Shrub and tree establishment on coal spoils in northern High Plains – USA

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ABSTRACT

Trickle irrigation, during establishment, increased survival two fold for seven species of shrubs and trees planted on coal mine spoil in the semiarid area of northeastern Wyoming, USA. Increased survival of irrigated plants persisted for five years after initiation of this study, which included two growing and winter seasons after cessation of irrigation. Species included green ash (*Fraxinus pennsylvanica*), Russian olive (*Elaeagnus angustifolia*), silver buffaloberry (*Shepherdia argentea*), Siberian peashrub (*Caragana arborescens*), American plum (*Prunus Americana*), ponderosa pine (*Pinus ponderosa*) and Rocky Mountain juniper (*Juniperus scopulorum*).

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THE STUDY PERSPECTIVE

Shrubs and trees are components of the natural vegetation mosaic throughout nearly all of the Great Plains, but in widely varying abundance and degree of dispersion. Trees and the taller shrubs are found almost exclusively along drainageways and around water impoundments in the more arid portions of the region. These areas of the landscape are zones of maximum biological activity and production. Water is a key element in this arid to subhumid climate.

One of the key surface mine reclamation requirements is restoration of terrain. Considering the characteristic undulating terrain of the surface coal mining areas of northeast Wyoming, this means the formation of drainageways and/or water impoundments where careful treatment and management can achieve maximum enrichment of the biological potential in a planned postmining land use. Trees and shrubs were important elements of the premining landscape; therefore, they should be an element in the postmining landscape, and designed topographic sites favorable for their establishment should be included in the reclamation plan. It appears it may even be possible to establish and manage such areas in a way that they can play an even greater role through improved management in the total biological activity than in the premining state.

Reports dealing with reclamation problems and potentials of the northern Great Plains emphasize moisture supply as the most limiting factor in most places.[5,8] In areas receiving annual precipitation of less than 10 inches, the probability of successful reclamation is so low that surface mining without modifications must be considered as eliminating productive use perhaps for centuries.[3,7] Revegetation can be accomplished under such conditions only with major effort and then not with any assurance of enduring success. Where precipitation exceeds 10 inches per year, reclamation is more feasible, but site specific information is lacking to insure success of specific management goals.

Annual precipitation in the general study area averages about 14 inches. This means that, in 40% of years, precipitation is less than 10 inches, making the successful establishment of vegetation a high risk.[2] The cost of revegetation and the regulatory requirements of prompt reclamation are strong incentives to develop and use treatments that can help insure success.

The Belle Ayr Mine of AMAX Coal Company, the site of this research is located about 18 miles south southeast of Gillette in Campbell County, Wyoming. Numerous operating mines are in this area and additional areas are under lease all along the eastern boundary of the Powder River Basin. The area encompassing these mines and lease areas is collectively called the Wyodak outcrop.[6] The Wyodak outcrop coal beds are 20 feet or more thick with less than about 200 feet of overburden. Overburden at Belle Ayr is basal Wasatch composed of shales and weak sandstones with scattered lenses.

The climate, topography, soils, and spoils are typical of the northwestern Great Plains. Desired postmine uses are growing and insufficient information exists to define reclamation and revegetation treatments with a satisfactory degree of certainty.

THE STUDY LAYOUT AND METHODS

A study plot of two acres was established and fenced in the spring of 1973 on replaced overburden removed from the initial cut (1972) of the Belle Ayr Mine, which was opened along Caballo Creek. The reconstructed spoil profile consisted of a 4- to 5-foot depth of the surface 10 feet of overburden removed from that initial cut. The finish lift of overburden was deposited by end dump trucks backing up and dumping against the fill on the travel level; thus, the trucks did not travel on and compact the final lift. A blade equipped crawler tractor was then used to level and finish the surface.

The area was drilled with a mixture of western wheatgrass (*Agropyron smithii*), green needlegrass (*Stipa viridula*), and four-wing saltbush seed (*Atriplex canescens*). The shrub tree plot was superimposed on this earlier planting.

The experimental design was a randomized complete block with 5-block replication. Each of 7 species was assigned at random to one 45-plant row in each of the blocks. Bare-root stock was planted by hand in holes dug with a portable post-hole auger. Plants were set 6 feet apart in rows 8 feet apart. Thus, the arrangement provided for a total 225 plants of each of 7 species in the 5 blocks. The area was fenced to exclude rabbits, deer and antelope.

Trickle irrigation was randomly placed into the basic design so that half of each row was irrigated and the other half was not irrigated. Supplemental water was applied for three successive growing seasons. The trickle irrigation system was designed to apply 1 gallon of water in 1 hour every 4 days to individual plants starting as early as possible in May and continuing through September. Water was obtained from a deep well at the site. The trickle system consisted of the following primary elements: filter, pressure regulator, timer, flow rate meter, pressure gauges, low density polyethylene tubing distribution system, and a calibrated emitter at each plant designated to receive water. The components were designed to deliver a constant flow of the specified amount of water to all parts of the system at between 12 and 15 psi at the point of entry into the system.

All plantings were weeded each spring in a 1-foot wide strip along each side of the row. Survival counts were made at the end of each dormant season (spring) and growing season (fall) each year during the 6 year study.

Species selected for study were:

- Green ash – *Fraxinus pennsylvanica lanceolata*
- Russian olive – *Elaeagnus angustifolia*
- Silver buffaloberry – *Shepherdia argentea*
- Siberian peashrub – *Caragana arborescens*
- American plum – *Prunus Americana*
- Ponderosa pine – *Pinus ponderosa*
- Rocky Mountain juniper – *Junipers scopulorum*

These are species listed by the USDA, SCS[8] as suitable for consideration for planting in this geographic and climatic zone.

Spoil material was core (15 cores) and bulk (5 pits) sampled to a 54-inch depth for determination of physical properties of the study area. Core samples were used to determine moisture content and pit samples for other characteristics. Analyses were according to Vomocil.[9]

Precipitation was measured on site during the study period with an automatic recording gauge equipped with an Idaho reconnaissance type wind shield. Ethylene glycol was used to prevent freezing during winter.

Data analysis consisted of an ANOV on percentage survival for irrigated verses non-irrigated plants of 7 species combined. Species were not compared because the objective was to determine response to supplemental water and cessation of supplemental water. Differences after cessation of supplemental water were small; they required no analysis.

RESULTS

Spoil properties

Spoil in the plot area is a sandy clay loam, uniform both in depth and between sampling points. The process of evaluating and redepositing the overburden apparently resulted in a uniform mixture (Table 1).

Total pore volume in well developed soils ranges from about 40 to 50%. According to Baver[1], an ideal soil has the pore volume about equally divided between capillary and non-capillary. Examination of average pore volume values as determined according to Vomocil[9] and, according to Baver's specifications, indicate that the spoil was, at the time of the sampling, nearly an ideal planting medium (Table1).

Precipitation

Yearly variations and variations in distributions within years are common traits of precipitation of the semiarid areas such as the

Table 2 *Precipitation (inches) by growing season and year on the study site*

Year	*Growing season*[1]	*Total for year*
1974	4.5	10.4
1975	6.5	13.9
1976	8.5	14.0
1977	8.0	14.7
1978	12.2	19.0
1979	7.7	11.2
1980	6.7	11.8
Ave.	7.7	13.6

[1]May 1 – September 30

Table 1 *Basic physical properties of spoil at the shrub-tree experimental plots at Belle Ayr Mine*

Depth Interval (inches)	*Bulk*[1] *Density (gm/cc)*	*Total*[2] *Porosity % of Soil Volume*	*Retention Porosity % of Soil Volume*	*Detention Porosity % of Soil Volume*	*Moisture Content % Volume Basis*	*% Sand*	*% Silt*	*% Clay*
0-2	1.53	45	24	21	10	65	10	24
4-6	1.60	40	24	17	11	65	10	24
8-10	1.60	40	23	16	11	63	11	25
12-14	1.60	40	24	17	12	63	11	25
16-18	1.56	41	22	19	10	65	10	24
20-22	1.52	42	23	19	12	65	10	24
24-26	1.53	43	24	20	11	67	9	24
28-30	1.50	43	22	21	10	67	9	24
Ave.	1.55	42	23	19	11	65	10	24

[1]standard error 14.1% of the mean
[2]standard error 2.3%

northern Great Plains. In general, the annual precipitation was relatively low but did not fluctuate extremely (Table 2). However, fluctuations during the growing season (May – September) varied greatly between years. Precipitation during the growing season in the first year (1978) after cessation of trickle irrigation was exceptionally high.

Supplemental water

Survival varied widely among species and was significantly higher for irrigated than for non-irrigated plantings throughout the duration of the study (Table 3). Overall survival for irrigated plants was 14% higher than for non-irrigated plants after the first growing season. Survival was 30% greater for the irrigated plantings after overwintering, and the difference remained at about that level throughout the rest of the study. First winter losses of non-irrigated plants were double those of irrigated plants. Apparently, the young irrigated plants had better root systems and vigor, and thus were in better condition to cope with winter stress.

Six years after establishment, all plantings showed some decrease in survival from the first season evaluation. Sprouting of silver buffaloberry, Siberian peashrub, and American plum complicated counting of live and dead plants. The data showed apparent survival in the sixth year to be higher than the spring count after the first year.

Trickle irrigation was stopped after three years to answer questions such as (1) how long should irrigation continue to achieve establishment, and (2) what happens when irrigation is stopped. Survival at the sixth year differed between treatments but remained relatively constant after the second growing season. Comparing only deciduous species, the average losses during post-irrigation growing seasons were 11%. Conifer species lost an overall 50% two years after cessation of trickle irrigation, while green ash loss was 20% and Russian olive, silver buffaloberry, Siberian peashrub, and American plum did not lose any. Thus, the benefit of irrigation carried over into the post irrigation period.

DISCUSSION

The results are important not so much for selecting species as for determining how species with a potential for establishment in the study area can be treated to achieve successful establishment. Results also provide some clues to the order and interpretation of plant responses under conditions of rigorous climate and planting medium.

The success of earlier plantings of bare root stock without supplemental water in coal mine spoils in eastern Wyoming ranged from moderately high to low.[4] In those plantings green ash survived best; apparently it is not as sensitive to variations in adverse weather and planting medium as other species such as Russian olive, silver buffaloberry, Siberian peashrub, American plum, ponderosa pine, and Rocky Mountain juniper.[4] The conifers were obviously the most sensitive and thus the highest risk, although they may be adaptable if carefully planted and given supplemental treatments. Four species, silver buffaloberry, Siberian peashrub, American plum, and ponderosa pine, survived poorly in the earlier planting.4 Summer and overwinter losses were greatest the first year.4 There fore, a treatment to reduce first-year mortality would be highly beneficial.

In this study, survival percentages of trickle irrigated plants was considerable higher (often over 30% higher) than for non-irrigated plants for all species after the first winter. Thereafter, the difference between irrigated and non-irrigated plants did not change much. Thus, supplemental water applied during the growing season was of most benefit during the first winter. This highly significant benefit persisted without much relative change through six seasons (growing and dormant) after irrigation was stopped.

Green ash continued with the highest survival of the non-irrigated plants throughout the study. Survival of silver buffaloberry, Siberian peashrub, and American plum persisted with the best response to supplemental water in relation to other species.

CONCLUSIONS

1. All species benefit from supplemental water, particularly in terms of increased survival through the first winter and second growing season. Survival changed little thereafter.
2. Species studied differed substantially in response to supplemental water.

Table 3 *Percent survival of bare root stock of 7 species planted in spring 1975 and evaluated for 2 irrigation treatments*

Species	*Fall 1975*		*Spring 1976*		*Fall 1976*		*Fall 1980*	
	I[1]	*NI*[1]	*I*	*NI*	*I*	*NI*	*I*	*NI*
Green ash	99	90	96	59	87	57	77	60
Russian olive	73	53	53	26	50	24	52	23
Silver buffaloberry	89	56	77	31	77	29	80[3]	34
Siberian peashrub	96	84	74	44	63	40	80[3]	43
American plum	96	81	93	44	93	44	97[3]	46
Ponderosa pine	27	20	16	1	13	1	6	0
Rocky Mountain juniper	13	6	6	0	4	0	3	0
Average	70**[4]	56	59	** 29	55	** 28	56	** 29

[1]I = irrigated
[2]NI = non-irrigated
[3]Sprouting accounts for apparent increases in survival.
[4]Significantly different at .01 level between treatments.

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