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MASTER

REVEGETATION FOLLOWING ARTIFICIAL DISTURBANCE

Three Year Progress Report
for period 1 June 1975 - 28 February 1978

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Introduction

This project started with a contract effective 1 June 1975 between Colorado State University and the U. S. Atomic Energy Commission. The purpose of the study was to look at some of the potential problems associated with reseeding or reclamation in the buffer zone at the Rocky Flats nuclear weapons plant near Golden, Colorado and the potential for movement of soil with low level radionuclide contamination during the reclamation process as a result of wind erosion (resuspension).

During the course of the study, plots were prepared for seeding and seeded but the associated measurements of soil movement, as originally proposed, were not carried out. This part of the study was omitted because of the time commitment required and the lack of an adequate graduate student to do this part of the study.

During the period of time covered by this report, that part of another contract dealing with the Grasslands Irradiation Site was transferred to the contract. The objectives of the original study were continued. This transfer was made because I had planned and conducted the Grasslands Irradiation study and desired to continue the follow-up and recovery part of the study.

More recently, it was proposed that plant sensitivity to an internal alpha dose, such as might be encountered on Pu contaminated or uranium mine mill tailing contaminated soils, be measured using chromosome aberrations as the end point. A study was initiated to accomplish this objective.

This three year report is divided into two subproject reports; one dealing with the Rocky Flats work and one dealing with the grasslands irradiation study.

SUBPROJECT 1. THE POTENTIAL FOR RECLAMATION AT ROCKY FLATS FOLLOWING TOPSOIL REMOVAL OR DISTURBANCE

Introduction

The Rocky Flats plutonium fabrication plant is surrounded by approximately 20 km² of land that serves as a buffer zone to isolate the plant activities from the public.

Normal operations at the plant do not result in significant air concentrations or in significant soil contamination. Unusual conditions have existed in the past or may exist in the future that results in soil contamination such that it becomes desirable to remove the contaminated soil. Other plant operations may make it desirable to revegetate significant areas in the buffer zone. Low precipitation, average wind speeds of nearly 4 m/s, and rocky soil combine to make the potential for revegetation difficult, especially at a reasonable cost.

The objectives of this study were:

1. To determine a rapid and feasible method of revegetation.
2. Determine a revegetation method such that the vegetation will revert to a "natural" system as rapidly as possible.
3. Develop a predictive model for soil movement by wind during the revegetation period.

No work was done on objective #3 during this 3 year period.

Materials and Methods

In 1975, an initial effort was made to evaluate a seeding that had been made by Rocky Flats personnel several years earlier. This area was located south of the east portal road and about 500 metres east of the east portal. Line transects were established and 25 x 25 cm square quadrats randomly located along the transect. A species list, ground cover, and percent bare soil was determined for each quadrat. Twenty five percent of the quadrats were clipped for biomass determination.

Also in 1975, an area was selected in the southwest quadrant of the buffer zone on the top and southeast slope of a ridge (Fig. 1). The ridge was oriented

Fig. 1. General location and layout of Rocky Flats plant showing boundary prior to purchase of additional buffer area and potential plot location areas.

approximately 60° relative to true north. The soil on the ridge was typical of that on the western part of the Rocky Flats buffer zone, i.e., it was rocky. The basic design of the experiment was randomized complete block design within each seeding date with 3 seeding dates, spring, summer and fall; 6 seed mixtures; and seedings in each of 3 years (Fig. 2). The seed mixtures used are listed in Table 1. Due to curtailment of the experiment, no seedings were made in the fall of 1977 or in 1978.

Initially, an attempt was made to prepare a seedbed by plowing the plots with a moldboard plow. The soil in this area of the buffer zone was too rocky to plow. A landscape tool, scarifier, was tried and this worked fairly well with repeated scarifying until the soil was fairly loose and the existing vegetation fairly well eliminated.

The soil was too rocky for seeding with a mechanical seeder or any similar tool. Therefore, the seeding rate was doubled and the seed broadcast by hand. In order to give uniform distribution, soil was mixed with the seed to increase the volume and the soil-seed mixture scattered so that each plot was covered twice. In 1977, the scarifier and a chain drag were used on the plots after seeding to cover the seed.

The original design called for permanent quadrats in each plot to evaluate the seeding. Since the study was terminated prior to completion, Rocky Flats personnel will monitor the seeding success. The specific method to be used is not known.

Results

The seeding carried out by Rocky Flats personnel was done on topsoil purchased, brought in, and spread on the area to be seeded. The seed was planted using

Fig. 2. Design of the seeding experiment in the Rocky Flats buffer zone. The Fall 1977 and the three 1978 seedings were not done. See Table 1 for the make-up of the seed mixes.

		Block 1						Seed mix 2						3							
Plot No. →		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6		
Row 1	1976	5	Summer	4	6	1	3	5	4	Fall	3	6	1	2	3	4	1	2	5	6	
	1977							5	4	Summer	3	6	2	3	5	3	Spring	1	2	4	6
Row 2	1976	2	Summer	3	1	6	4	5	6	Spring	3	2	1	4	2	5	Fall	3	1	6	4
	1977							5	6	Spring	3	1	2	4	2	5	Summer	4	6	3	5

Table 1. Species in seed mixtures and seeding rates* used at Rocky Flats revegetation trials.

Mix Number	Species in Mix	Seeding Rate	
		g/m ²	lb/acre
1	Crested wheatgrass	1.4	12
	Western wheatgrass	1.1	10
	Sand dropseed	0.22	2
2	Crested wheatgrass	1.4	12
	Buffalograss	2.2	20
	Sand dropseed	0.22	2
3	Western wheatgrass	1.1	10
	Sideoats grama	0.68	6
4	Crested wehatgrass	1.4	12
	Western wheatgrass	1.1	10
	Sand dropseed	0.22	2
5	Western wheatgrass	1.1	10
	Sand dropseed	0.22	2
	Buffalograss	2.2	20
	Sideoats grama	0.68	6
6	None (plot left bare)		

*Above seeding rates gave approximately 450 seed/m².

a grain drill in the later summer, 1972. The seed mixture used is in Table 2. The seeded areas was irrigated for about 2 years after seeding. No attempt was made by Rocky Flats personnel to evaluate the seeding success on a quantitative basis.

The data (Tables 3 and 4) indicated that revegetation did occur although the diversity is quite low but a look at the species in Table 4 indicated that only one species of the 4 seeded was successful, Agropyron smithii (western wheatgrass). The other two species that showed a significant frequency were Bromus tectorum (cheatgrass) and Bromus inermis (smooth brome).

No specific quantitative data were taken on the seeded plots in the southwest section. The overall indications from general observation were that the seeding success was poor. The most visible species on most plots was Bromus sp., cheatgrass. Further observations will be made by Rocky Flats personnel.

Discussion

The appearance of only one seeded species in the 1972 seeded area indicates that the mixture used was probably not satisfactory for the conditions that existed at the time of seeding. The other two species that had a high frequency of occurrence probably had seed that came in with the soil or, in the case of Bromus sp., cheatgrass, probably blew in from adjacent areas since cheatgrass is common throughout the buffer zone and was observed as the primary invader along roads and firebreaks. The other species that appear in Table 4 are common to the grassland community on Rocky Flats. The biomass was similar to that found by Little (1976) in a nearby natural system but was composed mostly of non-native species.

The conditions that exist at Rocky Flats, especially the rocky soil, will make seedbed preparation and seeding by conventional methods impractical

Table 2. Seed mixture used at Rocky Flats in late summer 1972 seeding.*

Content	Percent
Andropogon scoparius (little bluestem)	21
A. gerardi (big bluestem)	18
Agropyron smithii (western wheatgrass)	17
Bouteloua curtipendula (sideoats grama)	10
Other crop	1
Weed	0.4
Inert	33

*Information supplied by Chuck Illsley, Rocky Flats.

Table 3. Selected parameters for transects 1 and 2 measured on area reseeded at Rocky Flats.

Transect	Standing crop (g/m ²)	Percent cover	Percent bare soil	Diversity
1	170 ± 56	40 ± 26	12 ± 18	1.2
2	133 ± 64	40 ± 23	22 ± 25	2.3

Table 4. Frequencies for all species sampled in Transects 1 and 2.

n = 21 for transect 1 and 57 for transect 2. Quadrat size was 25 x 25 cm².

Species	Frequency	
	Transect 1	Transect 2
<u>Agropyron desertorum</u> (crested wheatgrass)	--	0.053
<u>A. smithii</u> (western wheatgrass)	0.90	0.81
<u>Bouteloua curtipendula</u> (sideoats grama)	--	0.018
<u>B. gracilis</u> (blue grama)	--	0.075
<u>Bromus inermis</u> (smooth brome)	0.33	0.19
<u>Bromus tectorum</u> (cheatgrass)	0.38	0.58
<u>Liatris punctata</u> (dotted gayfeather)	--	0.035
<u>Sitanion hystrix</u> (bottlebrush squirreltail)	--	0.053
<u>Stipa comata</u> (needle and thread)	--	0.018
<u>Yucca glauca</u> (small soapweed)	--	0.018

or impossible. At best, seeding will be expensive and chances for success small regardless of the species seeded. The steep slopes on many of the ridges will prevent the use of farm type tractors and some type of tracked tractors will have to be used. The rocks necessitate the use of a scarifying type tool for seedbed preparation rather than a moldboard plow. The seeding will have to be done by broadcasting, perhaps from an airplane, which decreases the chance of success.

Importing topsoil along with irrigation can be used to alleviate some of the above mentioned problems. However, this would be expensive and may be impossible to do on some of the steeper slopes. Results from a previous seeding using topsoil and irrigation, however, do not indicate a high degree of success.

I recommend that the area seeded in 1972 be monitored to determine the rate of change of species present and to determine if the fraction of native species increases relative to the smooth brome and cheatgrass.

SUBPROJECT 2. EFFECTS OF RADIATION ON A SHORTGRASS PLAINS ECOSYSTEM

CHRONIC IRRADIATION

Methods

The basic experimental design and early results have been published (Fraley, 1971, Fraley and Whicker, 1974). The irradiation of the chronic sectors was initiated 3 April 1969 and has continued since that time. Recent data taken on the 25 x 25 cm permanently located quadrats has been limited to density by species or basal cover for Bouteleua gracilis (Bogr), blue grama. These data were converted to Diversity using the equation $D = k \sum_{i=1}^n p_i \ln(p_i)$ and to Coefficient of Community using the equation $CC = 2 C / (A + B)$. In the above equation, p_i was the

probability of sampling the i th species, A was the number of species in the irradiated plot, B was the number of species in the control plot and C was the number of species shared by each. More detail on the calculation on the calculations was in Fraley (1971). In addition, B. gracilus cover was used as a measure of radiosensitivity since it was the dominant species.

Results

Diversity: There was no change in diversity over the last 3 year period (Fig. 3 and Table 5). The diversity values have remained nearly constant since the second summer after initiation of the irradiation. More details of the early changes can be seen in Fig. 4.

Coefficient of Community: There was no change in coefficient of community over the last 3 year period (Fig. 5 and Table 6). The coefficient of community values have remained nearly constant since the second summer after initiation of the irradiation. More detail of the early changes can be seen in Fig. 6.

Bogr cover: There was no change in Bogr cover over the last 3 year period (Table 7). There has been a steady but slow decline in the exposure rate resulting in a Bogr cover equal to 50% of the no effects mean since the second year of irradiation. The data cannot be interpreted to determine whether or not that trend will continue.

Figure 3. Diversity as a function of exposure rate and time for native shortgrass vegetation chronically exposed to ionizing radiation from a ^{137}Cs photon source. Irradiation was initiated 3 April 1969.

Table 5. Exposure rate required to reduce diversity to 50% of the "no effects" value for native shortgrass vegetation. The irradiation was initiated 3 April 1969.

Sampling date	Exposure Rate (R/h)		
	-2 s.e.	D50	+2 s.e.
6-69	34	47	65
9-69	21	27	36
4-70	17	27	42
6-70	7.7	11	16
9-70	9.0	15	24
6-71	9.8	15	22
6-72	10	14	20
6-73	15	20	28
6-74	7.9	12	19
6-75	11	15	22
6-76	13	17	22
6-77	11	15	19

Figure 4. Diversity as a function of exposure rate and time for native shortgrass vegetation chronically exposed to ionizing radiation from a ^{137}Cs photon source. Irradiation was initiated 3 April 1969.

Figure 5. Coefficient of Community as a function of exposure rate and time for native shortgrass vegetation chronically exposed to ionizing radiation from a ^{137}Cs photon source. Irradiation was initiated 3 April 1969.

Table 6. Exposure rate required to reduce coefficient of community to 50% of the "no effects" value for native shortgrass vegetation. Irradiation was initiated 3 April 1969.

Sampling date	Exposure Rate (R/h)		
	-2 s.e.	CC50	+2 s.e.
6-69	74	90	108
9-69	18	24	33
4-70	23	32	44
6-70	13	18	24
6-71	12	16	22
6-72	12	16	21
6-73	10	15	21
6-74	8.5	13	21
6-75	12	17	24
6-76	9.3	13	19
6-77	11	14	18

Figure 6. Coefficient of Community as a function of exposure rate and time for native shortgrass vegetation chronically exposed to ionizing radiation from a ^{137}Cs photon source. Irradiation was initiated 3 April 1969.

Table 7. Exposure rate required to reduce Bogr (blue grama) cover to 50% of the "no effects" value. Irradiation initiated 3 April 1969.

Sampling date	Exposure rate (R/h)		
	-2 s.e.	C50	+ 2 s.e.
6-69	20	35	62
9-69	2.3	3.5	5.3
4-70	5.0	9.0	16
6-70	5.9	9.2	14
9-70	3.0	5.1	8.8
6-71	3.3	6.0	11
6-72	3.5	5.2	7.6
6-73	2.9	4.0	5.6
6-74	3.2	4.6	6.4
6-75	2.1	3.3	5.2
6-76	0.54	1.2	2.8
6-77	1.5	2.7	4.8

Discussion

The data indicate the plant community has nearly stabilized and is in equilibrium with the exposure rates received from the ionizing radiation. There has been a minor trend towards decreasing 50% cover values for Bogr (blue grama) which would indicate that the Bogr has not quite equilibrated with the ionizing radiation. Whether measured by the effects on diversity, coefficient of community or Bogr cover, all results indicated that the short-grass vegetation is very resistant to ionizing radiation.

SHORT-TERM, SEASONAL IRRADIATION

Results and Discussion

The irradiation of these plots took place in April, July or December of 1969 (spring, summer and late fall). The data taken over the last 3 years represents recovery. For diversity, recovery in all plots and seasons was essentially complete. As measured by coefficient of community, the recovery was not quite complete for those plots receiving the highest total exposure (>230 kR). These 2 data sets imply good recovery but not the same plant community as was originally present. There are several species which were present in the original plant community but are not yet present in the plots which had the greatest radiation effects. The 2 most common are Bouteloua gracilis, blue grama, and Opuntia occidentalis, plains prickly pear. These plots are moving through the seral stages normally associated with secondary succession.

When the radiation effects and recovery were determined as measured by Bogr (blue grama) cover, the plots fall into 2 distinct categories: those for which all of the Bogr was killed and those for which it was damaged but not eliminated. In those plots which received lethal exposures for Bogr (>130 kR for the spring, 230 kR for summer, and 49 kR for late fall) no recovery of the Bogr has been made except for spreading into the plots from plants adjacent to the plots. Some Bogr seedlings have been found in the plots but these have not affected the cover data. The recovery of these plots, as measured by Bogr cover, is predicted to be very slow.

For those plots in which the Bogr was heavily damaged, 83 kR for spring, 130 kR for summer or 32 kR for late fall, recovery has returned the Bogr cover to pre-irradiation values. This resulted from filling in of crowns of plants

that were already there and not completely killed rather than in new plants becoming established as a result of seed germination.

The shortgrass vegetation was very resistant to ionizing radiation when administered short-term (approximately 30 d). The vegetation was most sensitive when irradiated in the late fall (December) when an exposure of 49 kR was required for total Bogr lethality and the vegetation was least sensitive in the summer (July) when an exposure of 230 kR was required for lethality. For spring, 130 kR was required for lethality.

ARTIFICIAL DISTURBANCE

Results

Plots located adjacent to but outside the radiation field were burned, scraped or tilled in spring, summer and late fall of 1969 or 1970 to compare the effect and recovery with the irradiated plots. After one year there were no differences between season or year of treatment and results from all plots were combined by treatment. Recovery was measured using diversity and Bogr (blue grama) cover (Fig. 7). During the past 3 years the diversity in the scraped and tilled plots was the same as the control plot diversity. Burn plot diversity was lower.

Recovery as measured by Bogr cover shows different results (Fig. 8). The scraped and tilled plots showed almost no cover although there was a small increase since 1970. The burn cover was approximately the same as the control over the past 3 years.

Figure 7. Diversity in the burned, scraped, tilled and control plots as a function of time following treatment. The plots were located adjacent to irradiated plots but outside of the radiation field. Treatment was in 1969 or 1970.

Figure 8. Bogr (blue grama) cover for burned, scraped and tilled plots as a function of time following treatment. The plots were located adjacent to the irradiated plots of the same treatment. Treatment was in 1969 or 1970.

Discussion

The scraped and tilled plots were in the second or third seral stage of secondary succession. Several primary invaders were present and also several perennial grasses and semishrubs. Typical were Aristida longiseta, red threeawn; Sitanion hystrix, squirreltail bottlebush; Stipa comata, needle and thread, Eriogonum effusum, buckwheat; Gutierrezia sarothrae, broom snakeweed; Chrysothamnus nauseosus, rabbitbrush; and Chrysopsis villosa, hairy goldaster. This accounted for the relatively high diversity values found. Notably absent were Bouteloua gracilis, blue grama and Oppuntia polyacantha, plains pricklypear. Only an occasional individual of these two species was present. Most of the Bogr plants appeared to come from crowns of old plants that had not been completely destroyed rather than from seedlings although a few seedlings were present.

The lower diversity in the burned plots was due to the presence of enough of the dominant species, Bogr, to keep invasion from invader species to a minimum. Also, burning had killed some of the semishrubs and these have been slow in returning. The burning killed all of the O. polyacantha and only a very few of them were seen in the burned plots. These factors combined to keep the diversity in the burned plots lower than in the control.

The Bogr cover in the burned plots had returned to control values. The small amount of Bogr cover present in the scraped and tilled plots was due primarily to recovering Bogr crown pieces plus a few Bogr seedlings that have appeared in the last 2 years. Bogr recovery in the scraped and tilled plots is predicted to be very slow due to the exacting conditions necessary for germination of Bogr seeds and successful establishment of seedlings.

A comparison of the burned, scraped and tilled plots with the irradiated plots indicated that scraped and tilled plots responded similar to the irradiated plots that received exposures resulting in complete lethality to the dominant species, Bogr. This was $\bar{S}$ 130, 230, and 49 kR for the spring, summer and late fall irradiated plots, respectively.

The effect of burning the plots was similar to radiation exposures resulting in damage to, but not elimination of, Bogr. This happened in plots that received approximately 32 to 83, 32 to 130, and 20 to 30 kR for the spring, summer and late fall irradiated plots, respectively.

The above results indicate that an accurate prediction of effects and recovery of radiation damaged vegetation can be made if a general knowledge of the radio-sensitivity is known and information about secondary succession following various types of disturbance is known. All possible information about species within the plant community must be used, however, to account for possible species differences that might exist, such as certain modes of reproduction that might be affected by radiation but not by fire.

CHROMOSOME ABERRATIONS

Introduction

There are several mechanisms for the introduction of alpha emitting radionuclides into or on vegetation. The most important aspect of this contamination is probably the introduction of the alpha emitters into the food chain of various species of animals, including man. There is the possibility, however, that the internal concentrations of alpha emitters may result in damage to the contaminated plant. The most sensitive indicator of such effects will be the nuclear components of the cell. Very little specific data exist on the effects of internal alpha emitters on plants as measured by chromosome aberrations. It is important to be able to predict the radiation effect on plants that might become contaminated with alpha emitters at locations such as Rocky Flats, waste disposal sites such as INEL or Hanford, and in mill tailing disposal areas.

With this in mind, an experiment was designed with the following objective:

To determine the sensitivity of plant cells to alpha radiation dose as measured by chromosome aberrations.

Subobjectives include:

1. Determine a model plant species to use.
2. Determine the radiosensitivity of the model plant system using gamma photon LD50 as the criterion.
3. Develop the techniques necessary to make accurate aberration counts using a beta emitter, ^{32}P .
4. Determine the alpha dose sensitivity using the model plant system.
5. Correlate results from the gamma, beta and alpha doses and apply the results to predict possible effects in situations where alpha contamination might exist.

Materials and Methods

Sensitive species from the grasslands were evaluated but found to be undesirable due to large numbers of chromosomes and/or difficulty of raising in the greenhouse. Tradescantia occidentalis was tried but suffered rust infection and results were inconclusive. Ornithogalum virens was selected because of low chromosome number ($2n = 6$), ease of handling in the greenhouse and like genetic make-up (vegetative propagation).

Squash techniques for root tip cells and pollen grains have been developed and a ^{32}P experiment initiated. An LD50 study using a ^{60}Co source is ready to be carried out. Interphase chromosome volume (CV) values have been determined for root tip cells and pollen.

Results and Discussion

This experiment is still in its initial phase. No specific radiosensitivity values are available. The species is predicted to be relatively radiosensitive because of its large ICV values.

If all phases of this experiment are completed, then it will be possible to compare effects of alpha, beta and gamma doses on the amount of damage expected as measured by chromosome aberrations. Then it will be possible to predict minimum levels of contamination that will result in measurable effects.

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