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Seasonal patterns in cotton strip decomposition in soils

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1 *Summary*
Cotton strip assay can give a good indication of seasonal changes in soil decomposer activity, especially in temperate and sub-polar regions. Some examples are given, with comments on the interpretation of cotton strip data in relation to environmental changes. Some of the limitations of the assay, when used for this purpose, are also discussed.

2 *Introduction*
Cotton strip decomposition, measured by loss in tensile strength (CTSL), proceeds at rates such that, in most temperate soils, complete CTSL takes about 3 months, while in sub-polar and polar soils it may take a year or longer. Across this range of ecosystems, therefore, the rate of CTSL can be used to examine seasonal patterns of decomposition. Some common questions discussed in relation to soil decomposer activity are given below.

— At what time of year is decomposition most rapid?
— What is the difference in magnitude between the fastest and slowest seasonal rates?
— Do CTSL profiles (pattern of change with depth in the soil) vary during the year?

Three separate studies, in sub-antarctic (South Georgia), moorland (Glen Dye, Kincardineshire), and forest ecosystems (Gisburn, Lancashire), are used to illustrate the use of cotton strip assay to address these questions.

3 *Sub-antarctic*
Differences between CTSL rates and patterns of change with depth in soil profiles within sites on South Georgia were largely related to soil temperature and moisture changes, especially winter freezing, summer drought (in surface layers) and waterlogging (with consequent anoxia) at depth in mires (D W H Walton pers. comm.). These relationships may either be direct effects of soil microclimate on microbial activity or due to other causes, such as changes in rhizosphere exudates, soil microflora, etc.

4 *Moorland*
Freezing, drought and waterlogging are 3 factors which are said frequently to control soil organic matter decomposition rates. At first sight, this appears to be true in a comparison of changes in CTSL down soil profiles in a Scottish heather (*Calluna vulgaris*) moor. The cotton strips were inserted by the horizon method of French and Howson (1982) during 3 periods in the year (Table 1). The general increase in maximum decay rates is approximately related to temperature sum (deg–days >0°C). The trends down the soil profiles

Table 1. Cotton strip tensile strength loss (CTSL) at Glen Dye, during 3 contrasting periods in 1979–80, compared with some summary climatic data[1]

Period	Strip position[2]	CTSL Mean ± SE[3]	Deg-days (>0°C)	Precipitation (mm day^{-1})	Days with precipitation
October–March	Top	36 ± 1.4	469	3.03	59
	Side	36 ± 2.4			
	Bottom	25 ± 1.9			
	Whole strip	32 ± 1.3			
March–June	Top	36 ± 2.1	925	2.07	37[4]
	Side	46 ± 2.7			
	Bottom	48 ± 1.2			
	Whole strip	43 ± 1.3			
June–August	Top	44 ± 1.2	945	2.96	62[5]
	Side	46 ± 1.8			
	Bottom	42 ± 1.9			
	Whole strip	44 ± 1.0			

[1] Climatic data are from the nearest meteorological station (Banchory)
[2] Approximate depths are top = <1 cm, side = 1–5 cm, bottom = >5 cm
[3] n = 20 top and bottom, n = 10 side
[4] Nearly all rain fell in first 2 weeks or last week of this period
[5] Very even distribution of rainfall over the period

also indicate inhibition (i) by waterlogging (when not frozen) in bottom segments of cotton strips over winter, and (ii) by drought in surface segments of cotton strips in late spring and early summer, when nearly all the rain fell mostly in early April. No obvious soil microclimatic constraints appeared to operate in July and August, which were warm throughout and when rainfall was more evenly spread in time. Differences in CTSL between depths were significant (ANOVA, $P<0.05$) in the first 2 periods, but not in the third.

If, however, nutrients or carbohydrates were added to the soil before inserting the cotton strips (French 1988a), the CTSL differences between soil layers were nearly all eliminated or, in a few cases, very much reduced (Figure 1). Especially large increases in CTSL occurred at the depths where decomposition was apparently most limited by soil climate. Clearly soil climate variation does not explain entirely the patterns of CTSL with soil depth; these aspects are discussed further elsewhere (French 1988b).

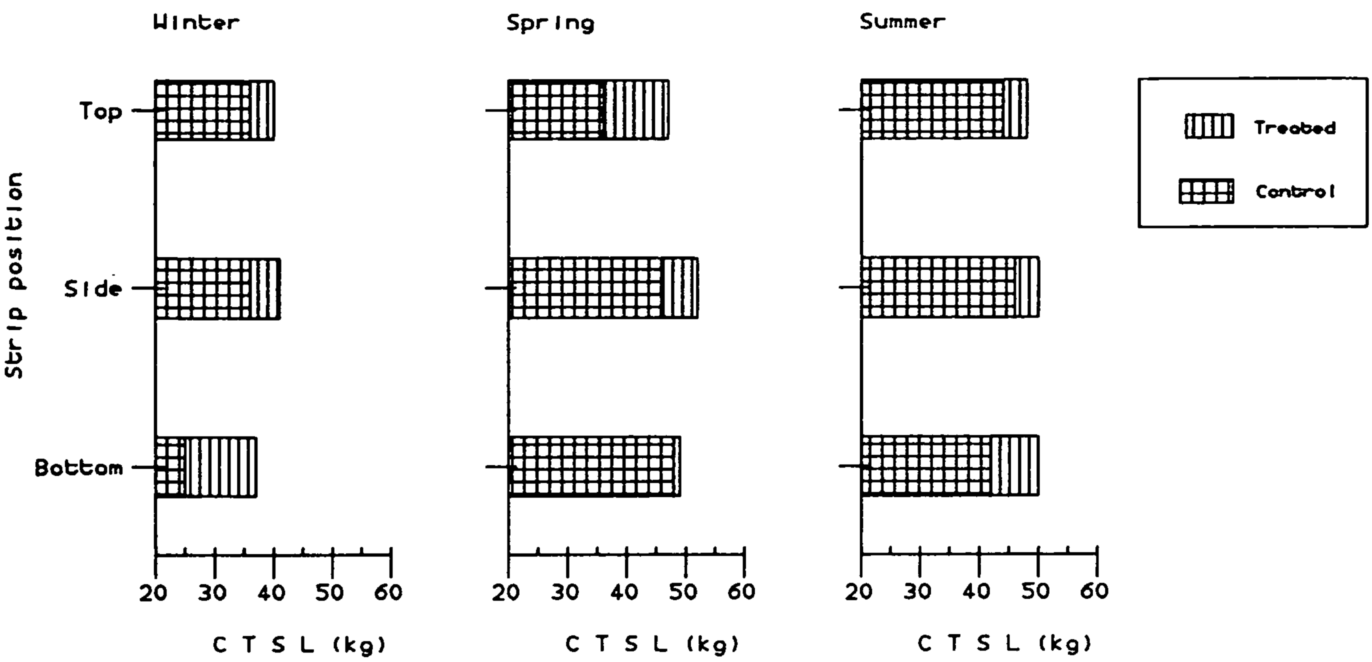

Figure 1. Some examples of elimination of differences between depths in CTSL, after 3 applications of nutrients or carbohydrates (CHO) to the soil (see French 1988a for details of method). Differences between depths in control plots were significant (ANOVA, $P<0.05$) in winter (CHO 4 gm^{-2}) and spring (P 24 gm^{-2}) but not in summer (N 40 gm^{-2}), when the range (42–46) is, however, still greater than the range in N-treated soil (48–50). There are no significant differences between depths in treated plots

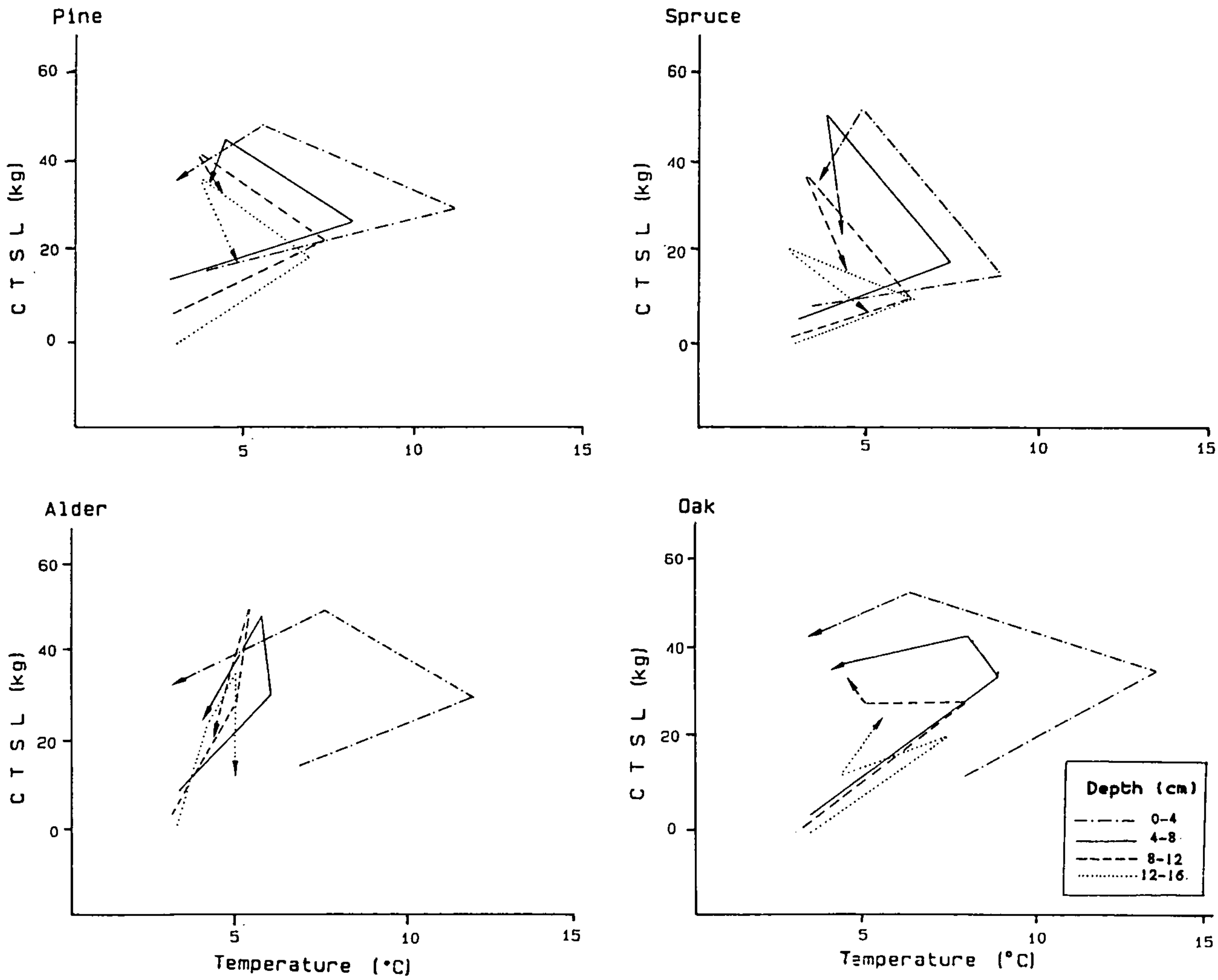

Figure 2. Changes in CTSL in relation to seasonal temperatures (measured by sucrose inversion) at 4 depths under 4 tree species at Gisburn Forest. Brown and Howson (1988) give details of method

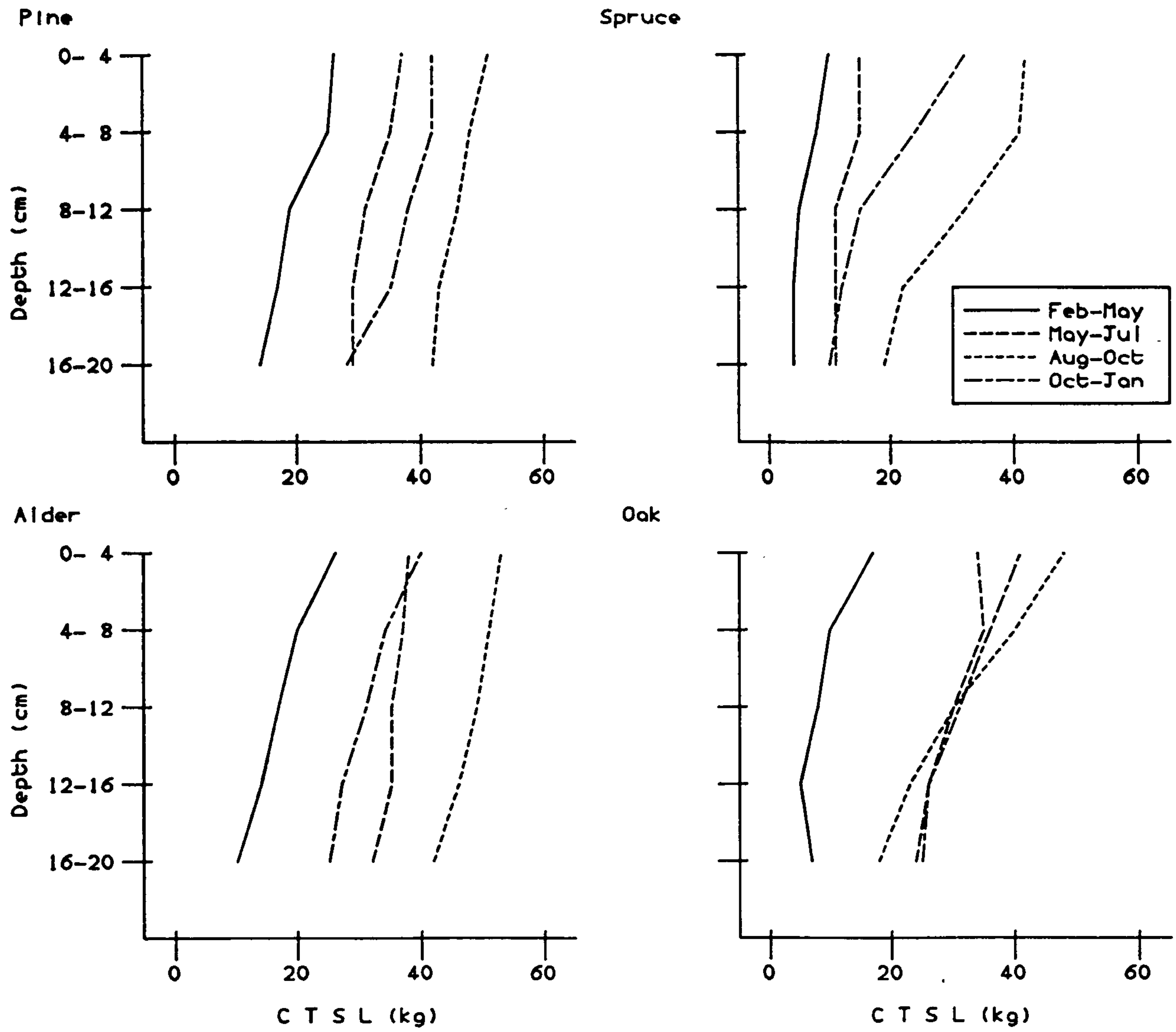

Figure 3. Seasonal changes of CTSL profiles under 4 tree species at Gisburn Forest

5 *Forest*

Cotton strips inserted in soils under 4 different tree species at Gisburn Forest (Brown 1988; Brown & Howson 1988) again showed very clear changes between seasons, in overall CTSL rates and, in some cases, in CTSL profiles (Figure 3). Somewhat similar patterns in cellulose decomposition were shown for oak (*Quercus* spp.) forest in Switzerland by Richard (1945), using cellulose cords. The CTSL data for Gisburn showed no relationship between soil moisture and CTSL at 0–4 cm, probably because soil moisture was never unfavourable. The optimal moisture content range in these or similar soil types is about 100–300% oven dried weight (OD) (Figure 12 in Heal *et al.* 1974; Figure 3c in Flanagan & Veum 1974). Similarly, any relationship of CTSL with temperature is not a simple linear response, but involves a delayed reaction (Figure 2), where changes in CTSL with temperature follow a 'cyclic' pattern, deviating markedly from the simple diagonal oscillation expected from an immediate direct relationship. As well as this lack of simple relationships between CTSL and soil climatic factors at any one soil depth, there are differences between tree species in the way CTSL profiles change (Figure 3), and these differences are not related in any clear manner to climatic patterns. Possible alternative or interactive mechanisms are discussed in detail by Brown and Howson (1988).

6 *Discussion*

The 3 studies referred to above indicate the value of the cotton strip assay in demonstrating seasonal patterns in decomposition processes. In each case, answers were obtained to the questions posed at the beginning of this paper. Furthermore, the observed deviations from simple relationships between CTSL and soil climatic variation forced a more detailed examination of the mechanisms of decomposition, and their implications for ecosystem functioning. In this context, it is more informative to have estimates of the full seasonal pattern of variation in decomposition rates than only a single integrated annual measurement, though that, in turn, may be better than a value for some shorter period (eg days or even hours) that cannot be related to the whole year. The cotton strip assay seems better suited to such investigations than either short-period measures such as soil respiration (with the attendant problem of root respiration) or litter weight loss which, in temperate and sub-polar regions, is generally more appropriate for longer-term estimates over several years.

However, if cotton strip assay is to be used in this way, we also need to know the extent to which it represents a general index of decomposition activity. Climatic factors seem to have similar effects on decomposition of litters (Kärenlampi 1971) and of standard cellulose substrates (Rosswall 1974), respectively, so broad agreement in seasonal patterns is likely.

I have discussed elsewhere (French 1988a) the limits to any general correlation between CTSL and litter weight losses over a complete annual cycle under different edaphic conditions. I concluded that CTSL can be taken as a reasonable general index for comparisons over a wide environmental range but, for finer analyses, the agreement between cotton strip assay results and litter weight loss, or between weight loss of different litters, is not sufficiently close for any one substrate to be used as a surrogate for any other(s). Is this also true of seasonal patterns?

Unfortunately, there appear to be very few studies which include both cotton strip assay and other measures of decomposition in directly comparable seasonal samples. In 4 sites in Norway, both litter bags and cotton strips were sampled on 2 occasions during a year, from comparable depths in the soil. In 2 sites, there was an equivalent pattern (summer/winter) in both cotton strips and plant litters; in one site some litters behaved like cotton strips and some (particularly bryophyte litter) did not; while in the fourth site no discernible seasonal pattern in CTSL was detected but litter weight losses increased in summer (cf data quoted in Heal & French 1974; Heal *et al.* 1974, from Hardangervidda sites). These very limited data indicate a fair degree of agreement among cotton strip and litter bag measures, but with enough exceptions to make any detailed relationship somewhat doubtful. As with annual rates, some caution is needed in the interpretation of seasonal patterns in CTSL as an indication of the patterns expected in decay of any other substrates, 'natural' or otherwise.

Finally, a warning must be given of the dangers of extrapolating annual estimates from a single period within the year. In both the moorland and the forest studies, the data from any single assay period, even if linearized and corrected for the 'average' expected effects of overall macroclimate, as in Hill *et al.* (1985), would give a highly biased estimate of annual loss rates or patterns of decomposition down soil profiles. For studies comparing different site or management effects, it is essential to have at least one full year's data made up of several seasonal measurements in order to estimate seasonal patterns in decomposition rates.

7 *References*

Brown, A.H.F. 1988. Discrimination between the effects on soils of 4 tree species in pure and mixed stands using cotton strip assay. In: *Cotton strip assay: an index of decomposition in soils,* edited by A.F.Harrison, P.M. Latter & D.W.H. Walton, 80-85. (ITE symposium no. 24.) Grange-over-Sands: Institute of Terrestrial Ecology.

Brown A.H.F. & Howson, G. 1988. Changes in tensile strength loss of cotton strips with season and soil depth under 4 tree species. In: *Cotton strip assay: an index of decomposition in soils,* edited by A.F. Harrison, P.M.Latter & D.W.H. Walton, 86-89. (ITE symposium no. 24.) Grange-over-Sands: Institute of Terrestrial Ecology.

Flanagan, P.W. & Veum, A.K. 1974. Relationships between respiration, weight loss, temperature and moisture in organic residues in tundra. In: *Soil organisms and decomposition in tundra,* edited by A.J. Holding, O.W. Heal, S.F. MacLean & P.W. Flanagan, 249-278. Stockholm: Tundra Biome Steering Committee.

French, D.D. 1988a. Patterns of decomposition assessed by the use of litter bags and cotton strip assay on fertilized and unfertilized heather moor in Scotland. In: *Cotton strip assay: an index of decomposition in soils,* edited by A.F. Harrison, P. M. Latter & D.W.H. Walton, 100-108. (ITE symposium no. 24.) Grange-over-Sands: Institute of Terrestrial Ecology.

French, D.D. 1988b. Some effects of changing soil chemistry on decomposition of plant litters and cellulose on a Scottish moor. *Oecologia.* In press.

French, D.D. & Howson, G. 1982. Cellulose decay rates measured by a modified cotton strip method. *Soil Biol. Biochem.,* **14,** 311-312.

Heal, O.W. & French, D.D. 1974. Decomposition of organic matter in tundra. In: *Soil organisms and decomposition in tundra,* edited by A.J. Holding, O.W. Heal, S.F. MacLean & P.W. Flanagan, 279-310. Stockholm: Tundra Biome Steering Committee.

Heal, O.W., Howson, G., French, D.D. & Jeffers, J.N.R. 1974. Decomposition of cotton strips in tundra. In: *Soil organisms and decomposition in tundra,* edited by A.J. Holding, O.W. Heal, S.F. MacLean & P.W. Flanagan, 341-362. Stockholm: Tundra Biome Steering Committee.

Hill, M.O., Latter, P.M. & Bancroft, G. 1985. A standard curve for inter-site comparison of cellulose degradation using the cotton strip method. *Can. J. Soil Sci.,* **65,** 609-619.

Kärenlampi, L. 1971. Weight loss of leaf litter on forest soil surface in relation to weather at Kevo Station, Finnish Lapland. *Rep. Kevo Subarct. Res. Stn,* **8,** 101-103.

Richard, F. 1945. The biological decomposition of cellulose and protein test cords in soils under forest and grass associations. I. The method of determining biological soil acidity by the so-called 'tearing' test. *Mitt. schweiz. Anst. forstl. VersWes.,* **24,** 297-397.

Rosswall, T. 1974. Cellulose decomposition studies on the tundra. In: *Soil organisms and decomposition in tundra,* edited by A.J. Holding, O.W. Heal, S.F. MacLean & P.W. Flanagan, 325-340. Stockholm: Tundra Biome Steering Committee.