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Title: EFFICACY OF SODIUM FLUOROACETATE IN REDUCING GROUND SQUIRREL DAMAGE TO ALFALFA

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Damage by Belding's ground squirrel (Spermophilus beldingi) to alfalfa (Medicago sativa) and the efficacies of various poisoning regimes to reduce damage were evaluated during March-July, 1976 and 1977. Regimes examined were designed to measure the effect of 3 variables on damage to alfalfa caused by squirrels, including; timing of application, in early or late spring; the number of applications, 1 or 2; and the inclusion of a border strip around the field on which poison baits are also applied.

Neither single nor multiple applications of poisoned baits resulted in significant ($P > 0.1$) control of ground squirrel damage to alfalfa in 1976. However, significant ($P < 0.05$) reductions of damage were obtained in 1977 with multiple applications and when both the field and a 60 m wide border were treated with poisoned baits.

Belding's ground squirrels caused an average of 46 percent loss of the first harvest of alfalfa in untreated fileds. Maximum application of poisoned baits reduced this loss to an average loss of 25 percent. Control of ground squirrel damage achieved between different fields and treatments was highly variable, and was directly related to the number of times poison was applied and whether or not a border strip was treated.

Efficacy of Sodium Fluoroacetate in Reducing Ground Squirrel Damage to Alfalfa

by

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As for me, all I know is that I know nothing.

Socrates

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EFFICACY OF SODIUM FLUOROACETATE IN REDUCING GROUND SQUIRREL DAMAGE TO ALFALFA

INTRODUCTION

Control of damage caused by agricultural pests involves a number of basic steps (Howard 1958). The identity of the pest must be determined. Estimates of actual and potential damage (lower crop yields) must be made. Finally, efficacies and costs of available control methods must be compared with projected damages to determine if control is justified economically.

Belding's ground squirrel is an agricultural pest in Oregon and northern California (Howell 1938, Turner 1972). At present, scant information exists concerning the magnitude of damage caused to crops by this squirrel. Sauer's (1976) estimate of a 61% reduction in the yield of a crop of alfalfa and bromegrass (Bromus spp.) over a period of 44 days in northern California is the only quantified account of Belding's ground squirrel damage to alfalfa.

Poisoning is the primary method for control of ground squirrels in alfalfa fields (White 1972). The effectiveness, however, of poisoning to reduce crop losses to ground squirrels has not been quantified. Specifically, the degree of reduction of alfalfa loss to ground squirrels associated with the timing and frequency of poisoning is unknown. Ideally, poisoning should be conducted: 1) when ground squirrels are

most susceptible; 2) before losses of alfalfa become economically unacceptable; and 3) a minimal number of times to reduce costs of control efforts and hazards to non-target wildlife.

The first period for potentially effective posioning is early spring when adult squirrels first readily accept bait (Paul Hatchett pers. comm. 1976, Sullins 1978) and damage to alfalfa is just beginning (Rodney Todd pers. comm. 1976). The first period of bait acceptance corresponds with a period of physiological change in the squirrels, from utilization of stored body fat to utilization of forage to meet energy needs. There is evidence to indicate that this change is brought about by two factors: a steady increase in the local food supply and several days of warm weather in succession (Heller and Poulson 1970, Morton 1975). The second period is in late May when young emerge from burrows and all age classes of squirrels have access to poison baits. Many farmers, who equate large numbers of ground squirrels killed with greatest reduction in crop loss, prefer to bait in May when squirrel density is highest and numbers of squirrels that can be killed by poison baits is greatest (Paul Hatchett pers. comm. 1976). Baiting in early spring and again in May might result in the greatest reduction in crop loss by: 1) killing a large proportion of adult squirrels immediately prior to initiation of feeding on alfalfa; and 2) killing "surviving" adults and young born to adult females that escape poisoning in April.

The effect of baiting a border strip around squirrel-infested fields on crop loss was unknown: such treatment might further reduce the level of loss of alfalfa by killing squirrels living in fringe areas around fields. Normally, poison baits are applied only on alfalfa fields, leaving them susceptible to losses incurred by ground squirrels entering fields from adjacent areas. The width of the border strip should be at least 60 m, which exceeds the normal movement radius (40 m) of adult Belding's ground squirrels (Turner 1972).

OBJECTIVE

The objective of this study was to compare the relative efficacies of several poisoning regimes to reduce losses of alfalfa caused by Belding's ground squirrels. Regimes were created by varying: timing of application of poison baits (before or after juvenile squirrels emerge from burrows); number of applications of toxic baits (one or two); and inclusion of a baited boundary strip around treated fields.

STUDY AREA

Thirteen privately owned alfalfa fields located in southern Klamath county were used as experimental units during this study (Figure 1). All fields were within 56 km of Klamath Falls, Oregon. All fields were irrigated by sprinkler systems. Of these 13 fields, 8 were used in 1976 and 11 were used in 1977 (Table 1). All fields except 1, 12, and 13 were bordered on at least one side by non-agricultural land. Non-agricultural plant communities were dominated by sagebrush (Artemesia spp.), juniper (Juniperus occidentalis) and ponderosa pine (Pinus ponderosa) (Table 1).

All fields contained 4 to 7 year old alfalfa stands and had a history of loss of alfalfa to ground squirrels. Prior to selection of a field for study, one count of squirrels was made for a 15 minute period in early March from a central location within candidate fields. Only fields with 30 or more ground squirrel sightings were selected as study fields.

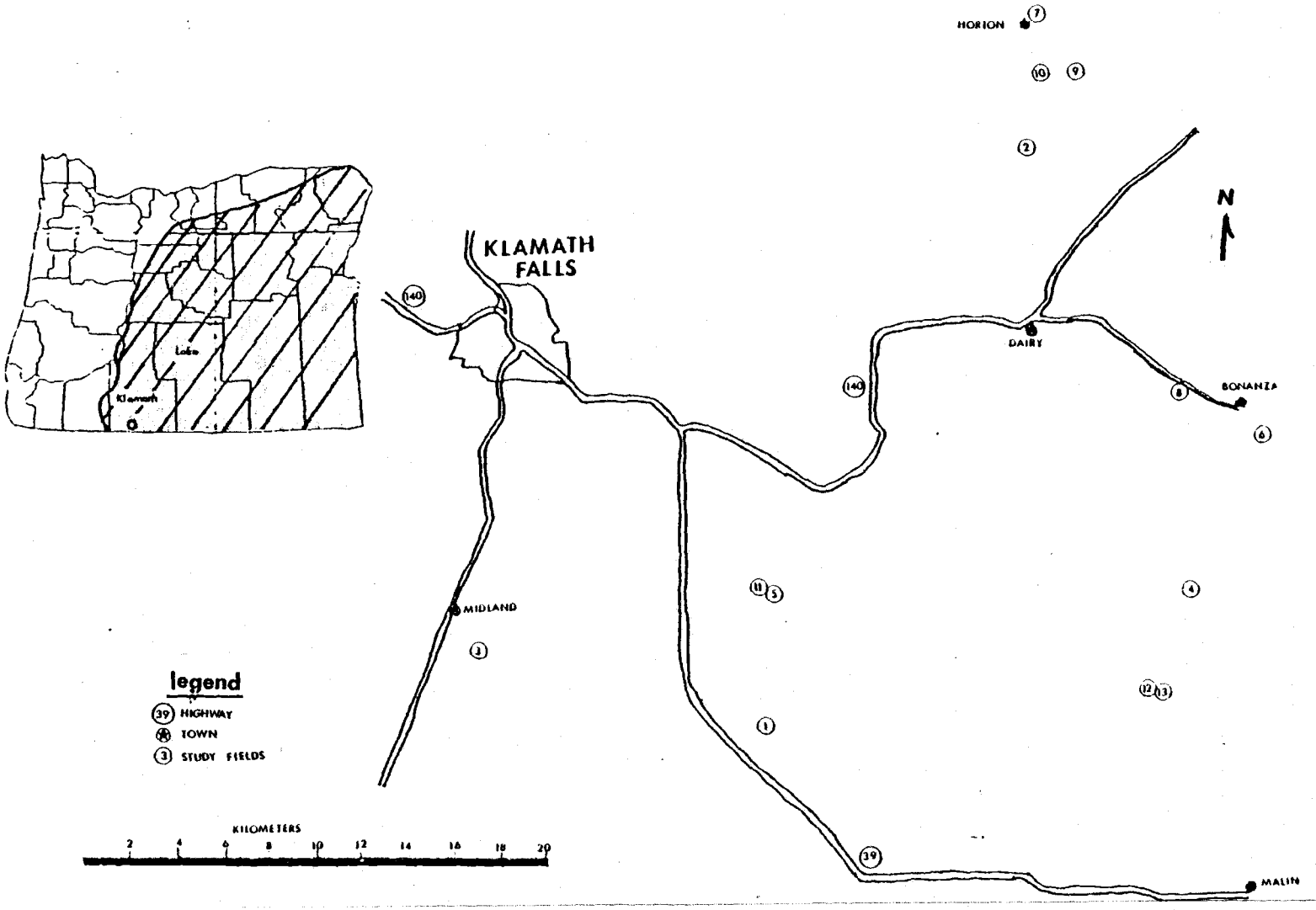

Figure 1. Map showing the location of experimental fields in Klamath County. Insert shows distribution of Belding's ground squirrel in Oregon (Turner 1972).

Table 1. Characteristics of experimental fields used in 1976-77 in Klamath County, Oregon.

Field No. 1976	Field No. 1977	Location	Size (ha)	Altitude (m)[a]	Soil Type[a]	Bordering Plant Association[b]
1	1	R. 10E. T. 40S 21	8.1	1250	Packed Loam	Agricultural
2	-	R. 11E. T. 38S. 3	4.0	1265	Sandy Loam	Pinus ponderosa/Purshia tridentata
3	3	R. 9E. T. 40S. 6	12.1	1219	Alkali Heavy Loam	Abandoned agricultural field
4	4	R. 12E. T. 40S. 5	16.2	1265	Sandy Loam	Juniperus occidentalis/Artemisia tridentata
5	5	R. 10E. T. 39S. 33	8.1	1250	Loam	Artemisia tridentata/Festuca idahoensis
6	-	R. 12E. T. 39S. 15	8.1	1250	Loam	Artemisia tridentata/Festuca idahoensis
7	7	R. 11E. T. 37S. 22	8.1	1372	Heavy Loam	Artemisia tridentata/Festuca idahoensis
8	8	R. 12E. T. 39S. 8	8.1	1250	Loam	Artemisia tridentata/Festuca idahoensis
-	9	R. 11E. T. 37S. 26	20.2	1372	Heavy Loam	Pinus ponderosa/Purshia tridentata
-	10	R. 11E. T. 37S. 27	8.1	1372	Heavy Loam	Pinus ponderosa/Purshia tridentata
-	11	R. 10E, T. 39S. 33	8.1	1250	Loam	Artemisia tridentata/Festuca idahoensis
-	12	R. 12E. T. 40S. 19	16.2	1265	Sandy Loam	Agricultural
-	13	R. 12E. T. 40S. 19	16.2	1265	Sandy Loam	Agricultural

[a] Information supplied by cooperating ranchers.

[b] From Franklin and Dyrness (1973).

METHODS AND MATERIALS

FORMULATION AND APPLICATION OF POISON BAITS

Two toxicants, strychnine and sodium fluoroacetate (1080) were considered for use in this study. Sodium fluoroacetate was chosen because it was a restricted-use pesticide and could be applied only by licensed personnel and their assistants, allowing strict control of poison bait application procedures.

Poisoned baits were prepared and applied under the supervision of the Klamath County Weed and Rodent Control supervisor. The bait mixture consisted of 99.02% oat groats, 0.01% auromine yellow dye and 0.07% 1080 by weight. Poison baits were broadcast with: 1) a hand seeder; 2) a fertilizer spreader mounted on the bed of a pickup truck; and 3) a fixed wing aircraft. Baits were applied at the rate of 5.6 kg per ha on alternative swaths 3 m to 5 m wide and 15 m to 30 m apart.

TIMING OF BAIT APPLICATIONS

In 1976 2 fields were assigned to each of 2 treatments: control (I, no baiting) and treated with poison baits only in early spring (II) (Table 2). In 1977 3 fields were assigned as controls (I) and 2 were treated with poison baits only in late spring (III). Only 2 fields were assigned to treatment III because a third field with similar

characteristics could not be found. Comparisons to be made were: treatments I vs. II, I vs. III and II vs. III.

NUMBER OF BAIT APPLICATIONS

In 1976, 2 fields were assigned to each of 3 treatments: control (I); treated with poison baits only in early spring (II); and treated with poison baits in early and late spring (IV) (Table 2). In 1977 3 fields were assigned as controls (I), 2 fields were treated with poison baits only in late spring (III), and 3 fields were treated with poison baits in early and late spring (IV) (Table 2). Early and late spring were defined as pre-emergence and post-emergence respectively, of juvenile ground squirrels from their burrows. All baiting was done between the last week in March and the first week in June. In both years comparisons to be made were: treatments I vs. IV, II vs. IV and III vs. IV.

BAITING FIELD BORDERS

In 1976, 2 fields including a 60 m wide border strip were treated with poison baits in both early and late spring (Table 2). This procedure was repeated in 1977, with 3 fields assigned to each treatment (Table 2). In both years comparisons of efficacies of baiting were made among fields baited twice including border strips (V), control fields (I) and fields baited twice without border strips (IV).

Comparisons to be made were treatments I vs. V and IV vs. V.

Table 2. Treatment assignments for experimental fields located in Klamath County, Oregon.

Field	1976 Treatment[a]	1977 Treatment
1	I	III
2	I	b
3	II	I
4	II	IV
5	IV	I
6	IV	b
7	V	V
8	V	III
9	b	V
10	b	V
11	b	I
12	b	IV
13	b	IV

[a] I = Control (no poison).
II = Baited only in early spring.
III = Baited only in late spring.
IV = Baited in early and late spring.
V = Field with 60 m boundary baited in early and late spring.

[b] Fields not used during that field season.

Fields were assigned to treatments randomly with the following restrictions imposed by farmers: 1) whether they would allow poison baits to be applied to their fields, 2) the number of applications for which the farmer was willing to pay. Ideally no field would be used more than one year. However, the required number

of fields could not be located in 1977 and 6 fields from the 1976 group of fields were added to the 5 new fields located for the 1977 field study. Treatments were assigned randomly to all fields to avoid unintentional bias resulting from effect of 1976 treatments on fields retained for the 1977 field study.

MEASUREMENT OF ALFALFA LOSS

Loss of alfalfa to ground squirrels was estimated by comparing the yields of alfalfa from plots exposed to squirrel depredation to yields from plots protected from squirrels by exclosures. Exclosures were constructed from 1.9 cm mesh hardware cloth, were 45 cm tall and 56 cm in diameter and enclosed an area of 0.25 m^2.

In March of 1976 and 1977, 8 and 10 exclosures respectively were located randomly in fields from points represented by a 0.3 m grid superimposed on each field. Each exclosed plot was paired with 4 unexclosed plots of the same size, which were located at the cardinal compass points 2 m from the center of each exclosure. Alfalfa within all plots was removed by clipping stems 4 cm above the ground with a Black and Decker cordless electric grass shear 1 to 10 days prior to harvest. Alfalfa clipped from each plot was dried in a forage oven at 60° C for 24-48 hours, then weighed to the nearest gram on a Toledo dash pot scale.

Losses of alfalfa to ground squirrels were calculated as a percentage of potential yield by the formula:

$$P = \frac{Y-\bar{y}}{Y} \times 100$$

where

P = percent of potential alfalfa yield lost to ground squirrels.

Y = yield (g) of alfalfa from individual exclosed plots (potential yield).

$\bar{y}$ = mean yield (g) of alfalfa from 4 paired unexclosed plots.

Mean loss of alfalfa to ground squirrels within fields was calculated by the formula:

$$\bar{P} = \frac{\Sigma P}{a}$$

where

$\bar{P}$ = mean percent of potential alfalfa yield lost to ground squirrels for all plots in a single field.

a = number of exclosed plots per field.

Mean loss of alfalfa to ground squirrels among fields within treatments was calculated by the formula:

$$MPD = \frac{\Sigma \bar{P}}{n}$$

where

MPD = the mean percentage differences in yield of alfalfa between exclosed and unexclosed plots for fields within treatments.

n = number of fields per treatment.

Paired t-tests (Sokol and Rohlf 1969:332) were used to determine if differences in alfalfa yields between exclosed and unexclosed plots $(Y-\bar{y})$ within fields were significant. Analysis of variance and the F-test (Sokol and Rohlf 1969:208-09, 233) were used to determine if mean losses in yield of alfalfa within $(\bar{P})$ and among (MPD) treatments were significant. The arcsine transformation (Sokol and Rohlf 1969:386) was used to normalize the distribution of percentages to facilitate statistical analysis. In all analysis the 95 percent confidence limits were accepted as indicating significance. The number of replications was increased from 2 in 1976 to 3 in 1977 to reduce within treatment variability.

RESULTS AND DISCUSSION

IMPACT OF GROUND SQUIRRELS ON ALFALFA YIELD

Ground squirrels removed significant amounts ($P < 0.05$) of the first cutting of alfalfa from unexclosed plots within all control fields as indicated by comparison with yields from exclosed plots (range 36.1-55.0%, $\bar{x}$ = 45.7%) (Tables 3, 4, 5).

These results were similar to Sauer's (1977) estimate of a 61% reduction in the yield of a mixed crop of alfalfa and bromegrass, and Fitch's (1948) estimates of crop loss which varied from 25 to 36% on a pasture with a known population of 30 California ground squirrels (Spermophilus beecheyi) per ha. Losses of this magnitude indicated the need for an effective means of control to reduce the economic impact of losses caused by ground squirrel depredations.

EFFECT OF EXCLOSURES ON ALFALFA YIELD

There was evidence to indicate that exclosures made of small mesh (0.5 cm) hardware cloth and approximately 0.9 m tall and 107 cm in diameter might increase the growth rate of the alfalfa enclosed (Sauer per. comm. 1976). The potential effect exclosures might have on the growth of alfalfa was evaluated by examination of both harvests in 1976.

Table 3. Comparison of mean yields of alfalfa harvested from exclosed and unexclosed plots within experimental fields from July 6 to 12 and from July 26 to August 2, 1976.

Field	Treatment	Exclosed Plots g dry wt.	Unexclosed Plots g dry wt.	Calculated t[a]	df
First Harvest					
1	I	66	37	3.72[b]	4
2	I	68	38	11.54[b]	5
3	II	87	87	1.16	4
4	II	-	-	-	-
5	IV	143	60	5.50[b]	6
6	IV	105	68	3.19[b]	3
7	V	65	41	2.55	3
8	V	116	82	3.71[b]	4
	mean	93	59		
Second Harvest					
1	I	28	31	-1.01	7
2	I	-	-	-	-
3	II	63	44	2.67[b]	5
4	II	26	29	-0.85	3
5	IV	45	38	1.36	7
6	IV	18	17	0.26	5
7	V	32	41	-1.62	4
8	V	29	26	0.76	6
	mean	34	32		

[a] t-value (paired t-test, Sokol and Rohlf 1968:332) obtained from paired comparison of yields of alfalfa from each exclosed plot with mean yield of 4 unexclosed plots surrounding the exclosed plot within each field.

[b] t-value significant at the 5% level.

Table 4. Comparison of mean yields of alfalfa harvested from exclosed and unexclosed plots within experimental fields between June 22 and June 29, 1977.

Field	Treatment	Exclosed Plot g dry wt.	Unexclosed Plot g dry wt.	Calculated t[a]	df
3	I	126	78	5.16[b]	7
5	I	139	59	5.55[b]	7
11	I	93	50	4.20[b]	6
1	III	87	47	5.84[b]	9
8	III	105	72	3.57[b]	8
13	IV	95	62	3.56[b]	8
12	IV	126	89	5.69[b]	7
4	IV	103	79	1.64	5
7	V	56	46	1.12	6
9	V	100	71	2.18	6
10	V	99	73	2.68	4
	mean	103	66		

[a] t-value (paired t-test Sokol and Rohlf 1969:332) obtained from paired comparison of alfalfa yields from each exclosed plot with mean yield of 4 unexclosed plots surrounding the exclosed plot within each field.

[b] t-value significant at the 5% level.

Table 5. Percentage loss and the arcsine transformations of the percentage loss from the first alfalfa harvest in 1976 and 1977.

Treatment	Field No.	Percent Loss	arcsin $\sqrt{P}$
1976			
I	1	40.9	39.7
I	2	55.0	47.8
II	3	14.9	22.7
II	4	--	--
IV	5	60.0	50.7
IV	6	34.0	35.7
V	7	37.0	37.5
V	8	28.0	31.9
1977			
I	3	36.1	36.9
I	5	53.8	47.2
I	11	42.8	40.9
III	1	40.0	39.2
III	8	28.8	32.5
IV	4	28.8	32.5
IV	12	29.8	32.4
IV	13	17.6	24.8
V	7	17.9	25.0
V	9	17.6	24.8
V	10	20.3	23.8

All control and treatment fields exhibited reduced yields of the first harvest of alfalfa from unexclosed plots (range 7.9-60.0%) in 1976; in 1977, 5 of 7 of these fields had differences in yields between exclosed and unexclosed plots that were significant ($P < 0.05$) (Tables 3, 4). With the exception of field 3, no significant differences ($P > 0.1$) of alfalfa yield were found between exclosed and unexclosed plots when alfalfa was harvested between July 26 and August 2, 1976. Belding's ground squirrels begin to enter hibernation during July (Turner 1972) and so caused little if any loss of the second harvest of alfalfa. The lack of differences in the yield of the second cutting of alfalfa from exclosed and unexclosed plots indicated that exclosures did not significantly influence yields of alfalfa.

EFFECT OF POISON BAITING ON DAMAGE

In 1977 fields treated with poison baits had significantly smaller ($F = 9.5$, $df = 3, 7$; $P < 0.01$) reductions in alfalfa yield than control fields. Reductions in yield varied significantly ($P < 0.01$) among treatments (Table 6). Reductions in yield were smaller for treated fields than for controls in 1976, but the difference in yields was not significant ($F = 3.1$, $df = 3, 4$; $P > 0.10$) (Table 6).

In 1976 the result obtained from field 5 (treatment IV) was similar to results obtained from control fields. The reasons for this

Table 6. Analysis of variance tables using the arcsine transformations of the mean yields of alfalfa harvested from experimental fields from July 6 to July 12, 1976 and June 22 to June 29, 1977.

Source	df	MS	F	P
1976				
Among Treatments I, II, IV, V	3	125.4	3.1	>0.25
Within treatments	4	40.3		
Total	7			
1977				
Among Treatments I, III, IV, V	3	215.2	9.5	<0.01
I vs III	1	40.6	1.8	>0.10
I vs IV	1	207.7	9.1	<0.025
I vs V	1	602.0	26.5	<0.005
III vs IV	1	42.5	1.9	>0.10
III vs V	1	242.5	10.7	<0.025
IV vs V	1	102.5	4.5	<0.10
Within treatments	7	22.7		
1976/77 Combined				
Among Treatments I, II, III, IV, V	4	195	3.42	<0.05
I vs II III	1	224	3.93	>0.05
I vs II	1	320	5.61	<0.05
I vs III	1	62	1.09	>0.25
I vs IV	1	137	2.40	>0.10
I vs V	1	640	11.23	<0.01
II vs III	1	113	1.98	>0.10
II III vs IV	1	224	0.41	>0.50
II vs IV	1	1	0.02	>0.75
III vs IV	1	1	0.02	>0.75
IV vs V	1	185	3.25	
Within treatments	13	57		

were not known. When data from both years were combined and subjected to analysis of variance levels of significance for differences among treatments did not change appreciably from those for 1977. The amount of damage to alfalfa in 1976 (48.0%) with no control was virtually identical to that for 1977 (44.2%) (Table 7), indicating that the differences of level of damage observed among treatments between years resulted from differences in the efficacy of the treatments, and not from differences inherent in the sample units.

Table 7. Treatment means and standard deviations of the percent damage to the first harvest of alfalfa from experimental fields located in Klamath County, Oregon in 1976 and 1977.

Treatments	1976 (Mean ± S.D.)	1977 (Mean ± S.D.)
Controls (I)	48.0 ± 10.0	44.2 ± 8.9
Treatment II	14.9 ± 0	-
Treatment III	-	34.4 ± 7.9
Treatment IV	47.0 ± 18.4	25 4 ± 6.8
Treatment V	32.5 ± 6.4	18.6 ± 1.5
II, IV, V combined	38.5 ± 15.4	-
III, IV, V combined	-	30.3 ± 11.9

BAITING REGIMES

Effect of Timing of Baiting on Damage

Data were collected from only 1 of 2 fields under treatment II in 1976, as one field was harvested by the farmer before samples could be collected. There were no significant differences ($P > 0.4$) between mean yields of alfalfa from exclosed (102 g) and unexclosed (87 g) plots for the one field sampled. Superficially, it appeared that this treatment was effective in significantly reducing the losses caused by ground squirrels to alfalfa. However, neither treatment IV or V in 1976 (requiring baiting early and late) exhibited levels of control as high as did II, so the apparent effect of treatment II was not consistent.

Under treatment III the yield of alfalfa from unexclosed plots was significantly lower ($P < 0.05$) than from exclosed plots for both fields, indicating that poisoning only in late spring does not prevent losses caused by ground squirrels (Table 4). Treatment III did not significantly reduce losses of alfalfa below levels found in control fields ($F = 1.8$, $df = 1, 7$, $P > .10$) (Table 6), indicating that baiting late only is not effective in reducing losses caused by ground squirrels.

Direct comparison between treatments II and III is inappropriate because of the lack of replication of treatment II and the

inconsistent results on the one field under treatment II that was harvested. Because there was no difference of alfalfa loss between treatments I and III ($F = 1.8$, $df = 1, 7$, $P > 0.10$), it appears that the application of baits only once does not result in significant control of ground squirrel damage to alfalfa.

Effect of the Number of Bait Applications on Damage

Although the difference between loss of alfalfa on control (44%) and treatment III (34%) fields in 1977 was not significant ($F = 1.8$, $df = 1,7$, $P > 0.10$), it was in the expected direction (Table 7). Similarly, although the difference between loss of alfalfa from treatment IV (34%) and V (25%) fields was not significant ($F = 4.5$, $df = 1, 7$, $P < 0.10$) the trend again was in the expected direction (Table 7). Thus, from examination of 1977 data, it appears that there was a relationship between the number of bait applications and damage: as the number of applications increased from 0 to 2 the amount of damage caused by squirrels to alfalfa decreased. This observation is verified by the significant difference ($P < 0.025$, Table 6) in loss of alfalfa from fields with no control (44%) and fields with 2 applications of control (25%). Analysis of data combined for both years indicated that the differences in losses of alfalfa between treatment I vs IV was not significant ($F = 2.4$, $df = 1, 13$, $P > 0.10$). By deleting the inconsistent results of field 5 under treatment IV from the analysis,

the difference in loss of alfalfa between treatment I and IV fields regains significance at the $P < 0.05$ level. However, even with 2 applications of poison baits, squirrels removed significant amounts of alfalfa from treated fields (Table 4).

Effect of Baiting a Border on Damage

During both years of this study, treatment V fields exhibited the highest reduction of damage. There were no significant differences of alfalfa yields between exclosed and unexclosed plots for 1 of 2 fields in 1976 and all 3 fields in 1977 (Tables 3, 4) indicating insignificant amounts of damage were caused by ground squirrels at this level of treatment. Although the difference in loss of alfalfa from fields between treatments IV (25%) and V (18%) was not significant at the 95% acceptance level ($F = 4.5$, $df = 1, 7$, $P > 0.1$, Table 6) the change in the level of damage was in the expected direction (Table 7). Thus from examination of both years' data it appears that there was a correlation between baiting fields with a border and damage: fields without a baited border had approximately 7 percent more crop damage than fields with a baited border. In 1977 this treatment significantly reduced losses of alfalfa below levels found in control fields ($F = 10.7$, $df = 1, 7$, $P < 0.025$).

RELATIONSHIP BETWEEN INTENSITY OF CONTROL AND DAMAGE

Application of 1080 treated baits on fields with infestations of Belding's ground squirrels reduced the damage these squirrels caused to alfalfa. Reduction of damage was directly related to the number of bait applications. Treating a border strip around infested fields with poison baits further reduced the amount of ground squirrel damage to alfalfa.

The degree to which control of damage was achieved in 1977 was greater than in 1976 (Table 7). The reasons for this difference were not evident. Possibly subtle changes in ambient temperature or precipitation may have made the squirrels more susceptible to poisoning by increasing squirrel activity during periods of low food supply or by lengthening the time the baits remained available to squirrels for consumption. A second possibility is that some natural regulatory mechanism interceded during 1977 to reduce the population of ground squirrels. This did not seem likely, however as no correlated reduction in damage was evident on control fields, as would be expected if there were a general decline in the numbers of squirrels present resulting from natural mortality agents.

Recommendations for using toxic baits to reduce ground squirrel damage to alfalfa are: 1) poison baits should be applied twice, once in early spring before the young of the year emerge from their

burrows and again in late spring after most young of the year are above ground; 2) a border strip 60 m wide and abutting the infested field on all sides should be included when fields are treated with poison baits.

RESIDUAL EFFECT OF POISON BAITING

Little or no carry-over effect of poison baiting was observed between years during this study. Six fields were treated in 1976 and 1977. Comparison of losses from these fields for 1977 with losses from fields with similar treatment in 1977 and dissimilar treatment in 1976 permits evaluation of carry-over effect of the poison baiting.

Fields with more intensive treatment in 1976 should exhibit lower loss of alfalfa than fields with less intensive treatment in 1976. Similarly, fields with less intensive treatment in 1976 should exhibit higher loss of alfalfa than fields with more intensive treatment in 1976.

Of the 7 possible comparisons, 4 agreed with expectations and 3 did not (Table 8). This distribution of results is what would be expected with random assignment of fields to treatments. However, further investigation into the possible effect of multiple year applications of poison baits might be considered a worthwhile endeavor.

Table 8. Expected and observed differences of alfalfa loss between fields with similar treatment 1977 and dissimilar treatment 1976.

Field No.	Treatment		Percent loss	Difference of loss[a]	
	1976	1977		Expected	Observed
1	I	III	40.0		
8	V	III	25.8	1 > 8	1 > 8
3	II	I	36.1		
5	IV	I	57.8	3 > 5	3 < 5[c]
3	II	I	36.1		
11	NF[b]	I	42.8	3 < 11	3 < 11
4	II	IV	28.8		
12	NF	IV	29.8	4 < 12	4 < 12
4	II	IV	28.8		
13	NF	IV	17.6	4 < 13	4 > 13[c]
7	V	V	17.9		
9	NF	V	17.6	7 < 9	7 > 9[c]
7	V	V	17.9		
10	NF	V	20.3	7 < 10	7 < 10

[a] > = first field of pair listed should have more damage than second field.
< = first field of pair listed should have less damage than second field.

[b] new field not used in 1976 field season.

[c] loss difference opposite expectated direction.

ENVIRONMENTAL CONSIDERATIONS

Unfortunately little is known about the impact of 1080 on the environment. Non-target animals are known to succumb either by primary or secondary poisoning (Howard, 1974). The toxicant leaches into the soil where it shows an affinity to organic material and is degraded to non-toxic components in 2-11 weeks by microbial action (Van Driesche, 1975). What long term effects 1080 may have on the environment are unknown. Short term as well as long term effects of 1080 on the population dynamics of non-target and target species are also unknown.

RESPONSE OF SQUIRREL POPULATIONS TO POISON BAITING

The use of poison baits did not eliminate ground squirrel depredations. Therefore, one or both of the following was occurring: poison baiting did not reduce the squirrel populations below replacement level or surrounding areas with reservoir populations supplied individuals for immigration. Either mechanism could account for the lack of total control over damage. Unfortunately there are no alternative methods for control of ground squirrel damage to agricultural crops.

Neither natural enemies nor density-dependent factors depress ground squirrel populations to levels where crop losses

are acceptable (Howard, 1974). Information is lacking for evaluating the potential of biological or cultural methods for the amelioration of ground squirrel depredations. To attain this essential information it is recommended that a study be conducted to evaluate responses by Belding's ground squirrel to manipulation of numbers. It is also recommended that the following two areas receive study: evaluation of the impact of 1080 treated baits on the local environment and development of more selective pesticides and alternative methods for control of ground squirrel depredations on alfalfa.

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