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A need for long-term monitoring of tea bag decomposition[*1]

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Taiki Mori: **A need for long-term monitoring of tea bag decomposition. Kyushu J. For. Res. 76 : 129 – 131, 2023** The Tea Bag Index approach is increasingly used as a standard method to evaluate soil organic matter decomposition. In the Tea Bag Index approach, an asymptote model is chosen to describe the decomposition curves of teas, and a single pair of 90-day mass loss data of green and rooibos teas are used to determine the decomposition curves, with several assumptions. A recent paper suggested that the assumptions required to determine the decomposition curves with only a single pair of mass loss data are not always satisfied, and time-series data are necessary to accurately determine the decomposition curves of teas, although the asymptote model remains suitable for describing decomposition curves. Here, I suggest that over longer periods, the asymptote model might be unsuitable for predicting decomposition curves of teas; other models might be more suitable. Additional time-series mass loss monitoring data over longer periods are necessary to accurately determine the decomposition curves and the appropriate model to fit the curves.

Key words: carbon dynamics; decomposition; Tea Bag Index

I. Introduction

The Tea Bag Index (TBI) approach, proposed by Keuskamp et al. (2013), is increasingly used as a standard method to evaluate soil organic matter decomposition. This approach utilizes two types of commercially available tea bags—green and rooibos teas—to determine two indexes: the decomposition constant k and the stabilization factor S. k is the decomposition constant of an asymptote model that describes the decomposition curve of rooibos tea and indicates early-stage decomposition rates (Keuskamp et al., 2013). In contrast, S is the ratio of the stabilized fraction of green tea to the total hydrolyzable fraction of green tea, which is presumed to indicate long-term carbon stability (Fanin et al., 2020; Fujii et al., 2017). The TBI approach enables determination of these indexes using only a single measurement (approximately 90-day incubation) of the mass loss data of green and rooibos teas, with two essential assumptions. First, the unstabilized hydrolyzable fraction of green tea is almost completely decomposed within the 90 days; second, green and rooibos teas have the same stabilization factor S (see Fig. 1).

In my recent report, I suggested that these two essential assumptions are not always true, and thus time-series data are needed to accurately determine the TBI, particularly with regard to k (Mori, 2022 a). Nevertheless, the decomposition curves of both green and rooibos tea exhibited close correspondence with the asymptote model, indicating that the asymptote model is suitable for describing tea decompositions as suggested by the TBI approach. In this short opinion paper, I report that additional data, obtained approximately 2 months after the end of the 90-day incubation previously described by Mori (2022 a), showed that the asymptote model might be unsuitable for predicting decomposition curves of teas over longer periods; other models might be more suitable.

II. Materials and Methods

Incubation experiment

The experimental parameters were identical to the parameters described by Mori (2022 a). Briefly, an incubation study was conducted using surface soil samples (0 – 10 cm) taken from four subplots established in a Japanese cedar [*Cryptomeria japonica* (L.f.) D. Don] plantation at the Tatsudayama research site in Kumamoto, Japan (32.82° N, 130.73° E). Green tea bags (EAN: 8714100770542; Lipton) and rooibos tea bags (EAN: 8722700188438; Lipton) were buried in 100-g fresh soil samples (sieved through a 4-mm sieve) that had been placed in a polyethylene terephthalate bottle after oven-drying (70° C for > 72 h). Because the manufacturer changed the mesh size of the tea bags, the tea bags were recreated by placing the tea contents from the purchased bags into new 0.25-mm mesh bags (Mori et al., 2021 a). The bottles were placed in a cold room (3° C) after the soil moisture had been adjusted to 45 %. This low temperature condition was chosen to test the validity of the first assumption of the TBI approach (i.e., the unstabilized hydrolyzable fraction of green tea is almost completely decomposed within 90 days) under conditions unfavorable for tea decomposition. Whereas previous papers reported results for 5, 13, 23, 58, and 90 days of incubation, this study reports results for 156 days. The dry

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weights of the teas were determined after they had been dried in an oven at 70°C (> 72 h).

Calculation and statistics

As previously reported (Mori, 2022 a), an asymptote model was fitted to the 90-day time-series data in each subplot, using nonlinear regression. These asymptote models were used to predict the remaining mass ratios on the 156 th day of the incubation. The predicted values were compared with the remaining mass ratios observed in the present study. One-way analysis of variance was used for the comparison. R version 4.0.2 (R Core Team, 2020) was used for the statistical analyses.

III. Results and Discussion

The remaining mass data observed approximately 2 months after the end of the 90-day incubation were consistently lower than the values predicted by the asymptote model fitted to 90-day time-series data for both green and rooibos teas (Fig. 2). The differences between the observed and predicted values were statistically significant (Fig. 3). These results indicated that the asymptote model constructed using 90-day time-series remaining mass data does not always provide an appropriate description of the decomposition curves of teas over longer periods. Models other than the asymptote model may be more suitable. In aquatic ecosystems, Mori et al. (2021 b) found that the double exponential model exhibited a better fit than the asymptote model. Longer monitoring of tea decomposition is necessary for more accurate determination of the decomposition curves of teas.

The remaining mass ratios observed on the 156 th day were smaller than the remaining mass ratios predicted by the asymptote model constructed using a 90-day incubation (Fig. 2); this finding is presumably because lignin degradation began between days 90 and 156 of the incubation, thereby accelerating tea decomposition. Mori (2021) reported that nitrogen addition significantly reduced rooibos tea decomposition during the 90-day incubation in an aquatic environment. Wang et al. (2019) also reported that tea decomposition was inhibited by nitrogen addition. Considering that the delayed decomposition of organic matter by nitrogen addition is generally attributed to the suppression of lignin decomposition, it is plausible that lignin degradation had already begun in these studies. If this hypothesis is correct, the lignin degradation begins considerably earlier than assumed in the TBI approach; the TBI approach assumes that lignin decomposition is negligible and therefore ignores the effect of this process (Keuskamp et al., 2013; see also Fig. 1). Assessments of lignin content or lignin-degrading enzyme activity are needed to test the above hypothesis.

Although a large number of studies have used tea bags to

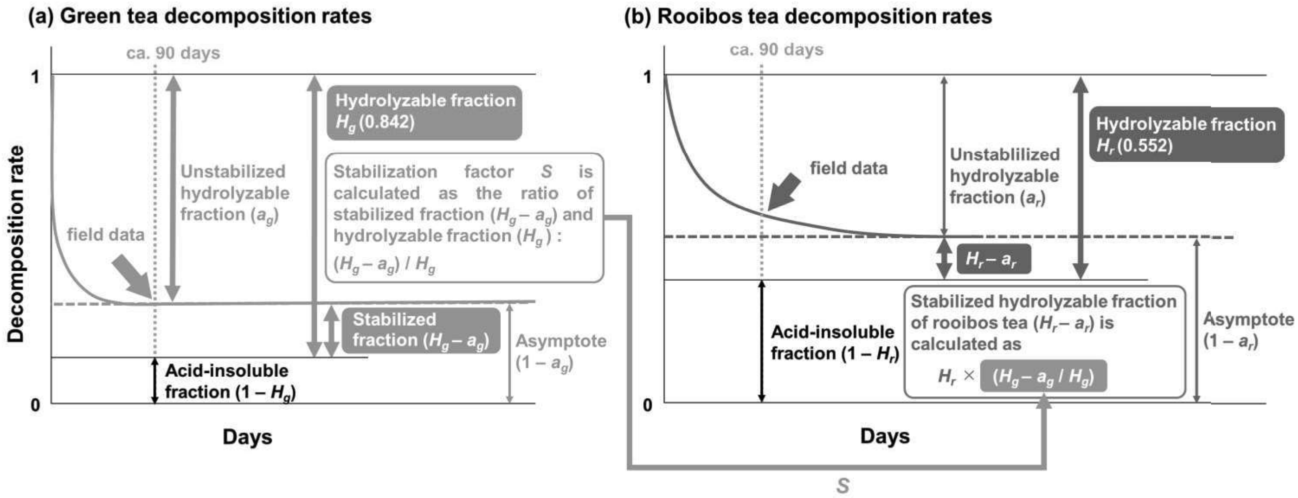

Fig. 1. Diagram describing the concept of the Tea Bag Index (TBI) approach (the figure is cited from Mori, 2022 a, with minor modification). Decomposition curves are shown for (a) green tea and (b) rooibos tea. Green and rooibos teas consist of hydrolyzable (H_g and H_r, respectively) and acid-insoluble fractions ($1-H_g$ and $1-H_r$, respectively). The hydrolyzable fractions of green and rooibos teas consist of unstabilized (a_g and a_r, respectively) and stabilized fractions (H_g-a_g and H_r-a_r, respectively). By assuming that the unstabilized hydrolyzable fraction of green tea is almost completely decomposed before the 90 th day of the incubation (the first assumption), a_g is approximated to the mass loss ratio of green tea at the 90 th day of incubation; therefore, the stabilization factor S is regarded as (H_g − mass loss ratio of green tea at 90 th day) / H_g. By assuming that green and rooibos teas have the same stabilization factor S (second assumption), the stabilized hydrolyzable fraction of rooibos tea (H_r-a_r) can be expressed as $H_r \times S$ and a_r can be defined as $H_r \times (1-S)$. The decomposition constant k can be determined by using mass loss data of rooibos tea at the 90 th day of the incubation and the asymptote model: remaining mass ratio of rooibos tea = $a_r \times e_{-k \times t} + (1-a_r)$, where t is the decomposition period (90 days).

evaluate organic matter decomposition, time-series data have rarely been reported (Mori, 2022 b, 2021 ; Teo et al., 2020). I suggest that additional time-series mass loss data, especially long-term monitoring, are needed to accurately determine the decomposition curves and an appropriate model to fit the curves.

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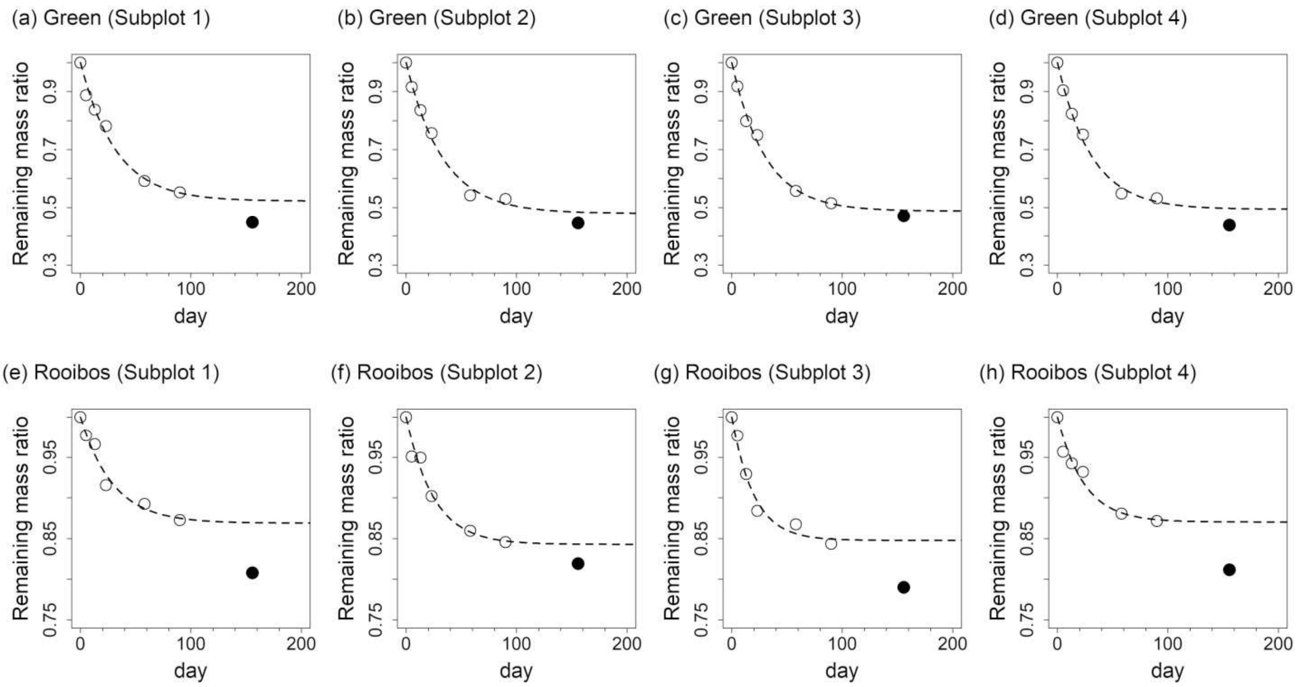

Fig. 2. Remaining mass ratios of (a–d) green and (e–h) rooibos teas during the incubation study. Open circles show remaining mass ratios of green tea during the 90 -day incubation. Filled circles indicate the remaining mass ratio on the 156 th day. Dashed lines indicate the asymptote model fitted to the time-series remaining mass data of the 90 -day incubation.

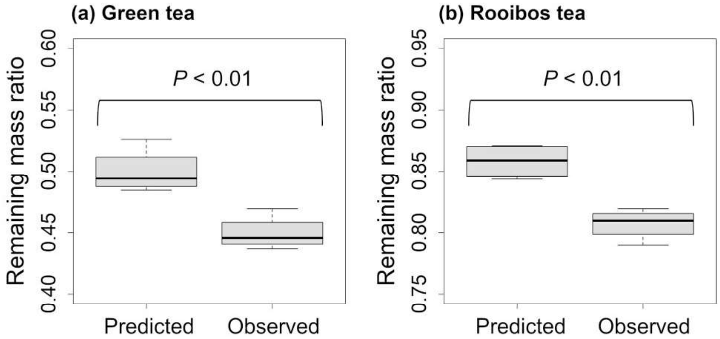

Fig. 3. Comparisons between predicted and observed values of the remaining mass ratio of (a) green and (b) rooibos teas on the 156 th day of incubation. Predicted values were calculated using the asymptote model constructed with time-series remaining mass data from the 90 -day incubation.