Percent aerial cover of shrub species was obtained using the line-intercept method (Canfield 1941). Along each transect, species canopy cover was recorded in centimeters and divided by the transect total (5000 cm). Gaps in the shrub canopy of 4 cm or less were considered to be continuous canopy.

Shrub canopy cover and density by species were converted to relative cover and relative density. Relative cover was calculated by dividing the absolute cover of each shrub species by total cover of all shrub species. Likewise, relative shrub density was calculated by dividing the absolute density of each species by total shrub density for all species. Shannon-Weiner diversity indices were calculated for each sample site (Shannon and Weaver, 1949). Higher diversity indices indicate greater plant community diversity. Antelope and sage grouse habitat requirements were used to assess wildlife habitat quality of shrub communities on reclaimed mined land since both are abundant sagebrush community wildlife species, economically important game species, they represent a mammal and bird species having uniquely different habitat requirements, and detailed habitat requirements of both species are documented in published literature (Hulet et al. 1984, Postovit 1981, Roberson 1984, Braun et al. 1977, Dobkin 1995, and Yoakum 1984). Although other wildlife species are associated with these reclaimed study sites, the absence of published detailed habitat specification for these species limits the evaluation of these sites adequacy for wildlife habitat.

E. Results and Discussion

Establishment Study

Topsoil baseline chemical and nutrient parameters showed the direct-placed topsoil to have significantly higher concentrations for most of the parameters measured (Table 3). Stockpiling the topsoil did not have as much effect on the edaphic properties as reported by others (DePuit 1988, White et al. 1989). This reduced response to stockpiling may be partly due to the topsoil stockpile being seeded to perennial grasses after it was salvaged and stockpiled. This practice generally enhances soil permeability, enhances soil biological functions through the contribution of organic matter to the soil system, and generally improves soil physical properties.

Sagebrush seedling densities exhibited a three-way interaction between topsoil management, mulch type and grass competition for all dates evaluated (Table 4-6). Sagebrush seedling densities responded differently in spring 1992, fall 1992 and spring 1993 compared to fall 1993 and 1994. The large increase in sagebrush seedling densities exhibited between spring 1993 and fall 1993 was due to the wet and cool spring and summer of 1993 (Table 7). Even though 1993 climatic conditions greatly increased the sagebrush seedling density, the density observed in 1992 on the direct-placed topsoil-no competition, mulched treatments (Table 4) exceeded the recently established shrub density standard (1 shrub/m^2) for Wyoming (Federal Register, 1996). This emphasizes the importance of good cultural practices especially since these seedling densities were achieved during a below average (87%) precipitation year. Direct-placed topsoil treatments resulted in 40% more sagebrush seedlings than the stockpiled topsoil treatment, and in 1992 and the spring 1993, the differences were generally 1 to 2 orders of magnitude greater for the direct-placed topsoil. The 1992 soil moisture content of the surface

Table 3. Chemical and nutrient concentrations in fresh and stockpiled topsoil.

Soil Mgmt	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	TKN	P	CEC
	------------------------------ mg kg^{-1}					------------------------------	me $100g^{-1}$
Fresh	342a	108a	79a	23b	950a	7.2a	23.0a
Stockpiled	170b	67b	84a	26a	740b	6.3b	10.9b

Values within a column with the same letter are not significantly different, $P \leq 0.10$.

Table 4. Sagebrush seedling density as affected by topsoil management, mulch type, and grass seeding rate, 1992.

	Topsoil Management					
	Fresh			Stockpiled		
Competition ($kgPLS\ ha^{-1}$)	0	16	32	0	16	32
Mulch Type	plants m^{-2}					
			Spring 1992			
stubble	5.78	1.11	0.04	0.11	0	0
surface	7.37	0.07	0	0.04	0	0
stubble + surface	1.59	1.56	0.63	0.11	0	0.04
control	0	0	0.04	0	0	0

$LSD_{0.10}$=2.48, within a mulch type with a topsoil management;
$LSD_{0.10}$=2.51, within a topsoil management with a seeding rate;
$LSD_{0.10}$=2.71, within a mulch type within a seeding rate.

	Fresh			Stockpiled		
			Fall 1992			
stubble	5.15	0.52	0.07	0	0	0.04
surface	6.07	0	0.15	0	0	0
stubble + surface	1.41	1.11	0.37	0.30	0.04	0
control	0	0	0	0	0	0

$LSD_{0.10}$=2.13 within a mulch type within a topsoil management;
$LSD_{0.10}$=2.16 within a topsoil management within a seeding rate
$LSD_{0.10}$=2.30 within a mulch type within a seeding rate.

Table 5. Sagebrush seedling density as affected by topsoil management, mulch type, and grass seeding rate, 1993.

	Topsoil Management					
	Fresh			Stockpiled		
Competition ($kgPLS\ ha^{-1}$)	0	16	32	0	16	32
Mulch Type	plants m^{-2}					
	Spring 1993					
stubble	6.30	2.04	1.81	1.63	0.04	0.15
surface	8.74	0.30	0.89	0.44	0.04	0.93
stubble + surface	4.07	2.48	1.52	1.56	0.33	0.11
control	1.26	0.56	0.22	0.37	0.14	0.04

$LSD_{0.10}$=2.01, within a mulch type with a topsoil management.
$LSD_{0.10}$=2.07, within a topsoil management with a seeding rate.
$LSD_{0.10}$=2.73, within a mulch type within a seeding rate.

	Fall 1993					
stubble	9.67	3.93	2.93	5.41	2.11	.93
surface	13.48	1.00	1.22	2.74	1.81	2.18
stubble + surface	8.04	2.89	1.63	4.59	2.15	1.70
control	7.52	1.37	0.52	1.81	0.52	0.19

$LSD_{0.10}$=2.59 within a mulch type within a topsoil management;
$LSD_{0.10}$=2.89 within a topsoil management within a seeding rate;
$LSD_{0.10}$=2.91 within a mulch type within a seeding rate.

Table 6. Sagebrush seedling density as affected by topsoil management, mulch type, and grass competition, Fall 1994.

	Topsoil Management					
	Fresh			Stockpiled		
Competition ($kgPLS\ ha^{-1}$)	0	16	32	0	16	32
Mulch Type						
	plants m^{-2}					
stubble	8.15	9.82	7.11	3.44	2.78	3.26
surface	12.11	4.63	5.33	2.40	3.52	5.07
stubble + surface	9.11	3.78	4.26	3.30	3.85	2.52
control	7.22	5.88	4.56	4.48	2.52	1.70

$LSD_{0.10}$=3.00, within a mulch type with a topsoil management.
$LSD_{0.10}$=3.79, within a topsoil management with a seeding rate.
$LSD_{0.10}$=3.99, within a mulch type within a seeding rate.

Table 7. Monthly precipitation and mean monthly temperature, North Antelope Coal Company, Gillette, WY 1992-1994.

Month	1992		1993		1994	
	Precip (cm)	°C	Precip (cm)	°C	Precip (cm)	°C
Jan	0	-0.6	0	-7.2	0.20	-3.3
Feb	0.68	2.2	0.38	-7.7	0.15	-6.1
Mar	3.15	4.4	1.47	2.2	0.41	3.3
Apr	0.76	7.7	6.48	5.5	2.79	6.6
May	2.26	13.2	5.94	12.7	2.87	14.9
Jun	6.43	16.5	14.15	14.3	8.36	18.2
Jul	7.75	7.6	9.70	17	4.93	19.8
Aug	2.95	18.2	10.13	18.2	0.81	20.9
Sep	1.75	15.4	2.29	12	1.22	16.0
Oct	0.41	8.8	2.36	6.1	5.49	7.2
Nov	0.89	-0.6	0.36	-2.2	0.58	0
Dec	1.19	-6.6	0.10	-1.7	0.05	.7
Total	28.22		53.36		27.86	

1978 - 1955 year average is 32.3 cm

7.5 cm of the direct-placed topsoil was always higher than that observed in the stockpiled topsoil (Figure 4). This higher soil moisture condition undoubtedly aided in the improved sagebrush seedling establishment on the direct-placed topsoil in 1992. Topsoil management benefits were only observed in the treatments where no grass competition existed. No differences in sagebrush seedling densities were evident between the two topsoil management treatments for the 16 and 32 kg/ha grass seeding-rate treatments. Sagebrush seedling establishment clearly show the benefits of topsoil management, but this study has not clearly delineated all of the specific benefits from the direct-placed topsoil. Direct-placed topsoil did not act as a seed bank for sagebrush. Unseeded control plots in the adjacent Pioneer Study did not have any sagebrush seedlings present.

Arbuscular mycorrhizae spore numbers were 3088±1087 and 4500±1525 per gram of soil in the stockpiled and direct-placed topsoil, respectively. This difference was significant at $P \leq 0.10$; however, much greater differences were expected based on other literature (Allen and Allen 1980, McMahon and Warner 1984). Mycorrhizal infection in the sagebrush seedlings excavated in June 1993 from the two topsoil management treatments were not different (Table 8) in spite of the difference in AM spore levels observed at the start of the study. Loree and Williams (1984) found that native grasses became infected with AM within a year of establishment on long-term stockpiled topsoil indicating inoculum is spread quite rapidly under natural conditions. Since we have only spring and fall sagebrush density evaluations and these represent only those number of seedlings available on the specific date we have no way of assessing emergence and death of seedlings that might have occurred prior to our spring assessment and between our spring and fall assessment, that might be attributed to the absence of AM infection. Therefore, our estimate of sagebrush seedling infection may be biased upward and not represent the true population of sagebrush seedlings that germinated and emerged.

The presence of mulch greatly affected sagebrush seedling establishment in 1992. No seedlings were evident in the first year where mulch was not applied. The stubble and straw mulch treatments had similar or greater seedling densities than the stubble + straw mulch treatment. Soil moisture content of the surface 7.5 cm of topsoil was greater under all of the mulch treatments compared to the no-mulch treatment (Figure 5). Stubble mulch has been shown to affect seedling microclimate through reduced diurnal temperature fluctuations and increased soil moisture (Schuman et al. 1980).

Grass competition reduced sagebrush seedling densities throughout the duration of the study on the direct-placed topsoil treatment where stubble or surface straw mulch treatments were applied. Grass seedling numbers counted in the fall 1992 reflect the herbaceous competition. The 0, 16, and 32 kg/ha grass seeding rates resulted in 0. 196, and 250 grass seedlings/m^2. No differences in grass seedling density among topsoil management treatments and mulch were evident.

Arbuscular Mycorrhizae Study

Physiochemical characteristics of the soil used in this study are shown in Table 9.

Sagebrush seedlings from the mycorrhizal treatment developed AM on 65-86% of the root segments examined while root segments from the non-mycorrhizal treatment formed AM on only 1-2% of those examined ($P \leq 0.001$). All of the different sagebrush seedling age groups (30, 45, 60, 90, 120, and 150 days old) that were mycorrhizal were able to tolerate greater soil tension conditions before dying than the non-mycorrhizal seedlings (Figure 6). At 45 days of

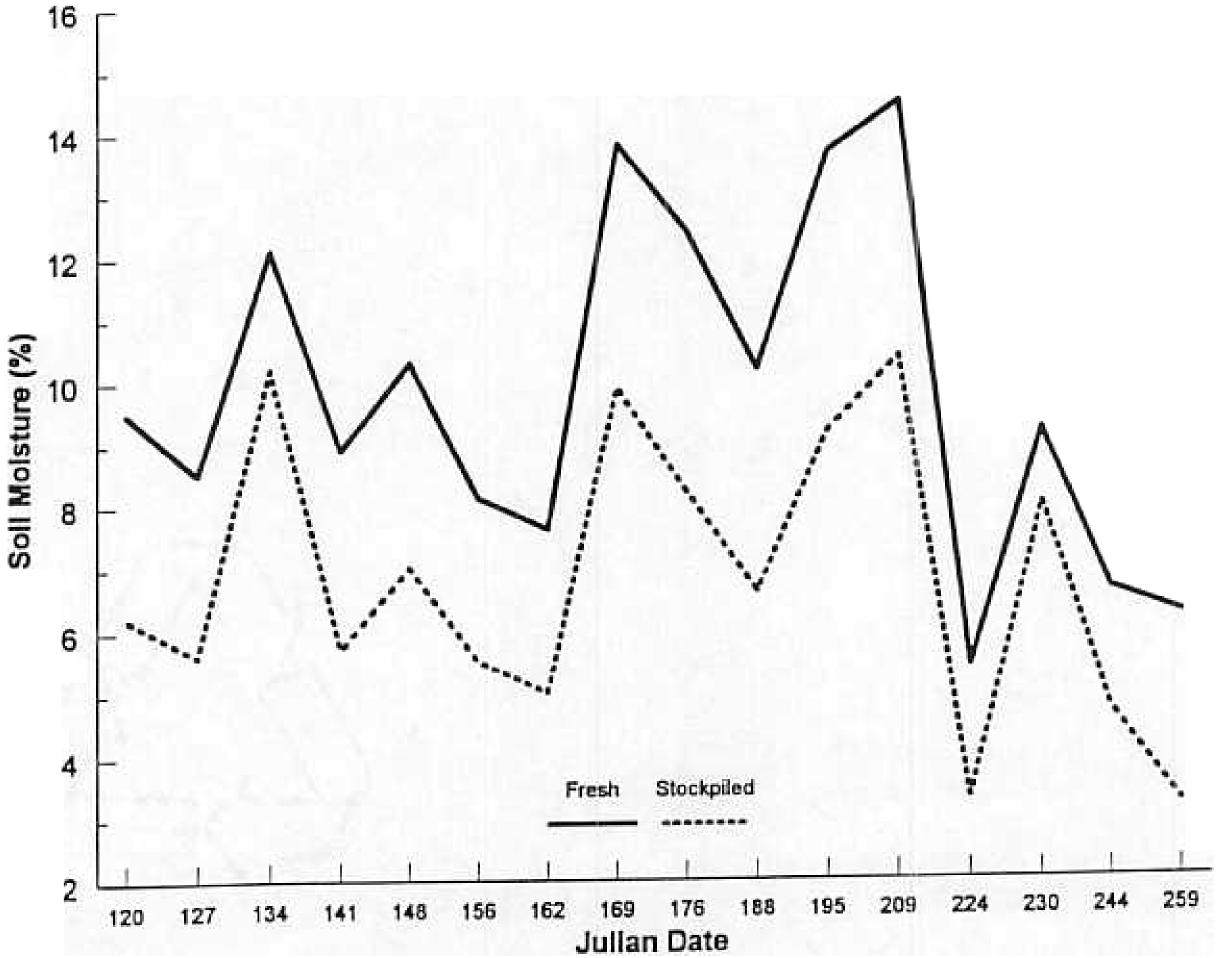

Figure 4. Soil moisture content in 0-7.5cm topsoil depth as affected by topsoil management, Establishment Study.

Table 8. VAM infection percentage of sagebrush seedlings as affected by topsoil management, mulch type, and grass competition.

Treatment	% Infection	Number of Seedlings Evaluated
Topsoil Mgmt		
Fresh	66	66
Stockpiled	76	66
Mulch Type		
Stubble	73	36
Surface	71	36
Surface + Stubble	72	36
Control	67	24
Grass Competition ($kg\ PLS\ ha^{-1}$)		
0	73	69
16	68	63
32		

[a] Insufficient sagebrush seedlings available for evaluation.

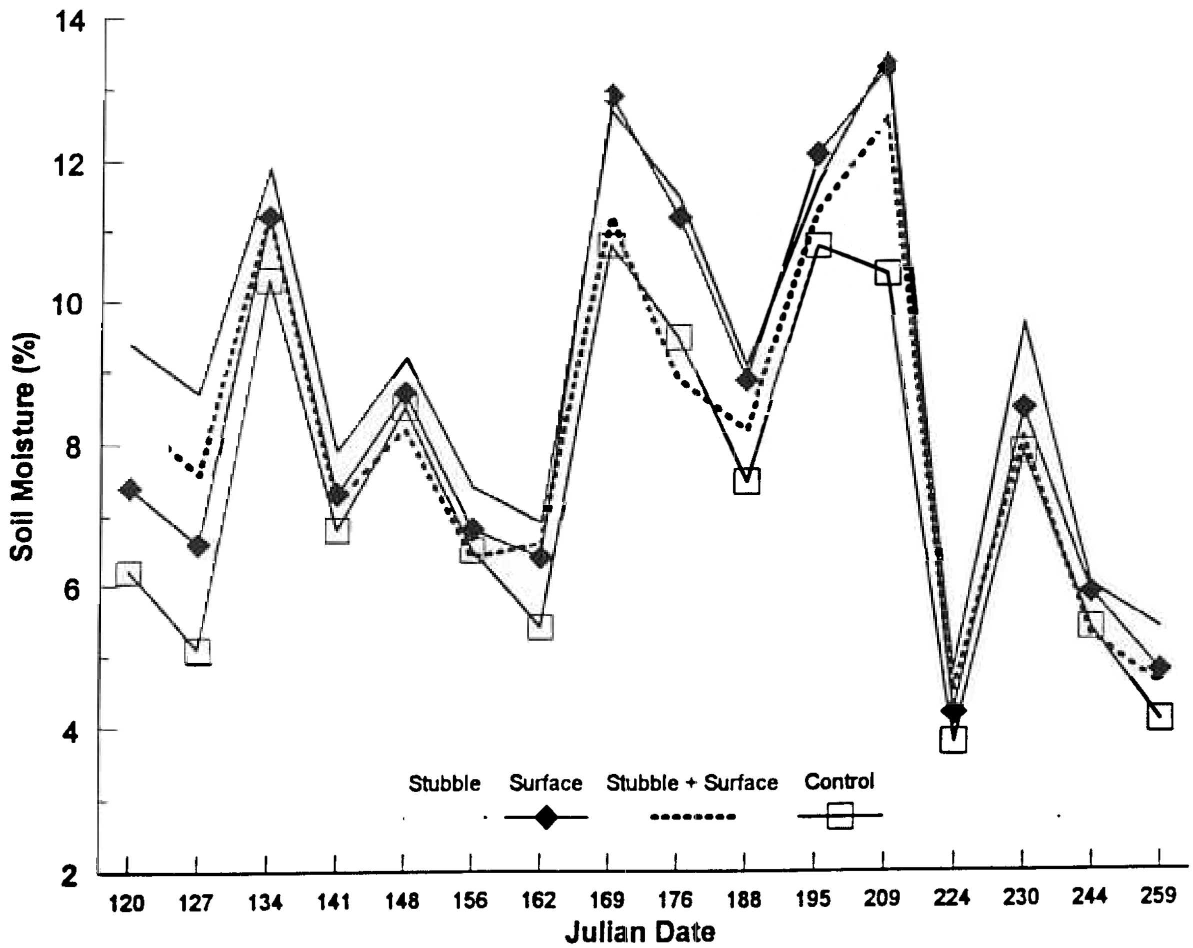

Figure 5. Soil moisture content as affected by mulch type, Establishment Study.

Table 9. Physiochemical characteristics of soil used in the mycorrhizal study.

pH	EC ($dS\ m^{-1}$)	CEC ($meq\ l^{-1}$)	texture	soluble cations Mg	Ca ($mg\ kg^{-1}$)	Na	K	Kjeldahl Nitrogen (mg kg-1)	inorganic phosphorus (mg kg-1)
7.2	2.3	15.7	sandy clay loam	47	449	10	20	362	2.6

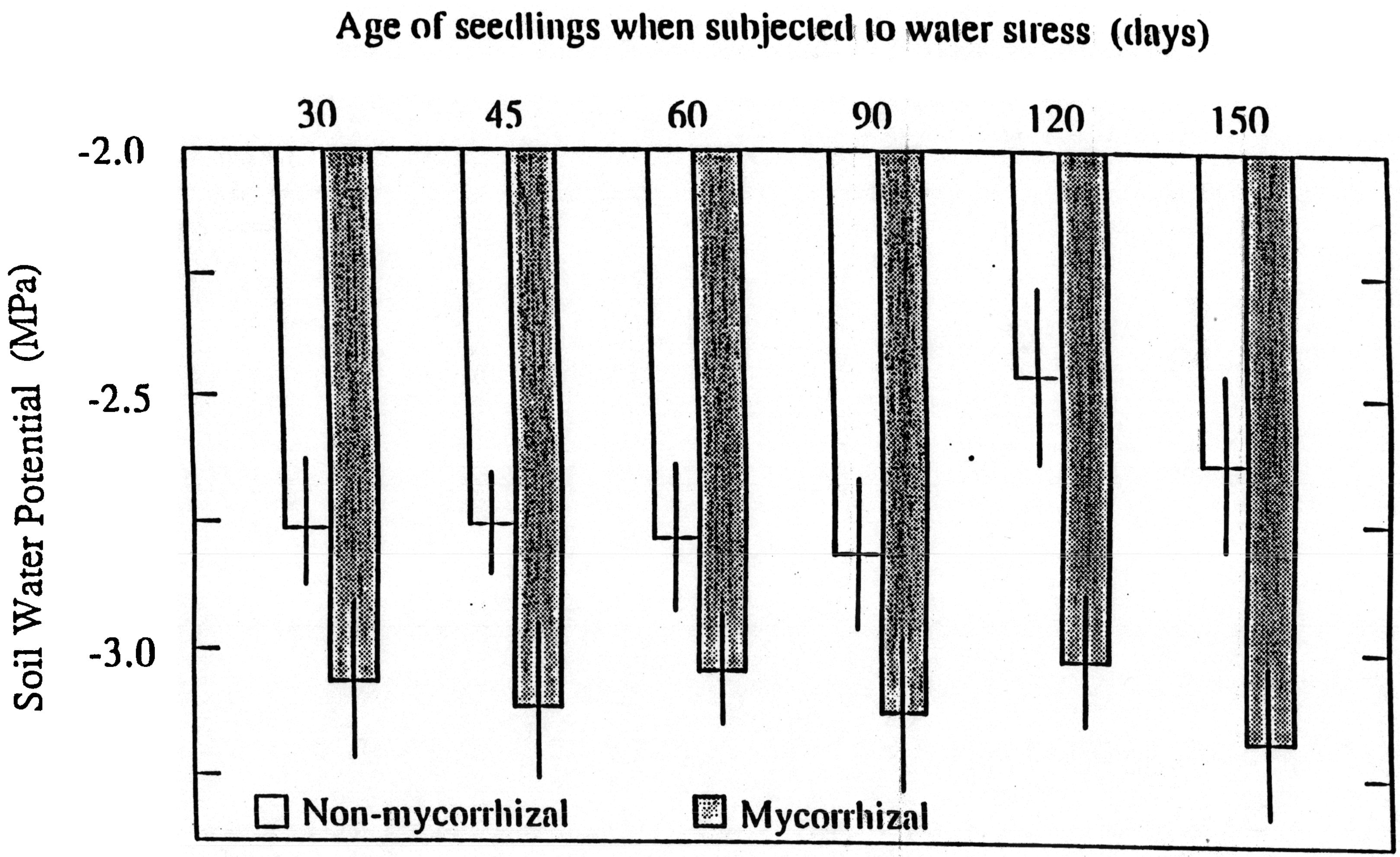

Figure 6. Average soil water potentials resulting in death of mycorrhizal and non-mycorrhizal sagebrush seedlings. Vertical bars on each column represent 1 standard deviation. Differences between mycrrhizal and non-mycorrhizal treatments were statistically significant at P<0.01 for each age group.

growth, the average soil water potential resulting in the death of non-mycorrhizal seedlings was -2.77 MPa compared to the mycorrhizal seedlings which tolerated soil water tensions of -3.22 MPa before dying. No non-mycorrhizal seedlings survived in soils with water potentials less than -3.3 MPa, whereas some mycorrhizal seedlings survived in soils as dry as -3.7 MPa (Figure 6). Sagebrush seedling age and mycorrhizae treatment exhibited an interaction, indicating that as sagebrush seedlings age the beneficial influence of AM on soil moisture stress tolerance increases (Figure 7). The research clearly indicates that those seedlings ≥120 days of age that are non-mycorrhizal are much less tolerant of soil moisture stress than younger non-mycorrhizal seedlings. Therefore, the sagebrush seedlings become more dependent upon the benefits of mycorrhizae as they age.

Pioneer Study

The direct-placed topsoil had greater concentrations of Kjeldahl-nitrogen, calcium, and potassium, and higher electrical conductivity and cation exchange capacities than the stockpiled topsoil. However, the stockpiled topsoil had greater concentrations of NH^3-N, NO^3-N and sodium than that observed in the direct-placed topsoil (Table 10).

Total shrub (saltbush and sagebrush) seedling densities on stockpiled and direct-placed topsoil averaged 8.2±6.2 and 3.7±3.6, 9.5±8.1 and 6.6±6.4, and 4.0±3.1 and 10.0±9.3 seedlings/m^2 for replication 1, 2, and 3 respectively. The lack of a significant benefit for direct-placed topsoil seems to contrast with the benefits noted in the Establishment Study. However, these seedling densities represent multiple species in a single treatment and the aspect of this study site was facing slightly into the predominant wind direction which could affect the evaporation and potential accumulation of snow. Whatever the reason, long-term seedling survival was also greater on the stored topsoil treatment (Table 11). The photographic data provide clear evidence of sagebrush establishment three and four growing seasons after the last seeding in March 1993 (Table 12). This is consistent with other evidence that a significant amount of Wyoming big sagebrush seed will carry over in the soil (Schuman, et al. 1998). Seedling age classes show 1994 to have the largest cohort (Table 13). The plots seeded to sagebrush 2 consecutive years, after 5 growing seasons and averaged across topsoil treatments, had 7 sagebrush seedlings/m^2 compared to 6 sagebrush seedlings/m^2 when plots were fallowed for 1 year and then seeded to sagebrush (Table 12). This increase in sagebrush seedling density seems insignificant if one considers that the two consecutive seedings represent 4.4 kg/ha of sagebrush seed compared to 2 kg/ha when only seeded after fallowing. Plots seeded to fourwing saltbush the first year and then seeded to sagebrush the second year had 4.6 fourwing saltbush seedlings and 3.4 sagebrush seedlings/m^2 (Table 12). Sagebrush seedling density and height were less when seeded after saltbush establishment than when sagebrush was seeded during the initial year or after fallowing for 1 year (Table 13 & 14). There were no differences in sagebrush seedling heights due to topsoil source, seeding treatment, or their interaction. There were also no differences in the 1996 sagebrush heights among seedlings within a 7.6-cm radius of a saltbush seedling, versus sagebrush seedlings at a greater distance from a saltbush. This implies that the saltbush was neither detrimental, nor beneficial for the sagebrush seedlings. However, total shrub density was greater where the fourwing saltbush and sagebrush were both seeded which is to be expected since these two species have quite different germination and

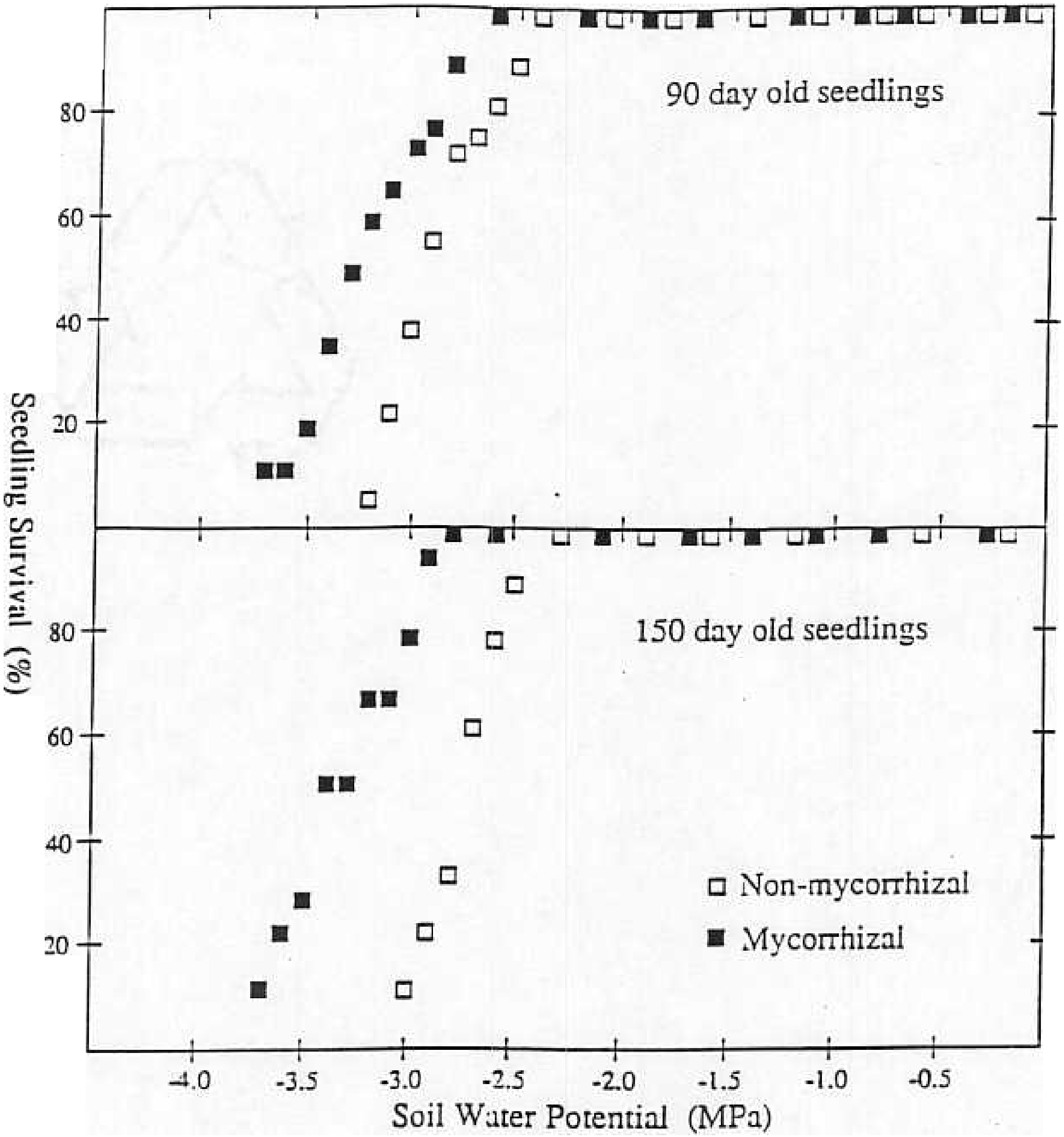

Figure 7. Survival rates for 150 and 90 day old mycorrhizal and non-mycorrhizal sagebrush seedlings at different levels of soil dryness.

Table 10. Baseline soil characteristics of fresh and stockpiled topsoil.

Soil	Ca	K	Mg	Na	NH_4-N	NO_3-N	P	TKN	EC	CEC
	(mg/kg)								(mmhos/cm)	(me/100g)
Fresh	359a	23.4a	107a	71b	1.96b	4.72b	21.2a	645a	2.6a	5.2a
Stockpiled	178b	24.2a	66b	81a	2.61a	5.75a	11.7b	469b	1.7b	4.9b

Values within a column followed by the same letter are not significantly different ($P \leq 0.05$).

Table 11. Percentage sagebrush, fourwing saltbush, and all-shrub seedling survival as influenced by shrub-seeding treatment and topsoil source.

Seeding Treatment	Yr. Max. Seedlng Den.	1996 Density / Max	
		STS	FTS
		--------- % ---------	
ARTRx2	1994	69	60
Fallow-ARTR	1994	81	61
ATCA-ARTR			
ARTR	1994	68	56
ATCA	1995	86	92
All shrubs	1995 and 1994	86	73

Table 12. Mean (+ SD) shrub seedling densities by seeding treatment and topsoil source for the years 1993 - 1996.

	Year	Signif.	ARTR/STS	ARTR/FTS	F-ARTR/STS	F-ARTR/FTS	ATCA-ARTR/STS	ATCA-ARTR/FTS
			Seedling Treatments / Topsoil Source					
			Seedings/m²					
ARTR	1993	(P=0.35)	7.3±7.5	3.4±5.5	3.3±6.7	3.9±7.0	0.8±3.2	2.1±6.4
ATCA-ARTR		(P=0.28)					1.5±2.2	6.3±7.6
ARTR	1994	(P=0.15)	14.0±15.9	7.2±11.3	5.7±5.8	11.9±15.3	3.8±6	7.3±9.6
ATCA-ARTR		(P=0.16)					3.9±3.4	16.8±16.4
ARTR	1995	(P=0.12)	10.8±8.7	4.9±6.8	5.1±4.5	9.1±11.3	3.1±6.2	5.1±6.5
ATCA-ARTR		(P=0.14)					4.3±3.1	12.4±11.8
ARTR	1996	(P+0.10)	9.6±7.7	4.3±5.9	5.1±5.3	7.3±8.8	2.6±5.2	4.1±5.1
ATCA-ARTR		(P=0.12)					7.1±5.7	8.8±6.2
Means across topsoil treatments:			7.0		6.2		8.0	

ARTR = Sagebrush seedlings. The ARTR treatment means that sagebrush was seeded in 1992 and 1993.
F-ARTR = Plots fallowed in 1992 and seeded to sagebrush in 1993.
ATCA-ARTR = Fourwing saltbush seedlings + sagebrush seedlings. The ATCA-ARTR seeding treatment means that fourwing saltbush was seeded in 1992 and sagebrush overseeded in 1993.
STS = Stockpiled topsoil
FTS = Fresh-stripped topsoil

Table 13. Sagebrush seedling density in 1996 [(mean seedlings/m^2) ± SD] by ageclass, seeding treatment, and topsoil source. The year of germination is indicated in paranthesis.

Treat	Topsoil	1-Year-Olds (1995)	2-Year-Olds (1994)	3-Year-Olds (1993)	4-Year-Olds (1992)
ARTR	Fresh	0.2±0.6	0.8±2.6	2.0±3.4	1.3±4.8
	Stored	0.7±1.1	0.9±1.1	4.4±4.3	4.0±4.8
F-ARTR	Fresh	0.6±0.9	0.7±1.0	4.2±4.9	1.3±2.4
	Stored	0.3±0.8	0.5±1.1	2.4±2.2	1.9±3.3
ATCA-ARTR	Fresh	0.2±0.5	0.2±0.8	3.0±3.6	0.7±2.3
	Stored	0.2±0.4	0.2±0.8	1.5±2.6	0.6±2.3

ARTR = sagebrush was seeded in 1992 and 1993.
F-ARTR = plots fallowed in 1992 and seeded to sagebrush in 1993.
ATCA-ARTR = fourwing saltbush was seeding in 1992 and sagebrush overseeded in 1993

Table 14. Sagebrush seedling heights as measured fall 1996. Means by seeding treatment and topsoil source.

Treatment	Seedling Height ± SD (mm)
Fallow-ARTR / Stored Topsoil	52.5±23
Fallow-ARTR / Fresh Topsoil	46.9±21
ARTR / Fresh Topsoil	46.3±22
ARTR / Stored Topsoil	45.8±25
ATCA-ARTR / Fresh Topsoil	45.7±21
ATCA-ARTR / Stored Topsoil	37.1±25

ARTR = sagebrush was seeded in 1992 and 1993.
F-ARTR = plots fallowed in 1992 and seeded to sagebrush in 1993.
ATCA-ARTR = fourwing saltbush was seeded in 1992 and sagebrush overseeded in 1993.

establishment requirements. The saltbush-sagebrush treatment provides a comparison in seed establishment efficiency. On the surface the data implies that the saltbush reduced sagebrush seedling establishment but when evaluating the seed establishment efficiency (Table 15) it appears that the use of saltbush as a pioneer species neither improved or reduced the establishment success of sagebrush. In fact, as noted earlier, planting saltbush and sagebrush resulted in greater overall shrub density than when either was planted alone.

Survey Study

Total shrub densities varied between sites within a mine and between mines. Densities for all shrub species on the saltbush sites ranged from 0.09 to 0.70 giving a mean of 0.23 plants/m^2 (Table 16). Total shrub densities on the saltbush-sagebrush sites ranged from 0.09 to 1.92 giving a mean of 0.61 plants/m^2. The Bridger Coal Co. site had the highest shrub densities which can partially be attributed to the high number of sagebrush seedlings that became established in 1993 when the climate was cool and wet. When evaluating these shrub densities on the basis of the Wyoming Shrub Standard approved in August 1996, total shrub densities on one of five saltbush communities and seven of nine saltbush--sagebrush communities evaluated were significantly greater than 0.2 shrubs/m^2 (Table 16). While this extrapolation provides a means of comparing the pre-1985 reclamation plantings to the new shrub standard, we recognize its limitations. The extrapolation ignores the current requirement of shrub patch spatial diversity because it represents an average over the entire area reclaimed in a given year. If you evaluate these sites as a patch and use the 1 shrub/m^2 then only the Bridger I site would meet the shrub standard in spite of the fact that high and diverse seeding rates were used on many of the sites evaluated. Concentrating one's effort to establish shrubs on the most suitable parts of the landscape should result in greater average shrub densities.

Shrub densities on saltbush-sagebrush sites was closely correlated to seeding rates ($P \leq 0.001$). However, no correlation was found between seeding rates and shrub density among the saltbush sites. High seeding rates coupled with seed dormancy in Wyoming big sagebrush appear to increase seedling recruitment (McDonough and Harniss, 1974; Booth et al., 1995).

The number of standing-dead shrubs was quite low on most of the sites. However, among the saltbush communities, the Pathfinder Mine site had about equal numbers of live and dead shrubs while the Seminoe I site had one dead shrub for every two live ones (Table 17). The other sites had a much greater proportion of live shrubs compared to dead ones. Heavy browsing by wildlife was evident at the mines with the greatest number of standing dead shrubs. The sites where the greatest number of standing dead saltbush occurred was Pathfinder and Seminoe I and these sites don't appear to have naturally occurring stands of saltbush. Therefore, adaptability of saltbush at these sites may be the cause of the high standing dead counts observed.

General observations of the sites surveyed provide insight into the effectiveness of reclamation procedures used prior to 1985. Grass seeding rates ranged from 15 to 29 kg PLS/ha (Table 2) and no correlation was found between shrub density and grass seeding rates. This observation also agrees with our findings reported in the Establishment Study portion of this project. Sagebrush immigration into 3 of the 4 saltbush communities where it was not included in the original seed mixture indicates that over time sagebrush can become established through

Table 15. Number of 1996 seedlings per 1000 seeds sown for each seeding treatment. Data were calculated using means across topsoil treatments from Table 12 and using 107,930 "Wytana" seeds /kg (J. Sheetz, personal communication) and 4.0 million Wyoming big sagebrush seeds/kg (Meyer 1998).

Seeding Treatment	Number of Seedlings
ARTRx2	4.0
Fallow-ARTR	7.5
ATCA-ARTR	
ATCA	16.3
ARTR	4.2
All Shrubs	7.4

Table 16. Shrub densities (plants/m²) for dominant shrub and total shrubs compared to proposed standard with single paired t-tests by site.

Mine Site	ATCA/ARTR[1] ± SD	t-value	Total Shrubs ± SD	t-value	Critical T (P = 0.05)
			Atriplex canescens Communities		
Black Thunder	0.09+0.04	-11.9	0.10+0.05	-11.9	1.73
Belle Ayr	0.14 ±0.07	-1.9	0.14 ±0.08	-1.8	2.13
Kemmerer #1	0.69 ±0.14	16.0	0.70 ±0.29	39.3	1.73
Pathfinder	0.08 ±0.04	-5.9	0.12 ±0.09	-11.4	1.73
Seminoe I	0.06 ±0.04	-17.1	0.09 ±0.03	-35.4	1.73
Overall Mean	0.22		0.23		
Mine Site	Atriplex canescens - Artemisia tridentata Communities				
Bridger #1	1.71 ±0.51	13.3	1.92 ±0.62	71.8	1.73
Bridger #2	0.77 ±0.3	8.4	1.11 ±0.36	50.0	1.73
Dave Johnston	0.16 ±0.09	-1.7	0.51 ±0.15	21.6	1.73
Kemmerer #2	0.09 ±0.07	-6.6	0.09 ±0.05	-18.9	1.73
Kemmerer #3	0.02 ±0.02	-43.7	0.22 ±0.09	2.3	1.73
Pathfinder	0.03 ±0.04	-23.6	0.14 ±0.06	-11.0	1.7
Seminoe I	0.17 ±0.18	-0.7	0.22 ±0.10	1.8	1.73
WyoDak #1	0.45 ±0.18	4.4	0.64 ±0.25	11.1	1.8
WyoDak #2	0.37 ±0.30	1.7	0.62 ±0.21	8.8	0.8
Overall Mean	0.42		0.61		

[1] ATCA = Atriplex canescens, ARTR = Artemisia tridentata

Table 17. Number of standing-dead per live shrubs, and mean height (cm) with standard deviation for the dominant shrubs by shrub community, at 14 study sites. Data are from 20 transects unless otherwise indicated. Data for living shrubs are given for comparison.

Mine Site	Atriplex canescens			Atriplex canescens - Artemisia tridentata		
	Ratio	Mean height + SD		Ratio	Mean Height + SD	
Atriplex Canescens communities	Dead / Live	Dead	Live	Dead / Live	Dead	Live
		------------- cm -------------			------------- cm -------------	
Black Thunder	11/328	30.3±16	73.2±18.3	1/1		11.0
Belle Ayr (5 transects)	2/89	82±7.0	74.3±23.2	0/0		
Kemmerer #1	13/392	50.9±25.8	51.5±24.5	0/6		27.7±9.7
Pathfinder #1 (30 transects)	226/256	35.6±13.2	45.9±18.1	0/4		10.5±2.4
Seminole I, #1	83/166	52.8±17.0	72.2±25.6	0/40		11.6±10.4
Artemisia tridentata Communities						
Bridger #1	0/46		38.2±23.6	5/562	12.6±5.9	34.7±15.5
Bridger #2	3/416	17.3±24.5	55.4±41.5	3/242	8.0±6.5	33.1±14.4
Dave Johnston	0/5		20.2±8.8	77/331	18.9±7.9	20.1±6.7
Kemmerer #2	28/255	56.4±17.9	65.8±29.2	1/80	17.0	42.2±20.6
Kemmerer #3	0.0		--	4/267	81.0[1]	59.4±25.3
Pathfinder (30 transects)	80/568	47.0±26.8	51.2±24.7	26/123	8.2±2.6	10.0±4.0
Artemisia tridentata Communities						
Seminoe I, #2	0/46	--	82.3±28.0	15/638	33.2±25.2	46.4±26.8
WyoDak #1 (10 transects)	0/50		14.1±10.0	0/186		64.1±31.1
WyoDak #2 (10 transects)	0/1		84.0	24/156	29±12.0	33.5±12.6

[1] Height measured on only one plant. Other standing-dead plants were trampled by grazing livestock.

natural recruitment processes on reclaimed sites to enhance shrub diversity and density. Sagebrush was also successfully oversown into 3- and 4-year-old reclaimed sites of saltbush and grass at Bridger #1 and #2. Therefore, this survey of pre-1985 reclamation sites in Wyoming suggest that sagebrush will become established in fourwing dominated plantings. However, natural immigration is limited to areas adjacent to established sagebrush communities (Young and Evans, 1989; Lyford, 1995). Significant natural immigration of other shrub species into saltbush dominated communities will likely require several decades unless overseeded. Therefore, overseeding should be considered as an effective means of increasing shrub density and diversity of earlier reclamation. The concern of whether saltbush stands will persist for more than 10 years was also shown to be unfounded. The fourwing saltbush sites surveyed showed that it was reproducing in all but one of the sites and that it had persisted in all 14 sites for more than 10 years. These surveys also suggest that non-local species of sagebrush such as basin big sagebrush can be successfully established in Wyoming big sagebrush habitat (Kemmerer #2 & 3, Seminoe I). Our data indicate that significant stands of non-local subspecies of sagebrush can be established.

Evaluation of the survey study data in terms of wildlife habitat resulted in several interesting and important findings. Shrub cover of the 5 saltbush sites ranged from 1.95 to 15.70% for all shrub species with an overall mean of 5.81% (Table 18). For the 9 saltbush-sagebrush sites mean cover ranged from 1.00 to 13.29% with an overall mean of 5.59%. *Atriplex canescens* clearly comprised the major portion of the canopy cover on the saltbush sites (Table 18). Six of the saltbush-sagebrush sites (WyoDak #1 & #2, Dave Johnston, Seminoe I, Kemmerer #2, and Bridger Coal #1) showed that the sagebrush was the major contributor to overall canopy cover (Table 19). At the Black Thunder saltbush site, large numbers of mule deer, white-tailed deer and antelope were observed; however, browse utilization was insignificant indicating that these wild herbivores used this site more for cover than browsing. Among the saltbush-sagebrush sites, Pathfinder sustained the greatest utilization of shrubs by wild herbivores. Saltbush dominated the canopy cover of this site, probably due to the higher sagebrush mortality from heavy browsing noted earlier. Browsing impacts on the Pathfinder site corroborates findings of browsing induced mortality of sagebrush by McArthur et al. (1988) and Bilbrough and Richards (1993). When comparing shrub cover to Yoakum's (1984) recommended cover (5-20%) needs for antelope, only the saltbush sites at Black Thunder and Kemmerer #1 provided adequate cover (Table 18). Total shrub cover of the saltbush-sagebrush sites at WyoDak # 1 & 2 and Bridger Coal #1 & #2 were marginally acceptable (Table 19). In regard to cover needs for sage grouse, only the saltbush site at Kemmerer #1 provided enough cover to meet recommendations by Postovit (1981). The saltbush-sagebrush sites at WyoDak #1 & #2 and Bridger Coal #1 & #2 also exhibited adequate canopy cover for sage grouse based on Postovit's recommendations. However, none of the sites sampled displayed enough canopy cover for sage grouse according to Hulet et al. (1984) and Roberson (1984). The present shrub reclamation guidelines in Wyoming focus solely on shrub density, rather than cover, to evaluate reclamation success. Research findings emphasize that shrub cover is equally important to shrub density when evaluating reclaimed mined lands for wildlife habitat adequacy (Postovit, 1981; Cook, 1984; Roberson, 1984; Nydegger and Smith, 1984). Shrub density data indicate that only the Bridger Coal #1 site had adequate sagebrush density for sage grouse (Table 19). However, over 90% of the sagebrush plants measured at this site were less than 10 cm in height and therefore would not provide adequate habitat at this time but may in the future. Shrub heights varied greatly between species within and among study sites. Mean shrub heights for all

Table 18. Summary of shrub plant community characteristics for fourwing saltbush/grass reclaimed mined sites.

Site	Mean Height (cm)	Mean Cover (%)	Mean Density (plants/m²)	Importance Value	Diversity Index
Black Thunder					0.010
Artemisia tridentata	11.0		<0.01	0.003	
Atriplex canescens	71.7±19.8[1]	5.30±0.4	0.10±0.04	1.997	
All Shrubs	41.4[2]±20.1	5.30[3]			
Belle Ayr					0.018
Atriplex canescens	74.3±23.2	1.95±0.3	0.14±0.07	1.990	
Eurotia lanata	34.0±2.8		<0.01	0.010	
All Shrubs	54.1±23.7	1.95	0.14		
Pathfinder					0.016
Artemisia tridentata	10.5±2.4		<0.01	0.010	
Atriplex canescens	41.1±16.8	2.70±0.4	0.12±0.09	1.990	
All Shrubs	25.8±17.0	2.70	0.12		
Seminoe I					0.430
Artemisia tridentata	11.6±10.4	0.02	0.01	0.120	
Atriplex canescens	65.7±24.9	2.48±0.3	0.06±0.04	1.430	
Chrysothamnus spp.	28.1±10.1		<0.01	0.020	
Gutierrezia sarothrae	35.9±10.8	0.04	<0.01	0.030	
Atriplex confertifolia	37.3±12.7	0.23±0.2	0.01	0.140	
Sarcobatus vericulatus	87.0±30.5	0.63±0.6	0.01	0.250	
All Shrubs	44.3±30.4	3.40	0.09		

Table 18 continued...

Site	Mean Height (cm)	Mean Cover (%)	Mean Density (plants/m²)	Importance Value	Diversity Index
Kemmerer #1					0.020
Artemisia tridentata	27.7±9.7		<0.01	0.003	
Atriplex canescens	51.5±24.6	15.70±0.5	0.69±0.17	1.989	
Gutierrezia sarothrae	23.9±7.7		0.01	0.009	
Atriplex confertifolia	14.3±13.3		<0.01	0.001	
Sarcobatus vermiculatus	94.0		<0.01	<0.001	
All Shrubs	42.3±24.9	15.70	0.70		
Mean (All Sites)	41.6	5.81	0.23	0.100	

[1] Standard deviation
[2] Mean of mean shrub species heights
[3] Sum of mean shrub species cover and density

Table 19. Summary of shrub plant community characteristics for fourwing saltbush/big sagebrush/grass reclaimed mined sites.

Site	Mean Height (cm)	Mean Cover (%)	Mean Density (plants/m^2)	Importance Value	Diversity Index
WyoDak #1					0.258
Artemisia tridentata	64.1±31.1[1]	7.40±0.4	0.45±0.3	1.650	
Atriplex canescens	13.0		<0.01	0.002	
Artemisia frigida	14.1±10.0	<0.01	0.08±0.1	0.140	
Eurotia lanata	28.7±19.5		<0.01	0.003	
Artemisia cana	28.5±14.8	0.40±0.6	0.11±0.2	0.210	
All Shrubs	29.7[2]±32.2	7.803	0.64[3]		
WyoDak #2					0.283
Artemisia tridentata	32.9±12.7	4.70±0.4	0.37±0.3	1.430	
Artemisia frigida	17.0±8.8	0.90±0.2	0.24±0.1	0.550	
Chrysothamnus spp.	64.0		<00.1	0.002	
Gutierrezia sarothrae	16.2±4.9		0.01	0.020	
Rosa woodsii	84.0		<0.01	0.002	
All Shrubs	39.1±13.7	5.60	0.62		
Pathfinder					0.220
Artemisia tridentata	10.0±4.0	<0.01	0.03	0.200	
Atriplex canescens	50.7±25.1	4.00±0.5	0.11±0.1	1.740	
Artemisia frigida	7.3±3.8		<0.01	0.010	
Eurotia lanata	22.0±11.6		0.01	0.040	
Chrysothamnus spp.	6.4±2.3		<0.01	0.010	

Table 19 continued...

Site	Mean Height (cm)	Mean Cover (%)	Mean Density (plants/m²)	Importance Value	Diversity Index
Atriplex confertifolia	37.0	0.10	<0.01	0.010	
All Shrubs	22.2±27.7	4.10	0.15		
Dave Johnston					0.421
Artemisia tridentata	19.9±6.9	0.60±0.1	0.16±0.1	0.900	
Atriplex canescens	20.2±9.9	<0.01	<0.01	0.020	
Artemisia frigida	9.5±5.6	0.30±0.1	0.31±0.2	0.930	
Eurotia lanata	23.4±19.8	0.10±0.1	0.04	0.160	
Chrysothamnus spp.	20.5±7.8		<0.01	0.002	
Gutierrezia sarothrae	23.0±12.7		<0.01	0.002	
All Shrubs	19.4±10.5	1.00	0.51		
Seminoe I					0.336
Artemisia tridentata	46.1±26.8	2.20±0.3	0.17±0.2	1.490	
Atriplex canescens	82.3±28.3	0.70±0.4	0.01	0.270	
Chrysothamnus spp.	32.9±27.6	0.30±0.2	0.03	0.240	
Gutierrezia arothrae	35.7±4.5		<0.01	0.005	
Sarcobatus vericulatus	25.3±31.1		<0.01	0.005	
All Shrubs	44.5±28.8	3.20	0.21		
Kemmerer #2					0.040
Artemisia tridentata	59.9±25.3	2.16±0.4	0.09±0.1	1.970	
Amelanchier alnifolia	14.0		<0.01	0.010	

Table 19 continued...

Site	Mean Height (cm)	Mean Cover (%)	Mean Density (plants/m²)	Importance Value	Diversity Index
Chrysothamnus spp.	37.5±10.6		<0.01	0.020	
Gutierrezia sarothrae	24.0±7.0	0.02	<0.01	0.003	
All Shrubs	33.9±25.6	2.18			
Kemmerer #3					0.194
Artemisia tridentata	41.9±20.8	0.41±0.6	0.02	0.194	
Atriplex canescens	64.9±28.4	4.30±0.4	0.18±0.2	1.716	
Chrysothamnus spp.	31.4±10.5	0.20±0.2	0.01	0.074	
Gutierrezia sarothrae	16.4±4.5		<0.01	0.009	
Artemisia tripartata	18.3±4.3		<0.01	0.005	
All Shrubs	34.6±29.1	4.91	0.21		
Bridger Coal #1					0.453
Artemisia tridentata	34.6±15.6	4.14±0.4	1.71±1.0	1.390	
Atriplex canescens	38.5±24.7	0.49±0.4	0.02	0.070	
Eurotia lanata	19.2±10.0	0.02	<0.01	0.003	
Chrysothamnus spp.	18.2±15.4	0.13	0.02	0.030	
Gutierrezia sarothrae	21.4±12.7	0.01	0.01	0.010	
Atriplex confertifolia	36.3±15.3	0.60±0.3	0.02	0.080	
Atriplex gardnerii	11.8±5.7	1.96±0.3	0.12±0.1	0.300	
Sarcobatus vermiculatus	43.7±36.5	0.91±0.3	0.02	0.120	
All Shrubs	28.0±19.3	8.26	1.92		

Table 19 continued...

Site	Mean Height (cm)	Mean Cover (%)	Mean Density (plants/m^2)	Importance Value	Diversity Index
Bridger Coal #2					0.421
Artemisia tridentata	32.9±14.5	1.40±0.4	0.77±0.6	0.800	
Atriplex canescens	55.4±41.5	10.69±0.7	0.27±0.1	1.050	
Chrysothamnus spp.	21.3±11.0		0.001	0.010	
Gutierrezia sarothrae	16.2±12.1	<0.01	<0.01	0.010	
Atriplex confertifolia	29.8±17.7	0.80±0.6	0.04	0.090	
All Shrubs	28.1±33.7	13.29	1.11		
Mean (All Sites)	31.1	5.59	0.61	0.296	

[1] Standard deviation
[2] Mean of mean shrub species heights
[3] Sum of mean shrub species cover and density

species ranged from 25.8 to 54.1 cm on the saltbush sites, while mean shrub height on the saltbush-sagebrush sites ranged from 19.4 to 44.5 cm (Table 18 & 19). Mean shrub heights of sagebrush ranged from 10.0 to 64.1 cm, while saltbush heights ranged from 13.0 to 82.3 cm when averaged across all sites. Differences in growth rates and browsing preference by antelope and mule deer may explain the overall lower heights of sagebrush compared to saltbush (McArthur et al., 1988; Bilbrough and Richards, 1993). When evaluating sagebrush heights, 5 of the 9 saltbush-sagebrush sites had heights great enough to fall within Cook's (1984) criteria (22-46 cm), Table 19. Only one of the saltbush sites had sagebrush plant height that fell within the standard established by Yoakum (1984) and Cook (Table 18). Sage grouse sagebrush height requirements for nesting habitat was met at the Kemmerer #1 of the saltbush sites and at 8 of the saltbush-sagebrush sites (Roberson, 1985; Postovit, 1981; Hulet et al., 1984). Shannon-Weiner diversity indices averaged 3 times higher on saltbush-sagebrush sites compared to saltbush sites. Diversity indices for the saltbush sites averaged 0.100; whereas, it averaged 0.296 on the saltbush-sagebrush sites (Tables 18 & 19). An individual site analysis showed that 4 of the saltbush sites had the lowest indices, while 8 of the saltbush-sagebrush sites reflected the highest diversity (Figure 8).

Individual shrub species canopy cover was low by any wildlife habitat standard on all sites evaluated, rarely exceeding 5%. Differential growth rates among shrub species and browsing by wild herbivores may be the primary reason for this observation, rather than reclamation practices. Therefore, reclamation specialists may need to intensify wildlife damage control efforts on newly reclaimed sites in an effort to enhance and successfully achieve shrub covers needed and desired for respective wildlife species. Shrub densities were likewise considered low when evaluated against an extrapolation of the regulation of 1 shrub/m^2 on 20% of the land. The data indicate that the more shrub species that are included in the initial seed mixture the greater the overall shrub density. Several of the saltbush-sagebrush sites displayed encouraging signs of increased shrub densities by the presence of an age stratified population. Higher diversity indices on the saltbush-sagebrush sites indicate that more species in the initial seed mixture enhances plant community diversity, a highly desired characteristic for optimum wildlife habitat. Sites where more shrub species were included in the initial seeding mixture more closely resemble the diversity of the pre-mine plant community. Inclusion of multiple species in the initial seed mixture enhances overall canopy cover, density, and diversity in the reclaimed plant community, all important components of quality wildlife habitat.

F. Conclusions and Recommendations

Establishment of big sagebrush on mined lands in Wyoming can be enhanced by the improved understanding of seedbed ecology and the ecological factors that influence seed germination and seedling development.

Big sagebrush seedling establishment can be improved by using either surface applied straw or grain stubble mulch and direct-placed topsoil. Sagebrush seedling densities can also be improved if the sagebrush is not seeded with competitive herbaceous species. Therefore, to achieve the required sagebrush seedling densities one should seed sagebrush in small "island" plantings without any grass but surrounded by the normal grass-forb-shrub reclamation community. These sites should be on relatively flat areas to ensure erosional stability of the landscape. Direct-placed topsoil, on the Establishment study, also resulted in greater seedling establishment in the initial year after seeding