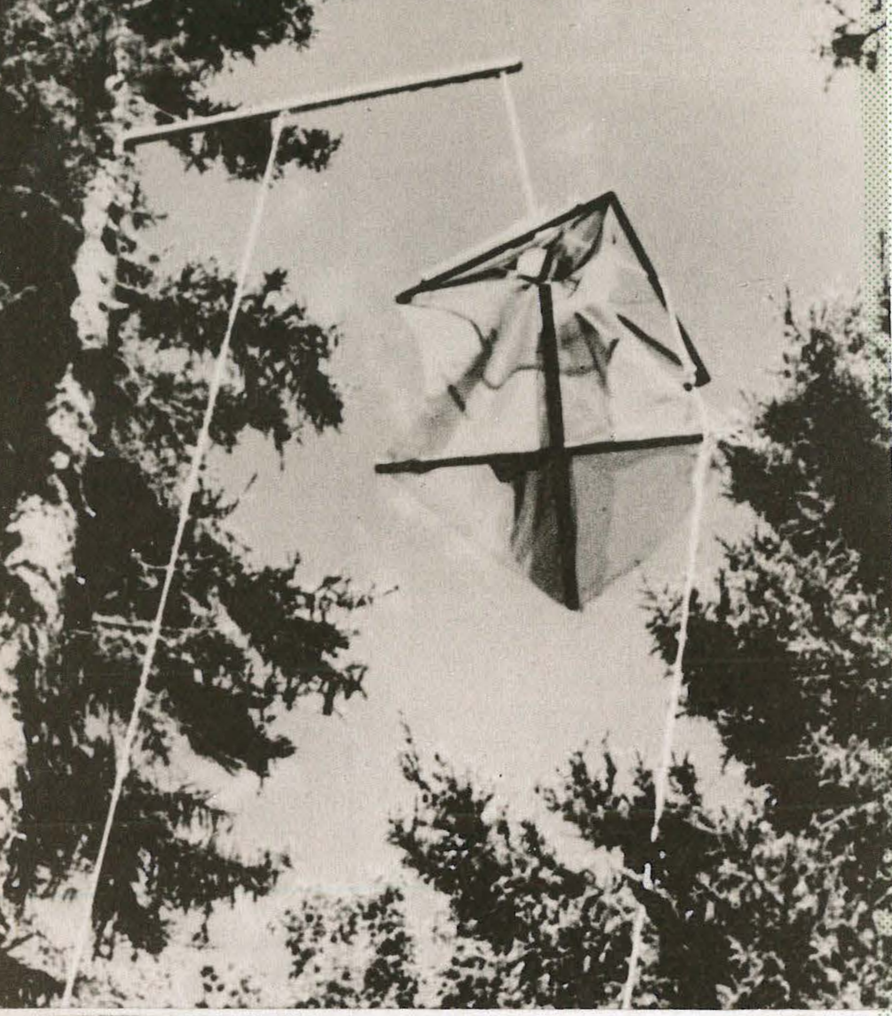

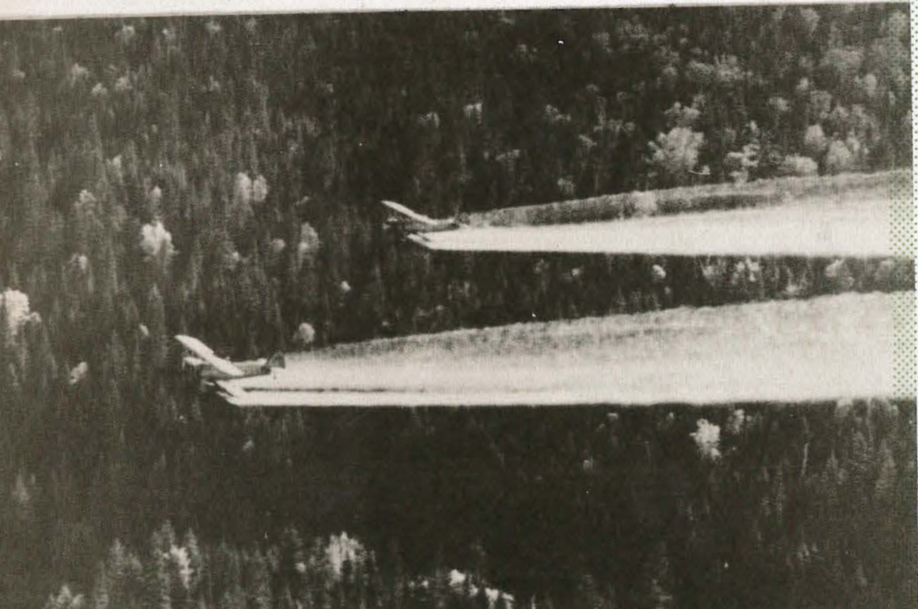

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SPRUCE BUDWORM ADULT SPRAY TESTS NEW BRUNSWICK 1977

by

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MARITIMES

CANADIAN FORESTRY SERVICE

MARITIMES FOREST RESEARCH CENTRE

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ABSTRACT

Adult spray trials were conducted in New Brunswick in 1977 to determine whether an early application of insecticide, timed to kill males, would significantly reduce insemination of females and thus reduce egg laying; and to determine whether motor stimulants combined with insecticide would increase the mortality of young females. The early spray application resulted in 85% male mortality, a 35% reduction in mating success, and a 31% reduction in oviposition. The motor stimulants (pyrethrin and piperonyl butoxide) had no effect on the mortality of young females.

RESUME

On a mené au Nouveau- Brunswick en 1977 des essais d'arrosage aérien sur des insectes adultes afin de déterminer si une application hâtive d'insecticide, synchronisée pour exterminer les mâles, réduirait significativement l'insémination des femelles et réduirait ainsi la ponte d'oeufs, et si oui ou non l'emploi de stimulants moteurs combinés à l'insecticide augmenterait la mortalité chez les jeunes femelles. L'application hâtive d'insecticide eut comme résultat un taux de mortalité de 85% des mâles, de même qu'une diminution de 35% du succès des accouplements et de 31% de la ponte. Les stimulants moteurs (pyréthrine et butoxyde de pipéronyle) n'eurent aucune influence sur la mortalité des jeunes femelles.

GENERAL INTRODUCTION AND OBJECTIVE

The use of insecticides to kill female spruce budworm, *Choristoneura fumiferana* (Clem.), adults and thus minimize egg laying has been under investigation in New Brunswick since 1969 as a joint research program of the Maritimes Forest Research Centre and Forest Protection Limited (Miller *et al.* 1973, Kettela and Miller 1975, Miller *et al.* 1977). In these spray tests, up to 80% of the female moth population was estimated to have been killed but reductions in egg masses were never greater than 50%. The relatively high egg-mass densities can be attributed to invasion by egg-carrying females after the application of insecticide and to the non-susceptibility of young females to aerially applied insecticides at the rate of 70 g a.i. in 0.73 L of formulation per hectare. The observation that young females were non-susceptible (Thomas 1978) led to the hypothesis that fully gravid females which rest in foliage are rarely exposed to a lethal dose of insecticide. Failure to kill young females would compromise any adult spray program and thus laboratory experiments were conducted to determine whether certain chemicals, added to the insecticide, might stimulate moth flight or movement and increase the incidence of droplet impingement. Those experiments were successful (Volney and McDougall 1979).

In contrast to the females, male moths are especially susceptible to aerially applied insecticides. However, as applications are normally timed to kill females (the first spray is usually applied when about 50% of the females have emerged) the susceptibility of the males has rarely been exploited. Because male emergence is usually three days ahead of female emergence, the efficacy of the kill of males would be reduced because some insemination of females would have already occurred.

In 1974, 800 000 ha in north central New Brunswick were sprayed with an adulticide and one study block was treated three times when 8, 68, and 90% of the males and 0, 31, and 58% of the females had emerged. Drop sheets were used in this block to collect moths that died in the trees and fell to the ground. Of the 1533 females collected, 73% were unmated and less than 1% had mated more than once. This dramatic result, when coupled with the observation that young females were non-susceptible to aerially applied insecticides led to the idea that the target in adult spraying should be male moths rather than females.

The joint research program between Forest Protection Ltd. and the Maritimes Forest Research Centre was continued in 1977 to determine:

i) whether an early application of insecticide, timed to kill males, would significantly reduce insemination of females and thus reduce egg laying, and

ii) whether motor stimulants combined with insecticide would increase the mortality of young females.

The spray tests were conducted at the Acadia Forest Experiment Station near Fredericton, and near Heath Steele, Northumberland County. Because each study had a different objective and was conducted in a different area the results are presented separately in this report. The side effects on non-target species have been briefly reported elsewhere (Varty 1978).

EARLY SPRAY APPLICATIONS: HEATH STEELE

Objective

The major objective of the spray test conducted at Heath Steele was to determine the effect on the insemination of resident females, of air-to-ground spraying timed to kill males. The aim was to reduce the number of eggs laid by these females.

Aerial Spray Application

A 3237-ha block was treated with three aerial applications of 70 g a.i. phosphamidon in 0.73 L of formulation per hectare. Sprays were applied at 8, 60, and 85% male emergence which coincided with 0, 40, and 70% female emergence. A nearby stand of untreated forest served as a check block.

Sampling Methods

The sampling design consisted of 10 plots within each block. Host trees, balsam fir (*Abies balsamea* L. (Mill.)) and spruces (*Picea* spp.), were sampled for budworm in each plot. Pupae and pupal cases were counted to determine resident moth densities; pheromone traps were used to estimate male mortality caused by the treatment; and observations on flight activity were made. Adult sampling techniques included spraying trees from the ground with a "quick-knockdown" insecticide (Boethel *et al.* 1976); erecting Malaise traps and light traps in the midcrown; and using trays to collect moths that died from both the aerial spray and from natural causes. Light traps were operated in clearings in an attempt to detect moth invasions.

Females were weighed and measured to estimate the number and proportion of eggs they had laid (Thomas 1978). They were then dissected and the spermatophores were counted to determine the number of times they had mated. Egg masses were also counted to evaluate the effect of the treatment.

RESULTS

Resident Moth Densities

Pupae and pupal cases were counted on one midcrown branch from each of five fir and five spruce trees per plot, at 25% adult emergence, to determine budworm densities. There were great variations in densities between plots but the average density was higher in the treatment block than in the check block. Also, more budworm were found on the fir than on the spruces:

No. of pupae and pupal cases/10 m^2 of foliage, mean (range)

Block	Fir
Treatment	104 (6-261)
Check	23 (<1-132)
Block	**Spruces**
Treatment	56 (13-103)
Check	14 (<1-57)

Pupal cases were also counted on the fir branches which were sampled for egg masses, i.e. after 100% adult emergence. These averaged 115/10 m^2 in the 10 treatment plots and 86/10 m^2 in five of the 10 check plots. Thus, moth densities were similar in the plots where egg masses were assessed .

The pupal sex ratio was 53% males; the adult sex ratio was 51% males.

Estimated Male Mortality Based on Pheromone Traps

Five traps were placed in each of the 10 plots in the treatment block and five were placed in each of the 10 plots in the check block. The traps used were 1.13-litre milk cartons cut in half, with Tanglefoot sticker applied to the inside. The pheromone attractant sources were 4-mm diameter × 10-cm long plastic sticks impregnated with 3% pheromone (97:3, E:Z ratio) pinned in the inside middle of the trap; one pheromone emitter per trap.

The pretreatment count of males in the check block (1467 males in 50 traps in 8 days) was almost identical to the pretreatment count in the treatment block (1446) which is surprising as the pupal density averaged five times higher in the treatment block. The post-treatment count of males in the check block was 33,115 as compared with 5,008 in the treatment block; suggesting a male mortality of 85%.

Average counts per trap declined sharply in the treatment block after the first aerial spray and never recovered (Table 1). An increase in numbers in both blocks was noticed on 23 and 24 July; this is discussed later under "Evidence for Moth Invasions".

Observations on Flight Activity

The flight activity of spruce budworm moths was observed from a platform built above the canopy of the treatment block. Buzzing flight activity of male moths decreased markedly after the first spray, counts being one-tenth to one-fortieth of those in unsprayed areas in other years, in areas supporting similar moth densities. Either the spray treatment had greatly reduced the male population or had suppressed local flight activity. Only one moth was seen from the observation platform in exodus flight from the treated stand. In other years, hundreds of moths were seen, on several nights, taking off before dark from stands in which the local moth population was similar to that at Heath Steele.

Spraying Trees

Each day, five fir and five spruce trees were sprayed in the early afternoon on preselected plots in the check block and in the treatment block using an hydraulic sprayer capable of reaching the top of a 15-m tree. A commercial insectice "Pyrocide" was used as the knock-down spray. Dead moths were collected on sheets (5 × 10 ft; 4.65 m^2); one sheet per tree. Moths were collected 1, 2, and 3 days after the trees were sprayed and the females were examined for mating status (Tables 2 and 3).

The high proportion of unmated females in the check block collections on 12 and 13 July (Table 2) was due to the time of spraying in relation to the time of moth eclosion and mating. Moth emergence begins in the late morning and continues throughout the warmest part of the day. Mating does not occur until sunset. During each day there is an accumulation of unmated females that do not become inseminated until the late evening. Spraying trees in the early afternoon at the beginning of the female emergence period resulted in a high proportion of unmated females being killed. Later in the female emergence period, i.e. at about 70% female emergence, the newly emerged unmated females are outnumbered by the older mated females.

In the treatment block the proportion of unmated females averaged 50% (Table 3). When adjusted for the unmated females in the check block (9%), there was a 45% reduction in mating success in the treatment block. The incidence of multiple matings was reduced in the treatment block from an expected 45% (in the check) to 6%.

Malaise Trap Catches

Ten flight-interceptor traps were placed in the midcrown of the treatment block and five were placed in the check block. The total seasonal catch of 1.1 males per trap in the treatment block compared to 46.2 males per trap in the check block clearly shows high male mortality or a significant change in behaviour due to the treatment. The difference in sex ratio of trapped moths between blocks also indicated high male mortality. In the check block, 72% of the budworm were males whereas in the treatment block only 7% were males.

The mating status of the 55 females examined from the check block and the 164 females from the treatment block was:

Number of matings	Percentage of females: Check	Percentage of females: Treatment
0	0	27
1	49	65
2	36	8
3	15	0

These data suggest that the treatment reduced mating success by 27%, and reduced the incidence of multiple matings from an expected 51% to 8%.

It was estimated that the females trapped in the Malaise traps in the check block had laid an average of 145 eggs each before being trapped. The mated females in the treatment block had laid an average of 90 eggs each. When the total number of eggs laid (90 × 119 mated females) was divided by the total number of females examined (164) we obtained an average of 65 eggs per female in the treatment block. The implication is that, up until capture, 80 fewer eggs per female were laid in the treatment block. The reason for this is unknown but we suspect that because of the relative scarcity of males, insemination of the females and subsequent oviposition were delayed by several days. Thus, females of the same chronological age would have laid fewer eggs if they had originated in the treatment block, than those females which originated in the check block.

Canopy Light Trap Catches

There were 10 light traps suspended at midcrown in the treatment block and five traps in the canopy of the check block. In the treatment block, the mean male catch per trap per night before the first spray application (i.e. prior to 11 July) was 62 and the mean male catch per trap on post-treatment nights was 42. In the check block, the corresponding catches were 41 males before 11 July and 319 males after 11 July. Based on these average catches, it is calculated that the phosphamidon treatment killed or otherwise altered the flight behaviour of 91% of the males.

In the check block, the canopy

light traps captured a total of 1146 females and 11,973 males providing a sex ratio of 9% females. This was consistent with earlier analyses of light trap records (Greenbank 1957) and was due to females being less active than males within the canopy and to a sex difference in the reaction of budworm moths to light. In the treatment block, 5761 females were taken in light traps: this represents 47% of the total budworm catch. This is a result of the relative scarcity of males and further substantiates the efficiacy of aerial sprays against male moths.

Based on the pretreatment counts in the treatment block (1.5 females/trap/night) and in the check block (1.9 females/trap/night), and compared with the post-treatment counts in the same blocks (61.3 and 31.7), we concluded that the phosphamidon regime did not lower the survival of females.

There was little difference in the mating status of the females from each block. All the females examined from the check block (171) and 93% of the 421 females examined from the treatment block had mated. Most of the females attracted to light traps had mated once:

Number of matings	Percentage of females: Check	Percentage of females: Treatment
0	0	7
1	82	84
2	17	8
3	1	1

The mating status of females collected in canopy light traps in the check block is shown on a daily basis in Table 4, and for similar females from the treatment block in Table 5.

The oviposition history of females collected in canopy light traps was remarkedly constant throughout the season. It was estimated that the trapped females in both blocks had laid about 130 eggs each.

Fallout of Dead Moths

Collecting trays (each 3 × 6 ft, 1.67 m^2) were placed beneath fir and spruce trees in each of the 10 plots in the treatment and check blocks to collect moths that fell from the trees. There was a total of 50 m^2 of collecting surface beneath each tree species in each block. These trays were examined once a day and, although most of the moths on them were dead, some live moths were also collected. The actual number of live moths collected was not recorded but it was assumed that a live moth on the ground that could be picked up by hand would be unable to contribute any further progeny to the next generation; for reproductive purposes it was considered dead.

Table 6 shows the number of dead moths per 100 m^2 of tray surface in both blocks. Male mortality began within a few hours of the first application, peaked on 15 July on fir and 18 July on the spruces, and continued until 29 July after a minor peak on 25 July. Interestingly, there was a 2-to 3-day delay to peak mortality after each spray. It is evident that this mortality was not natural, but was induced by the spray treatment.

Forty-one percent of the 1,540 females collected on drop trays and supplementary collecting mats in the treatment block were unmated (Table 7). The proportion of females which had not mated varied daily but was about 50% for an 8-day period after the second application of insecticide. In the check block, a total of 94 females was collected on trays and mats, 9% of which were unmated.

The treatment has a significant effect on mating frequency in that only 7% of the females mated more than once; in the check block, 41% of the females mated more than once:

	Percentage of females	
Number of matings	Check	Treatment
0	9	41
1	50	52
2	36	6
3	4	< 1
4	1	< 1

The mated females that died in the check block, from natural causes, had laid an estimated 143 eggs. The mated females that died in the treatment block, from natural causes and insecticide treatment, had laid an estimated 111 eggs.

The effect of the treatment can be interpreted as causing a 35% reduction in mating success and reducing the number of eggs laid per mated female from an average of 143 eggs to 111 eggs.

However, as 7 of the 84 females examined from the check block died as virgins, the average number of fertile eggs laid by these females was (143 eggs × 77 mated females ÷ 84 females) equal to 131 eggs. Similarly, as 904 of the 1,540 females examined in the treatment block died as virgins, the average number of fertile eggs laid by these females was (111 eggs × 904 mated females ÷ 1,540 females) equal to 65 eggs. The net effect of the treatment on oviposition can therefore be interpreted as having reduced the average number of fertile eggs laid by a female from 131 to 65; a reduction of 50%.

Egg-Mass Counts

Egg masses were counted in August after all moth activity had ceased. The efficacy of the treatment was based on the ratio of egg masses: emerged females (E:F ratio).

The actual mean number of egg masses per 10 m^2 of fir foliage varied within and between blocks, being affected by budworm density and the insecticide treatment:

No. of egg masses/10m^2 fir foliage

	Check	Treatment
Low population plots	121	64
High population plots	282	187
All plots	196	146

Direct comparison of egg masses per 10 m^2 of foliage was not valid. The E:F ratio in the high population density plots was 1.69 in the check, and 1.17 in the treatment block. Thus there were 31% fewer egg masses per female pupa in the treatment block; this figure can be taken as a measure of the efficacy of the treatment.

Evidence for Moth Invasions

There is evidence that moth invasions occurred after the aerial application of insecticide. Such invasions increase the difficulty of evaluating treatment effects.

One indication of invasion comes from the pheromone trap catches (Table 1); a noticeable increase in male catches in both blocks on the nights of 22/23 and 23/24 July is evidence of an invasion.

Another indication of invasions comes from light traps in clearings (100 m or more in diameter). It is generally accepted that the presence of large numbers of budworm moths in such traps indicates that the area was invaded (Greenbank 1957). Two light traps were placed in clearings in the treatment block and one in a clearing in the check block in an attempt to detect invasions. The data suggest that there were moth invasions on the nights of 15/16, 16/17, and 17/18 July (Table 8). The budworm catches increased considerably on these nights and the proportion of females in the catch was typical of migrating budworm (i.e. greater than 9%). Any invasion occurring after the night of 17/18 July would go undetected by light traps because before or shortly after dark, temperatures near the ground repeatedly fell below the threshold for flight.

A third indication of invasion is that the mating status of the females found dead on trays and sheets in the treatment block changed abruptly on 23 July, from about 50% unmated to about 20% unmated (Table 7). This suggests that mated females entered the block before 23 July.

A fourth indication of invasion comes from counts of unhatched egg masses on balsam fir foliage collected on plot 5 of the treatment block. Ten branches were cut and washed daily in boiling water to "float off" unhatched egg masses. Washing began on 18 July at 90% female emergence and thus only the late-season trend in oviposition was observed. The counts show an unusual U-shaped trend when plotted over sampling data (Fig. 1). Historical data show that the maximum number of unhatched egg masses occurs when about 100% of the females have emerged. On succeeding days, the counts of unhatched egg masses drop sharply as the first eggs deposited begin to hatch. This trend is suggested in Fig. 1 between 18 and 23 July. The increase in counts from 25 July to 29 July was entirely unexpected and was most likely caused by invading females laying eggs.

SUMMARY

Aerial sprays of phosphamidon were applied on three dates which coincided with 8, 60, and 85% male moth emergence and with 0, 40, and 70% female moth emergence. The first application (a.m., 11 July) was well-timed to kill males before female emergence had begun. Female emergence began on 11 July and with the continuous emergence of males and females, considerable mating could have occurred in the late evenings of 11, 12, and 13 July. A similar "mating window" was available on the night of 15 July before the third spray application.

Male mortality was estimated as 85% from pheromone trap catches, 91% from canopy light trap catches, and 98% Malaise trap catches.

A 7% reduction in mating was estimated from females in canopy light traps catches, 27% from females in Malaise traps catches, 35% from females on drop trays, and 45% from females obtained by spraying trees from the ground.

Estimates of the frequency of multiple matings (i.e. females

having more than one spermatophore) obtained by four sampling methods showed significant lower frequencies in the treatment block than in the check block. In the check block, the frequencies of multiple matings were 18% in the canopy light traps, 41% on drop trays, 46% from females obtained by spraying from the ground, and 51% from Malaise traps. The corresponding figures for the treatment block were 9, 8, 7, and 8%. Although the biological significance of multiple matings is not known, reduction in this frequency may prove a useful measure for evaluating treatment effects against males.

Estimates of the average number of eggs per female were made from four sampling methods in each block. From the Malaise trap catches, oviposition was estimated to have been reduced from 145 eggs per female in the check block to 65 eggs per female in the treatment block (a 55% reduction). Corresponding data for the other methods were: canopy light traps, no reduction; fallout of dead moths, reduced from 131 to 65 eggs per female (a 50% reduction); egg-mass counts reduced from 1.69 to 1.17 masses per female (a 31% reduction).

CONCLUSIONS

i) Our most conservative estimate of 85% male mortality resulted in, what we consider our best estimate, a 35% reduction in mating success.

ii) Oviposition, based on egg-mass counts was reduced by 31%. Direct measurements on females indicated that oviposition was reduced by as much as 55%. However, it is believed that the data from egg masses give the best estimates of egg reduction.

iii) Early application of insecticide to kill males holds some promise particularly when we can achieve a relatively high male mortality with light dosages of insecticide per application. On the other hand, it is necessary to spray often, possibly five times during an 8-day emergence period; this could create major operational problems.

iv) It is tempting to speculate that if mating could be prevented for an 8-day period by the pheromone confusion technique, a single application of insecticide at the time when all males had emerged might have the same effect as five insecticide sprays at intervals.

Table 1. Average number of males per pheromone trap per day: Heath Steele[1]

Date traps emptied	Average number of males/trap Check Block	Treatment block
July 4	5	4.1
5		
6		
7	1	1.6
8	1	2.4
9		
10		
11	22	21
11		Aerial spray
12	20	11
13	22	8
14	26	2
14		Aerial spray
15	24	1.8
16	29	2.2
16		Aerial spray
17	32	1.8
18	36	0.9
19	38	0.9
20	44	0.3
21	36	0.4
22	39	5.2
23	48	14.0
24	54	14.6
25	31	4.7
26	29	1.2
27	20	0.9
28	27	2.8
29	27	7.2

[1] Based on 5 traps/plot; 10 plots/block = 50 traps/day/block.

Table 2. Mating status of females killed by applications of "Pyrocide" from an hydraulic sprayer; Check Block: Heath Steele

Date of Spray	% Female emergence	No. of females	Number of females having these numbers of spermatophores					% Unmated
			0	1	2	3	4	
July 11	0							
12	10	3	3					100
13	25	11	7	3	1			64
14	40							
15	54	1	1					
16	69	6	1	3	2			17
17	76	25	7	15	3			28
18	86	6		6				0
19	90	39	6	19	10	4		15
20	97	1			1			
21	100	16	1	3	10	2		6
22		16	1	9	6			6
23		16		9	5	2		0
24		53	1	27	21	3	1	2
25		70		26	35	8	1	0
26								
27		51	1	23	24	3		2
28		1		1				
29		5		1	3	1		0
Total		320	29	145	121	23	2	
Percentage			9	45	38	7	<1	

Table 3. Mating status of females killed by applications of "Pyrocide" from an hydraulic sprayer; Treatment Block: Heath Steele

Date of Spray	% Female emergence	No. of females	Number of females having these numbers of spermatophores					% Unmated
			0	1	2	3	4	
July 11			Aerial spray					
11	0	4	1	2	1			
12	10	69	46	23				67
13	25							
14	40	223	137	84	2			61
14			Aerial spray					
15	54	157	103	52	2			66
16			Aerial spray					
16	69	202	137	60	4		1	68
17	76	40	13	26	1			33
18	86	40	18	22				45
19	90	28	13	15				46
20	97	8	5	2	1			63
21	100	36	21	13	2			58
22		37	18	16	3			49
23		63	1	35	21	5	1	2
24		288	117	163	7	1		41
25		90	17	62	10	1		19
26		40	17	16	7			43
27		10	2	4	3	1		20
Total		1335	666	595	64	8	2	
Percentage			50	45	5	<1	<1	

Table 4. Mating status of females in canopy light traps in Check Block: Heath Steele

Date traps emptied	No. of females examined	Number of females having these numbers of spermatophores			
		0	1	2	3
July 9	17		14	3	
10	1		1		
11					
12	1		1		
13	17		17		
14	2		2		
15	6		4	2	
16	41		31	10	
17	34		28	6	
18	40		33	5	2
19	5		4	1	
20					
21					
22	7		5	2	
Total	171	0	140	29	2
Percentage		0	82	17	1

Table 5. Mating status of females in canopy light traps in Treatment Blocks: Heath Steele

Date traps emptied	No. of females examined	Number of females having these numbers of spermatophores 0	1	2	3	% Unmated
July 9	16		15	1		0
10						
11	3		2	1		
11	---Aerial spray---					
12	2		2			
13	49		45	4		0
14	4		3	1		
14	---Aerial spray---					
15	48	2	43	3		4
16	54	2	51	1		4
16	---Aerial spray---					
17	50		38	12		0
18	49	10	38	1		20
19	22		20	2		0
20	11	4	7			36
21	50	9	39	2		18
22	50	2	42	5	1	4
23	5	2	3			
24	8		7	1		0
Total	421	31	355	34	1	
Percentage		7	84	8	<1	

Table 6. Number of dead moths/100 m^2 of tray surface in the Treatment and Check Blocks: Heath Steele

Collection date	Moths per 100 m^2 of tray surface							
	Treatment Block				Check Block			
	Males		Females		Males		Females	
	Fir	Spruce	Fir	Spruce	Fir	Spruce	Fir	Spruce
July 11, a.m.	------Aerial spray------							
11	18	20	0	0	0	0	0	0
12	32	72	0	4	0	0	0	0
13	80	50	6	6	0	0	0	0
14	102	82	18	12	0	0	0	0
14, p.m.	------Aerial spray------							
15	186	126	104	58	0	0	0	0
16, a.m.	------Aerial spray------							
16	124	76	60	36	0	0	0	0
17	104	124	186	138	0	0	0	0
18	164	174	210	162	2	2	0	2
19	74	70	52	52	4	0	2	0
20	66	66	72	74	12	0	6	0
21	74	48	48	66	0	0	0	0
22	40	80	42	38	4	2	2	2
23	20	8	10	6	14	8	0	4
24	52	44	48	36	14	18	10	4
25	94	86	76	64	6	4	2	4
26	42	26	32	40	16	10	10	2
27	68	8	6	8	24	22	4	8
28	16	4	12	4	10	8	4	2
29	8	10	2	2	36	16	0	0

Table 7. Mating status of females on drop trays and collecting mats in the Treatment Block: Heath Steele

Collection Date	Total Females	Number of females having these numbers of spermatophores					% Unmated
		0	1	2	3	4	
July 11	----------Aerial spray----------						
12	8	1	5	2			13
13	10	2	8				20
14	33	7	22	4			21
14	----------Aerial spray----------						
15	124	59	60	5			48
16	----------Aerial spray----------						
16	98	55	39	4			56
17	325	122	189	13	1		38
18	287	158	119	8	2		55
19	67	33	33	1			49
20	96	47	42	7			49
21	88	49	38	1			56
22	56	34	21	1			61
23	12	4	6	2			33
24	130	32	84	13		1	25
25	95	15	57	22		1	16
26	73	14	47	11	1		19
27	12	1	10	1			8
28	9	1	7		1		11
29	17	2	12	2	1		12
Total	1,540	636	799	97	6	2	
Percentage		41	52	6	<1	<1	

Table 8. Average number of moths per light trap situated in clearings: Heath Steele

Date traps emptied	Average number of moths per traps			
	Treatment Block		Check Block	
	Males	Females	Males	Females
July 8	0	0	0	0
9	7	2	0	0
10	16	0	6	0
11	3	0	19	0
12	2	0	6	0
13	13	6	6	1
14	3	0	16	4
15	1	0	8	0
16	74	141	96	36
17	2	16	2	0
18	26	24	4	8
19*	1	0		
20	2	1		
21	6	4		
22	6	5		
23	5	0		
24	2	1		
25	2	0		

* Check block, traps not operating 19-25 July.

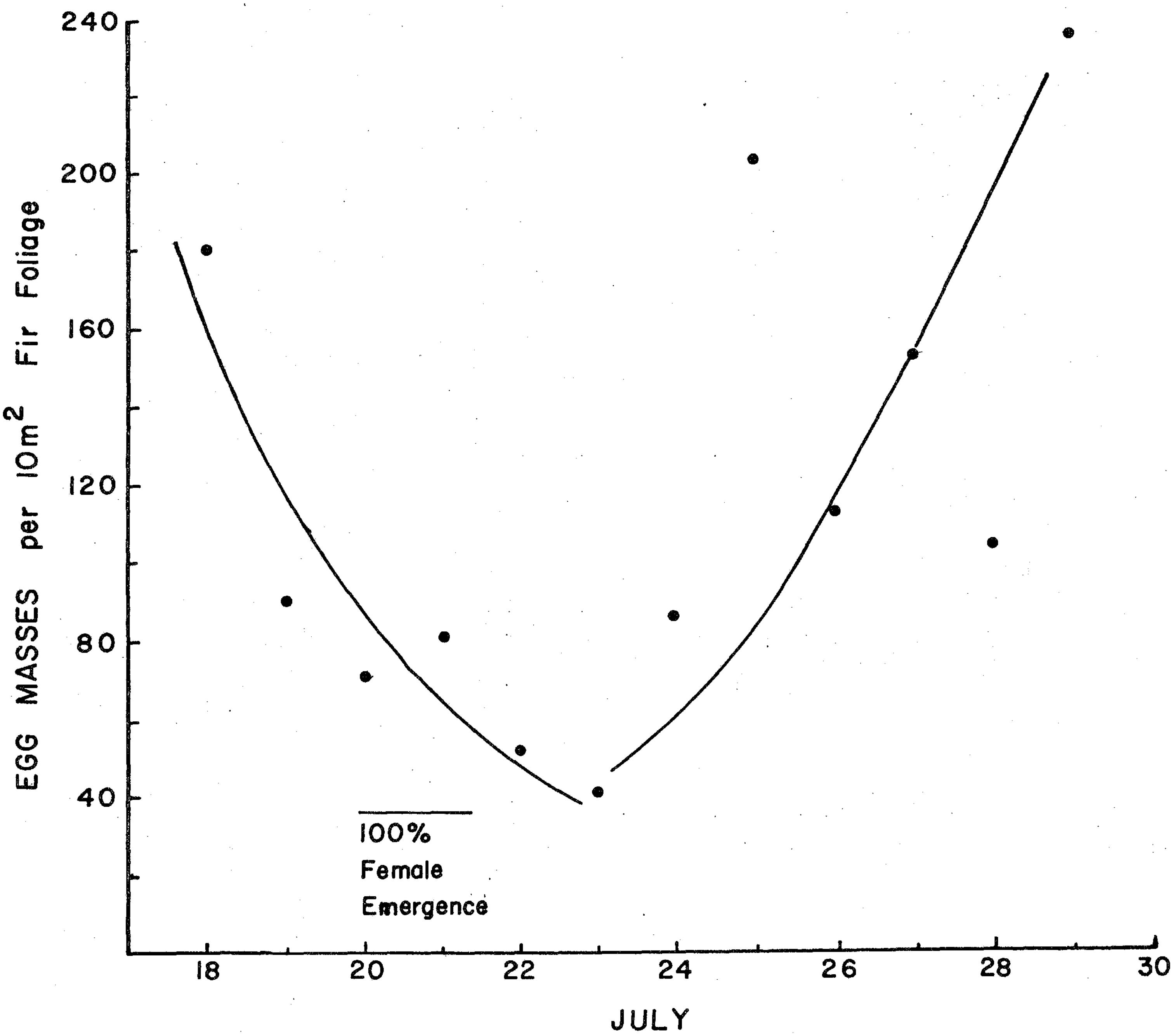

Fig. 1. Trend in unhatched egg-mass counts: Heath Steel, Treatment Block.

LATE SPRAY APPLICATION AND THE USE OF MOTOR STIMULANTS: ACADIA FOREST EXPERIMENT STATION

Objectives

The objectives of the spray test conducted at Acadia were to: i) check the conclusion from the 1976-tests that air-to-ground spraying selectively kills old females, and ii) determine if motor stimulants, pyrethrin and piperonyl butoxide, combined with the insecticide formulation would significantly increase the mortality of young females. In addition, we were able to check the conclusion from previous adult spray trials that males are especially susceptible to such sprays.

Aerial Spray Applications

Two applications of insecticide were planned, the first at 25% female emergence and the second at 60% female emergence. The first spray (9, 10 July), coincided with about 25% female emergence but the second application was delayed, by poor flying weather, until about 80% female emergence. Three small treatment blocks, each about 100 ha, having central access roads were selected in the Acadia Forest Experiment Station.

BLOCK 1: Forest of spruce and some fir

Treatment:
70 g a.i. phosphamidon + 1.7 g pyrethrin concentrate + 7 g piperonyl butoxide in 0.73 L formulation/ha

Application Dates:
10 July, 0600 h
14 July, 1300 h

BLOCK 2: Forest of spruce

Treatment:
70 g a.i. phosphamidon in 0.73 L formulation/ha

Application Dates:
9 July, 1900 h
10 July, 0800 h
14 July, 1100 h

BLOCK 3: Forest of spruce and some fir

Treatment and Application Dates: Same as BLOCK 2

CHECK BLOCK: Forest of spruce and fir

A series of plots formed a Check Block.

Sampling Methods

All moths killed by the treatments were collected on 10 drop trays (each 3 × 6 ft, 1.67 m^2) in each of the four plots within each treatment block; a total of 20 trays beneath fir and 20 beneath spruce in Block 1, 40 trays beneath spruce in Block 2, 23 trays beneath fir and 17 beneath spruce in Block 3. There were 64 trays beneath fir and 36 beneath spruce in the check block to obtain data on natural mortality. Nine Malaise traps were operated to detect moth activity in the canopy; three traps were in Block 1, and two traps in each of Blocks 2, 3 and the check block.

Ten light traps were operated to detect moth activity and invasion into the area; two traps were in the canopy in each of the three spray blocks and in the check block, and two traps were in clearings in the check block.

Ten pheromone traps were operated in each block to determine the effect of the treatment on males.

The treatments were evaluated by estimating the number of eggs laid by each female and by expressing it as a proportion of her expected fecundity. For example, if a female had laid an estimated

120 eggs and had an expected fecundity of 200 eggs, she would be recorded as having laid 60% of her eggs.

RESULTS

Fallout of Dead Moths

The numbers of dead moths collected on drop trays are listed in Table 9. As every tray in the three treatment blocks was not examined each day between 11-14 July, the total number of moths collected on these four days has been tabulated as an average number per day. There were no significant differences between the number of dead moths collected beneath fir and spruce in each block, therefore the data were combined.

Moth mortality in the check block peaked about 18 July with few females dying between 9-16 July. Mortality in the treatment blocks peaked on 15 July with many insects dying between 10-14 July. Comparison of the time of appearance of dead moths on the drop trays (Table 9) shows that the treatments were effective. It is also apparent that moths were not eliminated from the treatment blocks as they continued to appear on the drop trays until late July. We could detect no significant differences between the number of moths killed by the phosphamidon (Block 3) and the number killed by the phosphamidon + the motor stimulants (Block 1). The fewer number of dead moths in Block 2 (phosphamidon spray) is attributed to the lower population of moths in this all-spruce stand. However, the drop tray collection method was not designed to detect quantitative differences but primarily to obtain females for the determination of their oviposition status, this being the major objective of the spray trials.

The oviposition status of the females collected in the treatment and check blocks is shown in Table 10. Females killed by the first application of spray in Block 1 (the motor stimulant block) had laid, on average, 59% of their eggs; whereas females killed by the first two applications in Blocks 2 and 3 had laid between 39 and 62% of their eggs. Females dying after the last spray application (14 July) had laid, on average, more than 66% of their eggs. Most of the females that died in the check block had laid most of their eggs. Thus, in terms of our objective neither spray regime was effective in killing young females.

Malaise Trap Catches

Malaise traps intercept flying moths and measure the natural activity of moths in the air space. Thus, they can be used to quantify activity and the females can be examined to determine their oviposition status.

The daily catch of moths per trap in the treatment and check blocks is shown in Table 11. There was a noticeable reduction in the number of males expected in the treatment blocks, an apparent mortality of 85-90%, but there was no apparent reduction in the number of females caught. We conclude that neither treatment had any significant effect on female mortality or on female behaviour.

The oviposition status of the females trapped (Table 12) shows that they were old. Old females are a result of survival of young females and thus the Malaise trap evaluation indicated that the spray applications had no significant effect on young females.

Canopy Light Trap Catches

There was a noticeable reduction in the expected number of males trapped in canopy light traps in the treatment blocks which suggests that a 60-70% mortality of males occurred. No difference in mortality was detected between the phosphamidon blocks and the phosphamidon + motor stimulant block.

No reduction was noticed in the number of female moths trapped. Thus, from the evaluation of the light trap data we conclude that neither spray regime had any effect on the females.

Evidence for Moth Invasions

Very few budworms were collected in the clearing light traps and thus there was no evidence of mass invasion into Acadia Forest Experiment Station. However, catches of budworm moths in the canopy light traps were inordinately high on the nights of 8/9, 11/12, and 12/13 July. These catches, high relative to those on the nights immediately earlier or later, cannot be explained by temperature. Invasion into the area is a possibility.

Estimated Male Mortality Based on Pheromone Traps

The reduction in the number of males expected in the treatment blocks suggests a male mortality of 60-70% (Table 13). This further confirms all previous studies that males are extremely susceptible to aerial sprays of insecticide.

SUMMARY

Two applications of a phosphamidon formulation containing motor stimulants were applied to a block of forest at 25 and 80% female moth emergence, to determine if young females would be killed. A similar formulation, but lacking the motor stimulants, was applied three times to other blocks of forest.

The females killed by the first application of phosphamidon, and phosphamidon + motor stimulants had laid, on average, 59% of their eggs; those killed by the last applications had laid more than 66%.

Most of the females captured in Malaise traps were old; an indication of the survival of young females.

Mortality of males was estimated as 85-90% from Malaise trap catches, 60-70% from light trap catches, and 60-70% from pheromone trap catches.

CONCLUSIONS

i) The conclusion from the 1976 spray trials that air-to-ground spraying selectively kills old females was confirmed.

ii) The motor stimulants (pyrethrin and piperonyl butoxide) combined with insecticide did not kill young females.

iii) A male mortality of about 70% was obtained with insecticide; it was not increased with the addition of motor stimulants.

Table 9. Number of dead moths/100 m^2 of tray surface in the Treatment and Check Blocks: Acadia

Collection Date	Moths per 100 m^2 of tray surface							
	Block 1		Block 2		Block 3		Check	
	Males	Females	Males	Females	Males	Females	Males	Females
July 8							2	0.6
9	6						11	5.2
9			----------Aerial Spray--------					
10	------------------Aerial Spray------------------							
10	10.5	3	64.5	40.5	295	101.7	20	5.2
11	168	93.4	48	21.3	150	109.5	11	3.1
12	168	93.4	48	21.3	150	109.5	8	3.7
13	168	93.4	48	21.3	150	109.5	28	6.2
14	168	93.4	48	21.3	150	109.5	41	11.2
14	------------------Aerial Spray------------------							
15	455	463.4	144	87	425	571	47	9.3
16	159	97.2	114	45	107	56.8	83	6.9
17	67.5	41.9	69	13.5	54	23.9	78	11.2
18	102	91.2	102	55.5	45	31.4	132	43.6
19	52.5	58.3	28.5	24	27	34.4	88	51.1
20	37.5	97.2	42	82.5	26	29.9	61	26.8
21	28.5	20.9	27	33	11	19.4	51	38.0
22	18	22.4	21	37.5	27	17.9	35	17.4
23	21	8.9	13.5	18	8.5	13.5	12	13.7
24	12	16.4	13.5	10.5	8.5	4.5	15	19.9
25	7.5	10.5	13.5	13.5	4.4	6.0	12	10.6
26	4.5	10.5	9	7.5	7.4	7.5	12	4.4

Table 10. Oviposition status of dead females recovered from drop trays in the Treatment and Check Blocks: Acadia

Collection Date	Number of females examined*, and estimated percentage of eggs laid**							
	Block 1		Block 2		Block 3		Check	
	*	**	*	**	*	**	*	**
July 8								
9							8	7
9			-----Aerial spray-----					
10	---------------Aerial spray----------							
10			26	57	65	39	6	17
11	60	59	13	62	68	48	5	32
12	60	59	13	62	68	48	6	6
13	60	59	13	62	68	48	10	68
14	60	59	13	62	68	48	12	35
14	---------------Aerial spray----------							
15	229	68	56	72	127	70	14	66
16	60	75	29	77	38	74	9	82
17	20	74	9	81	14	67	17	83
18	59	83	36	85	19	87	64	93
19	38	86	15	83	21	86	48	88
20	62	90	50	88	20	88	31	92
21	13	97	20	92	12	90	42	93
22	15	96	23	96	10	93	21	101
23	6	94	10	100	9	84	21	99
24	11	97	7	102	4	88	27	99
25	7	90	9	101	4	107	14	96
26	5	90	3	101	4	85	3	107

Table 11. Daily catches of moths in Malaise Traps in the Treatment and Check Blocks: Acadia

Collection Date	Average number of moths per trap							
	Block 1		Block 2		Block 3		Check	
	Males	Females	Males	Females	Males	Females	Males	Females
July 4					1		1	
5					0.5		0.5	
6					0.5			
7					0.5			
8	1.3	0.3					0.5	0.5
9	15.3	3	2.5	1	8	2	3	2
9			--------Aerial spray-------					
10	23	3.3	0.5		10	3.5	4.5	2.5
10	-----------------Aerial spray---------------							
11	8.3	1.3	1	1.5	0.5		8.5	4
12	14	10.7	6	1.5	3	3	32.5	9
13	7	11	12.5	6	15.5	3	37	7
14	6.7	1.3	1		3.5	0.5	18	0.5
14	-----------------Aerial spray---------------							
15	7	18.7	6	3	2	3.5	130	26.5
16	7.7	26.7	8	6.5	2.5	4	119	17.5
17	4.3	31	5.5	10	2.5	9.5	93	22
18	3.7	69.7	8.5	36.5	1.5	14	96.5	10.5
19	1	23.3	1.5	4.5		5.5	23.5	6
20	2	41.3	4	29.5	2	20.5	68	14
21	1.3	36	6.5	53.5	0.5	7.5	55	7
22	1	14	2.5	16	0.5	3.5	10.5	2
23	0.7	1		1.5		3	2.5	
24	1.7	6	2.5	4		2.5	1.5	3.5
25	5	12.3	6	12.5		3	7	5.5
26		0.7		0.5				
27	27							1
28		2.7	0.5	1.5		0.5		0.5
29	0.7	1		3.5		1	0.5	
Totals/trap	112	315	75	193	55	90	713	142

Table 12. Oviposition status of females in Malaise Traps in the Treatment and Check Blocks: Acadia

Collection Date	Number of females examined*, and estimated percentage of eggs laid**							
	Block 1		Block 2		Block 3		Check	
	*	**	*	**	*	**	*	**
July 8	1	3						
9	9	36	2	63	4	55	4	53
9			-----Aerial spray-----					
10	10	18	0		6	53	5	35
10	------------Aerial spray------------							
11	4	51	3	67	0		8	51
12	31	41	3	59	6	50	17	48
13	33	47	12	54	6	60	14	45
14	3	49	0		1	53	1	20
14	------------Aerial spray------------							
15	56	58	6	77	7	60	49	58
16	79	65	13	78	8	64	35	68
17	92	66	20	72	19	75	43	66
18	208	75	73	84	28	78	19	72
19	70	73	9	68	11	79	12	75
20	124	78	55	81	40	84	26	74
21	108	76	106	89	15	86	12	76
22	41	82	33	94	7	88	4	75
23	3	82	2	79	6	88	0	
24	18	84	8	89	5	90	7	62
25	36	77	25	93	6	92	10	86
26	2	69	1	94	0		0	
27	0		0		0		2	103
28	7	90	3	98	1	104	1	96
29	3	84	7	94	2	100	0	

Table 13. Average number of males in pheromone traps in the Treatment and Check Blocks: Acadia

Date Traps Emptied	Average number of males/trap			
	Block 1	Block 2	Block 3	Check
July 1	2.3	2	6.6	1.8
2	2.3	2	6.6	1.8
3	2.3	2	6.6	1.8
4	3.4	2.6	2.4	7.8
5	12.4	8.0	10.9	18.3
6	7.8	5.1	6.4	4.1
7	4.4	4.2	5.3	9.1
8	5.5	3.3	3.3	9.3
9	5.7	3.0	6.3	7.1
9		---Aerial spray---		
10	5.1	6.7	1.7	5.8
10	-----------Aerial spray-----------			
11	13.1	12.1	12.7	30
12	12.3	14.9	5.1	40.3
13	12.7	10.7	11.9	47.9
14	13.3	17.7	17.9	42.3
14	-----------Aerial spray-----------			
15	6.3	13.4	19.7	63.7
16	3.3	8.8	17.7	>80
17	10.6	22.7	25.1	>80
18	2.3	9.1	14.8	64.3
19	0.6	5.1	5.8	28.1
20	5.4	5.0	7.0	34.3
21	5.1	3.5	4.2	30.4
22	5.6	3.6	2.4	43.2
23	8.7	13.9	11.8	19.4
24	7.7	8.7	2.9	13.4
25	3.1	7.1	4.6	23.6
26	2.4	2.9	2.2	7.4
27	1.3	3.3	2.1	3.1
28	1.9	3.8	3.1	1.9
29	0.7	6.5	0.8	36

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