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Decomposition rate of two tea types in two different forestry niches

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Original article

Abstract

Organic matter decomposition is one of the most important processes associated with flow of energy and recirculation of organic matter in natural environments. Using commercially sold tea bags of Lipton Sencha green tea (SGT) and Lipton Ceylon black tea (CBT) their decomposition was studied in mixed and coniferous forest. At both stations 25 bags of each tea were buried for a period of 3 months. After elapsed time, the bags were dug up, dried, and the mean weight loss of organic material for each tea type and ecosystem was calculated. In the mixed forest the average weight loss of tea bags was 46.8% for Sencha and 32.1% for Ceylon tea and respectively 44.6% and 30.6%, in the coniferous forest. Statistical analysis test (ANOVA) revealed a statistically significant difference ($p < 0.05$) in rate of decomposition between tea types, however the differences between the decomposition of the same type of tea on both type of forest were insignificant.

Keywords

- soil
- rate of decomposition
- tea bags index
- TBI

Authors contributions

A – Conceptualization
B – Methodology
C – Formal analysis
D – Software
E – Investigation
F – Data duration
G – Visualization
H – Writing – original draft preperation
I – Writing, reviewing & editing
J – Project administration
K – Funding acquisition

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Conflict of interest

None declared.

Introduction

Soil is one of the most important and basic component of the biosphere building natural environment [1]. As soil is the outer layer of the lithosphere, which is formed from the rock waste by soil-forming processes [2], it is also shaped by geological, climatic, morphological, hydrological conditions and microorganisms [3]. All biotic and abiotic conditions and factors acting simultaneously cause specific soil-forming processes [2] and prepare it for the settlement of microorganisms and edaphon [4]. Decomposition is very important for the functioning of the whole forest ecosystem. Every year, from 1.5 to 6 Mg of litter per hectare are produced in temperate zone forests [5]. The rate of decomposition is strongly dependent on the type of organic materials being decomposed, their chemical composition, and the total number and diversity of microorganisms in the soil and climatic conditions, mainly temperature and humidity [5–8].

Knowledge about the decomposition processes is still insufficient. In part, this may be due to the fact, that the decomposition process of organic matter is highly complex. It involves a number of different soil microorganisms that are difficult to identify, active simultaneously or sequentially [9]. Decomposition has become an increasingly common topic of research because of soil pollution, a large amount of rubbish and climate changes affecting the decomposition process [7]. To study the rate of decomposition of organic matter, several methods can be used. One of them is the measurement of the total mass loss in the material subjected to soil microbial activity for some time. Among the different matters and methods used for this purpose, the tea bag used to measure the rate of organic matter decomposition seems to be a simple and cheap method which can be widely applicable. This method is known as the Tea Bag Index [10,11] and consists of using the two types of tea bags with different rates of decomposition.

The aim of this study was to use the idea of TBI method to compare the rate of decomposition of two types of tea leaves on two different types of forest.

Materials and methods

Study area

The study area was located in the central part of Radłowsko-Wierzchosławicki Obszar Chronionego Krajobrazu, in the area of Lasy Radłowskie about 1.5 km from Brzeźnica and 4.5 km from Radłów. The experiment was carried out in the area of Leśnictwo Waryś and included in branch no. 321a and 321b of the Państwowe, Gospodarstwo Leśne, Lasów Państwowych (Figure 1). The sites are situated 730 m away from each other along the communal road crossing the entire forest complex.

Figure 1. Locations of the sites

Source: Authors' own elaboration based on maps available from: https://www.bdl.lasy.gov.pl/portal/mapy [cited 2020 May 11].

Sites description

The experiment was carried out on two sites located in two different forests whose habitat type is defined as mixed forest (Station I) and coniferous forest (Station II). Both types of forests in southern Poland often border with each other. These habitats are sufficiently fertile and are formed on sandy clay formations with favorable or excessive moisture [12]. In the described area, there are mainly excessively wet soils, whose distribution is most often associated with flat terrain and hardly permeable formations such as loam, clay, or loess [12,13].

Station I (mixed forest)

The different species composition of the station was formed by the common oak (*Quercus robur*), beech (*Fagus sylvatica*) and pine (*Pinus sylvestris*) (Figure 2 a–d). The admixture of the upper and lower layers of the stand includes papillary birch (*Betula pendula*), spruce (*Picea abies*), maple sycamore (*Acer pseudoplatanus*), black alder (*Alnus glutinosa*) and fir (*Abies alba*). Frequent species in the groundcover are the wood anemone (*Anemone nemorosa*), the creeping bugle (*Ajuga reptans*), scented bow (*Polygonatum odoratum*), lily of the valley (*Maianthemum biforium*), tremendous sedge (*Carex brizoides*) and the violet (*Viola reichenbachiana*).

Station II (coniferous forest)

The tree stand of station II consisted mainly of pine (*Pinus sylvestris*) as the dominant species with the admixture of weeping birch (*Betula pendula*), common beech (*Fagus sylvatica*) and the common oak (*Quercus robur*) (Figure 3 a–e). The underbush was mainly composed of rowan berry (*Sorbus aucuparia*), alder buckthorn (*Rhamnus frangula*) and bird cherry (*Prunus padus*). In the

Figure 2. Mixed forest with the dominance of beech and common oak (a), soil profile of brown soil glued (b) and the frequent plant species of the undergrowth: lesser periwinkle (*Vinca minor*) (c), and wood anemone (*Anemone nemorosa*) (d); (phot. P. Żelazo, 12.05.2020)

undergrowth, the bilberry (*Vaccinium myrtillus*) and the brake (*Pteridium aquilinum*) were the most dominant. Other species noted on this station in mixed humid forest are the chickweed wintergreen (*Trientalis europaea*) and wood sorrel (*Oxalis acetosella*).

Tea bag material

Following the method, we used commercial Sencha green tea (SGT) and Ceylon black tea (CBT) bags as standardized materials for organic plant material decomposition (Figure 4a–b). According to the information provided by the manufacturer on the tea packaging, SGT bags contain: 89% green tea, 10% aromatics and 1% rose petals and CBT bags contain 100% black tea leaves. Dried SGT consists of crushed pieces of tea leaves and stems, while CBT resembles small granules due to the strong fragmentation of the tea leaves. The tea bag envelopes were pyramid-shaped, made from polyethylene terephthalate (PET) which is indecomposable in short period of time [14,15]. Of total, 100 tea bags, 50 bags of SGT, and 50 bags of CBT were used, respectively. Before the start of experiment, the bags were dried at 60°C for 5 hours. Then, each tea bag was weighed accurately to within 0.01 g. The tea bags weighed about 2 g (SGT 1.95 ± 0.06 g, CBT 1.95 ± 0.05 g). Next, the tea bags were tied to two cotton ropes at a distance of 20 cm each from others (Figure 4c–d). Both ropes with tea bags were buried in the soil at both sites at 8 cm depth and incubated over a 3 month period from 18th February to 18th May 2020. After 3 months, the bags were dug out, carefully cleaned from the ground, and dried at 60°C for 5 hours. From Station I in total 50 bags of both tea types were recovered, however on station 2 two bags of SGT were damaged and lost. After drying, the bags were re-weighed and the organic matter mass loss was calculated based on the initial weight.

Figure 3. Coniferous forest (Station II) with domination of pine trees (*Pinus sylvestris*) (a), soil profile of the sod-glue fallout soil (b) and the frequent plant species of the undergrowth: bilberry (*Vaccinium myrtillus*) (c), chickweed-wintergreen (*Trientalis europaea*) (d), and short-legged sheriffin (*Dryopteris carthusiana*) (e); (phot. P. Żelazo, 12.05.2020)

Figure 4. Commercially available CBT and SGT used in the experiment (a), content of tea bags (b), and preparation of tea bags for burying in soil at the start of experiment at Station I (c) and Station II (d); (phot. P. Żelazo)

The rate of decomposition of tea bag contents was determined from the irruptive model presented in formula [6,9,16]:

$$X = X_0 e^{-kt},$$

where: X – is the weight of the substrate after incubation time t; X_0 – labile fraction; k – constant rate of decomposition; t – time (in days).

Data analysis

After the normality of distributions has been checked using Statistica ver.13.3 two-way ANOVA and Tukey post-hoc tests were performed to analyze the differences among the mass loses of both tested type of tea on station in mixed and coniferous forest.

Results

After three months of the duration of the experiment, differences in the rate of decomposition of tea bags content was found. The weight of tea bags decreased in both types of forests (Table 1). The average percentage of weight loss of the bags and the value of standard deviation at both sites proclaim that the difference in the rate of decomposition between the SGT and CBT was statistically significant (Table 2).

Table 1. Weight of both SGT and CBT bags before and after experiment and percentage of organic matter decomposition in the mixed wet forest (Station I), and coniferous forest (Station II); '–' indicates loss of bag. Mean, SD, Min. and Max. of data was given

No.	Station I						Station II					
	Before [g]		After [g]		% of decomposition		Before [g]		After [g]		% of decomposition	
	SGT	CBT	SGT	CBT	SGT	CBT	SGT	CBT	SGT	CBT	SGT	CBT
1.	1.90	2.03	1.03	1.36	45.79	33.00	2.02	1.89	0.96	1.29	52.48	31.75
2.	1.89	1.95	0.98	1.29	48.15	33.85	1.97	1.91	1.05	1.34	46.70	29.84
3.	1.87	1.93	1.00	1.23	46.52	36.27	1.90	1.91	0.98	1.37	48.42	28.27
4.	1.90	1.93	0.96	1.28	49.47	33.68	1.93	1.95	1.05	1.38	45.60	29.23
5.	1.93	1.97	–	1.31	–	33.50	1.97	2.10	1.11	1.51	43.65	28.10
6.	2.00	2.02	1.05	1.37	47.50	32.18	1.92	1.95	1.13	1.42	41.15	27.18
7.	2.02	1.93	1.16	1.25	42.57	35.23	1.83	1.91	1.17	1.33	36.07	30.37
8.	2.04	2.00	–	1.35	–	32.50	1.95	1.97	1.01	1.41	48.21	28.43
9.	1.97	1.95	1.13	1.37	42.64	29.74	1.91	1.96	1.18	1.35	38.22	31.12
10.	1.90	1.89	1.00	1.24	47.37	34.39	1.74	1.88	1.09	1.32	37.36	29.79

No.	Station I						Station II					
	Before [g]		After [g]		% of decomposition		Before [g]		After [g]		% of decomposition	
	SGT	CBT	SGT	CBT	SGT	CBT	SGT	CBT	SGT	CBT	SGT	CBT
11.	1.94	1.95	1.01	1.28	47.94	34.36	1.90	1.91	1.18	1.28	37.89	32.98
12.	1.99	1.95	1.00	1.30	49.75	33.33	1.84	2.00	1.08	1.37	41.30	31.50
13.	2.06	2.00	1.10	1.39	46.60	30.50	2.01	1.95	1.02	1.31	49.25	32.82
14.	2.00	1.93	0.98	1.31	51.00	32.12	1.89	1.97	1.13	1.43	40.21	27.41
15.	1.96	1.95	1.02	1.41	47.96	27.69	1.94	2.01	1.12	1.31	42.27	34.83
16.	1.98	1.92	1.09	1.34	44.95	30.21	1..95	2.00	1.14	1.34	41.54	33.00
17.	2.00	2.02	1.15	1.39	42.50	31.19	1.96	2.01	1.05	1.37	46.43	31.84
18.	2.04	2.00	1.00	1.44	50.98	28.00	2.03	1.93	1.15	1.35	43.35	30.05
19.	1.91	1.91	1.21	1.28	36.65	32.98	1.93	1.88	1.06	1.22	45.08	35.11
20.	1.91	1.95	1.02	1.35	46.60	30.77	1.90	1.95	0.94	1.36	50.53	30.26
21.	1.86	1.90	0.99	1.26	46.77	33.68	1.91	1.95	1.01	1.34	47.12	31.28
22.	2.01	1.95	1.11	1.41	44.78	27.69	2.00	1.95	0.98	1.36	51.00	30.26
23.	1.92	1.97	0.96	1.39	50.00	29.44	1.97	1.91	1.06	1.32	46.19	30.89
24.	1.97	1.91	0.98	1.32	50.25	30.89	2.03	1.89	1.15	1.37	43.35	27.51
25.	1.97	1.87	1.00	1.22	49.24	34.76	1.96	2.02	0.97	1.39	50.51	31.19
Mean	1.96	1.95	1.04	1.33	46.78	32.08	1.93	1.95	1.07	1.35	44.55	30.60
SD	0.06	0.04	0.07	0.06	3.37	2.38	0.07	0.05	0.07	0.06	4.62	2.15
Min	1.86	1.87	0.96	1.22	36.65	27.69	1.74	1.88	0.94	1.22	36.07	27.18
Max	2.06	2.03	1.21	1.44	51.00	36.27	2.03	2.10	1.18	1.51	52.48	35.11

From all tea bags at both stations, the minimum weight of a SGT bag before burying was 1.74 g and the maximum 2.06 g. Respectively, the minimum weight of the CBT bag before burying was 1.87 g and the maximum 2.10 g. In the mixed wet forest (Station I), after the elapsed time of experiment, the average weight of SGT bag was 1.04 ± 0.07 g and that of CBT bag was 1.33 ± 0.06 g. In the coniferous forest (Station II), at the end of experiment the average weight of tea bags was 1.07 ± 0,07 g and 1.35 ± 0.06 g for SGT and CBT respectively (Table 1).

Table 2. ANOVA of the effect of forest type on percentage of decomposition of two studied tea types

Source	d.f.	MS	*F* ratio	*P*
Forest type	1	84.0	7.83	0.006239
Tea type	1	5023.7	468.02	0.000000
Forest type × tea type	1	3.4	0.32	0.573584
Error	94	10.7		

The organic matter decomposition was faster in the mixed forest than in the coniferous one. The loss of weight of SGT bags in the mixed forest (Station I) ranged from 36.65% to 51.0% and in the coniferous forest (Station II) from 36.07% to 52.48%. As expected, the weight loss of CBT bags was lower and ranged from 27.69% to 36.27% in Station I and from 27.18% to 35.11% in Station II. The loss of weight at the end of experiment reach approximately 46.78% of SGT and 32.08% of CBT on Station I and approximately 44.55% and 30.60% respectively on Station II (Figure 5).

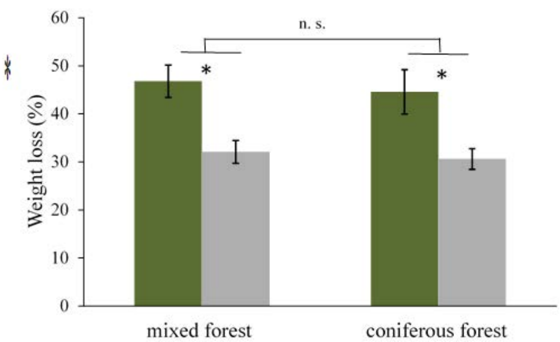

Figure 5. Percentage of average (±SD) weight loss of SGT (green) and CBT (gray) tea bags after three months of exposition in mixed and coniferous forest

* – shows statistical significance.

Statistical analysis showed that the differences between the percentage of weight loss of SGT and CBT in the mixed forest and in the coniferous forest were statistically significant (ANOVA, $p < 0.05$). Tukey post-hoc test revelated that there were no statistically significant differences in weight loss of the same tea type on both sites.

At both stations, the rate of organic matter decomposition was faster for SGT. The calculated decomposition coefficient for green tea was $k = 0.003$ ($d - 1$) for the mixed forest and $k = 0.002$ ($d - 1$) for the coniferous forest. For CBT the coefficient k reached 0.001 ($d - 1$) for both kinds of forest (Figures 6, 7).

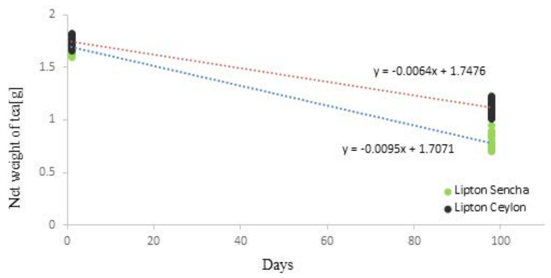

Figure 6. Loss of net masses of tea bags on subsequent days of the experiment in the mixed forest (Station I)

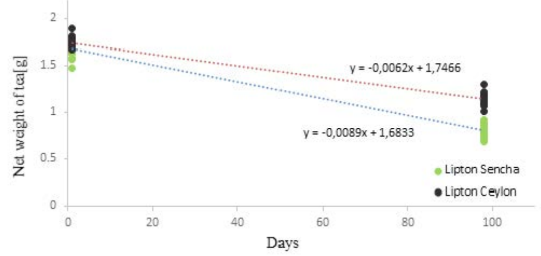

Figure 7. Loss of net masses of tea bags on subsequent days of the experiment in the coniferous forest (Station II)

The distribution was characterized by linear weight loss during the duration time of experiment. The regression indexes were significant for both sites, R2 values at $p < 0.05$ are close to 1, ranging from 0.969 to 0.982.

Discussion

For study of decomposition not only the litterbags were used [17–19] but also the method proposed by Keuskamp et al. [15] which use tea bags as a standard material to estimate the decomposition rate. Tea Bags Index (TBI) method is frequently used for field studies, because it is cheap, easy and repetitive [20–22]. It provides the possibility to estimate not only the decomposition rate but also the carbon release intensity from different terrestrial ecosystems. Although this method does not allow for direct quantitative estimates of carbon release, it may reveal general spatial patterns of decomposition intensity which in turn may be quantitatively recalibrated also into absolute carbon fluxes. The TBI value can increase the reliability of soil carbon flux estimates based on extrapolation of directly measured decomposition, while other factors such as temperature, pH and humidity affecting on this process, can be measured directly. In his work Keuskamp et al. [15] proposes to use standard, commercial tea bags Lipton Green tea (EAN 87 22700 05552 5) and Rooibos tea (EAN 87 22700 18843 8). In our experiment we use Lipton Green tea as suggested and because of problems with achievement of this specific Rooibos tea, we decided to use Lipton Ceylon Black tea. As the other type of tea was used there is no possibility to directly apply our results to the Keuskamp TBI model but the results give a possibility to estimate the decomposition of SGT in comparison with decomposition of CBT at both stations.

For experiment two adjacent forest stands of approximately the same age, studied at the same time and at the same climate conditions were selected. The stations differed only in vegetation dominated with broadleaf trees vs. conifer (Figures 2a and 3a), litter and soil type (Figures 2b and 3b) and undergrowth plant species composition (Figures 2c–d and 3 c–e). This visible stations differences could point to differences in decomposition intensity [23–26].

The decomposition rates of Sencha Green tea and Ceylon Black tea were expressed as difference of masses of tea bags before and after experiment and as percentage of mass losses. As it has been assumed, the decomposition rate of SGT was higher than these of CBT. Moreover, the SGT decomposition process was going quicker in mixed forest (Station I) than in coniferous forest (Station II). This results was similar to that received in experiments measuring decomposition rates of natural litter which stated that conifer litter decomposing much more slowly than broadleaf litter. The overall decomposition rate of SGT was faster than was reported for natural litters by other authors [23,25,26]. In case of CBT the decomposition of the content of bags was slower in both stations comparing to SGT, and had similar to SGT decomposition pattern showing lower decomposition rate in coniferous than in mixed forest. Apart from ecological and physical differences between the stations, this can be also the result of the tea bags content which according to the producer in case of SGT consist of Green Tea (89%), Nature Identical Pear

Flavouring (9.3%), Rose Petals (1%) but in case of CBT it was only a black tea. As our experiment lasted only three-month and we did not check the tea bags mass in the meantime, we could not extrapolate decomposition rates in the both forest stands for longer period of time. However, in spite of the overall decomposition rates of CBT slower than in SGT, soluble fraction of both tea types decomposed faster than reported for natural litters by Laskowski et al. [23], Vesterdal et al. [25] and Hobbie et al. [26]. The difference in decomposition rate between used tea bags and natural litter known from literature may partly be explained by direct measurements of litter bags which last usually for several month or sometimes years in soil and include cold seasons, when decomposition is slowed down, while the exponential function is fitted to the whole period. Also tea bags material used in experiment is deprived of its own microbiome, so exposed in both stations, in fact shows rather the differences between the local microbiomes and edaphon but not the actual intensity of decomposition of the litter. Hobbie et al. [26] showed that the same broadleaf litter exposed in various forest types may have different decomposition rates. This means, that the conclusions based on tea bags index should be taken with precaution, because they may differ substantially from the spatial patterns of the decomposition intensity of the local dead organic matter.

In case of both tea types the differences in loss of mass between the same kind of tea was not dependent on type of the forest and were not statistically significant. However, at both stations the loss of weight was higher for SGT then CBT. This suggest that the litter microbiocenosis in mixed forest (Station I) may be more efficient in decomposing green tea, than that of coniferous forest at Station II. Moreover this result can be also influenced by the tea bags content which according to the producer in case of SGT consist not only from the green tea leaves but also flavouring and rose petals. In case of CBT it was only oxidized tea leaves. Our results of experiment showed that the effect of the forest type upon decomposition rates of tested bags content was not significant. Since the environmental conditions and the timing of experiments in the both study plots were identical, the only explanation is that the local microbiome (bacteria and fungi) are more efficient in decomposing SGT in the mixed forest, while the decomposition of the black tea was more difficult.

More studies including microbiocenosis and edaphon diversity in both kind of forests are necessary to better understand the decomposition process in time of global climate changes.

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