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AERIAL FIELD TRIALS WITH A NEW FORMULATION OF *BACILLUS THURINGIENSIS* AGAINST THE SPRUCE BUDWORM, *CHORISTONEURA FUMIFERANA* (CLEM.)

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CHEMICAL CONTROL RESEARCH INSTITUTE
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ABSTRACT

Mixtures of Dipel 36B, a highly concentrated commercial formulation of *Bacillus thuringiensis* (B.t.) and acephate (Orthene®) (O,S-dimethylphosphoramidothioate), an organophosphate insecticide, were applied by aircraft onto 20 to 30-hectare blocks of white spruce *Picea glauca* Moench) and balsam fir (*Abies balsamea* (L.)) trees infested with spruce budworm, *Choristoneura fumiferana* (Clem). The formulation contained carboxymethylcellulose (CMC), polyvinylpyrrolidone (PVP) and a sunlight screen, Uvinul DS49. Dosage rate applied was 30 Billion International Units of B.t. with and without 42 g AI of acephate in 9.4 ℓ/hectare. Drop density was generally high with one plot receiving 88 drops/cm^2 at ground level. In spite of this, efficacy of the treatments in terms of population reduction and foliage protection was low, due most likely to the presence of PVP in the formulation and to unusually high natural budworm mortality. The treatments had no immediate deleterious effect on the spruce budworm parasite complex.

INTRODUCTION

The choice of a formulation in the practical application of microbial insecticides may be of critical importance to its efficacy. In aerial application of such insecticides, the most important formulation characteristics are: 1. Suitable viscosity or flowability in order to facilitate emission of the fluids through aircraft nozzle systems; 2. A humectant designed to reduce evaporation during vertical descent of the spray droplets; 3. Antidrift additives to reduce lateral movement of droplets; 4. Liquid suspendors to maintain the particulate materials in suspension during spray application; 5. Sunlight protectants to decelerate solar ultra-violet inactivation of the microorganisms; 6. Spray stickers and spreaders to improve spread and adhesion of the pathogens onto the target surface and 7. Other chemicals which might enhance the toxicity of the disease agents.

During the past 10 years or so considerable improvements have been achieved by commercial manufacturers of *Bacillus thuringiensis* but the presently available commercial formulations for forestry use still lack many of these desireable characteristics. This report presents the results of experiments designed to further improve *B. thuringiensis* formulations for aerial applications against forest insect pests.

MATERIALS AND METHODS

The formulations used in the present tests are outlined in Table 1. Dipel 36B is a high potency formulation of *B. thuringiensis* manufactured by Abbott Laboratories (North Chicago, Illinois) containing 36 Billion International Units of biological activity per U.S. gallon. Sodium carboxymethylcellulose (Chemical Developments of Canada Ltd., Montreal) (CMC-R295) is a water soluble cellulose ether used in the food industry particularly for its unique film forming, suspending, stabilizing, emulsifying, thickening and adhesive properties. CMC is most easily dissolved in water after wetting with ethanol and is non-toxic to animals. The Erio Acid Red XB tracer dye is compatible with *B. thuringiensis* at up to 1% concentration in bacterial growth culture. Uvinul DS49 (Chemical Developments of Canada Ltd.) is used commercially as a sunlight ultra-violet absorber in water base paints, cosmetics and textiles to protect against loss of dimensional stability, fading of colors and skin damage. It exhibits low oral toxicity and no irritation to skin and eye. Polyvinylpyrrolidone (PVP-K30) is a water soluble polymer characterized by its unusual complexing and colloidal properties and its physiological inertness. As a protective colloid it is used in drugs, detergent formulations, and cosmetic preparations and was widely used as a blood plasma extender during World War II. PVP films become tacky at 70% RH and at 50% RH they contain 18% moisture, a property which suggests its utility for aerial application in low humidity conditions. Oral and acute toxicities and eye and skin irritation for animals are low. Perhaps one disadvantage for microbial formulations is that it forms complexes with many toxins,

viruses, drugs, and toxic chemicals thereby reducing their toxicity and irritation.

Chevron spray sticker (Chevron (Canada) Ltd., Montreal) was added to the formulation for improving sticking of the spray droplets to white spruce (*Picea glauca* (Moench) and balsam fir (*Abies balsamea* (L)) needles. Acephate (Orthene^{R}) (0,S-dimethyl-acetylphosphoramidothioate) was added at about 9000 ppm to the spray mix to enhance B.t. effectiveness against the budworm (Morris *et al* 1975).

As a prelude to application in the field, laboratory tests were conducted to determine the spore and crystal content and toxicity of the Dipel formulation slated for field use, the effect of the additives (CMC and PVP) on *B. thuringiensis* spore germination, and to check the dye-complexing ability of PVP with Erio Acid Red.

Forest stands at Rankin, Ontario, consisting mainly of white spruce and balsam fir trees varying in height from 9 to 15 m were selected for aerial testing of the new formulation. The application procedure and the assessments of the effectiveness of the sprays were similar to those previously described (Morris *et al* 1975).

RESULTS AND DISCUSSION

The data in Table 2 show that the ratios of spores to crystals were approximately the same in a standard laboratory sample, in the unformulated material used for the 1976 field trials and in the formulated tank mix sample taken just before loading into the aircraft. This indicates that the content of basic active ingredients (spores and crystals) of the spray sample was normal.

In the laboratory test designed to compare spore viability and B.t. toxicity of unformulated and formulated Dipel 36B used in the field (Table 3), it was found that viable spore content and LC_{50}s were not significantly different in the two materials. This indicated that the additives used in the spray formulation (CMC, PVP, DS49) did not affect spore viability or toxicity of the spore-crystal mixture for budworm under laboratory test conditions.

The 1976 field sample was also bioassayed using L_4 budworm to compare its toxicity with the standard Dipel 36B sample which had been stored in the refrigerator for 2 years. This standard was also compared in toxicity (LD_{50}) with its toxicity when newly received 2 years previously. The laboratory sample was reported by the manufacturers to contain 7800 International Units (IU) of biological activity/mg and the 1976 field sample 9000 IU/mg. If both label claims are true with respect to potency, then the relative potency of the field sample could be expressed as 1.15 (*i.e.* 9000/7800) using the laboratory sample as reference. This hypothesis was not rejected by the bioassay results (Table 4) because, the predicted potency ratio is within the 95 confidence limits of the

experimental value. The data indicate that the laboratory sample had lost some potency during the two-year storage period. Note that in spite of the large difference in LD_{50}s between the two replicates, the potency ratios are relatively constant.

Studies on the compatibility of PVP and CMC with *Bacillus thuringiensis* (Table 5) indicated that these additives had no detremental effects on spore germination. The PVP did not appear to bind the Erio Acid Red based on the results summarized in Table 6. However, the effect of PVP on the toxic crystals or the chemical insecticide (Acephate) is unknown.

Data from the field trials showed that larval development on the spray date (May 30) was 84% L_3 and L_4 (Table 7). With the possible exception of Plot 1 (Dipel + DS49-1), tree growth was about the same on both white spruce and balsam fir when sprays were applied (Table 8) (see appendix). The deposit rates in terms of IU/ha and number of viable spores/ha reaching ground surface varied widely between treatments (Table 8). The ratios of BIU: number of viable spores deposited were identical for the two replicated Dipel-Orthene formulations (1:1) but differed from the Dipel alone treatment (1:2). Drop density on Plot 1 was very high (88/cm^2) and moderately high on the other two plots (23-36/cm^2). Drop size was low on all plots ranging from 33 to 40 µm in average diameter (Table 8) with 94 to 99% of all drops in the 30-60 µm range (Table 9).

Data from the study of survival of spores on white spruce and balsam fir foliage (Table 10) suggested a drastic reduction in spore viability as early as one day after spray application. Samples from the same branches used for spore viability studies when bioassayed for

infectivity for L_4 budworm larvae caused no appreciable mortality amoung the test insects even on foliage taken immediately after spray application, suggesting that the spray deposits may have been non-toxic for the budworm (Table 11). The reason for this is not yet clear. We can only speculate at this time PVP may have reduced toxicity (due to its complexing with the bacterial toxin and with acephate) or may have formed a hard film after drying which became indigestable by the insect larvae. PVP is known to be rendered insoluble when oxidized under the influence of light. The trees used for residual activity studies were open grown and fully exposed to sunlight.

The treatments caused no significant reduction in population density (Table 12), moth emergence (Table 13), defoliation and moth oviposition (Table 14) or budworm parasitism (Tables 15 and 16). The overall failure of this new formulation appears to have been partly due to the inclusion of polyvinypyrrolidone and partly to high natural budworm mortality in the population (Table 12). The aerial tests are being repeated with PVP.

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REFERENCES

MORRIS, O. N., J. A. ARMSTRONG and M. J. HIDEBRAND. 1975. Laboratory tests and field trials of low volume aerial applications of *Bacillus thuringiensis* Orthene® combinations against the spruce budworm, *Choristoneura fumiferana* (Clem.). Chemical Control Research Institute Information Report CC-X-110.

Table I

Formulations of *Bacillus thuringiensis* (Dipel 36B) used at Rankin, Ontario, in 1976

Plots	Area (ha)	Dipel 36B (gals.)	Water (gals.)	CMC (gms)	Ear Dye (gms)	DS49 (gms)	Orthene (gms)	Chevron Sticker (mℓ.)	PVP (gms)
1	20	20	40	568	228	2271	1275	228	2271
2	20	20	40	568	228	Nil	Nil	228	2271
3	30	30	60	852	342	3408	1918	342	3408

Plots 1 and 2:application Sun. May 30, a.m. 1976.

Plot 3:application Sun. May 30, p.m., 1976.

[1] 0.25%; [2] 0.1%; [3] 1.0%; [4] 9000 ppm; [5] 0.1%; [6] 1.0%

Table 2

Spore-Crystal Counts of Standard Dipel 36B Sample Compared with Formulated and Unformulated Dipel used in Field Trials, 1976*

	Percent	
	Spores	Crystals
Refrigerated Laboratory Sample (unformulated)	50	50
Refrigerated 1976 Field Sample (unformulated)	48	52
Spray Tank Mix (Refrigerated 3 months)	52	48

* A thin smear of the B.t. suspension was made in duplicate from each mix and the percentage of spores and crystals counted in 10 oil inversion field per slide.

Table 3

Comparison of Formulated and Unformulated Dipel 36B used in Field Trials, Rankin, Ontario, 1976.

	Viable Spores/mℓ*	LC50 (µg per gm of Diet)**
Formulated Dipel	2.050×10^9	1.5
Unformulated Dipel	0.834×10^9	3.5

* Values are not significantly different.

** Potency ratios of field:check (95% C.L) = 1.3 (0.7 - 2.7) indicating no difference in biological potency. L_4 spruce budworm was used in the bioassay.

Table 4

Results of Laboratory Assay of Potency of Dipel SC (36B) Used in 1976 Field Trials Using a Laboratory Refrigerated Sample for Reference Standard*

	LD_{50} (µg/mℓ) Single Line Analysis		LD_{50} (µg/mℓ) Parallel Line Analysis		Potency Ratio (95% C.L.)
	Field	Lab.	Field	Lab.	
Laboratory Sample Bioassay 1974	-	3.0	-	-	-
Field Sample 1976 Rep. #1	42	46	43	45	1.03 (0.21-5.21)
Field Sample 1976 Rep. #2	17	16	19	14	0.76 (0.30-1.92)
Field Samples 1976 Pooled	-	-	-	-	0.79 (0.67-1.18)

* Values are for duplicate tests.

Table 5

Effects of Polyvinylpyrrolidone and Carboxymethylcelluslose Additives on Germination of *Bacillus thuringiensis* (Dipel 36B) Spores and on Parasporal Crystal[1]

	Percent		
	Spores	Crystals	Vegetative Cells
Untreated Dipel	18	42	40
Dipel + PVP	5	47	48
Dipel + CMC	17	40	43
Dipel + PVP + CMC	20	35	45

[1] 24 hr. culture in brain heart infusion broth; Smirnoff Stain.

Table 6

Spectral Transmittance of Various Formulations of Dipel 36B as a Measure of the Dye-Complexing Ability of Polyvinyl Pyrrolidone (PV) Additive and Erio Acid Red.

Formulations plus 0.1% Erio Acid Red	Percent Transmittance at 565 m of 1:400 Dilution[1]	
	Suspension Not Smeared on Slides	Suspensions Smeared
Dipel	71	73
Dipel + 1% PVP	72	71
Dipel + 0.5% PVP	71	72
Dipel + 0.1% PVP	71	72
Dipel + 1% CMC*	72	73
Dipel + 1% CMC + 0.5% PVP	72	73
Dipel + 1% CMC + 0.25% PVP	72	73
Dipel + 1% CMC + 0.1% PVP	72	72

[1] Mean of 2 replicates

* Carboxymethylcellulose

Table 7

Spruce Budworm Development at Rankin, Ontario on White Spruce and Balsam Fir, 1976. Expressed as Percentages of Various Instars

Date	L_2	L_3	L_4	L_5	L_6	Pupae
May 26	20	67	13	-	-	-
May 30	4	38	46	11	1	-
June 6	—	—	1	0	30	69

Table 8

Ground Deposit Rates - Dipel - Orthene Aerial Trials

at Rankin, Ontario, 1976

Treatments/hectare		Deposit Rates/ha							
		BIU of B.t.	No. Viable Spores x 10^9	Orthene (g)	Percent of Emitted Volume Deposited	Average Number Drops/cm^2	Dia. Drop of Av. Vol. (µm)		
							WS	bF	Total
Plot 1 -	30 BIU Dipel + Orthene + DS 49	6.9	6.7	9.7	23.2	87.7	39	40	40
Plot 3 -	30 BIU Dipel + Orthene + DS 49	3.1	3.0	4.4	10.5	22.9	41	45	43
Plot 2 -	30 BIU Dipel Alone	1.9	3.6	2.7	6.5	36.0	33	32	33

Based on colorimetic analysis of glass plate deposits

Table 9

Average percent of drop in class sizes with spread factor of 2

Plot	Drop Class Diameters (mm)				
	30	60	100	200	250
1	76.8	18.1	5.0	0.2	0
2	65.0	30.4	4.6	0	0
3	94.0	5.4	0.5	0.1	0

Table 10

Survival of *Bacillus thuringiensis* (Dipel 36B) Spores on White Spruce and Balsam Fir Trees in Aerial Spray Plots, Rankin, Ontario, 1976

Number of Days After Spray	Cumulative Solar Radiation Kcal/cm^2	Number of Viable Spores/gm Foliage x 10^3					
		Dipel - DS49 - 1		Dipel - DS49 -2		Dipel alone	
		wS	bF	wS	bF	wS	bF
0*	0	806	978	960	1608	1930	1020
1	0.52	280	810	N.D.	N.D.	56	391
5	2.59	7	15	27	378	4	6
10	5.05	3	7	89	7	86	3
19	8.90	252	104	34	2	1	4
31	14.26	1	2	22	158	2	0
Check		0	0	0	0	0	0

N.D. - Not Done
Drop density (drops/cm^2) at site of test trees were: Dipel + DS49-1, 163(wS) and 162(bF); Dipel alone, 91(wS) and 36(bF).
*Samples taken immediately after spray application.

Table 11

Residual Activity of Dipel 36B Aerially Applied to Balsam Fir Trees, Rankin, Ontario, 1976

Number of Days After Spray Application	Cumulative Solar Radiation in the Field (Kcal/cm^2)	Number of Budworm Larvae Tested	Percent Mortality
0*	0	189	14.3
1	0.52	174	16.1
5	2.59	95	5.3
10	5.05	97	2.1
19	8.90	93	1.0
31	14.26	82	12.2
Untreated Check	-	-	26.1

Average of 2 replicates each. Plot 1.

* Samples taken immediately after spray application.

Table 12

Effects of Treatments on Population Reduction

Treatments	Pre-Spray Density Larvae/100 Buds (Larvae/18" Branch)		Corrected % Population Reduction (Based on Bud Counts)[1]		Residual Population Density/100 Buds	
	wS	bF	wS	bF	wS	bF
Dipel + DS49-1	13(20)	7(8)	92	81	1.0	1.3
Dipel + DS49-2	12(14)	7(6)	92	92	0.9	0.5
Dipel Alone	9(11)	6(6)	86	96	1.3	0.2
Untreated Check	12(17)	7(9)	(83)	(73)	2.0	1.9

[1]Corrected by Abbotts formula.

Total solar radiation from date of application to the final larval density assessment was 11.07 kCal/cm^2. Mean max. and min. temperature for the same period were 26.1 and 12.1°C, respectively. Total rainfall, 4.5 cm.

Table 13

Effect of Treatments on Moth Emergence

Treatments	Number of Pupae Caged		Average Pupal Weights (mg)		Percent Moth Emergence		
	Males	Female	Males	Females	Males	Females	Total
Dipel + DS49-1	209	152	54	76	53	42	58
Dipel + DS49-2	194	125	57	79	59	62	60
Dipel alone	213	159	58	84	60	45	53
Untreated Check	296	252	65	93	56	63	59

Table 14

Effects of Treatments on Defoliation and Oviposition, Rankin, Ontario, 1976

Treatments	Percent Defoliation wS	bF	Successful Egg Masses per 100 s.ft of Foliage
Dipel + DS49-1	10	7	3
Dipel + DS49-2	10	3	1
Dipel Alone	10	5	2
Untreated Check	18	16	4

Table 15

Percent Larval, Pupal and Egg Mass Parasitism in Treated and Untreated Plots

Rankin, Ontario, 1976

Treatments	Larval	Pupal	Totals	Egg Masses[1]
Dipel + DS49 -1	9	11	20	18
Dipel + DS49-2	0.6	7	7.6	22
Dipel Alone	5	11	16	15
Untreated Check	9	6	15	28

[1] Trichogramma sp.

Table 16

List of Parasites Emerging from Larvae and Pupae from Treated and Untreated Plots, Rankin, Ontario 1976

Treatments Plots	Parasite Species	
	Larval	Pupal
Dipel - DS49-1	14 *Apanteles fumiferana* 2 *Apanteles sp.* 3 Unidentified	14 *Itoplectis conquisitor* 9 *Phaeogenes hariolus* 1 *Glypta fumiferanae* 17 *Omatoma fumiferanae*
Dipel - DS49-2	1 Unidentified	15 *Itoplectis conquisitor* 9 *Phaeogenes hariolus* 2 *Omatoma fumiferanae* 1 Tachinidae
Dipel Alone	4 *Apanteles fumiferanae* 1 *Glypta fumiferanae*	16 *Itoplectis conquisitor* 1 *Apecthis ontario* 2 *Phaeogenes hariolus* 17 *Omatoma fumiferanae* 2 Tachinidae
Untreated	16 *Apanteles fumiferana* 2 *Campoplex* sp.	17 *Itoplectis conquisitor* 2 *Phaeogenes hariolus* 2 *Apecthis ontario* 5 *Omatoma fumiferanae* 1 Sarcophagidae 1 Ichneumonidae 1 Dolichopodidae 2 Ascogaster sp.

[1] Identifications by F. Titus, Maritimes Forest Research Centre.

APPENDIX I

****
* CHECK PLOT 1, RANKIN *
* PRE-SPRAY *
* MAY 24, 1976. *
****

NO OF TREES	II INSTAR	III INSTAR	IV INSTAR	V INSTAR	VI INSTAR	PUPAE	EMERGED PUPAE	DEAD SBW	PARA-SITES	ASSOC SP	LIVE SBW
ALL SPECIES											
50	294	900	61	1	0	0	0	17	0	4	1256
	(23.4%)	(71.7%)	(4.9%)	(.1%)	(.0%)	(.0%)	(.0%)				
WS ONLY											
25	208	590	32	1	0	0	0	15	0	1	831
	(25.0%)	(71.0%)	(3.9%)	(.1%)	(.0%)	(.0%)	(.0%)				
BF ONLY											
25	86	310	29	0	0	0	0	2	0	3	425
	(20.2%)	(72.9%)	(6.8%)	(.0%)	(.0%)	(.0%)	(.0%)				

SBW POPULATION DENSITY

	ALL SPECIES	WS	BF
PER BUD	.0970	.1199	.0707
PER SQ M	89.8	123.2	58.7
PER 100 SQ FT	834.	1145.	545.
PER BRANCH	12.56	16.62	8.50

TREE VIGOR

BUDS PER SQ M	925.7	1028.0	830.5

****
* PLOT 1 RANKIN *
* PRE-SPRAY *
* MAY 23, 1976. *
****

NO OF TREES	II INSTAR	III INSTAR	IV INSTAR	V INSTAR	VI INSTAR	PUPAE	EMERGED PUPAE	DEAD SBW	PARA-SITES	ASSOC SP	LIVE SBW
ALL SPECIES											
50	560	742	66	1	0	0	0	6	3	37	1369
	(40.9%)	(54.2%)	(4.8%)	(.1%)	(.0%)	(.0%)	(.0%)				
WS ONLY											
25	452	513	25	1	0	0	0	2	3	20	991
	(45.6%)	(51.8%)	(2.5%)	(.1%)	(.0%)	(.0%)	(.0%)				
BF ONLY											
25	108	229	41	0	0	0	0	4	0	17	378
	(28.6%)	(60.6%)	(10.8%)	(.0%)	(.0%)	(.0%)	(.0%)				

SBW POPULATION DENSITY

	ALL SPECIES	WS	BF
PER BUD	.1001	.1283	.0635
PER SQ M	103.5	147.9	57.9
PER 100 SQ FT	961.	1374.	538.
PER BRANCH	13.69	19.82	7.56

TREE VIGOR

BUDS PER SQ M	1034.2	1153.1	912.1

****
* PLOT 2 RANKIN *
* PRE-SPRAY *
* MAY 21, 1976. *
****

NO OF TREES	II INSTAR	III INSTAR	IV INSTAR	V INSTAR	VI INSTAR	PUPAE	EMERGED PUPAE	DEAD SBW	PARA-SITES	ASSOC SP	LIVE SBW
ALL SPECIES											
50	522	301	10	0	0	0	0	2	3	7	833
	(62.7%)	(36.1%)	(1.2%)	(.0%)	(.0%)	(.0%)	(.0%)				
WS ONLY											
25	368	185	4	0	0	0	0	2	2	4	557
	(66.1%)	(33.2%)	(.7%)	(.0%)	(.0%)	(.0%)	(.0%)				
BF ONLY											
25	154	116	6	0	0	0	0	0	1	3	276
	(55.8%)	(42.0%)	(2.2%)	(.0%)	(.0%)	(.0%)	(.0%)				

SBW POPULATION DENSITY

	ALL SPECIES	WS	BF
PER BUD	.0761	.0936	.0553
PER SQ M	60.4	84.0	38.6
PER 100 SQ FT	561.	780.	358.
PER BRANCH	8.33	11.14	5.52

TREE VIGOR

BUDS PER SQ M	793.5	897.5	697.0

****
* PLOT 3 RANKIN *
* PRE-SPRAY *
* MAY 19,20, 1976. *
****

NO OF TREES *****	II INSTAR ******	III INSTAR ******	IV INSTAR ******	V INSTAR ******	VI INSTAR ******	PUPAE ******	EMERGED PUPAE ******	DEAD SBW ****	PARA-SITES *****	ASSOC SP *****	LIVE SBW ******
ALL SPECIES											
50	634	388	17	0	0	0	0	17	4	11	1039
	(61.0%)	(37.3%)	(1.6%)	(.0%)	(.0%)	(.0%)	(.0%)				
WS ONLY											
25	454	255	12	0	0	0	0	13	2	8	721
	(63.0%)	(35.4%)	(1.7%)	(.0%)	(.0%)	(.0%)	(.0%)				
BF ONLY											
25	180	133	5	0	0	0	0	4	2	3	318
	(56.6%)	(41.8%)	(1.6%)	(.0%)	(.0%)	(.0%)	(.0%)				

SBW POPULATION DENSITY
****

	ALL SPECIES	WS	BF
PER BUD	.0929	.1153	.0645
PER SQ M	77.3	110.9	45.8
PER 100 SQ FT	718.	1030.	426.
PER BRANCH	10.39	14.42	6.36

TREE VIGOR
****

BUDS PER SQ M	832.2	961.7	710.8

APPENDIX II

****
* CHECK PLOT 1 RANKIN *
* POST SPRAY I *
* JUNE 14, 1976. *
****

NO OF TREES	II INSTAR	III INSTAR	IV INSTAR	V INSTAR	VI INSTAR	PUPAE	EMERGED PUPAE	DEAD SBW	PARA-SITES	ASSOC SP	LIVE SBW
ALL SPECIES											
50	0	1	6	16	217	218	6	5	0	26	464
	(.0%)	(.2%)	(1.3%)	(3.4%)	(46.8%)	(47.0%)	(1.3%)				
WS ONLY											
25	0	1	4	6	90	122	4	4	0	16	227
	(.0%)	(.4%)	(1.8%)	(2.6%)	(39.6%)	(53.7%)	(1.8%)				
BF ONLY											
25	0	0	2	10	127	96	2	1	0	10	237
	(.0%)	(.0%)	(.8%)	(4.2%)	(53.6%)	(40.5%)	(.8%)				

SBW POPULATION DENSITY

	ALL SPECIES	WS	BF
PER BUD	.0493	.0449	.0544
PER SQ M	34.1	31.0	37.8
PER 100 SQ FT	317.	288.	351.
PER BRANCH	4.64	4.54	4.74

TREE VIGOR

BUDS PER SQ M	692.4	690.3	694.8

****
* PLOT 1 RANKIN *
* POST SPRAY I *
* JUNE 9, 1976. *
****

NO OF TREES	II INSTAR	III INSTAR	IV INSTAR	V INSTAR	VI INSTAR	PUPAE	EMERGED PUPAE	DEAD SBW	PARA-SITES	ASSOC SP	LIVE SBW
ALL SPECIES											
50	2	21	78	151	197	11	0	10	0	64	460
	(.4%)	(4.6%)	(17.0%)	(32.8%)	(42.8%)	(2.4%)	(.0%)				
WS ONLY											
25	2	12	51	96	144	9	0	7	0	59	314
	(.6%)	(3.8%)	(16.2%)	(30.6%)	(45.9%)	(2.9%)	(.0%)				
BF ONLY											
25	0	9	27	55	53	2	0	3	0	5	146
	(.0%)	(6.2%)	(18.5%)	(37.7%)	(36.3%)	(1.4%)	(.0%)				

SBW POPULATION DENSITY

	ALL SPECIES	WS	BF
PER BUD	.0434	.0598	.0273
PER SQ M	32.9	44.4	21.1
PER 100 SQ FT	305.	413.	196.
PER BRANCH	4.60	6.28	2.92

TREE VIGOR

BUDS PER SQ M	757.9	743.0	773.1

****
* PLOT 2 RANKIN *
* POST SPRAY I *
* JUNE 10, 1976. *
****

NO OF TREES	II INSTAR	III INSTAR	IV INSTAR	V INSTAR	VI INSTAR	PUPAE	EMERGED PUPAE	DEAD SBW	PARA-SITES	ASSOC SP	LIVE SBW
ALL SPECIES											
50	0	4	66	126	137	6	0	8	0	20	339
	(.0%)	(1.2%)	(19.5%)	(37.2%)	(40.4%)	(1.8%)	(.0%)				
WS ONLY											
25	0	2	46	91	100	5	0	1	0	18	244
	(.0%)	(.8%)	(18.9%)	(37.3%)	(41.0%)	(2.0%)	(.0%)				
BF ONLY											
25	0	2	20	35	37	1	0	7	0	2	95
	(.0%)	(2.1%)	(21.1%)	(36.8%)	(38.9%)	(1.1%)	(.0%)				

SBW POPULATION DENSITY

****

	ALL SPECIES	WS	BF
PER BUD	.0474	.0607	.0304
PER SQ M	24.0	34.9	13.3
PER 100 SQ FT	223.	324.	123.
PER BRANCH	3.39	4.88	1.90

TREE VIGOR

****

BUDS PER SQ M	505.3	575.1	437.1

****
* PLOT 3 RANKIN *
* POST SPRAY I *
* JUNE 11, 1976. *
****

NO OF TREES	II INSTAR	III INSTAR	IV INSTAR	V INSTAR	VI INSTAR	PUPAE	EMERGED PUPAE	DEAD SBW	PARA-SITES	ASSOC SP	LIVE SBW
ALL SPECIES											
50	1	8	21	58	150	15	2	14	0	23	255
	(.4%)	(3.1%)	(8.2%)	(22.7%)	(58.8%)	(5.9%)	(.8%)				
WS ONLY											
25	1	2	9	46	127	14	2	5	0	19	201
	(.5%)	(1.0%)	(4.5%)	(22.9%)	(63.2%)	(7.0%)	(1.0%)				
BF ONLY											
24	0	6	12	12	22	1	0	9	0	4	53
	(.0%)	(11.3%)	(22.6%)	(22.6%)	(41.5%)	(1.9%)	(.0%)				

SBW POPULATION DENSITY

	ALL SPECIES	WS	BF
PER BUD	.0295	.0462	.0129
PER SQ M	20.7	30.3	9.7
PER 100 SQ FT	193.	281.	90.
PER BRANCH	2.55	4.02	1.10

TREE VIGOR

BUDS PER SQ M	702.9	654.5	754.7

APPENDIX III

****
* CHECK PLOT RANKIN *
* POST-SPRAY 2 *
* JUNE 24, 1976. *
****

NO OF TREES *****	II INSTAR ******	III INSTAR ******	IV INSTAR ******	V INSTAR ******	VI INSTAR ******	PUPAE ******	EMERGED PUPAE ******	DEAD SBW ****	PARA-SITES *****	ASSOC SP *****	LIVE SBW ******
ALL SPECIES											
50	0	0	0	2	36	67	183	4	1	14	288
	(.0%)	(.0%)	(.0%)	(.7%)	(12.5%)	(23.3%)	(63.5%)				
WS ONLY											
24	0	0	0	1	18	35	103	1	0	10	157
	(.0%)	(.0%)	(.0%)	(.6%)	(11.5%)	(22.3%)	(65.6%)				
BF ONLY											
25	0	0	0	1	18	32	80	2	1	3	131
	(.0%)	(.0%)	(.0%)	(.8%)	(13.7%)	(24.4%)	(61.1%)				

SBW POPULATION DENSITY

	ALL SPECIES	WS	BF
PER BUD	.0319	.0347	.0332
PER SQ M	21.9	24.6	19.8
PER 100 SQ FT	203.	229.	184.
PER BRANCH	2.88	3.27	2.62

TREE VIGOR

BUDS PER SQ M	685.9	709.3	596.4

****
* PLOT 1 RANKIN *
* POST-SPRAY 2 *
* JUNE 23, 1976. *
****

NO OF TREES	II INSTAR	III INSTAR	IV INSTAR	V INSTAR	VI INSTAR	PUPAE	EMERGED PUPAE	DEAD SBW	PARA-SITES	ASSOC SP	LIVE SBW
ALL SPECIES											
50	0	0	1	1	36	75	39	2	0	13	152
	(.0%)	(.0%)	(.7%)	(.7%)	(23.7%)	(49.3%)	(25.7%)				
WS ONLY											
25	0	0	1	1	20	27	20	1	0	12	69
	(.0%)	(.0%)	(1.4%)	(1.4%)	(29.0%)	(39.1%)	(29.0%)				
BF ONLY											
25	0	0	0	0	16	48	19	1	0	1	83
	(.0%)	(.0%)	(.0%)	(.0%)	(19.3%)	(57.8%)	(22.9%)				

SBW POPULATION DENSITY

	ALL SPECIES	WS	BF
PER BUD	.0198	.0175	.0221
PER SQ M	11.4	10.2	12.7
PER 100 SQ FT	106.	95.	118.
PER BRANCH	1.52	1.38	1.66

TREE VIGOR

BUDS PER SQ M	577.6	580.7	574.4

****
* PLOT 2 RANKIN *
* POST-SPRAY 2 *
* JUNE 23, 1976. *
****

NO OF TREES	II INSTAR	III INSTAR	IV INSTAR	V INSTAR	VI INSTAR	PUPAE	EMERGED PUPAE	DEAD SBW	PARA-SITES	ASSOC SP	LIVE SBW
ALL SPECIES											
50	0	0	0	1	28	68	52	8	7	7	149
	(.0%)	(.0%)	(.0%)	(.7%)	(18.8%)	(45.6%)	(34.9%)				
WS ONLY											
25	0	0	0	1	21	37	43	4	2	5	102
	(.0%)	(.0%)	(.0%)	(1.0%)	(20.6%)	(36.3%)	(42.2%)				
BF ONLY											
25	0	0	0	0	7	31	9	4	5	2	47
	(.0%)	(.0%)	(.0%)	(.0%)	(14.9%)	(66.0%)	(19.1%)				

SBW POPULATION DENSITY

	ALL SPECIES	WS	BF
PER BUD	.0098	.0239	.0043
PER SQ M	11.0	13.8	7.6
PER 100 SQ FT	102.	129.	70.
PER BRANCH	1.49	2.04	.94

TREE VIGOR

BUDS PER SQ M	1120.7	577.8	1764.7

****
* PLOT 3 RANKIN *
* POST-SPRAY 2 *
* JUNE 24, 1976. *
****

NO OF TREES	II INSTAR	III INSTAR	IV INSTAR	V INSTAR	VI INSTAR	PUPAE	EMERGED PUPAE	DEAD SBW	PARA-SITES	ASSOC SP	LIVE SBW
ALL SPECIES											
50	0	0	0	4	28	27	23	2	11	7	82
	(.0%)	(.0%)	(.0%)	(4.9%)	(34.1%)	(32.9%)	(28.0%)				
WS ONLY											
25	0	0	0	1	14	21	19	2	7	7	55
	(.0%)	(.0%)	(.0%)	(1.8%)	(25.5%)	(38.2%)	(34.5%)				
BF ONLY											
25	0	0	0	3	14	6	4	0	4	0	27
	(.0%)	(.0%)	(.0%)	(11.1%)	(51.9%)	(22.2%)	(14.8%)				

SBW POPULATION DENSITY

	ALL SPECIES	WS	BF
PER BUD	.0118	.0152	.0082
PER SQ M	7.3	9.9	4.8
PER 100 SQ FT	68.	92.	44.
PER BRANCH	.82	1.10	.54

TREE VIGOR

BUDS PER SQ M	617.7	654.1	582.1