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RODENT PROBLEMS IN RANGE REHABILITATION

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ABSTRACT: Seed predation by rodents has limited successful re-establishment of desirable shrubs, forbs, and grasses on degraded western rangelands. We need to develop methods that temporarily reduce rodent numbers or their predation of planted seed if we are to establish diverse rangeland plant communities. Range site conversion treatments of chaining, prescribed burning, spraying, or drilling have not been effective in reducing deer mice populations. However, seed predation has been reduced by adopting seeding strategies that mimic natural seed predation avoidance mechanisms. Seedings have been designed to mimic the "satiation" strategy for plant establishment by providing more seed and sacrifice foods than can be utilized by the resident rodent population. Seed has been planted in the spring when rodent populations are low, seed has been buried to hinder location, and seeded species have been selected for low rodent preference. Chemical repellents and rodenticides have also enhanced seeding success, but environmental concerns have limited their application.

INTRODUCTION

Because of previous abuse and loss of desirable grass, forb, and shrub species, millions of acres of degraded sagebrush-grass, chaparral, and pinyon-juniper rangelands are unable to reach their potential for livestock forage or wildlife habitat (Vallentine 1977). To rehabilitate these rangelands usually requires removal of existing undesirable plants through mechanical, chemical, or burning techniques followed by seeding of desired species. This paper focuses on rodent problems in rehabilitating rangelands by direct seedings. The reader is referred to Marsh (1985) for other rodent-rangeland interactions.

Past failures to achieve desired species composition or plant densities from seedings have, in part, been attributed to rodent predation of planted seed (Nord 1965, Nelson et al. 1970, Sullivan and Sullivan 1982). Birds and ants have also been implicated in seeding failures (Howard 1950, Goebel and Berry 1976, Sullivan and Sullivan 1982) and, together, all seed predators can consume a majority of planted seed (Nelson et al. 1970).

Rodent predation of seed has not been limited to seedings but is an integral part of the development and maintenance of natural range plant communities. Although rodents consume the majority of seed produced in natural communities, their seed caches are instrumental in plant recruitment and reintroduction of plant species to disturbed sites (West 1968, McAdoo et al. 1983). By understanding the role of rodents and seed predation avoidance in natural communities, we may be better able to design site treatments and seeding practices that improve establishment of desirable range species by direct seeding. An integrated approach utilizing combinations of vegetation control, seeding methods, sacrifice foods, seeding mixes of species less preferred by rodents, and/or chemical seed protectants may be desirable.

RODENTS-A NATURAL PART OF THE RANGELAND ECOSYSTEM

As consumers and distributors of seeds on western rangelands, rodents are closely tied to the establishment and maintenance of range plant communities and have value in themselves as part of the wildlife of rangeland ecosystems (Reichman 1977, Smith and Urness 1984). Price and Jenkins (1986) provided a comprehensive review of rodent predation of seed and describe the process in a "Seed Fate Diagram." A modified diagram for direct seedings describes seed fate of rodent-harvested and nonharvested seed (Fig. 1). For many species the optimum seed path for plant recruitment may involve no rodent interaction or secondary plant recruitment from rodent scatterhoards (caches). The seed path driven by high rodent numbers is characterized by seed consumption and caching, with additional loss from rodent grazing of seed cache germinants (La Tourette et al. 1981).
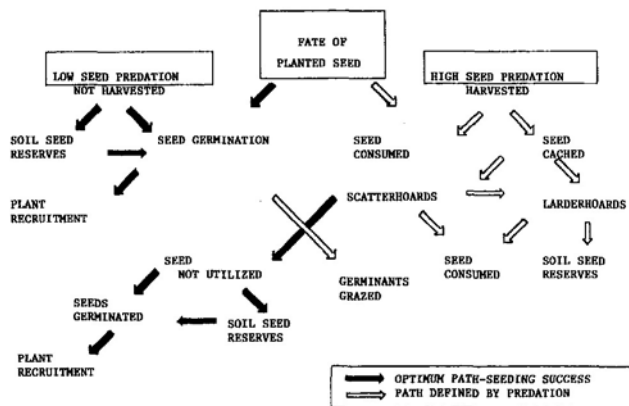

Figure 1. Seed fate diagram for seedings subjected to different levels of seed predation. (Adapted from Price and Jenkins 1986)

Although rodents consume large amounts of seed, their seed caches are a major source of plant recruitment (West 1968, Evans et al. 1983, McAdoo 1983). Large seeded species have difficulty in germinating and establishing from

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seed on the soil surface and may require burial in seed caches for seedling establishment to occur (La Tourette et al 1981, Evans et al. 1983). Rodent caches of antelope bitterbrush (Purshia tridentata), snowbrush (Ceanothus velutinus), squawcarpet (C. prostratus), green rabbitbrush (Chrysothamnus viscidiflorus), cheatgrass (Bromus tectorum) and Indian rice grass (Orhyzopsis hymenoides) have been reported (West 1968, La Tourrette et al. 1981, McAdoo et al. 1983).

Rodent caches provide opportunities for species to reoccupy disturbed sites as seen by caches of bitterbrush and snowberry (Symphoricarpos sp.) on recently burned pinyon-juniper and sagebrush sites (Everett and Kulla 1976, Evans et al. 1983). Rodents transport mycorrhizae associated with range plants and therefore could establish both plant species and their associated mycorrhizae on denuded range sites (Maser et al. 1988). Rodent caching has benefited some species such as bitterbrush that establish more readily from caches than as individual seedlings (Ferguson and Basile 1957).

RODENTS' IMPACT ON RANGE SEEDINGS
Rodent Predation of Seeded Species
Unfortunately for our range seedings, rodents have identified seed of commonly seeded species as a preferred food item within 1 to 4 days even though the plant species did not occur on site (Lockard and Lockard 1971, Kelrick et al. 1986). Captive deer mice ate or destroyed seed of commonly seeded species equal to approximately one-third of their body weight daily (Everett et al. 1978); however, the amount of broadcast seed taken in the field was directly proportional to the amount available (Sullivan 1978).

Rodent predation of large forb and shrub seed was greater than on small grass seed in mixed seedings (Howard 1950). In range interseedings reported by Stevens et al. (1981), shrubs and forbs from large seed had poorer plant establishment than smaller seeded species. Nord (1965) reported that 87% of planted bitterbrush seed had been harvested by rodents before it could germinate.

Impact of Site Conversions on Rodent Populations
Common range site conversion treatments that have reduced cover and food for rodents include prescribed burning, spraying with herbicides, chaining, rotobeating, disking, tree harvest, and their combinations (Vallentine 1977). Following spraying with 2,4-D (2,4-dichlorophenoxy acetic acid) or rotobeating of black sagebrush (Artemisia nova), populations of deer mice and pocket mice (Perognathis parvus) remained near those of controls, but the least chipmunk (Eutamias minimus) did not occur in rotobeaten plots (Zou et al. 1989). Spraying sagebrush-grass ranges with 2,4-D had little effect on density of deer mice, but there was a sharp decline in northern pocket gophers (Thomomys talpoides) and least chipmunks, and an increase in montane voles (Microtis montanus) (Johnson and Hansen 1969). Density of deer mice and pocket mice remained similar to pretreatment levels the first year but dramatically increased the second year following chaining and windrowing of Utah juniper (Juniper osteosperma) sites (Baker and Frischknecht 1973). Rodent species that require large amounts of cover such as voles, western jumping mice (Zapus princeps), and masked shrew (Sorex cinereus) decreased in numbers immediately after burning in sagebrush communities (McGee 1982). However, deer mice populations remained close to preburn conditions. In transitional range seedings on cutover lodgepole pine (Pinus contorta) forests of British Columbia, numbers of deer mice and voles were 2 to 2.2 times greater than on untreated areas (Sullivan and Sullivan 1984).

Site conversions were most successful at reducing the density of rodent species that have specific niche requirements (McGee 1982). Deer mice appeared to be habitat generalists and were not as severely affected by range site treatments as other rodent species.

Seeding Methods and Rodent Predation
Range seedings mimic the "satiation" strategy of plant recruitment where a large food source (the seeding) occurs in such a short time that seed predators cannot fully exploit the resource (Janzen 1971). However, we have not seeded in amounts to fully utilize this strategy nor would it be cost effective for shrub and forb seed. Other alternatives need to be developed to reduce or satiate rodent demand. In nature some plants have adapted seed dispersal times to coincide with reduced presence of seed predators (Pulliam and Brand 1975). Similarly, spring seedings capitalize on the annual depression in rodent populations and reduce the time seeds are subject to predation before germination occurs (Sullivan and Sullivan 1984, Zou et al. 1989). Late winter seedings may be required for seed species that require cold stratification (Plummer et al. 1968).

There is overwhelming evidence that rodents operate under an "optimal foraging" strategy where they preferentially harvest seeds from dense patches or clumps rather than dispersed seeds (Pyke et al. 1977, Price and Jenkins 1986). This phenomenon suggests our seeding methods should place seeds as randomly as possible. Broadcasting seeds on the soil surface provides a random pattern, but seeds are restricted to a single plane and readily accessible. Wheatgrass seeds broadcast in the fall on mechanically prepared seedbeds were almost entirely consumed (98%) by spring (Nelson et al. 1970).

Buried seeds are less preferred than seeds on the soil surface because of the energy required in digging (Price and Jenkins 1986). Drilling seed has been a common range practice but seeds are nonrandom in both horizontal and vertical planes, and rodent mining of seeds in rows has been reported (Nord 1965). Standley's (1988) findings that fewer small seeds were harvested when drilled separately from large seeds suggest some seed predation could be avoided by seeding different species or preferred sacrifice foods in different furrows. Burying seeds randomly by using a seed dribbler mounted on a tracked vehicle or the Brillion seeder has been recommended for seeding shrubs (Plummer et al. 1968, Richardson et al. 1986). Evans et al. (1983) reported only 8% of randomly cached bitterbrush seed was found compared to complete seed removal of broadcast seed.

Selecting Seed Species to Avoid Predation
The ability of the plant species to meet management objectives has been the primary selection criteria, but where there is a choice among species, the selection for reduced seed predation would be desirable (Standley 1988). Predation problems have been most severe on large seeded shrubs and forbs (Howard 1950) because they are more easily located (Price and Jenkins 1986) and appear to be the more preferred food items (Everett et al. 1978). Food preference is driven by energy gain and required nutrients balanced against energy lost in foraging and handling time (Reichman

1977, Kaufman and Collier 1981). Large seeds may be preferred to small seeds because of the relative number of seeds required to meet daily energy demands. Using an estimate of the daily energy requirement of deer mice (7.56 kcal), Kelrick and Macmahon (1985) calculated that the number of seeds required of each seed species varied from 134 for bitterbush seed to 130,027 for the small seed of big sagebrush. In a 36-day field test by Standley (1988), all of the large barley (Hordeum vulgare) seed was harvested from drill rows, while more than 70% of small panicgrass (Panicum antidotale) remained.

Everett et al. (1978) found deer mice generally preferred the big seed (large endosperm) of tree, shrub, and forb species [pinyon pine (Pinus monophylla). antelope bitterbrush, arrowleaf balsamroot (Balsamorhiza sagittata), and small burnet (Sanguisorba minor) over grass species or smaller seeded forbs (Table 1). However, seed preference was highly correlated to other available food items.

Sacrifice Foods to Reduce Seed Predation

Sacrifice foods have been provided as a substitute food to satiate rodent predation so that the desired seed species escapes predation (Sullivan and Sullivan 1982). Optimally, sacrifice foods should be more preferred than the desired seeded species, causing the latter to drop out of the diet (Pyke et al. 1977, Everett et al. 1978). Predation of seeded species declines when the rodents "olfactory search image" changes to the sacrifice food (Sullivan 1979). Defining the seed preference of rodents for commonly seeded species, indigenous weeds (natural sacrifice food) and artificial sacrifice foods should allow us to predict which seeded species will have greatest predation and which sacrifice foods will provide predation relief (Kelrick and Macmahon 1985). The use of sacrifice foods doesn't appear to immediately increase rodent numbers on site, but seedings have caused rodent immigration from adjacent areas (Sullivan and Sullivan 1984).

In caged feeding trials with deer mice, rolled barley and wheat were offered as artificial sacrifice foods and indigenous weeds as natural sacrifice foods (Everett et al. 1978). Although barley and wheat were preferred less than bitterbrush or sainfoin seed (Table 1), these sacrifice foods reduced seed intake of the latter species. Indigenous weed seed, lambsquarter (Chenopodium album), cheatgrass and coyote tobacco (Nicotiana attenuata) were more preferred than commonly seeded smooth brome or sheep fescue (Festuca ovina) and may alleviate seed predation of the latter. Prickly poppy (Argemone munita), a weedy species invading burns and disturbed sites, is preferred over many commonly seeded species (Table 1).

Millet was found to be more preferred than bitterbrush or Indian rice grass (Kelrick and Macmahon 1985, Kelrick et al. 1986). They ascribed rodent preference for millet to high-soluble carbohydrate (77% total weight), cell content (97% oven dry weight) and free water (9.5% air dry weight). To date no one has evaluated sacrifice foods in protecting range seedings but laboratory and field feeding trials suggest millet, sunflower, and rolled barley as potential sacrifice foods. Feeding sacrifice food (sunflower 7:1 Douglas-fir seed) increased conifer seed survival from 5 to 70% (Sullivan 1979).

Table 1. Deer mouse preference for commonly seeded species, indigenous seed and sacrifice foods (Everett et al. 1978).

Preference rankings	Commonly seeded species	Indigenous seed	Sacrifice foods
1	Antelope bitterbrush		
2		Singleleaf pinyon	
3	Arrowleaf balsamroot		
4	Small burnet		
5	Sainfoin		
6	Mountain mahogany		
7			Rolled barley
8	Lewis flax		
9	Stiffhair wheatgrass		
10		Prickly poppy	
11	Big bluegrass		
12	Russian wildrye		
13	Alfalfa		
14	Green ephedra		
15			Wheat
16	Cicer milkvetch		
17	Fairway wheatgrass		
18		Lambsquarter	
19		Cheatgrass	
20		Coyote tobacco	
21	Sheep fescue		
22	Bulbous bluegrass		
23	Fourwing saltbush		
24	Smooth brome		
25	Utah juniper		

If sacrifice foods are less preferred than the desired seeded species, there may be opportunities to enhance preference of sacrifice foods through chemical mimicry of more preferred seed species. When Howard and Cole (1967) added safflower oil to whole wheat, the detection of buried seed increased from 78.3 to 97.3% and percent of seed taken increased from 20.6 to 97.2% of those detected. Evans et al. (1983) found nocturnal rodents did not disturb artificial caches of crested wheatgrass, but all wheatgrass caches were raided that also contained finely ground bitterbush seed. Both studies indicate that treating sacrifice foods with a more desirable odor may enhance their consumption and we speculate this may reduce predation of desired seed species.

Seed Treatments to Reduce Predation

Natural seed repellents are effective in reducing rodent predation. Seeds of Datura metaloides contain alkaloids, and seeds of jojoba (Simmondsia chinensis) contain an appetite-suppressing compound that limit seed predation by most rodents (Sherbrook 1976, Hay and Fuller 1981). Much work has been done on application of chemical seed repellents to reduce seed predation and, although successful, these treatments are often prohibited because of environmental concerns. Endrin has been used with good success in the past to reduce seed predation of range seedings (Plummer et al. 1968) but is no longer available for use on federal lands. (Mention of a commercial or proprietary product does not constitute endorsement by the USDA.) Everett and Stevens (1981) found alpha-napthylthiourea (ANTU) reduced deer mouse consumption of bitterbrush seed more than mestranol, R55, and red squill, but less than 0.5% or 1% endrin-treated seed (Fig. 2). To date field trials with ANTU-treated shrub or forb seed has not occurred, but Passof et al. (1974) utilized ANTU-treated conifer seed to effectively double seedling stocking rates.

Reducing Rodent Populations

As mentioned previously, site treatments that reduce cover and food sources have limited populations of niche-specific rodent populations for short periods. Rodenticides have been more effective in reducing rodent predation of planted seed.[2] Nelson et al. (1970) enhanced seed survival in a range seeding in Nevada by using strychnine-treated grain. Broadcast wheatgrass seed was consumed (98%) within 6 weeks of fall seeding on nonpoisoned plots, with little or no seed depredation on plots protected by poison. The use of strychnine, however, is currently banned from use on federal lands. There are new rodenticides that are effective and viewed as environmentally safe (Marsh 1975). Marsh et al. (1977) found 0.02% chlorophacinone gave 100% mortality of caged deer mice, and diphacinone provided 70 to 90% mortality in 2 to 4-day feeding tests.
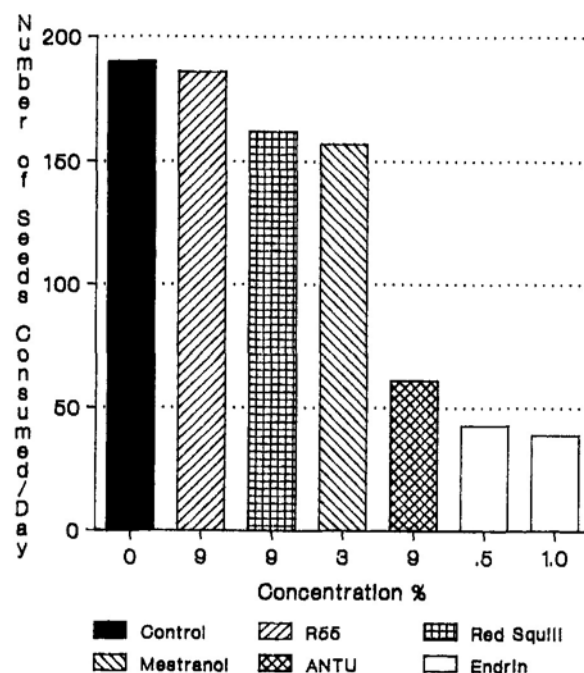
Figure 2. Number of seeds consumed per day per deer mouse for control and repellent treated seed (Adapted from Everett and Stevens 1981).

Rodent reoccupation of seeded range sites is rapid unless poison is continuously available. Howard and Kay (1957) found 29 mice had reoccupied a 20-acre seeding 45 days after poison grain had been applied. Sheltered bait traps had to be used to maintain low rodent populations. Radvanyi (1980) used a poison bait feeder station to effectively reduce vole populations on revegetated mine spoils in Canada.

The validity of long-term removal of rodents from seedings is questioned because of rodent consumption of insects that damage emerging plants. Rodent omnivores and insectivores consumed large quantities of insects, and even herbivores utilized insects at certain periods of the year (Jameson 1952, Johnson 1961, Flake 1973). The effect of rodent removal on insect populations was seen when exclusion of meadow mice from California grasslands caused an increase in arthropods (Batzli and Pitelka 1970). In fall-seeded bitterbrush, 90% of emerging seedlings were destroyed by variegated cutworm (Peridroma saucia) (Hubbard 1956), and Evans et al. (1983) found that only insecticide (Diazinon)-treated bitterbush seed caches survived the first growing season.

CONCLUSION

Rodents have had a major role in plant establishment in natural range communities and continue that role when direct seedings occur. Opportunities to reduce rodent seed predation by site preparation treatments were diminished because of constant deer mice populations or the rapid return of rodents to treated sites. However, we have capitalized on low rodent populations in the spring or winter seedings and reduced the predation period prior to seed germination. Although direct seeding mimics the "satiation" strategy for plant establishment, we have not fully utilized the concept by increasing seeding rates or providing sacrifice foods in range seedings. When different seed species meet management

objectives, we have the opportunity to reduce rodent seed location and predation by using small seeded species or less preferred food items. Past research suggests that we should investigate the potential to reduce rodent location of planted seed by a more random seed placement or by planting preferred and nonpreferred species in different drill rows. There are also opportunities to chemically enhance the preference of sacrifice foods and perhaps reduce predation on the desired seed species. When natural control practices are ineffective, an integrated approach using chemical seed repellents or rodenticides may be required. However, removal of rodents and their consumption of insects may create insect predation problems on seeded species.

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