II.12 Bait Acceptance by Different Grasshopper Species and Instars

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The Grasshopper Integrated Pest Management (GHIPM) Project provided unique resources and opportunities that allowed investigators to gather a large amount of data on the responses of rangeland grasshoppers to carbaryl bait. A total of 39 different species were recorded in 24 different control experiments at 14 different sites in the western parts of North Dakota and South Dakota. All species were not present in sufficient numbers to provide useful information, but the data base allowed GHIPM-funded investigators to study many questions that could not have been examined without it.

Data Collection

The monitoring procedure was to establish from 4 to 10 monitoring sites, each consisting of 40 0.1-m^2 rings spaced about 5 m apart in circles, both in plots that were scheduled for treatment and in adjacent plots that remained untreated. Density counts and sweep-net collections were made as close as possible (usually 24 hours) before scheduled treatments, and again as close as possible to 48 hours after treatment. The information from all sample sites per plot for each sampling date was then combined for further study.

Each sweep sample was examined to determine the species and stage of development for every grasshopper in the sample. Each total density count was then converted to density per instar per species by multiplying observed total density times the appropriate proportions of composition within the sweep samples. The procedure is identical to that described in chapter II.2, "Evaluation of Rangeland Grasshopper Controls," except that density was estimated for each instar of a species as well as for all individuals of a species.

Computer tabulations of different species recorded in different experiments revealed a potential for 253 independent determinations of species-specific response to carbaryl bait. Pretreatment and posttreatment data for each species in each experiment were then examined to assess which of the possible determinations would be meaningful. A total of 101 potential data sets were declared useless, leaving 152 legitimate determinations.

Reasons for rejecting some data sets included initial presence in such low density that subsequent reduction would not be measurable (in most cases, at least five specimens in pretreatment samples were required), absence of specimens at untreated sample sites (which prohibited estimation of mortality in the absence of treatment), and higher estimated mortality in untreated plots than in treated plots (a common artifact of sampling error among low-density samples).

The 152 data sets accepted as legitimate provided opportunities to study a variety of questions about response to carbaryl bait. The simplest assessment concerned the average percent control among all individuals of a species. This average percent control was calculated with a variation of the formula by Connin and Kuitert (1952):

Percent control = $100(1 - (Ta \times Ub \div Tb \div Ua))$, where
Tb is density in treated plots before treatment,
Ta is density in treated plots after treatment,
Ub is density in untreated plots before treatment, and
Ua is density in untreated plots after treatment.

The formula does not yield "simple" or "raw" control data—that is, the percentage of the total infestation that "disappeared" in treated plots. Rather, it yields "adjusted" control data: the percentage of the total infestation that most likely was killed by carbaryl bait.

The formula is useful for two major reasons. First, grasshopper infestations suffer some mortality each day due to natural causes, so the formula "removes" that natural mortality from consideration. The formula essentially uses data from untreated sites to estimate what the posttreatment counts at treated sites would have been in the absence of treatment. Percent control then represents the difference (if any) between expected and observed posttreatment density in treated plots. Second, without the formula, the percent control that is estimated will be grossly different, depending on how much time elapses between pretreatment and posttreatment counts. These problems can be illustrated with an example.

Let us assume that an infestation of 30 grasshoppers/yd^2 comprises 6 *Aeropedellus clavatus,* 15 *Melanoplus sanguinipes,* and 9 *Amphitornus coloradus.* We decide to treat half and leave half, and we sample both halves on the day before treatment (day –1), and on days 2, 3, 4, and 5 after treatment. Table II.12–1 shows typical density data.

Table II.12–1—A representative example of typical grasshopper density data in untreated plots versus plots that were treated (on day zero) with carbaryl bait

Time	*A. clavatus*		*M. sanguinipes*		*A. coloradus*		All species	
(days after treatment)	Untreated plot	Treated plot	Untreated plot	Treated plot	Untreated plot	Treated plot	Untreated plot	Treated plot
–1	6	6	15	15	9	9	30	30
+2	3.68	2.95	13.69	3.42	7.71	7.56	25.08	13.93
+3	3.13	2.51	13.28	3.32	7.33	7.18	23.74	13.01
+4	2.66	2.13	12.88	3.22	6.96	6.82	22.5	12.17
+5	2.26	1.81	12.49	3.12	6.61	6.48	21.36	11.41

Looking only at the raw density for "All species" in only the treated plot, a reader might believe that this bait treatment achieved about 54- to 62-percent average control of the infestation. The fallacy is that if a similar strategy is applied to data from untreated plots, a reader could estimate 16- to 29-percent control where nothing was done. Use of the formula yields more conservative and more realistic estimates of about 44- to 46-percent adjusted control of "All species."

Raw estimates for individual species can also be very misleading. For example, *A. clavatus* usually is the first species that hatches in the spring. By the time of typical bait treatments to control later-hatching major pest species, *A. clavatus* often is present as very old adults that suffer very high daily mortalities likely associated with the process of aging. Raw estimates indicate 51- to 70-percent population reduction, but adjusted estimates reveal only 20-percent control due to the bait, meaning the raw estimates placed control at 2.5 to 3.5 times higher than it actually was.

Notice in the example that discrepancies between raw and adjusted mortalities for *A. coloradus* are even greater than they were for *A. clavatus.* This is because adjusted response to treatment (2-percent control) was less than the daily loss due to natural mortality (5 percent per day). In such a case, raw estimates yield greatly distorted results. As one might then expect, raw estimates are closest to adjusted estimates in cases like the *M. sanguinipes* example, where natural mortality was relatively low (3 percent per day) and adjusted control was relatively high (75 percent). Nevertheless, it should be noted that all raw estimates for *M. sanguinipes* still were too high, and the degree of error increased as the amount of time between pretreatment and posttreatment samples was increased. Similar errors are guaranteed to occur in real life (in field experiments or commercial control projects) if natural mortality is ignored.

Relative Susceptibility of Different Species

The results of GHIPM experiments were combined with a number of previous studies by the authors and others (see Swain [1986] and Quinn et al. [1989]) to produce table II.12–2. It divides grasshoppers into three broad classes of susceptibility. The "sensitive" class contains species that readily seek out and eat wheat bran bait and therefore usually suffer a high degree (average = 56–87 percent) of adjusted (true) mortality. The "vulnerable" class contains species that usually either suffer only a moderate degree (30–55 percent) of adjusted mortality or else exhibit such great variation among different tests that one cannot safely depend on more than moderate results. The "nonsusceptible" class (less than 30-percent adjusted mortality) contains species that eat little or no bait and therefore usually are not markedly affected by bait.

Most of the experiments that contributed to table II.12–2 were applied when the majority of target pest grasshopper species were in third, fourth, or fifth instars. A few very early species like *A. clavatus* and *M. confusus* typically were treated as adults or fifth instars, while some relatively late species like *P. nebrascensis* and *P. quadrimaculatum* were occasionally treated as first or

Table II.12–2—Classification of grasshopper species according to susceptibility to carbaryl wheat bran bait

Class and expected levels of control	Species
Sensitive (>55-% control) Control is expected to average about 70%. Worst-case and best-case scenarios will be about 55% and 85%, respectively.	*Ageneotettix deorum* *Anabrus simplex* *Aulocara elliotti* *Camnula pellucida* *Hadrotettix trifasciatus* **Melanoplus bivittatus* *Melanoplus confusus* *Melanoplus dawsoni* *Melanoplus foedus* **Melanoplus infantilis* **Melanoplus occidentalis* **Melanoplus packardii* *Melanoplus sanguinipes* *Spharagemon equale* *Stenobothrus brunneus* **Mermiria bivittata*
Vulnerable (30- to 55-% control) Control is expected to average about 42%. Worst-case and best-case scenarios will be about 12% and 72%, respectively.	**Aulocara femoratum* *Eritettix simplex* *Melanoplus femurrubrum* *Oedaloenotus enigma* *Opeia obscura* *Phoetaliotes nebrascensis* *Psoloessa delicatula*
Nonsusceptible (<30-% control) Control is expected to average about 15%. Worst-case and best-case scenarios will be about 0% and 30%, respectively.	*Aeropedellus clavatus* *Amphitornus coloradus* *Cordillacris crenulata* *Cordallacris occipitalis* *Hesperotettix viridis* *Metator pardalinus* **Phlibostroma quadrimaculatum* *Trachyrhachys kiowa*

*These species are not likely to suffer best-case scenario levels of control.

second instars where they were incidental rather than primary target species.

Relative Susceptibility of Different Developmental Stages

Some of the GHIPM experiments provided data that allowed the comparison of the relative susceptibility of different instars of a species to bait. In general, the requirements for a meaningful test were the presence of at least four or more different stages in reasonable numbers (usually at least five individuals per instar in pretreatment sweep samples) in two or more different experiments. In those cases, the authors calculated adjusted percent control for each instar and used analyses of covariance, with instar as the covariant, to test susceptibility by instar. When covariance was significant (when percent control was affected by instar), the slope of the relationship indicated whether larger or smaller instars were most susceptible.

A total of eight species were tested, six of which were considered in table II.12–2 to be sensitive. Younger instars of three species, *A. deorum, M. packardii,* and *M. sanguinipes,* were found to be significantly more susceptible to bait than older instars. Susceptibility was not affected by instar in the cases of *A. elliotti, C. pellucida, M. infantilis, P. nebrascensis,* or *T. kiowa.*

Relative Susceptibility of Different-Aged Populations

Some of the GHIPM experiments provided data that allowed the researchers to examine the effect of age on susceptibility of populations to bait. Age was expressed as average instar, which is calculated as the sum of each instar number multiplied by the number of grasshoppers in the instar (adults are considered instar 6 for this procedure) divided by the total number of grasshoppers present. The requirements for a meaningful test were significant adjusted control observed in three or more experiments (incidences of zero control were excluded from these calculations). The relationship between average instar and percent adjusted mortality was examined by linear regression techniques.

A total of 17 species was tested, 10 of which were considered in table II.12–2 to be sensitive or vulnerable. For three of those species, *A. elliotti, A. deorum,* and *M. sanguinipes,* percent adjusted control increased significantly with average instar.

Summary and Recommendations

Grasshopper species vary considerably in their inclination to feed on wheat bran and in their susceptibility to carbaryl-treated bait. In addition, levels of control that follow bait treatments are considerably lower and much less predictable than control achieved with liquid sprays. The GHIPM Project greatly increased the knowledge base for both acknowledged pest grasshopper species (the primary target species) and for incidental (nontarget) species. Project researchers now feel that they can offer some general guidelines, based on species susceptibility (table II.12–2), for the appropriate use of carbaryl bait.

Individuals should not attempt to control nonsusceptible pest species with bait. If such species comprise a significant proportion of an infestation, a conservative manager should simply assume that bait will give no control of that proportion. Vulnerable species may or may not be markedly controlled by baits, but what regulates that degree of success remains unknown, and at this time those results cannot be predicted. Past situations have documented dramatic reductions in vulnerable species from the use of bait, as well as cases of almost total failure. In the future, managers should not use bait against vulnerable species without seriously weighing the consequences of failure. Control of the sensitive species with bait is generally reliable.

Questions about optimum timing for bait treatments remain somewhat perplexing, but it fortunately appears that timing is not of extreme importance, perhaps because of compensatory factors. Some tests support early treatments in that, at least for some species, younger instars were more susceptible than older instars. This is logical because smaller grasshoppers are killed by smaller doses of toxicant. Another advantage of early bait treatment is that natural control agents have more time to act upon surviving grasshoppers.

Other tests, however, support late treatments in that total percent control was greater for older populations than for younger populations. While these results may seem contrary, they also can be considered strong evidence that something like changes in behavioral traits (perhaps searching capabilities) or habitat characteristics (perhaps cover, litter, or bare ground) make baits more accessible as the season progresses. If such compensating factors exist, the mechanisms cannot be accurately described at the present time. Fortunately, however, for most species (14 of 17 tested), adjusted percent control was not markedly affected by population age. It therefore appears that timing of bait treatments is not of extreme importance as long as it occurs when most of the primary target grasshoppers are in third, fourth, or fifth instars.

References Cited

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