Destruction of Gypsy Moth Egg Masses (Using Surfactants, Detergents, Oils or Conventional Insecticides) for Quarantine and Community Action Programs[1, 2]

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ABSTRACT A series of studies were conducted, beginning in 1976, at the Otis Methods Development Center, Otis ANGB, MA, and beginning in 1982 at the Beltsville Agricultural Research Center, Beltsville, MD, to evaluate surfactants, detergents, oils, and insecticides as egg mass destruction agents for use in quarantine and community action programs. Surfactants, oils, and detergents tended to be more active when applied in the fall, while conventional insecticides were generally more active when applied in the spring. Some products, especially soybean oil, were highly active throughout the gypsy moth egg stage (July-March). A soybean-oil based product has been registered for this use. A 50% concentration of soybean oil is recommended for quarantine purposes, while a 25% concentration should be suitable for homeowners and arborists.

KEY WORDS Ovicides, quarantine treatments, shade tree pests, *Lymantria dispar,* gypsy moth.

The identification of safe, effective materials for gypsy moth, *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae), egg mass destruction is of interest to quarantine officials to help prevent interstate spread of the North American gypsy moth and as a regulatory treatment of ships infested with egg masses of the Asian gypsy moth. Treatments must preclude hatch to be considered for quarantine work. Research has been ongoing since 1976 at the Otis Methods Development Center of the Animal Plant Health Inspection Service (APHIS), USDA, Otis ANGB, MA, on regulatory treatments for gypsy moth egg masses. A number of conventional insecticides, insecticide/emulsifiers, detergents, detergent/insecticides, and oils have been screened in the laboratory at Otis. Methods and results of these laboratory screening tests are given in the Annual Reports of the Otis Methods Development Center.

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The gypsy moth is an important pest of shade trees in residential communities. Research has been conducted at the Beltsville Agricultural Research Center of the Agricultural Research Service, USDA, since 1982 on the gypsy moth as a shade tree/urban park pest. This has included the evaluation of barrier bands (Webb and Boyd 1983), systemic-insecticide implants and injections (Webb et al. 1988, Reardon and Webb 1990), the use of Gypchek as a homeowner control strategy (Webb et al. 1990), and the development of a management program for the use of *Bacillus thuringiensis* Berliner in public parks (Webb et al. 1991, Thorpe et al. 1992).

The combination of egg mass destruction and tree banding was a widely used control strategy for reducing gypsy moth depredations in early control programs (Collins and Hood 1920). However, with the advent of DDT and the increased cost of labor, this strategy fell into disuse except by some homeowners. Eighteenth (Beling 1932) and nineteenth (Forbush and Fernald 1896) century European workers recommended scraping egg masses to the ground as a form of control, but McManus (1983) demonstrated that this tactic does not prevent egg hatch. Other early mass destruction remedies included burning (on thick barked trees and locations off trees; this would damage less robust trees (Baeta Neves 1945, Forbush and Fernald 1896)) and petroleum applications (Thiem 1921, Hayashi 1928). However, as pointed out by Gruescu (1958), petroleum used to destroy egg masses on thin-barked trees, such as alder, poplars, and willows, leads to bark necrosis, wood discoloration and fungal infection.

Egg mass destruction by homeowners has typically consisted of physical removal (scraping) or painting with creosote. The recommended method for egg mass destruction in the United States for many years consisted of treating the mass with creosote (Burgess 1910, Rogers and Burgess 1910). Collins and Schaffner (1931) developed an air-pressure extension brush for applying creosote to gypsy moth egg mass clusters. This material lost favor when creosote was found to be a low-level carcinogen, and all insecticidal uses were cancelled (Federal Register notice 15 May 1986). Physical removal and subsequent destruction of egg masses is effective, but can expose the scraper to the allergenic hairs with histamine that cover egg masses (Sharma et al. 1982). Laboratory personnel who regularly work with gypsy moth often experience dermatologic and/or pulmonary reactions (Etkind et al. 1982). Newly-hatched gypsy moth larvae climb trees and other objects and release themselves into the airstream, utilizing silken threads to distribute themselves downwind (McManus 1973, McManus and Mason 1983). Large numbers of such windborne caterpillars from egg mass aggregates can lead to epidemics of urticaria in exposed human populations (Anderson and Furniss 1983, Beaucher and Farnham 1982). Insecticides applied by powered equipment to large aggregates of egg masses in areas of substantial human population might reduce such epidemics of urticaria, as well as dampen the general distribution of wind-blown caterpillars onto the community's shade trees in yards and parks. Thus, our community-related research had two objectives: (1) to find safe (for humans, trees, and the general environment), effective, readily obtainable products for use by homeowners, and (2) to identify products that can be applied by power equipment to destroy large aggregates of egg masses. Our studies were designed to determine the material to use, the timing and method of application

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appropriate to destroy gypsy moth egg masses. Since users include a broad range of expertise (quarantine officials, arborists, homeowners), a range of control materials (restricted and general use) were examined.

Materials and Methods

Field Studies - Otis, 1976-1977. Six candidate products promising in laboratory screening studies were selected for testing on gypsy moth egg masses at various concentrations in the field. They included FC-206 CE Light Water Brand Aqueous Film Forming Foam (a fire extinguishing agent containing butyl carbitol with surfactants and detergents manufactured by 3M Industrial Chemical Products Division, St. Paul, MN 55144) at 5, 10, and 25%; liquid floor wax (Do All Chemical Co., Brooklyn, NY 11211) at 10, 25, and 50%; Top Job® (Procter and Gamble, Cincinnati, OH 45202) at 10, 25, and 50%; GP66® Wax Remover (P66 Chemical Co., Baltimore, MD 21224) at 10, 25, and 50%; Pine Scent® (The Clorox Co., Oakland, CA 94612) at 10, 25, and 50%; and diflubenzuron (Dimilin® 25W, Uniroyal Chemical Co., Middlebury, CT 06749) at 0.06, 0.1, and 1.0%. Seven parallel lines were established on woodland in Dighton, MA containing 500-1000 large and healthy egg masses per ha. Lines were established in which trees bearing egg masses within 2.1 m of the ground were marked with colored survey tape, each line being identified by the color of tape used. A hand-held 0.47-liter plastic container with an adjustable spray nozzle was used to treat egg masses. Ten squirts (approximately 7.5 ml) were deposited on each egg mass from a range of 30-48 cm. Ten egg masses were treated (once) at each dosage on a monthly schedule from August, 1976 through April, 1977. At the end of each monthly treatment on the line, a tag was placed indicating the start and the end of the treatments. Individual, treated egg masses were marked with colored tacks. Of the ten egg masses treated at each dose/treatment, five were left exposed to the elements for the rest of the season, and the remainder were covered with 10 × 10 cm squares of tar paper attached by staples. The lower edges of the paper flaps were left open to minimize fumigant effects. During April, 1977, all treated and control egg masses were taken to the laboratory for incubation and hatch. A special effort was made to keep the masses intact. Individual egg masses were placed in 10 × 1.5 cm Petri dishes and held at 26.6°C and 50% relative humidity. As hatch occurred, larvae were counted and removed. When all eggs had hatched, recordings were discontinued, and hatch from that mass was referred to as 100+.

Otis, 1983-1984. During 1983-84, 16 materials were evaluated in the field against gypsy moth egg masses near Otis Air National Guard Base, MA. Starting 27 September 1983, 10 egg masses per treatment per date (each egg mass treated only once) were treated with candidate materials using a small hand sprayer using methods similar to those used in the 1976-77 study. Materials evaluated at full strength (100%) included (1) light water, (2) Top Job, (3) Pine Scent, (4) creosote (Falmouth Lumber, East Falmouth, MA 02536); (5) KPOCO (kerosene + pine oil + caster oil) (6) TCOPO (trichloroethane + caster oil + pine oil); and (7) Norpine (Northwest Petrochemical Corp., Anacortes, WA 98221). Products evaluated as 50% concentration (in water) included (8) Triton X-100 (Rohm and Haas Co., Philadelphia, PA 19105), (9) soybean oil (Arrowhead

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Mills, Inc., Hereford, TX 79045), (10) Sponco AK 16-95 (Witco Chemical Corp., New York, NY 10017), (11) Sponco H-44C, and (12) Safer Insecticide, an insecticidal soap (Safer Inc., Newton, MA 02159). Also evaluated were: (13-15) the insecticides permethrin (Pounce 3.2E, FMC Agrochemical Group, Philadelphia, PA 19103), fenvalerate (Pydrin 2.4E, E. I. du Pont de Nemours & Co., Inc., Wilmington, DE 19898) and diflubenzuron (as Dimilin 25% WP), all three at the rate of 7.2 g AI/liter. Additionally, (16) trichlorphon (as Spray N Kill, Hercon Environment Co., Emigsville, PA 17318) was applied at its recommended label rate (16 ml formulated material per liter final solution) and at twice the recommended rate. Finally, egg masses were identified and marked as controls with separate egg masses identified for all dates. Egg masses were treated to the point of complete saturation (the point at which the entire surface of the egg masses is visibly saturated) on a monthly schedule (27 September, 3 October, 11 November, 2 December, 22 December 1983, and 5 January and 9 April, 1984. Treated egg masses were left in the field until mid-April. Egg collection was accomplished using two techniques. In the first collection group, five intact masses from each treatment date were collected into plastic Petri dishes. In the second group, plugs of approximately 50 eggs each were removed from each of the five remaining egg masses. Untreated masses were collected at two locations within the study area. All egg masses were incubated in the laboratory at 27° C and 70% relative humidity. After 10 days, percent hatch was estimated in the dishes with complete masses. All eggs from each plug sample were counted and checked for hatch.

Otis, 1984-1985. During 1984-85, seven materials (15 material/dose combinations) were evaluated in the field against gypsy moth egg masses near Otis Air National Guard Base, MA. Starting 21 November 1984, ten egg masses were treated with candidate materials using a small hand sprayer using methods similar to those using in the 1983-1984 study. Materials and rates evaluated included (1-3) soybean oil as a 25% concentration diluted with isopropyl alcohol and as 50 and 100% concentrations diluted with water, and (4-6) Sunspray Ultra-Fine Spray Oil (98.8% refined petroleum distillate, 1.2% emulsifier, Mycogen Corp., San Diego, CA 92121) as 25, 50, and 100% concentrations diluted with isopropyl alcohol; (7-9) Norpine as 25, 50 and 100% concentrations diluted with water; (10-12) citrus oil (Helena Chemical Co., Memphis TN 38119) as 25, 50 and 100% concentrations diluted with water; and (13-15) isopropyl alcohol (Fisher Scientific, Pittsburg, PA 15219), acetone (Fisher Scientific), and kerosene (S and P Oil Co., Cataumet, MA 02534), all as 100% solutions. Finally, egg masses were identified and marked as controls, with separate egg masses identified for each date. Egg masses were treated to the point of saturation on a monthly schedule: 21 November, 12 December, 1983; 18 January and 19 February, 22 March, and 15 April, 1984. Treated egg masses were left left in the field until mid-April. Egg collection and subsequent evaluations were accomplished as per the 1983-84 study.

Otis, 1992. During the winter of 1992, a commercial soybean oil product, Golden Natur'l Spray Oil, Stoller Chemical Co., Inc., Houston, TX 77024, was evaluated at four dosages (5, 25, 50, 100%) against naturally occurring gypsy moth egg masses at Freetown State Forest, Freetown, MA using methods similar to previous studies, except that treatments were applied using a 3.8 liter

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hand-pump sprayer. Twenty egg masses were treated with each dosage on six treatment dates between 29 January 1992 and 29 April 1992, with 20 untreated egg masses identified as controls for each treatment time. The spray nozzle was held approximately 20-30 cm from the egg mass at time of application. Egg masses were sprayed until saturated with the oil mixture. All dosages appeared to be rapidly absorbed by the egg masses. On 24 April 1992, egg masses were removed from the trees and held as in previous studies until hatch.

Beltsville, 1984. Tests in 1982 (Webb et al. 1984) indicated that bendiocarb (Ficam 76 WP, NOR-AM Chemical Co., Wilmington, DE 19805) effectively controlled gypsy moth egg masses when applied at rates of 49 or 98 g/100 liters one, two or three weeks prior to expected hatch. Mortality occurred prior to hatch to the pharate larvae overwintering within the eggs rather than to neonate larvae after hatch. However, when applied at a lower rate of 25g/100 liters, some hatch was observed in the field and in the laboratory, but all observed (laboratory) larvae died soon after hatch. Subsequently, Ficam 76 WP was registered as a gypsy moth egg mass treatment at the rate of 18.5 g/100 liters (EPA Registration Number 45639-1). The label states that application can be made up to three weeks before gypsy moth hatch. The purpose of this study was to evaluate the label claim. In this study, bendiocarb (Ficam 76% WP) was applied at two doses (18.5 g/ active ingredient (AI)/100 liters, 37 g AI/100 liters) in 3.7 liters tap water to 60 gypsy moth egg masses per dose using a 7.4-liter hand pump sprayer. Sixty additional egg masses were identified and left untreated as controls. The treatments were made to healthy egg masses occurring 0.2-2 m above ground on bole of trees in the Elk Neck State Forest, Cecil County, MD on 9 April 1984. Twenty egg masses from each treatment along with 20 control egg masses were returned to the laboratory at three, seven, and 10 days after treatment, placed individually in 5.2 cm diam plastic Petri dishes and held at variable room temperature and humidity. Hatch was checked daily until 30 April 1984, by which time all control masses had hatched. All egg masses were rated for degree of hatch on a 1 to 4 rating,with 1 = no hatch, 2 = $<$ 10% hatch, 3 = $<$ 50% hatch, and 4 = $>$ 50% hatch. Three days after hatch, larvae emerging from the egg masses were rated on a 1 to 4 rating, with 1 = no live larvae, 2 = $<$ 10% alive, 3 = $\geq$ 10% and $<$ 50% alive, and 4 = $\geq$ 50% alive.

Beltsville, 1986. This study was designed to quantify the lethal and sublethal effects of applying diflubenzuron to gypsy moth egg masses in the context of egg mass suppression in suburban areas. The treatments were made to healthy egg masses occurring 0.2-2 m above ground on boles of trees on Sugar Loaf Mountain, Frederick County, MD, on 18 March 1986, and to a separate group of egg masses on 10 April 1986, each time using a 7.4-liter hand pump sprayer. Diflubenzuron (Dimilin 25% WP) was applied on each date at three dosages: 75, 300, and 1200 ppm AI; additional egg masses were identified and left untreated as controls. After drying, all egg masses for each treatment date, treated and control, were removed (without bark) from the trees and returned to the laboratory, placed individually in 240 ml waxed-cardboard cups with plastic lids, and held at variable room temperature (25 ± 2°C) and humidity (45 ± 10% RH). The study was designed to evaluate diflubenzuron effects on the egg mass itself, so that when emerged larvae left the egg mass, they would have no further contact with diflubenzuron residues (although a few might wander

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back onto the mass). All egg masses were checked daily, with the date of hatch noted. On the first day after hatch, 10 caterpillars from each mass were placed, five per cup, in 30-ml rearing cups half-filled with gypsy moth diet (Bell et al. 1981). All larvae were evaluated 14 days after placement on the diet for mortality, morbidity (dead + larvae still in the first instar + larvae that had molted into characteristically deformed second instars, losing weight in the process), with all living larvae being individually weighed at that time. On the fourth day after hatch, all egg masses were rated for hatch and mortality using the rating system developed in 1984. Larval mortality (from those in diet cups) and morbidity data were analyzed by means of a two-way analysis of variance (GLM procedure, SAS 1985), with mean separation (comparison-wise error rate of 0.05) accomplished using LSD (GLM procedure, T option, SAS 1985). Percent morbidity data from both collection dates were analyzed untransformed. Variance homogeneity for each dependent variable was tested by determining the Spearman correlation between the predicted values and the absolute values of the residuals (actual minus the predicted response). A significant correlation coefficient indicated that a transformation was needed to stabilize variance. In that case, the transformation giving a constant resulting in the most homogeneous variance was used. Percent mortality data for the March 18 collection received a square root transformation, while data for the April 10 collection received a log (x + 1) transformation, prior to analysis.

Beltsville, 1990-1991. Three candidate materials, found active in earlier studies and with desired characteristics of human and environmental safety, were selected for an in-depth comparison against bendiocarb, a currently registered material in the fall of 1990. The materials included Safer Insecticide (as 1, 10, 25, and 100% solutions), soy oil (Hain Soy Oil, Pure Food Co., Inc., Los Angeles, CA 90061) (as 10, 25, and 100% solutions), Sunspray Ultra-Fine Spray Oil (98.8% refined petroleum distillate, 1.2% emulsifier, Safer Inc., Newton, MA 02159) (as 10, 25, and 100% solutions), and bendiocarb (Ficam 76% WP) was applied at two doses (18.5 and 37 g AI/100 liters), with egg masses treated with distilled water as controls. All treatments were made to a final volume of 160 ml, with the lower two solutions of the soybean oil and the Sunspray oil including 8 ml of an emulsifier (Triton B-1956, Rohm and Haas, Philadelphia, PA 19105) to maintain suspension. All materials were mixed with distilled water just before field application on 1 November 1990 (fall application) and 15 March 1991 (spring application). A line of egg masses was established which was divided into 10 sections, with two egg masses (color-coded by treatment using surveyor's tape) in each section receiving a randomly-assigned treatment, one in the fall, or one in the spring. Treatments were applied using a 400 ml trigger-pump hand sprayer (ServiStar All-Purpose Sprayer, American Hardware Supply Co., Butler, PA 16001). Each egg mass received 5 trigger pulls of the appropriate solution which seemed to thoroughly soak it. Egg masses were collected on 1 April 1991, returned to the laboratory, held at variable room temperature and humidity, and were checked daily. Hatch occurred between 5 April and 10 April 1991. On the first day after hatch, 10 caterpillars from each mass were placed, one per cell, in 3 ml rearing cells in 128-celled plastic bioassay trays (C-D International Inc., Pitman, NJ 08071), each cell was half-filled with gypsy moth wheat germ diet (Bell et al. 1981). Mortality was assessed on

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April 20, which was at least 10 d after placement in the cell. After all hatch was complete, egg masses were dehaired and all hatched larvae and unhatched eggs were counted. Percent survival was computed as percent hatch x percent mortality of hatched larvae placed on diet. All percent hatch and survival data were converted to log (x + 1) prior to analysis, as in the 1986 Beltsville experiment.

Beltsville, 1992. This study was conducted on Wye Island, Queen Anne's County, MD, to evaluate a commercial spray adjuvant, Bio-Shield (Spray Tech Inc., Minneapolis, MN 55421) that contained 95% soybean oil and 5% inert ingredients (including emulsifiers). The treatments (soybean oil as 10, 25, 100%, or untreated controls which received distilled water) were applied on 13 March 1992, as in the 1991-1992 Beltsville study, except that the lower two doses of soybean oil did not receive additional emulsifier. Egg masses were returned to the laboratory on 1 April 1992, and observed for hatch daily until April 28.

Results and Discussion

Field Studies - Otis, 1976-77. In general, hatch was higher than expected, based on previous laboratory data. Although there was a slight reduction of hatch in most treatments, no treatment at any concentration gave sufficient reduction to warrant its use as a regulatory treatment. Pine Scent at the 50% concentration reduced hatch more than other treatments; no consistent effect of timing of application was seen with this treatment. Although diflubenzuron did little to reduce hatch, complete (100%) mortality occurred when larvae from treated egg masses (all dates) were removed from further contact with the diflubenzuron-treated egg mass and placed on artificial diet for 9-18 days. It is difficult to explain why the materials tested were effective in reducing hatch in the laboratory and not in the field. Possibly, penetration of the test material into the egg masses was inadequate under field conditions. Alternatively, a fumigation effect may have occurred during laboratory tests in which egg masses were incubated in Petri dishes. A fuller examination of results is given in the Report of the Otis Methods Development Center for 1 April - 30 September 1977 (pp 5-8).

Otis, 1983-84. All control egg masses hatched normally. Zapper (containing creosote), permethrin, soybean oil and Norpine were effective in preventing hatch for all seven treatment dates. Permethrin and fenvalerate were effective over the last half of the treatment period. With materials such as diflubenzuron, permethrin, and fenvalerate, hatch was not affected, but larval mortality took place as they emerged from the egg case and contacted the toxicants. With permethrin and fenvalerate, morality occurred immediately as the larvae emerged. In the case of diflubenzuron, larvae from treated egg masses from all treatment dates were placed on artificial diet, 100% mortality occurred in 8 d. Spray N Kill, a registered gypsy moth egg mass treatment containing trichlorphon, gave poor results even when used at twice the recommended dosage, although there was some residual activity when the higher dose was applied in the spring. All other materials failed to prevent significant hatch from egg masses treated on most treatment dates, although several detergents and soaps (light water, Pine Scent, Sponco AK 16-95, and Sponco H-44C) gave excellent control in the first fall treatment (27 September). In general, soaps and detergents

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were more active in fall applications, while the conventional insecticides were more active in the spring, as reported by Webb et al. (1984). A fuller examination of results is given in the Report of the Otis Methods Development Center for 1 October 1983 - 30 September 1984 (pp 1-7).

Otis, 1984-85. All control egg masses hatched normally. Sunspray oil and soybean oil both prevented hatch at all dosages, including the lowest dose (25%), for all six treatment dates. Norpine demonstrated for the second year that it will prevent nearly all hatch when applied at any time during the fall or winter, even at the lowest dose used (25%). None of the other compounds (Citrus oil, isopropyl alcohol, acetone, and kerosene) gave consistent suppression of egg hatch even at the highest dose (100% concentrations) used. A fuller examination of results is given in the Report of the Otis Methods Development Center for 1985 (1-2).

Otis, 1992. Untreated egg masses hatched between days 4 and 6 after being brought into the laboratory. Control hatch was estimated to be 90%. Some hatch (3-21%) occurred from egg masses treated with the lowest (5%) dose of spray oil, with no effect of treatment date seen. No hatch occurred from egg masses treated with the three higher dosages (25, 50, 100%), for any treatment date.

Golden Natur'l Spray Oil was effective in preventing North American gypsy moth from hatching when sprayed directly onto the individual egg masses between January 29th and April 22nd. This usage is registered by the U. S. Environmental Protection Agency (EPA Registration Number 57538-11). A 50% concentration in water is recommended for quarantine purposes. These data are supported by results from 1983-84 and 1984-85 that demonstrated soybean oil's effectiveness when applied from September through April. Therefore, it is reasonable to conclude that Golden Natur'l Spray Oil would be effective throughout the gypsy moth egg stage.

Beltsville, 1984. The control egg masses received an average hatch rating of 4.0, and an average 3-day survival rating of 4.0 for all three sample dates. Egg masses receiving the 37 g AI/100 liters dosage of bendiocarb received average ratings of 1.3, 1.2, and 1.4, respectively, for the 3, 7, and 10 day samples, and 3-day survival ratings of 1.0, 2.5, and 1.1, respectively, for the three sampling periods. Egg masses receiving the 18.5 g AI/100 liters dosage of bendiocarb received average ratings of 1.3, 1.2, and 2.4, respectively, for the 3, 7, and 10 day samples, and 3-day survival ratings of 1.6, 1.5, and 1.8, respectively, for the three sampling periods. The higher dosage of bendiocarb resulted in a significant reduction in egg hatch, probably suitable for use by arborists for population suppression in generally infested communities, but not enough for quarantine purposes. The lower (labeled) rate of bendiocarb would suppress initial gypsy moth populations arising from treated egg masses, but some survival would be anticipated.

Beltsville, 1986. Treatment with diflubenzuron had no effect on rate of hatch or on 4-day survival (Table 1). There is a delayed response for gypsy moth after the ingestion of dilfubenzuron. Affected larvae do not die until the first molt after treatment, when they die from a rupture of the malformed new cuticle or from starvation (White et al. 1981). When rated 14 days after treatment, a number of seriously malformed larvae were moribund; these moribund plus dead larvae were grouped to calculate percent morbidity. Percent mortality and

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Table 1. Results of egg mass treatments with indicated solutions of diflubenzuron. Egg masses sprayed on indicated dates and evaluated after four days for percent hatch and mortality, and after 14 days for mortality and larval instar and weight (in mg)

Treatment (Diflubenzuron ppm)	4-Day Rating		14-day Measurements by Instar									14-day Totals	
				First		Second		Third		Fourth		%	%
	Hatch*	Mortality**	N	n	wt	n	wt	n	wt	n	wt	Mortality†	Mortality†,‡
			Egg Masses Sprayed and Collected 3/18/86										
0	4.0	3.2	100	3	*11*	30	*22*	39	*36*	21	*66*	7b	10c
75	3.9	3.6	100	13	*12*	27	*21*	38	*35*	15	*66*	7b	20c
300	4.0	3.6	100	28	*8*	15	*22*	24	*35*	15	*76*	18b	46b
1,200	4.0	3.3	90	19	*6*	2	*16*	0	–	4	*49*	72a	93a
			Egg Masses Sprayed and Collected 4/10/86										
0	3.9	4.0	100	10	*9*	18	*20*	19	*35*	51	*71*	2b	12b
75	3.9	3.9	100	22	*7*	10	*20*	23	*37*	41	*74*	4b	26b
300	3.9	4.0	90	44	*5*	8	*20*	9	*41*	5	*54*	27a	76a
1,200	4.0	4.0	100	33	*5*	7	*20*	4	*37*	6	*66*	50a	83a

* All egg masses were rated for degree of hatch on a 1 to 4 rating, with 1 = no hatch, 2 = < 10% hatch, 3 = < 50% hatch, and 4 = > 50% hatch.

** Three days after hatch, larvae emerging from the egg masses were rated on a 1 to 4 rating, with 1 = no live larvae, 2 = < 10% alive, 3 = < 50% alive, and 4 = > 50% alive.

† Means in a column followed by the same letter are not significantly different at $P \leq 0.05$, using LSD (GLM procedure, T option, SAS 1985). Means are for untransformed data.

‡ Morbidity = dead + those larvae still in the first instar 14 days after eclosion from the egg.

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percent morbidity for the larvae placed in the diet cups increased significantly with increasing dosage of diflubenzuron that had been applied to the egg masses on March 18 ($F = 13.33$; df = 3,35; $P = 0.0001$ for % mortality, and $F = 23.60$; df = 3, 35; $P = 0.0001$ for % morbidity) and also for those treated on April 10 ($F = 34.28$; df = 3, 35; $P = 0.0001$ for % mortality, and $F = 27.15$; df = 3, 35; $P = 0.0001$ for % morbidity). Mortality occurred at the first instar molt; larvae surviving into later instars generally had normal survival and weight (Table 1).

In this study, once the larva left the egg mass, it was free from further contact with the diflubenzuron, while in practice, the bark around the egg would also be treated. Since newly-emerged gypsy moth larvae typically climb trees before being dislodged and dispersed by light winds (McManus 1973), they would come in contact with additional residues of diflubenzuron after leaving the egg mass. Thus, this study probably underestimated the amount of mortality that would be experienced with this treatment in nature. In this study, a few larvae, even at the highest dosage, made it safely out of the egg mass and were apparently developing normally 14 days after placement on diet. These data argue for the use of a rate of at least 1,200 ppm AI when diflubenzuron is used against gypsy moth egg masses. This rate is probably suitable for use by arborists for population suppression in generally infested communities, but not enough for quarantine purposes.

Beltsville, 1990-91. Results of this study are given in Table 2. Significant treatment effects were noted for percent hatch ($F = 24.8$; df = 12, 108; $P = 0.0001$ for fall treatments, $F = 17.4$; df = 12, 108; $P = 0.0001$ for spring treatments) and for percent survival ($F = 11.3$; df = 12, 108; $P = 0.0001$ for fall treatments, $F = 8.6$; df = 12, 108; $P = 0.0001$ for spring treatments). The higher concentrations of Safer Insecticide gave significant reductions in hatch in both the fall and spring applications, but overall hatch at even the highest concentration (100%) was disappointing compared with previous screening results. Sunspray Ultrafine Spray Oil gave excellent results in the fall applications at all concentrations, but only the highest concentration (100%) gave complete reduction in egg hatch in the spring applications. Bendiocarb failed to provide an acceptable level of suppression of hatch at the 37 g/100 liter rate seen in 1984, although activity was noted. At the labeled rate of 18.5 g/100 liters, bendiocarb was relatively ineffective. Soybean oil (100%) gave complete suppression of hatch in both fall and spring applications. This rate is probably suitable for use both by arborists for population suppression in generally infested communities and for quarantine purposes. The 25% concentration of soybean oil gave excellent, but not complete, reduction of egg hatch with both the fall and the spring applications, while the 10% concentration was less effective at both application timings. Hatched larvae emerging from egg masses treated with the oils, and subsequently placed on artificial diet, generally survived.

Beltsville, 1992. Control egg masses (n = 10) all hatched normally (averaging 69% hatch) in early April. No larvae emerged from egg masses treated with Bio-Shield (soy oil) as a 100% treatment (n = 10) or as a 25% treatment (n = 10). A few larvae emerged from 3 egg masses treated with a 10% soybean oil solution. This study confirmed previous findings that a 25% solution of soybean is an appropriate material to control gypsy moth egg masses for homeowners and arborists, although a 50% solution is desirable for quarantine work where an extra measure of caution is required.

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Table 2. Percent hatch and survival of gypsy moth eggs/larvae for egg masses receiving treatments with indicated solutions of selected materials, Beltsville, MD, 1990-1991.

	Fall Application		Spring Application	
Treatment (% Conc.)	% Hatch (SE)*	% Survival (SE)*,**	% Hatch (SE)*	% Survival (SE)*,**
Safer Soap				
(100%)	21.1 (6.6) cd	4.9 (2.5) def	34.1 (11.0) b	23.2 (8.7) bcd
(25%)	22.8 (7.2) cd	8.3 (3.7) cde	14.4 (4.7) bc	11.7 (3.9) cde
(10%)	33.8 (7.9) bc	18.2 (6.6) bcd	41.7 (7.0) a	31.6 (6.4) ab
(1%)	64.7 (7.8) ab	31.1 (8.4) b	68.5 (3.0) a	49.7 (8.4) a
Soy oil				
(100%)	0.0 (0.0) e	0.0 (0.0) g	0.1 (0.1) d	0.1 (0.1) f
(25%)	1.8 (1.2) e	0.7 (0.5) fg	10.3 (5.9) c	5.4 (3.2) ef
(10%)	16.6 (5.0) d	13.1 (4.0) bcd	16.9 (7.6) b	10.5 (5.2) de
Sunspray				
(100%)	0.1 (0.1) e	0.1 (0.1) g	0.0 (0.0) d	0.0 (0.0) f
(25%)	0.0 (0.0) e	0.0 (0.0) g	53.2 (7.2) a	32.2 (7.7) ab
(10%)	6.3 (6.3) e	6.3 (6.3) efg	18.5 (5.7) b	12.2 (4.4) cde
Ficam 76% W				
(37 g/100 liters)	23.4 (6.1) cd	14.4 (5.5) cd	32.1 (4.7) a	11.3 (5.5) de
(18.5 g/100 liters)	54.9 (7.8) ab	21.5 (7.1) bc	44.9 (5.8) a	28.0 (7.3) abc
Controls	57.6 (4.1) a	49.9 (4.0) a	55.5 (6.2) a	44.5 (6.7) a

* Means in a column followed by the same letter are not significantly different at $P < 0.05$, using LSD (GLM procedure, T option, SAS 1985). Means and SE are for untransformed data.

** Percent survival = percent hatch × percent mortality of hatched larvae placed on diet.

A number of regulatory personnel in the field were contacted by APHIS to ascertain their need for gypsy moth egg mass treatments. In general, they need a treatment for house trailers, recreational vehicles, and yard equipment and furniture. They desire treatments that can be used either when larvae are active or after egg masses have been deposited on the surface of regulated articles. Log treatments were lower down on the list of priorities. Thus, the lack of effective quarantine treatments for recreational vehicles and mobile homes was identified as a major deficiency in the APHIS gypsy moth regulatory programs. We have found a number of insecticides, detergents, waxes, and solvents that appear promising as egg mass destruction agents, each offering certain advantages for use. The urgency for gypsy moth egg mass treatments has greatly increased due to the recent findings of Asian gypsy moth egg masses on Russian grain and cargo vessels in ports of the United States and Canada (Gibbons 1992). The need for a material that can be safely applied in oceanic environments has apparently been met by the finding that soybean oil is an effective egg mass destruction agent.

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In summary, a number of different oils, surfactants, detergents and conventional insecticides were evaluated against gypsy moth egg masses. As a rule, oils, surfactants, and detergents were more effective when applied in the fall than in the spring, apparently acting to decrease winter egg survival. Conventional insecticides were generally more effective when applied in the spring than in the fall, since greater residue levels would be available to kill newly hatched larvae. Several products (Sunspray Ultrafine Spray Oil, soybean oil) were effective from July through March. Soybean oil was found active as a grocery product (Hain soy oil; an emulsifier must be added if diluting with water), as a spray adjuvant (Bio-Shield; has its own emulsifier), or as an insecticidal oil (Golden Natur'l Spray Oil has its own emulsifier). Based on the work at Otis, Golden Natur'l Spray Oil has been registered (EPA Registration Number 57538-11) for use on gypsy moth egg masses. If only a few egg masses are present at a homesite, a trigger pump sprayer (five squeezes per mass) is an effective application method. A compressed-air sprayer is suitable for dealing with large quantities of egg masses or for use by arborists or quarantine officials. Products that are registered for this use (bendiocarb, trichlorfon as Spray N Kill) were not effective in our studies when used at labeled rates. It should be noted that the materials mentioned here have not been thoroughly evaluated for phytotoxic effects, nor are their effects on gypsy moth egg parasites known. Research is needed to refine control of gypsy moth egg masses using power equipment and to support the registration of an appropriate insecticide at an effective dose.

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