215.

Vilkiene M., Ambrazaitiene D., Karcauskiene D., Dabkevicius Z. (2016): Assessment of soil organic matter mineralization under various management practices. Acta Agriculturae Scandinavica, Section B – Soil & Plant Science, 66: 641–646.

Volungevičius J., Eidukevičienė M., Amalevičiūtė-Volungė K., Vaisvalavičius R., Povilaitis V., Velykis A., Liaudansienė I., Gregorauskienė V. (2018): The Peculiarities of Soil Cover in the Lowlands of Northern Lithuania. Akademija, ASU: 23–28. (in Lithuanian)

Wieder R.K., Lang, G.E. (1982): A critique of the analytical methods used in examining decomposition data obtained from litter bags. Ecology, 63: 1636–1642.

Zhang D., Hui D., Luo Y., Zhou G. (2008): Rates of litter decomposition in terrestrial ecosystems: global patterns and controlling factors. Journal of Plant Ecology, 1: 85–93.

Žydelis R., Weihermüller L., Herbst M., Klosterhalfen A., Lazauskas S. (2018): A model study on the effect of water and cold stress on maize development under nemoral climate. Agricultural and Forest Meteorology, 263: 169–179.

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