Grower Evaluation of California Ground Squirrel (*Spermophilus beecheyi*) Control using Anticoagulant Baits

Victor J. Kowalski
University of California Cooperative Extension – San Diego County, San Diego, California
Rachel Long
University of California Cooperative Extension – Yolo/Solano Counties, Woodland, California
Jim Sullins
University of California Cooperative Extension – Tulare County, Tulare, California
Sergio Garcia
University of California Cooperative Extension – San Benito County, Hollister, California
Terrell P. Salmon
University of California Cooperative Extension – San Diego County, San Diego, California

ABSTRACT: California ground squirrels continue to present a significant problem for many facets of California agriculture. The use of diphacinone- and chlorophacinone-treated baits remains the most frequent control method for ground squirrels in agricultural settings. Research suggests no difference in efficacy between the two bait types or between broadcast and spot baiting strategies or bait stations. However, these studies were limited in scope and were conducted exclusively on rangeland sites where there is limited availability of alternate food sources. Studies also suggest that a reduced baiting strategy may be as effective as current label recommendations, but this has received only limited attention in field research. We utilized a new approach in conducting field evaluations of anticoagulant baiting efficacy in different agricultural settings and locations throughout the state. We solicited agricultural producers as cooperators to participate in a field-based evaluation to determine if the reduced baiting strategies are effective under specific agricultural operating conditions. Cooperators were trained in a simple research design and monitored to ensure consistent data collection. The training program included a comprehensive manual on squirrel biology, behavior, and control, as well as information on toxicants and legal measures regarding endangered species. An informal survey was sent to cooperators at the end of the project to evaluate their opinions on the efficacy of control methods. We found no difference in efficacy between baiting methods or strategies. Differences in efficacy were found between chlorophacinone and diphacinone and efficacy was lower in nut orchards than in other settings. Despite no difference in efficacy between baiting methods, more cooperators indicated they would use bait stations than other methods in future ground squirrel control operations.

KEY WORDS: activity index, anticoagulant, bait station, broadcast baiting, California ground squirrel, chlorophacinone, cooperative research, diphacinone, *Spermophilus beecheyi*, spot baiting

Proc. 22nd Vertebr. Pest Conf. (R. M. Timm and J. M. O'Brien, Eds.) **Published at Univ. of Calif., Davis. 2006.** Pp. 142-147

INTRODUCTION

The California ground squirrel (*Spermophilus beecheyi*) has posed a problem for California's agriculture industry for many years (Gilson and Salmon 1990, Marsh 1998). Ground squirrels damage food crops by consuming them in the field or caching resources for later use (Salmon *et al.* 2006). Their burrow systems present infrastructure problems and may weaken levees and dams (Grinnell and Dixon 1918, Storer 1938, Marsh 1985), contribute to erosion (Longhurst 1957), and create hazards to livestock (Marsh 1998). In addition, the California ground squirrel is a known vector of various human diseases including bubonic plague (Salmon *et al.* 2006).

The most common method for California ground squirrel control in agricultural settings is the application of the grain-based anticoagulant baits diphacinone and chlorophacinone (Whisson *et al.* 2000). These baits are available in two concentrations (0.01% and 0.005% seed spreader, distributed by hand using a bait spoon, or placed in bait stations. Research suggests there is no difference in efficacy between bait strength, bait type, or application method (Baroch 1996, Salmon *et al.* 2002). However, these studies were limited to rangeland sites in central California that did not provide squirrels with other attractive food resources.

Previous comparisons of bait application frequency suggest that two bait applications, separated by three days, is as effective as the label instructions of three applications, two days apart (Whisson and Salmon 2002*a*,*b*). Our objective was to expand on previous field trials and make the same comparisons in multiple agricultural settings and environments where alternate food sources may be available. In addition, we compared the efficacy of the label application rate of three treatments, two days apart, with the alternate strategy of two treatments, four days apart. Reducing the number of baiting days could decrease potential secondary risk to non-target species as well as reduce the cost of baiting

The large sample size needed to account for increased site variation, and the overall logistics to complete these tests made previous approaches, like those employed by Salmon *et al.* (2002), impractical and cost prohibitive. We recruited the help of agricultural producers, landowners and other interested parties (hereafter "cooperators") to participate in a field-based evaluation project to determine if the proposed alternate baiting strategies are effective under specific commercial operating conditions. With cooperator participation, we were able to increase sample sizes over previous studies and include study sites from 10 counties throughout California. In addition, we were able to compare efficacy data from four different commodities and settings: nuts, grain crops, greens (row crops other than grasses or related commodities), and non-agricultural areas (i.e., parks, golf courses, etc.). For informational purposes, we conducted an informal follow-up survey to evaluate grower preferences for baiting strategies and contrasted those preferences with efficacy data.

MATERIALS AND METHODS

Study Area

Studies were conducted on private agricultural land in Orange, Sacramento, San Benito, San Diego, San Joaquin, Tulare, Yolo, and Ventura Counties (Figure 1). Field work, conducted by 24 cooperators and 11 Extension farm advisors, took place from late May until early November 2005.

Training Materials

We compiled information from the current ground squirrel Best Management Practices project (Salmon *et al.* 2003), and previous anticoagulant studies (Salmon *et al.* 2002) to create project manuals and multimedia presentations for use in training cooperators. The project manual distributed to cooperators included a summary of ground squirrel ecology and control methods. Cooperators were trained in rodenticide safety, endangered species concerns, selecting research sites, mapping research plots, conducting bait acceptance tests, surveying squirrel populations, treating sites with anticoagulant baits, carcass searching and disposal, and collecting and compiling data. The project workbooks were collected upon completion of the study.

Figure 1. California counties containing research plots.

Baiting Materials

We provided cooperators with bait and baiting equipment, including Ev-N-Spread 3200 seed spreaders (Earthway Products, Inc., Bristol, IN), 45.4-g bait spoons (⅓-cup), and inverted "T" bait stations. Prior to distribution, we calibrated the seed spreaders as described by Clark (1994), with minor modifications to accommodate the manual hand-crank spreaders, to distribute bait at the label rate of 11.4 kg/ha (a setting of "15" for these spreaders). For spot baiting, bait was distributed according to the label at 45.4 g bait scattered over 3.7-4.6 m^2 near active burrows. For spot and broadcast baiting, two strategies were employed using the 0.01% a.i. diphacinone and chlorophacinone. The first strategy followed the label instructions by performing applications on Days 1, 3, and 5 for spot baiting and on Days 1 and 3 for broadcast baiting. The alternate strategy was to apply bait on Days 1 and 5 for both methods. Bait stations were filled with approximately 2.3 kg of 0.005% a.i. diphacinone or chlorophacinone, checked daily, and re-filled as needed. We spot baited three plots with clean, untreated steam rolled oat groats to demonstrate the overall efficacy of anticoagulants and to check for other factors that may influence squirrel populations, such as aestivation or disease. All baits were obtained from the Fresno and King's County Agriculture Commissioners.

Data Collection and Analysis

As with the Salmon *et al.* (2002) and Baroch (1996) studies, we used a visual activity index adapted from Fagerstone (1983). This method requires five visual scans daily for three consecutive days, with the highest count for each day averaged over the three-day census period. Because we felt it inappropriate to ask our volunteer cooperators to spend a significant portion of their day conducting censuses, we developed an abridged survey method. By analyzing raw data from the Salmon *et al.* (2002) study, we determined that two scans on a single day prior to the first treatment and another 28 days later provided an index that was within 75% of the highest count obtained using the full three-day census method. The abridged method was tested in limited field trials (Kowalski, unpubl. data), and we were willing to accept this margin of error in exchange for the larger sample size and a more "user friendly" census method.

During the spring and early summer, the diet of California ground squirrels changes from green, leafy material to seeds (Marsh 1994). Grain baits should not be used until this change in diet has occurred. To determine whether ground squirrels were eating seeds, bait acceptance tests were performed. Five small piles of clean untreated squirrel oats were placed near five active burrows throughout each treatment area (Mahl and Salmon 2003) and marked with a colored, plastic flag. Baits were placed in the morning and checked for consumption in the afternoon of the same day. Research plots were considered ready for treatment if ≥75% of the bait had been consumed. If cooperators could not achieve ≥75% bait acceptance after one day, they were instructed to two days and try again. Two cooperators orchards in San Joaquin County.

Visual index count data was entered into Microsoft Excel (Microsoft Corp.). Percent efficacy (E) was calculated using the equation:

$$E = \{(Pre\text{-}Post)/pre\} \times 100\%$$

where "pre" and "post" refer to pre-treatment and post-treatment counts, respectively.

Data were checked for normality using a Chi-square goodness of fit test. Analysis of variance (ANOVA) was used to compare the amount of bait used for each strategy. All other data were analyzed using the Kruskall-Wallace non-parametric test for non-normally distributed data. Analysis was performed using JMP IN© 5.1 statistical software (Sall *et al.* 2005). Results were considered significant at $\alpha = 0.05$.

Follow-Up Survey

After collecting the data notebooks, an informal survey was sent to participants. In the survey, they were asked to categorize their impressions of the efficacy of the baiting methods they used as 1) very effective, 2) somewhat effective, or 3) not effective. Next, they were asked to indicate whether they would use these methods to control future ground squirrel problems with 1) yes, 2) maybe, and 3) no. These data were collected for informational purposes only and no statistical analyses were performed.

RESULTS

Twenty-four cooperators conducted baiting trials on 87 plots in 10 counties. Efficacy trended slightly higher for bait stations and broadcast baiting than for spot baiting (Table 1), however this difference was not statistically significant ($P = 0.3150$). No significant difference in efficacy was detected between the broadcast 1, 3; broadcast 1, 5; spot 1, 3, 5; or spot 1, 5 strategies ($P = 0.3687$), although the spot 1, 5 strategy had the lowest efficacy (Table 2).

Overall efficacy of anticoagulants was significantly lower in nut crops than in grains, greens, or in non-crop settings ($P = 0.0004$, Figure 2). Overall efficacy was higher for chlorophacinone than for diphacinone ($P < 0.0001$, Table 3). Our limited control plots showed an overall increase in the activity index ($P = 0.0126$). ANOVA showed no difference in the amount of bait used in each baiting strategy ($P = 0.4792$), although more bait

Table 1. Percent efficacy by baiting method.

Method	Mean % (SE)	*n*
Overall Broadcast	81.4 (5.4)	32
Overall Spot	74.7 (7.1)	29
Bait Stations	82.4 (6.7)	26

Table 2. Percent efficacy by baiting strategy.

Strategy	Mean % (SE)	*n*
Broadcast 1,3	83.3 (8.3)	13
Broadcast 1,5	80.1 (7.2)	19
Spot 1,3,5	87.6 (7.1)	14
Spot 1,5	87.6 (7.1)	15

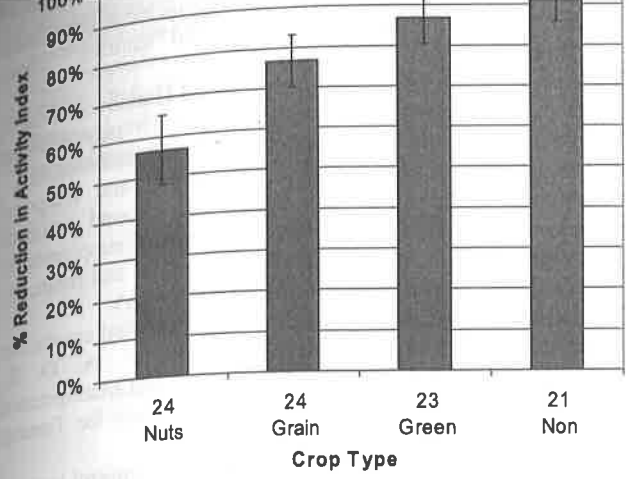

Figure 2. Mean efficacy grouped by crop type (error bars represent 1 standard error).

Table 3. Percent efficacy by bait type (active ingredient).

Bait Type	Mean % (SE)	*n*
Chlorophacinone	94.2 (3.1)	46
Diphacinone	63.0 (6.0)*	41

*statistically significant

Table 4. Average amount of bait used (kg) per ha.

Strategy	Kg Bait (SE)	*n*
Broadcast 1,3	9.8 (2.1)	6
Broadcast 1,5	8.1 (2.0)	8
Spot 1,3,5	8.6 (3.1)	5
Spot 1,5	6.6 (1.6)	6
Bait Stations	16.1 (7.1)	7

was used in bait station plots than in any other method (Table 4).

Of 24 surveys mailed to cooperators, 18 were completed and returned. Several cooperators used multiple baiting strategies, resulting in overlapping totals in the number of responses. For cooperators using broadcast baiting (n = 15), 33% felt the method was very effective, 60% reported the method was somewhat effective, and 7% said it was not effective. For spot baiting (n = 12), 50% reported it to be "very effective", 42% "somewhat effective", and 8% "not effective". For those using bait stations (n = 14), 50% chose "very effective", 42% reported the method as "somewhat effective", and 7% chose "not effective". For those who used broadcast baiting, 38% said they would use the method in the future, 46% said "maybe", and 15% said they would not use this method again. For spot baiting, 66% said "yes" to future use, 11% said "maybe", and 22% said "no". For those who used bait stations, 82% said they would use them in the future, and 9% each said "maybe" and "no" to future use of this method.

DISCUSSION

Our ability to involve cooperators in the implementation of this research allowed us to more fully evaluate the efficacy of anticoagulant baiting strategies in a variety of these differences was significant. Thus, our results were similar to results from previous studies. The higher efficacy of bait stations could also be the result of a larger amount of bait being used for this method. The noticeable, but statistically insignificant difference between the spot 1, 3, 5 and spot 1, 5 suggests there might be factors affecting the efficacies of these baiting strategies, but without further research they cannot be fully evaluated.

Overall, the highest efficacy for anticoagulant baits was seen in non-crop settings. Our data suggest that control efficacy decreases from non-crop settings, to row crops, grain crops, and nuts. This result is not surprising, since in agricultural settings there are multiple food sources available that may result in less bait consumption. This was particularly evident in nut orchards, which had the lowest overall efficacy in this study, thus supporting anecdotal reports that it is more difficult to control ground squirrels in nut orchards than in any other agricultural setting. It appears that conducting California ground squirrel control using seed-based baits becomes less effective when the squirrel's alternate food source contains seeds, the naturally preferred food resource for ground squirrels (Clark 1994, Dochtermann 2005). Finally, the results for the comparison in baiting strategies support previous research, which suggests that two treatments separated by three days (alternate strategy) is as effective as the current recommendation of three treatments at two-day intervals (Whisson and Salmon 2002*a*,*b*). An increase in the population index on our non-treated plots helped confirm that decreases on treated plots were the result of treatment with anticoagulant baits rather than other factors, such as aestivation or disease.

The difference in efficacy between chlorophacinone and diphacinone is somewhat surprising. It is probable that this difference is a result of a confounded experimental design, and not true difference in the efficacy of the toxicants. Previous lab (Whisson *et al.* 2000) and field (Salmon *et al.* 2002) studies have not detected any difference in efficacy between these two active ingredients. Due to logistical constraints, we could not achieve a balanced distribution of the two baits throughout our geographic range. This resulted in diphacinone being used primarily in the northern (Colusa, Sacramento, San Joaquin, and Yolo) and central (Mariposa, San Benito, and Tulare) counties, with the bulk of the chlorophacinone used in the southern counties (San Diego, Orange, and Ventura). Because there were more cooperators with nut orchards in the northern and central counties (22) than southern counties (3), more diphacinone was used in nut orchards, where there was lower overall efficacy.

While evaluating the survey data, we found an interesting discrepancy: although we found no differences in efficacy among the broadcast, spot, and bait station methods, cooperators indicated that they found spot baiting and bait stations to be more effective than broadcast baiting and were more likely to use the former methods (primarily bait stations) in future control efforts. This is interesting in light of the fact that the cooperators were directly involved in collecting efficacy data. Overall, more bait was used in bait stations, and despite

the fact that the data showed no difference in efficacy between baiting methods, cooperators were more likely to use bait stations in the future. Given that bait stations are a common control method, it is possible that cooperator perceptions of efficacy may be related to previous experiences (Marsh 1985).

MANAGEMENT IMPLICATIONS

The results of the baiting method comparison suggest that when attempting to control ground squirrels, one should choose an appropriate application method based on local conditions, time constraints, and economic concerns. Broadcast baiting seems to be best suited for larger, open areas and may cost less on a per-ha basis, while bait stations are more adaptable to cluttered or busy areas or in situations where time is a limiting factor. The convenience and economical feasibility of spot baiting is likely dependant upon the level of ground squirrel infestation and the size of the treatment area. Ground squirrel control using anticoagulant baits may not be economically feasible in sparsely infested areas or low-value crops, where the cost of control might exceed the damage incurred.

The findings involving spot baiting warrant future research to determine if the drop in efficacy can be attributed to palatable alternative food resources (nuts) or a smaller amount of bait available to squirrels (two applications instead of three). The crop-type findings also necessitate further investigation to clarify the role of favorable alternate food sources in ground squirrel control. Based on this study, we conclude that the reduced baiting strategy for spot and broadcast baiting is a viable alternative to current label recommendations in most situations. However, in nut orchards our results suggest the availability of a more palatable food source likely resulted in reduced bait consumption, and thus lower efficacy. Further research is required in this arena to make definitive conclusions.

Overall, we found the use of cooperators to assist in conducting research to be a valuable resource. This technique allowed us to conduct research in multiple agricultural settings throughout the state of California and provide valuable information on the efficacy of using anticoagulant-treated baits in ground squirrel control.

ACKNOWLEDGEMENTS

Funding was provided by the California Dept. of Food and Agriculture's Vertebrate Pest Control Research Advisory Committee, Contract #03-0326. We express our deep gratitude to our staff: A. Berentsen, T. Ellis, A. Sartain, R. Miller, S. Lawrence, P. Gorenzel, G. Flores, and S. Parker. Special thanks to the Farm Advisors who assisted us in selecting participants: G. Bender, D. Shaw, R. Lobo, J. Kabashima, B. Faber, R. Phillips, M. Freeman, K. Robb, and J. Grant. We are grateful to D. Schnabel, R. Baker, and R. Marsh for their contributions and to our 24 cooperators: D. Albert, G. Bessinger, E. Brill, E. & B. Dockins, S. Fisher, M. Hillebrecht, J. Jackson, R. Koetsier, W. Latimer, G. & R. McDonald, D. McPeck, D. Peters, H. Sada, C. Stone, D. Sehnert, S. Schwabaker, B. Thompson, T. Wheyland, and B. Wohlford, without whom this research could not have been completed. This project was conducted under the UC Davis

LITERATURE CITED

BAROCH, J. A. 1996. Field efficacy of diphacinone grain used to control the California ground squirrel. Vertebr. Pest Conf. 17:322-325.

CLARK, J. P. 1994. Vertebrate Pest Control Handbook, Ed. Calif. Dept. of Food and Agriculture, Division of Industry, Integrated Pest Control Branch. Sacramento,

DOCHTERMANN, E. A. 2005. The spatial and temp foraging behavior of the California ground squ (*Spermophilus beecheyi*) under conditions of suppleme resources: implications for control programs and meth M.S. thesis, University of California, Davis, CA.

FAGERSTONE, K. A. 1983. An evaluation of visual counts censusing ground squirrels. Pp. 239-246 *in*: D. Kaukeinen (Ed.), Vertebrate Pest Control and Managem Materials, ASTM STP 817, American Society for Test and Materials, Philadelphia, PA.

GILSON, A., AND T. P. SALMON. 1990. Ground squirrel burn destruction: control implications. Proc. Vertebr. Pest Co 14:97-98.

GRINNELL, J., AND J. DIXON. 1918. Natural history of t ground squirrels of California. Bull. Calif. State Comm Hort. 7:597-708.

LONGHURST, W. M. 1957. A history of squirrel burrow gul formation in relation to grazing. J. Range Manage. 10:18 184.

MAHL, U. H., AND T. P. SALMON. 2003. Within-burrow ar surface feeding of oat grain by California ground squirrel Proc. Wildl. Damage Manage. Conf. 10:370-377.

MARSH, R. E. 1985. Competition of rodents and other sma mammals with livestock in the United States. Pp. 485-50 *in*: S. M. Gaafar, W. E. Howard, and R. E. Marsh (Eds.) Parasites, Pests and Predators. Elsevier Science Publishers B.V., Amsterdam, The Netherlands.

MARSH, R. E. 1994. Current (1994) ground squirrel control strategies in California. Proc. Vertebr. Pest Conf. 16:61-65.

MARSH, R. E. 1998. Historical review of ground squirrel crop damage in California. Int. Biodeter. Biodegrad. 42:93-99.

SALL, J., L. CREIGHTON, AND A. LEHMAN. 2005. JMP® Start Statistics: A Guide to Statistics and Data Analysis Using JMP® and JMP IN® Software, Third Ed. Brooks/Cole-Thompson Learning, Belmont, CA. 560 pp.

SALMON, T. P., D. A. WHISSON, AND W. P. GORENZEL. 2002. Field efficacy studies comparing 0.005% and 0.01% diphacinone and chlorophacinone baits for controlling California ground squirrels (*Spermophilus beecheyi*). Report to Calif. Dept. of Food and Agriculture, Contract 00-0471. (Unpubl.) 131 pp.

SALMON, T. P., D. A. WHISSON, AND W. P. GORENZEL. 2003. Best management practices (BMP) for California ground squirrel control. Report to Calif. Dept. of Food and Agriculture, Contract 98-0533. (Unpubl.) 210 pp.

SALMON, T. P., D. A. WHISSON, AND R. E. MARSH. 2006. Wildlife Pest Control Around Gardens and Homes, Second Ed. Publication 21385, University of California, Agriculture and Natural Resources, Oakland, CA. 122 pp.

STORER, T. I. 1938. Control of injurious rodents in California. Calif. Agricural Extension Service Cir. 79, Davis, CA.

WHISSON, D. A., AND T. P. SALMON. 2002*a*. Effect of diphacinone on blood coagulation in *Spermophilus beecheyi* as a basis for determining optimal timing of field bait applications. Pest Manage. Sci. 58:736-738.

WHISSON, D. [illegible] of applications and amount consumed on mortality of California ground squirrels (*Spermophilus beecheyi*). Crop Protect. 21:885-889.
WHISSON, D. A., T. P. SALMON, AND W. P. GORENZEL. 2000. Reduced risk anticoagulant baiting strategies for California ground squirrels. Proc. Vertebr. Pest Conf. 19:362-364.