INTERNAL REPORT 161

TERRESTRIAL DECOMPOSITION 1973:

A SYNOPSIS

Robert Fogel
USDA Forest Service

Kermit Cromack
Oregon State University

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ABSTRACT

This report describes decomposition studies conducted in the H. J. Andrews Forest, Oregon in 1973. Changes in weight loss and nutrient content of leaves, cones, branches, and bark of Douglas-fir and leaves of big-leaf maple, vine maple, Rhododendron, red alder, sword fern Oregon oak, and Chinkapin were recorded in a variety of habitats ranging from wet to dry. Weight loss is related to the moisture content of the forest floor and percent lignin content of the material. Decomposition is slowed in the dry summer months, and there are differences in weight loss of substrates between habitat types.

INTRODUCTION

Nutrient cycling and energy flow are two ecological processes which de-lineate the structure and dynamics of ecosystems. In terrestrial ecosystems an important set of energy flows and nutrient transfers result from litter-fall and its subsequent decomposition.

Macfayden (1963), Whittaker (1970) and Odum (1971) estimate that from 70 to 90 percent of terrestrial net primary production is ultimately utilized by decomposers. Litterfall and litter decomposition also account for a substantial portion of internal nutrient cycling in terrestrial ecosystems. In the mesic, oak dominated forest floor studies by Carlisle et al. (1966a; 1966b), litterfall accounted for approximately 60 percent (mean of phos-phorus, potassium, calcium, and magnesium) of nutrient return to the forest floor. In a similar study on the H. J. Andrews Experimental Forest, Abee and Lavender (1972) found 72 percent (mean of phosphorus, potassium, calcium, and magnesium) of nutrient return in litterfall of a 450 year-old Douglas-fir forest.

Considerable litter biomass and nutrient capital can accumulate in the forest floor. Youngberg (1966) reported estimates of accumulated litter biomass in Oregon Coast Range Douglas-fir stands ranging from 23.2 metric tons ha^{-1} in a stand with no shrub understory to 86.0 metric tons ha^{-1} with a salmon-berry-sword fern understory. He also reported data on N, P, K, Ca, Mg, and S. Nitrogen accumulation, for example, in the forest floor ranged from 202 kg in the Douglas-fir stand with no shrub understory to 1345 kg in the stand with a salmonberry-sword fern understory.

In a recent review paper, Witkamp (1971) discussed litter decomposition and nutrient loss as a complex interaction of biotic factors (microorganisms, soil animals, chemical content of litter) and abiotic factors (temperature, moisture). Soil animals and microorganisms are synergistic in their litter decomposition roles, because feeding upon litter by soil animals enhances decomposition rate and stimulates growth of microbial populations in litter (Mafayden 1961, 1963; Witkamp and Crossley 1966). Soil fauna are dependent upon litter microflora for enzymatic degradation of litter, since they lack the enzymes necessary to biodegrade all but the simplest forms of structural carbohydrates (Nielson 1962).

Temperature and moisture are important environmental variables influencing microbial respiration rates, nutrient transformation rates, and the activities of soil animals (Witkamp 1971). The forest floor environment is subject to extreme fluctuations in temperature and moisture. For a given location, soil and litter respiration will double for each 10°C increment ($Q_{10} = 2$) within the normal range of field temperatures (Drobnik 1962; Wiant 1967). A $Q_{10} = 2$ exists for respiration of many arthropods (D. A. Crossley, pers. comm.) and can occur for litter respiration (Witkamp 1969).

Moisture has the greatest effect on litter decomposition either when it is low enough to adversely affect litter organisms or when it is present sufficiently in excess to hinder oxygen diffusion (Alexander 1961). Witkamp (1966) observed litter moisture to significantly affect forest floor respiration rate. He found evidence for microbial inhibition at low moisture levels; conversely, rewetting of dry litter stimulated forest floor respiration considerably. The lower limit for bacterial activity is probably -80 bars to -100 bars (Griffin 1972). Some fungi, however, can tolerate a litter water potential as low as -400 bars; most fungi have their most rapid growth at water potentials exceeding -60 to -80 bars (Griffin 1972). Growth of soil Streptomyces becomes neglibible at -80 bars (Griffin 1972).

Chemical nature of the substrate is also important in influencing litter decomposition rate. The carbon/nitrate (C/N) ratio and lignin content of litter are two chemical-structural features which influence its decomposition (Alexander 1961; Bollen 1953). The resistance to microbial attack of litter materials high in lignin-cellulose rather than available nitrogen controls the rate of decomposition of such litter (Bollen 1953). In Douglas-fir both woody materials and non-woody litter such as needles are high in lignin and also have high C/N ratios.

OBJECTIVES

The objectives of our research during 1973 were: (1) Determine temporal changes in weight loss and nutrient content, (2) Measure litter moisture and temperature as abiotic environmental factors necessary for modeling decomposition, (3) Test the hypothesis that substrate chemical quality affects decomposition, (4) Test the M. A. Strand-C. Grier decomposition model, (5) Test the hypothesis that decomposition rate will reflect differences in habitat types on the H. J. Andrews environmental grid.

METHODS

Gravimetric soil moisture of the forest floor and A_0, as percent dry weight, was determined after drying samples at 60° C until a constant weight was obtained. Ten samples of each layer were collected whenever a stand was visited, usually biweekly during the summer and monthly fall and winter after field capacity was reached. This information has been keypunched and filed with the Oregon Data Bank.

Temperature monitoring on Reference Stand 2 (RFS 2) was initiated in August using a battery powered Grant miniature temperature recorder, Model D. Twenty-eight thermistor probes were polled hourly and recorded on a pressure sensitive strip chart. Accuracy for the 50°C range being recorded was ± 2%. The recorder was housed in a central shelter with probes distributed among five meteorological stations and four decayed logs. Each station had an air temperature

probe protected under an insulated A-frame shield at 1 m above the ground
surface, one probe placed horizontally in the litter layer, one at the
forest floor-mineral soil interface, and one buried at 5 cm below the inter-
face. In addition, two probes were inserted 10 cm in each of four decayed
logs. Resulting data was reduced to hourly means for each substrate and
filed with the Oregon Data Bank.

Litter substrates used in the decomposition study were placed in consecutively
numbered 20 x 20 cm nylon mesh bags (Crossley and Hoglund 1962). Mesh size
was 1 mm, which was small enough to contain Douglas-fir (Psme) needles, yet
large enough to permit aerobic microbial activity and free entry of small
soil animals. Substrates studied (abbreviation, Zobel et al. 1973a) were:
(1) Green Psme leaves, *Pseudotsuga menziesii* (Douglas-fir), (2) Freshly fallen
Psme leaves, (3) Psme ♀ cones, (4) Psme bark, (5) Psme branches, ca 1-1.5 cm
diameter, (6) Acma leaves, *Acer macrophyllum* (Bigleaf maple), (7) Acci leaves
Acer circinatum (Vine maple), (8) Rhma leaves, *Rhododendron macrophyllum*
(Rhododendron), (9) Alru leaves, *Alnus rubra* (Red alder), (10) Pomu leaves
Polystichum munitum (Sword fern), (11) Quga leaves, *Quercus garryana* (Oregon
oak), (12) Cach leaves, *Castanopsis chrysophylla* (Castanopsis or Chinkapin).

Five g of leaves were placed in the leaf litter bags. Two cones, weighing
approximately 20 g, were placed in the litterbags containing cones. A 20 g
small branch section was placed in each branch litterbag and between 30 and
100 g of bark, owing to variability in specific gravity, was placed in each
litterbag containing bark. The completed litterbags were then used in three
different experiments. Green Psme leaves, cones, branches, and bark were
used to test for differences in decomposition rate between reference stands
on the H. J. Andrews Experimental Forest. Three replicated habitat types
(Dyrness and Franklin, in press) or treatments were selected (Table 1), with
each replicate designated as an individual site for each habitat type. Green
Psme leaves were placed on six sites, Psme, cones, branches, and bark on nine
sites, and the remaining substrates placed on RFS 2 were used to develop a
lignin model. The Psme substrates were also placed on RFS 1 (Psme/Hodi habitat
type) for comparitive purposes, as this habitat is the driest of the low
elevation types on the Andrews Forest.

Within each replicate site of each habitat type, 15 bags of each substrate
were placed 1 m apart on the forest floor in rows which were 1 m apart.
If more than one Psme substrate was used per site each point on a row had
one bag of each substrate. In the lignin study on RFS 2 each substrate was
restricted to a row of its own.

Bags containing non-woody substrates were destructively sampled seasonally
by randomly selecting 15 litterbags of each substrate per site for analysis
and weight loss measurement. Woody substrates were similarly sampled six
months after the study started.

After collection, litterbags were dried at 50°C to constant weight. The
substrate was then removed, weight loss determined, and Wiley mill ground
to pass a 40 mesh screen. Samples were then submitted to the central chemical
testing laboratory for nutrient analysis. Total nitrogen was determined using

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the micro-Kjeldahl method, percent carbon after ignition and absorption on a Burrell Carbotrane, and K, P, Ca, Mg, Mn, Fe, Cu, B, Zn, Al after ashing and dissolution in HCl on a Jarrell-ash Model 750 atom counter AC spark emission spectrophotometer (Noonan and Holcombe, in press). Cellulose and lignin content were determined using the detergent method (Van Soest 1963).

RESULTS AND DISCUSSION

Decomposition, defined as the reduction by organisms, of dead organic material to carbon dioxide and soluble products containing minerals, is very complex involving both biotic and abiotic agents. While decomposition is theoretically influenced by many different abiotic or environmental factors, model construction is restricted pragmatically to those factors for which information or "Best guess" is available. As a first approximation, temperature and moisture are considered the dominant abiotic environmental factors due to the drought conditions present in Western Oregon during the period of optimum temperature for growth.

It was felt that the temperature data available for air (1 m) and soil (20 cm) did not offer a closeenough approximation of forest floor conditions to be useable in modeling decomposition (Zobel et al. 1973a). Consequently, after some delay by the manufacture, a 28 channel Grant temperature recorder was installed on RFS 2 in August. When a temperature conversion model relating air (1 m) and forest floor temperatures becomes available, air temperature data from any of the reference stands could be used to drive the decomposition model developed by M. A. Strand and C. Grier.

Gravimetric samples collected biweekly or monthly were used to represent moisture conditions of the forest floor and A_0 horizon in the various sites under study. After plotting forest floor moisture content for RFS 2 and weekly precipitation collected at the H. J. Andrews climatic station (R. Fredriksen pers. comm.) the buffering capacity of the forest floor is clearly demonstrated (Figure 1).

Preliminary results from the approximately eight month old litter bag experiments show some interesting trends. Cumulative weight loss data for green Psme leaves, presented for RFS 2, in all sites showed almost no weight change during the summer months (Figure 2). This is the expected result of the low precipitation (Figure 1) during this period. Similar but not as pronounced examples of this seasonal weight loss pattern have been reported by Olson and Cossley (1963).

Weight loss data for green Psme leaves (Figure 3) but not cones, branches, and bark, (Figure 4) showed significant differences between habitat types in weight loss during the first year. Longer term trends may become evident in the planned three year studies for these substrates. Maximum plant moisture stress of understory conifer in various habitat types on the H. J. Andrews Forest was found to be closely correlated with the position of each community along one axis of a vegetation ordination (Zobel et al. 1973b). There exists a possible correlation between decomposition rate of needle litter and moisture stress of understory conifers in different habitat types. This work demonstrates that the litter bag approach can provide a fine enough resolution of moisture

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effects upon decomposition. Another possibility is that the forest floor
of various habitats have other characteristics affecting litter decomposition,
such as the different chemical quality of understory litter. The small
differences in litter depth of the various habitat types and potential
moisture reserve would not be reflected in the weight loss data. Consequently,
differences in forest floor weights reported by Youngberg (unpublished data)
may be due to variations in chemical quality of litter as well as to habi-
tat moisture differences affecting carbon loss. Recent data (C. Grier, pers.
comm.) has shown that approximately one-half of current leaf litter input
on the old-growth Douglas-fir habitat types is due to understory vegetation--
thus enhancing forest floor mixed litter composition differences. Plant
moisture stress would continue to reflect the larger water storage capacities
in the effective rooting depth of various habitat types.

Differences in weight loss between Douglas-fir needle and woody-litter sub-
strates (Figures 3 and 4) could be interpreted as representing a difference
in weight loss due to substrate quality. When lignin content was used to
predict weight loss (Figure 5) a better correlation was found, $r^2 = 0.56$,
than when C/N was used, $r^2 = 0.49$. The poor fit of Alru to the lignin re-
gression line may be due to in part its higher nitrogen content compensating
for its lignin content. At this time an adequate explanation for the de-
viation of Pomu from this line cannot be advanced. Cromack (1972) working
with a smaller number of species also found lignin content to be a better pre-
dictor of weight loss than C/N.

Litter nutrient data is presently being obtained and will be available in a
later internal report during 1974.

PROPOSED RESEARCH

From 1974 through 1975 data will be obtained for decomposition rate and
turnover time of litter components (leaves and woody litter) including carbon
and other nutrients such as N, P, K, Ca, etc. These data are necessary for
comparison of decomposition rates among Biomes and for synthesis of decomposi-
tion data within the Coniferous Biome. Data for factors regulating litter
decomposition rates, i.e. chemical quality of substrate (lignin, cellulose,
C/N, polyphenols) and abiotic environmental information (litter temperature
and moisture content) will continue to be collected. Nitrogen dynamics such
as nitrogen fixation and nitrification will also be studied. Nutrient con-
tent and weight loss data resulting from our study of understory species will
also be useful in modeling succession and nutrient cycling following harvest
of Watershed 10.

During 1973 several additional sites were added to our study. Sites added
within Oregon included an east-west transect composed of Cascade Head
Experimental Forest on the coast (mixed Douglas-fir and red alder site),
William Finley Natural Area near Corvallis (Oregon oak closed forest),
H. J. Andrews Experimental Forest (low elevation Douglas-fir site), and
Pringle Butte Natural Area near Lapine in central Oregon (ponderosa pine
stand). A north-south transect of Douglas-fir sites including Bull Run
Watershed in Clackamas County, Wildcat Mt., H. J. Andrews Experimental
Forest and Coyote Creek drainage near Tiller was also established. Wildcat
is a high elevation (4000 ft) site dominated by Abies with some Douglas-fir
present. Studies were also instigated in cooperation with R. Waring,

R. Emmingham and with the generous support of the U.S. Forest Service on a Biome-wide grid. These additional sites were located near Priest River, Idaho (hemlock and Douglas-fir), Logan, Utah (spruce and Abies), Flagstaff, Arizona, (ponderosa pine) and Ft. Collins, Colorado (lodgepole pine). Results from our and cooperating scientists work on the Oregon and Biome-wide grids will facilitate our characterization of the decomposition subsystem on a regional basis. This characterization will be more complex than that of other Biomes due to the diversity of habitat types and climates within the Coniferous Forest Biome.

There exists a need to expand decomposition ecology research to an examination of the role of important microbial components (mycorrhizal fungi, non-mycorrhizal saprobic fungi, nitrifying bacteria) and important soil arthropods (feeding rates of slugs, millipedes, mites, etc.). Particularly important is some data on root decomposition for modeling erosion processes and belowground nutrient cycling. Contemplated work on the seasonal dynamics of root biomass and car- bohydrate pools in roots and other vegetation components will help meet this need.

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Table 1. H. J. Andrews Experimental Forest study sites.

Habitat type[a] (treatment)	Replicate 1	Replicate 2	Replicate 3
Tshe/Pomu-Oxor (wet)	Ref. Stand 7	near lower road off Watershed 10	between Ref. Stands 2 and 17
Tshe/Rhma/Bene (intermediate)	Ref. Stand 2	Ref. Stand 17	between Ref. Stands 2 and 17
Tshe/Cash (dry)	ridge crest opposite Ref. Stand 6	Ref. Stand 16	300 yards west of Ref. Stand 16
Psme/Hodi (very dry)	Ref. Stand 1	none	none

[a]Bene = Berberis nervosa
Cach = Castanopsis chrysophylla
Hodi = Holodiscus discolor
Oxor = Oxalis Oregnana
Pomu = Polystichum munitum
Psme - Pseudotsuga menziesii
Rhma = Rhododendron macrophyllum
Tshe = Tsuga heterophylla
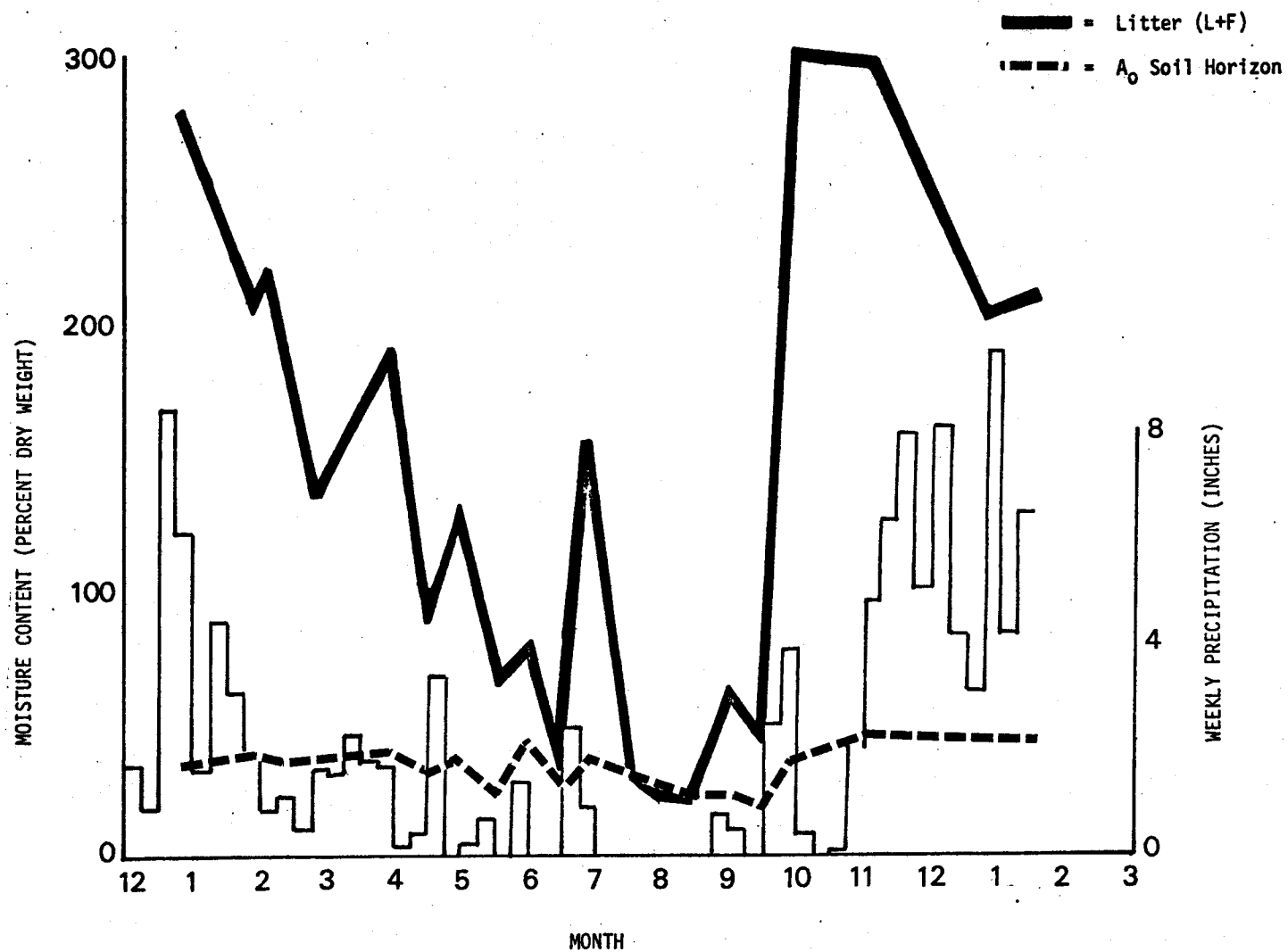
Figure 1. Moisture content of forest floor, Reference Stand 2, and A_0 layer in relation to weekly precipitation.
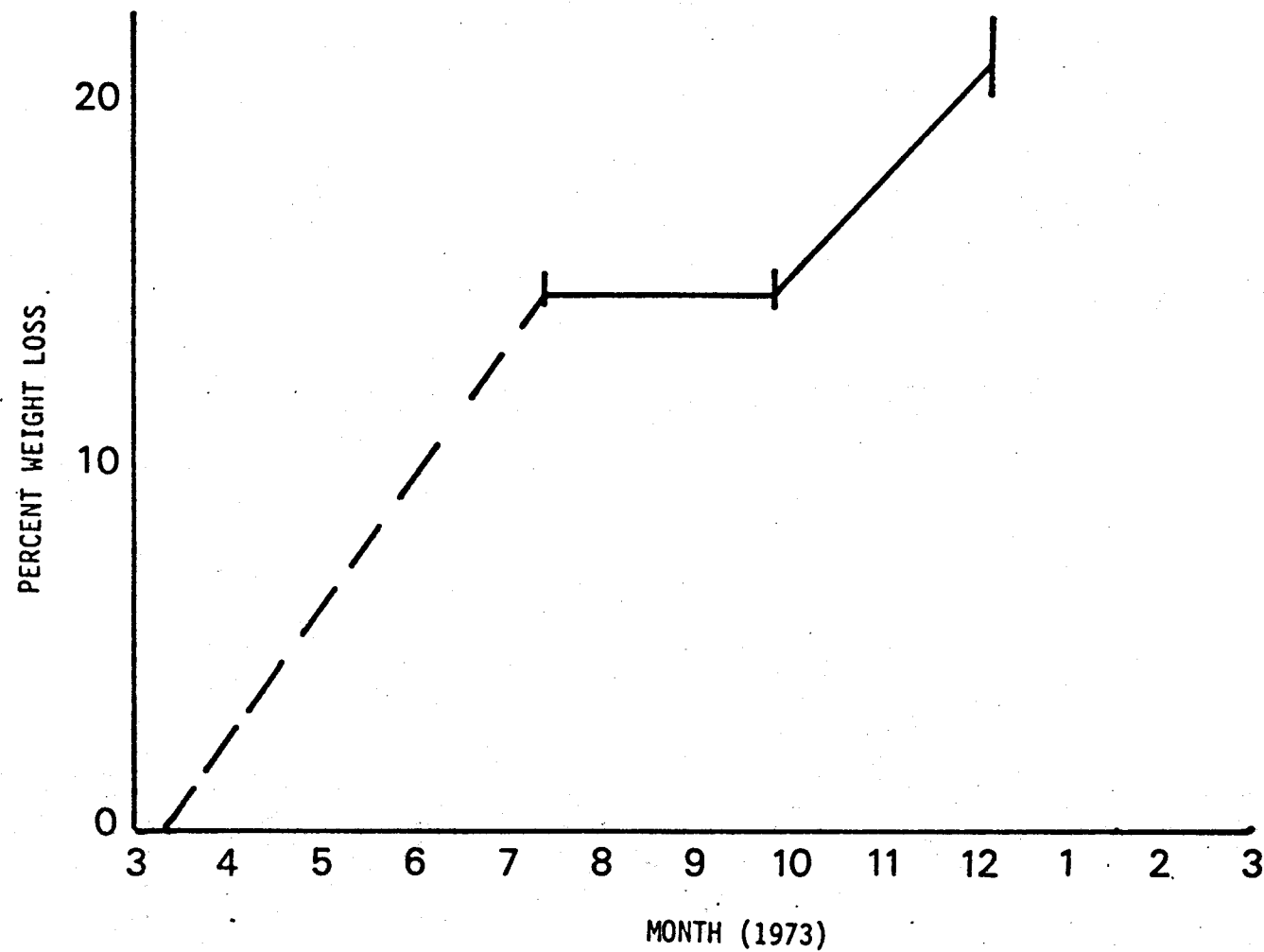
Figure 2. H.J. Andrews, Reference Stand 2, weight loss of Psme needles, 95% confidence intervals.
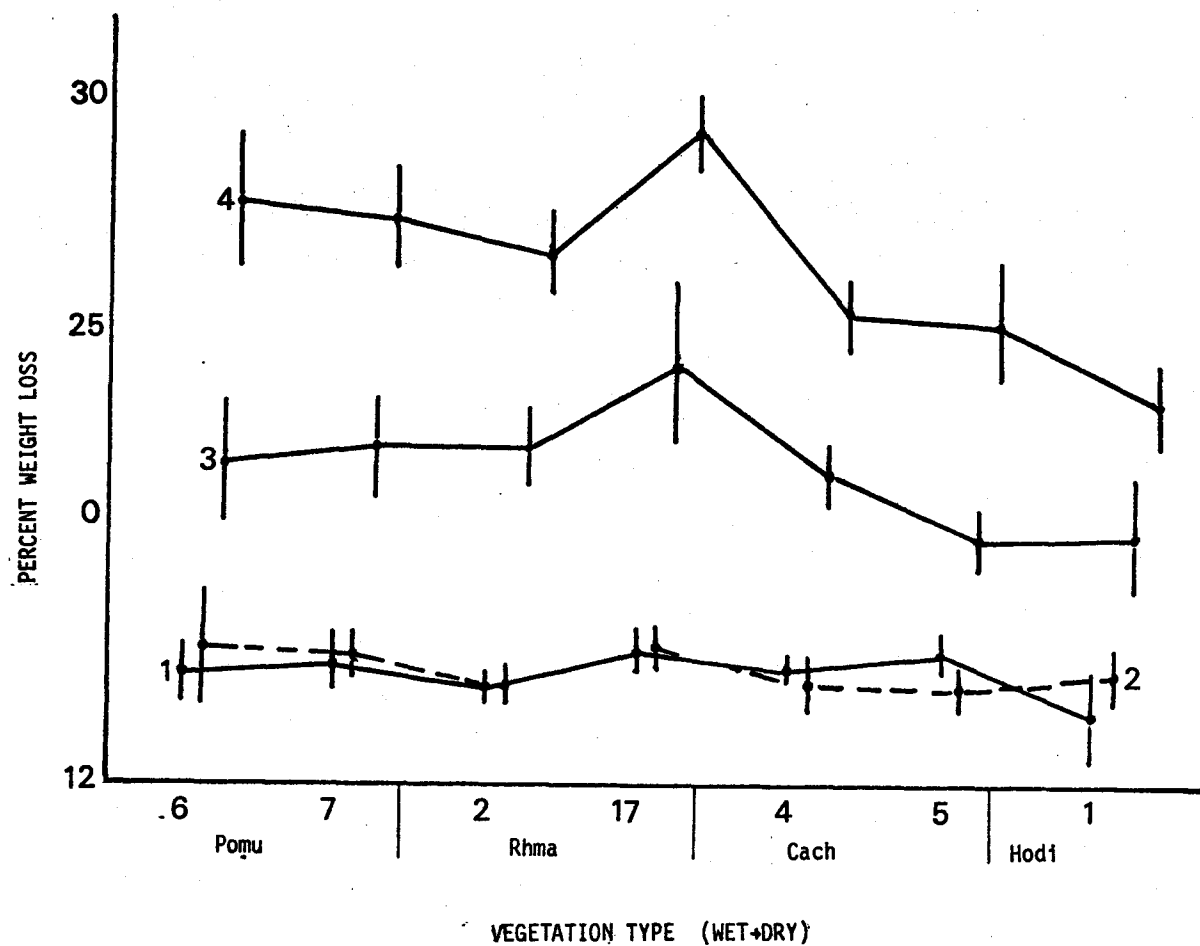
Figure 3. H.J. Andrews, comparison of green Douglas-fir needle weight loss between various habitat types, start 10 March 1973, 95% confidence intervals.
1. = 11 July, 2. = 19 September, 3. = 4 December, 1973. 4. = 20 March 1974.
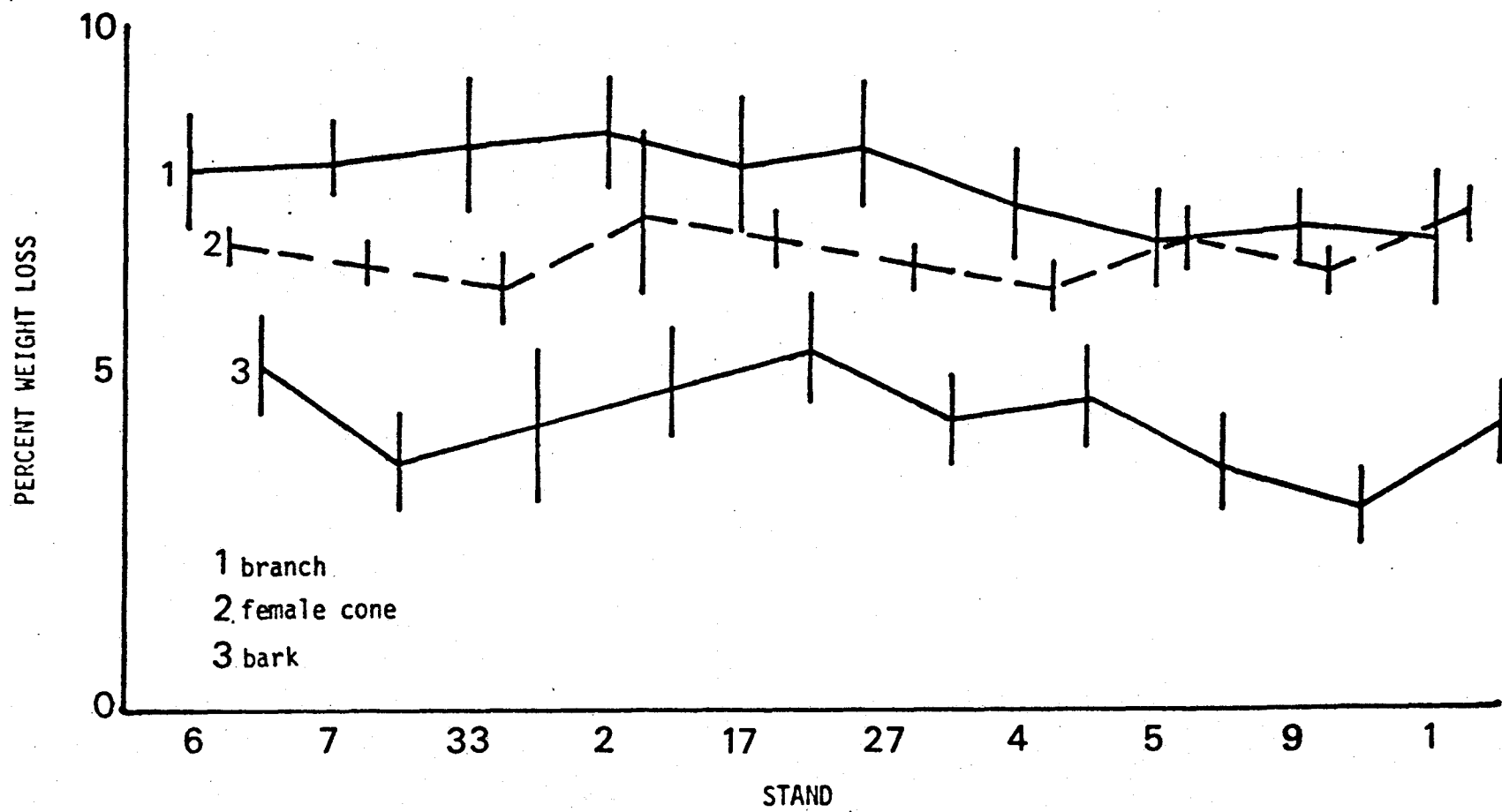
Figure 4.   H.J. Andrews, weight loss of woody Psme litter, start 11 May 1973, 95% confidence levels.
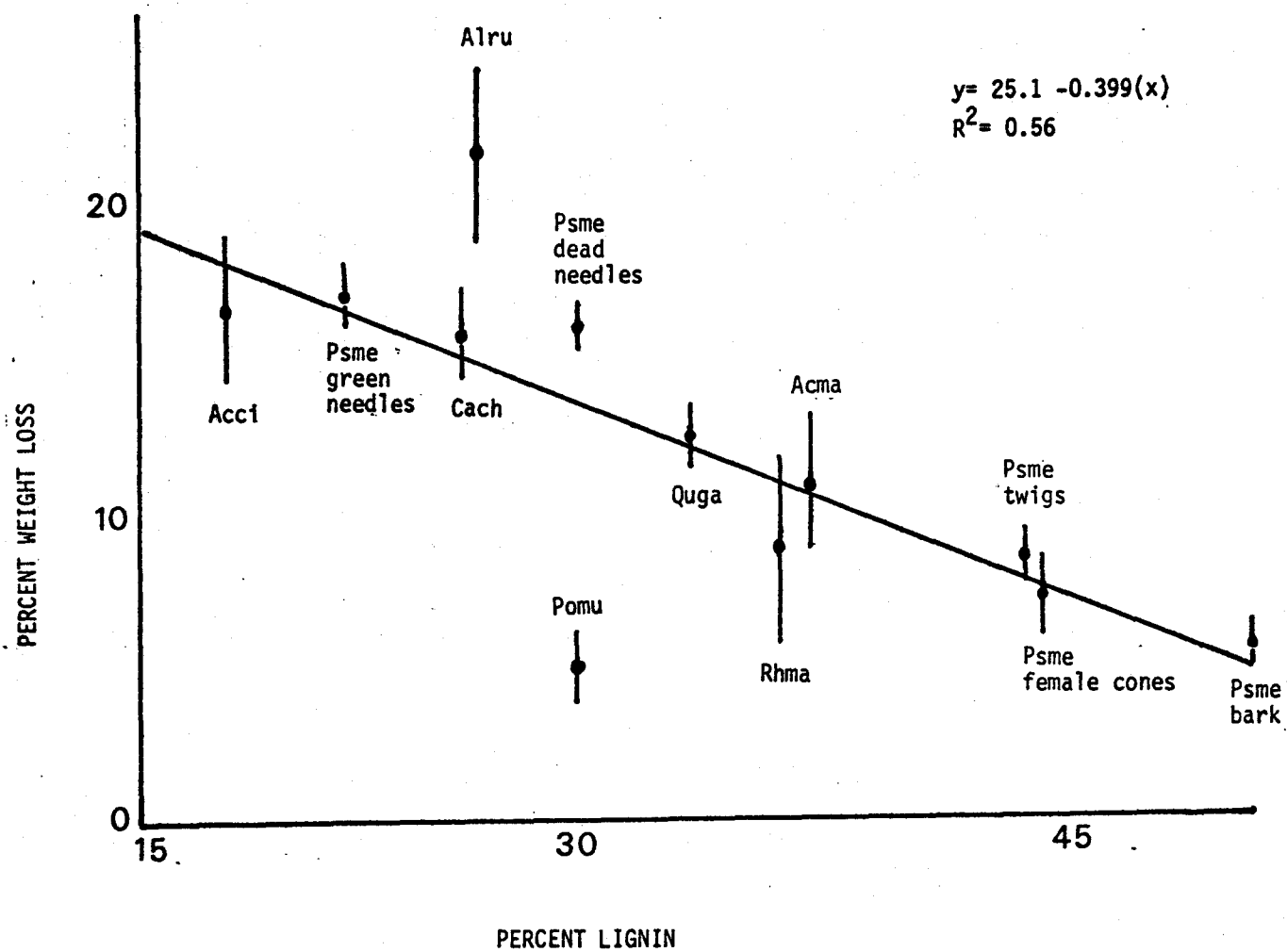
Figure 5. H.J. Andrews, Reference Stand 2, substrate test, start 29 May 1973, finish 4 December 1973, 95% confidence interval.