INTERNAL REPORT 77

ENERGY FLOW AS DETERMINED BY RATES OF LITTER DECOMPOSITION

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INTRODUCTION

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Litter decomposition is a dissimilation process mediated by a succession of organisms and associated enzyme systems (Alexander 1971, Halworth and Crawford 1965). Of primary importance are the hydrolytic and oxidative processes which characterize the conversion of raw litter carbon to carbon dioxide and stabilized organic matter or humus. The mineralization of organic carbon to carbon dioxide represents a major carbon loss or output route whereas humus formation may be regarded as a key carbon reservoir or conservation pathway.

The decomposition process is initiated prior to litter fall and may be recognized by the physical-chemical changes which the forest canopy undergoes. The decomposition which occurs on live standing trees may be measured in part by net loss in foliage weight and by changes in chemical constituents of the needles. However, it should be recognized that the breakdown of canopy carbon is extremely difficult to follow in terms of tree accessibility problems and an acceptable data retrieval procedure. At the soil surface the fallen needles undergo an initial rapid mineralization of organic carbon (Jenkinson 1965). Subsequently, decomposition occurs at a much slower rate and my indeed attain an approximate steady state. These decomposition rate trends may be depicted as shown in Figure 1.

It is evident that when attempting to simulate the rate of the net change in energy of input litter carbon that such rates may be expressed for various carbon species and also for more stabilized humus fractions. Various investigators (Olson 1963) have expressed the rate of loss from all reservoirs and related accumulation of organic matter by the parameter k (carbon loss per unit of time). It follows that composite forest litter samples will exhibit variable experimental k values depending upon the degree to which decomposition has previously proceeded under field conditions. For example, under "climax" or steady state conditions litter samples should exhibit slow turnover rates characteristic of phases b, σ and d whereas canopy needles and possibly newly fallen needles will haver higher values peculiar to phase a.

The influence of temperature, moisture and pH on rates of decomposition is well documented. Suffice to say that such factors also influence the turnover rate of litter carbon.

The primary objectives of the Oregon State and University of Idaho research team was: 1. to measure the net weight and chemical composition of surface litter, and 2. to determine the net loss or output of carbon by decomposition of litter organic carbon.

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METHODS

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Site Selection and Sampling Design

The initial phases of the study were carried out at the H. J. Andrews Experimental Forest. Sampling sites were selected in stands already being studied by the blome investigators. At four randomly selected litter traps, forest floor samples were obtained from a cluster of four 30.48 cm square plots located 1 m from the center of the trap. The forest floor was sampled by layers of horizons representing various stages of human development. In two reference stands on Watershed #10 samples were collected along a transect in the buffer zone around the stand. Litter samples were dried and weighed to determine mase in kg/ha. After grinding (Wiley Mill) to give a homogeneous mix, samples were stored in cardboard containers at 5°C.

Determination of Rates of Carbon Turnover

Ten gram samples of the stored litter samples were placed in respiration flasks and the moisture level adjusted to 60 percent of the litter water saturation value. The flasks were then placed in an incubator at a temperature of 25° C \pm 1°C. Time course interval and cumulative recoveries of evolved carbon dioxide in sodium hydroxide and titration of the resulting carbonates. Data was expressed as mgC evolved as carbon dioxide per unit time interval.

In addition to the above procedure, carbon dioxide evolution and oxygen uptake were measured by means of an Electrolytic Respirometer (McGarity et al. 1958).

Total Carbon and Persulfate Oxidizable Carbon

Total carbon was determined by wet combustion using acidified dichromate (Walkley and Black 1934). Water soluble carbon was performed by persulfate oxidation of litter extracts and solid litter samples (Gilmour et al. 1961).

RESULTS

Observed Decomposition Rates

Reference to the litter decomposition trends shown both in Figures 2 and 3 show that approximately 7 percent of the input carbon from stands III and IV has evolved as carbon dioxide over the three-month experimental period. This must be regarded as an extremely slow turnover rate and would indicate that the surface litter had reached stabilization prior to sampling. Essentially similar rate trends were obtained for sites 1, 3, 6 and 9 forest stand II, and sites 2, 6, 7 and 8 - forest stand VIII.

The data shown in Tables 1 and 2 again attest to slow carbon turnover rate. In stand 111, the composite litter sample obtained at site 1 exhibited the slowest rate of carbon turnover whereas sites 2, 5 and 6 showed approximately similar decomposition rates. An essentially similar decomposition trend was observed for stand IV.

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The short term oxygen uptake and carbon dloxide evolution values measured by means of the electrolytic respirometer were quite similar to the long term trends obtained by conventional absorption in alkali. Representative data are shown in Table 3.

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Water Soluble Carbon (P O C)

The high degree of litter stabilization noted previously decreased the effectiveness of the water soluble carbon fraction as a predictor of carbon dioxide output. The following percent persulfate oxidizable carbon were obtained for the various test stands: 11 - 12, 111 - 13, 1V - 10, VI - 11 and VIII - 12. Approximately equal values were obtained attesting to the similar maturity of the litter samples. Interestingly enough, Broadfoot and Pierre (1939) obtained water soluble carbon values for Scrub and Pine pine needles in the same range (10-112) as was observed in the present study.

Calculation of Carbon Losses

Warlous approaches and formulas have been used to determine decay rates of forest litter. These have been reviewed by Olson (1963). Ordinarily, the net rates of change for a specific period of time may be modeled in terms of an Texponential decay equation as follows:

$$k = \frac{2,303}{t} \frac{\log C_o}{C}$$

Half-life =
$$t \frac{1}{2} = \frac{0.693}{k}$$

Under simulation conditions the decay rates obtained for the H. J. Andrews forest litter samples are based on the following assumptions:

1. Input carbon is the carbon contained in the respiration flask.

2. No additional input of carbon takes place.

- No carbon losses occur as a result of surface runoff and leaching.
- 4. Major loss route is via oxidation of litter carbon to carbon dioxide.
- 5. The litter has reached a steady state and constant reaction (k value).

The variable reaction rates shown in Table 4 indicate that the litter samples under study have not attained a true steady state. In consequence, first order kinetics and the related calculation of decay rates applicable

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to such litter samples cannot be regarded as valid predictable values. However, the half-life calculation based on the time interval between 10 and 12 weeks may be regarded as the minimum time for turnover of the input organic carbon.

At lower temperatures, the 3.0 year half-life would at least double in value and for the complete decay of these samples, ten-year decay intervals would not overstate the decomposition time period.

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SUMMARY

- 1. A methodology has been developed for the determination of litter decomposition rates.
- 2. Decomposition rates for five H. J. Andrews forest litter samples have been determined.
- 3. All samples exhibited an extremely slow carbon turnover rate but on the basis of variable reaction, rates had not attained a constant decomposition rate.
- 4. Under optimum conditions, a minimum half-life of 3.0 years is proposed until such time as additional information is obtained.

REFERENCES

- ALEXANDER, MARTIN. 1961. Introduction to soil microbiology. John Wiley and Sons, Inc. New York. p. 472.
- BROADFOOT, W. M., and W. H. PIERRE. 1939. Forest soil studies. I. Relation of rate of decomposition of tree leaves to their acidbase balance and other chemical properties. p. 329-348.
- GILMOUR, C. M. et al. 1961. Persulfate oxidizable carbon and B.O.D. as a measure of organic pollution in water. Proc. Indust. Waste Conference. 106:143-149.
- HALLWORTH, E. G., and D. V. CRAWFORD. Ed. 1965. Experimental Pedology. Butterworths, London. p. 413.
- JENKINSON, D. S. 1965. Studies on the decomposition of plant material in soil. I. Losses of carbon from ¹⁴C labelled ryegrass incubated with soil in the field. Soil Sci. 16:104-115.
- McGARITY, J. W., C. M. GILMOUR and W. B. BOLLEN. 1958. Use of an electrolytic respirometer to study denitrification in soil. Canadian Journal of Microbiology. 4:303-316.

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OLSON, J. S. 1963. Energy storage and the balance of producers and decomposers in ecological systems. Ecology. 44:322-330.

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WALKLEY, A., and BLACK, T. A. 1934. An examination of the Degtjaroff Method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37:29-38.

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		Sa	ampling Site				
Time	-1	2	5	6	avg.		
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2	10.3	17.7	13.2	12.9	13.5		
4	16.0	24.6	19.9	19.9	20.1		
6	19.9	28.6	23.3	24.4	24.1		
8	22.9	31.6	26.3	28.5	27.3		
10	26.0	34.0	29.0	32.4	30.4		
12	29.0	36.3	31.6	36.7	33.4		

Table 1. Losses of surface litter carbon as carbon dioxide (Stand III)^a

^aData expressed as mg C as CO₂/gm of litter

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	<u></u>	Sa	mpling Site		
Time		2	7	8	avg.
2	15.0	13.8	12.2	15.8	14.2
4	21.5	20.0	19.0	23.1	20.9
6	25.7	24.2	22.9	27.6	25.1
8	29.3	28.6	26.5	32.1	29.1
10	32.6	32.7	29.6	36.4	32.8
12	35.9	36.8	32.5	40.7	36.5

Table 2. Losses of surface litter carbon as carbon dioxide (Stand IV)^a

^aData expressed as mg C as CO₂/gm of litter.

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Site	mg C as CO ₂ per 10 gm litter			
	Cabinet incubator	Electrolytic Respirometer		
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1	65	85		
2	115	108		
5	82	80		
6	<u>85</u>	<u>84</u>		
avg.	86	89		
IV				
1	95	96		
2	84	83		
7	74	74		
8	<u>90</u>	<u>93</u>		
avg.	85	86		

Table 3.	Comparative carbon dioxide evolution values obtained wi	
-	conventional cabinet incubation and the electrolytic	
	respirometer [®]	

^aCumulative CO₂ values over a 6 day period.

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Stand	Time	Half-life (weeks)	k value
111			
	2	45.3	D.0150
	4	60.3	0.0110
	6	75.3	0.0090
	8	87.7	0.0080
	10	99.0	0.0070
	12	108.3	0.0060
IV			
	2	42.8	0.0160
	4	59.2	0.0120
	6	70.7	0.0009
	8	81.5	0.0080
	10	91.2	0.0076
	12	99.0	0.0070
Half-	life calculated	for 10-12 week period	in years
111 10-	12	3.7	0.0035
IV 10-	12	3.0	0.0044

Table 4. Litter half-life determinations

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Figure 1. Decomposition rate fluctuations as a function of litter stabilization status, where a = initial rapid mineralization of litter carbon, b, a = slow turnover of litter carbon, and d = climax or steady state condition.

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Figure 3. Percent retention of surface litter carbon over a 12-week period (Stand IV).

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