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ENTOMOLOGY

Effects of Aerial Application of Chemical Insecticides on Spruce Budworm Parasites.—Entomophagous parasites that attack spruce budworm are an important element of the ecosystem in which this lepidopterous pest occurs. The possible effect of aerial application of chemical insecticides on these parasites continues to be of concern. In Quebec in recent years, the time of the first application of insecticides has been advanced, and in 1976 it was at the beginning of larval emergence in the spring. Although the main reason given for this advanced timing is to prevent serious bud loss during early larval development, it has been suggested that early completion of operations would reduce the effect of treatment on parasites.

In Quebec in 1976, during studies on the impact of budworm larvae on balsam fir foliage throughout the feeding period, observations were made on the presence of larval parasites with respect to host development.

TABLE I

Presence of *Apanteles fumiferanae* Vier. and *Glypta fumiferanae* (Vier.) in relation to host population and development in four localities in Quebec in 1976

Plot no.	Date	Budworm population	Parasite population[1]		Budworm development in %					Parasite development in %			
			Apanteles	*Glypta*	IV	V	VI	Pupae	Adult	*Apanteles* Cocoon	*Apanteles* Adult	*Glypta* Cocoon	*Glypta* Adult
1	11-06	293	8 (3)	0	15	21	63	1	0	100	0	0	0
	16-06	242	19 (7)	0	7	17	71	5	0	100	0	0	0
	21-06	162	38 (18)	12 (6)	1	11	48	40	0	71	29	100	0
	29-06	60	36 (30)	25 (21)	0	10	33	16	41	61	39	88	12
2	9-06	260	2 (1)	0	24	66	10	0	0	100	0	0	0
	14-06	356	3 (1)	0	7	25	68	0	0	100	0	0	0
	17-06	237	13 (5)	0	5	4	88	3	0	100	0	0	0
	22-06	154	23 (12)	10 (5)	1	1	53	45	0	74	26	100	0
	28-06	114	29 (18)	19 (12)	0	0	26	66	8	93	7	100	0
3	10-06	573	3 (1)	0	57	36	7	0	0	100	0	0	0
	15-06	670	19 (3)	0	43	29	28	0	0	100	0	0	0
	18-06	694	114 (14)	0	18	18	63	1	0	98	2	0	0
	23-06	308	165 (33)	29 (6)	7	8	54	31	0	95	5	100	0
	2-07	231	172 (35)	90 (18)	1	3	18	76	2	75	25	100	0
4	22-06	312	4 (1)	0	11	66	23	0	0	100	0	0	0
	30-06	239	23 (9)	0	10	16	73	1	0	100	0	0	0
	8-07	277	39 (11)	31 (9)	1	1	26	72	0	87	13	100	0

Percentage parasitism shown in brackets.

Studies were conducted in four localities within a 112-km radius of Quebec City. The localities were chosen in different phenological zones and in areas with varying budworm populations. The study plots were visited approximately every 4 days throughout larval and pupal development. At each visit to each plot, 10 46-cm branch tips were obtained with pole pruners equipped with a basket, from the midcrown of each of 10 mature fir trees. The branches were placed in individual plastic bags and brought to the laboratory for examination. All larvae were counted and preserved in alcohol by date of collection, and head measurements were eventually made to determine instars (McGugan, Can. Entomol. 86:439-454, 1954). Parasite cocoons found on the branches were identified as to species and classified as emerged or unemerged.

At the egg, larval, and pupal stages the budworm are attacked by parasites. Most chemical control operations are aimed at the larval stage, and larval parasites are the ones likely to be affected by commercial spraying operations. Two principal hymenopterous parasites emerge from budworm larvae: *Apanteles fumiferanae* Vier. and *Glypta fumiferanae* (Vier.). Numerous studies conducted by various workers in Ontario, Quebec, and New Brunswick during the past 30 years indicate that these two parasites are usually the most abundant of the 15 or so species found during an outbreak. Upon emergence from the host, they spin cocoons that remain on the foliage; adults that emerge from the cocoons are, presumably, vulnerable to chemical sprays. Cocoons of these species are easily differentiated, and empty cocoons from which adults have emerged can readily be recognized.

Budworm populations varied between plots; at peak third instar they averaged 19, 29, 95, and 118 per 46-cm branch tip for plots 1, 2, 3, and 4 respectively.

The number of parasites in relation to host population and the development of host and parasites by collection date for each study plot are shown in Table 1. Parasitism was high in the study plots; it amounted to 30, 18, 35, and 11% for *Apanteles*, and to 21, 12, 18, and 9% for *Glypta* for plots 1, 2, 3, and 4 respectively. *Apanteles* was the first parasite to appear. Larvae of this parasite left the retarded fourth-instar host larvae when unparasitized budworm were already in the late sixth instar. Such representatives of the host population that were not in the ultimate larval instar when the first *Apanteles* cocoons appeared on the branches, were retarded individuals that would eventually produce either *Apanteles* or *Glypta*. When *Apanteles* adults emerged from the cocoons, close to 50% of the host population was in the pupal stage. *Glypta* larvae left retarded fifth-instar host larvae when 50% of unparasitized hosts had reached the pupal stage. Adults of this parasite were synchronized with the presence of budworm moths. Since larval spraying operations have normally ceased by the time budworm larvae reach the late sixth instar, it can be concluded that *Apanteles* and *Glypta* are not exposed to the sprays because they occur as adults sometime later.

Many studies indicate that there is generally no difference between treated and untreated stands in the complex of parasite species or in budworm mortality caused by parasites (Blais, Can. Entomol. 92:384-396, 1960; Varty, Inf. Rep. M-X-67, 1976; Dorais, Que. Dep. Lands Forests, pers. comm., 1976). A study conducted in New Brunswick between 1952 and 1958, in areas that were repeatedly treated with DDT (ranging from 2 to 6 years), showed an increase in parasitism by *Apanteles* in treated stands compared with check plots. The highest increase occurred in the location sprayed for six consecutive years. There was no difference in the incidence of *Glypta* between treated and untreated localities (Macdonald, Can. Entomol. 91:330-336, 1959). The observations on the presence of larval parasites with respect to host development conducted in 1976, provide an explanation for the immunity of *Apanteles* and *Glypta* to the larval sprays.

Although the argument that spraying late-instar larvae can be detrimental to budworm parasites is not valid, spraying budworm adults is probably detrimental to budworm parasites. The practice of controlling budworm damage by reducing egg populations through spraying of moths is still in the experimental stage. It should be recognized that most budworm parasites, including *Apanteles* and *Glypta* are in the active adult stage during the moth stage of the host. Should spraying of budworm moths become common practice over extensive areas, this could seriously disrupt the relationship of the budworm and its parasites.—J.R. Blais, Laurentian Forest Research Centre, Sainte-Foy, Que.

Stand Treatments and Spruce Budworm Damage.—A combined fertilization and thinning experiment in semimature to mature black spruce stands was established near Lake Bond in central Newfoundland by the provincial Department of Forestry and Agriculture in 1972 and 1973. In 1972, 95.5 ha were thinned at reduction rates of 54 m^3/ha from the stands, which ranged in volume from 135 to 180 m^3/ha, and 24.3 ha of this area were fertilized. A further 36.4 ha were fertilized in 1973. Urea was applied to these 60.7 ha at the rate of 493 kg/ha.

Natural color vertical aerial photographs (1:12,500) were taken on July 18, 1975, as part of the provincial forest inventory program. The forest in the experimental area on these photographs (NFA 31031, prints nos. 78, 79, 80 incl.) appeared reddish brown, which was interpreted to be a fertilization burn. The forest adjacent to the experimental area showed a uniform green.

In May of 1976, a request was made for personnel from the Newfoundland Forest Research Centre to investigate the damaged area. This note describes the results of that investigation.

The dosage of fertilizers applied was checked and found to be similar to that used in other fertilization experiments conducted in Newfoundland (van Nostrand and Bhure, Environ. Can., Nfld. Forest Res. Centre Inf. Rep. N-X-95, 1975) and was therefore unlikely to create any nutrient imbalance problems. Further air photo interpretation revealed that white birch and other scattered hardwoods within the damaged area were green and well foliated.

The experimental area was visited in mid-June and in early September of 1976. The site conditions are as follows: the dominant forest type is black spruce-moss on a well to moderately well drained, moderately coarse textured Orthic Humo-Ferric Podzol. In the slight depressions, a heavy cover of Lycopodium-Alder with a good mixture of mature tamarack is present. Soils are Gleyed Podzols on alluvium with a large number of boulders and stones directly under the organic mantle and eutrophic muck over alluvium. A mixture of white birch and scattered balsam fir also occurs to some extent.

The coloration of the foliage and the general appearance of the black spruce and balsam fir verified that the area was under stress. On-site examination revealed that the standing live spruce trees were suffering from moderate-to-severe spruce budworm damage. The ground vegetation, which is often very sensitive to scorching by excessive quantities of chemicals, was quite healthy, further suggesting that the fertilizer application rate was not heavy enough to cause tree damage.

Several trees in the experimental area were measured for height growth, dbh, and age. Trees were some 10.7 to 13.2 m in height, 15 to 22.9 cm in diameter and 50 to 70 years old, and it was observed from increment cores that there had been no noticeable increase in growth during the preceding 5 years. However, the results of Roberge, Weetman, and Knowles (pages 73-96 *in* Tree Growth and Forest Soils, Oregon State University Press, 1968) indicate that trees of this type and age do respond greatly after fertilization and thinning. After consultation with personnel of the Newfoundland Forest Research Centre Forest Insect and Disease Survey, it was ascertained that the light-to-severe spruce budworm infestations (L.J. Clarke, pers. comm., results of aerial survey 1973, 1974, 1975) of the preceding 3 years may partly explain this poor response.

Apparently the treatments had created a more favorable condition for spruce budworm development than occurred in untreated stands, and the larvae in the treated stands were larger and in a more advanced stage of development than those in adjacent stands. The thinning of the stands probably increased the canopy temperature, and the increase would advance the development of the spruce budworm larva by several weeks. Roberge et al., 1968, recorded temperature increases in thinned stands and Blais (Can. Entomol. 90:354-361, 1958) confirmed that average colder temperatures retarded spruce budworm development; hence the converse should hold true. Thinning also stimulates shoot growth of black spruce and increases biomass (Weetman, page 18 *in* Woodlands Rep., WR 132, Pulp Pap. Res. Inst. Can., 1970). New foliage is preferred for oviposition by adults and needed for survival of young larvae. Foliage of fertilized trees may therefore be more attractive to ovipositing moths, and the attraction would result in higher populations in fertilized areas.

The foliage of the current year and the previous ones was moderately to severely reddened and was partially shed as a result of the budworm damage. Hence the trees in the thinned stands appear dead on the vertical air photos.

The question of advanced spruce budworm development in treated stands is one of interest, especially if forest improvement programs of thinning and fertilization are planned during any year of infestation. A more detailed investigation is being conducted to confirm this preliminary observation and to separate the effect of fertilizer and thinning on spruce budworm damage.—B.A. Roberts and T.L. Chow, Newfoundland Forest Research Centre, St. John's, Nfld.

The European Pine Shoot Moth and Plantations of Mixed Ages. — During the studies of the European pine shoot moth in Ontario, it was shown (Green, Can. Entomol. 94:314-336, 1962) that the half-grown, overwintering larvae could not tolerate temperatures below -28.8° C (-20° F). From this, it was deduced that all larvae not protected by snow and exposed to these extreme temperatures would die. Further, in trees more than 5 m tall with no branches below the snow line, virtually all shoot moth larvae would be expected to be killed by temperatures lower than -29° C. Such trees would remain free of shoot moth unless reinfested from an outside source. In our experience, where young, susceptible trees were planted beside a block of tall (5-6 m) trees and subsequently supported a large population of shoot moth, the adjacent large trees, though previously free of shoot moth, would sustain moderate-to-severe attack presumably from the moths flying from the nearby, heavily infested small trees. Green (Can. Entomol. 94:282-299, 1962) has shown that the behavior of female moths would lead to such attack. It was concluded, therefore, that it would be imprudent to plant new red pine (*Pinus resinosa* Ait.), Scots pine (*P. sylvestris* L.) or Mugho pine (*P. mugho* Turra var. *mughus* Zenari) adjacent to larger pine in an area where shoot moth existed or might be introduced easily (Syme, Can. For. Serv. Rep. 0-X-244, 1976).

In the winter of 1975-76, an unusually low minimum temperature (-30.6° C) at Elmira, Ont. presented an opportunity to demonstrate this point. Routine fall samples from large (9 m +) trees, taken in anticipation of such a cold winter, showed that these trees supported a moderate population of shoot moth from year to year (Table 1). They were within a large plantation that included smaller trees with a similar population of shoot moth (Table 1).

TABLE 1

Numbers of shoot moth larvae per 100 available shoots, on large and small trees, as determined by samples taken in the fall (except where noted) at Elmira, Ont.

	Large trees		Small trees	
Year	Living shoot moth per 100 shoots	Avg tree ht (m)	Living shoot moth per 100 shoots	Avg tree ht (m)
1972	29.8	9.66	29.5	1.74
1973	30.6	9.94	37.7	1.65
1974	50.4	10.06	55.5	1.56
1975	—	—	29.7	1.77
Spring 1976	0.1	10.45	10.3	1.68
Fall 1976	1.3	—	4.8	1.83

A sample of the overwintering survivors, taken in the spring of 1976, showed 0.1 live shoot moth per 100 available shoots in the large trees. Adjacent small trees held an average of 10.3 larvae per 100 shoots (Table 1). In the fall of 1976 a further sample showed a tenfold increase in the shoot moth population in the large trees, whereas the small tree population suffered a twofold decrease (Table 1). This demonstrates the ability of shoot moth to recolonize large trees from a relatively low population in the small trees.

It is apparent that blocks of large and small red pine in close proximity to each other can prolong an infestation of the European pine shoot moth in the larger trees. This in turn can lead to stem deformity (Syme, 1976) despite the beneficial effects of lower limb pruning and lethal low winter temperatures.—P.D. Syme, Great Lakes Forest Research Centre, Sault Ste. Marie, Ont.

The Effect of Moth Dispersal on the Dynamics of a Local Spruce Budworm Population.—Mass dispersal (movement in and out of an area) of egg-carrying spruce budworm moths, *Choristoneura fumiferana* (Clem.), takes place in some years but not in others.

Consequently, the ratio of egg-mass density in a given area (laid by both local and immigrant females) to the density of locally emerged female moths (measured by the number of female pupal cases on the foliage) exhibits considerable fluctuation from year to year. Naturally, one supposes that such a yearly fluctuation of the egg-to-female ratio (E/F ratio, i.e. average apparent fecundity) would inevitably influence the dynamics of a local budworm population.

Fig. 1 shows the yearly fluctuation of the E/F ratio (solid line) observed at Plot G4 of the Green River Project between 1947 and 1958 and that of the intergeneration rate of change in egg-mass density (broken line), i.e. the rate of change between the egg stage of one year and the egg stage of the following year (or E-E rate of change) expressed in natural logarithms. The fluctuation of the E-E rate of change exhibits a downward trend during the period observed while the fluctuation of the E/F ratio shows no trend. A comparison between the two graphs reveals that with allowance for the difference in trend, there is a high correlation in fluctuations. In other words, the fluctuation of the E-E rate of change about its downward trend is largely determined by the fluctuation of the E/F ratio. Needless to say, the E-E rate of change comprises two independent components: (1) the apparent fecundity (i.e. E/F ratio) and (2) intrageneration survival (i.e. egg to moth, E-M, survival). Fig. 2 shows that the E-M survival (also expressed in natural logarithms) exhibits much smaller yearly fluctuations than the E-E rate of change in Fig. 1 but retains the downward trend.

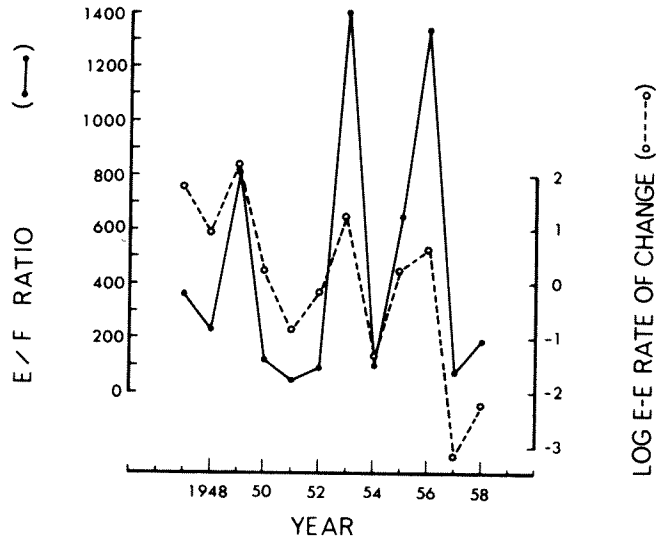

Figure 1. Yearly fluctuations of the egg-to-female (E/F) ratio (solid line) and of the intergeneration rate of change in egg-mass density (E-E rate of change) in natural logarithm (broken line). The E/F ratio observed in the fall of 1950, for instance, corresponds to the E-E rate of change between 1949 and 1950, plotted on year 1950. Data from Plot G4 of the Green River Project.

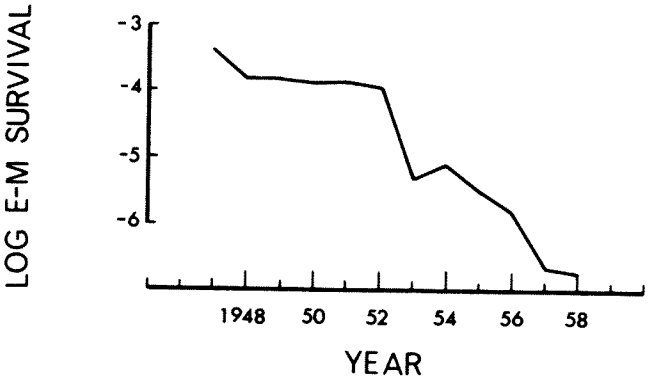

Figure 2. Yearly fluctuation of the intrageneration (egg to moth, or E-M) survival in natural logarithms. The E-M survival of the 1949-50 generation is plotted on year 1950. Data from Plot G4 of the Green River Project.

Although the possibility that an outbreak in a given locality will be triggered by a mass invasion of egg-carrying moths is not excluded, the above finding suggests that, once the outbreak is triggered, the course of development to an epidemic level and the termination of the epidemic are largely uninfluenced by further movements of moths. In other words, the downward trend of the E-E rate of change is determined by the E-M survival and, hence, by factors other than moth dispersal. Certainly, moth dispersal influences the steepness of the trend in the E-E rate of change; i.e., frequent mass invasions by immigrant females during the epidemic period may prolong the length of the epidemic or *vice versa*. Nonetheless, the influence seems small. This is partly because the E/F ratio tends to alternate frequently between high and low values and tends to cancel any opposing effect over a fairly short period. Also, the data from Green River indicate that a high density of young instar larvae following a high E/F ratio tends to lower the survival of older instar larvae of the same generation, compensating for the effect of moth invasions. The cause of the downward trend in the E-M survival is not known, but it is perhaps a density-dependent process with time lags, and not climatic factors. A more detailed discussion of this will be published elsewhere.

The foregoing analysis was done only on data from Plot G4 of the Green River Project, where the budworm density never really reached an extremely high level and, hence, no severe defoliation was observed. In this sense, the data may be atypical. However, this is one of the few plots where detailed long-term studies have been carried out without being disturbed by spray operations. In areas of much higher budworm density, the picture is clouded either by the effect of spray programs or by the lack of detailed observations over an adequate period. Nevertheless, similar analyses on data collected from unsprayed areas or areas that have only been sprayed a few times indicate that the essential conclusion reached above would not change. That is, while moth invasions cause considerable yearly fluctuations in local budworm densities, overall population trends seem to be influenced little by invasions.—T. Royama, Maritimes Forest Research Centre, Fredericton, N.B.

PATHOLOGY

Essential Oils as Sapstain Fungicides.—Environmentally compatible fungicides are now in demand. As pressure is brought to bear to remove noxious chemicals from the marketplace, new substances with equal effect but low mammalian toxicity must be found. The antifungal effect of essential oils has been investigated (Vichkanova et al., Fitontsidy, Mater. Soveshch. 6:123-126, 1969; Galustyan, Vopr. Mol.-Kletochnoi Biol. Immunol., Mater. Nauch. Konf. 3:106-108, 1969; Rao and Narasimha, Riechst. Aromen, Koerperpflegem. 21[11]:405-406, 408, 410, 1971). It was thus of interest to investigate the use of natural terpenes to prevent blue stain in pine in the hope of finding a treatment alternative to sodium pentachlorophenate.

A number of terpenes from various chemical suppliers were screened for antifungal activity by the use of a simple agar medium with the terpene in the vapor phase. Malt agar, surface-inoculated with typical stain and mold fungi, was saturated with terpene vapors by charging small, sterile watch glasses placed on the central surface of the agar in enclosed petri dishes with individual terpenes. This test showed that a large number of terpenes including delta-3-carene, cedryl acetate, p-cymene, dipentene, limonene, alpha-phellandrene, pinene, L-terpinolene, borneol, camphor, cineole and eucalyptol, of which many are hydrocarbons, were not inhibitory.

TABLE 1

Growth of typical sapstain and mold organisms in the presence of terpenes (vapor or liquid) on malt agar and in shake culture

Terpene	*Cladosporium* agar* (vapor)	*Ceratocystis* agar* (vapor)	*Ceratocystis* shake** (liquid)	*Trichoderma* agar* (vapor)	*Trichoderma* shake** (liquid)
Citral	0	0	0 †	trace	0
Citronellol	trace	++	" †	+++	"
Geraniol	trace	+++	"	++++	"
Nerol	++	0	"	-	"
Piperitone	+++	0	"	+	"
Terpineol	0	+++	"	trace	"
Carvone	0	0	"	trace	15
Fenchyl alcohol	-	0	"	-	190
Citronellal	+	+++	15	trace	280
Linalool	0	0	133	trace	165
Fenchone	+	0	298	++++	375
Control (water)	++++	++++	286	++++	275

*Maximum growth is expressed ++++
**Growth is expressed as mg mycelium (ovendry)/100 ml medium.
†Terpene concentration was 0.01%; otherwise it was 0.1% for shake cultures. Shake culture conditions: 0.2% yeast extract, 1.0% glucose, medium distributed 80 ml/250 ml in Erlenmeyer flasks, gyratory shaking at 130 rpm for 5-6 days at 28°C.

TABLE 2

Effect of treating pine sapwood with terpenes for the control of sap stain and mold

Treatment	Test A (0.2-0.3%)	Test B (1.5%)	Test C (1.0%)
Citral	0	1/2 (3)	1 (1)
Citronellol	1/2	1/2 (3)	1 (1)
Geraniol	0	1/2 (6)	1 (1)
Nerol	-	-	1 (1/2)
Piperitone	3	-	1/2 (1)
Terpineol	6	1/2 (6)	1/2 (1)
Carvone	6	1/2 (6)	1 (3)
Acetone	-	-	1 (1)
Arquad	-	1/2 (1)	-
Water	6	1/2 (3)	-

Stain rating: 1/2, up to 5% surface stained; 1, 5-25% surface stained; 3, 25-50% surface stained; 6, 50% and over surface stained.
Mold rating: ( ) and values as for stain.
Test A: Terpene treatment was in emulsions with 0.01% sodium lauryl sulfate; the inoculum contained *Alternaria, Pullularia, Cladosporium,* and *Graphium*; the test was carried out in stoppered test tubes (Stranks, Wood Sci. 9(2):110-112, 1976).
Test B: Terpene treatment was in emulsions with 0.1% Arquad 2C-75, Armour Industrial Chemicals Ltd., Toronto. Inoculum was as in Test A.
Test C: Terpenes were dissolved in acetone; inoculum was *Ceratocystis.*

Other terpenes had a varied effect depending upon the test organism and the phase (vapor or liquid) of the terpene tested. This can be seen from Table 1. Citral, citronellol, geraniol, nerol, piperitone, terpineol and carvone (all alcohols, aldehydes or ketones) in low concentration (0.1% vol/vol or less) inhibited growth almost completely in shake culture when tested with *Ceratocystis* and *Trichoderma.* Some of these were less impressive in the vapor (agar) test. Linalool vapor was inhibitory, but inhibition was less with the liquid in shake culture. Fenchone gave a mixed reaction: the vapor was sometimes inhibitory, yet the liquid stimulated growth.

The terpenes that showed the most toxicity in shake culture were tried as preservatives against blue stain in tests with wood. In most of the tests, pine sapwood blocks (3 x 35 x 100 mm) having holes drilled in the central face of one end were dipped in terpene-in-water emulsions prepared with either sodium lauryl sulfate or Arquad as emulsifiers, or were dipped in acetone solutions of terpenes. The treated wood samples along with controls dipped in water, Arquad, or acetone were inoculated with spore suspensions of stain fungi as indicated in Table 2, tests B and C. These specimens were threaded onto glass rods, suspended in glass tanks, and incubated for 3 to 4 weeks with positive ventilation under humid conditions. The controls stained only with difficulty in these tests and only in a separate test, test A (Table 2), in which smaller wood specimens and stoppered test tubes were used, did they stain well. In Test A citral, geraniol, citronellol, and, to a lesser extent, piperitone inhibited stain development. The tank tests did not confirm these results despite the use of higher terpene concentrations, nor did the terpenes prevent mold growth.

The toxicity of terpenes in low concentration noted in shake culture is possibly explained by the better contact between fungus and toxicant and the better retention of vapor with stoppered flasks. In tanks the vapor loss may be greater and the effect therefore less. Test A (Table 2) may support this, since these specimens were confined in stoppered test tubes and the best inhibitory effect was then observed. Acetone-terpene solution did not give better distribution or penetration of the terpenes (test C, Table 2).

These data indicate that a number of terpenes are toxic to blue stain fungi, but that their application as antistain preservatives to wood is probably not workable. Alcohol, aldehyde, and ketone terpenes seem to be most effective against fungal activity. Should any effective terpene eventually emerge, it would have to be readily available and inexpensive.—D.W. Stranks, Eastern Forest Products Laboratory, Ottawa, Ont.

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