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Molluscicides and mechanical barriers against slugs, *Vaginula plebeia* Fischer and *Veronicella cubensis* (Pfeiffer) (Stylommatophora: Veronicellidae)

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Thirteen molluscicides containing metaldehyde, three molluscicides containing metaldehyde plus carbaryl, one molluscicide containing metaldehyde plus methiocarb and one molluscicide containing methiocarb alone were tested for efficacy against the brown slug, *Vaginula plebeia* Fischer, and the two-striped slug, *Veronicella cubensis* (Pfeiffer). With the exception of Corry's Liquid Slug, Snail and Insect Killer against *V. plebeia*, all tested molluscicides caused significant mortalities against both species. Selected molluscicides were further evaluated for persistence under simulated rainfall; Deadline One Last Meal for Slugs and Snails, Deadline 40, Deadline Bullets and Slug and Snail AG Pelleted Bait, all of which contain metaldehyde as the active ingredient, consistently produced high mean percentage mortalities against both species. Efficacy of certain molluscicides decreased steadily with time, whereas efficacy of other molluscicides increased initially before declining. Mold grew on the majority of molluscicides after application. Liquid paste and liquid formulations were more resistant to mold development than pelleted, granule or coated granule formulations. In a separate study, physical barriers composed of copper or fiberglass screens repelled both slug species. © 1997 Elsevier Science Ltd

Keywords: *Vaginula plebeia*; *Veronicella cubensis*; copper barriers

Introduction

The brown slug, *Vaginula plebeia* Fischer, and the two-striped slug, *Veronicella cubensis* (Pfeiffer), were first reported in Hawaii in 1978 and 1985, respectively (HDOA, 1994). Since initial reports, populations of these slugs have significantly increased, resulting in severe damage to many ornamental, vegetable and landscape plants. Of particular concern is the impact on Hawaii's $US104 million vegetable and floriculture industries (Hawaii Agriculture Statistics Service, 1995). Export shipments of vegetable and floriculture crops have been delayed or rejected by quarantine officials due to the presence of slugs or slug eggs (CDFA, 1993). Several states, including Alabama, Arkansas, Louisiana, Mississippi, Oregon, Tennessee, Virginia and Florida, have imposed strict quarantine regulations to prevent the accidental introduction of mollusks (Parrella *et al.*, 1985). Nurseries certified by the Hawaii Department of Agriculture to export plants must be slug-free.

In Hawaii, slugs are present throughout the year and are especially active during periods of high rainfall. Tropical agriculture in Hilo, Hawaii, on the island of Hawaii, experiences a mean annual rainfall of 328 cm (National Oceanic and Atmospheric Administration, personal communication) encouraging high slug populations and short molluscicide activity. Growth of mold on molluscicides may also contribute to reduced efficacy and is a problem in high humidity locations where molluscicides are used repeatedly. An additional concern to ornamental growers is the reduction of quality due to mold growing on the molluscicide placed on the media of potted plants. Several manufacturers incorporate mold inhibitors to retard mold development.

We report here: (1) the efficacy of certain molluscicides and physical barriers against *V. plebeia* and *V. cubensis*, (2) the persistence of certain molluscicides subjected to simulated rainfall and (3) the resistance of certain molluscicides to mold development.

Materials and methods

Trials were conducted from 18 January 1994 through 22 January 1995 in a fiberglass-covered greenhouse with polypropylene shade cloth sides located at the University of Hawaii at Manoa, Waiakea Agricultural

Research Station in Hilo, Hawaii (183 m in elevation). Field-collected slugs were held in a 76 L glass aquarium with a screen cover and fed 'Iceberg' lettuce daily until tests began. A 7.6 cm-thick layer of moistened peat moss covered the bottom of the aquarium. Inverted plastic plant saucers 23.0 cm in diameter provided shelter for the slugs during the day. Slugs used in all tests were $\geq$2.5 cm long to represent the size that has been observed causing the majority of damage on ornamentals. Unless specified otherwise, all molluscicides were applied according to the manufacturers' rates and instructions (*Table 1*). During the study, the average daily maximum and minimum greenhouse temperatures were 24.4 ± 3.4 and 17.0 ± 2.7°C, respectively; the average daily maximum and minimum humidities were 98.5 ± 5.6 and 69.5 ± 17.4%, respectively.

Bioassay tests

Molluscicides were applied to 30 × 30 cm Plexiglas cages. A Plexiglas cover with 1.3 cm holes blocked with a 1.4 × 1.4 × 0.7 mm mesh aluminum insect screen (Phifer Wire Products, Inc., Tuscaloosa, AL) provided air circulation. Each cage contained a 2.5 cm-thick layer of moistened peat moss, a leaf of 'Iceberg' lettuce and a 7.6 cm diameter plastic pot cut longitudinally and pushed partially into the peat moss to provide shelter for the slugs during the day. Immediately after treatment, 10 slugs were added to each cage. Treatments were replicated four times for each species. Mortality was assessed 1, 3 and 6 days after treatment. The criterion of slug mortality was absence of skin surface movement when probed with a dissecting needle and observed under a dissecting microscope.

Simulated rainfall and persistence

Tests were conducted to determine the persistence of certain molluscicides under wet conditions. Each molluscicide was applied to 8 cages (30 × 30 cm) consisting of a wooden frame, an aluminum insect screen bottom and a Plexiglas cover. Each cage contained moistened peat moss, lettuce and a plastic pot shelter as previously described. Rainfall was simulated for 5 min every 24 h (500 ml per cage) using overhead irrigation. Over 8 days, 10 slugs were added daily to one of the eight cages per treatment then covered to prevent further watering. Experiments were replicated four times for both species. Mortality assessment was identical to the bioassay tests.

Mold inhibition

Tests were conducted to determine the resistance of molluscicides to mold development. Molluscicides were applied to 30 × 30 cm wooden cages as previously described and observed for mycelia development daily. Each treatment was replicated four times. The number of days to development of fungal mycelia was recorded.

Mechanical barriers

Barriers (30 × 30 cm) created from copper, aluminum, fiberglass or corrugated paperboard were located on a 15 × 20 × 41 cm hollow tile concrete block that simulated greenhouse bench legs (*Figure 1*). The tile block was situated in the center of a 0.5 × 0.6 m plastic arena. Specifications for the barrier screens were: 1.4 × 1.4 × 0.6 mm mesh copper screen (Flynn and Enslow, Inc., San Francisco, CA); 1.4 × 1.4 × 0.7 mm mesh aluminum insect screen (Phifer Wire Products, Inc., Tuscaloosa, AL); 1.4 × 1.4 × 0.3 mm mesh fiberglass insect screen (Hanover Wire Cloth, Hanover, PA); and 30 cm × 30 cm × 2.0 mm corrugated paperboard. Tests were conducted in a dark ventilated room and replicated three times with 100 slugs per repetition for both species. A 2.5 cm-thick layer of moistened peat

Table 1. Active ingredient, test rate and manufacturer of various molluscicides used in tests

Product name (formulation description)[a]	Active ingredient	Rate per 1.0 m^2 (formulated)	Manufacturer
Corry's Slug, Snail and Insect Killer (P)	Metaldehyde 2%, carbaryl 5%	2.8 g	E.M. Matson Jr. Co., Inc.
Corry's Liquid Slug, Snail and Insect Killer[b] (L)	Metaldehyde 2%, carbaryl 5%	20.0 ml	E.M. Matson Jr. Co., Inc.
Corry's Liquid Slug and Snail Control[b] (L)	Metaldehyde 4%	20.0 ml	E.M. Matson Jr. Co., Inc.
Corry's Slug and Snail Pellets (P)	Metaldehyde 2%	2.8 g	E.M. Matson Jr. Co., Inc.
Corry's Slug and Snail Death (P)	Metaldehyde 2%	2.8 g	E.M. Matson Jr. Co., Inc.
Deadline 40[c] (LP)	Metaldehyde 4%	10.0 ml	Pace International LP
Deadline Bullets (P)	Metaldehyde 4%	4.9 g	Pace International LP
Deadline Granules (G)	Metaldehyde 4%	4.9 g	Pace International LP
Deadline One Last Meal for Slugs and Snails (L)	Metaldehyde 4%	30.0 ml	Pace International LP
Durham Metaldehyde Granules 3.5 (CG)	Metaldehyde 3.5%	4.4 g	Amvac Chemical Corp.
Durham Metaldehyde Granules 7.5 (CG)	Metaldehyde 7.5%	1.9 g	Amvac Chemical Corp.
Metaldehyde Methiocarb Granules 2-1 (CG)	Metaldehyde 2%, methiocarb 1%	4.9 g	Amvac Chemical Corp.
Ortho Bug-Geta Plus Snail, Slug and Insect Granules (G)	Metaldehyde 2%, carbaryl 5%	2.4 g	Chevron Chemical Co.
Ortho Bug-Geta Snail and Slug Pellets (P)	Metaldehyde 3.25%	4.9 g	Chevron Chemical Co.
Ortho Slug-Geta Snail and Slug Bait (P)	Methiocarb 2%	4.9 g	Chevron Chemical Co.
RCO Slug and Snail Pellets (P)	Metaldehyde 3.25%	4.4 g	Meerkat Environmental Industries
RCO Slug and Snail Pellets (rain resistant) (P)	Metaldehyde 3.25%	4.4 g	Meerkat Environmental Industries
Snail and Slug AG Pelleted Bait (P)	Metaldehyde 3.5%	4.4 g	Hacco, Inc.

[a]Formulation description: CG = coated granule, G = granule, L = liquid, LP = liquid paste, P = pellet. [b]Corry's Liquid Slug, Snail and Insect Killer, and Corry's Liquid Slug and Snail Control tested at 20.0 ml/1.0 m^2 (label rate is 709.7 ml/429.2 m^2 = 1.7 ml/1.0 m^2). [c]Deadline 40 tested at 10.0 ml/1.0 m^2 at manufacturer's request (label rate is 15.1 L/0.4 ha = 3.7 ml/1.0 m^2).

moss covered the bottom of the arena and a 2.5 cm-wide band of NaCl embedded on petroleum jelly (Valu-Rite, San Francisco, CA) along the perimeter of the arena prevented slugs from escaping. The slug bait (Slug and Snail AG Pelleted Bait, Hacco, Inc., Madison, WI) was contained in a 19.7 cm diameter saucer located on the barrier. The efficacy of the barrier was evaluated by the number of slugs foraging up the hollow tile block, crossing the barrier and feeding on the attractive, moistened slug bait. The number of dead slugs in the saucer was counted daily for 7 days.

Data analysis

The number of live and dead slugs was counted and percentage mortality and standard errors of the mean were calculated. Unless otherwise stated, only the percentage mortality taken 6 days after treatment is presented. Percentage mortality was transformed to arcsine square root and analyzed by ANOVA (PROC GLM, SAS Institute, 1987). Means were separated by the Waller–Duncan k-ratio t-test, $k = 100$. In evaluating molluscicide persistence, linear and polynomial regression models between time (x) and percentage mortality (y) for *V. plebeia* and *V. cubensis* were determined (SAS Institute, 1987). The criterion for selecting the best-fit regression equation was the smallest obtainable p-value for the model and the largest coefficient of determination (r^2). In addition, the percentage mortality over the 8 day test period was pooled for analysis and analyzed by ANOVA. In the barrier study, the cumulative percentage mortality over 7 days is presented.

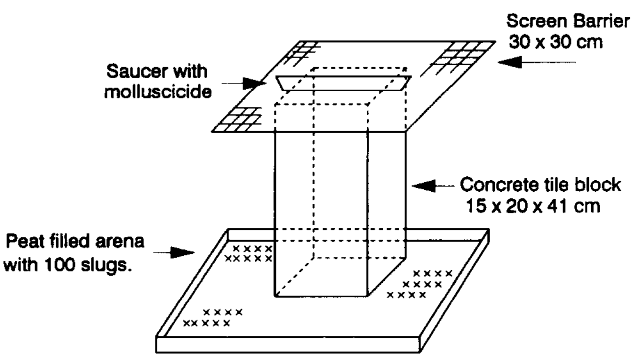

Figure 1. Schematic diagram of the method used in evaluating screen barriers for efficacy against *V. plebeia* and *V. cubensis*

Results and discussion

Bioassay tests

With the exception of Corry's Liquid Slug, Snail and Insect Killer against *V. plebeia*, all tested molluscicides had significantly higher mortality than the control against both species (*Table 2*). Deadline Granules, Deadline Bullets, Snail and Slug AG Pelleted Bait, Metaldehyde Methiocarb Granules 2-1, Ortho Bug-Geta Snail and Slug Pellets and RCO Slug and Snail Pellets (original formulation) were most effective against *V. plebeia*; there was no significant difference among these molluscicides. Deadline Granules, Deadline Bullets, Slug and Snail AG Pelleted Bait and Durham Metaldehyde Granules 3.5 were most effective against *V. cubensis*; there was no significant difference among these molluscicides. *Vaginula plebeia* and *V. cubensis* did not recover after ingesting various formulations of metaldehyde.

Simulated rainfall and persistence trial

Vaginula plebeia. Corry's Slug, Snail and Insect Killer, Corry's Liquid Slug and Snail Control, Deadline One Last Meal for Slugs and Snails, Durham Metaldehyde Granules 3.5 and Metaldehyde Methiocarb Granules 2-1 increased in efficacy 4 to 6 days after application before decreasing in efficacy (*Table 3* and *Figure 2*). The rate and duration of effectiveness varied with the individual molluscicide. The effectiveness of Corry's Liquid Slug, Snail and Insect Killer, Deadline Bullets, Deadline Granules, Durham Metaldehyde Granules

Table 2. Percentage mortality ±SE of *V. plebeia* and *V. cubensis* six days after treatment with molluscicides

Product	% mortality[a]			
	V. plebeia		*V. cubensis*	
Deadline Granules	81.2 a	±3.2	83.5 a	±3.3
Deadline Bullets	76.3 ab	±1.0	65.8 ab	±1.0
Snail and Slug AG Pelleted Bait	62.4 abc	±0.7	60.1 abc	±0.2
Metaldehyde Methiocarb Granules 2-1	60.3 abc	±0.9	33.3 bcde	±2.1
Ortho Bug-Geta Snail and Slug Pellets	57.5 abc	±0.1	41.0 bcd	±2.3
RCO Slug and Snail Pellets	55.1 abcd	±2.0	44.9 bcd	±0.3
RCO Slug and Snail Pellets (rain resistant)	48.2 bcde	±2.0	39.5 bcde	±1.3
Durham Metaldehyde Granules 7.5	47.9 bcde	±1.4	63.0 ab	±0.8
Durham Metaldehyde Granules 3.5	47.2 bcde	±0.1	28.4 cde	±0.7
Corry's Slug and Snail Pellets	42.4 cdef	±0.2	44.9 bcd	±1.0
Deadline One Last Meal for Slugs and Snails	40.5 cdef	±0.8	29.9 cde	±1.3
Corry's Slug, Snail and Insect Killer	38.1 cdefg	±0.2	27.4 de	±0.1
Ortho Bug-Geta Plus Snail, Slug and Insect Granules	34.6 cdefg	±0.5	11.8 e	±2.2
Corry's Slug and Snail Death	25.9 defgh	±3.9	42.7 bcd	±1.2
Ortho Slug-Geta Snail and Slug Bait	20.3 efgh	±1.9	35.9 bcde	±4.7
Deadline 40	18.0 fgh	±0.1	17.7 de	±0.1
Corry's Liquid Slug and Snail Control	13.6 gh	±2.0	17.5 de	±2.3
Corry's Liquid Slug, Snail and Insect Killer	6.8 hi	±2.7	16.8 de	±1.0
Control	0.0 i	±0.0	0.0 f	±0.0

[a]Significant by ANOVA ($P < 0.001$). Means followed by the same letter in a column are not significantly different by Waller–Duncan k-ratio t-test, $k = 100$.

Table 3. Mean percentage mortality ±SE (ANOVA) and regression analysis between time (x) and percentage mortality (y) of *V. plebeia*. Daily rainfall simulated over an 8 day period

Treatment	% mortality[a]	Regression equation y' = arcsine (sq. rt (y))	r^2	P
Deadline One Last Meal for Slugs and Snails	48.7a ± 0.2	$y' = 6.2+19.5x-1.9x^2$	0.95	0.01
Snail and Slug AG Pelleted Bait	47.5ab ± 0.1	$y' = 48.6-1.6x$	0.81	0.02
Deadline 40	46.6ab ± 0.1	$y' = 32.1+2.3x$	0.59	0.03
Deadline Bullets	45.6ab ± 0.1	$y' = 52.4-2.2x$	0.75	0.01
RCO Slug and Snail Pellets	42.2ab ± 0.1	$y' = 45.6-1.5x$	0.72	0.03
Corry's Liquid Slug and Snail Control	37.4bc ± 0.1	$y' = 20.7+7.0x-0.6x^2$	0.78	0.02
Deadline Granules	32.1cd ± 0.2	$y' = 51.0-4.4x$	0.89	0.01
Ortho Bug-Geta Snail and Slug Pellets	23.9de ± 0.1	NS[b]		
Corry's Slug, Snail and Insect Killer	21.5ef ± 0.2	$y' = 0.8+10.2x-0.8x^2$	0.94	0.01
Metaldehyde Methiocarb Granules 2-1	21.0ef ± 0.2	$y' = -2.08+17.9x-2.0x^2$	0.97	0.01
Corry's Liquid Slug, Snail and Insect Killer	17.6ef ± 0.2	$y' = 29.3-1.4x$	0.67	0.05
Durham Metaldehyde Granules 3.5	15.6fg ± 0.2	$y' = -9.55+16.8x-1.7x^2$	0.91	0.02
Durham Metaldehyde Granules 7.5	14.8fg ± 0.3	$y' = 44.2-4.7x$	0.88	0.01
Ortho Bug-Geta Plus Snail, Slug and Insect Granules	10.1g ± 0.3	NS		
Control	0.4h ± 0.1	NS		

[a]Pooled mortality over the 8 day period. Significant by ANOVA ($P<0.0001$). Means followed by the same letter in a column are not significantly different (Waller–Duncan k-ratio t-test, $k = 100$). [b]NS = not significant.

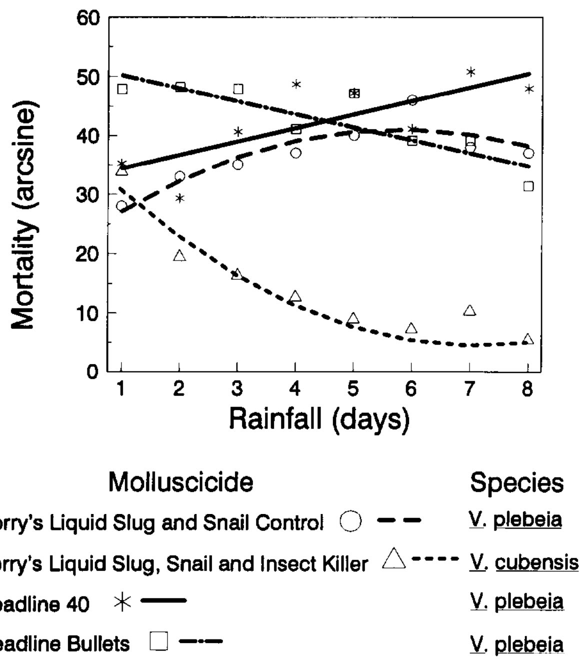

Figure 2. Linear and polynomial models describing the persistence of molluscicides subjected to 500 ml of simulated rainfall for 8 consecutive days

7.5, RCO Slug and Snail Pellets and Slug and Snail AG Pelleted Bait decreased steadily with time. Deadline 40 increased in efficacy with time. Ortho Bug-Geta Snail and Slug Pellets and Ortho Bug-Geta Plus Snail, Slug and Insect Granules produced low cumulative mean percentage mortalities and did not fit linear or polynomial models.

Simulated rainfall and persistence trial

Veronicella cubensis. Corry's Slug, Snail and Insect Killer, Corry's Liquid Slug and Snail Control, Deadline Granules, Durham Metaldehyde Granules 3.5, Metaldehyde Methiocarb Granules 2-1, RCO Slug and Snail Pellets and Snail and Slug AG Pelleted Bait efficacy decreased steadily with time (*Table 4*). The efficacy of Deadline One Last Meal for Slugs and Snails and Deadline 40 gradually increased for 6 consecutive days after application before decreasing. Corry's Liquid Slug, Snail and Insect Killer and Deadline Bullets rapidly decreased in efficacy within the first 4 days of application. Ortho Bug-Geta Snail and Slug Pellets produced low cumulative mean percentage mortalities and did not fit linear or polynomial models.

Table 4. Mean percentage mortality ±SE (ANOVA) and regression analysis between time (x) and percentage mortality (y) of *V. cubensis*. Daily rainfall simulated over an 8 day period

Treatment	% mortality[a]	Regression equation y' = arcsine (sq. rt (y))	r^2	P
Deadline Granules	44.3 a ± 0.1	$y' = 57.2-3.8x$	0.89	0.01
Deadline Bullets	44.3 a ± 0.1	$y' = 65.5-9.7x+0.8x^2$	0.92	0.01
Deadline One Last Meal for Slugs and Snails	39.3 ab ± 0.2	$y' = 24.7+6.2x-0.5x^2$	0.98	0.01
Deadline 40	37.7 ab ± 0.1	$y' = 27.6+4.9x-0.4x^2$	0.98	0.01
Snail and Slug AG Pelleted Bait	36.7 ab ± 0.1	$y' = 48.1-2.4x$	0.82	0.01
RCO Slug and Snail Pellets	33.3 bc ± 0.1	$y' = 42.1-2.0x$	0.84	0.01
Corry's Liquid Slug and Snail Control	25.7 c ± 0.1	$y' = 44.1-3.8x$	0.96	0.01
Metaldehyde Methiocarb Granules 2-1	16.5 d ± 0.2	$y' = 44.6-4.4x$	0.98	0.01
Durham Metaldehyde Granules 3.5	8.4 e ± 0.2	$y' = 29.7-2.7x$	0.68	0.02
Corry's Slug, Snail and Insect Killer	8.3 e ± 0.2	$y' = 35.6-4.5x$	0.88	0.01
Corry's Liquid Slug, Snail and Insect Killer	6.1 ef ± 0.1	$y' = 40.2-10.0x+0.8x^2$	0.93	0.01
Ortho Bug-Geta Snail and Slug Pellets	3.2 fg ± 0.1	NS[b]		
Control	0.8 g ± 0.1	NS		

[a]Pooled mortality over the 8 day period. Significant by ANOVA ($P<0.0001$). Means followed by the same letter in a column are not significantly different (Waller–Duncan k-ratio t-test, $k = 100$). [b]NS = not significant.

Molluscicides were most effective when moistened; however, in most instances efficacy diminished steadily thereafter. Of the tested molluscicides, Deadline One Last Meal for Slugs and Snails, Deadline 40, Deadline Bullets and Slug and Snail AG Pelleted Bait were most effective against both slug species over the 8 day period with simulated daily rainfall.

Deadline 40 (liquid paste formulation) and Deadline One Last Meal for Slugs and Snails (liquid formulation) were still toxic to the slugs after 8 days. Granule and pelleted formulations crumbled and deteriorated after initial swelling with moisture, but liquid and liquid paste molluscicides diffused with simulated rainfall resulting in increased coverage over time. Although more labor is required to apply liquid and liquid paste formulations than broadcast formulations, liquid and liquid paste molluscicides applied as barriers around crops may provide long molluscicidal activity.

Certain molluscicides that had high initial kill and deteriorated slowly over time were comparable with molluscicides that increased in efficacy 4 to 6 days after application before decreasing in efficacy. After one day of simulated rainfall, Snail and Slug AG Pelleted Bait ($y' = 48.6 - 1.6x$) killed 58% of *V. plebeia* while Corry's Liquid Slug and Snail Control ($y' = 20.7 + 7.0x - 0.6x^2$) killed 22% (data not shown). After 8 days of simulated rainfall Corry's Liquid Slug and Snail Control killed 42% of *V. plebeia* while Snail and Slug AG Pelleted Bait killed 37% (data not shown). The average daily kill of *V. plebeia* over the 8 day test period was 37 and 48% for Corry's Liquid Slug and Snail Control and Snail and Slug AG Pelleted Bait, respectively, with no significant difference between these molluscicides (*Table 3*). A split application of two lower rates in time rather than a single heavy dose may be more effective for molluscicides that decreased rapidly with time (e.g. Deadline Granules and Durham Metaldehyde Granules 7.5 against *V. plebeia*).

There was no significant difference ($P > 0.05$) in the cumulative mean percentage mortality among molluscicides between species (data not shown); however, daily mortality differed between the two species. The daily mortality response of *V. plebeia* to Corry's Liquid Slug and Snail Control increased for a few days after application before decreasing while the mortality response of *V. cubensis* steadily decreased over time. This clearly demonstrates that there are differences in slug species response to the same molluscicide. Both *V. plebeia* and *V. cubensis* were observed to forage on similar plants in the field; however, feeding or environmental preferences possibly exist. *Veronicella cubensis* was the dominant species at three of the four collection sites. All four collection sites were located within a 3.2 km radius.

Mold inhibition

Slugs foraged on moldy slug baits; however, once mold developed, molluscicide deterioration accelerated. Liquid and liquid paste formulations were more resistant to mold development (*Mucor* sp. and *Fusarium* sp.) than pelleted, granule and coated granule formulations (*Table 5*). Only Corry's Liquid Slug, Snail and Insect Killer did not develop mold. Corry's Liquid Slug and Snail Control, Deadline One Last Meal for Slugs and Snails (liquid) and Deadline 40 (liquid paste) either did not develop mold in $\geq 50\%$ of replicated trials or inhibited mold for ≥ 10 days. During the mold study, the average daily maximum and minimum greenhouse temperatures were 24.8 ± 1.6 and 18.3 ± 0.7°C, respectively; the average daily maximum and minimum humidities were 92.2 ± 2.5 and $67.8 \pm 8.6\%$, respectively.

Mechanical barriers

Copper and fiberglass screen barriers substantially reduced slugs from foraging to the slug bait (*Table 6*). Only 3 mean percent of *V. cubensis* and 1.7 mean percent of *V. plebeia* passed the copper barrier. The fiberglass screen reduced foraging apparently because the weight of the slugs collapsed the screen. There was no significant difference between the aluminum barrier and the paperboard control. Previous bioassay tests demonstrated that Slug and Snail AG Pelleted

Table 5. Number of days prior to visible mold development on certain molluscicides

Product name	Minimum days to mold development	Percentage of replicates without mold development
Corry's Slug, Snail and Insect Killer	4	50
Corry's Liquid Slug, Snail and Insect Killer	NM[a]	100
Corry's Liquid Slug and Snail Control	10	75
Corry's Slug and Snail Pellets	6	0
Corry's Slug and Snail Death	6	0
Deadline 40	10	50
Deadline Bullets	2	0
Deadline Granules	2	0
Deadline One Last Meal for Slugs and Snails	12	75
Durham Metaldehyde Granules 3.5	3	25
Durham Metaldehyde Granules 7.5	3	0
Metaldehyde Methiocarb Granules 2-1	3	25
Ortho Bug-Geta Plus Snail, Slug and Insect Granules	3	25
Ortho Bug-Geta Snail and Slug Pellets	3	0
Ortho Slug-Geta Snail and Slug Bait	2	0
RCO Slug and Snail Pellets	3	25
Snail and Slug AG Pelleted Bait	2	0

[a]No mold growth observed.

Table 6 Efficacy of mechanical barriers against *V. cubensis* and *V. plebeia*

Barrier	Mean number crossing barrier	
	V. cubensis[a]	*V. plebeia*[a]
Copper	3.0 b ± 2.6[b]	1.7 b ± 1.5
Fiberglass	4.3 b ± 3.2	5.3 b ± 1.5
Aluminum	19.7 a ± 7.2	11.7 ab ± 10.8
Paperboard	26.3 a ± 2.1	23.0 a ± 1.0

[a]Significant by ANOVA, $P < 0.01$. Means followed by different letters in a column are significantly different by Scheffe multiple-comparison procedure.
[b]Standard deviation.

Bait (Hacco, Inc.) killed only 62 and 60% of *V. plebeia* and *V. cubensis*, respectively; therefore, some slugs may have crossed the barrier and returned to the peat arena. Dead slugs were recovered from the peat arena, but the exact cause of mortality is unknown. Mortality in the peat arena may have been natural, from the salt barrier or from the molluscicide, but the mean percent mortality did not exceed 13 ± 2% for *V. cubensis* and 22 ± 12% for *V. plebeia*.

In actual field conditions, slug populations would be unlikely to exceed the test population of 100 slugs per 0.3 m^2. As a quarantine management strategy, export nurseries of potted plants should be required to use molluscicides in conjunction with copper and fiberglass barriers (a fiberglass screen placed below a copper barrier). Combining molluscicides with slug barriers would reduce slugs foraging onto benches thus decreasing dependency on the barrier alone. For example, under ideal conditions our tests indicated that an effective molluscicide, such as Deadline Granules, is about 80% effective. After combining molluscicides and copper barriers, the number out of 100 slugs actually passing the copper barrier would be less than one, or 0.6 slug per bench leg: 20 (% survivors of molluscicides) × 0.03 (proportion of *V. cubensis* passing barrier) = 0.6. Although molluscicides are highly effective under wet conditions when slugs are actively foraging, our study indicates that molluscicide persistence is reduced under these wet conditions. The efficacy of copper barriers is also reduced when wet (Godan, 1983). Therefore, the addition of a fiberglass barrier below the copper barrier will provide added security under wet conditions.

The molluscicides or slug barriers evaluated in this study were not 100% effective against either slug species. This level of control does not meet the quarantine security required for export commodities. Export nurseries will require a quarantine management strategy that incorporates a combination of control methods, including cultural (elimination of breeding sites), chemical (broadcast and barrier applications with effective molluscicides) and physical (copper or fiberglass screen barriers, or a combination of both) control.

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