COST AND BENEFIT IN CONTROL OF THE GRAY FIELD SLUG IN WESTERN OREGON

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Introduction

Controlling slugs in western Oregon agricultural fields can be problematic during wet winter and spring conditions when slug damage to newly emerging seedlings can be severe. The rising cost of products and operating inputs, and an increased awareness of environmental concerns, have been coupled with increasing slug populations partly caused by disappointing attempts to reduce slug populations. In this study, a large greenhouse study was conducted to quantify the effect of slug baits and poison, and combinations of these products, on slug mortality and percent seedling survival. We also quantified egg fecundity to determine whether specific control strategies might reduce the number of slugs during future cycle outbreaks.

Laboratory Methods

Experiments were conducted in a cool (10 °C) greenhouse under winter light conditions utilizing the products and product combinations listed in Table 1. Ten gray garden slugs were placed in round arenas (30 cm diameter) that were covered with screened lids, and partially filled with native soil (Dayton/Woodburn, 25% soil moisture). Slugs were field collected and held in growth chambers (10°C, 8 hrs. daylength) for three weeks before use in experiments and fed lettuce twice per week. Sixty perennial ryegrass seeds were planted in a center row arrangement and emerged seedlings were used in the experiment when they reached five days of age.

A complete randomized-block design experiment was laid out to provide equal cooling and lighting. To achieve the 6 repicates of each product and rate combination, tests were run in three groups (time blocks), 2 reps of each combination of product and rate, in each time block (for a total of 6 replicates). Pre-moistened cotton felt pads (3mm thick) were used in each arena as slug rests and egg-laying sites. Experiments were conducted for two weeks after which seedling damage, slug mortality, and egg laying were quantified. Surviving slugs were maintained for an additional 14 days to validate recovery.

The baits used in this study were: Deadline MP (DMP, 4% metaldehyde, pellet); OR-CAL Blue, 3.25% metaldehyde, pellet; MetaRex (MR, 4% metaldehyde, pellet); Sluggo shorts (1% iron phosphate. We investigated Durham 3.5 and Durham 7.5 a granular, sand-based product, enhanced with an attractant and weathering protection (3.5 and 7.5%, metaldehyde, respectively), two non-bait products that are not attractive to earthworms, and SlugFest AWF (all-weather-formula, 25%, metaldehyde), a liquid spray product. These non bait products do not need to be discovered by slugs, a potentially limiting factor in slug control. SlugFest is sprayed onto foliage and is consumed by the slugs, while slugs acquire metaldehyde from Durham by trans-dermal absorption across its foot when crawling over the fine granules. Liquid treatments were applied using a calibrated sprayer (15 psi; 20 gal/a rate; 80-02 nozzle, Tee-Jet®) and allowed to dry for thirty minutes. All other dry formulations were calibrated per surface area (60% of $1ft^2$).

Results

The greenhouse experiment showed that there is a diminishing improvement in slug control and seedling survivorship as the rates and cost of the applications increased. For all the single product regressions of Slug Death versus Cost, the polynomial factor was significant at $P < 0.05$ (Figure 1a). This means that with increasing cost the improvement in slug mortality declined for a given increase in dollars spent. There were differences among products. The most cost effective was Sluggo ($P < 0.0001$), while the MetaRex, Durham 3.5 and OR-CAL were least effective. SlugFest AWF effectiveness was poor at the lower three rates, but high at the three higher rates. Some of the product differences could be attributed to the moisture conditions of the experiment (25% soil moisture). For example Sluggo has been shown to be more effective in low moisture conditions, while MetaRex requires higher amounts of rain/soil moisture to become palatable, and it retains effectiveness under high moisture conditions. The three combination treatments (Combinations 12, 13, and 15)with highest cost effectiveness relative to single products all contained Sluggo as a component.

There was a significant increase in seedling survival with increased application rates and cost (Figure 1b). However the relationship between Seedling Survival and Slug Death (0.0162) was not significant ($P = 0.7975$). This can be most clearly seen in the Sluggo treatment group. Although Sluggo was most cost effective in causing slug death (Fig 1a), it was least effective in protecting seedlings (Fig 1b). Overall SlugFest AWF was the most effective in protecting seedlings ($P < 0.05$), although it was relatively poor in causing slug death. These relationships may in part be due to the fact that SlugFest is sprayed on the seedlings and slugs consume it along with the foliage. It is possible that a learned repellency is also involved, which limits slug death but protects the plant. Conversely, slugs can feed on seedlings before they encounter Sluggo pellets. In addition, Sluggo is a stomach poison that requires several days to cause slug death. There may be additional slug feeding damage until the active ingredient (iron phosphate) takes effect.

Combinations (Treatments 9 and 11) were as cost effective in increasing seedling survival as the most effective single product application, SlugFest (Fig 2b). Both of these combination

treatments contained Sluggo; in Treatment 9 it is combined with Durham 3.5, and in Treatment 11 with OR-CAL. Combination Treatments 14 and 15 were the least effective of the combinations. These contained Sluggo and SlugFest as ingredients. This poor performance was not expected given that Sluggo is the most effective slug mortality product, and SlugFest is the most effective at protecting seedlings.

Egg Fecundity (numbers of eggs laid) also had a polynomial relationship with Cost, with decreasing reductions in egg laying as costs increased above $20-$25 (data not shown). SlugFest, Deadline MP, and MetaRex were the most cost effective at reducing slug egg laying. Of the product combinations tested, Treatment 13 which contained MetaRex and Sluggo was the most cost effective at reducing egg laying, but was no more effective than straight SlugFest at the same cost.

These results make it difficult to come to a conclusion on the best product, rate or combination to use. In experimental conditions with higher moisture, the effectiveness of Sluggo can be expected to decline while the relative effectiveness of MetaRex could increase. It is clear that in this test environment spending more than $20-$25 per acre on an application gave diminishing returns for both slug mortally and seedling survivorship. Is also appears that the most effective combinations of products are no more cost effective at killing slugs, reducing damage, or reducing egg fecundity than the most effective single products.

Conclusions

We learned that there is a point at which higher application rates result in diminished increases in slug mortality and seedling survival. This occurs when only 30-45% of the slugs have been killed, and 50% of the seedling have survived. While slugs can be killed by ingesting or absorbing poison baits, the direct impact of slug mortality on reducing seedling loss is unclear. It is likely that there is need to think beyond the concept of slug mortality equals slug “control” when evaluate slug control / seedling protection tactics are evaluated.

These results suggest that growers should limit the amount of slug control product used at each application. Unfortunately however, it is also possible to apply too little bait to be truly effective, i.e., the minimum rates used in this study. This study does indicate the range of application rates that should be cost effective, and in general, those rates that constituted cost effective slug control differed among the products tested as far as how they affect slug mortality, seedling survival, and slug egg laying.

a.

b.

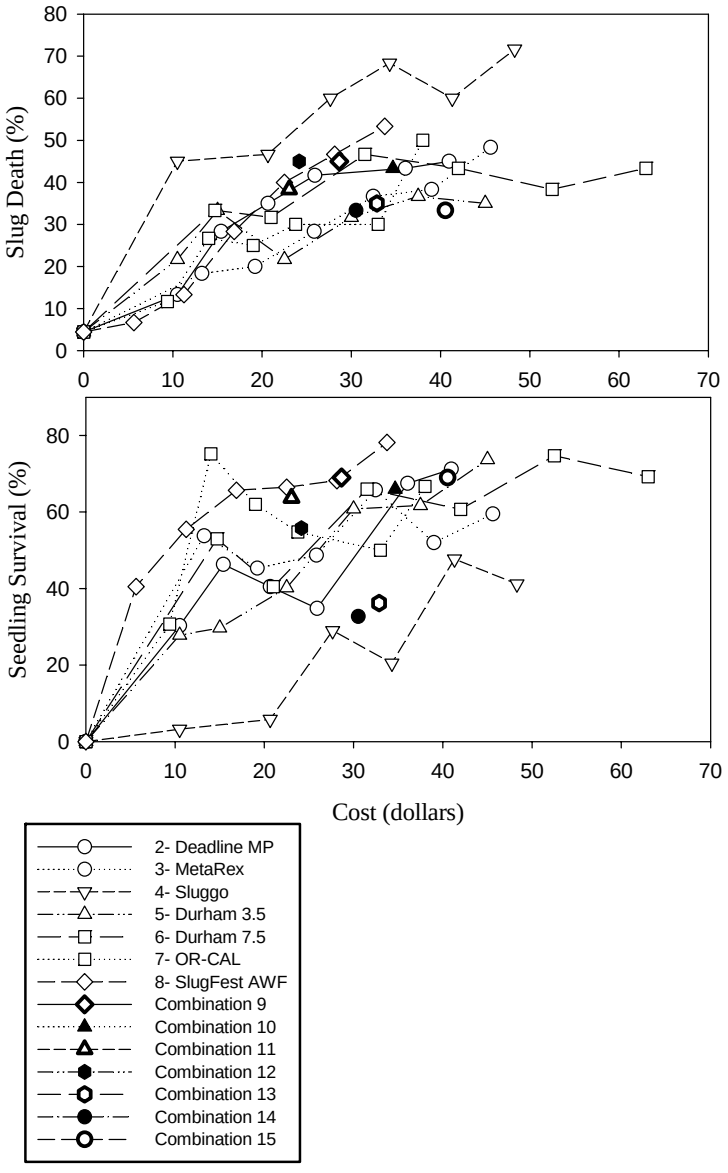

Figure 1a**:** Regression of percent Slug Death (7 products at 6 rates) versus Cost of the product. The regression equation [Slug Death = block + Cost + CostSquared + Product] was significant at $P < 0.0001$. The treatments (9-15) that were comprised of a combination of products are incorporated into the figure to assess whether on a cost basis product combinations are more effective than single product applications.

Figure 1b. Regression of percent Seedling Survival (7 products at 6 rates) versus Cost of the product. The regression equation [Seedling Survival = block + Cost + CostSquared + Product] was significant at $P < 0.0001$.

Table 1. Product, rate, and cost data. All bait rates were adjusted to normalize the cost/acre, when possible.

Treatment Number	Treatment	% Slug Death	SEM	% Seedling Survival	SEM	No. of Eggs	SEM	Cost
1	Control 1	4	2.413	0	0.000	67	3.654	$0.00
	Deadline MP 7.25 lbs/a	13	2.109	6	4.888	47	3.128	$10.50
	Deadline MP 11.25 lbs/a	28	8.852	7	9.663	35	2.692	$15.40
2	Deadline MP 14.75 lbs/a	35	8.335	16	7.302	21	4.752	$20.65
	Deadline MP 18.5 lbs/a	42	10.140	21	5.096	16	2.114	$25.90
	Deadline MP 25.75 lbs/a	43	8.467	35	1.546	7	1.721	$36.05
	Deadline MP 29.75 lbs/a	45	10.855	47	3.590	6	2.156	$40.95
	MetaRex 5 lbs/a	17	4.945	2	5.657	47	5.597	$13.25
	MetaRex 7.35 lbs/a	20	4.473	6	7.758	22	1.642	$19.21
3	MetaRex 10 lbs/a	27	10.222	16	11.119	16	3.023	$25.84
	MetaRex 12.5 lbs/a	35	7.639	16	5.970	16	1.564	$32.46
	MetaRex 15 lbs/a	37	6.668	22	12.895	6	2.445	$39.00
	MetaRex 17.25 lbs/a	45	9.576	47	3.515	2	1.424	$45.61
	Sluggo shorts 7 lbs/a	42	11.669	6	7.562	44	8.440	$10.50
	Sluggo shorts 14 lbs/a	47	7.603	9	2.454	30	3.440	$20.65
4	Sluggo shorts 18.75 lbs/a	60	5.775	22	9.433	30	7.610	$27.65
	Sluggo shorts 23.5 lbs/a	60	5.775	30	7.336	22	1.587	$34.30
	Sluggo shorts 28 lbs/a	68	6.010	30	6.690	9	3.294	$41.30
	Sluggo shorts 32 lbs/a	72	7.033	44	2.167	6	1.500	$48.30
	OR-CAL 7.5 lbs/a	12	9.191	8	3.480	46	4.249	$9.38
	OR-CAL11.5 lbs/a	25	9.918	27	2.977	41	5.499	$14.00
5	OR-CAL 15.25 lbs/a	27	3.652	29	6.870	35	3.192	$19.00
	OR-CAL 19 lbs/a	30	9.663	35	8.179	29	3.199	$23.75
	OR-CAL 26.5 lbs/a	30	14.609	41	4.643	27	4.673	$33.00
	OR-CAL 30.5 lbs/a	50	4.774	46	6.605	8	2.405	$38.00
	Durham 3.5 7 lbs/a	13	7.033	10	9.627	46	3.767	$10.50
	Durham 3.5 10 lbs/a	18	11.549	15	8.022	44	3.566	$15.00
6	Durham 3.5 15 lbs/a	22	4.945	26	5.125	28	2.405	$22.50
	Durham 3.5 20 lbs/a	28	9.100	28	5.547	26	3.795	$30.00
	Durham 3.5 25 lbs/a	30	7.925	44	10.452	15	9.592	$37.50
	Durham 3.5 30 lbs/a	33	7.603	46	4.986	10	6.965	$45.00
	Durham 7.5 7 lbs/a	32	8.029	7	8.682	42	2.527	$14.70
	Durham 7.5 10 lbs/a	33	8.726	17	8.503	41	4.234	$21.00
7	Durham 7.5 15 lbs/a	38	12.826	22	5.810	36	5.674	$31.50
	Durham 7.5 20 lbs/a	43	9.890	36	9.077	22	6.477	$42.00
	Durham 7.5 25 lbs/a	43	10.778	41	7.693	17	2.861	$52.50
	Durham 7.5 30 lbs/a	47	10.543	42	7.310	7	5.305	$63.00
	SlugFest AWF 1 pt/a	7	2.109	4	3.878	55	4.303	$5.63
	SlugFest AWF 2 pts/a	13	4.945	6	6.445	43	1.764	$11.25
8	SlugFest AWF 3 pts/a	32	10.140	22	7.108	30	1.834	$16.88
	SlugFest AWF 4 pts/a	37	12.826	30	5.556	22	7.957	$22.50
	SlugFest AWF 5 pts/a	47	16.059	43	6.110	6	2.667	$28.13
	SlugFest AWF 6 pts/a	53	13.084	55	6.727	4	1.283	$33.75
9	Durham 3.5 10 lbs/a + Sluggo shorts 9.25 lbs/a	45	9.918	23	9.308	23	2.376	$28.65
10	Durham 7.5 10 lbs/a + Sluggo shorts 9.25 lbs/a	43	6.668	23	10.923	23	8.161	$34.65
11	OR-CAL 7.5 lbs/a + Sluggo shorts 9.25 lbs/a	38	4.774	36	6.344	36	5.565	$23.03
12	Deadline MP 7.25 lbs/a + Sluggo shorts 9.25 lbs/a	45	5.628	54	8.110	54	6.652	$24.15
13	MetaRex 7.35 lbs/a + Sluggo shorts 9.25 lbs/a	35	5.628	6	8.257	6	4.121	$32.86
14	SlugFest AWF 3 pts/a + Sluggo shorts 9.25 lbs/a	33	13.827	20	14.900	20	3.049	$30.53
15	SlugFest AWF 3 pts/a + Phor-Ti-Phy 4 G/a + Sluggo shorts 9.25 lbs/a	33	10.543	36	12.147	36	6.191	$40.53