SEASONAL DEVELOPMENT OF A YOUNG PLANTATION OF EUCALYPTUS NITENS

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ABSTRACT

A 5-year-old plantation of **Eucalyptus nitens** Maid. grew over 4 m in height and added basal area of 4.6 m^2/ha in 12 months. Production of dry matter in the above-ground portion of the stand averaged 36 tonnes/ha/annum over a 2-year period with over 70% in bole material. The season of sampling was unimportant in determining the biomass of stand components since foliage production was closely linked with leaf litterfall. Branch and stem mass increased with time as woody litterfall was small compared with production. Nutrient concentrations in living tissue tended to decrease with increased tree size and often varied among seasons. Although season of sampling affected estimates of stand nutrient content, no simple pattern of change was observed. Calorific values of foliage and live branches were highest in summer or autumn but seasonal differences in stem components were not statistically significant.

Keywords: biomass; litterfall; nutrients; energy; **Eucalyptus nitens**.

INTRODUCTION

Numerous studies of forest biomass and nutrient content have been published in recent years. Few of these consider effects of season of sampling. Canopy weight of pines changes systematically throughout the year (Madgwick 1983) but few data are available for hardwoods (Langkamp *et al.* 1982; Satoo & Madgwick 1982). A knowledge of seasonal changes is important both for theoretical studies of dry matter production and for applied studies of the implications of whole-tree harvesting for such uses as energy.

We wished to determine whether season of sampling influenced biomass, energy, or nutrient contents of *Eucalyptus* in the central North Island of New Zealand.

MATERIALS AND METHODS

Sample Stand

A 5-year-old *E. nitens* plantation located in Cpt 905 of Kaingaroa State Forest was chosen for study. The site is flat and is at an altitude of 550 m. The soil is derived from Taupo ash overlain with Kaingaroa silty sand (Frederick *et al.* 1984). Previous cover was a *Pinus nigra* Arn. plantation which had been clearfelled. Site preparation included ripping, double discing, and V-blading into beds 75 to 90 cm high at 3-m intervals. *Eucalyptus nitens* was planted in 1975 at a 3 × 2-m spacing using 1/0 bare-rooted stock grown at the Forest Research Institute nursery from seed collected from Nimmitabel, New South Wales. Seedlings were planted on top of the beds.

Field Sampling

During October 1980, when the plantation was 5 years old, a permanent sample plot 20 × 20 m (0.04 ha) was randomly located for sampling stand structure and stocking. In October 1980 and at three successive 3-month intervals all trees in the permanent plot were measured for diameter at breast height (dbh). A final measurement was made in October 1982 shortly before the stand was clearfelled to establish a coppice study. At each measurement date a stratified random sample of nine trees was selected based on dbh. The first four such selections were taken from the stand around the permanent plot and the fifth from within the permanent plot. Methods for handling sample trees followed those detailed earlier (Frederick *et al.* 1984, 1985). In addition the height of the lowest leaf-bearing branch on the stem was recorded. For each tree the dry weight of leaves, twigs, live branches, dead branches, stem wood, and stem bark were determined. No reproductive structures were found on any sample tree. All foliage was of the adult form. Stem diameters were measured, but no sample trees taken, 1 year after the start of observations.

Stand weights were independently estimated at each sampling date using the basal area ratio method (Madgwick 1981). Accurate error estimates for calculated stand component weights cannot be obtained with "small" numbers of sample trees using the basal area ratio method. However, replicated sampling of known populations suggests that such errors are likely to be about 12% of the calculated stand weights (Madgwick 1981). This level of error was also indicated using estimates of stand weight based on logarithmic regressions of weight on size.

In December 1980, ten 1-m^2 litter traps were located randomly within the permanent plot. Litterfall was collected at 4- to 6-week intervals for the next 13 months. Litterfall was separated into leaves, woody material, and miscellaneous litter prior to oven-drying at 70°C.

Laboratory Analyses

Chemical analyses were made on the first four tree samplings and litterfall. Stem wood samples were chipped and all tree samples were ground to pass 2-mm and 1-mm-mesh sieves for wood and foliage components respectively. Samples of tree material and litterfall were sent to Analytical Services Limited for chemical analysis. Nitrogen was determined using Kjeldahl digestion with selenium catalyst followed by colorimetry. After wet digestion with nitric and perchloric acid, potassium and calcium were determined by flame emission; magnesium, manganese, zinc, and copper by atomic absorption; phosphorus by colorimetry, and sulphur turbidimetrically. Calorific values were determined using a bomb calorimeter (Leith 1965).

The relationships between nutrient concentrations, tree dbh, and season of sampling were examined using covariance analysis. Sampling times were represented by dummy variables.

RESULTS

At the beginning of observations the *E. nitens* stand had attained a top height of 12.5 m and contained 72 tonnes dry matter/ha in above-ground parts of trees (Table 1). Substantial growth occurred in height, basal area, volume, and stem weight in each season of the year from October 1980 to July 1981. Top height increased almost 4 m, basal area 3.7 m^2/ha, and stem weight by 25 tonnes/ha. A further 0.9 m^2 basal area/ha was added between July and October 1981. Neither leaf material nor live branch weight showed any clear seasonal trend, with changes between sampling dates being masked by sampling variation. Foliage mean weight was 6.9 tonnes/ha and live branch weight 12.6 tonnes/ha. Over the same period the weight of dead branches on the trees doubled from 5 to 10 tonnes/ha.

TABLE 1—Stand characteristics and dry matter content of a stand of **Eucalyptus nitens** sampled at five dates

	Oct 1980	Jan 1981	Apr 1981	July 1981	Oct 1982
Stocking (stems/ha)	1675	1675	1675	1675	1675
Basal area (m^2/ha)	23.4	25.4	26.7	27.1	32.5
Mean diameter (cm)	13.0	13.5	13.9	14.0	15.2
Average height (m)	11.1	12.5	13.7	14.0	15.6
Top height (m)	12.5	14.4	15.9	16.3	18.4
Height to lowest live branch (m)	2.7	3.4	5.0	5.0	7.2
Volume under bark (m^3/ha)	102	126	140	155	209
Dry weight (tonnes /ha)					
Trees					
Leaves	6.3	7.0	6.4	8.0	7.2
Live branches	11.3	15.9	10.4	12.9	9.4
Dead branches	5.3	6.3	7.8	10.6	14.4
Fruits	0.0	0.0	0.0	0.0	0.0
Stem wood	42.6	50.8	53.7	64.8	90.9
Stem bark	6.2	7.1	7.8	9.2	10.8
Tree above-ground	71.6	87.0	86.1	105.5	132.6

Litterfall collections commenced in January 1981 and showed a marked seasonal trend with leaves making up almost 90% of the total litterfall over 13 months of observation (Fig. 1). Maximum leaf fall occurred in summer but in late winter leaf fall was negligible. Annual leaf litterfall amounted to 77% of mean foliage weight on the stand, suggesting an average leaf life of between 1 and 2 years. Rate of branch

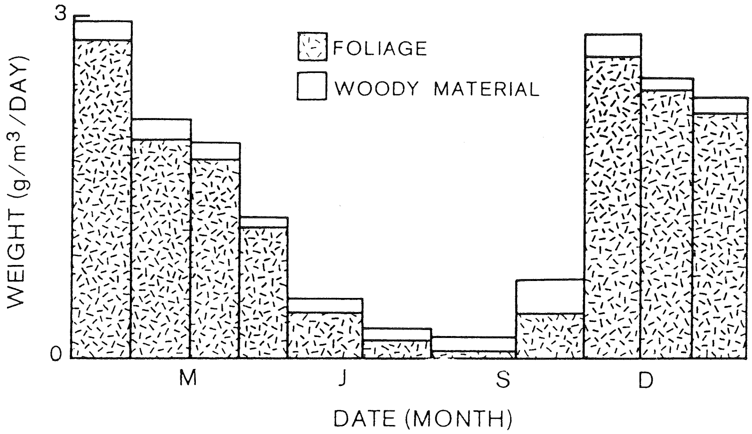

FIG. 1—Seasonal pattern of litterfall in a 5-year-old **E. nitens** plantation.

fall was similar for all months except for November when over one-quarter of total branch fall occurred. Total litterfall over the first 12 months of observation was 5.3 and 0.7 tonnes/ha of leaves and woody material, respectively (Table 2). The base of the live crown rose 2.3 m from October 1980 to July 1981. Most branches dying within this period remained on the trees. Branch litterfall represented only about 10% of increment of dead branches on the trees.

TABLE 2—Annual dry matter and nutrient content of litterfall in a **Eucalyptus nitens** plantation, January 1981–January 1982, and the weight and nutrient content of the forest floor (n.d. = not determined)

Component	Dry matter (t/ha)	N	P	K	S	Ca	Mg	Mn	Cu	Zn
		(kg/ha)								
Litterfall										
Leaves	5.3	46.7	2.7	11.5	4.1	32.3	5.0	4.5	0.03	0.06
Woody	0.7	3.4	0.2	0.9	0.4	4.0	0.8	0.3	0.01	0.01
Forest floor	11.7	121	8	13	n.d.	181	11	n.d.	n.d.	n.d.

Total nutrient content of the stand was closely related to dry weight (Table 3). Thus the content of most nutrients in the stand increased from the first to the fourth sampling. This trend was clearest for dead branches, which doubled in total dry weight over the period, and for elements such as calcium which were relatively more important in the woody material. Weights of nutrients in foliage were greatest for the fourth sampling when estimated dry weight was also highest.

TABLE 3—Total nutrient content of a stand of **Eucalyptus nitens** (kg/ha)

	N	P	K	S	Ca	Mg	Mn	Cu	Zn
	(kg/ha)							(g/ha)	
October									
Leaves	99	7.3	39	9.1	37	7.1	6.4	28	102
Twigs	34	4.2	39	4.0	43	4.5	2.6	35	85
Branches									
Live	14	1.7	18	2.4	23	2.8	2.1	16	65
Dead	9	0.5	7	2.3	61	5.2	3.0	30	80
Stem									
Bark	22	2.4	35	3.5	82	8.5	7.1	13	47
Wood	64	11.9	103	15.3	25	8.7	2.6	94	188
Total	244	27.9	241	36.6	271	36.7	23.9	216	568
January									
Leaves	97	6.8	52	8.7	46	9.5	6.5	26	100
Twigs	13	1.8	19	1.8	25	2.4	1.1	11	39
Branches									
Live	30	4.7	53	6.1	79	8.9	4.9	49	160
Dead	11	0.9	16	2.9	75	6.2	3.5	39	111
Stem									
Bark	24	2.5	47	3.0	105	8.3	7.1	23	72
Wood	57	13.7	122	20.4	35	9.5	2.5	125	233
Total	233	30.4	309	43.0	365	44.8	25.7	273	714
April									
Leaves	107	7.2	43	9.7	31	8.1	5.2	24	100
Twigs	10	1.3	12	1.2	14	1.6	0.8	5	26
Branches									
Live	28	3.4	38	3.7	43	5.6	3.1	23	116
Dead	20	1.1	14	3.3	97	7.4	5.2	37	160
Stem									
Bark	28	2.8	46	2.6	124	10.0	8.7	15	83
Wood	70	13.9	120	15.2	35	9.8	3.4	81	274
Total	263	29.5	273	35.7	345	42.6	26.3	185	760
July									
Leaves	120	8.8	48	10.4	49	9.7	6.8	35	118
Twigs	20	2.4	21	2.6	31	3.2	1.6	14	56
Branches									
Live	25	3.1	32	4.0	45	4.7	3.0	36	90
Dead	20	0.8	12	4.9	117	8.7	5.7	57	144
Stem									
Bark	33	2.9	47	3.7	154	10.7	11.1	17	81
Wood	78	17.5	139	18.6	44	11.8	4.3	110	212
Total	296	35.5	299	44.1	440	48.7	32.4	270	702

Concentrations of nitrogen, phosphorus, potassium, sulphur, magnesium, and copper within each living component all tended to decrease with increased dbh at each sampling (Table 4). The effect of sampling date on the slope of the relationship between nutrient concentrations was not statistically significant. Nutrient concentrations varied among sampling occasions but trends with time were not consistent.

TABLE 4—The effects of dbh and time of sampling on nutrient concentrations in tissues of **Eucalyptus nitens**. For dbh, - means a significant negative correlation with nutrient concentration. For time, the symbol indicates direction of effect. One symbol means significant at the 5% level, double symbols at the 1% level assuming all tests independent. Effects of sampling date are relative to October 1980 (ns = not significant)

Variable	Nutrient								
	N	P	K	S	Ca	Mg	Mn	Cu	Zn
Leaves									
d.b.h.	--	-	-	ns	ns	-	ns	-	ns
January	-	-	ns	--	ns	ns	--	ns	-
April	ns	ns	+	ns	-	+	--	-	ns
July	--	--	++	--	ns	++	ns	-	ns
Live branches									
d.b.h.	--	--	--	-	ns	-	ns	-	ns
January	+	++	+	ns	ns	ns	-	+	-
April	+	+	++	ns	ns	ns	-	ns	ns
July	ns	ns	+	ns	+	ns	-	ns	+
Dead branches									
d.b.h.	ns	ns	ns	ns	ns	ns	-	-	-
January	ns	ns	ns	ns	ns	ns	ns	ns	ns
April	++	+	+	ns	ns	ns	ns	ns	+
July	ns	+	++	ns	ns	ns	ns	ns	ns
Stem bark									
d.b.h.	-	--	-	-	ns	--	ns	--	-
January	ns	--	ns	--	+	ns	ns	ns	ns
April	ns	-	++	--	+	ns	ns	ns	ns
July	--	-	ns	--	ns	ns	-	++	+
Stem wood									
d.b.h.	--	ns	ns	-	ns	ns	ns	ns	-
January	--	ns	--	--	+	ns	ns	-	ns
April	-	ns	-	--	+	ns	ns	--	+
July	--	ns	ns	+	++	ns	--	ns	ns

Calorific values of leaves and live branches were significantly different among sample dates with minimum values in October (Table 5). Effect of sampling date on calorific values in stem components was not statistically significant, though for stem bark there was a consistent decline in value throughout the period of observation.

TABLE 5—Calorific values (kJ/g) of components of a **Eucalyptus nitens** stand

Component	Sampling date				s.e.
	October	January	April	July	
Leaves	22.2	23.0	22.7	22.5	0.09
Live branches	19.2	19.5	19.7	19.4	0.08
Dead branches	18.8	19.1	18.9	19.2	0.17
Stem bark	18.0	18.0	17.9	17.6	0.13
Stem wood	19.4	19.3	19.5	19.3	0.09

DISCUSSION

Eucalyptus nitens is noted for its fast early growth and in Australia has been found to out-produce *E. regnans* F. Muell. up to 15 years of age on a number of *E. regnans* sites (Pederick 1979). Lack of an adequate growth and yield model for *E. nitens* prevents an accurate assessment of relative productivity of our study plot but growth in height and basal area was less than that found for a range of *E. regnans* stands also growing in the central North Island of New Zealand (Frederick *et al.* 1985). Differences in over-all performance could be due to seed source of the *E. nitens* which has proved of poor to average performance in provenance trials (Pederick 1979; Franklin 1980). At age 5 the Nimmitabel provenance in Pederick's study had a dominant height close to that of our stand, while the best-producing provenances were 15% taller and dominant trees had 60% more volume than the Nimmitabel provenance. In contrast, seed collected from the area including our *E. regnans* sample plots has performed better than average in provenance trials (Griffin *et al.* 1982; Wilcox 1982). Differences in basal area growth could partly reflect the lower stocking of the *E. nitens* stand. Mean annual increment at age 5 years was 14 tonnes/ha compared with 20 tonnes/ha in a close-spaced, 4-year-old stand which contained almost four times as many stems per hectare (Madgwick *et al.* 1981). Foliage mass on the present stand was lower than that on either *E. regnans* plantations or the close-spaced *E. nitens*.

Litterfall patterns in the *E. nitens* stand were similar to those found in a wide range of *Eucalyptus* species with a summer maximum and a winter minimum (Baker 1983; Frederick *et al.* 1985). Lack of a discernible seasonal trend in total foliage mass on the stand suggests that leaf production and abscission follow similar seasonal trends. This hypothesis would be extremely difficult to test on a stand basis since conventional biomass sampling would require a large number of sample trees, while direct observation of leaf initiation and development on a sufficient scale to determine precise relationships would appear infeasible given the size of the trees.

Nutrient pools in woody tissue were strongly dependent on total dry weight so that time trends were dominated by the accumulating woody biomass in the stand. Detecting seasonal changes in nutrient pools in foliage and live branch components does not appear amenable to conventional biomass sampling because of variability among individual trees. Even when foliage nutrients are monitored at monthly intervals, and maturation state of individual leaves is taken into account, foliage nutrients in *Eucalyptus* spp. tend to vary considerably (Bell & Ward 1984) and may be related to rainfall (Schönau 1983). In our stand maturation state of the leaves will have varied throughout the canopy especially during the season of maximum leaf fall and production.

Variability from whole-tree sampling was more important than season of sampling in the determination of biomass and nutrient content of canopy components of this *E. nitens* stand. If our findings are confirmed in other environments the omission of information on sampling date in studies of eucalypt stand weights would be of little importance. Data on nutrient contents of other stands are required to determine whether there is a consistent pattern of seasonal change in this genus.

Over the 2-year period in which dry-matter measurements were made, the above-ground portion of the stand increased by 61 tonnes/ha or 30 tonnes/ha/annum. In addition, litter production was 6 tonnes/ha/annum giving a current annual increment of 36 tonnes/ha/annum. This annual increment is comparable to that found in close-spaced *Pinus radiata* D. Don also growing in the central North Island of New Zealand (Madgwick & Oliver 1985).

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