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REVEGETATION PROBLEMS FOLLOWING NUCLEAR TESTING ACTIVITIES AT THE NEVADA TEST SITE

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Abstract. Wherever vegetation has been destroyed at the Nevada Test Site as the result of nuclear activities, the Salsola species and native annual species and grasses have grown abundantly in subsequent years on those areas. Experience indicates, however, that decades of time are necessary for the perennial shrub vegetation on a disturbed site to return to its original state. In disturbed areas on Pahute Mesa, the germination and survival of native shrub seedlings has been abundant in recent years and sufficient to return that portion of the southern Great Basin Desert to its original condition. After severe drought periods many new seedlings have disappeared, not directly because of drought but because of browsing animal activity. In the Mojave Desert portion of the Nevada Test Site, the germination and survival of shrub seedlings have been much slower on disturbed sites than at Pahute Mesa. Animals have destroyed virtually all shrubs which we have transplanted into disturbed areas. Nevertheless, transplanting has been successful when protected from browsing animals, and this appears to be a practical means of shortening the vegetational recovery time for these disturbed areas.

INTRODUCTION

Natural vegetation in some areas of the Nevada Test Site has been destroyed, either directly or indirectly, by nuclear testing activities. Certain areas involved with site installations, storage yards, and roadway networks have been denuded of original vegetation by blading and other forms of mechanical disturbance. Target and ground zero sites of air-dropped and balloon or tower-mounted nuclear devices have been denuded by blast and fire. In addition, the radiation from radioactive fallout debris has destroyed or damaged the natural vegetation in some areas near underground and surface excavation tests. This report describes some observations relating to revegetation of areas in which the natural vegetation was previously destroyed by nuclear testing activity.

FIELD OBSERVATIONS

Target and Ground Zero Sites in Yucca Flat

Early nuclear testing at the Nevada Test Site primarily involved above-ground detonations of air-dropped or tower and balloon-mounted devices which denuded target and ground zero sites of natural vegetation. The damage from blast and fire at these sites generally masked fallout irradiation effects. Work on studies of nuclear effects and vegetational recovery at these sites during the first decade has been reported (Shields and Rickard 1960; Shields and Wells 1962, 1963, Rickard and Shields 1963, and Shields et al. 1963).

Upon visiting these areas nearly two decades after testing began, one observes a generous revegetation of winter and summer annuals, especially the Salsola species, and some mixed grasses, but virtually no recovery of the original perennial shrub species. Those few shrubs which are present apparently are crown sprouts from original plants which were seriously damaged but not destroyed by blast and fire. We have seen ample evidence of seed germination in these areas, but the new shrub seedlings have not survived the rigorous environmental conditions of this transitional zone between the southern Great Basin and northern Mojave Deserts. Yucca Flat lies at 1200 to 1500 m elevation with annual rainfall varying from 8 to 22 cm. We have reason to believe, from evidence presented elsewhere in this report, that browsing rabbits and other small mammals play an important regulatory role in the survival of shrub seedlings in these disturbed areas. Small mammals are plentiful at these sites. Beatley (1969) recently presented evidence on the dependance of desert rodents on winter annuals and precipitation.

Plowshare Nuclear Excavation Fallout Areas

Project Sedan was an event in the Plowshare program designed to study peaceful uses of nuclear energy for excavation purposes. This 100 kt explosion on 6 July 1962, in Yucca Flat, ejected approximately 5×10^6 m^3 of material over an area of about 1000 ha (2500 acres). The depth of ejecta varied from 5 to 30 m at the crater edge and from 1 to 5 m at a distance of 500 m from the crater. It varied from 5 to 20 cm depth at a distance of 1 km and from 1 to 2 cm at 2 km from the crater. A heavy blanket of dust from the base surge cloud was deposited over an area extending out to about 4 km from the crater. Native vegetation was destroyed or damaged within this area and in the downwind fallout pattern to a distance of about 6 km. Work has been reported on the early effects of Sedan on vegetation (Martin 1963, Beatley 1965a, b, 1966, Koranda 1967).

The recovery of vegetation at Sedan has followed essentially the same pattern observed at the above-ground nuclear detonation sites. The Salsola species have dominated new plant cover in the ejected area and in the outlying areas disturbed by blast. Other winter and summer annuals and several species of grass are now prevalent in disturbed areas not heavily covered by throwout ejecta. The lack of sustained soil moisture in areas covered by ejecta has contributed to the poor recovery of vegetation other than Salsola species. After nearly a decade of passing time, there has been virtually no recovery of the original perennial shrubs except in areas where regrowth has occurred from original root crowns which survived the blast and fallout radioactivity. Again, there is evidence of shrub seed germination but the new shrub seedlings have not survived. Our continued observations on crown sprouting and seedling survival strongly indicate that browsing animals seek out and consume this new succulent plant material. High populations of small mammals are present in areas disturbed by Sedan.

Revegetation studies have been conducted in the fallout patterns of two small Plowshare nuclear excavation tests on Pahute Mesa. Details of these events and their radiological effects on vegetation have been reported (Rhoads et al. 1969a, b). Our Pahute Mesa study plots are located within discrete fallout patterns where the natural vegetation was destroyed or damaged by radiation without the effects of blast and fire. This area is in the Great Basin Desert's southern extremity at an elevation of 1800 to 1900 m. Annual rainfall varies from 12 to 28 cm. The Palanquin test (U20K) occurred on 14 April 1965; Cabriolet (U20L) occurred on 26 January 1968.

Figure 1 is a view of the fallout pattern 5 years after the original vegetation was destroyed by radiation from Palanquin debris. The woody remains of the original trees and perennial shrubs are still present and revegetation at this time includes mixed grasses, winter and summer annuals, and new seedlings of the two Artemisia species common to the area (Artemisia tridentata and Artemisia arbuscula subsp. nova). Sufficient seedlings of these Artemisia species have germinated and, if they continue to survive, they will assure the return of this area to its original state. We estimate from ring counts that an average life span of Artemisia species which dominate this area is about 35 years. Data in Tables 1 and 2 indicate the renewed vegetative cover and the numbers of new plants in some study plots 3 years after the original vegetation was completely destroyed by radioactive fallout. The ground cover of grasses (Table 1) was calculated from mean basal crown diameters, so their apparent contribution appears to be less than what visibly occurs in the area. The new plant populations shown in Table 2 give a better indication of the manner in which these fallout areas have recovered at the present time to a grassland succession.

The initial revegetation in the fallout area included Salsola species (Salsola iberica and Salsola paulsenii) and several species of winter and summer annuals. Mixed grasses (Hilaria jamesii, Oryzopsis hymenoides, Poa sandbergii, and Sitanion jubatum) became established during the second and third years after fallout and they have continued to dominate the area. Figure 2 indicates how the new vegetative cover primarily involved the Salsola species and a few clumps of mixed grasses 2 years after radiation destroyed the original vegetation. A view of the same site after 5 years (Fig. 3) indicates how the mixed grasses have begun to dominate the fallout-disturbed area.

At these Pahute Mesa sites, new seedling germination and survival of the Artemisia species began during the second year after fallout occurred. Far greater numbers have germinated and survived at the time of this report than eventually can be supported by the area, and there is an interesting case study ahead to follow the return of these areas to their climax vegetation state. Figure 4 illustrates the density of new Artemisia tridentata seedlings in some areas. During the second and third years after the original shrubs were destroyed, most of the new seedling germination occurred in the open areas between the remains of dead shrubs. We saw virtually no new Artemisia seedlings under what would have been the canopy of the original shrubs. This pattern changed during the fourth and fifth year and new seedlings started to germinate and survive underneath the remains of original shrubs. An apparent case of allelopathy is involved wherein a chemical substance from the original shrubs inhibited new seedling germination and survival until it was inactivated with passing time (Muller 1966).

Germination and survival of other shrubs common to the area has occurred in sufficient amounts to eventually return the fallout-disturbed sites to their original population. These include some Atriplex, Chrysothamnus, Ephedra, and Tetradymia species along with Grayia spinosa and Lycium andersonii. One species, Cowania mexicana, generally survived the radioactive fallout. We have not yet seen any significant survival of Juniperus osteosperma seedlings.

Drought conditions have inhibited the survival of new Artemisia seedlings but these effects have not been nearly so pronounced as we had expected. Further investigation showed that very little above-ground growth occurred during periods of severe drought, whereas the root system continued to develop deeply in the soil. Three-year-old seedlings whose top growth remained about 5 cm in height and width had well-developed root systems as deep and wide as 50 cm, unless restricted by impervious substrata. In spite of low rainfall, there has been sufficient soil moisture in these fallout-disturbed areas to support shrub seedlings and grasses. The annual plant species have been most seriously affected by lack of seasonal moisture. The total rainfall recorded on Pahute Mesa near these study sites was 27.5 cm (1965), 12.4 cm (1966), 26.7 cm (1967), 18.6 cm (1968), 23.6 cm (1969), and 12.0 cm (1970).

Damage to new seedlings by browsing small mammals appears to have played a greater role in the control of seedling survival than other envi-onmental factors. They were especially active during the summer and fall of 1970 which was a period with low rainfall, poor annual plant production, and very little new shoot production on shrubs. Figure 5 illustrates the kind of damage to new *Artemisia* seedlings caused by browsing rabbits. They seem to be more partial to the young stem tissue than to leaf tissue of this species.

Artificial Revegetation Studies in Disturbed Areas

We have made some attempts to transplant seedlings and rooted cuttings of native shrubs into disturbed areas. Well established specimens produced in our laboratory propagation facilities and hardened for the desert environment were transplanted to sites in Yucca Falt, Frenchman Flat, and Mercury Valley. Species included *Atriplex canescens*, *Atriplex confertifolia*, *Coleogyne ramosissima*, *Ephedra nevadensis*, *Eurotia lanata*, *Franseria dumosa*, *Grayia spinosa*, *Larrea tridentata*, *Lycium andersonii*, *Prunus fasciculata*, *Yucca brevifolia*, and *Yucca schidigera*. Additional moisture was supplied to transplanted shrubs as needed. Within a few weeks the browsing small mammals had destroyed virtually all shrub specimens which had been left unprotected (Fig. 6). Rabbits were primarily involved based upon the evidence of fresh fecal droppings alongside the destroyed and severely damaged specimens. Again, they seemed to be attracted as much, or more, to the stem tissue of these shrubs as they were to leaf tissue. Our experience from these trials indicates that a more rapid revegetation than that which naturally will occur could be achieved in the disturbed areas of the Nevada Test Site by transplanting native shrubs under conditions that will protect them from browsing animals until they become well established. Late fall or early spring transplanting is most practical in order that specimens can take advantage of the soil moisture input which normally occurs during the late fall and winter months.

CONCLUSIONS

Experience at the Nevada Test Site indicates that decades of time are necessary for the vegetation in areas disturbed by nuclear testing activities to return to its original state. Shrub seedling germination and survival is much better at the higher elevation test areas on Pahute Mesa than at the lower elevation test areas on Yucca Flat and Frenchman Flat. It should be clearly understood, however, that the same pattern of vegetational recovery observed in areas disturbed by nuclear testing also has occurred in other areas on Pahute Mesa and Yucca Flat which were disturbed only by mechanical means. Therefore, we must emphasize that the slow recovery rate for the perennial shrub species is not the result of area disturbance by blast, fire, and radiation effects of nuclear detonations but of the combined effects of severe environmental conditions and browsing animals. Artificial revegetation studies indicate that the vegetational recovery time can be shortened markedly by transplanting native shrubs into disturbed areas under conditions which will protect them from browsing animals.

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Table 1. Revegetation on 25 m^2 plots 3 years after the original vegetation was completely destroyed by radioactive fallout.

Plant species	Per cent ground cover on 25 m^2 plots* U20K site 2	U20K site 4	U20L site 1
Perennials			
Artemisia arbuscula	—	0.10	0.12
Artemisia tridentata	1.14	—	—
Chrysothamnus parryi	—	0.11	—
Ephedra nevadensis	2.19	—	0.04
Grayia spinosa	1.05	0.59	—
Juniperus osteosperma	—	—	0.05
Lycium andersonii	0.17	—	—
Sphaeralcea ambigua	3.34	0.31	0.02
Grasses			
Oryzopsis hymenoides	0.04	0.22	0.10
Poa sandbergii	0.02	0.24	0.63
Sitanion jubatum	0.84	—	0.32
Annuals			
Eriogonum ovalifolium	0.06	—	—
Machaeranthera leucanthemifolia	5.94	1.01	—
Other mixed annuals	<0.10	<0.20	<0.20
Original *Artemisia* species	15.32	13.43	14.49

*Mean of 5 replicates. Ground cover was calculated from mean canopy diameter of annuals and perennials and from mean crown diameter of grass clumps.

Table 2. Numbers of new plants in 25 m^2 plots after the original vegetation was completely destroyed by radioactive fallout.

Plant species	U20K site 2 1968	U20K site 2 1969	U20K site 4 1968	U20K site 4 1969	U20L site 1 1968	U20L site 1 1969
Perennials						
Artemisia arbuscula	0	0	1	4	87	403
Artemisia tridentata	46	73	0	0	0	0
Chrysothamnus parryi	0	0	2	1	0	0
Ephedra nevadensis	18	16	0	0	11	10
Eurotia lanata	0	1	1	1	0	0
Grayia spinosa	3	3	7	7	0	0
Juniperus osteosperma	0	0	0	0	2	1
Lycium andersonii	3	3	0	0	0	0
Sphaeralcea ambigua	61	40	4	4	3	5
Grasses						
Oryzopsis hymenoides	8	17	36	50	16	20
Poa sandbergii	3	5	106	140	436	450
Sitanion jubatum	575	600	0	3	106	125
Annuals*						
Eriogonum ovalifolium	6	11	0	0	0	1
Machaeranthera leucanthemifolia	376	468	37	782	17	12
Original population of *Artemisia* species	315		346		370	

***Salsola* species were numerous but not counted.

Figure legends

Fig. 1. View in fallout pattern 5 years after the original vegetation was destroyed by radiation from the Palanquin (U20K) nuclear cratering event. Revegetation at this time includes mixed grasses, winter and summer annuals, and new seedlings of Artemisia species.

Fig. 2. View of site 2 years after the original vegetation was destroyed by fallout radiation at which time revegetation primarily included the Salsola species and a few clumps of mixed grasses.

Fig. 3. View of the same site shown in Fig. 2 five years after the original vegetation was destroyed by radiation. Note how the mixed grasses have begun to dominate this area.

Fig. 4. New seedlings of the Artemisia species are surviving in sufficient numbers to assure revegetation of the areas destroyed by fallout radiation on Pahute Mesa.

Fig. 5. New seedlings of the Artemisia species suffer damage from browsing rabbits which are thought to play an important regulatory role in seedling survival. Note pieces of shoots which have been clipped off and lying on ground near fecal droppings.

Fig. 6. Seedlings and rooted cuttings of Mojave Desert shrub species including this Yucca brevifolia, suffered heavy damage from browsing rabbits when transplanted to unfenced revegetation study plots.