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SILVICULTURE

The Effect of Defoliation on Conifer Seedling Root Initiation.—A positive relationship between conifer seedling root growth and photosynthetic activity has been suggested by several workers (Keller, Forstwiss. Centralb. 85:65-79, 1966; Etter and Carlson, Can. J. Plant Sci. 53:395-399, 1973). Since root initiation in lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and white spruce (*Picea glauca* [Moench] Voss) seedlings was stimulated by light (Carlson, Bi-Mon. Res. Notes, 32:21-22), it was suggested that the light affects the hormonal composition and/or chemical balance, which directly affects root initiation. The extent to which the light-intercepting area of a seedling affects root initiation is the subject of this report.

Dormant 2-0 lodgepole pine and 3-0 white spruce seedlings were partially defoliated to test the effect of needle loss on root initiation. Three defoliation treatments were used for pine (0, 50, and 100% foliage removed) and four for spruce (0, 25, 50, and 75% foliage removed). In lodgepole pine the needles were removed starting at the top until the desired percentage of defoliation was attained. Attempts to remove needles from the spruce resulted only in extensive injury to the seedlings; therefore, defoliation was attained by cutting the tops to the desired sizes. The seedlings were potted in sand and grown for 30 days in the greenhouse. Greenhouse conditions were the same for all treatments, i.e. minimum light intensity was 10 500 lux, day length was 18 h, air temperature ranged from 15 to 30°C, and sand temperature was maintained at 18.5 ± 1°C. The seedlings were excavated after 30 days and new root tips counted. The data are expressed as means of 80 seedlings per treatment. The means were compared using a modified range test (Snedecor, Statistical methods, Iowa State Coll. Press, 1959, pp. 251-253).

Lodgepole pine seedling that had 50% or 100% of their needles removed produced (significantly) fewer new roots than the nondefoliated control (Table 1). Those that had 100% of the needles removed produced fewer new roots than those with 50% defoliation. However, only when 100% of the needles were removed did the number of seedlings with new roots decrease. These data are similar to those shown for reduction in light intensity for lodgepole pine (Carlson, *op. cit.*). A 50% reduction in light intensity or in needles did not result in fewer plants with new roots, but the number of roots per plant was less. A 100% reduction in light intensity or needles resulted in fewer plants with roots and fewer roots per plant.

In white spruce, 25% reduction in foliage (tops) significantly increased root initiation. However, the total number of plants with new roots remained unchanged. In fact, none of the defoliation treatments on white spruce appreciably affected the number of plants with new roots. Only the 75% top reduction resulted in significantly fewer roots per plant.

In general, reduction of the photosynthetic area significantly reduced root production for both species. However, it took a greater amount of defoliation to initialy reduce root production in white spruce than it did for pine. The difference in the white spruce response could possibly be due to the method of defoliation. Increased root initiation by partial defoliation (25% and 50%) could be related to removal of the terminal bud and needles rather than needles only (as in pine) and its effect on the hormonal balance. The hormonal effect of bud removal stimulating root production may have obscured the effect of reducing the photosynthetic needle area.

TABLE 1

The effect of defoliation on conifer root initiation

Species	Amount of defoliation	Roots per living plant	Plants with new roots -%
Pine	None	49.1a*	93.8
	50%	40.8b	93.8
	100%	8.9c	68.8
Spruce	None	41.3b	100.0
	25%	48.8a	100.0
	50%	45.2ab	100.0
	75%	33.6c	96.3

* The letters indicate multiple range groupings of treatments which do not differ significantly at the 5% level.

The data presented here on defoliation and those on the effect of light regimes (Carlson, *op. cit.*) show that root initiation of conifers is directly related to activity in the shoots. That activity may be photosynthetic and/or hormonal in nature depending on the conifer species. The extent to which either photosynthesis or hormones affect root initiation will need further investigation.—Lester W. Carlson, Northern Forest Research Centre, Edmonton, Alta.

Germination of Black Spruce and Jack Pine Seed on Soil and Germination Paper Media Following Paraquat Herbicide Spraying.—Several herbicides have been found to have an inhibitory effect on the germination of tree seed, and a toxic effect on young seedlings (Kozlowski, Growth and development of trees. Vol. 1, Acad. Press, 1971). To date, no studies have been reported on the effects of paraquat (1,1′-dimethyl-4,4′-bipyridilium), which is reported to lose its effectiveness upon contact with soil (Costen, Ont. Prof. For. Assoc., Herbic. Semin., Toronto, Ont. 11 p, 1968; Winston and Haavisto, Bi-mon. Res. Notes 30(6):37-38, 1974). The following note summarizes the results of three tests on the effects of paraquat on the germination of black spruce (*Picea mariana* [Mill.] B.S.P.) and jack pine (*Pinus banksiana* Lamb.) seed.

In the first study, paraquat, at rates equivalent to 0.00, 0.56, 1.12 and 2.24 kg/ha dissloved in 336 *l*/ha of water, was applied by mist blower to 0.01 ha field plots in peatland conditions. Four petri dishes (two covered to act as controls), each containing 100 pre-imbibed black spruce seeds on moistened germination paper, were located in each plot. Spray was applied uniformly to drip point. Each treatment was replicated four times. Immediately after spraying, all seeds were subjected to a 28-day laboratory germination test at 25°C.

Significantly more seeds germinated in the controls than in the paraquat treatments at any concentration (Table 1). Germination of the fully imbibed black spruce seeds on germination paper in petri dishes decreased with increasing concentrations of herbicides.

In the second study, we attempted to determine whether a low concentration of paraquat might affect germination of dry seeds, i.e., seeds not pre-imbibed. Black spruce (seed from a different source than that used in the first study) and jack pine seed were set out on pre-moistened germination paper in petri dishes (2 species × 4 replicates × 100 seeds per replicate) in the laboratory. Paraquat was sprayed by hand-held mist sprayer at a rate equivalent to 0.56 kg/ha dissolved in 336 *l*/ha of water on each container. These containers were then covered and placed in a germinator at 25°C. Untreated controls were maintained throughout the 28-day test.

All seeds started to germinate normally and it appeared that the low concentration of herbicide did not affect germination. The seeds, once germinated (radical length ⩾ 3 mm), were not removed from the containers, but were allowed to continue growing. It soon became apparent that radicles in the treated petri dishes were not continuing to

TABLE 1

Effect of paraquat herbicide on germination of pre-imbibed black spruce seed on germination paper

Paraquat (kg/ha)	Percent germinated
0.00	77.7a*
0.56	18.9b
1.12	7.5c
2.24	0.0d

* All values differ significantly (P .05)

TABLE 2

Effect of paraquat (rate equal to 0.56 kg/ha) on the germination and radicle development of jack pine and black spruce seed (not pre-imbibed) on germination paper

	Treated (%)	Control (%)
Jack pine		
(radicles > 3 mm)	72	84
Black spruce		
(radicles > 3 mm)	29	99
(radicles < 3 mm)	12	0

elongate and that the seed coats were not being held aloft, as in the controls. By the end of the test period, 72% of the treated jack pine seed had germinated (Table 2), and most of the remainder had split seed coats. Only 29% of the herbicide-treated black spruce had germinated. Thus if seeds are kept in a medium that has been treated with even a low concentration of paraquat, it is apparent that germination processes can begin, but the delicate juvenile portions (hypocotyl, cotyledon) of the plant can be affected by the herbicide.

As the previous two studies had been done on sterile germination paper with no buffering capacity or exchange sites, we did a third study using loamy sand and peat as growing media. The study was a 2 soils × 2 species × 2 herbicide levels split plot factorial with 3 replications. Large tub containers (34 × 30 × 19 cm deep) were filled with either loamy sand or peat. One-half of each tub was surface-sown with 100 jack pine seeds (not pre-imbibed), while 100 black spruce seeds were sown onto the other half. Paraquat (at a rate equivalent to 0.56 kg/ha dissolved in 336 *l* of water) was sprayed on three tubs of each soil type. The other three tubs of each soil type were retained as controls. Germination and seedling development were assessed weekly for the next 4 weeks.

There was no apparent difference in germination (Table 3) or seedling development between the treated and the control seeds. As all seeds that germinated developed into healthy seedlings, we concluded that paraquat was deactivated upon contact with the soil and did not cause damage to germinating seeds or seedlings.

In tests similar to ours, several authors (Sasaki and Kozlowski, Nature 209:1042-3, 1966, and Bot. Gaz. 129 (3):238-246, 1968; Kozlowski and Torrie, Soil Sci. 100(2):139-146, 1965; Dawson, Weeds 11(1):60-67, 1963) have reported that various herbicides produce poorer germination and seedling development when tested on germination paper than when tested on soil media. We found no detrimental effects attributable to paraquat when containers with deep loamy sand or peat were used, whereas both germination and seedling development were severely curtailed in the petri dishes with germination paper. Sasaki and Kozlowski (1968) suggest that the high absolute toxicity of herbicides is often masked in soil culture because of difficulties in determining herbicide uptake by plants. Our studies suggest that paraquat has a high absolute toxicity which is reduced on contact with soil.

In summary, our results indicate that paraquat may be applied at the time of sowing black spruce or jack pine seed (in a soil medium)

TABLE 3

Effect of paraquat (rate equal to 0.56 kg/ha) on the germination of black spruce and jack pine seed in a loamy sand or peat

	Black spruce		Jack pine	
	Loamy sand (%)	Peat (%)	Loamy sand (%)	Peat (%)
Control	99	98	80	81
0.56 kg/ha paraquat	99	99	80	79

without detriment to seed germination and seedling development. Furthermore, they indicate the necessity for adopting standard procedures for testing the effects of herbicides on germination of tree seed.—V.F. Haavisto and D.A. Winston, Great Lakes Forest Research Centre, Sault Ste. Marie, Ont.

ENTOMOLOGY

Effect of Age on Calling Behavior and Mating Success of Whitemarked Tussock Moths.—Aging frequently accounts for reduced fecundity and other changes in many insects (Englemann, The Physiology of Insect Reproduction, Pergamon Press, Oxford 1970). We describe here several factors related to aging which affect mating and fecundity in the whitemarked tussock moth, *Orgyia leucostigma* J. E. Smith.

At emergence whitemarked tussock moth females contain a full complement of mature eggs and are ready to mate. If females fail to mate within the first few days following eclosion, they usually show a substantial reduction in mating success thereafter. For example, when we compared the mating success of newly emerged females with 2-day-old females we found that 83% of the newly emerged females mated overnight while only 33% of the 2-day-old females had mated within the same period. Moreover, the egg masses from these older females were generally smaller than those from mated, newly emerged females.

Undoubtedly one factor contributing to the reduced mating success of the older virgin females is related to decreased pheromone production and hence decreased female attractiveness. For example, it has been shown (Grant, Can. Ent. 107:303-309, 1975) that sex pheromone extracts from females more than 2 days old were 13- to 173-fold less potent than similar extracts from newly emerged females. In addition, Percy *et al* (Can. Ent. 103:706-712, 1971) using a flight olfactometer found that females on the day of eclosion were the most attractive to males and that attractiveness declined thereafter. The poorest responses were obtained with females more than 2 days old.

However, not only is pheromone production reduced in older females but the pheromone releasing mechanism (i.e. calling behavior) is altered and, in fact, is replaced by oviposition behavior. Characteristically virgin whitemarked tussock females, like other lymantriids (Doane, Ann. Entomol. Soc. Am. 61: 768-773, 1968), lay unfertilized eggs either singly or in irregular scattered masses, a habit known as spewing. We observed that as this oviposition behavior of virgin females increased the number of females calling at any one time decreased.

To quantitate this relationship, we recorded the number of eggs deposited by virgin females held on a natural photo-periodic regime (approx. 16:8 h light/dark) recording at the same time the percentage of females that were calling. The results shown in Figure 1 compare the percentage of females calling at 9 AM on each day (wild females normally call at this hour) with their accumulated egg deposition over a period of 3 1/2 days. As can be seen calling behavior progressively decreased as egg deposition (and hence oviposition behavior) increased. Calling behavior recorded at other times of the day also showed the same decrease with female age. The most abrupt change in oviposition (spewing) occurred after 48 h which coincided with the greatest decrease in calling behavior. We found that at this time females not calling were

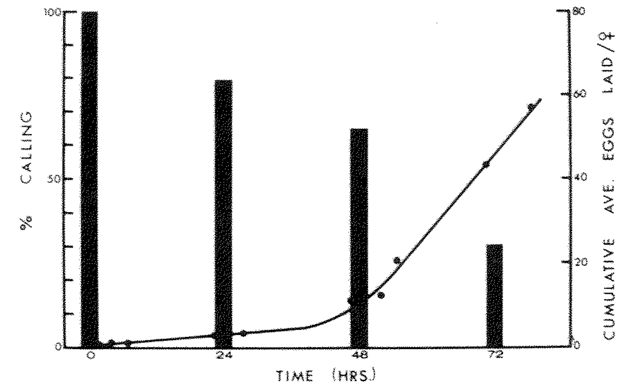

Figure 1. Comparison of calling behavior and egg deposition of 23 virgin *O. leucostigma* females over a 3 1/2-day period. Vertical bars represent female calling and continuous line represents oviposition.

usually ovipositing and only rarely were behaviorally inactive. This relationship between calling and oviposition is not surprising because in moths these behaviors are mutually exclusive although some pheromone may be released during oviposition (Grant, 1975).

Figure 1 also demonstrates that by the time females are more than 2 days old they have deposited a considerable number of unfertilized eggs. As a consequence these females are noticeably smaller than newly emerged females. Undoubtedly this accounts for the smaller masses of fertilized eggs laid by older females.

Thus the consequences of aging for whitemarked tussock moth females are reduced fecundity because of spewing and a decreased frequency of calling behavior which ultimately reduces the chances of mating. Concomitantly, pheromone production declines further decreasing the attractiveness of females. Clearly it is advantageous for whitemarked females to mate as soon as possible after eclosion. In field populations, the emergence of males before females may be one mechanism to ensure such early mating, but other mechanisms, perhaps related to pheromones and mating behavior, should also be looked for.—G. G. Grant and L. McCarty, Insect Pathology Research Institute, Sault Ste. Marie, Ont.

Weather and Outbreaks of the Eastern Hemlock Looper in Newfoundland.—The eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.), is a native pest of the coniferous forests of eastern North America, and periodic outbreaks, at 5-7-year intervals, have been reported from Newfoundland Island since 1912. The outbreaks usually lasted from 4 to 6 years but individual infestations collapsed in about 2 years (Otvos *et al.*, Inf. Rep. N-X-68, 1971).

Weather is generally believed to be a major factor affecting fluctuations of insect populations. This paper examines the population changes of the eastern hemlock looper in Newfoundland in relation to temperature and precipitation during the period of 1947-1971 with the utlimate goal of using this relationship to facilitate forecasting the course of future outbreaks.

Information on looper population levels on balsam fir, *Abies balsamea* (L.) Mill., black spruce, *Picea mariana* (Mill.) B. S. P. and white spruce, *P. glauca* (Moench) Voss, was obtained from Island wide surveys conducted annually by the Forest Insect and Disease Survey. The average number of larvae per tree was calculated for the Island and plotted for each year from 1951 to 1971. Earlier records on insect numbers were incomplete and were not included in the analysis.

Temperature and precipitation data during the larval and pupal stages of the looper (May-August) recorded at three weather stations across the Island (St. John's, Gander and Stephenville) were obtained from the Monthly Record (Atmospheric Environment Service, Environment Canada). The average difference from the 30-year (1941-1970) normal for temperature and precipitation during May to August was computed and plotted for each year.

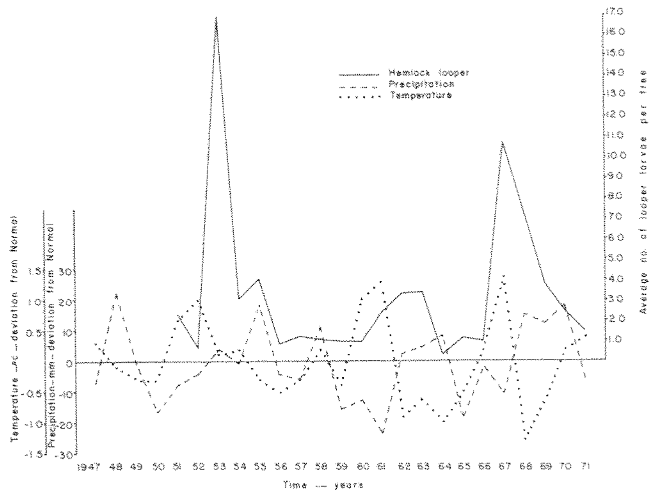

Figure 1. Average number of hemlock looper larvae per tree and deviations of temperature and precipitation from their 30-year normals (1941-1970).

Three peaks in looper numbers shown in Figure 1 represent the outbreaks during the period of 1951 to 1971: the first from 1947 to 1954 (Carroll, Can. Ent. 88:587-599, 1956) and the second and third from 1959 to 1963 and from 1966 to 1971, respectively (Otvos *et al.*, Inf. Rep. N-X-68, 1971). The increase in looper numbers to epidemic levels was preceded by about 2 years of warmer than normal temperatures for two of the three outbreaks and above-normal temperatures occurred for 2 years during the third outbreak. Precipitation generally was less than normal during the three outbreaks. Similarly a number of spruce budworm epidemics in different parts of Canada were preceded by a period of 3 to 4 years of warm, dry weather (Wellington *et al.*, Can. J. Res. (D) 28: 308-111, 1950; Ives, Inf. Rep. NOR-X-118, 1974; and Pilon and Blais, Can. Ent. 93: 118-123, 1961). Thomson (Bi-mon. Progr. Rep. 8(3):3, 1952) working on the western hemlock looper in British Columbia reported that weather was usually extremely dry in September (when mating of this insect occurs in B.C.) for 3 years prior to a major increase in adult numbers.

In Newfoundland, the decline of the eastern hemlock looper numbers was generally preceded by a period of lower than normal temperatures. Precipitation usually was above the normal during the decreasing phase of the outbreaks. Silver (Can. Ent. 95:58-61, 1963) reported that epidemic blackheaded budworm populations decreased or collapsed during or following periods of above average precipitation.

The results of this preliminary investigation suggest that deviation of temperature and precipitation from the normal was correlated with fluctuations of looper population levels. These and possibly other weather parameters affect looper populations, in part directly, by influencing larval development and in part indirectly, through their affect on biotic control factors such as parasites and diseases. A more detailed analysis of the patterns between weather and looper population levels will be conducted to develop a system for forecasting the development and decline of hemlock looper outbreaks.—Imre S. Otvos, Newfoundland Forest Research Centre, St. John's, Nfld.

Mortality of Overwintering Eggs of the Eastern Hemlock Looper in Newfoundland.—The eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.) is an important pest of balsam fir, *Abies balsamea* (L.) Mill., forests. The eggs of the looper are about 1 mm in length and are laid from late August to October, usually singly or in groups of two or three on a variety of substrates including bark and lichens on trees and moss on the forest floor (Otvos, Clark and Clarke, Nfld. For. Res. Centre, Inf. Rep. N-X-68, 1971). The insect overwinters in the egg stage and hatches in June of the following year (Carroll, Can. Ent. 88: 587-599, 1956). This note presents data on the mortality of overwintering looper eggs in four generations.

One square foot (929 cm²) of birch bark (*Betula* spp.) and sphagnum moss (*Sphagnum* spp.) or samples of the lichen, old man's beard (*Usnea* sp.) were collected twice in looper infested stands near Robinson's River in western Newfoundland and at Salmonier River and Bellevue Beach in eastern Newfoundland. The first collection was made between late October and mid-November after egg laying was completed and the second collection during the following spring before larval hatching had begun. The samples collected in the fall were stored for about two months at 90% R. H. and 2°C to break diapause and those collected in the spring were processed without storage.

The eggs were extracted by soaking the samples in 2% aqueous bleach solution which releases the looper eggs without affecting hatching of the larvae or the emergence of egg parasites (Otvos and Bryant, Can. Ent. 104: 1511-1514, 1972). The extracted eggs were classed as fertile or sterile (Otvos and Bryant, 1972) and the fertile eggs were reared in petri dishes (85 mm x 10 mm); 25 eggs/dish, at 21 ± 20.0°C and 70% R. H., under 12-hour light regime. The emergence of looper larvae and adult parasites was recorded daily until both larval and parasite emergence was completed. Hatching and parasitism were calculated as percentages based on the number of fertile eggs. The difference in hatching between the fall and spring samples collected at the same location was considered to be due to mortality of overwintering eggs. The total monthly precipitation and the mean monthly temperature during the winter (from October to May) and their deviations from the 30-year average (1941-1970) were analysed to determine if these parameters were related to mortality of overwintering eggs. Precipitation and temperature data were obtained from Monthly Records (Atmospheric Env. Serv., Environ. Can.) for two stations near the study areas (Colinet and Port aux Basques).

Percent hatch from eggs collected in the fall varied between 66% and 86% in the four generations (Table 1). This range of hatching success agrees closely with the average of 70% based on rearings of 5,000 looper eggs collected at 11 widely separated locations in Newfoundland (Otvos, unpublished data). Less than 5% of the unhatched eggs contained pharate larvae or partly developed embryos, in the remainder the content of the eggs appeared to be desiccated. The highest percentage of hatch occurred at Bellevue where the infestation was the youngest. Infestations at the other locations were older but still in the increasing phase. Proportionately more larvae hatch from eggs at the beginning of an infestation than during the latter stages (Otvos, unpublished data).

Percent hatch from eggs collected in the spring ranged between 10% and 25% in the first three generations (Table 1). The percentage of eggs killed by parasites was about the same for eggs collected in the fall and spring, therefore, parasitism cannot be the cause of the decrease in hatching success.

The difference between the hatching of the eggs collected in the fall and spring (i.e., mortality of overwintering eggs) in the four generations was 45.4%, 58.3%, 65.3% and 1.9%. The difference of 1.9% in the fourth generation is so small that it can be ignored. The sum of the differences of the monthly mean temperatures from their respective normals during the overwintering period of the eggs in the four generations was -9.1°C, -13.5°C, -8.9°C and -2.3°C suggesting that mortality of over-wintering hemlock looper eggs is inversely related to the difference between the mean temperature and the normal. The exceptionally high survival of the eggs at Bellevue is considered to be the result of the relatively early stage of the infestation and the higher winter temperatures at this location.

The average hatchings from the four fall and spring collections, regardless of substrates, were 73.0% and 31.4% respectively (Table 1) showing a 41.6% egg mortality over the winter. Although the lethal low temperature for overwintering looper eggs is not known, it could be assumed that low winter temperature was mainly responsible for the mortality of overwintering eggs. Snow is generally considered as an excellent insulation and it should have provided good protection from

TABLE 1

Percent hatching of hemlock looper larvae and parasitism of eggs collected in the fall and spring in four generations

Sample				No. eggs	Percent	
date	location	substrate	size[d]	reared	hatching	parasitism
Fall 72	Salmonier River	B.B.[a]	29	319	66.1	2.5
		Moss[b]	26	77	70.1	1.3
		Total		396	66.9	2.3
Spring 73	Salmonier River	B.B.	30	162	25.9	0
		Moss	20	108	14.8	0
		Total		270	21.5	0
Fall 73	Salmonier River	B.B.	25	57	77.2	1.8
		Moss	20	10	70.0	0
		Total		67	76.1	1.5
Spring 74	Salmonier River	B.B.	30	137	21.9	1.5
		Moss	20	71	9.9	0
		Total		208	17.8	1.0
Fall 74	Robinson's River	B.B.	20	64	75.0	9.4
		Moss	10	11	81.8	9.1
		Total		75	76.0	9.3
Spring 75	Robinsons's River	B.B.	20	48	8.3	12.5
		Moss	10	8	25.0	0
		Total		56	10.7	10.7
Fall 75	Bellevue Beach	O.M.B.	45	152	84.9	0
		Moss	10	7	100.0	0
		Total		159	85.5	0
Spring 76	Bellevue Beach	O.M.B.	48	111	88.3	0
		Moss	10	8	87.5	0
		Total		119	87.4	0
Fall		B.B.		440	68.9	3.4
		B.B. & O.M.B.		592	73.0	2.5
		Moss		105	73.3	1.9
		Total		697	73.0	2.4
Spring		B.B.		347	21.9	2.3
		B.B. & O.M.B.		458	38.0	1.8
		Moss		195	16.4	0
		Total		653	31.4	1.2

[a]B.B. = Birch bark; [b]Moss = Sphagnum moss; [c]O.M.B. = Old man's beard

[d]Sample size are in ft² except for O.M.B., where samples were 'moderately' packed in wire baskets (25 cm x 15 cm x 10 cm) before processing.

temperature extremes for eggs in the sphagnum moss and partial protection for eggs on the trees, yet mortality among the eggs was similar even during the winter of 1974-75 when about 45% of the total winter precipitation (958.90 mm) was snow. The form of precipitation during the winter does not appear to influence the mortality of the overwintering hemlock looper eggs.—Imre S. Otvos, Newfoundland Forest Research Centre, St. John's, Nfld.

PATHOLOGY

Transmission of *Entomophthora egressa* MacLeod and Tyrrell to *Malacosoma disstria* (Hbn.), a Non-host Species.—It is difficult to assess the real effect of supplementing a pathogen present in an insect population at a low level. One approach is to introduce a pathogen to which the host is susceptible but which does not occur naturally on the particular insect under study.

Entomophthora egressa MacLeod and Tyrrell was first isolated in 1972 (Tyrrell and MacLeod, J. Invertebr. Pathol. 19: 354-360, 1972) from the eastern hemlock looper *Lambdina fiscellaria fiscellaria* (Guen.). Other strains of *E. egressa* have since been isolated from several other lepidopterous species. The forest tent caterpillar larvae (*Malacosoma disstria* Hbn.) proved readily susceptible to the fungus by injection of the protoplast state (Tyrrell and MacLeod, 1972), but it has never been observed in natural populations of this insect. Furthermore, the pear shaped conidia of *E. egressa* can be readily distinguished from the oblong to ellipsoidal conidia of the natural *Entomophthora* pathogen of the forest tent caterpillar.

Preliminary tests under greenhouse conditions showed that fourth instar forest tent caterpillar larvae could readily be infected with *E. egressa* via the conidial stage of the fungus. The conidia came from forest tent caterpillar larvae which had been injected with *E. egressa* protoplasts. A small scale field test was therefore set up to determine whether an *E. egressa* infection could be established in a natural population of forest tent caterpillar.

Twelve hundred fourth instar laboratory-reared forest tent caterpillar larvae were injected with protoplasts of *E. egressa* strain 519 on 3-4 June, 1974, and groups of 100 were placed in 1-quart cardboard containers and held in the laboratory until 6 June, when they were transported to a field location near Alban, Ont. One container was fastened to each of 12 separate poplar trees (*Populus tremuloides* Michaux) about 4 ft above the ground and the top was left open to allow the larvae to crawl out of the container. The trees, already partially defoliated, were about 15-20 ft in height and supported a population of forest tent caterpillars visually estimated to be at least 10^4 per tree. The population was sampled on this date (about 15-25 insects per tree) and subsequently at 3-4 day intervals. The sample insects were pooled and reared in the laboratory on poplar foliage for 7 days. Any which died were examined microscopically for the presence of fungus. Injected larvae retained in the laboratory died approximately 4-7 days after injection and mortality was greater than 90%.

Table 1 presents a summary of the results. The dates are those on which the sample was collected; the associated mortality is that recorded over the next 7 days. Observations on 10 June revealed that many of the injected larvae had died withour leaving the cups in which they were placed on the tree. This number could not be estimated due to decomposition of the larvae, but dead, sporulating larvae were observed on the tree trunks in the vicinity of the cups. It is reasonable to assume that most, if not all, artificially-infected insects had died before the sample was taken on 10 June, and certainly by 13 June. As a further check, 50 additional laboratory-infected insects had been placed on a small (4 ft) tree adjacent to the sample trees and enclosed in a wire mesh screen. These insects were recovered on 10 June, and mortality was 100%. The results therefore show that the fungus was successfully transmitted to insects in the natural population. Despite the fact that the fungus on all infected insects in the laboratory-reared samples produced conidia, the disease failed to maintain itself in the field population. However, complete defoliation of the trees occurred about the 13-17 June and the insects entered the wandering phase which precedes pupation.

TABLE 1

Date	Sample size	Total mortality in laboratory rearing	Diagnosis		
			E. egressa	E. spp.	Other
6/6/74[a]	N.R.[b]	0	-	-	-
10/6	187	54	54(28.5%)	0	0
13/6	280	71	70(25.0%)	1(0.4%)	0
17/6	186	4	1(0.5%)	0	3
20/6	265	29	1(0.4%)	6(2.3%)	22
24/6	316	36	0	17(5.4%)	19
27/6	159	38	0	10(6.3%)	28

[a] Date on which laboratory-infected insects were introduced into field populations.
[b] N.R. = not recorded.

Interestingly, the natural pathogen did not appear in the population until this time, although our results show that the insects are susceptible to *Entomophthora* infection prior to this time.

In summary, it was shown that the fungus *E. egressa* can be transmitted from laboratory-infected insect larvae to field populations of another host insect, and with suitable modifications to the experimental procedure may provide an alternative method of studying the dynamics of fungus epizootics.—David Tyrrell, Insect Pathology Institute, Sault Ste. Marie, Ont.

Comparison of Field-propagated Nuclear Polyhedrosis Virus from Douglas-fir Tussock Moth with Laboratory-produced Virus.—The virus used in the trials was a strain of white-marked tussock moth, *Orgyia leucostigma* (J. E. Smith), nuclear polyhedrosis virus (NPV) originally isolated in Nova Scotia. To propagate it in the field, 36 Douglas-fir trees (mean weight 4.5 m) with a population of 30-150 Douglas-fir tussock moth, *Orgyia pseudotsugata* (McD.), larvae per 46 cm branch tip were sprayed in the Kamloops area in British Columbia on June 7th, 1975 using a mist blower. The larvae were mainly in the fourth and fifth instar and 7.6 *l* of aqueous spray containing 10^8 polyhedra/ml were applied.

First deaths due to virus were recorded 10 days after the application. Larvae were harvested by shaking each tree and collecting them on a beating sheet after 14 days. They were removed from the debris, lyophilized and ground to a fine powder. This operation yielded about 7,000 larvae which in turn gave 188 g of powder with 4 billion polyhedra/g. Approximately 20 man-hours were utilized in this field propagation experiment and there was sufficient virus to spray 3 ha at the operationally recommended dosage of 250 billion polyhedra/ha (Stelzer *et. al.*, J. Econ. Entomol., in press).

To compare the efficacy of this field-produced virus with laboratory-produced virus, a sample of the latter, propagated in white-marked tussock moth larve, was supplied by the Insect Pathology Research Institute (IPRI). This lyophilized material contained 10 billion polyhedra/g. Both virus samples were formulated in water to give 25 billion polyhedra per 9.4 *l* and 25% (v/v) molasses was added as an anti-evaporant and UV protectant.

Three 2 ha plots were selected in the Kamloops area, one for each virus treatment and one as a check. Pre-treatment counts were made on first and second instar larvae and are shown in Table 1. The applications were made the following day on June 2nd, 1976 using a Cessna *Agtruck A188* equipped with 22 1810 "Tee Jet" nozzles set at 45° to the airflow. With a boom pressure of 2.8 kg/cm^2 and a swathe width of 30 m the delivery rate was 9.4 *l*/ha. The plots were sprayed twice in order to obtain an application of 125 billion polyhedra/ha at 18.8 *l*/ha which is half the operationally recommended dosage. This was selected to avoid overkill and make the comparison of the two treatments more meaningful.

Larval population density estimates were made 17, 24 and 31 days following the spray and the mortality due to the treatment was calculated by Abbott's formula (Abbott, J. Econ. Entomol. 18: 265-267, 1925). These results are shown in Table 1. Larvae sent to IPRI for virus identification 33 days after the application showed 30% NPV infection from the field-produced virus plot, 30% NPV from the laboratory-

TABLE 1

Virus Efficacy Trial

	Prespray	Post-spray (days)			
		17	24	31	38
Density of larvae/6,450 cm^2 of foliage					
Check	115.2	100.8	100.4	72.9	55.9
Field-produced virus	227.0	41.9	45.1	34.9	19.9
Laboratory-produced virus	291.8	101.9	54.3	25.4	14.7
Percentage larvae surviving					
Check	100	87.5	87.2	63.3	48.5
Field-produced virus	100	18.5	19.9	15.4	8.8
Laboratory-produced virus	100	34.9	18.6	8.7	5.0
Percentage mortality (adjusted by Abbott's formula)					
Field-produced virus		78.9	77.2	75.7	81.8
Laboratory-produced virus		60.1	78.7	86.3	89.7

produced virus plot and 10% NPV from the check plot. Positive results from the check plot showed that there was some naturally occurring NPV in the area.

The results from these treatments, using 125 billion polyhedra/ha, showed that control could be obtained with this dosage and the efficiency was similar to the operationally recommended dosage of 250 billion polyhedra/ha tested in the same area in 1975 (Stelzer *et. al.*, J. Econ. Entomol., in press). Hence, it may be possible to reduce the operational dosage. The efficacy of laboratory-produced and field-produced NPV was similar.

There are advantages and disadvantages to both methods of virus production. For laboratory production, trained personnel and a well-organized insect rearing program are required. Both white-marked and Douglas-fir tussock moth larvae shed hairs which cause skin irritation and people working with these species frequently contract allergies. Much less organization and expertise are required to propagate virus in larvae in the field and the problem of allergies is almost eliminated. However, due to virus already present in the population and other naturally occurring pathogens, the purity of field-produced virus cannot be guaranteed.—S. Ilnytzky, Pacific Forest Research Centre, Victoria, B.C. and J. R. McPhee and J. C. Cunningham, Insect Pathology Research Institute, Sault Ste. Marie, Ont.

Relative Susceptibility of Red Pine and Jack Pine to *Gremmeniella abietina*.—Both jack pine (*Pinus banksiana* Lamb.) and red pine (*P. resinosa* Ait.) are damaged by the fungus *Gremmeniella abietina* (Lagerb.) Morelet in portions of the Great Lakes-St. Lawrence Forest Region (Dorworth, Can. J. Bot. 50:751-765, 1972). Little damage apart from loss of branches below breast height is experienced after the trees surpass 2 m in height, whereas stems of smaller trees are often girdled or develop extensive basal cankers (Dorworth, Can. For. Serv. Rep. O-X-252, 1976). Mortality greater than 75% is common in red pine plantations wherein *G. abietina* proliferated during the first several years of plantation development. Various degrees of success have been evident where jack pine was used. These two species are the ones most widely employed for afforestation of the sand-gravel outwash plains that abound in the region. Provincial foresters in Sault Ste. Marie and Blind River (Ontario) districts have begun to plant jack pine in areas where *G. abietina* repeatedly caused failures of attempts to establish red pine. The present study evaluated relative susceptibility of red pine and jack pine planted adjacent to one another and challenged equally with inoculum.

Red pine and jack pine seedlings (2+0) were planted in 1970 in four blocks on a site influenced by a pronounced kettle frost pocket. Each block contained two rows of inoculated and one row of uninoculated red pine, and two rows of inoculated and one row of uninoculated jack pine for a total of 1,350 each of inoculated and 450 each of uninoculated red pine and jack pine. Rows extended from the bottom of the pocket to the plain above.

Survival after 1 year included nearly the same number of red pines (648) as jack pines (680). It was presumed that spores of *G. abietina* produced on site after 2-3 years would cause infection of both healthy uninoculated seedlings and those of the inoculated seedlings which escaped initial infection. Both the procedures followed and survival 1 year after inoculation have been discussed in detail elsewhere (Dorworth, Eur. J. For. Pathol. 3:232-242, 1973) and the following deals mostly with survival of seedlings after 6 years.

A recount of survival in the fall of 1976 revealed that 103 or 6% of the red pine, and 294 or 16% of the jack pine were still alive. Most of the surviving red pine were severely deformed as a consequence of infection by *G. abietina*, and the average height was 0.7 m (range 0.3 m to 1.2 m). This species will probably be absent from the site within 5 years. Those jack pines which escaped initial infection generally exhibited adequate form and achieved an average height of 2.0 m (range 0.8 m to 2.6 m). Relatively little jack pine mortality is expected although lower branch infections will yield an unknown percentage of cankered mainstems.

Since symptoms of infection by *G. abietina* are indistinct by autumn, 210 dying branches were removed for laboratory culture on a medium consisting of 200 ml Campbell's V-8 juice: 800 ml water plus 20 g Difco agar to verify the presence of the pathogen. Of the red pine cultured, *G. abietina* was recovered from 80% of the samples taken outside the frost pocket and from 87% of those taken within, whereas *G. abietina* was recovered from 50% of jack pine samples taken outside the pocket and from only 36% of those taken within.

Neither 6% (red pine) nor 16% (jack pine) seedling survival appears satisfactory for afforestation efforts but these figures were calculated on the basis of total outplanting. If trees to which spores were directly applied in 1970 are left out of the calculations and only those which were naturally infected in the course of time by air- and water-borne spores are considered (900 original uninoculated controls), survival percentages are 23% for red pine and 65% for jack pine. These percentages are also valid since only the controls remain alive on the planting site. Direct application of spores in aqueous suspension in 1970 may in some way have circumvented the natural resistance mechanism of jack pine, and this would explain why no difference in survival was recorded in 1971. In any case, three conclusions may be drawn:

1. Jack pine is two to three times as resistant as red pine to *G. abietina* on dry sites in the Great Lakes-St. Lawrence Forest Region and the preference of provincial foresters for replanting with jack pine is entirely justified.
2. Frost damage does not alter the susceptibility of pines to infection by *G. abietina* although frost or other damaging agents may accelerate the rate and extent of ultimate tree mortality.
3. Up to 90% recovery of *G. abietina* from samples known to be infected is expected in early spring, whereas in summer when *G. abietina* is quiescent only 30-40% of such samples generally yield the fungus in culture. This implies that the fungus has resumed active growth by October and is occupying new woody tissues unaccompanied by those various fungal associates which have themselves become quiescent and now fail to compete with *G. abietina*.—C. E. Dorworth, Great Lakes Forest Research Centre, Sault Ste. Marie, Ont.

Fungicide-drenches Ineffective against Damping-off of Sitka and White Spruces.—In 1971, field trials were started using seed-treatments and fungicide-drenches in an attempt to control pre- and post-emergence damping-off losses in British Columbia Forest Service (BCFS) nurseries. Reports have been prepared on the fungicide-seed treatment experiments with the major seedling species grown in B.C. (Lock, Sutherland and Sluggett, Tree Planter's Notes 26:16-18, 28, 1975) and on the use of fungicide-drenches for control of *Fusarium* root rot (late damping-off) of Douglas-fir (Bloomberg, Phytopathology 64:1153-1154, 1974). Field trial results with fungicide-drenches for control of damping-off of Sitka [*Picea sitchensis* (Bong.) Carr.] and white [*P. glauca* (Moench) Voss] spruce are reported here.

TABLE 1

Seedling emergence, damping-off losses, seedling survival and shoot lengths of Sitka and white spruce in fungicide soil-drench trials at Koksilah and Surrey nurseries.

Species, nurseries and parameters measured[a]	Treatments[b]				
	Captan 31.4 kg/ha	Captan 15.7 kg/ha	Benlate 3.9 kg/ha	Vitavax 4.4 kg/ha	Control
Sitka spruce, Koksilah					
Emergence, %	55.9aa	60.9a	61.5a	60.9a	62.5a
Early damping-off, %	0.6a	0.2a	0.0a	0.0a	0.1a
Late damping-off, %	2.5a	1.3a	1.8a	1.4a	1.4a
Survival, %	52.1a	57.5a	58.4a	57.4a	59.5a
Shoot length, cm	3.5a	3.3a	3.4a	2.8a	3.2a
Sitka spruce, Surrey					
Emergence, %	78.3ab	80.0ab	83.7a	75.5b	81.6a
Early damping-off, %	15.1ab	11.0ab	6.2c	19.2b	7.5ab
Late damping-off, %	4.8a	6.5a	2.8a	4.6a	4.3a
Survival, %	63.2a	66.5a	74.9b	55.7c	71.4ab
Shoot length, cm	2.7a	3.0a	3.1a	2.3a	2.9a
White Spruce, Surrey					
Emergency, %	69.3ab	71.5ab	74.0a	68.3b	74.5a
Early damping-off, %	9.3a	5.0ab	2.0b	6.6ab	1.6b
Late damping-off, %	4.1a	3.0a	2.9a	1.8a	3.2a
Survival, %	59.3a	64.3ab	67.3ab	61.8ab	70.7b
Shoot length, cm	1.9a	2.0a	1.9a	1.9a	2.2a

[a] Seedling emergence and survival based on number of seeds sown, early and late damping-off based on number of germinants, shoot length is soil line to base of the terminal bud.

[b] Values are means of 15 replicates; reading across, means followed by the same letter are not significantly different ($P = .05$).

The trials were made during the 1973 growing season at the Koksilah (near Duncan) and Surrey nurseries of the BCFS. The experimental design was a randomized complete block, with each treatment and control replicated 15 times. Within each 3.1-m-long block, each of the four treatments, and a control, were applied to randomly selected 1-m-long sections of drill rows 2, 4 and 6 (the other rows were unsown). Each 1-m-long section was sown (May 7 to 15) with 100 evenly-spaced, stratified (van den Driessche, Res. Notes No. 48, B.C. Forest Service, Victoria, 1969) seeds which were covered with 0.6 mm of coarse sand. The germination capacities of the Sitka and white spruce seeds were 82 and 78% respectively.

The fungicides, applied as drenches at 10, 20 and 40 days after seed sowing, and their application rates per ha of seedbed were: Captan 50W, 31.4 kg; Captan 50W, 15.7 kg; Benlate 50W, .9 kg; Vitavax 75W, 4.4 kg. The common and chemical names of these fungicides are given in the CFS, Chemical Control Res. Inst. Inform. Rep CC-X-19, 1975. Control plots received only the same amount of water as used for the fungicide-drenches.

Seedling counts were made 8, 16 and 20 weeks after sowing at Koksilah and after 8, 9, 10, 11, 16 and 20 weeks at Surrey to determine emergence and numbers of seedlings killed by early and late damping-off. Dead seedlings were removed from the plots when counted. The data were subjected to an analysis of variance, using the cumulated data for each parameter for the entire growing season. Percentage data were transformed when needed to correct for heterogeneity of variance. Seedling shoot height (soil line to base of the terminal bud) was measured at the end of the growing season. Treatment means were compared, using the Student-Newman-Keuls' test (Steel and Torrie, Principles and procedures of statistics. McGraw-Hill, N. Y., 1960). The effects of time and time-fungicide interactions were also determined and these data are available from the authors.

None of the treatments (Table 1) significantly affected emergence, disease or shoot growth of Sitka spruce at Koksilah. At Surrey, emergence of Sitka spruce was not improved by any of the treatments; Vitavax caused some reduction in emergence. Disease losses were greater at Surrey than at Koksilah, and Vitavax and the highest dosage of Captan tended to increase early damping-off losses. The significant ($P=.05$) reduction in seedling survival in the Vitavax-treated plots was probably attributable to the effect of this fungicide on reducing seedling emergence and increasing early damping-off. The highest treatment level of Captan significantly increased early damping-off incidence of white spruce at Surrey. However, no significant treatment effects were evident for the late damping-off, survival or shoot growth parameters. We conclude from these experiments that, even with repeated applications and very high dosages, the test fungicides provided no protection against damping-off of Sitka and white spruce seedlings. Perhaps drenches with these or other fungicides might be of value in nurseries where damping-off is more prevalent, but we do not recommend their use on spruce seedlings in coastal B.C. nurseries.—Jack R. Sutherland and W. Lock, Pacific Forest Research Centre, Victoria, B.C.

FIRE

Effect of Slope on Fire Spread Rate.—As interest in the prediction of actual fire spread rate increases, some way of accounting for the effect of slope is desirable. The literature contains a few references on this question, and five of these are compared here. They are:

1. Anon. 1958. Manual for forest fire control (Table 2, p. 205). Northeastern Forest Fire Prot. Comm., Chatham, N.Y.
2. McArthur, A.G. 1966. Forest fire danger meter, Mark IV. Forest Res. Inst., Forest. and Timber Bureau, Canberra.
3. Van Wagner, C.E. 1968. Fire behaviour mechanisms in a red pine plantation: field and laboratory evidence. Dep. Forest and Rural Develop. Publ. 1229.
4. Sheshukov, M.A. 1970. (Effect of steepness of slope on the propagation rate of fire.) Lesnoe Khozyaystvo 1970 (1): 50-54. Translation 185672, Forest Fire Res. Inst., Ottawa.
5. Rothermel, R.C. 1972. A mathematical model for predicting fire spread in wildland fuels. U.S. Forest Serv. Res. Pap. INT-115. Intermtn. Forest and Range Exp. Sta., Ogden, Utah.

In spite of the large number of forest fires in countries where fire research programs exist, good field observations of the effect of slope on spread rate are scarce if not non-existent. Two of these references (1 and 2) are probably based on informal field observation, although the sources are not explicit. The other three describe laboratory experiments, one of which (described in 3) was performed at this station using 1.2-m-long beds of red pine needles. No matter how carefully such lab experiments are done, however, the question remains whether the results are valid when applied to full-scale real forest fires.

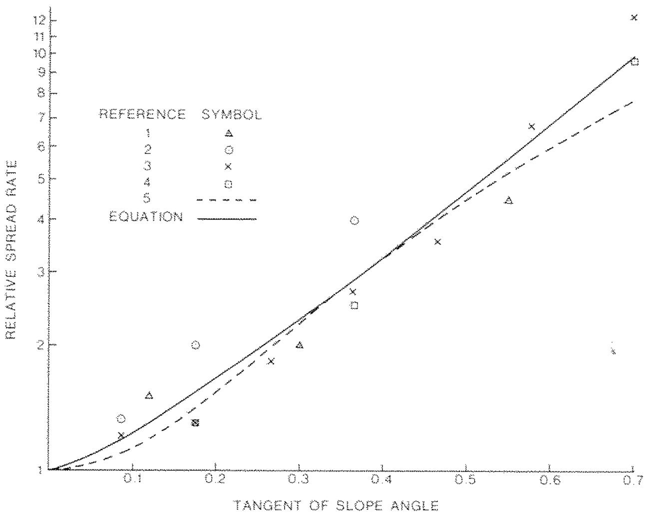

Figure 1. Graph of effects of slope on fire spread rate from five references plus equation in text.

The five relations were plotted (Figure 1) as relative spread rate, based on 1 for level ground, versus the tangent of the slope angle S. References 1 to 4 give individual values shown as points, whereas 5 provides an equation shown as a dotted line. This equation contains an additional variable, namely the "packing ratio" or proportion of fuel bed space occupied by fuel. A value of 0.04, appropriate for most litter layers, was used in this work. Plotted on semi-log paper, the five relations are reasonably similar and roughly exponential. Since good cause for preferring any one over all the others is lacking, a subjective average line was drawn through them, matching the equation

$$SF = e^{3.533 (\tan S)^{1.2}}$$

where SF is spread factor relative to 1 for level surface, and S is the angle between slope and horizontal. The equation is tabulated by percent slope (100 tan S) and angle S in Table 1.

TABLE 1

Relative spread factor by slope percent and slope angle

Slope %	Slope, deg.	Spread factor
0	0	1.00
10	6	1.25
20	11	1.67
30	17	2.30
40	22	3.24
50	27	4.65
60	31	6.78
70	35	10.00

This relation refers to upslope effect on spread rate. Downslope fires spread more slowly than level fires and another relation would be required. Also, it is suggested for use only up to 60 or 70% slope. References 3 and 4 both noted that as slope increased the flames leaned more and more toward the slope surface, even in still air. Above this limit flames would tend to bathe the slope directly, and fire behaviour would become very intense and unstable. This relation can be regarded as a digest of currently available knowledge about slope effect on fire spread, and a better one will probably come from more observation in the field rather than in the laboratory.—C.E. Van Wagner, Petawawa Forest Experiment Station, Chalk River, Ont.

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12 **Hatton, John V. 1976.** The potential of process control in kraft pulping of hardwoods relative to softwoods. *TAPPI* 59(8):48-50.

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