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Short communication

Identifying possible alternative rodenticide baits to replace strychnine baits for pocket gophers in California

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ABSTRACT

Rodents cause substantial damage to crops in California and rodenticides have been major tools for reducing that damage. While strychnine has been heavily relied upon to control pocket gophers in California, its future availability is in question because of increased import costs. We conducted efficacy trials with captive, wild-caught Botta’s pocket gophers to identify potential alternative rodenticides to strychnine. The rodenticide baits tested included three categories: acute rodenticides, first generation anticoagulant rodenticides, and combination rodenticides (containing an acute toxicant and an anticoagulant). There was a wide range of efficacies (0–100%) with these rodenticides. The first generation anticoagulants performed poorly, while a distinct regional variation in efficacy occurred with the strychnine and zinc phosphide baits. The combination baits performed the best overall, averaging 90% efficacy. We also reported on the average bait consumption and days-to-death for the various rodenticides tested. We discussed the potential advantages of combination baits and especially the potential for lower concentrations of active ingredients. Finally, we recommend that a field trial be conducted to determine the efficacy of the combination baits to control pocket gophers.

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1. Introduction

Pocket gophers cause various types of damage to agricultural and rangeland resources and to forests in North America (Witmer and Engemann, 2007). Pocket gophers (Thomomys spp.) are generally considered one of the most damaging wildlife pests in California (Marsh, 1992). Recent studies estimated average losses ranging from 5.3 to 8.8% across a variety of crops in California (Baldwin et al., 2013).

Primary control options for pocket gophers include trapping, burrow fumigation and baiting with rodenticides (Baldwin, 2012; Witmer and Engemann, 2007). Both trapping and burrow fumigation can be highly effective at controlling pocket gophers (Proulx, 1997; Baker, 2004), but are typically more time consuming and costly than baiting (Marsh, 1992; Engeman and Witmer, 2000). As such, baiting is often preferred by many growers, pest control advisors, and pest control operators. Three baits are used to control pocket gophers: strychnine, zinc phosphide, and first generation anticoagulants. However, there are varying efficacies for each of these rodenticide baits across a wide array of rodent species and settings (Salmon et al., 2000; Stewart et al., 2000; Bourne et al., 2002; Balliette et al., 2006; Schmit, 2008; Proulx et al., 2010).

Strychnine is an acute toxicant that has been widely used for many decades for controlling pocket gophers (Marsh, 1992). Strychnine has been the preferred bait for controlling gophers given its acute toxicity, more palatable flavor than zinc phosphide, and its effectiveness (Case and Jasch, 1994). However, in some areas, gophers have developed a behavioral resistance to strychnine baits (Marsh, 1992). More importantly though, there is now a current shortage of strychnine baits in the United States (U.S.) due to burgeoning costs of imported strychnine (B. Hazen, Wilco Distributors, Inc., pers. comm.). In fact, Wilco Distributors, Inc., who has been the primary importer of strychnine for pest control purposes into the U.S., recently stopped the importation of strychnine and halted all production of strychnine baits. Unless a new source of strychnine is obtained in the near future, most or all strychnine applications will cease once current supplies of strychnine are exhausted. As such, the identification of an equally or more effective bait is needed to provide individuals with a viable alternative for controlling high density gopher populations where other control options are cost prohibitive.
Zinc phosphide is an alternative acute toxicant and has been used for pocket gopher control (e.g., Tickes et al., 1982; Proulx, 1998). Unfortunately, zinc phosphide has not typically performed as well as strychnine in field trials (e.g., Barnes et al., 1982; Proulx, 1998; but see Tickes et al., 1982), perhaps due to taste aversion (Engeman and Witmer, 2000). However, new formulations are available that may increase effectiveness potentially making the use of zinc phosphide a viable option for controlling gophers.

Anticoagulant baits (chlordane and diphacinone) are also available for controlling pocket gophers. Anticoagulant baits are less toxic than strychnine and zinc phosphide, thereby reducing potential mortality from incidental ingestion of these baits by non-target species. These baits require multiple feedings over 3–5 days to control gophers. Therefore, greater amounts of bait are required with anticoagulants. As such, these baits have not always tested well (e.g., Tickes et al., 1982; Stewart et al., 2000). However, new formulations have come out that warrant efficacy testing.

Some researchers are investigating new “combination” rodenticides. These rodenticides combine an anticoagulant and an acute active ingredient (e.g., cholecalciferol). Eason et al. (2010) found that one test bait with two active ingredients, cholecalciferol and coumatetralyl, produced promising results with rats and mice. Interestingly, they were able to obtain high efficacy with lower concentrations of the active ingredients than the concentrations used when either active ingredient is used alone. Hence, there may be some synergistic effect. This is noteworthy because if lower concentrations can be effectively used, there could be a lower secondary risk of harm to non-target animals. Witmer et al. (2014) and Baldwin et al. (2016) found that a cholecalciferol plus diphacinone pelleted bait was very effective with California voles in cage and field efficacy trials, respectively. While the second generation anticoagulant, brodifacoum, is not registered for pocket gopher control in the U.S., we included it as a combination bait (combined with cholecalciferol) so that its effectiveness could be compared with the cholecalciferol plus diphacinone combination.

The objective of this study was to identify effective new formulations of rodenticides for the control of Botta’s pocket gophers. These rodenticides contained combinations of active ingredients or new formulations of existing active ingredients. We hypothesized that some of the test baits would exhibit a high efficacy (>80% mortality) when presented to the pocket gophers.

### 2. Methods

Botta’s pocket gophers (*Thomomys bottae*; henceforth, gophers) were live-trapped in California for this study and transported to the United States Department of Agriculture’s (USDA) National Wildlife Research Center (NWRC), Fort Collins, Colorado. The gophers came from two regions of California: the southern group was from the San Diego County area, and the northern group was from the Sonoma County area. In the southern region, gophers were from areas where rodenticide baits have been heavily used for decades, whereas the gophers from the northern region were from areas where there is little rodenticide use with kill-trapping being used more so. Gophers were kept in individually numbered plastic cages in an animal room at NWRC and were fed a maintenance diet of rodent chow pellets and carrot chunks, and received water *ad libitum*. They were provided with bedding, a den tube, and wood blocks to chew on. There were four rounds of trials with various treatment groups of five animals each. Animals were randomly assigned to treatment groups for the two-choice trials. The 12 different rodenticide formulations used in the trials are listed in Table 1. Some of the baits are registered, commercial baits. Others were experimental baits formulated by one of three rodenticide companies. While the formulations varied (and are proprietary), all 3 companies have many years of experience in manufacturing effective, palatable rodenticide baits. There was also a control group of five gophers maintained on the maintenance diet. Both males and females were included in each group. The gophers were of various ages because their initial weights varied from 44 g to 120 g. Experimental rodenticide baits were generally tested on both gopher groups from the southern region and from the northern region.

The weight, sex, cage number, and treatment of each gopher was recorded before the initiation of a trial. On Day 1 of the trial, a bowl of pre-weighed rodenticide bait was added to the appropriate cages. All animals continued to receive the maintenance diet. For the next ten days, maintenance diet materials were added daily to the cages, whereas rodenticide baits were added as needed so that the gophers always had access to bait during the exposure period. All new bait was weighed before being added to the cages so that the total consumption could be determined at the end of the exposure period. At the end of the 10-day rodenticide exposure

<table>
<thead>
<tr>
<th>Rodenticide Type</th>
<th>% Efficacy, Southern Region (No. dead/no. in group)</th>
<th>% Efficacy, Northern Region (No. dead/no. in group)</th>
<th>Ave. Bait Consumption g (S.D.), Survivors</th>
<th>Ave. Bait Consumption g (S.D.), Non-survivors</th>
<th>Ave. Days-to-Death (S.D.) for Non-survivors</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01% chlordane, coated grain</td>
<td>40% (2/5)</td>
<td>60% (3/5)</td>
<td>24.9 (6.2)</td>
<td>24.3 (7.1)</td>
<td>9.6 (4.6)</td>
</tr>
<tr>
<td>0.005% chlordane, pellet</td>
<td>40% (2/5)</td>
<td>60% (3/5)</td>
<td>27.3 (11.8)</td>
<td>20.3 (16.9)</td>
<td>6.2 (3.0)</td>
</tr>
<tr>
<td>0.005% diphacinone, pellet</td>
<td>0% (0/5)</td>
<td>N/A (not applicable)</td>
<td>15.6 (7.9)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>0.005% diphacinone, pellet</td>
<td>40% (2/5)</td>
<td>20% (1/5)</td>
<td>2.7 (1.5)</td>
<td>5.4 (6.1)</td>
<td>15.3 (3.5)</td>
</tr>
<tr>
<td>0.03% cholecalciferol + 0.0025% brodifacoum, pellet</td>
<td>100% (5/5)</td>
<td>N/A</td>
<td>5.1 (1.1)</td>
<td>10.8 (4.0)</td>
<td></td>
</tr>
<tr>
<td>0.015% cholecalciferol + 0.0025% brodifacoum, pellet</td>
<td>100% (5/5)</td>
<td>100% (5/5)</td>
<td>N/A</td>
<td>7.0 (8.0)</td>
<td>6.4 (2.8)</td>
</tr>
<tr>
<td>0.03% cholecalciferol + 0.005% 60% (3/5)</td>
<td>100% (5/5)</td>
<td>7.2 (3.4)</td>
<td>6.5 (2.7)</td>
<td>5.3 (3.6)</td>
<td></td>
</tr>
<tr>
<td>diphacinone, pellet</td>
<td>0% (0/5)</td>
<td>100% (5/5)</td>
<td>15.8 (3.4)</td>
<td>2.7 (4.6)</td>
<td>1.0 (1.2)</td>
</tr>
<tr>
<td>0.5% strychnine, coated grain</td>
<td>20% (1/5)</td>
<td>100% (5/5)</td>
<td>13.3 (9.8)</td>
<td>2.3 (0.7)</td>
<td>1.0 (0.6)</td>
</tr>
<tr>
<td>2.0% zinc phosphide, pellet</td>
<td>60% (3/5)</td>
<td>40% (2/5)</td>
<td>1.0 (0.3)</td>
<td>0.8 (0.4)</td>
<td>0.8 (0.4)</td>
</tr>
<tr>
<td>2.0% zinc phosphide, pellet</td>
<td>0% (0/5)</td>
<td>80% (4/5)</td>
<td>0.5 (0.8)</td>
<td>1.3 (0.8)</td>
<td>1.5 (0.6)</td>
</tr>
<tr>
<td>0.075% cholecalciferol, pellet</td>
<td>40% (2/5)</td>
<td>N/A</td>
<td>4.9 (4.7)</td>
<td>5.8 (5.7)</td>
<td>3.5 (0.7)</td>
</tr>
</tbody>
</table>
period, gophers were placed in clean cages and put back on the maintenance diet for a 14-day post-exposure period. The uneaten rodenticide baits in the dirty cages was collected and weighed to determine the amount consumed by gophers.

Gophers were examined twice daily by the study staff and their condition and any mortalities were recorded. Dead gophers were placed in individual, labeled zip-lock bags and refrigerated for later necropsy. When necropsied, those provided with anticoagulants were examined for signs of anticoagulant poisoning (Stone et al., 2006). Also, gophers often will not eat much anticoagulant bait when other preferred foods are available. Hence, the advantage of a more toxic bait that only requires a small amount to be consumed.

When the days-to-death is only one of the certain symptoms occur such as excessive bleeding or convulsions. Therefore, we note that the average days-to-death of the combination bait, while still higher than that of the acute baits, was somewhat lower than that of the anticoagulant in the combination bait. Finally, with regard to the humaneness issue, we note that the average days-to-death of the combination bait, while still higher than that of the acute baits, was somewhat lower than that of the first generation baits. We note, however, that the days-to-death is only one measure of humaneness; other aspects include whether or not certain symptoms occur such as excessive bleeding or convulsions. We recommend that a field efficacy study of the combination baits be conducted in agricultural fields infested with pocket gophers.

Acknowledgments

This study was conducted under the National Wildlife Research Center JACUC-approved study protocol QA-2146. We thank several rodenticide companies for providing experimental formulations for these trials. We also thank the Pala Band of Mission Indians and the Gallo Family Vineyards for access to their properties for gopher live trapping. The mention of a commercial product or company does not represent an endorsement by the U. S. government. The authors declare that they have no conflict of interest.

References


### Table 2

Comparisons of efficacy, days to death, and bait consumption across the three categories of rodenticide.

<table>
<thead>
<tr>
<th>Rodenticide Category</th>
<th>No. of Formulations</th>
<th>Ave. % Efficacy* (S.E.)</th>
<th>Ave. Days to Death* (S.E.)</th>
<th>Ave. Grams Bait Consumption* (S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute Rodenticides</td>
<td>5</td>
<td>50.0 (7.5)*</td>
<td>1.6 (1.3)*</td>
<td>2.6 (2.3)*</td>
</tr>
<tr>
<td>Combination Rodenticides</td>
<td>3</td>
<td>93.3 (9.7)*</td>
<td>7.5 (1.6)*</td>
<td>6.2 (3.0)*</td>
</tr>
<tr>
<td>1st Generation Anticoagulant Rodenticides</td>
<td>4</td>
<td>32.5 (8.4)*</td>
<td>10.4 (1.6)*</td>
<td>16.7 (3.0)*</td>
</tr>
<tr>
<td>ANOVA Result</td>
<td></td>
<td>F&lt;sub&gt;2&lt;/sub&gt;, P&lt;sub&gt;0.05&lt;/sub&gt;</td>
<td>F&lt;sub&gt;2&lt;/sub&gt;, 10.01</td>
<td>F&lt;sub&gt;2&lt;/sub&gt;, 7.12</td>
</tr>
<tr>
<td>P value</td>
<td>0.0032</td>
<td>0.0067</td>
<td>0.0167</td>
<td></td>
</tr>
</tbody>
</table>

* Averages in each column with the same letter are not significantly different.
129–135.


