RESPONSE OF RESEEDED COAL MINE SPOILS TO SEASON AND INTENSITY OF DEFOLIATION: PRELIMINARY FINDINGS[1]

by

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Abstract. Two principal questions facing managers of revegetated coal mine spoils in the semiarid Southwest are how seasonal defoliation patterns and intensities of defoliation affect forage production and plant stability on reclaimed sites. Preliminary findings were obtained from a study conducted on revegetated coal mine spoils near Gallup,NM, during 1982-1984. Five mine spoil sites, recontoured and seeded to a mixture of predominantly wheatgrasses (*Agropyron* spp.) between 1975 and 1980, were selected for study. Each site was subdivided into six split plots that were randomly assigned defoliation seasons of early spring, late spring, summer, fall, winter or a control. All plots except the control were subdivided and were assigned defoliation intensities of 7.5 cm or 15 cm. Defoliation treatments were applied two consecutive calendar years, early spring 1982 to winter 1984. Treatment effects were assessed in late August 1984. Preliminary findings indicate neither wheatgrasses nor total standing herbage was influenced by seasonal defoliation, but other grasses were less productive when defoliated in the summer and winter than when defoliated in the fall. Total herbage production diminished when defoliated at the 7.5-cm stubble height every season except early spring and fall compared to the control. Generally, defoliation at 15 cm did not impact total herbage production. Neither the time since seeding of the coal mine spoils nor topsoiling consistently influenced total herbage production.

Additional Key Words: forage production, wheatgrasses, New Mexico

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Introduction

By the year 2000 coal strip mining is expected to alter more than 200,000 acres (Fisher et al., 1986) of western range. These lands provide forage for wild, feral and domestic herbivores as well as cover and nesting habitat for numerous species of animals, birds, reptiles and amphibians. The Surface Mining Control and Reclamation Act of 1977 and its supporting regulations require the reestablishment of vegetation with cover that is at least equal to the natural vegetation of the area, capable of stabilizing the soil from surface erosion and compatible with the plant and animal species of the area. The technical literature on mined land reclamation, as assembled by Aldon and Oaks .(1983), Williams and Schuman (1987) and Wright (1978), has dealt almost exclusively with aspects of revegetation, such as environmentally adapted plant species, seeding mixtures, preseeding site preparation techniques, fertilization, irrigation, mulching, other cultural treatments and unique soil chemical and physical properties. For example, Lang (1982) found that forage production on 2.5 year old Wyoming mine spoils equalled or exceeded that on native range. Several studies examined forage production and livestock gains on revegetated coal mine spoils and adjacent native range in Colorado (Laycock and McGinnies, 1985; Laycock and Layden, 1986), Montana (DePuit and Coenenberg, 1979) and North Dakota (Hofmann and Ries, 1988). In a 3-year study of light, heavy and nongrazed Wyoming pastures, Schuman et al. (1986) concluded that successfully reclaimed mined lands will support livestock grazing without deteriorating the basal ground cover of vegetation. Laycock and Layden (1986) found no differences in animal performances among summer-long heavy, summer-long light or short duration grazing systems in a 2-year study on reclaimed mined lands. After 5 years of study, Hofmann and Ries (1988) concluded that with 59 percent or less total vegetation removal in early summer, the reclaimed mine spoils provided sustained grazing use with no deterioration. However, for semiarid range only limited information is available on the effects of biomass removal on stability of vegetation and associated mine spoil material or on how the season and intensity of biomass removal may influence productivity of reclaimed coal mine spoils.

The objectives of this study were to: (1) determine how seasonal biomass removal patterns and intensities of biomass removal to simulate grazing affect forage production on reseeded coal mine spoils of varying ages and spoil management practices, and (2) synthesize the data into management guidelines concerning suitability of grazing revegetated coal mine spoils in western New Mexico.

Study Area

This study was conducted on the McKinley Coal Mine, approximately 35 km northwest of Gallup, NM. Elevation at the study area is approximately 2100 m but varies because of a series of rolling ridges and valleys. Area soils have weathered predominantly from sandstone, although heavy clay soils derived from shale occur on adjacent alluvial fans. On unmined areas, Colorado pinyon (*Pinus edulis* Engelm.) and one-seed juniper (*Juniperous monosperma* (Engelm.) Sarg.) are typically the codominant native species on sandstone ridges (Wagner et at., 1978). Big sagebrush (*Artemisia tridentata* Nutt.) is a common understory shrub on the sandstone ridges and is the dominant species on alluvial fans. Other species common in both associations include Greenes rabbitbrush (*Chrysothamnus greenei* (Gray) Greene subsp. greenei), fourwing saltbrush (*Atriplex canescens* (Pursh) Nutt.), galleta (*Hilaria jamesii* (Torr.) Benth.) and western wheatgrass (*Agropyron smithii* Rydb.).

Annual precipitation at McKinley Mine (averaged over 40 years) is 30 cm and approximately 4 cm per month are received between July and October from convectional thundershowers (Sellers and Hill, 1974). Periodic snow showers occur from November to May. Extended dry periods are common during the spring and early summer. During the 3-year study, annual precipitation at the McKinley Mine averaged 22.6 cm, ranging from 29.8 cm in 1982 to 18.3 cm in 1983. Monthly average temperatures ranged from a high of 21°C in July to a low of -1°C in January.

Methods and Design

Five revegetated coal mine spoil sites were selected for study; all differed in spoil management and age since seeding. The regraded spoil material on all sites generally consisted of a mixture of loamy soil, sandstone and shale. However, the physical and chemical properties of individual spoil sites varied widely, depending upon depth of the original cut, ratio of sandstone to shale and time since exposure (Scholl and Pase 1984). Three sites were topsoiled before seeding, but the other two sites were seeded directly on the raw spoil material. The five sites also reflect four seeding dates; sites were seeded during the summers of 1975, 1977 (2 sites), 1979 and 1980.

Sites were seeded with one of four seed mixtures, depending upon year, but all mixtures were predominantly western wheatgrass and other *Agropyron* spp. such as pubescent wheatgrass (*A. trichophorum* (Link) Richt.), tall wheatgrass (*A. elongatum* (Host) Beauv.), thickspike wheatgrass (*A. dasystachyum* (Hook.) Scribn.), streambank wheatgrass (*A. riparium* Scribn. & Smith), crested wheatgrass (*A. cristatum* (L.) Gaertn.) and intermediate wheatgrass (*A. intermedium* (Host) Beauv.). Smooth brome (*Bromus inermis* Leyss.) and yellow sweetclover (*Melilotus officinalis* (L.) Lam.) were also included in the 1975 and 1977 seed mixtures. Sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), Indian ricegrass (*Oryzopsis hymenoides* (R. & S.) Ricker) and dewinged fourwing saltbush were included in the 1979 and 1980 seed mixtures. Sites were seeded with pure live seed at a rate of approximately 7.71 kg/ha.

Each site was subdivided into six equal plots that were randomly assigned defoliation seasons of early spring (April 9), late spring (June 15), summer (August 3), fall (October 2), winter (January) and a control (nondefoliated). Plots were 12.2 by 9.15 m. All plots except the control were then subdivided into two equal subplots and randomly assigned one of two defoliation intensities (stubble heights), 7.5 cm or 15 cm, providing 11 treatment cells per replication. Subplots were 6.1 by 9.15 m. A rotary lawn mower adjusted to cut at the prescribed stubble height was used to apply defoliation treatments. The 11 treatment cells were replicated three times on each of the five sites, providing a total of 165 treatment cells. Defoliation treatments (seasons and intensities) were applied to the same cells during two consecutive calendar years immediately preceding assessment of treatment effects. Treatments were applied in 1982 and again in 1983, except for the winter defoliation, which was applied in January 1983 and January 1984.

Treatment effects were assessed in late August 1984 by hand clipping the standing live herbage at ground level on four 0.093-m^2 quadrats on each treatment cell. During clipping, herbage on each quadrat was separated into two groups, wheatgrasses and all other perennial grasses. Herbage production is reported as oven-dry weights.

The experimental design was a split-split plot. Means were tested for significance by analysis of variance (ANOV) followed by Tukey's procedure (Steel and Torrie, 1960). Means with heterogeneity of variances were compared by Welch's test (Milliken and Johnson, 1984) followed by Dunnett's T3 procedure (Dunnett, 1980). Differences at the 0.05 level of probability were considered significant.

Results and Discussion

Total standing herbage on revegetated coal mine spoils in western New Mexico was not influenced by seasonal defoliation treatments applied for two consecutive years (table 1). Regardless of defoliation season, total standing herbage averaged 785 kg/ha, but it ranged from 709 to 943 kg/ha. Also, the wheatgrasses, as a group, were not influenced by defoliation season. Production of wheatgrasses averaged 370 kg/ha over the five defoliation seasons, and the extremes in seasonal production ranged only from 342 to 397 kg/ha. The other grasses group, however, was less productive when defoliated in summer and winter (336 and 312 kg/ha, respectively) than when defoliated in the fall (579 kg/ha). Production of other grasses when defoliated during the spring did not differ from production after other defoliation treatments.

The appearant tolerance of wheatgrasses to defoliation treatments may be due to the study procedure of treatment applicaton. The defoliation treatments were applied two consecutive years at 12-month intervals; vegetation responses to treatments were evaluated 8-17 months after application of the final treatment. Thus, the wheatgrasses had only an 8-month

Table 1.--Standing live herbage (kg/ha) at end of the growing season on reseeded coal mine spoils in western New Mexico by season of defoliation.

Defoliation Season	Herbage Groups: Wheatgrass spp.	Other grasses	Total
Early spring	361 (93.5)a[1]	399 (63.6)ab[2]	760 (104.0)a
Late spring	342 (65.9)a	447 (68.1)ab	789 (88.8)a
Summer	387 (69.9)a	336 (70.1)b	724 (90.5)a
Fall	364 (59.5)a	579 (90.1)a	943 (96.5)a
Winter	397 (60.0)a	312 (55.8)b	709 (69.3)a
Average	370	415	785

[1]Values within parentheses are standard errors.
[2]Values within columns followed by the same letter are not significantly different (P=0.05).

rest after the final winter clip; however, the plants were dormant then, and clipping treatment only minimally impacted succeeding plant growth. Clipping wheatgrasses in the spring during their rapid growth and culm elongation would probably be detrimental to succeeding plant growth. However, after 12 months of rest and probable regrowth, the impact of spring clipping on wheatgrasses was probably minimal.

Dahl and Hyder (1977) reviewed in detail the developmental morphology of grasses, Branson (1953) described growth, and Rechenthin (1956) discussed morphological characteristics of grasses which affect their tolerance to defoliation. Jewiss (1972) reported that removing of the apical meristem prevents further development of the culm and stimulates axillary buds at the base, however, this stimulation does not necessarily result in a greater biomass production. The probable cause of diminished production in the other grasses following summer and winter defoliations can only be partially explained. The other grass group consisted predominantly of warm-season species, and the summer defoliation treatment apparently removed the apical meristem thus restricting further plant growth (Vogel and Bjugstad, 1968). No explanation for response to winter defoliation is apparent, and it may be an artifact of this study.

Defoliation intensities used in this study generally influenced total herbage production to different degrees for different seasons (table 2). For example, when compared with

Table 2.--Standing live herbage (kg/ha) at end of the growing season on reseeded coal mine spoils in western New Mexico by defoliation season and stubble height.

Defoliation season Herbage group	Stubble Height 15 cm	 7.5 cm	 Control
Early spring			
Wheatgrasses	353 (93.1)a[1]	368 (163.1)a	453 (110.2)a
Other grasses	332 (81.1)b[2]	466 (97.8)ab	726 (158.8)a
Total	685 (111.3)b	834 (176.2)ab	1179 (172.0)a
Late spring			
Wheatgrasses	483 (121.4)a	202 (46.0)b	453 (110.2)a
Other grasses	532 (118.9)ab	362 (65.9)b	726 (158.8)a
Total	1015 (159.7)a	564 (67.7)b	1179 (172.0)a
Summer			
Wheatgrasses	421 (114.1)a	354 (81.5)a	453 (110.2)a
Other grasses	398 (126.1)ab	274 (61.8)b	726 (158.8)a
Total	819 (156.0)ab	628 (91.4)b	1179 (172.0)a
Fall			
Wheatgrasses	474 (103.5)a	254 (56.0)a	453 (110.2)a
Other grasses	567 (121.7)a	592 (135.6)a	726 (158.8)a
Total	1041 (139.9)a	846 (132.9)a	1179 (172.0)a
Winter			
Wheatgrasses	400 (94.7)a	394 (74.6)a	453 (110.2)a
Other grasses	296 (71.9)b	329 (85.8)b	726 (158.8)a
Total	696 (101.0)b	723 (95.7)b	1179 (172.0)a
Average			
Wheatgrasses	426 (47.1)a	314 (41.9)a	453 (110.2)a
Other grasses	425 (47.7)a	405 (41.9)a	726 (158.8)a
Total	851 (60.9)ab	719 (53.3)b	1179 (172.0)a

[1]Values within parentheses are standard errors.
[2]Values within rows followed by the same letter are not significantly different (P=0.05).

the control, total herbage production diminished when defoliated at the 7.5-cm stubble height every season except early spring and fall. Average total herbage production was less on the 7.5-cm stubble height treatment than on the control (719 vs 1179 kg/ha). On the whole, defoliation at 15 cm did not appear to impact total herbage production. The reduction in production of other grasses and the reduction in total herbage after defoliation at 15 cm in winter and early spring is inconsistent with the other results and may not be a true reflection of the biological effects. Under most seasonal defoliation treatments, clipping to a 15-cm stubble height did not significantly depress total herbage production, although total production was depressed after defoliation in late spring, summer and winter at the 7.5-cm stubble height.

Wheatgrasses were not influenced by season or intensity of defoliation, except when defoliated at 7.5 cm in late spring. Apparently the apical meristem in wheatgrass tillers was located between 7.5 and 15-cm above the soil surface during the late spring harvest since production on the 15-cm defoliation treatment was similar to the control at end of the growing season. Production of the other grasses was reduced by the 7.5-cm defoliation during all seasons except the fall. Apparently most species within this predominantly warm-season group had matured by the fall and were relatively tolerant to defoliation intensity. Production on the plots defoliated at 15 cm, was generally not greater than on the 7.5 cm treatment or less than on the control treatments.

Total herbage production was greatest on the 1979 and 1980 topsoiled sites and on the 1977 non-topsoiled site (table 3). Total production was significantly less on the 1977

Table 3.--Standing live herbage (kg/ha) at end of the growing season on reseeded coal mine spoils in western New Mexico by spoil management and seeding date.

Soil management Seeding date	Herbage Group Wheatgrass spp.	Other grasses	Total
Non-topsoiled 1975	328 (43.3)b[1,2]	223 (65.5)b	551 (72.3)b
Non-topsoiled 1977	297 (43.4)b	709 (89.8)a	1006 (92.3)a
Topsoiled 1977	296 (58.4)b	259 (42.8)b	556 (71.7)b
Topsoiled 1979	873 (112.8)a	171 (58.6)b	1044 (119.9)a
Topsoiled 1980	94 (27.3)c	853 (75.9)a	947 (74.4)a
Average	378	443	821

[1]Values within parentheses are standard errors.
[2]Values within columns followed by the same letter are not significantly different (P=0.05).

topsoiled and on the 1975 non-topsoiled sites. Neither the time since seeding of the coal mine spoils nor topsoiling consistently influenced total herbage production. Individual herbage groups also varied in production with study sites. The extremes in wheatgrass production occurred on the two most recently seeded sites and leveled off in production on the older reclaimed sites. *Agropyron* spp. included in the seed mixture do not adequately explain differences in production. Production of other grasses also varied with site, although seed mixture and stand composition did have a major influence. For example, in 1980 two cool-season grasses, squirreltail (*Sitanion hystrix* (Nutt.) J. G. Smith) and Indian ricegrass, were the major contributors to the other grass group. Smooth brome, another cool-season grass, was the major contributor of the other grass group on the 1977 sites; however, general observations indicate it was 2 to 3 times more abundant on the non-topsoiled sites even though the same seed mixture was used on both sites. Many confounding effects apparently influenced herbage production on the reclaimed sites; thus differences in wheatgrasses, other grasses, and total production could be due to differences in seed mixture, stand composition, cover, aspect, slope and spoil material composition.

Management Recommendations

Preliminary findings, based upon simulated grazing, indicate that revegetated coal mine sites in western New Mexico can be defoliated during any one of five seasons without significantly influencing wheatgrass production. Summer defoliation may, however diminish subsequent production of warm-season grasses. Plant response to defoliation intensity was variable, but generally, defoliation at a stubble height of 7.5 cm decreases production more than defoliation at 15 cm.

Topsoiling was a variable factor in production of herbage on reclaimed coal mine sites in western New Mexico. Although not specifically tested in this study, cool-season grass species established sooner or appeared to establish and produce more herbage than warm-season species.

Future research should test the compatibility of grazing on the long-term stability and multiple-use values of reclaimed mine spoils, including establishment of proper stocking rates, livestock utilization patterns, the botanical composition of livestock diets and plant responses to grazing.

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Literature Cited

Aldon, Earl F.; Oaks, Wendall R., eds. 1983. Reclamation of mined lands in the Southwest. Proceedings of a symp http://dx.doi.org/10.2134/agronj1988.00021962008000010009x 1982 October 20-22; Albuquerque, NM: New Mexico Chapter of the Soil Conservation Society of America: 198-200.

Branson, Farrel A. 1953. Two new factors affecting resistance of grasses to grazing. Journal of Range Management. 6:165-171. http://dx.doi.org/10.2307/3893839

Dahl, B. B.; Hyder, D. N. 1977. Developmental morphology and management implications. In: Sosebee, Ronald E., ed. Rangeland plant physiology. Range Science Series No. 4. Denver, CO: Society for Range Management: 257-290. Chapter IX.

DePuit, Edward J.; Coenenberg, Joe G. 1979. Plant response and forage quality for livestock grazing on coal mine spoils in Montana. In: Wali, Mohan K., ed. Ecology and coal resource development. Vol. II. New York: Pergamon Press: 892-898.

Dunnett, Charles W. 1980. Pairwise multiple comparisons in the unequal variance case. Journal of the American Statistical Association. 75(372):796-800. http://dx.doi.org/10.1080/01621459.1980.10477552

Fisher, James A.; Fancher, Gregory A.; Neumann, Robert W. 1986. Survival and growth of containerized native juniper (*Juniperus monosperma*) on surface-mined lands in New Mexico. Forest Ecology and Management. 16:291-299. http://dx.doi.org/10.1016/0378-1127(86)90029-0

Hofmann, L.; Ries, R. E. 1988. Vegetation and animal production from reclaimed mined land pastures. Agronomy Journal. 80:40-44.

Jewiss, O. R. 1972. Tillering in grasses--its significance and control. Journal of British Grassland Society. 27:65-82. http://dx.doi.org/10.1111/j.1365-2494.1972.tb00689.x

Lang, Robert. 1982. Biomass and forage production from reclaimed stripmined land and adjoining native range in central Wyoming. Journal of Range Management. 35:754-755. http://dx.doi.org/10.2307/3898257

Laycock, William A.; McGinnies, William J. 1985. Reclamation and grazing management on a surface coal mine in northern Colorado. In: Proceedings, second annual meeting, American Society for Surface Mining and Reclamation; 1985 October 8-10; Denver, CO. 2:73-76. http://dx.doi.org/10.21000/JASMR85010073

Laycock, W. A.; Layden, T. 1986. Cattle production on reclaimed mined lands in northern Colorado. In: Joss, P. J., Lynch, P. W.; Williams, O. B.,eds. Rangelands: a resource under siege: Proceedings of the second international rangeland congress; 1984 May 13-18; Adelaide, South Australia. Canberra, A.C.T. Australia: Australian Academy of Sciences. 2:196.

Milliken, George A.; Johnson, Dallas E. 1984. Analysis of messy data. Vol. I. Designed experiments. New York: Van Nostrand Leinhold Company. 473 p.

Rechenthin, C. A. 1956. Elementary morphology of grass growth and how it affects utilization. Journal of Range Management. 9:167-170.
http://dx.doi.org/10.2307/3894384

Scholl, David G.; Pase, Charles P. 1984. Wheatgrass response to organic amendments and contour furrowing on coal mine spoil. Journal of Environmental Quality. 13(3):479-482.
http://dx.doi.org/10.2134/jeq1984.00472425001300030030x

Schuman, G. E.; Booth, D. T.; Waggoner, J. W.; Rauzi, F. 1986. The effects of grazing reclaimed mined lands on forage production and composition. In: Joss, P. J.; Lynch, P. W.; Williams, O. B., eds. Rangelands: a resource under siege: Proceedings of the second international rangeland congress; 1984 May 13-18; Adelaide, South Australia. Canberra, A.C.T. Australia: Australian Academy of Sciences. 2:163-164.

Sellers, W. D.; Hill, R. H. 1974. Arizona climate 1931-1972. Tucson, AZ: The University of Arizona Press. 616 p.

Steel, Robert G. D.; Torrie, James H. 1960. Principles and procedures of statistics. New York: McGraw-Hill. 481 p.

Vogel, W. G.; Bjugstad, A, J. 1968. Effects of clipping on yield and tillering of little bluestem, big bluestem, and Indiangrass. Journal of Range Management. 21:136-140.
http://dx.doi.org/10.2307/3896131

Wagner, Warren L.; Martin, William C.; Aldon, Earl F. 1978. Natural succession on strip-mined lands in northwestern New Mexico. Reclamation Review. 1:67-73.

Williams, R. Dean; Schuman, Gerald E., eds. 1987. Reclaiming mine soils and overburden in the western United States: Analytic parameters and procedures. Ankeny, IO: Soil Conservation Society of America. 336 p.

Wright, Robert A., ed. 1978. The reclamation of disturbed arid lands. Albuquerque, NM: University of New Mexico Press. 196 p.