

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<sup>2</sup> 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

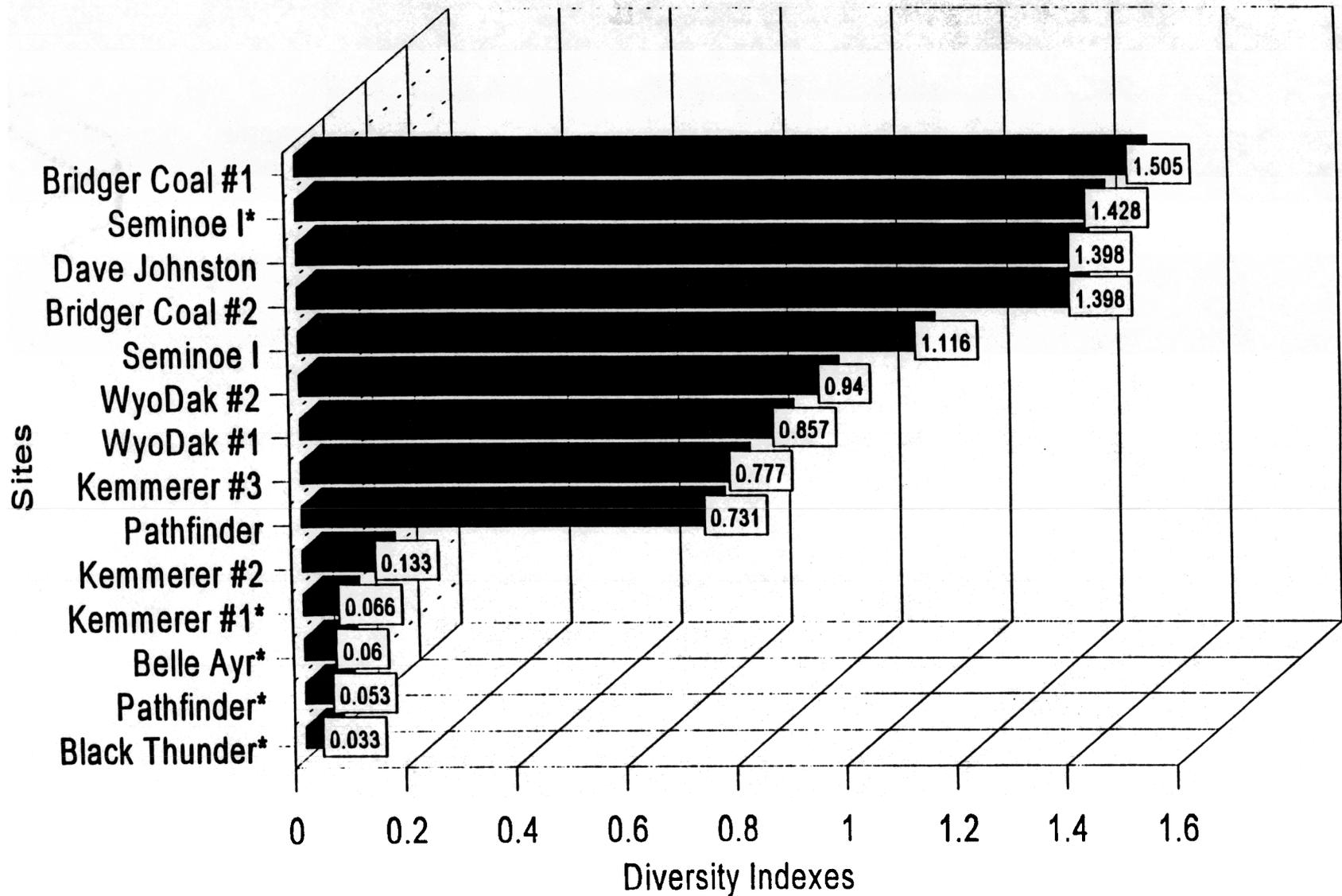


Figure 8. Diversity indexes for fourwing saltbush/grass (denoted by \*) and fourwing saltbush/big sagebrush/grass sites. Refer to Booth et al. 1997 for a list of seeding mixture used at each site.

compared to 5-year old stockpiled topsoil. However, for unexplained reasons the direct-placed topsoil did not exhibit similar benefits on the Pioneer study. This is surprising and unexplainable considering that numerous research studies in the 1970-80's have shown multiple benefits of direct-placed topsoil. The improved establishment was attributed to the greater soil moisture and better physiochemical characteristics of the direct-placed topsoil.

Arbuscular mycorrhizae infection of sagebrush seedlings significantly increased the seedlings' drought stress tolerance. This research was conducted in a greenhouse environment to enable full assessment of AM role in seedling survival under drought stress. The enhanced drought stress tolerance of the seedlings was even more pronounced as the seedlings aged (>120 days old). The field study design did not allow us to fully assess this issue since AM inoculum was probably spread via of the wind within the first 12-18 months. Therefore, even though we found no difference in AM infection between the seedlings grown on direct-placed and stockpiled topsoil in the field we feel it is desirable to practice good topsoil management if feasibly possible. Infection at the earliest stages of development definitely improve the seedlings' survival of the many drought periods that occur in a field environment.

The use of fourwing saltbush as a pioneer species to improve recruitment success of big sagebrush did not show any improved sagebrush establishment nor did it result in any reduction in sagebrush establishment; however, the simple seeding of two shrub species resulted in greater shrub densities and greater diversity.

The survey of 14 sites at 8 Wyoming coal mines reclaimed prior to 1985 showed that pre-1985 reclamation technology did not produce mature shrub densities that would meet the 1996 Wyoming shrub standard. However, the study pointed out several important factors related to shrub establishment. Greater shrub densities were achieved with greater seeding rates up to 1000 seeds/m<sup>2</sup>, non-local subspecies may be used successfully to achieve desired shrub densities, fourwing saltbush is long lived and self regenerating on reclaimed mine lands and can play an important role in cover and diversity for wildlife habitat, and greater species diversity was achieved with more diverse seed mixtures. Many of these points highlight things that should be obvious; however, many of these findings are still not fully accepted by reclamationist and regulatory personnel when developing reclamation plans. Wildlife browse can be a critical issue in the success of shrub establishment and growth. How the detrimental aspects of excess wildlife browse are addressed in evaluating reclamation success will be very important in some situations.

Recommendations from this research will result in improved sagebrush establishment on mined lands in Wyoming. However, some of the findings of this research are not fully delineated and will require further study to obtain detailed understandings of the factors involved in sagebrush germination and growth.