RECENT FIELD STUDIES ON THE USE OF *BACILLUS THURINGIENSIS* TO CONTROL THE GYPSY MOTH (*LYMANTRIA DISPAR* L.)

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Efforts to improve the effective use of *B. thuringiensis* and reduce its application costs has stimulated the development of higher potency formulation. Recent field studies have shown that a single application at 30 BIU/ha (12 BIU/acre) is as effective as the split double application of 20 BIU/ha (8 BIU/acre) formerly recommended. Also results of using volumetric application rates of less than 9.6 L/ha (gallon/acre) are discussed.

Results of early studies on the field use of *Bacillus thuringiensis* (*Bt*) against the gypsy moth were encouraging but inconsistent. Aerial applications were often aggravated by incompatibility of *Bt* with its suspending medium (fuel oil) which often resulted in clogged nozzles and uneven spray coverage (Lewis and Connola, 1966). Development of standardization procedures based on insecticidal activity (Burges et al. 1967, Dulmage et al. 1971), formulation improvements, and the isolation and development of better and more potent *Bt* strains such as the HD-1 strain (Dulmage, 1970) all contributed to the resolution of difficulties associated with the *Bt* product and its application. Field studies that were done with these newer formulations (Thuricide 16B, Dipel WP, Dipel 4L) prepared with the HD-1 strain showed that *Bt* could be applied aerially to protect the foliage and reduce the density of the pest populations (Dubois and Lewis, 1981).

Until recently the recommended procedure for aerial use of *Bt* to control the gypsy moth was two applications, each at 20 BIU/hectar (8 BIU/acre) sprayed at cre/ a volumetric rate of 9.5 to 19 liters per hectare (1 to 2 gallons per acre). The first application was made when oak foliage expansion was about 50% and the majority of the larvae were still in the first instar. This treatment was repeated 7-10 days later when most of the larvae matured to second and third instar (Yendol et al. 1973, Lewis et al. 1974). Unfortunately the high cost of both the double application and the product itself discouraged general and large-scale use of *Bt* even in environmentally sensitive areas.

Two improvements of *Bt* products are contributing to the renewed interest for general and large-scale use of *Bt*; one, newer formulations are several times more potent and have longer residual activity than previously available; two, new strains of *Bt* that are significantly more potent that the HD-1 strain are continually being uncovered and evaluated for commercial development. It is becoming increasingly clear that as more and more strains of *Bt* are isolated, some are found to be more potent than the HD-1 strain against specific insect pests including forest and ornamental tree pests, agricultural pests, as well as disease vectors (Dulmage, et al., 1981).

Several studies were reported on the successful use of a single application of *Bt* compared to two applications previously recommended for use against the gypsy moth and spruce budworm (Morris et al., 1982, Morris, 1983, Reardon et al., 1982). Against the gypsy moth in particular, studies by different investigators (Table 1) have confirmed that one application at 30 BIU/hectare (12 BIU/acre) compared favorably to two applications at 20 BIU/hectare (8 BIU/acre). Regardless of the manufacturer or the formulation used (water or oil based), better foliage protection was achieved when *Bt* was applied once at the 30 BIU/hectare rate than when applied twice at/or lower than 20 BIU/hectare.

Table 1. Summary of *Bacillus thuringiensis* aerial spray tests conducted in Pennsylvania, Massachusetts and Connecticut comparing the effectiveness of single and double applications against instar II gypsy moth.

Applic. Rate	No. of Applic.	Popul. Trend	% Final Defol.	Ref.
10[c]	1	1.55 R	25	McLane and Finney (1982)
10	2	1.10 R	41	
20	1	1.30 R	42	
20	2	1.38 R	38	
30	1	1.12 D	8	
30	2	1.60 D	5	
Control	-	1.75 R	70	
20[d]	1	13.30 D	37	Andreadis *et al.* (1982)
20	2	15.00 D	15	
Control	-	6.50 D	61	
20[a]	2	975.30 D[f]	3.7	Andreadis *et al.* (1983)
30	1	21.30 D	5.6	
40	1	13.10 D	7.6	
Control	-	23.70 D	72.3	

a/ rate of BIU applied at 9.5 liters per hectare

b/ ratio of egg mass change: $\frac{\text{Post spray}}{\text{Prespray}}$ R = Rising population; $\frac{\text{Prespray}}{\text{Postspray}}$ D = declining population

c/ Thuricide 16B (Zoecon, Inc.)

d,e/ Dipel 4L (Abbot Laboratories)

f/ Because of extreme variability, ratio is not significantly different from others.

In areas where the populations were on the decline, the trend was somewhat accelerated. Noteworthy is that in areas where populations were rising use of the single 30 BIU/hectare application rate reversed that trend and actually showed a decline in the egg mass change. Generally in these studies significant differences in relative larval densities were observed between treated and untreated blocks but differences between treatments were not significant. Furthermore, McLane and Finney

(1981) also showed that stickers effectively improved the residual activity of the Bt formulations. Eight days after application as much as 80% of the original insecticidal activity was retained on the sprayed foliage when acrylamide type stickers were incorporated into either oil or water based formulations. Without stickers insecticidal activity was reduced to 10 to 25% of its original activity. Undoubdedly the extended activity and improved physical formulation characteristics of these newer formulations contributed to the success of reducing application costs by eliminating the need for a second application. Slippey (1983) also reported that in declining populations, 30 BIU/hectare applications was as effective as higher dose rates (40 BIU/hectare) but when used against rising populations, results at 30 BIU/hectare were inconsistent.

Newer formulations of Bt designed for low volume application rates are from two to four times more concentrated than previously available. Such concentrated formulations contain from 12.7 to 16.7 BIU/liter (48 to 64 BIU/gallon) and permit the application of the 30 BIU/hectare rate at reduced volumetric rates. Against the spruce budworm, Dimond (1982) demonstrated that at 30 BIU/hectare, Bt could be used successfully at volumetric rates as low as 2.9 liters hectare (32 oz/acre). McLane and Finney (1982) reported that the same 30 BIU/hectare dose could be applied at a volumetric rate of 4.75 liters per hectare (64 oz/acre) against the gypsy moth and still provide excellent foliage protection and population reduction. Balaam (1983) also reported similar success of reduced volumetric rates at the same dose rate against gypsy moth infestations in New Jersey. The successful use of a single application of 30 BIU/hectare to control the gypsy moth must be applied when larvae are still in the second instar stage. Applications that are delayed until larvae are fourth instar will not be effective at 30 BIU/hectare. Higher dose rates of 40 to 50 BIU/hectare (16 to 20 BIU/acre) will only have a limited effect on the pest population (McLane et al., 1983).

Efforts to improve Bt formulations also include the development and evaluation of new strains. Andreadis and others (Andreadis et al., 1982) reported on the field evaluation of two experimental strains against a gypsy moth infestation. The strains, HD-243 and HD-263, were as efficacious as the commercially developed HD-1 as measured by relative larval densities and foliage protection. Noteworthy is that HD-243 was actually applied at half the dose rate of HD-1. Laboratory studies (Dubois unpublished data) had shown that HD-243 was about twice as potent as HD-1.

Recently a new strain of Bt labelled NRD-12 was isolated, which shows considerable promise for operation use (Dubois unpublished data). In a recent field study against a spruce budworm infestation it was significantly more effective than Thuricide ®32 LV. Both final defoliation estimates (12%) and the residual larval population (3.2 larvae per 45 cm branch tip) present in the block treated with SAN 415[1] were significantly lower than in the Thuricide ®32 LV treated block (25% and 7 larvae per branch tip) when both formulations were applied at 30 BIU per branch hectare. Laboratory studies of the SAN 415 formulation also show that NRD-12 may be more effective than the HD-1 strain against the gypsy moth. Results of parallel bioassays (Table 2) show the SAN 415 32 LV is 3.9 times more potent than Thuricide ®32 LV. Both strains were formulated at the same potency of 8.5 BIU per liter (Thuricide ®32 LV BIU per gallon). Whether this increased effectiveness will also be apparent under field operational conditions remains to be confirmed.

Table 2. Laboratory bioassays[a/] comparing HD-1 (Thuricide 32® LV) and NRD-12 (SAN 415 32 LV) formulations against instar II gypsy moth.

	SAN 415 32 LV	Thuricide 32® LV
Bt strain	NRD-12	HD-1
Serovar	H_{3ab}	H_{3ab}
Slope	5.37	3.73
S.E.[b/]	0.60	0.15
C.V.[c/]	0.19	0.07
LC_{50} (IU/ml)	45.20	173.7
S.E.	3.82	10.97
C.V.	0.15	0.11
Ratio[d/]	3.86	--

a/ average of 3 bioassays
b/ standard error
c/ C.V. coefficient of variation
d/ ratio of LC_{50} of Thuricide 32® LV to SAN 415 32 LV

[1]Commercial formulation based on the NRD-12 strain. Mention of a commercial product does not constitute an endorsement by the USDA-FS.

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