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Comparison of Callery pear (*Pyrus calleryana*, Rosaceae) leaf decomposition rates with those of the invasive shrub Amur honeysuckle (*Lonicera maackii*, Caprifoliaceae) and two native trees, red maple (*Acer rubrum*, Sapindaceae) and American sycamore (*Platanus occidentalis*, Platanaceae)¹

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Abstract. Invasive plants can alter nutrient cycling rates, because the leaves of many invasive species decay more quickly than those of native plants. *Pyrus calleryana* (Callery pear) is a relatively new woody invader in the eastern USA that rapidly colonizes open and disturbed areas. Invasive woody plants can alter forest nutrient cycling, yet the leaf decomposition rates of *P. calleryana* have not been previously determined. In this study, *Pyrus calleryana* leaf decomposition rates were compared against two widely distributed native trees, *Acer rubrum* (red maple) and *Platanus occidentalis* (American sycamore), with different levels of nitrogen (N), carbon (C):N, lignin, and lignin:N. It was also compared to that of the invasive shrub Amur honeysuckle (*Lonicera maackii*), which is known to have very fast decomposition rates. Litter bags were placed in four locations in a Callery pear-dominated stand in northern Kentucky in November 2014 and sampled at 3, 90, 12, and 18 mo. Dry weight and %N measurements were fit to a single exponential decay equation. Mass and N loss of *P. calleryana* leaf litter were both similar to those of *A. rubrum*, and they were lower than those of *L. maackii*; however, lignin and lignin:N levels were most similar to *L. maackii*. *Platanus occidentalis* decayed very slowly and immobilized rather than mineralized N. *Pyrus calleryana* is thus not predicted to greatly alter leaf litter decomposition in invaded forests, although litter decomposition dynamics might be different in mixtures with native species and in other locations.

Keywords: C:N ratio, invasive plants, leaf litter, lignin, nutrient cycling

Decomposition of leaf litter is an important process in terrestrial ecosystems that affects nutrient cycling, including the availability of nutrients to plants (Chapin *et al.* 2002). In temperate ecosystems, leaves are deposited to the forest floor every fall. Nutrients in the leaf litter of fast-decomposing species can be available for new leaf growth in the next growing season, whereas nutrients in more slowly decomposing species are not released as fast. Because the nutrients released by decomposing leaf litter provide such a large part of nutrient demand by new leaves, decomposition rates are important in regulating a number of important ecosystem functions, including plant growth, nutrient cycling, and net primary production.

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The introduction of invasive species can greatly alter nutrient cycling rates, with major effects on ecosystem and plant community processes. In many cases, leaf litter from invasive species decays more quickly (*e.g.*, Ashton *et al.* 2005, Aragón *et al.* 2014, Hornbach *et al.* 2021), although this is not always the case (Jo *et al.* 2016). For example, the leaves of the nonnative shrub Amur honeysuckle (*Lonicera maackii* (Rupr.) Herder) decay much more quickly than those of the native woody plants that account for most of the leaf litter inputs in eastern deciduous forests (Blair and Stowasser 2009, Arthur *et al.* 2012, Poulette and Arthur 2012). This is because the leaf litter of *L. maackii* generally has higher levels of nitrogen (N), lower carbon (C):N ratios, and lower lignin levels than native trees. Studies have shown that *L. maackii* greatly affects the microarthropod and microorganism communities (Arthur *et al.* 2012, Poulette and Arthur 2012), in turn affecting rates of nutrient cycling.

Callery pear (*Pyrus calleryana* Decne.) is a relatively new woody invader in the eastern US. ‘Bradford’, the first horticultural cultivar, was introduced in 1960 (Vincent 2005, Culley 2017). *Pyrus calleryana* is self-incompatible; because

cultivars are propagated by cuttings, the resulting trees cannot reproduce with one another (Culley 2017). However, problems with the Bradford cultivar led to the development of several other cultivars (Gilman and Watson 1994, Culley 2017). Many of these cultivars were planted next to existing plantings of Bradford and other cultivars. In addition, the rootstocks used for all cultivars can sometimes sprout and flower. This has led to the production of viable seed, and because the fruit is attractive to birds, seeds are readily spread (Culley and Hardiman 2009, Hardiman and Culley 2010, Culley *et al.* 2011, Culley 2017). This species is now reported to be invasive in 35 states (EDD-MapS 2022; USDA NRCS 2022). Vincent (2005) and White *et al.* (2005) noted that this small tree can rapidly invade open and disturbed areas, forming dense thickets. However, its diameter distributions, which are typical of a shade-intolerant/midtolerant species, suggest that it is unlikely to invade forest understories (Boyce and Ocasio 2020), unlike *L. maackii*.

At present, leaf decomposition rates of *P. calleryana*, and thus its impacts on nutrient cycling, are unknown. Decomposition rates vary from site to site because of differences in many factors, including temperature and precipitation, and so a typical approach is to compare the rates of decomposition of various litters in the same site. In this case, leaves from two native and widely distributed trees were also used; the two species chosen were expected to have quite different litter decomposition rates. Red maple (*Acer rubrum* L.) litter has moderate to high levels of nitrogen, a C:N ratio higher than many other native species, low lignin levels, and moderate to fast decomposition rates (Day 1982, Blair 1988, Blair and Crossley 1988, Finzi and Canham 1998, Alexander and Arthur 2014, Jones and Swan 2015, Kay and Hone 2016). Little work has been done on leaf litter of American sycamore (*Platanus occidentalis* L.), but it has been reported to decay very slowly in aquatic environments and to have both high N and lignin levels (Ostrofsky 1997, Jones and Swan 2015). Both of these trees are common across the eastern USA (USDA NRCS 2022), and seedlings of both species establish in the same type of open and disturbed sites that are heavily invaded by *P. calleryana* (Burns and Honkala 1990). Leaves from *L. maackii* were also included, because it is an example of an invasive species with high leaf decomposition rates, and it often invades the same

sites as *P. calleryana* (Boyce and Ocasio 2020). Thus, the overall objective of this study was to compare the leaf decomposition rates of *P. calleryana* against two native trees and one invasive shrub.

Materials and Methods. Leaf litter was collected in the fall of 2014. Because the focus of this study was on invasive species, the native tree litter was collected from single trees in early November 2014 in the author's yard in Anderson Township, OH, whereas the litter from the two invasive species was collected on the campus of Northern Kentucky University in Highland Heights, KY (NKU), approximately 15 km away. The decomposition experiment was carried out at the latter site. The characteristics of this site are described by Castellano and Boyce (2007) and Boyce *et al.* (2014); it is on a road cut approximately 1 ha in area that overlooks Interstate-275. The part of the site used for this study was dominated by *P. calleryana* and *L. maackii* (personal observation).

The litter bags for this study were used in the EREN (Ecological Research as Education Network)/DATIS (Decomposition in Aquatic and Terrestrial Invaded Systems) project (EREN/DATIS 2022, Hornbach *et al.* 2021). These were ~20 cm × 20 cm custom nylon bait bags obtained from Memphis Net & Twine Co. (Memphis, TN) with ~1.5 mm openings on the bottom and ~6.4 mm openings on the top.

Fresh litter samples of ~20 g were loaded into litter bags and placed in the field on November 11, 2014. Samples of each plant type were also oven-dried for 3 days at 70 °C so that fresh sample weights could be converted into dry weight equivalents. Samples of each leaf type were placed at four locations within the *P. calleryana*-dominated stand on NKU's campus in a randomized-block design, and one bag of each species from each block was randomly sampled at 3, 9, 12, and 18 mo. Thus, there were 4 species × 4 blocks × 5 dates (0, 3, 9, 12, and 18 mo) for a total of 80 litter samples. After collection, drying, and weighing, samples were ground in a Wiley mill for homogenization. Portions were combusted at 500°C for at least 4 h to convert dry weights to ash-free dry weights (AFDW). In addition to determining AFDW, %C and %N were determined using a Carlo Erba CHN analyzer. Lignin was determined using the acid-detergent method as

Table 1. Mass and nitrogen (N) loss k -values and initial litter N concentration, carbon (C):N ratios, lignin, and lignin:N ratios in leaf litter. Values for mass and N loss show best fit \pm 95% confidence interval, obtained from the package nlstools (R Core Team 2022). Lignin values are means from two replications. Values for N and C:N are mean \pm standard errors ($n = 4$). Lowercase letters indicate significant differences (95% confidence intervals are for mass and N loss k values; Tukey test for N and C:N).

Litter type	Mass loss k (yr^{-1})	N loss k (yr^{-1})	N (%)	C:N	Lignin (%)	Lignin:N
<i>Pyrus calleryana</i>	1.32 \pm 0.28b	1.44 \pm 0.17b	1.25 \pm 0.01b	36.0 \pm 0.4b	12.9	10.3
<i>Lonicera maackii</i>	2.26 \pm 0.49b	1.97 \pm 0.58b	1.35 \pm 0.02c	33.1 \pm 0.5a	15.7	11.6
<i>Acer rubrum</i>	1.50 \pm 0.14b	0.89 \pm 0.13b	0.84 \pm 0.01a	53.0 \pm 0.4c	20.6	24.6
<i>Platanus occidentalis</i>	0.23 \pm 0.04a	-0.11 \pm 0.09a	1.31 \pm 0.01c	35.2 \pm 0.4b	49.8	38.0

described by Hach Company (1990); two replications of each litter type were made. Dry weight and %N measurements across time were fit to the single exponential decay equation of Olson (1963), $X(t_i)/X(t_0) = e^{-kt}$, where $X(t_i)$ was the measurement at time t_i , $X(t_0)$ was the initial measurement, $t =$ time (yr), and k is a decay coefficient (yr^{-1}). Data for each species were fit to this equation with nonlinear regression using the package nlstools in the statistical package R (R Core Team 2022). Data were also fit to the other decomposition curves proposed by Rovira and Rovira (2010), but the best fits were obtained with the single exponential decay equation. Differences between species for N and C:N levels were determined with a one-way ANOVA followed by Tukey tests, and 95% confidence intervals were calculated for mass loss and N loss k -values using nlstools and were examined for overlap.

Results. At the start of the study, *A. rubrum* leaves had the lowest N levels, and *P. occidentalis* had the highest (Table 1). *Lonicera maackii* leaves had the lowest C:N ratio, whereas *A. rubrum* had the highest. *Lonicera maackii* also exhibited the highest decomposition rate (Table 1, Fig. 1a), although its k value did not differ statistically from those for *P. calleryana* and *A. rubrum*. Mass loss values of the four species were best correlated with lignin values (Pearson $r = -0.86$, $P = 0.14$), although lignin values for the three species other than *Platanus occidentalis* did not differ greatly from each other. Nitrogen decomposition rates followed a similar pattern for *L. maackii*, *P. calleryana*, and *A. rubrum*, in that *L. maackii* was the highest, but not differing statistically from the other two species (Table 1, Fig. 1b). However, the k value for *P. occidentalis* was negative, showing that N immobilization was occurring. N loss rates were highly correlated with lignin:N values (Spearman $r = -0.96$, $P = 0.04$). Lignin and

lignin:N values followed similar trends, with *P. calleryana* having the lowest values and *P. occidentalis* having the largest.

Discussion. Many studies have found that lignin concentration and lignin:N ratios are much better predictors of leaf litter decomposition rates than other factors (Shure *et al.* 1986, Blair 1988, Blair and Crossley 1988, Finzi and Canham 1998, Gartner and Cardon 2004, Alexander and Arthur 2014). High lignin concentrations can also hinder N mineralization (Finzi and Canham 1998, Shure *et al.* 1986). Measurements by Ostrofsky (1997) indicated that *P. occidentalis* has lignin:N ratios almost twice that of *A. rubrum*; aquatic mass loss rates of *P. occidentalis* were about one-third of *A. rubrum*, consistent with the terrestrial mass loss rates found in the current study. In the current study, mass loss rates were weakly correlated with lignin levels, although not significantly. On the other hand, N loss rates were significantly correlated with lignin:N ratios.

There were no statistically significant differences among *L. maackii*, *P. calleryana*, and *A. rubrum*, although leaf litter of *L. maackii* had the highest rates of mass and N loss of the four species in this study. In addition, *L. maackii* had the highest %N and lowest C:N ratio, as well as low %lignin and lignin:N ratio; values for N, C:N, lignin, and mass loss were similar to those found in other upland sites (Blair and Stowasser 2009, Arthur *et al.* 2012, Poulette and Arthur 2012, Jo *et al.* 2016), whereas N loss was lower (Jo *et al.* 2016). By comparison, leaf litter of *P. calleryana* had a lower %N and a higher C:N ratio; lignin and lignin:N levels were similar, but mass and N loss rates fell below those of *L. maackii* (although 95% confidence intervals of the k values did overlap). In fact, the mass loss rate of *P. calleryana* was most similar to that of *A. rubrum* (Fig. 1a). The N loss rate for *P. calleryana* was higher than that of *A.*

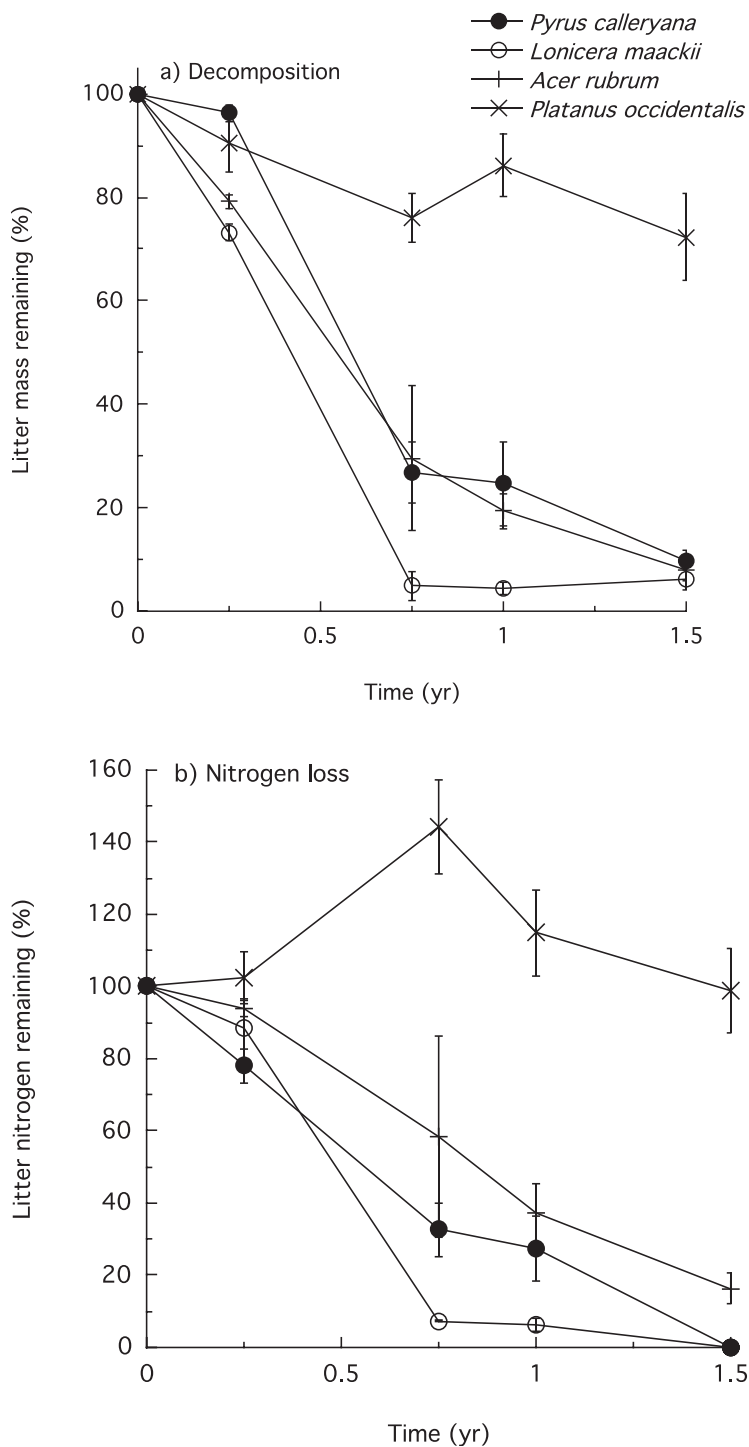


FIG. 1. (a) Decomposition (% initial litter mass remaining) and (b) nitrogen dynamics (% of initial litter nitrogen remaining). Error bars show mean \pm SE.

rubrum and fell below that of *L. maackii*, although none of these were found to differ statistically (Fig. 1b). Overall, decomposition dynamics of *P. calleryana* were most similar to *A. rubrum*.

Despite the similarity of its mass and N loss rates to *P. calleryana*, *A. rubrum* had the lowest %N and the highest C:N ratio in this study, whereas lignin and lignin:N values were both higher than in *P. calleryana*. The %N and C:N ratio fell within the range seen in previous studies, while lignin, lignin:N, and the mass loss rate were slightly higher (Melillo *et al.* 1982; Aber *et al.* 1990, Delaney *et al.* 1996, Blair and Crossley 1988, Carreiro *et al.* 2000, Finzi and Schlesinger 2002, Ball *et al.* 2008, Alexander and Arthur 2014). The %N of *P. occidentalis* did not differ significantly from that of *L. maackii*, and its C:N ratio did not differ significantly from *P. calleryana*, but *P. occidentalis* had a very low rate of mass loss, and its negative *k* value for N loss indicates that it immobilized rather than mineralized N during the decomposition period of this study. This species also had the highest lignin and lignin:N values. Compared to Ostrofsky (1997), N and lignin were higher, C:N was lower, and lignin:N was very similar. Overall, N and C:N ratios were not useful in predicting decomposition rates in this suite of species. Lignin and lignin:N levels were better indicators, but they still did not completely predict these rates.

In summary, *Pyrus calleryana* had %N and C:N ratios that fell in the middle of the ranges for the species examined in this study, while lignin and lignin:N values were similar to those of *L. maackii*. Its mass loss rate was most similar to that of *A. rubrum*, but its N loss rate was somewhat higher. Thus, unlike *L. maackii*, *P. calleryana* appears to have litter decomposition dynamics that are similar to those of *A. rubrum*, an important native tree in eastern North America, and so *P. calleryana* is not predicted to greatly alter leaf litter decomposition in forests in which it invades. This is an example of an introduced species that does not display enhanced decomposition, as noted by Jo *et al.* (2016). A limitation of this study is that it only occurred in one location, and relative decomposition rates might differ at other sites. Also, many studies have shown that mixtures of leaf species do not behave additively (Gartner and Cardon 2004), so it will be important to look at *P. calleryana* litter decomposition dynamics in mixtures with native species. This is particularly important because its

lignin and lignin:N values are similar to *L. maackii*, and *L. maackii* might accelerate mass and N loss rates when it occurs in mixtures (*e.g.*, Blair and Stowasser 2009, Poulette and Arthur 2012).

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