

Some Calculations Relevant to Field Applications of *Bacillus thuringiensis*.—Data have recently become available that permit some calculations relevant to the field use of *Bacillus thuringiensis* (B.t.) against forest pests, particularly, spruce budworm.

We have found by force feeding, that the LD₅₀ for pure crystals of B.t. strain HD-1 against newly moulted VIth instar spruce budworm larvae is 0.04 ± 0.01 μg/larva. Abbott Laboratories states that Dipel WP contains 2,000 spores and the same number of crystals per international unit (IU) and that there are 16,000 IU/mg. Thus the LD₅₀ found by us is equal to 1280 crystals or 0.6 IU. The LD₅₀ dose is approximately 0.22 μg/larva or 7,000 crystals equivalent to 3.5 IU.

Morris reported at the Symposium on Microbial Control of Spruce Budworm sponsored by Abbott Laboratories in Montreal, January 1976, that when B.t. was sprayed at 8/BIU in 0.5 gal of water/acre, spray droplets 100 μ in diameter contained 288 particles, 144 of which were spores and 144 were presumably crystals, equivalent to 0.07 IU/drop. Smaller droplets had proportionately fewer particles. A VIth instar spruce budworm larva would therefore have to eat the equivalent of 9-10 100 μ drops in order to ingest an LD₅₀ dose or 48 100 μ drops to ingest an LD₅₀ dose. At a reasonable droplet frequency of 30/cm² this is equivalent to eating 0.3 cm² of foliage to obtain an LD₅₀ dose and 1.6 cm² of foliage to get an LD₅₀ dose. Since many of the droplets are smaller than 100 μ even larger areas of foliage will be required. Foliage consumption of this magnitude must require at least several hours of feeding.

Our experience with assays using dipped foliage suggests that at low dosages feeding inhibition alternates with feeding periods as the effect of the toxicant wears off. If the larva has access to clean foliage when the inhibition wears off, the insect survives, but if the foliage remains toxic the larva eventually succumbs. The residual life of toxicant on foliage in the field is often relatively short due to the frequency of rain showers during spray season, and the net effect of the low dosages used may be to protect the insect from the full effect of the B.t. applied. Some foliage protection would occur.

Food consumption and LD₅₀ both are directly related to body weight. While the regression equations for food consumption and toxicity with body weight may differ it is probably reasonable to assume that it will take as long for a IIIrd or IVth instar budworm to get a toxic dose if it is feeding in an exposed position as for a VIth. If it is mining in a bud the likelihood of ingesting an LD₅₀ or LD₅₀ dose is even smaller.

We are led therefore, to suggest that the dosages reaching the target site for spruce budworm control when sprayed at the recommended 8 BIU/acre are marginal and that much of the observed variability in effectiveness may be ascribed to the marginal nature of these dosages. Our data on the relative toxicological effect of crystals vs spore:crystal mixtures (to be published elsewhere) indicate that the presence of spores will not materially affect these conclusions.—P. G. Fast, Insect Pathology Research Institute, Sault Ste. Marie, Ont.

SYLVICULTURE

Root Initiation of Lodgepole Pine and White Spruce Seedlings Grown Under Varying Light Conditions.—It has been suggested that root growth of conifer seedlings is directly related to photosynthetic activity of the seedlings (Keller, Forstwiss. Centralbl. 85:65-79, 1966; Etter and Carlson, Can. J. Plant Sci. 53:395-399, 1973). The effect of light on hormone transport and metabolism has been demonstrated (Yamaki and Fujii, Biochemistry and Physiology of Plant Growth Substances, Runge-Press Ltd., 1968, pp. 1025-1036; Zenk, *op. cit.*, pp. 1109-1128), and therefore it is postulated that root initiation is the function of light effects on both the photosynthetic mechanism

and hormone levels. Stimulation of root initiation by varying light conditions was the subject of two preliminary studies reported here.

In the first experiment bare-root dormant (dormant buds and inactive roots) 2-0 lodgepole pine [*Pinus contorta* var. *latifolia* Engelm.] and 3-0 white spruce [*Picea glauca* (Moench) Voss)] seedlings, fall-lifted and stored at -1°C for 2 months, were potted in sand. The seedlings were covered with a black plastic hood that blocked out all light for 0, 10, 20, and 30 d in various combinations with periods of light. In all combinations the dark period preceded the light period. The following greenhouse conditions were maintained: a minimum light intensity of 10 500 lux and day length of 18 h using artificial lighting, air temperature of 15°-30°C, and sand temperature 18.5° ± 1°C. In the second experiment similar spotted seedlings were maintained in the greenhouse for 30 d in full light (minimum of 10 500 lux) during the daytime (18-h photoperiod), half light (minimum of 5250 lux), or in complete darkness. One-half light was attained by using screening that intercepted 50% of the incident light and complete darkness was attained by using black plastic. Greenhouse conditions remained as described above. In the first experiment groups of seedlings were excavated after 10, 20, or 30 d at the completion of the treatment and new unsuberized root tips were counted. In the second experiment new root tips were counted after 30 d. The data are recorded as averages of 50 seedlings per treatment in the first experiment and of 40 seedlings per treatment in the second experiment. The data were analyzed using ANOVA for single classification.

Data from the first experiment (Table 1) indicate that light stimulated root initiation in lodgepole pine within 10 d after planting. The initial 10-d dark period suppressed root

TABLE 1
Effect of varying periods of light on root initiation of lodgepole pine and white spruce seedlings

Light regime (days dark + days light)	Lodgepole pine		White spruce	
	Plants with new roots %	New roots per plant ¹	Plants with new roots %	New roots per plant ¹
0 + 10	94	27.8 b ²	94	11.1 b
0 + 20	100	12.8 c	98	7.6 bc
0 + 30	96	33.9 a	98	16.7 a
10 + 0	0	0 d	90	6.4 c
20 + 0	0	0 d	78	5.0 c
30 + 0	28	1.6 cd	66	5.0 c
10 + 10	22	1.3 cd	86	6.1 c
20 + 10	22	1.5 cd	84	5.2 c
10 + 20	50	13.7 c	100	20.7 a

¹ Average of 50 plants.

² The small letters indicate Duncan's Multiple Range groupings of treatments which do not differ significantly at the 5% level.

initiation over the following 10-20 d: after 10 d of dark and 10 d of light 22% of the seedlings had new root tips (1.3/plant) compared with 94% for the 0 + 10 treatment and 27.8 new tips per plant. Comparisons of data for the 10 + 20 and 0 + 20 treatments with the 0 + 10 treatment are similar. While root initiation in white spruce did not seem dependent on light, as 94% of the seedlings had new root tips after 10 d of light and 90% had new root tips after 10 d of darkness, there was a significant difference in the number of new roots produced. The apparent decrease in the percentage of white spruce seedlings with new roots from the 10-d dark and 0-d light treatment (90%) to the 30-d dark and 0-d light treatment (66%) could not be explained. However, the numbers of new roots produced were not significantly different.

Data from the second experiment confirm that lodgepole pine seedling root initiation responds to a light stimulus. The stimulation is not necessarily due to photosynthetic activity

TABLE 2

Effect of the amount of light on root growth of lodgepole pine and white spruce seedlings

Light regime for 30 d	Lodgepole pine		White spruce	
	Plants with new roots %	New roots per plant ¹	Plants with new roots %	New roots per plant ¹
Full light (10 500 lux)	95	37.4 a ²	93	11.5 a
1/2 light (5250 lux)	95	29.0 b	85	13.2 a
No light	45	6.1 c	98	5.3 b

¹ Average of 40 plants.² The small letters indicate Duncan's Multiple Range groupings of treatments which do not differ significantly at the 5% level.

since the number of new root tips per plant did not vary greatly under full and half light conditions. This experiment also confirms that white spruce differs from lodgepole pine in root initiation under dark conditions (98% and 45% respectively). The species are similar in that both responded positively to light in terms of numbers of roots per plant.

The data presented in this report suggest that root initiation is related to a light stimulus but not dependent on photosynthetic activity. As root growth may be related to photosynthetic activity (Keller, *op. cit.*; Etter and Carlson *op. cit.*), these experiments point out a difference between root growth and root initiation. The latter appears to be related to a hormonal response. Clarification of the effect of the two mechanisms on root initiation and growth will require further study.—L. W. Carlson, Northern Forest Research Centre, Edmonton, Alberta.

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Vol. 32, No. 4, JULY-AUGUST, 1976



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