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ABSTRACT. Living trembling aspen (*Populus tremuloides* Michx.) trees were felled to create woody litter in two dense stands 35 to 45 yr old growing on medium textured soils in northern Minnesota. Bole and branch sections were removed at felling and after 2, 3, 4, and 5 yr and evaluated for 10 attributes: bark cover, current-volume specific gravity (CVSG), concentrations of N, P, K, Ca, Mg, Fe, Zn, and Mn. Decline patterns were nonlinear for bark cover, apparently linear for CVSG, exponential or linear for K, P, Ca, Mg, and nondescript for Fe, Zn, and Mn. Branch N declined for 3 or 4 yr, then increased; bole N did not change markedly. Mean times observed or projected to half the original values of declining variables ranged from 1 yr for K in branches to 14 yr for CVSG in boles. Findings enable tentative estimation of large-litter contribution to nutrient turnover in aspen ecosystem studies. FOREST SCI. 29:351–356.

ADDITIONAL KEY WORDS. Nutrient, element, specific gravity, *Populus tremuloides*.

DECOMPOSITION OF WOODY LITTER results from leaching, microbial action, consumption or export by animals, weathering, and other processes. Rates of microbial wood decomposition have been much investigated under controlled conditions but field studies are few (Käärik 1974). Moreover, field studies involving temperate hardwoods have rarely encompassed more than 2 yr (MacLean and Wein 1978).

In middle-aged to mature stands of trembling aspen (*Populus tremuloides* Michx.), estimates of total litterfall range from 1.4 to 3.3 t ha^{-1} of which 13 to 24 percent is woody (Bartos and DeByle 1981, Cragg and others 1977, Crow 1974, Van Cleve and Noonan 1975). The woody component may be underestimated because studies are not always designed to intercept large litter or to include standing dead wood. Conspicuous quantities of large litter amounting to several times the above estimates may build up. Large litter disintegration must be regarded as one of the least known aspects of nutrient dynamics in aspen forests, perhaps in forest ecosystems generally (Aber and Melillo 1980).

To elucidate large litter decomposition and contribution to turnover, living trembling aspen trees were felled to create woody litter. Bole and branch sections were removed at felling and after 2, 3, 4, and 5 yr for observation of change in 10 attributes: bark cover, current-volume specific gravity (CVSG), and concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), and manganese (Mn).

MATERIALS AND METHODS

Two stands within 50 km of International Falls, Koochiching Co., Minnesota, were used. Overstories were nearly pure 35- to 45-yr-old trembling aspen with basal areas of 24.8 and 25.2 m^2 ha^{-1}. Each stand was gridded to make 256 plots of 20 × 20 m dimensions. Based on soil site examinations in eight or more plots

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per stand, the sites were very poorly to moderately well drained. Identified soil series were Indus silty clay loam, Wildwood silty clay loam, and Taylor; soils not fitting the ranges of current series were fine-loamy, mixed, frigid Typic Ochraqualfs, Histic Humaquepts, and Typic Haplaquepts. The soil profiles are described elsewhere.[1]

Each litter source tree came from the center of a plot selected by random process. Equal numbers of such trees were used in each stand. Samples were taken from 12 source trees in yr 0 and from 4–6 trees each in yr 2–5. Each source tree was sampled only once. Felling and sampling were done between mid-June and mid-August.

One bole section 0.5–1 m long was removed from each source tree at the midpoint between ground and top of crown. Two basal branch sections 1 m long were also removed from each source tree, one each from upper and lower crown halves. Bark cover was recorded to the nearest 10 percent for each bole and branch section just before removal. Distance above ground of bole sections, and whether or not branch sections touched the ground, were recorded for yr 2–5 samples.

Volumes of bole and branch sections were obtained with Smalian's formula (Forbes and Meyer 1956). A test with 12 branch sections showed that Smalian volumes differed on average less than 1 percent from volumes obtained by displacement of water in a large graduated cylinder.

Samples were weighed after ovendrying for 2 wk at 70°C, and CVSG determined according to Forbes and Meyer (1956). They were hammer-milled without separation of wood and bark, then Wiley-milled to pass a 40-mesh screen. Nitrogen was determined by the micro-Kjeldahl technique and other elements were determined by emission spectrometry (ES) at dilutions of 2× for K and Mn and 5× for others (1.5 m spark emission spectrometer, direct reader). Samples were analyzed singly except for eight samples systematically selected for analysis in triplicate and two analyzed in duplicate to verify outlying values. Individual analyses of elements fell within 9 percent of duplicate or triplicate means, most much closer.

Statistical analysis consisted of analysis of variance of attribute values by litter type, age, position relative to the ground, and stand. In addition, some attributes were regressed on age by litter type after element concentrations were transformed to natural logarithms (ln). Coefficients of regression were examined by analysis of variance.

Results and Discussion

Litter source trees averaged 13.7 cm dbh, and diameters of bole litter sections, lower crown branch litter sections, and upper crown branch litter sections averaged 7.7 cm, 2.0 cm, and 1.7 cm, respectively (Table 1). Size differences among litter ages were due to sampling variability and the fact that each age's source trees were different. Bole sections for yr 2–5 were in fallen positions between 0 and 10 cm above ground, averaging 4 cm. Most branch sections for yr 2–5 were not touching the ground, but many of these were overtopped by herbaceous and other low foliage. Attribute differences associated with litter resting position and stand were not significant, however, so data were pooled in later analyses.

Bark cover changed little the first two years, then declined rapidly (Table 2). Patterns of decline appeared linear for CVSG and exponential or linear for concentrations of K, P, Ca, and Mg (Fig. 1). Although all slope coefficients for declines of these variables were significant ($P_F < 0.05$), differences among years beyond

[1] Nyberg, P. Undated. US Soil Conservation Service soil site investigation. 10 p. On file at North Central Forest Experiment Station, St. Paul, Minnesota.

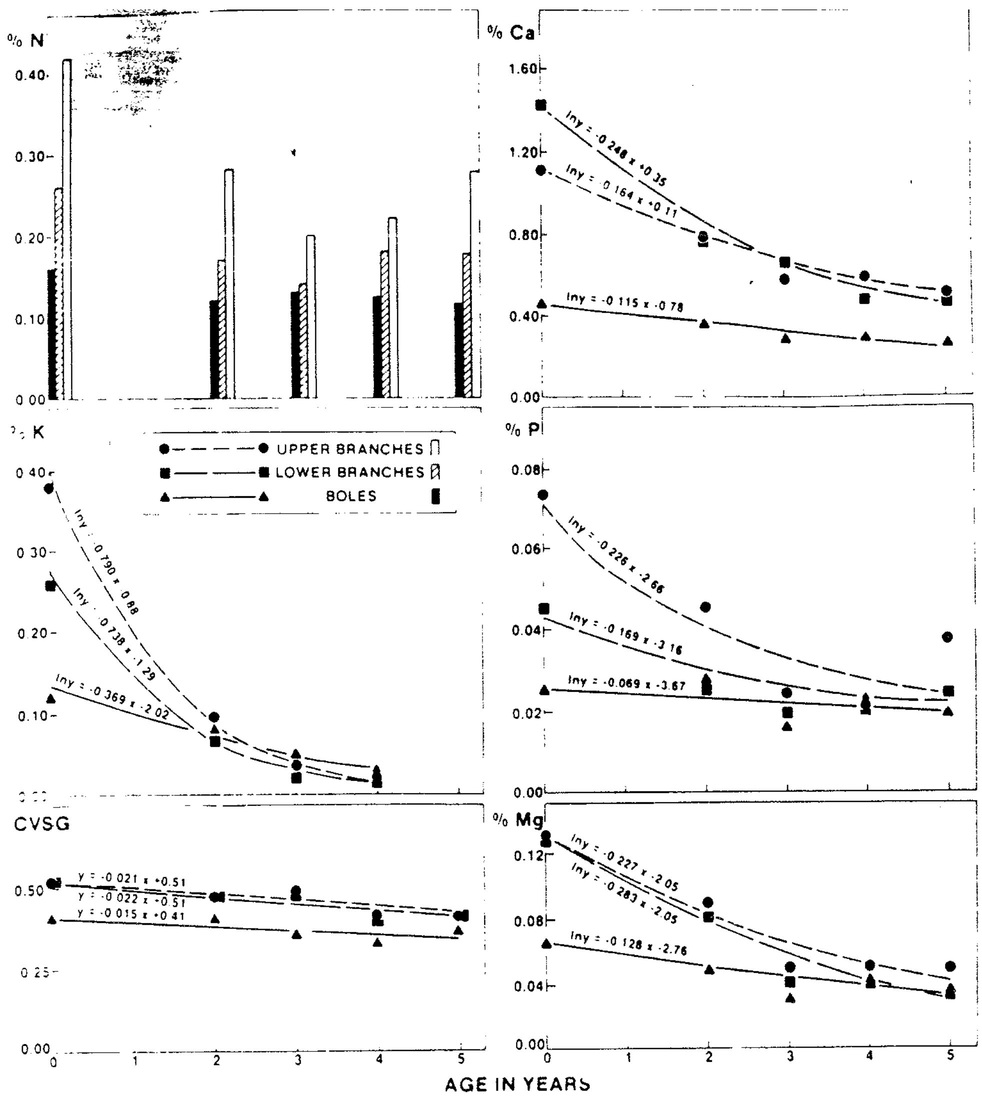

FIGURE 1. Yearly mean values and time trends for current volume specific gravity (CVSG) and concentrations of major elements. Means are based on observations from two stands, totalling 12 in yr 0 and 4–6 in yr 2–5. Regressions are based on individual observations, not yearly means. Standard errors in %N among years for boles, lower branches, and upper branches, respectively, are 0.01 to 0.04, 0.01 to 0.06, and 0.03 to 0.06. Standard errors of estimate (SEE) for bole, lower branch, and upper branch regressions, respectively, are, for CVSG, 0.05, 0.06, and 0.08; for ln %K, 0.330, 0.351, and 0.356; for ln %Ca, 0.299, 0.338, and 0.426; for ln %P, 0.436, 0.386, and 0.431; and for ln %Mg, 0.304, 0.236, and 0.326. When back-transformed from ln to arithmetic scale, SEE must be interpreted as $\hat{y} \times$ SEE or $\div$ SEE.

the second year usually were not. Equation forms are arbitrary and tentative; other forms also fit the data. Fifth-year means for K are not shown in Figure 1 because most of the values were below ES detection limits. Patterns of decline in Fe, Zn, and Mn were nondescript (Table 3).

Changes in N concentration were complex and no attempt was made to describe them mathematically (Fig. 1). In upper and lower branches, N declined for 2 or

TABLE 1. *Dimensions of sample litter and source trees. Yearly means ± standard errors are based on observations from two stands, totalling 12 in yr 0 and 4–6 in yr 2–5.*

Litter age (yr)	Mean dbh of source trees	Mean midlength diameter of sections		
		Bole	Lower branch	Upper branch
	cm		*cm*	
0	13.4 ± 0.7	7.2 ± 0.7	1.7 ± 0.2	1.6 ± 0.2
2	11.8 ± 1.4	7.3 ± 0.6	1.6 ± 0.1	1.4 ± 0.1
3	17.6 ± 3.0	10.1 ± 1.7	2.8 ± 0.4	2.0 ± 0.4
4	12.9 ± 0.4	7.9 ± 0.3	1.7 ± 0.2	1.9 ± 0.1
5	13.7 ± 0.7	8.0 ± 0.8	1.8 ± 0.1	1.9 ± 0.4
Mean	13.7 ± 0.6	7.7 ± 0.4	2.0 ± 0.1	1.7 ± 0.1

more yr then increased; a corresponding pattern in boles may or may not have occurred. Nitrogen is expected to increase over original levels due to importation by micro-organisms (Aber and Melillo 1980). Upward transport by animals from the soil is also possible (Witkamp and Ausmus 1976). Some of the decline probably resulted from bark sloughing, and invading organisms may not have been able to flourish until the wood had aged for several years.

Declines were sharper in branches than boles for all elements including N during its declining phase, and sharper in upper than lower branches for K, P, and N (Fig. 1, Table 3). Bark-to-wood ratio may explain these differences. Bark-to-wood ratio increases with decreasing diameter (Zavitkovski 1971), and element concentrations in bark are usually several times higher than in wood (Johnston and Bartos 1977). Moreover, bark sloughed faster from branches than from boles (Table 2). Some of the yearly variability in declines may be explained by bark-to-wood ratio also. For example, 3-year-old litter, which had the largest average diameters (Table 1) and hence the lowest bark-to-wood ratios, also showed the greatest departures from trends in P, Mg, and Fe (Fig. 1, Table 3).

Observed or projected times to half of original values, termed half times, ranged from 1 to 12 yr for upper and lower branches and from 2 to 14 yr for boles (Table 4). Potassium declined fastest, CVSG slowest.

Few comparisons of results with previous findings are possible. Reports concerning decomposition of hardwood bole litter are few, and those concerning branch litter encompass spans less than 5 yr. Major element levels and declines are roughly similar to those of MacLean and Wein (1978) for trembling aspen

TABLE 2. *Yearly mean values for bark cover. Means ± standard errors are based on observations from two stands, totalling 12 in yr 0 and 4–6 in yr 2–5.*

Litter age (yr)	Mean bark cover of sections		
	Bole	Lower branch	Upper branch
		Percent	
0	100 ± 0	100 ± 0	100 ± 0
2	98 ± 2	96 ± 2	96 ± 2
3	88 ± 12	71 ± 12	71 ± 12
4	53 ± 16	34 ± 11	44 ± 16
5	71 ± 12	56 ± 15	55 ± 14

TABLE 3. Yearly mean concentrations of minor elements. Means ± standard errors are based on observations from two stands, totalling 12 in yr 0 and 4–6 in yr 2–5 for boles and twice as many for branches.

Litter age (yr)	Fe: Bole	Fe: Upper and lower branches	Zn: Bole	Zn: Upper and lower branches	Mn: Bole	Mn: Upper and lower branches
	ppm					
0	110 ± 6	226 ± 18	63 ± 2	114 ± 6	7 ± 1	22 ± 1
2	61 ± 13	89 ± 9	46 ± 4	75 ± 10	8 ± 1	18 ± 2
3	88 ± 6	110 ± 7	44 ± 7	64 ± 4	6 ± 1	10 ± 2
4	77 ± 7	90 ± 7	46 ± 8	54 ± 4	6 ± 2	10 ± 1
5	82 ± 14	106 ± 12	46 ± 4	75 ± 12	4 ± 1	9 ± 1

branches during two yr except for lower levels of N here. The branch CVSG half time of 12 yr here is more than three times the corresponding value in the foregoing report, but the authors suggest that values derived from a short period are likely to be underestimated. The CVSG half time for branches here is 5 yr more than corresponding values estimated by a different method for four other temperate hardwoods (Swift and others 1976).

Blow-down of living trees is the form of litter production represented in the present study. However, most large aspen litter is produced by death of branches

TABLE 4. Estimated half times of declining variables. Means exceeding 5 yr are projections.

Variable	Litter type	Mean half time (nearest yr)[a]
Bark cover	Upper branch	4
	Lower branch	4
	Bole	6
Current volume specific gravity	Upper branch	12
	Lower branch	12
	Bole	14
P	Upper branch	3
	Lower branch	5
	Bole	11
K	Upper branch	1
	Lower branch	1
	Bole	2
Ca	Upper branch	4
	Lower branch	3
	Bole	6
Mg	Upper branch	3
	Lower branch	2
	Bole	6

[a] Bark cover means based on linear equations obtained when yr 0 data were omitted. Remaining means based on equations in Figure 1.

or trees from causes that allow them to remain standing. Whether elements are appreciably translocated among woody tissues prior to standing death is unknown. At least for CVSG, declines reported here may apply to standing material as well: Swift and others (1976) found little difference in density declines between branch litter on the ground and that in tree crowns.

In conclusion, the changes detailed here may not be equivalent to complete decomposition and element transfer between ecosystem compartments. However, the findings indicate upper limits of several important transfers and provide a basis for tentatively estimating them in aspen ecosystem studies.

Literature Cited

Aber, J. D., and J. M. Melillo. 1980. Litter decomposition: Measuring relative contributions of organic matter and nitrogen to forest soils. Can J Bot 58:416–421.

Bartos, D. L., and N. V. DeByle. 1981. Quantity, decomposition, and nutrient dynamics of aspen litterfall in Utah. Forest Sci 27:381–390.

Cragg, J. B., A. Carter, C. Leischner, E. B. Peterson, and G. N. Sykes. 1977. Litter fall and chemical cycling in an aspen (*Populus tremuloides*) woodland ecosystem in the Canadian Rockies. Pedobiol 17:428–443.

Crow, T. R. 1974. Temporal and spatial patterns of pretreatment litter production in site 1 and the control area. *In* The Enterprise, Wisconsin, Radiation Forest: Preirradiation ecological studies (T. D. Rudolph, ed), p 105–113. US Atomic Energy Comm TID-26113. 150 p.

Forbes, R. D., and A. B. Meyer, eds. 1956. Forestry handbook. Ronald Press Co., New York. Pagination not continuous.

Johnston, R. S., and D. L. Bartos. 1977. Summary of nutrient and biomass data from two aspen sites in western United States. USDA Forest Serv Res Note INT-227. 15 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Käärik, A. A. 1974. Decomposition of wood. *In* Biology of plant litter decomposition. vol 1 (C. H. Dickinson and G. J. F. Pugh, eds), p 129–174. Academic Press, London. 146 p.

MacLean, D. A., and R. W. Wein. 1978. Weight loss and nutrient changes in decomposing litter and forest floor material in New Brunswick forest stands. Can J Bot 56:2730–2749

Swift, M. J., I. N. Healey, J. K. Hibberd, J. M. Sykes, V. Bampoe, and M. E. Nesbitt. 1976. The decomposition of branch-wood in the canopy and floor of a mixed deciduous woodland. Oecologia 26:139–149.

Van Cleve, K., and L. L. Noonan. 1975. Litter fall and nutrient cycling in the forest floor of birch and aspen stands in interior Alaska. Can J Forest Res 5:626–639.

Witkamp, M., and B. S. Ausmus. 1976. Processes in decomposition and nutrient transfer in forest ecosystems. *In* The role of terrestrial and aquatic organisms in decomposition processes (J. M. Anderson and A. Macfadyen, eds), p 375–396. Blackwell, Oxford. 474 p.

Zavitkovski, J. 1971. Dry weight and leaf area of aspen trees in northern Wisconsin. *In* Forest biomass studies, p 193–205. Univ Maine, Orono, Life Sci Agric Exp Stn Misc Publ 132. 205 p.