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# Strychnine Baits to Control Richardson's Ground Squirrels: An Old Story, a New Twist

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**Abstract:** We conducted field trials during 2000 to compare the effectiveness of 0.4% strychnine commercial ready-to-use (RTU) hull-less oat and canary seed (CS) bait to control Richardson's ground squirrels (*Spermophilus richardsonii*) and during 2001 to compare the effectiveness of RTU and freshly prepared from concentrate (FFC) hull-less oat bait. Each study was conducted at 30 locations in ungrazed pastures and unharvested forage crops in southern and central Alberta from mid-June to mid-August. Effectiveness was measured using pre and post treatment visual, dead and in 2000 active burrow counts. In both trials visual counts increased with daily maximum temperature ( $P < 0.05$ ), decreased with rainfall intensity ( $P < 0.001$ ) and were not affected by wind speed or start time ( $P > 0.05$ ). The 2000 field trials indicated that adjusted visual counts of ground squirrels were significantly lower than controls in CS than RTU baited plots (77.6% and 59.6% reduction, respectively,  $P = 0.002$ ) and the mean number of dead ground squirrels was higher (6.43 and 2.13, respectively,  $P < 0.001$ ). Additionally, there were significantly ( $P < 0.001$ ) fewer re-opened holes by ground squirrels in the RTU (41.6%) and CS (71.7%) treated plots compared to control plots. All 3 measures indicated greater effectiveness using canary seed than hull-less oat bait. The 2001 field trials indicated that adjusted visual counts of ground squirrels were significantly lower than controls in FFC than RTU baited plots (92.7% and 65.6% reductions, respectively,  $P < 0.0001$ ) and the adjusted mean number of dead ground squirrels was higher (4.28 and 1.21, respectively,  $P < 0.0001$ ). Both measures indicated greater effectiveness using freshly prepared from concentrate than manufactured ready to use hull-less oat strychnine baits. In conclusion, we advocate further research into freshness as bait freshness may be the single most important factor affecting effectiveness

**Key Words:** Richardson's ground squirrel, strychnine, canary seed, ready to use bait, hull-less oats, bait freshness, dead counts, visual counts

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## INTRODUCTION

Richardson's ground squirrel (*Spermophilus richardsonii*) is the most widespread, occupies the most diverse habitat, and is the most colonial of the 5 of species of ground squirrel found in Alberta (Smith 1993). This species causes the most damage to pastures and forage, cereal grain, and oil seed crops. The greatest economic loss to agricultural production is through consumption and destruction of forage and cereal plants. Other losses to productivity include crop loss due to mounds and trails, damage to harvesting equipment, and downtime for repairs. The most extensive damage occurs as a result of the synchrony of young sprouting crops (often less than 20 cm high) and the above ground emergence of weaned, juvenile squirrels.

In Alberta agricultural systems, larger scale control of Richardson's ground squirrels is done primarily through the use of toxicants in food baits. Registered toxicants for use in Canada include strychnine alkaloid, cholecalciferol, zinc phosphide, and the anti-coagulants diphacinone and chlorophacinone (Canada Department of Health, Pest Management Regulatory Agency (PMRA) Web Site).

In the mid-1900s, 2% strychnine was manufactured for convenient use, as a liquid concentrate in a suspension of light mineral oil or water and a scented food attractant such as anise or licorice. This product was effective in controlling ground squirrels, but because of off-label and other misuse during the mid 1980s the product was withdrawn from the marketplace in 1993. It was replaced by pre-mixed bait, comprised of strychnine and grain bait, primarily hull-less oats (*Avena sativa*). The new bait was formulated and registered as 0.4% ready to use (RTU) strychnine bait.

Since that time, there have been numerous complaints of poor performance of RTU strychnine baits by farmers and ranchers who advocate re-registration of the 2% concentrate. Cafeteria style feeding trials in Alberta indicated that canary seed (*Phalaris canariensis*) (CS) was a more palatable substrate to conventional substrates used in ground squirrel RTU baits including hull-less oats wheat or barley (Bourne 1999). Therefore we tested the effectiveness of RTU versus freshly prepared canary seed, and because bait freshness was at issue, we tested freshly prepared (from 2% strychnine concentrate) hull-less oat bait versus RTU bait to control Richardson's ground squirrels.

## **METHODS**

### **Study Site**

This study was conducted between mid June and mid August, 2000 and 2001, when all age classes of ground squirrels were foraging above-ground. The study was conducted in ungrazed pastures and unharvested forage crops in south (Cardston area) and central (Kinsella-Elk Point-Smoky Lake area) Alberta. The temperate weather patterns of both regions are similar with winter lasting up to 120 days in the south and up to 160 days in the central region (Alberta Agriculture 1999). Average annual rainfall varied between the two regions with the south receiving an average 15 cm and the central region 30 cm. No livestock were permitted on the study area prior to the study and forage harvesting was delayed until study completion.

Three measures of bait performance were used: visual, dead, and hole activity counts (in 2000 only).

### **Visual Counts**

Fifteen census locations were established in the south and central areas, respectively. Each of the census locations was large enough to contain three 100 × 100-m treatment plots with a minimum 100-m buffer strip between plots. The four cardinal corners of each plot were identified with colored wire flags. Different colors were used for different treatment plots. A central observation point was established for each census location and either a parked vehicle or a 3-m observation tower was erected for visual counting. The distance from the central observation point to the treatment plots was between 50 and 65 m to reduce interference with ground squirrel movements. At each census location, treatment plots were randomly assigned in 2000 to receive the RTU bait, CS bait, or untreated control (C) with no bait; and in 2001 RTU bait, fresh from concentrate (FFC) bait, or untreated control (C) with no bait.

Visual counts of ground squirrels were made from the observation point following the guidelines set out by Fagerstone (1983). Visual counts were carried out on consecutive days 1, 2, and 3 pre-treatment and on days 5, 6, and 7 post-treatment. Plots were baited on day 4 by placing 15 ml (one tablespoon) of bait directly into each burrow. Ground squirrel numbers were recorded using binoculars from each of 3 consecutive sweeps, with a 5-minute interval between sweeps, across each treatment plot on each count day. The daily maximum temperature was recorded according to local meteorologist forecasts and wind velocity and rainfall were described as calm, light (<9 km/h), moderate (10-29 km/h) or high (>30 km/h) and none, drizzle, light rain, or heavy rain, respectively.

### **Dead Counts**

Dead counts were simply the total number of dead ground squirrels found on each plot of the 30 census areas used for the visual counts. Dead ground squirrels were counted and collected each day post-treatment (days 5, 6, and 7) preceding visual counts.

### **Hole Activity Counts**

Hole (burrow system entrance) activity counts were measured at 8 additional locations in 2000 only. Four locations each consisted of a CS baited plot and an unbaited control plot and 4 locations each consisted of a RTU baited plot and an unbaited control plot. Fifty open holes on each plot at each location were identified with colored, sequentially numbered wire flags. On day 1, these holes were covered with soil, checked for activity and active holes were baited. The active holes from day 1 were again covered with soil and checked again for activity on day 3.

### **Baits**

The RTU bait used in 2000 was “Fairview Gopher-Cop” (Maxim Chemicals, 1305 Halifax Street, Regina, Saskatchewan, S4P 1T9). The CS bait was freshly custom manufactured for this study by Maxim Chemical. Ingredients and manufacturing protocols were consistent with the production of the RTU bait. The RTU bait was verified at 0.4% + 0.05 strychnine and the CS bait at 0.364% strychnine by Norwest Laboratories, Surrey, B.C.

The RTU bait and the strychnine 2% concentrate used for the 2001 study were manufactured by Nu-Gro Corporation (10 Craig Street, Brantford, Ontario, N3R 7J1). Both products were aqueous based, contained emulsifiers and licorice flavoring, and were mixed to 0.4% strychnine on oat groats (mechanically de-hulled oats). The FFC was mixed in batches in 22.5-L pails, hand-stirred for a minimum 10 minutes, and used within 2 h of mixing.

### **Statistical Analyses**

An equally-spaced repeated measures model for the sweep mean measure, which represents the mean number of ground squirrels seen over the 3 daily sweeps for each treatment (C, CS, RTU in 2000 and C, RTU and FFC in 2001), day (5, 6, 7) and replications (30 locations) was fit using SAS mixed procedure (Littell et al. 1996). Treatment, day, and treatment by day were included as fixed effects while replication and replication by treatment were included as random effects and the pre-treatment sweep mean was included as a covariate in the model. A similar model was fit using maximum rather than mean values. Other factors included in the model were categorical measures of precipitation and wind, daily maximum temperature, and start time. A log-transformation was used on the sweep mean and sweep maximum dependent variables and the pretreatment covariate to normalize the data. Tukey-Kramer adjusted comparisons were used to test for pair-wise differences.

The SAS Mixed procedure (Littell et al. 1996) was also used to fit a model for the number of ground squirrels found dead at the end of the study in 2000 and on day 5 and 6 (no dead were found on day 7) in 2001 for each treatment group and replicate (location). A log-transformation was used on the number of dead in order to normalize the data. Treatment in 2000 and treatment, day, and treatment by day interactions in 2001 were included as a fixed effect while replicate and replicate by treatment in 2000 and replicate and replicate by

treatment interaction in 2001 were included as random effects. The pre-treatment sweep mean was included as a covariate in the models. A similar model was fitted using sweep maximum instead of sweep means.

In 2000 a separate study on hole activity measured by counting the number of holes re-opened following fill-ins was used to contrast the efficiency the RTU and CS treatments. Chi-square tests were used to determine if there was an association between the number of holes re-opened and the treatment. Each treatment (RTU and CS) was compared to matched controls.

## RESULTS AND DISCUSSION

Because there were no differences between visual and dead counts between northern and southern census areas ( $P > 0.05$ ), location was not incorporated into any of the statistical models.

### Visual Counts

The mean and maximum number of ground squirrels counted on sweeps were highly correlated ( $r = 0.99$ ,  $P < 0.01$ ). Since the analyses using both parameters produced similar results only the mean results are presented in this report.

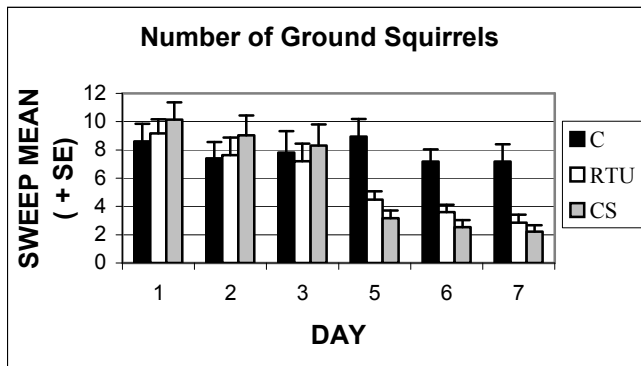


Figure 1. Mean number of ground squirrel counted per sweep per day in control (C) and ready to use (RTU) and canary seed (CS) strychnine (0.4%) baited plots in Alberta, June to August 2000.

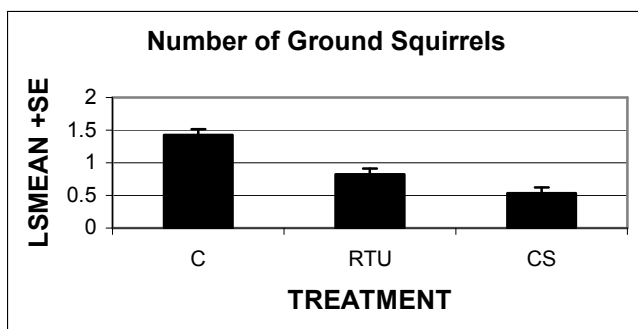


Figure 2. Adjusted log-transformed mean number of ground squirrels counted per sweep on control (C) and ready to use (RTU) and canary seed (CS) strychnine (0.4%) baited plots in Alberta, June to August 2000.

The models used were:

$$\begin{aligned} \text{LOG}_e(\text{SWEEP MEAN} + 1) = & \text{TREATMENT} + \text{DAY} + \\ & \text{TREATMENT} \times \text{DAY} + \text{LOG}_e \text{PRE-TREATMENT} \\ & \text{SWEEP MEAN} + \text{REPLICATE} + \text{REPLICATE} \times \\ & \text{TREATMENT} + \text{WIND} + \text{PRECIPITATION} + \\ & \text{TEMPERATURE} + \text{START TIME}. \end{aligned}$$

Since wind and start time were not significant in either year they were dropped from the models.

### RTU and CS 2000

Treatment ( $F = 78.65$ ,  $P < 0.001$ ), pre-treatment sweep mean ( $F = 21.46$ ,  $P < 0.001$ ), precipitation ( $F = 78.95$ ,  $P < 0.001$ ), and temperature ( $F = 3.69$ ,  $P = 0.056$ ) were all significant. There was no significant difference between days ( $F = 0.41$ ,  $P = 0.666$ ) or treatment-day interaction effects ( $F = 0.77$ ,  $P = 0.545$ , Figure 1). RTU resulted in a significantly lower mean sweep count than the control ( $P < 0.001$ ), while CS resulted in a significantly lower mean sweep count than both the control and RTU (both  $P < 0.001$ , Figure 2). Back-transformation of the adjusted mean number of ground squirrels indicated a reduction of 59.6% and 77.6% from control levels for RTU and CS, respectively.

### RTU and FFC 2001

Treatment ( $F = 95.93$ ,  $P < 0.0001$ ), pre-treatment sweep mean ( $F = 55.10$ ,  $P < 0.0001$ ), precipitation ( $F = 36.19$ ,  $P < 0.0001$ ), and temperature ( $F = 12.95$ ,  $P = 0.0004$ ) were all significant. There were no significant differences between days ( $F = 2.32$ ,  $P = 0.1014$ ) or treatment-day interaction effects ( $F = 1.07$ ,  $P = 0.3724$ , Figure 3). RTU resulted in a significantly lower mean sweep count than the control ( $P < 0.0001$ ), while FFC resulted in a significantly lower mean sweep count than both the control and RTU (both  $P < 0.0001$ , Figure 4). Back-transformation of the adjusted mean number of ground squirrels indicated a reduction of 65.6% and 92.7% from control levels for RTU and FFC, respectively.

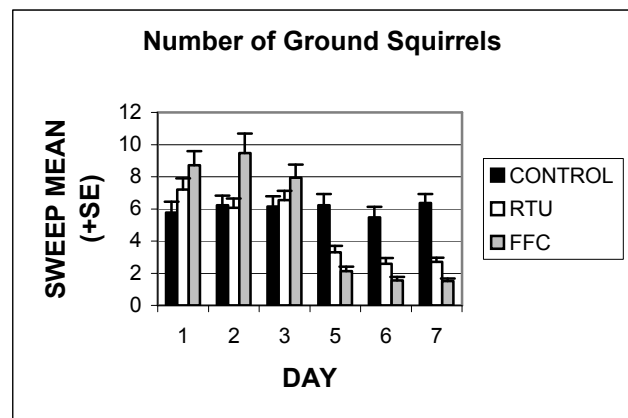


Figure 3. Mean number of ground squirrels counted per sweep per day in control and ready to use (RTU) and fresh from concentrate (FFC) strychnine (0.4%) baited plots in Alberta, June to August 2001.

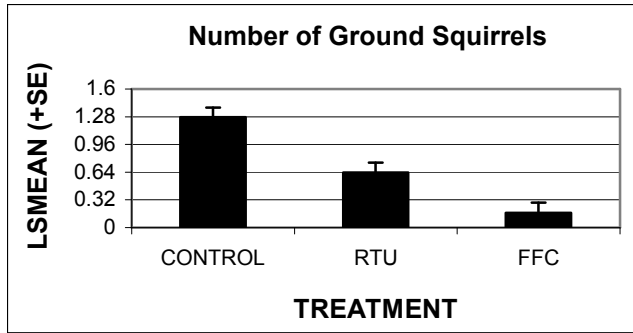


Figure 4. Adjusted log-transformed mean number of ground squirrels counted per sweep on control and ready to use (RTU) and fresh from concentrate (FFC) strychnine (0.4%) baited plots in Alberta, June to August 2001.

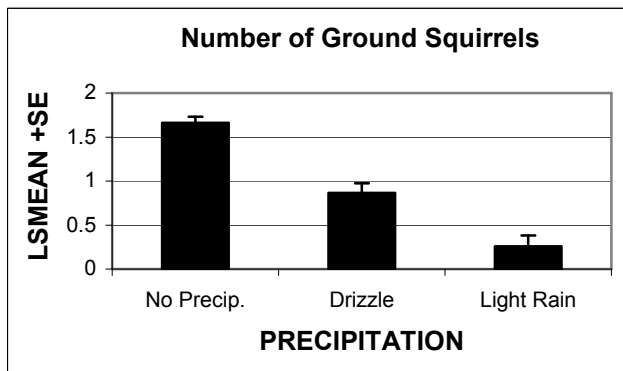


Figure 5. Comparison of adjusted log-transformed mean number of ground squirrels counted per sweep per category of precipitation (0 = no precipitation, 1 = drizzle, 2 = light rain) in Alberta during June to August 2000.

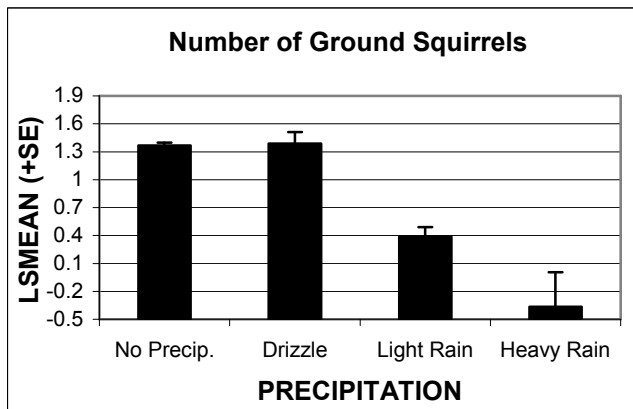


Figure 6. Comparison of log-transformed mean number of ground squirrels counted per sweep per category of precipitation (0 = no precipitation, 1 = drizzle, 2 = light rain, 3 = heavy rain) in Alberta, June to August 2001.

In both years, higher levels of precipitation resulted in lower mean sweep counts than lower levels of precipitation (Figure 5 and 6). The log sweep mean was positively correlated with the log pre-treatment sweep mean and temperature ( $r = 0.19$  and  $r = 0.46$ , respectively in 2000; and  $r = 0.22$ ,  $P < 0.01$  and  $r = 0.11$ ,  $P = 0.06$ , respectively in 2001). Weather conditions played a large factor in above ground activity. Ground squirrel numbers, seen above ground, increased with ambient temperature and decreased with rainfall intensity. Wind and time of day between 0815 and 1530 h did not affect visual counts.

#### Dead Counts

The model used in 2000 was:

$$LN(DEADS + 1) = TREATMENT + PRE-TREATMENT SWEEP MEAN + REPLICATE + REPLICATE \times TREATMENT.$$

Since start time was not significant, it was removed from the model. Both treatment and pre-treatment sweep mean covariates were significant ( $P < 0.001$ ). RTU had a significantly higher number of dead ground squirrels than the control ( $P < 0.001$ ) and CS had a significantly higher number of dead ground squirrels than both the control and the RTU ( $P < 0.001$ , Figure 7). The back-transformed adjusted mean number of dead ground squirrels per plot was 2.13 and 6.43 for the RTU and CS treatments, respectively.

The model used in 2001 was:

$$LOG_e(DEADS + 1) = TREATMENT + DAY + TREATMENT \times DAY + LOG_e PRE-TREATMENT SWEEP MEAN + REPLICATE + REPLICATE \times TREATMENT.$$

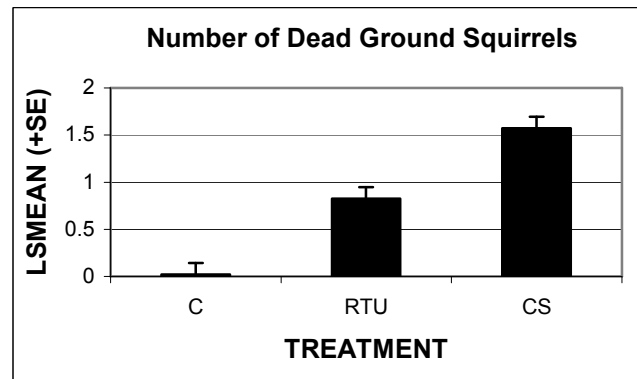
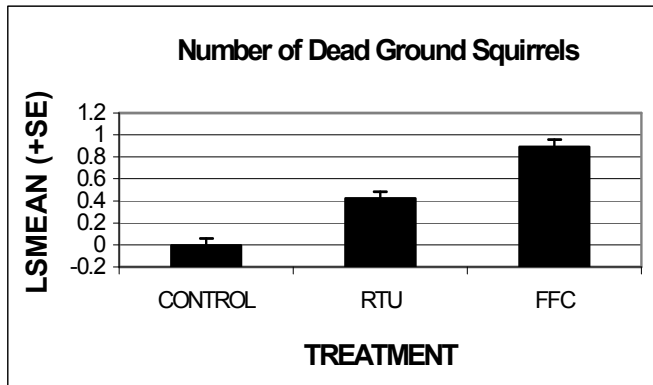


Figure 7. Adjusted log-transformed mean number of ground squirrels found dead in control (C) and ready to use (RTU) and canary seed (CS) strychnine (0.4%) baited plots in Alberta during June to August 2000.

Treatment ( $F = 50.63$ ,  $P < 0.0001$ ), day ( $F = 159.09$ ,  $P < 0.0001$ ) and treatment by day interaction ( $F = 53.85$ ,  $P < 0.0001$ ) were significant. There was no significant effect for the pre treatment sweep mean ( $F = 0.27$ ,  $P = 0.6054$ ). RTU had a significantly higher number of dead ground squirrels than the control ( $P < 0.0001$ ) and FFC had a significantly higher number of dead ground squirrels than both the control and the RTU ( $P < 0.0001$ , Figure 8). The number of dead



**Figure 8. Adjusted log-transformed mean number of ground squirrels found dead in control and ready to use (RTU) and fresh from concentrate (FFC) strychnine (0.4%) baited plots in Alberta, June to August 2001.**

ground squirrels found on day 5 (N = 210) were significantly higher ( $P < 0.0001$ ) than on day 6 (N = 11). No dead ground squirrels were found on day 7. The back-transformed adjusted mean number of dead ground squirrels found per plot was 1.21 and 4.28 for the RTU and FFC treatments ( $P < 0.0001$ ), respectively.

In 2000 and 2001, 257 and 221 dead ground squirrels, respectively, were found above ground on the plots following treatment. Most carcasses appeared fresh and untouched by scavengers. Non-target species found on the plots included 12 dead deer mice (*Peromyscus maniculatus*) and 1 disabled herring gull (*Larus argentatus*) in 2000 and 7 deer mice in 2001. A field autopsy of the gull revealed a partially decomposed deer mouse in the stomach. Dead ground squirrels and non-target species were not analyzed for the presence of strychnine. Several species of raptors, scavenging birds and mammals were observed in the study area. Raptors included Swainson's hawk (*Buteo swainsoni*), red-tailed hawk (*Buteo jamaicensis*), and golden eagle (*Aquila chrysaetos*); scavenging birds included crow (*Corvus brachyrhynchos*) and magpie (*Pica pica*); and mammals included coyote (*Canis latrans*), red fox (*Vulpes vulpes*), striped skunk (*Mephitis mephitis*), badger (*Taxidea taxus*), and ermine (*Mustela erminea*).

### Hole Activity Counts

There were significantly fewer holes re-opened by ground squirrels (active holes) in the RTU (53.3%) treated plots than in the control (94.9%) (Chi-Square = 62.2,  $P < 0.001$ , Table 1) and significantly fewer active holes in the CS treated plots (24.3%) than the control (95.9%) (Chi-Square = 136.5,  $P < 0.001$ , Table 1). Overall reduction of ground squirrel activity was 41.6% for the RTU and 71.7% for the CS.

### RECOMMENDATIONS

In 2000, all 3 effectiveness measures indicated that freshly prepared CS was more effective than RTU. In 2001,

**Table 1. Number of ground squirrel burrow holes opened (active) 24 h following application of 0.4 % strychnine ready to use (RTU) and canary seed (CS) baits in Alberta during June to August 2000.**

Hole Status	RTU	RTU Control	CS	CS Control
Opened	73	131	33	118
Not Opened	64	7	103	5

both activity and dead counts indicated that FFC was more effective than RTU. CS in 2000 and FFC in 2001 met the Environmental Protection Agency's rodenticide effectiveness standard of 70% reduction (EPA 1994) whereas RTU in 2000 and 2001 did not. RTU may still be effective in controlling ground squirrels earlier during emergence in the spring when alternate food sources are unavailable and palatability is less important (Salmon et al. 2000). However, we believe that freshness is the critical component linked to effectiveness of food baits for control of Richardson's ground squirrels and potentially other problem wildlife species.

Problems of non-target and secondary poisoning, arguably the most indefensible issues surrounding the use of strychnine poison, will not likely change and no doubt will continue to be a central issue. Other issues such as indiscriminate killing of wildlife, humaneness of poisons, and food safety issues will also play a major role in the future use of strychnine toxicants. With the inevitable upturn and expansion of the livestock industry in Alberta, the demand and competition for forage and cereal crop production will no doubt intensify. Needless to say, so will the requirements to protect crops from fossorial rodent damage. Clearly, other equally or more effective means of ground squirrel damage control must be investigated and developed to manage ground squirrels. Future research should include investigation of different toxicants that are more selective to the target species and that do not result in the availability of toxic carcasses for non-target uptake. Judicious use of selective toxicants, coupled with improved farming practices, are needed to achieve environmentally sustainable long-term management and control of crop damage.

Until we can ascertain the role of strychnine concentration, water content of the bait, and other freshness characteristics of the bait and test FFC on oat groats against FFC CS to ascertain the role of the bait substrate, we recommend use of 0.4% FFC and freshly prepared CS strychnine baits for control of Richardson's ground squirrel in mid to late summer in Alberta.

Secondary poisoning issues can be partly alleviated by immediate removal of the target and non-target carcasses. Based on the data, most of the carcasses were found within 24 h of treatment. We recommend mandatory carcass removal the evening, next morning, and next evening following treatment.

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