INTEGRATED PEST MANAGEMENT ANALYSIS FOR CONTROLLING POCKET GOPHERS AT ADOBE ROAD VINEYARDS

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ABSTRACT

This study was undertaken to determine the economical threshold that commercial growers can endure before they need to begin controlling pocket gophers (*Thomomys bottae*), specifically in wine-grape vineyards. Pocket gophers cause extensive damage to grapevine roots year round and can cause economical loss from the elaborate underground tunnels they create while burrowing.

This report represents six different methods of controlling pocket gophers in a wine-grape vineyard during the late summer and early fall seasons. An analysis of control and cost analysis has been performed to forecast the most economical way for commercial growers to control gophers. Four different restricted use material pesticides were used in separate plots to measure the amount of emerged gopher holes after application of poisons. One plot measured the possible amount of gophers that can be trapped underground and one plot was left alone for a control measure. The cost to purchase the pesticides, the amount of time it took to apply the poisons, the rate at which they were applied, and the overall control were collected to determine the most effective method.

It was concluded that the most economical method for commercial growers to control pocket gophers in vineyards was to apply .05% or 1.8% Strychnine alkaloid gopher bait with a Rid-O-Rodent® gopher bait applicator. The conclusion is based on the effectiveness of the poison after it was applied and consumed, as well as the more economical cost per acre to apply. Strychnine can cause possible unwanted secondary poisonings therefore it is important to be aware of all native vertebrate species.

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CHAPTER 1

Introduction

In farming operations and home gardens, nothing can be as frustrating as losing crops and damaging equipment due to pocket gopher infestations. Pocket gophers (*Thomomys bottae)* are burrowing rodents that get their name from the fur-lined, external cheek pouches they use for carrying food and nesting materials (Salmon and Baldwin 2009). Pocket gophers are evolved for a lifetime of digging and tunneling with their powerfully built forequarters. Mature gophers have clawed front paws and fine short fur that does not cake in wet soils. Small eyes and ears as well as highly sensitive facial whiskers assist with moving about in the dark.

Uncontrolled gophers can cause extensive damage to plant life, as well as deteriorate household utility items. Pocket gophers commonly chew irrigation lines and utility cables. Their elaborate tunneling systems can undermine and weaken foundations of homes, buildings, pesticide sheds and containment areas. Gophers cause serious stem girdling, clipping, root pruning and even root exposure to the plants. Case and Jasch (1982) found that pocket gophers feed on plants in three ways: they feed on roots that they encounter when digging, they may go to the surface, venturing only a body length or so from their tunnel opening to feed on vegetation, or they pull vegetation into their tunnels from below.

The loss of a crop is devastating for growers who depend on high yields at the end of the growing season. In row crop systems, growers cannot afford to lose any crops or suffer any unsightly damage due to gopher feedings. In vineyard systems, gophers feed on roots of vines and cause extensive erosion problems, which can limit mechanical applications as well as harvest operations. Growers that purchase gopher probe bait applicators and strychnine poison will have tremendous savings at the end of the fiscal year, from cutting costs with labor contractors and protecting the crops they have already invested in.

Gophers are classified as non-game animals and can be legally trapped or killed at anytime without a permit. In order to successfully manage gophers, control measures should be put in place early on. Growers should locate the main burrows in order to control gophers with pesticides. The best option for growers that want to control high populations of gophers is to apply strychnine .05% gopher bait. Strychnine is one of the oldest and the most commonly used rodenticide in the world (Stroud and Kuncir 2008). It has been designated as a restricted use pesticide since 1978, and taken off the general use market except for materials containing less than .05% active ingredient. The only available form is for underground use in order to poison burrowing rodents. Other pesticides such as anticoagulants, Zinc Phosphide and fumigants also work well for controlling gophers, but only if applied at the right time of year. Trapping, shooting and natural controls also have been proven to work, but are much more tedious and difficult to control.

Problem Statement

What economical threshold can growers endure before they need to begin control measures against pocket gophers, and what is the most efficient method of control?

Hypothesis

The best method for controlling pocket gophers in commercial agriculture will come from applying strychnine .05% gopher bait with a gopher bait applicator. Strychnine bait will control pocket gopher populations within a plot better than: Anticoagulants, Zinc Phosphide, Aluminum Phosphide or trapping. The growers will see monetary returns from investing in a gopher probe in order to apply strychnine appropriately into pocket gopher burrows.

Objectives

1) To evaluate the economic benefits of controlling pocket gopher infestations.
2) To assess the rate of population growth in an uncontrolled area.
3) To determine the savings associated with controlling gophers when using a gopher bait applicator with strychnine .05% poison grain bait.

Justification

Agriculture in California has endured vertebrate pests such as pocket gophers since commercial agriculture moved to the west. Gophers can girdle plants, pull plants into their underground tunnels, eat plant roots and chew through water lines (Salmon and Baldwin 2009), which can cost growers thousands of dollars per year in labor and material costs. There is greater demand today for an economical and safe way of controlling large gopher infestations. In areas where row crops such as broccoli, lettuce, carrot and other vegetables are grown, when plants are not completely taken underground by gophers, unsightly chewing damage that is left behind devalues crops. The annual crop yield losses are creating a crucial need for gopher populations to be kept at a minimum. Gophers feed on crops in three ways: They feed on roots they encounter while digging, they may briefly surface to feed on above ground vegetation, or they pull vegetation into their tunnels from below (Case and Jasch 1994). If left unchecked, pocket gophers can cause irreparable damage to a farming operation through direct damage to crops and indirect damage to the soil structure from tunneling systems. It is much more economical for growers and farmers to control gophers with pesticides or traps early on in the growing season in order to protect the fruits, vegetables, vines and tree crops they have already invested money into planting.

CHAPTER 2

LITERATURE REVIEW

One of the major problem pests found worldwide in agricultural production systems are pocket gophers. Greek (1998) reports that annually these vertebrates damage crops, rangeland and home gardens, amounting to millions of dollars in damage, and cause growers and their employees to spend a significant amount of time baiting, trapping and shooting. Studies have been undertaken on what the most economical methods of control are and what method will have the least amount of impact on the environment. Demand for a more efficient and much easier solution is highly sought after in agriculture. Salmon and Baldwin (2009) stress the importance for farmers to develop a management program that will prevent gopher populations from spiking when crop loads are maturing or new planting are developing.

Uncontrolled gopher infestations can cause extensive damage to yards, gardens, rangeland, and commercial growing operations. They feed on many garden crops, row crops, ornamental plants, vines, shrubs, and trees (Salmon and Baldwin 2009) and begin to deteriorate house utility items by way of erosion. In agricultural systems, gophers have been known to chew up irrigation lines and utility cables. Forbes (1993) noted that their elaborate tunneling systems undermine and weaken foundations that hold up homes, buildings, pesticide storage and containment areas as well as keep them from remaining level. Controlling pocket gopher infestations can be a very tedious task if their populations are allowed to grow. Vossen (2003) has researched various methods of control for gophers and found that only two measures work well enough to invest in. The use of poison baits such as strychnine and anticoagulant rodenticides works best on keeping populations low in times when they typically would spike. Another successful method of control is trapping, whereas the traps must be checked consistently and dead gophers must be physically removed. Vossen (2003) asserted that it is nearly impossible to monitor gopher activity without physically going into the field and opening holes into their burrowing systems. Farmers are paid better today per ton of crop when they grow sustainable. Sustainability from a grower's perspective means limiting water use, conserving resources, and limiting pesticide use, which is monitored by the Department of Pesticide Regulation.

Gopher populations never become completely dormant and spend their entire lives underground except for brief feedings on above ground vegetation (Baker, Bradley and McAliley 2003). They live in small stable groups throughout their lives and vigorously defend den sites within their home range, although they are not recorded as being close to each other (Zinnel and Tester 1992). It is crucial for growers to educate themselves about damage prevention and control methods if they want to protect their crop. Howard and Childs (1959) studied gopher habits and found that some tunnels are more or less common property, which allowed gophers to move through other burrows without incurring a lethal fight. These common areas are a good place to begin controlling gophers. Methods such as exclusion and the use of plastic netting work well in small areas such as gardens but are not feasible in large farms and vineyards. Littrell (1990) found some pocket gophers would periodically surface when they need to cross borders, seek new territory or push soil up from their tunneling systems. Understanding the life cycles of gophers will help growers find the appropriate time of year to apply bait. If conditions in the soil are good, gopher tunnels can be three to four feet deep; however, the majority of activity and feeding takes place around eight to sixteen inches in depth in tunnels parallel to the ground surface found Vossen (2003).

Case and Jasch (1994) found that some growers have hybridized resistant varieties in alfalfa with hopes of deterring vertebrate pests. Rotating crops annually allows some growers to till the soil, which collapses many gopher burrows, but the damage to soil structure due to tilling makes digging easier for future gopher populations states Renz (2004). Flood irrigation is impractical today because of statewide shortages and repellants seem to be a waste of time in any area since gophers adapt to them reports Salmon and Baldwin (2009).

It is essential that growers have good field investigation and document each time an accurate diagnosis has been made. A field history should have observations of the number of individuals and species involved, both at the specific site as well as the general area. Field investigations are also be important in checking for non-target secondary or tertiary poisonings of wildlife.

Previous work in the vertebrate pest industry has narrowed down which control measures have the most success in the field at decreasing gopher populations. The most success has been attributed to the use of two poisons, which are strychnine and anticoagulants. Harrell (2003) suggests that all farmers, growers, and applicators conform to state and county regulations when applying strychnine bait into tunnels so secondary poisonings can be avoided. The use of a "bait applicator" device comes highly recommended for safety, economics, and effectiveness. In 1978 strychnine was designated as a restricted use pesticide and was taken off general market use, except for products containing less than 0.5% active ingredient (Stroud and Kuncir 2008). There is a lot of concern about overusing strychnine in agricultural areas that are near residential areas, schools, and areas with domestic and wild animals. Stroud and Kuncir (2005) published that strychnine is a rapidly acting neurotoxin that often has resulted in birds falling out of the sky in convulsions after ingestion of the poison. Growers should be very careful to only apply strychnine underground, and to dispose of any dead gophers on the surface.

Salmon and Baldwin (2009) found that strychnine was lethal in a single feeding, and baits containing 2.0% Zinc Phosphide are also available to large commercial growers. Anticoagulant rodenticides are available as well, but require multiple feedings per gopher, which results in about ten times the amount needed compared to strychnine (Baker, Bradley and McAliley 2003). Chlorophacinone and Diphacinone are available in the form of a wax grain pellet rather than a poison grain (Vossen 1990). Anticoagulants such as these are the preferred method of control in areas where children and pets might be present Salmon and Baldwin (2009) observed. Poisons have been proven to work well in some areas, but in other areas less than seventeen percent of the pocket gopher populations was controlled by any poison bait during reproductive and early fall periods found Proulx (1998).

Fumigants have been widely used in commercial agriculture, as well as home gardens, in order to smoke out or kill unwanted gophers. Fumigation with smoke or gas cartridges usually is not effective because gophers quickly seal off their burrow when they detect smoke or gas (Salmon and Baldwin 2009). A restricted-use material fumigant with the active ingredient Aluminum Phosphide is also available and is effective at controlling gopher population (Salmon and Baldwin 2009). Applicators need certification from the county agricultural commission in order to use the material (Greek 1998). Trapping also has been an effective method but requires physically checking main exits to tunnels and is hard to accomplish in large commercial fields (Case and Jasch 1994). Shooting is also an effective method but bullets are expensive and it is unsafe in populated areas. In areas where possible, buried utility cables and irrigated lines can be protected by enclosing them in materials that gophers cannot dig through.

Spring is the most optimal time for growers to begin aggressive control measures once the soil temperatures begin to rise (Vossen 1990). Presence of gophers can be seen during springtime as more digging occurs and holes become more pronounced within the field. Proulx (1998) asserts that populations should be reduced early in the season during reproductive and juvenile dispersal periods to prevent a spike in population. A second aggressive wave of bait should be applied in the fall after rain has begun to soften the soil. Industry professionals have stressed the importance of controlling gophers in large commercial fields as well as home gardens for decades. Pest control measures for vertebrate pests may have an environmental impact on non-target wildlife and pets. Greek (1998) reported that strychnine is extremely poisonous to people, birds, mammals and fish. Strychnine should be handled with great care and never placed above ground. Littrell (1990) reported at the fourteenth Vertebrate Pest Conference in Davis, California, that the best method for control, which was strychnine, "Is probably the worst because of its toxicity to a variety of species and because of its secondary persistence." Since poisons are the most effective method for control, safety precautions should always been taken and pesticides should always be locked in storage compartments out of harms way. The goal of integrating a pest management plan for controlling gophers in agriculture should be to remain environmentally sound, socially acceptable while keeping economics in mind.

CHAPTER 3

METHODOLOGY

Procedures for Data Collection

An experiment must be designed in order to determine the economical threshold for growers or homeowners to begin controlling gophers. In this experiment, the best method of controlling pocket gophers will also be determined. To collect the data, physically applying bait, fumigants, setting out traps and a medium for natural predators will be required. To apply strychnine poison, a gopher bait applicator device, as well as personal protective equipment must be worn. A Rid-O-Rodent bait applicator and pesticides will be purchased from Buttonwillow Warehouse Company in Paso Robles, under John Vineyard Applications restricted-use materials account. Personal protective equipment will include: eye protection, gloves, long sleeves, shoes, and masks. Personal protective equipment will be worn at all times when poisons, fumigant anticoagulants, or traps are applied. The experiment will be done at Adobe Road Vineyards in Paso Robles and will be completed over the course of ten weeks. Adobe Road Vineyards has ninety-six and a half bearing acres of grapes, with seventy-four acres of Cabernet Sauvignon, twelve acres of Merlot, and ten and a half acres of Syrah.

The six different treatments include: Strychnine .05% Wilco Gopher Getter bait, Diphacinone (P.C.Q.) anticoagulant bait made by Bell Laboratories, Zinc Phosphide 2.0% bait made by Bell Laboratories, Aluminum Phosphide (Weevilcide) fumigant made by United Phosphorous Inc., Macabee gopher traps, and one control area with no deterrents. Six treatments will be applied between seven plots and will be divided between four blocks of Cabernet Sauvignon, covering seventy-two bearing acres of grapes.

The six different treatments will be divided between the Cabernet Sauvignon blocks three, four, five and six in Adobe Road Vineyard. Blocks four, five and six will divided into half to make the experiment's data collection size feasible. Figure one illustrates how the four Cabernet Sauvignon blocks will be divided into seven plots, which will cover all six different treatments. Six treatments were randomly selected using a die, and an additional control plot, plot seven, will be located at block three since it is slightly more isolated to the west. Block four covers twenty and a half bearing acres of Cabernet Sauvignon, so plots five and six will cover ten and a quarter acres each. Block five covers nineteen and a half bearing acres of Cabernet Sauvignon, so plots three and four will be cover nine and three quarter acres each. Block six covers twenty one and a half bearing acres of Cabernet Sauvignon, so plots one and two will cover ten and three quarter acres each. Treatment one will have strychnine bait; it will be designated to plot five. Treatment two will have Diphacinone anticoagulant bait; it will be designated to plot six. Treatment three will have Zinc Phosphide bait; it will be designated to plot two. Treatment four will have Aluminum Phosphide fumigants; they will be designated to plot four. Treatment five will have Macabee traps placed into the holes; they will be designated to plot five. Treatment six will be a control block; it will be designated to plot one. Plot seven will be a control block as well as a buffer area between the Cabernet Sauvignon blocks and the Syrah and Merlot blocks.

The contact at Adobe Road Vineyards is the applicator, Will John, owner and operator of John Vineyard Applications. Time will be spent applying bait into main tunnels, setting traps, and removing dead gophers from successful traps as well as commuting to and from San Luis Obispo. The vineyard will be checked no less than three times per week for gophers in traps, dead gophers on the surface, and newly emerged holes in a plot.

Procedures for Data Analysis

Data analysis will be done in a few different ways. In plot five, Macabee traps will be used and a numerical value will be set to how many gophers are caught and killed. The data will be used to compare the time it takes to set and check traps, to how many gophers are actually killed in the timeframe of a field investigation. Before any traps are set, the entire plot will be checked, and all gopher holes will be collapsed and buried. Newly emerged holes will be documented, and then traps will be set in place. In areas where gophers have been caught, the gopher will be removed and disposed of, and the traps will be reset into the same hole. In areas where the traps have not worked within one week, the trap will be removed and placed into a newly emerged hole, and the previously used hole will be collapsed and buried. All successful trapped areas will be marked with an orange flag; unsuccessful holes that have been buried will be marked with a white flag.

In the poison bait and fumigated plots, trapping gophers will not occur. Instead the percent kill in the plots will be correlated to how many new gopher mounds emerge after treatment. During pre-application, all gopher mounds in the field will be leveled and compacted. All holes and burrows that have been probed with strychnine will be marked with a red flag. The most common place for gophers to die after strychnine poisonings is in the tunnel. They will slowly decompose underground over time, although strychnine is well known for causing secondary and tertiary poisonings. Any gophers found on the surface with a curled "sardonic grin and saw horse" appearance will be said to have died by strychnine (Stroud and Kuncir 2005). Gophers with an appearance of arms spread out in opposite direction, or the appearance of a sudden death will be categorized as a Zinc Phosphide poisoning. Zinc Phosphide has 2.0% active ingredient. Upon feeding, death is said to be almost instantaneous. Some gophers will die before reaching their holes, since ZP bait will be applied on the surface. No gophers will be collected from the fumigant plots, since they will die within the holes or escape from the smoke alive. The only natural controls manipulated by man, will be owl boxes and hawk perches. Pocket gopher skeletons collected under boxes and perches will measure success in natural control areas. Total savings can be calculated best at the end of the season once grapes have been harvested and sold. If Adobe Road Vineyards earns a higher price per ton of grapes in areas where treatment worked better than other, a correlation between successfully controlling gophers and price per ton will be created.

Assumptions

In this experiment there will be a margin of error because of the lack of boundaries that gophers have within any given area. Some may be poisoned in the treated area, and die in neighboring areas. Other gophers may be poisoned in neighboring areas and die within a control plot. Some dead gophers may be taken away by wildlife, although great care will be taken to prevent any secondary poisonings. Experiments with wildlife often have a lot of variation in the data analysis, natural fluctuations may impact gopher activity. In the trapping treatment, there will be a margin of error since not all of the holes will have traps in place at all times. Traps will be placed in fresh mounds created by gophers; old mounds will be collapsed and buried with a shovel after they have been documented. In the Zinc Phosphide treatment, it should be noted that ground squirrels are often attracted to the bait. They may contribute to some loss of bait, and may be poisoned themselves. Dead ground squirrels will be noted, but not included in the final data report. Many of the gophers will die in their holes after poisonings, therefore an actual numerical value to kills per week or overall kill cannot be fully reported without excavation. Previous years of control may also influence the number of active gophers in the vineyard. Gophers that emerge from neighboring vineyards or farms may also skew the data, since poisons, traps or fumigants will not directly influence them.

CHAPTER 4

Development of the Study

This study was undertaken at Adobe Road Vineyard in Paso Robles with the permission of the property manager, Will John. The objectives were achieved by setting up an experiment in which the six different methods of controlling Pocket Gophers could be tested. Pesticides were purchased from Buttonwillow Warehouse Company in Paso Robles under John Vineyard Applications restricted materials permit. Figure 1 in the appendix illustrates a map of Adobe Road Vineyard and the treated areas. The plots covered sixty-one and a half acres of bearing Cabernet Sauvignon grapes. Strychnine and Diphacinone bait were applied in block four; Aluminum Phosphide and Trapping were the methods applied in block five; Zinc Phosphide and the control plot were designated to block six of the Cabernet Sauvignon grapes. Data were collected each week on Tuesdays, Thursdays and Saturdays. Applications of Strychnine, Diphacinone, Zinc Phosphide and Aluminum Phosphide took place only on Tuesdays. Traps were checked during every data collection. If they had been triggered, or if the hole had been collapsed, or if a pocket gopher was caught, the traps were removed and placed in a burrow elsewhere within the plot. Ten acre plots were designated for each method of control, within these plots five rows were selected for treatment. The treated areas cover five-thousand seven hundred and sixty square feet, with approximately 7.5625 plots per acre. One ten acre plot is equivalent to 75.625 treated area plots.

All application were done by hand using personal protective equipment, Strychnine was applied using a Rid-O-Rodent® gopher applicator probe. Each row was counted for newly emerged gopher holes before applying any baits or poisons. Upon entering a treated area, the time would be noted, then the time would be noted again when the row had been treated and exited. Data were collected to find an average time it would take to apply each of the selected methods of control. Figures 3, 5, 7, and 9 represent the average application time per treated area per week.

In order to compare the average cost to control Pocket Gophers during the time-frame the experiment took place, the price per acre to control has to be multiplied by the amount of acres desired to be treated. A cost-analysis for the .05% Strychnine, P.C.Q. (Diphacinone), ZP Bait (Zinc Phosphide), and Weevilcide (Aluminum Phosphide) treatments was applied to the given field. Table 1 shows the cost comparison between the different pesticide treatments.

Table 1	Cost of Application for 10 Acre Plot						
PESTICIDE	COST/UNIT	RATE		Acreage		Amount required	COST
Strychnine	$249.93 / 25 lb Bag	2 lbs / Acre	X	10 Acres	=	20 Pounds	$249.93
P.C.Q.	$93.75 / 50 lb Bag	136.125 lbs / Acre	X	10 Acres	=	1,316.25 lbs (1 Bag / 50 lbs) = 28 Bags	$2625.00
Weevilcide	$23.73 / Bottle (~500 Tablets)	3-4 Bottles / Acre	X	10 Acres	=	30 – 40 Bottles	$711.90 – 949.20
ZP Bait	$73.58 / 50 lb Bag	6 lbs / Acre	X	10 Acres	=	60 lbs	$147.16

The most cost efficient method of controlling pocket gophers came from the Strychnine plot. Data collections and trends can be seen in the appendix. The treated area within the Strychnine plot began in week four of the experiment Table 1 in the appendix illustrates. Strychnine was applied to areas where newly emerged gopher burrows were found. With the use of the Rid-O-Rodent® gopher bait applicator, the Strychnine was dispersed into burrowing systems and the entrance to the burrow was covered with debris. Gopher populations began to decline swiftly after application days shows Figure 2 in the Appendix. Given the amount of population decline of pocket gophers and the lowest average time per application as shown in Figure 3, Strychnine was proven to work the best at controlling and declining pocket gopher infestations. The cost per acre, when combined with the rapid rate of bait dispersal, makes it the favorable choice in gopher pest management.

Fumigating gopher burrows with Aluminum Phosphide showed to be very efficient at this time of year at maintaining gopher populations. The graph in Figure 8 demonstrates how newly emerged gopher burrows were on a declining scale two days after fumigants were applied into the burrows. The high atmospheric moisture created a very moist environment in the soil acted rapidly upon the Phosphide tablets to produce phosphine (PH_3) gas. The populations slowly began to come back days after no fumigants were applied as seen in Table 4, but the trend shows that the population may be displaced if fumigation were to continue. The effectiveness of Weevilcide is proven, but the danger of the phosphide gas and the care that must be taken with each application cause the average application time to be slower than Strychnine as shown in Figure 9.

The plot treated with Zinc Phosphide grain pellets consistently kept the newly emerged gopher burrows on the decline but did not significantly drop the population at any point during the study as shown in Table 2. The grain bait was broadcasted in the treated area to allow the natural foraging habits of the gophers to lead them to the bait. Prior to the first application of bait, wild oats were applied to get the vertebrate pests familiar with a foreign food source. ZP bait is simple to broadcast but highly toxic. Personal protective equipment had to be worn at all times when handling the pesticide, the toxicity lead to a decline in the average application time shows Figure 5. The overall decline of newly emerged gopher burrows is clear in Figure 4. All five rows in the treated area had the average newly emerged burrows brought to an equilibrium which would be helpful in future control methods.

An unsuccessful method of controlling pocket gopher during harvest time is with the use of Diphacinone anticoagulant bait (P.C.Q.), as shown by the data in Table 3. The bait was broadcasted between the rows and under the vines at a rate of two ounces per forty to fifty square feet. The vines were spaced six feet apart, with eight feet apart between the rows which created forty-eight square feet of treatable area. A competing vertebrate species, the California ground squirrel (*Spermophilus beecheyi),* was a factor in the bait being consumed in the treated areas. The pocket gopher infestations were not impacted by the Diphacinone bait as the trend in Figure 6 shows. Average application times were moderate as shown in Figure 7; this was due to the bait being measured out to two ounces every six feet of ground walked.

One of the least successful methods of controlling pocket gopher infestations is trapping. Trapping was the most tedious method of control since each trap had to be hand set, and hand checked. It is not economical to try to control gophers with traps as Table 6 shows. There were many traps active and in burrows in the field but only a few of the traps successfully caught a gopher. The trends of newly emerged gopher holes in the control plot, shown in Table 5, demonstrate how destructive and rampant an uncontrolled area of pocket gophers can be.

When the trapping method is compared to the control plot, we see that even catching a few gophers a day will do almost nothing to a colony. Figure 10 demonstrates how gopher populations will stay at a high equilibrium if uncontrolled and there are resources for survival nearby.

CHAPTER 5

Summary

The most effective way of controlling gophers is to apply control measures year round and control gopher populations at specific vulnerable times during their life cycles. Economic thresholds are often reached rapidly in commercial agricultural environments during the growing season. To keep populations of pocket gophers to a minimum, different management techniques should be applied throughout the year. There is no single method of control that will continue to keep populations down and constant use of any one pesticide is never a good thing. It is clear that the rate of population growth in uncontrolled areas will remain constant or continue to grow very rapidly if vegetation is present and they have an available food source, such as a crop. Uncontrolled environments in agricultural settings quickly will show results in the commodities being sold. To avoid losing quality in fruit or a drop in yield, control measures need to be integrated to manage the pest.

Pocket gopher populations were controlled best with the use of 0.5% Strychnine bait, and the use of a gopher application probe such as the one used in this experiment. Once Strychnine is introduced into a burrowing system, gopher populations begin to show rapid decline, as shown in Figure 2. Strychnine is a fast acting alkaloid poison used in control of pocket gophers and it is much more economical for the grower to use. An application of

Aluminum Phosphide or Zinc Phosphide, either in combination with Strychnine bait, or alone for moderate population control, would be effective as well.

Conclusions

The best method for controlling Pocket Gophers in this study came from using 0.5% Strychnine with a gopher bait applicator. Strychnine treated areas showed the most dramatic and most rapid decline in newly emerged gopher holes. The toxic bait is fast acting and very cost effective when compared to treatments such as Diphacinone, Zinc Phosphide, and Aluminum Phosphide. Strychnine can be used year round for control of gophers which give it the advantage over other pesticides which mode of action targets specific periods in the gopher population's life cycle. The method of trapping proved to be very inefficient since most traps never caught a gopher and/or were never triggered. The time it takes to manually find holes and set the traps will not allow an agricultural professional to reduce or even maintain a population. Anticoagulant baits such as Diphacinone showed not to work well on decreasing populations. This may be due to the competition from native species of ground squirrels which will eat the bait, or due to the fact that gophers will not wander far from the hole when foraging. Zinc Phosphide has a similar effect when there are other vertebrate species such as ground squirrels, field voles and birds, competition over bait. Combining applications of Strychnine in some areas with applications of Aluminum Phosphide in areas of heavy gopher populations may prove to be the most cost effective method. The best way to maintain or decline pocket gophers in agricultural settings requires integrating a pest management strategy that is safe for the environment, economical for agricultural professionals and effective on the target pests.

Recommendations

Taking an integrated pest management approach to controlling vertebrate pest species such as pocket gophers is important if a grower wishes to produce high quality product and maintain the quality of the land holding the crop commodity. The most important recommendation is to always keep the time of year, soil temperatures and pest life and mating cycles in mind when attempting to control. Different techniques and different pesticides should be observed during the growing and dormant season.

This study may be replicated in the future so it is recommended that some of these techniques be applied to different cropping systems or similar vineyard environments. The methods of gathering data in this experiment are quite tedious, working with a team may allow more data to be gathered. The weather always will play a factor when dealing with an agricultural environment, be prepared for anything.

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