than for *B. cordifolia*. The feeding pattern of individual larvae on *B. papyrifera* consisted of many large feeding areas which tended to be contiguous, on *B. cordifolia* large feeding areas were scarce and tended to be scattered. This difference in feeding pattern caused severely attacked *B. cordifolia* trees to appear mottled, quite different from the uniform brown appearance of severely attacked *B. papyrifera*.

The number of eggs per leaf and number of overwintering larvae per branch crotch on *B. papyrifera* was about two and one-half times greater than on *B. cordifolia*. Means were compared with Student's *t* test, and both differed significantly at the 1% level.

TABLE 1
Difference in defoliation and birch casebearer numbers between *Betula payrifera* and *B. cordifolia*

	B. papyrifera			*B. cordifolia*		
	Avg	S.D.	Range	Avg	S.D.	Range
Percent defoliation	29	–	11-55	5	–	1-7
No. eggs per leaf	16.7	10.4	0-52	6.1	4.8	0-19
No. larvae in branch crotches	27.7	19.6	5-94	11.9	7.9	3-51

These differences in intensity of defoliation and insect numbers indicates that *B. cordifolia* is much less likely to be damaged by the birch casebearer. The difference in insect numbers indicates that birch trees must be correctly identified when sampling to obtain estimates of casebearer abundance or estimates of potential defoliation.—A. G. Raske, Newfoundland Forest Research Centre, St. John's, Nfld.

PATHOLOGY

Corky Root Disease of Douglas-fir Seedlings: Post-Plant Nematicide Trials to Control *Xiphinema bakeri*.—Since 1963, corky root disease (Bloomberg, Bi-Mon. Res. Notes 24:8, 1968) has ruined about 1.5 million Douglas-fir [*Pseudotsuga menziesii* (Mirb.)] Franco seedlings in coastal British Columbia forest nurseries. The nematode *Xiphinema bakeri* Williams is the primary pathogen (Bloomberg and Sutherland, Ann. Appl. Biol. 69:265-276, 1971). Corky root can be controlled by pre-plant application of nematicides (Bloomberg and Orchard, Ann. Appl. Biol. 64:239-244, 1969) or by bare fallowing accompanied by frequent disking of infested areas during the hot, dry, late summer - early fall period.

Although pre-plant controls are satisfactory, post-plant ones are needed to eradicate the nematode on seedbed seedlings and transplants. Generally, nematicides are injected or drenched into the soil. Recently attention has focused on systemic materials that can be applied to plant foliage and then translocated to the roots to act as nematicides. The objective of the two experiments reported herein was to determine the usefulness of two soil-applied nematicides (Diazinon and Nemagon) and a promising systemic (Vydate) (Radewald et al., Plant Dis. Rep. 54: 187-190, 1970; Birchfield, Plant Dis. Rep. 55: 362-365, 1971; Abawi and Mai, Plant Dis. Rep. 55: 617-620, 1971; Miller, Plant Dis. Rep. 56: 255, 1972) for post-plant of control *X. bakeri* on Douglas-fir.

Experiment 1

In March 1972, a sandy loam, *X. bakeri*-infested soil from the Campbell River nursery was thoroughly mixed, and put into plywood boxes (each 34 x 8 x 8 inch; 86.4 x 20.3 x 20.3 cm) lined with plastic sheeting. Thirty, 1-yr-old corky-root-diseased Douglas-fir from Campbell were selected for uniformity of size and disease severity and transplanted into each box with three equally-spaced rows of 10 seedlings each. The nematicides and their equivalent application rates (formulated as water-based emulsions) were: a) Diazinon® [0,0-diethyl 0-20 isopropyl-4-methyl-6-pyrimidyl phosphorothioate] at 35, 50 or 75 lb. a.i. per 120 Imp gal (546 l) of water per acre (39, 56 and 84 kg per hectare) applied as a soil drench; b) Nemagon® (1,2-dibromo-3-chloropropane) at 20, 40 or 60 lb. a.i. per 600 Imp gal (2,728 l) of water per acre (22, 45 and 68 kg per hectare) dribbled into 2.5 inches (6.4 cm) deep soil trenches on either side of each seedling row; after treatment, the trenches were filled with soil, and c) Vydate® [S-methyl 1-(dimethyl carbamoyl)-N-[(methyl carbamoyl) oxyl] thioformimidate] at 2, 4 or 6 lb. a.i. per 100 Imp gal (455 l) of water per acre (2.2, 4.5 and 6.7 kg per hectare) sprayed onto seedling shoots and soil surface. The nematicides, one per box, were applied 1 week after transplanting when the seedlings were still dormant. Vydate was also applied, 35 days after transplanting, to other seedlings that had broken dormancy. No water was applied to Vydate-treated foliage for 5 days after treatment; otherwise, all seedlings were watered as needed and greenhouse temperatures ranged from 98 to 64 F (41 to 11 C). Each treatment and control (distilled water) was replicated four times in a completely random design.

From 21 Aug to 28 Sept (145 to 183 days after transplanting), the seedlings were removed from the soil, the nematodes were obtained from the roots (Bloomberg et al., Bi-Mon. Res. Notes 26: 14-15, 1970), the second year's shoot growth was measured, and fresh weights were obtained for it and the roots. The data were transformed (natural log) for analysis of variance, and treatment means were compared, using the Newman-Keuls test (Miller, Simultaneous statistical inference, McGraw-Hill, New York).

The results showed that Nemagon was the only nematicide that produced a significant ($P = .05$) treatment effect; consequently only results for the Nemagon treatment are given in Table 1. Numbers of *X. bakeri*/g of root decreased as Nemagon rates increased up to 40 lb. per acre, but there was no significant ($P = .01$) difference between the 40 and 60 lb. per acre rates (Table 1). Nemagon also caused a reduction in root weight, i.e., it was apparently phytotoxic, whereas shoot weight and length were not affected. Although Nemagon has been reported (Ferris and Leiser, Plant Dis. Rep. 49: 69-71, 1965) to be phytotoxic to unthrifty, field-grown spruce, we observed no phytotoxic symptoms such as chlorosis or death on Douglas-fir seedlings.

TABLE 1
Effect of Nemagon (Experiment 1) and Vydate (Experiment 2) on numbers of *Xiphinema bakeri* nematodes and seedling growth [a]

Material and application rate (lb. a.i./acre)	No. nematodes /g fresh root	Fresh wt roots (g)	Second yr shoot wt (g)	Second yr shoot length (cm)
Nemagon				
0	33a	1.8b	0.36a	38a
20	17b	1.7ab	0.49a	44a
40	7c	1.5a	0.69a	51a
60	7c	1.6ab	0.51a	46a
Vydate				
Healthy seedlings				
0	49b	2.6a	0.38ab	33b
2	27a	2.4a	0.40ab	42a
4	23a	2.5a	0.44a	42a
6	35ab	2.0b	0.37b	39a
Diseased seedlings				
0	62b	1.5b	0.27b	35b
2	37a	1.9a	0.36a	44a
4	42a	1.9a	0.34a	41a
6	52ab	1.2c	0.29b	40a

[a] Values for Experiment 1 are means of 4 replicates, those for Experiment 2 are means of 30 replicates; means followed by a letter in common do not differ significantly ($P = .01$) for nematodes per g of root in the Nemagon treatment, $P = .05$ for all other differences).

Experiment 2

On 12 April 1972, 1-yr-old corky root diseased (from Campbell River) and healthy (container grown) Douglas-fir were transplanted, one seedling per 6 inches (15 cm) pot, into

X. bakeri infested Campbell River soil. After breaking dormancy (8 May), each seedling shoot was immersed three consecutive times into a Vydate solution and the seedling laid horizontally until dry. Seedlings were then arranged in a completely random design on a greenhouse bench, with each treatment (2, 4 or 6 lb. a.i. per 100 Imp gal of water per acre) and control (distilled water) replicated 30 times. Seedlings were not watered for 5 days after treatment; thereafter, water was applied only to the soil surface. The experiment was evaluated (1 – 12 Oct), using the same techniques as described for Experiment 1, except no data transformation was needed for the analysis of variance.

Foliage application of Vydate showed that (disregarding application rate) there was no overall difference ($P = .05$) between the number of *X. bakeri* nematodes on roots of healthy (34 per g) and diseased (49 per g) seedlings, i.e., Vydate nematode control was as good on diseased as on healthy plants. However, Vydate did reduce *X. bakeri* populations on both diseased and healthy seedlings (Table 1), especially at the 2 and 4 lb. application rates. The 6 lb. rate of Vydate reduced root weight of diseased and healthy seedlings. There was no clear-cut trend between seedling shoot weight and Vydate concentration, but the nematicide treatment did increase shoot length. No seedlings died or exhibited any shoot symptoms of phytotoxicity. We do not know why Vydate gave some control of *X. bakeri* here, but not in the first experiment.

Recent evidence (Sutherland and Sluggett, 1972, unpublished) indicates that corky root development depends upon the combined effects of *X. bakeri* root feeding and low soil fertility. Future nematicide tests should determine the value of applying both a nematicide and fertilizer to disease infested nursery areas. Our results indicate that both Nemagon, which has a low mammalian toxicity, and Vydate should be included in such trials.—S. Ilnytzky and Jack R. Sutherland, Pacific Forest Research Centre, Victoria, B.C.

Association of Some Physical and Chemical Properties of Nursery Soils with Corky Root Disease.—The nematode *Xiphinema bakeri* Williams is the "primary" pathogen of corky root disease because its feeding precedes root invasion by the soil-borne fungi *Cylindrocarpon destructans* (Zinnsm.) Schalten and *Fusarium oxysporum* Schletcht. (Bloomberg and Sutherland, Ann. Appl. Biol. 69: 265-276, 1971). Sutherland and Sluggett (Can. J. Forest Res., in press) found diseased seedlings and soil from a disease-infested area in the Campbell River nursery contained statistically lower amounts of several nutrients than their healthy counterparts, which suggested that disease development depends upon the combined effects of nematode feeding and low soil fertility. Related to this latter factor is the field observation that the disease prevails on the sandiest soils within infested fields. Because the implication of soil fertility had been studied only at the Campbell River nursery, the present study was made to determine some physical and chemical properties of Green Timbers and Haney (Alouette Lake) nursery soils where the disease has also occurred.

In August 1972, 10 randomly selected soil cores, taken to a 6-inches (15 cm) depth, were collected and bulked from adjacent 50 x 50 ft (15.2 x 15.2 m) plots with and without corky root disease. When sampled, Haney field 1 and Green Timbers field 4 were in bare fallow and Green timbers field 7 was in 2-0 Douglas-fir. The 4-5 lb. (1-5-2.0 kg) samples were air dried, sieved (10 mm sieve) and passed through a sample splitter, after which subsamples were analyzed for: texture (Bouyoucos, Soil Sci. 23: 343-353, 1927); total N by micro-Kjeldahl; P by acid fluoride extraction; exchangeable K, Mg, and Ca by ammonium acetate extraction; pH and conductance (soluble salts) by saturated soil paste; cation exchange capacity (CEC) by ammonium saturation; and total organic carbon by Leco carbon analyzer. These methods use the standard procedures for this laboratory (McMullan, Can. For. Serv. Inf. Rept. BC-X-50, 1971; McMullan, Can. For. Serv. Inf. Rept. BC-X-67, 1972).

Table 1 shows that corky root soils contained more sand and less silt and clay than non-corky root soils. The results also confirm our earlier Campbell River observation (Sutherland and Sluggett, Can. J. Forest Res., in press) that corky root soils are less fertile than disease free soils, e.g. they contained less N, K, Mg, and Ca and had lower CEC and carbon content values than non-corky root soils. Phosphorus and acidity (pH) levels of the two soils were similar and the conductance reading indicated that neither soil contained harmful amounts, 4000 to 8000 micromhos/cm for most plants, of soluble salts (Bower and Wilcox, pp. 933-940, in Methods of Soil Analysis, part 2, C. A. Black, Ed., Vol. 9 of Agron. Mono., 1965). The lower fertility levels of corky root soils are probably attributable to their lower clay and organic carbon contents, two factors influencing CEC (Lyon et al. The nature and properties of soils, MacMillan, New York, 1952). Their higher sand content likely results in greater available pore space, which favors nematode population build-up. We do not know why these areas of sandy soil occur, but perhaps they are exposed areas of interglacial sand (Fyles, *In* Day et al., Rep. No. 6, B.C. Soil Surv., 1959).

TABLE 1
Some physical and chemical properties of soil from corky root and non-corky root nursery areas[a]

	Non-corky root areas	Corky root areas	Adequate nutrient levels[b]
Physical properties			
Sand, %	58 ± 3.5	67 ± 3.3	—
Silt, %	14 ± 2.1	9 ± 0.9	—
Clay, %	28 ± 1.7	23 ± 2.4	—
Chemical Properties			
N (total), %	.59 ± 0.20	.36 ± 0.05	.20
P, ppm	14 ± 5.4	15 ± 3.7	100
K, ppm	86 ± 7.3	51 ± 14.2	78
Mg, ppm	55 ± 25.9	28 ± 8.5	170
Ca, ppm	625 ± 285	497 ± 207	1000
pH	5.7 ± 0.4	5.5 ± 0.3	—
conductance[c]	637 ± 115	425 ± 77	—
CEC[d]	44 ± 5.3	36 ± 1.2	—
Carbon (total organic), %	4.3 ± 1.3	3.2 ± 0.4	—

[a] Value are means of three samples, ± SE of the mean.
[b] For Douglas-fir nursery seedlings (van den Driessche, B.C. For. Serv. Res. Note No. 48, 1969).
[c] Micromhos/cm.
[d] Cation exchange capacity = meq/100 g air-dry soil.

The adequate nutrient level values (Table 1) indicate that N is adequate in both corky root and disease free soils while P, Mg, and Ca are deficient in both soils and K is adequate in "healthy" but not corky root soils. Such comparisons may be misleading because they do not consider the minimum nutrient levels at which seedlings can grow and still not exhibit deficiency symptoms. For example, 170 ppm Mg is adequate for seedling growth and even a 55 ppm in non-corky root soils (Table 1) growth may be uneffected, but the low (28 ppm) Mg levels in corky root soils may be critical, especially when seedlings are subjected to the additional stress of *X. bakeri* nematode root feeding.

Because past cultural and cropping practices have varied widely within and among nurseries, it may not be possible to pin-point specific nutrient deficiencies for corky root soils. Probably their only common characteristics are that they are sandier and less fertile than their "healthy" counterparts. Fallowing increases the organic matter and nutrient content of corky root soils would help seedlings offset the effects of *X. bakeri* feeding.—Jack R. Sutherland, L. J. Sluggett, and W. Lock, Pacific Forest Research Centre, Victoria, B.C.