MEASUREMENT OF FOLIAR DEPOSITS OF BT AND THEIR RELATION TO EFFICACY

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Introduction

Interest in and discussion of the relationship between droplet spectrum emitted and droplet spectrum deposited, spray cloud behaviour, the relationship between droplets deposited and efficacy, and optimum droplet size, has increased in recent years and has resulted in a number of collaborative studies addressing aspects of these questions. The questions are particularly pertinent to operational use of Bacillus thuringiensis (Bt) preparations because Bt must be ingested, probably repeatedly, (Fast and Reginiere, Can. Ent. 116: 123-130; 1984) before it can act. Therefore, numbers of droplets deposited, their distribution on foliage, the probability of a larva encountering them, and the dose in a given droplet are important to efficacy. These considerations are as equally important to optimization of applications of contact insecticides, but they do not seem to have been adequately explored. The studies of spray cloud behaviour and deposition by the New Brunswick Spray Efficacy Research Group have established the optimum droplet size for deposition on coniferous foliage, as well as many of the parameters governing spray deposition. Fast and A. Sundaram, have begun the exploration of the effects of drop size, drop density (drops/needle or /cm. sq.) and Bt concentration on the efficacy of BT in laboratory bioassays on foliage. Here we present a narrative summary of the results of a field trial designed to measure the relationship of the number and spectrum of droplets deposited on balsam and spruce foliage in field applications to the emitted droplet spectrum and to the efficacy of BT. Space limits this discussion to a broad brush description of the experiment and the conclusions reached. A detailed description is in preparation. The experiment was jointly funded by Canadian Forestry Service, Forest Protection Limited, and USDA-Forest Service (CANUSA).

Formulation and Application

The Bt formulation chosen was Novabac 3 (32 BIU/gal) diluted to 6.3 BIU/L and applied at the rate of 30 BIU/ha. Tracer dye Erio Acid Red XB 400 was added at 0.2% w/w, and a sticker, Rhoplex AC33NP (Rohm and Haas) was added at the rate of 2.0%. Studies by W. MacLean, USDA - Aphis, have shown this sticker to be much superior to Chevron sticker.

Laboratory bioassays established that neither the dye nor the sticker affected the toxicity of the Novobac 3.

Evidence from studies carried out in New Brunswick, Cranfield, and in the United States, show overwhelmingly that efficient impaction of drops and coverage of conifer foliage with ultra low volume applications can be achieved only with droplet sizes well below one hundred microns. Steps were taken to ensure maximum delivery in the range 30-50 u after evaporation. Wind tunnel tests performed by the International Centre for the Application of Pesticides (ICAP) in Cranfield, Great Britain, established optimum settings for the AU 3000 Micronair atomizers to maximize the number of evaporated droplets in the < 85μ range. A test spray run prior to spraying the blocks confirmed that 71% of all droplets found on needles were in the 25-75 μ range. Application was made by Cessna 188 flying swaths of 110 feet.

Two plots were sprayed. The first on 27 May, was treated when the balsam shoot development index was 3.8 and the larval index was 3.9 (indices as described by Dorais and Kettela 1982). Rain began within 4 hours of spraying and continued for the next 4 days, so no useful efficacy data was obtained but deposit measurement and foliar bioassays were performed. The second spray was applied 8 June when the balsam shoot index was 5.0 (open shoots) and the larval index was 4.8. Weather following this spray was sunny and warm. While spray weather was grossly the same in both sprays smoke from smoke bombs operated at canopy level showed the air to be much more turbulent during the second spray.

Atomization

Comparison of the volume fractions deposited on needles with the evaporated or target volume fractions reported in the ICAP study, shows that significantly more large drops were emitted than were found on foliage. Since the VMD was 85 μ, the 4% of droplets that were larger than 85 μ contained 50% of the Bt emitted. As drop size increases, this ratio becomes even more disadvantageous.

The effectiveness of Bt deposits on foliage is also directly related to the probability of an individual larva encountering and consuming a droplet, so deposit frequency is obviously a determining factor in efficacy. In the present case, the probability of encounter is approximately ten-fold higher for 30-85 μ drops than for drops over 85 μ in diameter.

Deposit

More droplets were deposited on fir needles than on spruce needles in both sprays, which may

reflect the inherently higher unit foliation of the spruce twigs (i.e. more and smaller needles). On the same species mean deposits were similar for the two sprays, 0.88 and 0.79 drops/needle on fir, 0.54 and 0.37 drops/needle on spruce. The median needle deposits were much lower, about 0.45 drops/needle.

Deposits on balsam fir buds differed significantly between the first and second sprays (.55 drops/bud and 2.8 drops/bud respectively), but on the basis of drops/cm^2 of bud, they were not significantly different, 6.0 and 6.9 drops/cm^2 of bud respectively.

Deposits on Kromekote cards did not correlate with or reflect foliar deposits, averaging 21.1/cm^2 in Plot 1 and 6.2/cm^2 in Plot 2.

Spectrum

Droplet spectra on needles of both balsam and spruce in both sprays were very similar with an average of 75% of all deposits falling in the 25-75 u range. The buds, which were expected to be somewhat inferior collectors of small droplets, in fact collected more in the 0-25 u range (20%) than the needles which averaged 6% in this range. At the present time deposit levels in the 0-25 u range are probably not important due to the low amount of bt carried in these drops; however, future highly concentrated formulations might change the toxicological significance of these size droplets.

Spectra deposited on Kromekote cards were significantly different from foliar spectra with greater numbers in the high diameter range reflecting the now well established differences in impaction efficiency between conifer foliage and large flat surfaces.

The Rhoplex AC33NP sticker appeared to give excellent adhesion in both dry and wet conditions. While no quantitative data on sticker performance were obtained, it was found that individual droplets on foliage were stable to manual handling and remained apparently intact even after prolonged exposure to rain. The dye was seen to wash out of the deposits which, however, remained intact. One question which remains is whether the spores and crystals were contained within the visible deposits or whether they tended to wash out like the dye.

Foliar bioassays

Foliage was collected from nine sites, and five terminal shoots from each site were bioassayed with 10 lab-reared newly-moulted vth instar budworm to give 50 larvae/site. The bioassay was identifical with that used for lab-sprayed foliage.

In the first spray, when the buds were still closed, there was no correlation between deposit and mortality. It was observed that larvae fed mainly inside the bud. This coupled with the low deposit (0.55 drops/bud) resulted in the lack of correlation. In the second spray a good correlation between mortality and deposit was observed. When the data were transformed and plotted as probit mortality and $\log_{10}$ drops/needle, a good regression was obtained with an R^2 of 81.5%. The 20% unexplained variation is probably due to within branch variation in deposit and the difference in deposition on old foliage, where the deposit was determined, and the new foliage where the larvae fed.

The LD_{50} (determined by bioassay) of 6.3 BIU/L Novobac applied at 4.7 L/ha having a droplet distribution with an NMD of 23 u then is just over 1 drop/needle. The median deposit experienced at the nine sites in this part of the study was 0.4 drops/needle. These bioassays clearly demonstrate the dependance of mortality in field applications on the foliar deposit, in terms of both drop size and drop density at a given concentration.

Field Evaluation of Efficacy

Observed survival and defoliation were corrected for expected effects based on prespray larval densities. Survival and defoliation in controls were separately plotted against prespray larval densities on the same sample trees, regressions derived, and the regression used to correct observed defoliation and survival on a sample by sample basis in the sprayed blocks. The corrected effects were then plotted against drops/needle. A clear relationship between drops/needle and both survival and defoliation was observed. Survival was noticeably decreased at 0.5 drops/needle and at the 6.3 BIU/L concentration the field LD_{50} was about 1.0 drop/needle which is in good agreement with the foliar assay and predictions from laboratory studies. Foliage protection (expected minus observed defoliation) also showed a relationship to drops/needle although, because of the low deposits observed (56% of samples had deposits of 0.5 drops/needle), the relationship was less clear than for survival.

No correlation was observed between deposit and total biomass/45 cm branch, biomass of buds/branch, or average pupal weight, because of extreme variation.

Several blocks in the same areas were sprayed under similar conditions with Bt at 12.8 and 14.0 BIU/L (Dipel 176 and Biochem Futura) again applied at the rate of 30 BIU/ha, but depsot was not monitored. These blocks gave significantly better control than the 6.3 BIU/L application used in the main experiment. Because the likelihood that budworm will encounter a droplet is low at the deposits measured on most branches, a higher concentration of Bt in those droplets will be expected to give more efficacious results. This hypothesis is to be tested in 1984 by relating deposit to field survival and defoliation at 32 BIU/gal, 48 BIU/gal and 64 BIU/gal concentrations.

No efficacy/deposit relationships were obtained on spruce in large part because the expected defoliation based on prespray larval counts was not observed.