Effect of Cultural Practices on Seeded Plant Communities on Intensively Disturbed Soils

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Abstract

A revegetation technique study was established in a disturbed sagebrush-juniper community in northwestern Colorado in the fall of 1976. The purpose of the study was to identify effective cultural practices for establishing diverse and productive plant communities on disturbed soils. A combination of 4 treatments was applied: (1) altering life form seeding ratios, (2) seeding mixtures, (3) fertilizer, and (4) irrigation. After 4 years there was no significant difference in aboveground biomass production and canopy cover between irrigated and nonirrigated treatments. Fertilization increased production of grasses and shrub growth but depressed forb growth somewhat. The aboveground production of native and introduced mixtures was similar following four growing seasons. In general, introduced grasses out-produced native grasses, introduced forbs produced more than native forbs, and native shrubs out- performed introduced shrubs. Altering ratios among life forms affected shrub biomass more than forb and grass production. The use of different seeding rates indicates that plant community composition will change and may be a function of not only seeding rates but also plant and environmental factors over time and space.

Increased demands for domestic energy sources will result in major land disturbances in the western United States. Revegetation of these disturbed sites will require a wide array of flexible techniques to be successful. Establishment of complex vegetation communities will require sophisticated techniques to meet the various environmental conditions and growth requirements of the seeded species.

Many revegetation studies have reported good grass establishment on disturbed sites of the pinyon-juniper, foothill sagebrush, and mixied prairie grassland types (Plummer et al. 1968, Depuit and Coenenberg 1980, Sindelar and Plantenberg 1978, Redente et al. 1981). However, the same studies reported difficulty in establishing shrub species from seed. Other revegetation studies have succeeded in establishing shrubs with limited grass establishment success (Institute for Land Rehabilitation 1979). Therefore, improvement of establishment techniques and testing of different combinations of techniques are still necessary.

Irrigation on semiarid rangelands can help overcome drought conditions during stand establishment and may increase plant density and production over nonirrigated areas (Ries and Day 1978, Farmer et al. 1974). Although irrigation improves the chance of reclamation success, it is not always feasible because of scarcity of water, cost, and availability of water rights. Therefore, irrigation should not be a mandatory cultural practice but should be considered on a site-specific basis. In addition, irrigation should be considered only as a temporary (first and second growing season) treatment to aid plant establishment in order to avoid producing dense stands that are dependent upon supplemental water indefinitely.

Fertilization of disturbed sites is often done without consideration of benefits versus costs. Fertilization has limited application in the southwest (Merkel and Herbel 1973). Dwyer (1970) indicated that fertilizer would not be effective in areas receiving less than 35 cm annual precipitation. Similarly, Cook (1965) demonstrated that a minimum of 27 mm of annual precipitation was needed for efficient use of fertilizer on Utah rangelands. Other research by Farmer et al. (1974), Depuit and Coenenberg (1979), and Woodmansee et al. (1980) reported that applications of nitrogen increased grass production. Increased grass production from fertilization increased grass competition with legumes thereby decreasing legume productivity (Depuit and Coenenberg 1979). In studies by Berg (1980), it was shown that shrub production was depressed due to increased moisture competition from grasses after fertilization. However, Aldon et al. (1976) in New Mexico found that applications of 90 to 180 kg N/ha with phosphorus increased fourwing saltbush *(Atriplex canescens)* production, when planted in pure stands, but nitrogen levels less than 90 kg N/ha had no effect. Other studies indicate the vegetation responses to fertilizer will vary according to seed mixture, seeding rate, precipitation, and soil moisture (Cook 1965, Burzlaff et al. 1968, and Dwyer 1970). Therefore, a broad spectrum of vegetation responses may be possible with a fertilizer application.

Both the type of species used and their seeding rate can have a profound effect on the expression of plant communities. Abiotic factors such as precipitation rate and frequency, temperature, and soil conditions will further modify seed mixture responses. Identical seed mixtures seeded under different weather regimes and soils will have different plant composition (Redente, unpublished data). Work by Depuit and Coenenberg (1980) reported that different seeding rates of the same seed mixture produced slightly different plant composition, but it was not in direct relation with the changes in the seeding rate among species in the mixture. Similarly, individual species responses to treatments reported by Depuit and Coenenberg (1980) varied from results of Sindelar and Plantenberg (1978) because of differences in seed mixtures, planting dates, and site conditions although both seedings were near Colstrip, Mont. Therefore, care must be taken in extrapolating seed mixture performance to areas even slightly different environmentally.

The objectives of the present study were to determine the success of revegetating intensively disturbed soil using 3 seed mixtures and 2 life form seeding ratios under fertilizer and irrigation treatments.

Study Site Location and Description

The study was located in the Piceance Basin 65 km northwest of Rifle, Colo., at an elevation of 2200 m. Sagebrush-grass was the dominant vegetation type. Big sagebrush *(Artemisia tridentata)*, western wheatgrass *(Agropyron smithii)*, prairie junegrass *(Koeleria cristata)*, Indian ricegrass *(Oryzopsis hymenoides)*, cheatgrass *(Bromus tectorum)*, and Russian thistle *(Salsola iberica)* were important species. Soils were loam to clay loam with the combined A and B horizons being 13 to 25 cm deep. The pH was 8.0, organic matter was 1.7%, electrical conductivity averaged 0.5 mmhos/cm, nitrate-nitrogen was 5 ppm (water extract), and phosphorus was 2.3 ppm (ammonium bicarbonate extract). Climate of the area is semiarid. Annual precipitation is approximately 30 cm, one-half of which is received as snow.

Materials and Methods

In 1976 vegetation was mechanically removed from a 1.9-ha area, and 1 m of soil (A, B, and C horizons) was removed, mixed together, and replaced creating a rocky plant growth medium with low levels of nitrogen (N) and phosphorus (P). The soil texture was sandy clay loam with a pH of 8.3, SAR was 4.8, electrical conduc-

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tivity was 0.6 mmhos/cm, nitrate-nitrogen was 2.2 ppm (water extract), and phosphorus was 1.0 ppm (ammonium bicarbonate extract). Slope was 3% and northfacing. Three seed mixtures consisting of diverse combinations of grasses, forbs, and shrubs were drill seeded in November 1976. The 3 mixtures contained either all native, all introduced, or a combination of native and introduced species (Table 1).

Two life form ratios were used for all seed mixtures in an attempt to establish adequate stands of grasses, forbs, and shrubs at one seeding. Life Form Ratio 1 had a higher seeding rate of grasses and forbs compared to Life Form Ratio 2, and Life form Ratio 2 had a higher seeding rate of shrub seed planted compared to Life Form Ratio 1 (Table 1).

Natural precipitation was supplemented during the 1977 and 1978 growing seasons on one-half of the study at a rate which brought the combined (natural and artificial) moisture to a total of 2.5 cm/week which was considered a favorable year for the area. This rate approximates the highest amount of precipitation that would be expected based on 20 years of previous data (Wymore 1974). In addition, supplemental water was provided to the nonirrigated portion of the study because of severe drought conditions prevailing during the summer of 1977. Approximately 2.6 cm of water was added between 26 and 29 June 1977 to prevent failure of seedling establishment. The irrigation water had a pH of 8.2, SAR of 1.7, and an EC of 1050 micromhos/cm, indicating that the sodium hazard was low and the salinity hazard moderate.

One-half of both irrigated and nonirrigated plots received fertilizer at 90 kg P/ha as triple superphosphate which was incorporated into the plant root zone prior to seeding. Ammonium nitrate was applied at a rate of 112 kg N/ha in the fall after the first growing season to reduce volitilization and increase efficient use by plants (Bauer et al. 1978). Wood fiber mulch was applied in a slurry at a rate of 2.2 MT/ha over all plots following seeding.

The experimental design was a randomized split-split plot (irrigation being the first split and fertilizer being the second split) with 3 replications. Vegetation was sampled in 1978, 1979, and 1980 using six 0.25-m² permanent quadrats in each 5×8-m subplot. Density, aboveground biomass, and canopy cover were recorded by species for seeded plants. Canopy cover was estimated by visually compressing the vegetation components together before assigning a cover value. Aboveground biomass (dry matter) was determined using double sampling techniques.

Data were analyzed using four-way analysis of variance and multiple regression techniques. Dependent variables were density, biomass, and canopy cover; independent variables were irrigation, fertilizer, seed mixture, and life form ratio changes. The analyses were run by life forms (grass, forb, shrub) and species within seed mixtures. Each year was analyzed separately. Sheffe's test was used at the .10 level of probability to identify significantly different means when *F* values were significant. There were few significant interactions found between treatments within years. Therefore, discussion has been limited, generally, to main treatment effects.

Results and Discussion

Effects of Irrigation

Irrigation during the first two growing seasons significantly increased mean production of grasses in 1978 and 1979 compared to the nonirrigated treatment (Fig. 1). Aboveground biomass and cover of grasses were not significantly different between irrigated and nonirrigated plots by 1980. Farmer et al. (1974) found that grass yields increased under irrigation compared to nonirrigated conditions on seeded areas after coal mining near Decker, Mont. However, irrigation was much more effective if mulch and fertilizer were used. The differences between these 2 studies may be a result of soils and rainfall more suitable for grasses at the Decker site compared to the Piceance Basin site.

Aboveground biomass of seeded grasses in the introduced mixture declined on irrigated plots from a high of 1600 kg/ha in 1978 to 1400 kg/ha in 1979 to 800 kg/ha in 1980. The biomass supported on the irrigated plots in 1978 and 1979 was higher than on nonirrigated plots by 1200 kg/ha in 1978 and 500 kg/ha in 1979. These values may have been artificially high and were reduced in 1980 as a result of physiological stress on plants due to 1980 drought conditions. Berg (1975) and Ries and Day (1978) predicted this natural thinning of irrigated stands from preliminary revegetation studies using irrigation.

Forb biomass was greater on irrigated plots compared to nonirrigated plots (Fig. 1). This was generally a result of increased amounts of cicer milkvetch *(Astragalus cicer)* and alfalfa *(Medicago sativa)* under irrigation.

Irrigation reduced shrub biomass (Fig. 1) and densities throughout the entire study period. Shrub densities in 1978 were 3.3 plants/m² on nonirrigated plots compared to only 2.4 plants/m² on irrigated plots. In 1980 densities were twice as great on nonirrigated plots (4.7 plants/m²) compared to irrigated plots (2.3 plants/m²). Similarly, shrub biomass was twice as great on nonirrigated plots compared to irrigated plots in 1980. Increased grass competition under irrigation hindered establishment of slower establishing shrubs. This interaction between grasses and woody plants under irrigated conditions has been documented by several authors (Hubbard 1957, Plummer et al. 1968).

On steep south-facing slopes where soil erosion control is critical, rapid grass establishment may be the goal of revegetation plans. Therefore, temporary use of irrigation may be one technique to ensure grass establishment. However, shrub-dominated communities are pervalent in some regions, and rapid grass establishment may not be the best long-term goal on these sites. The use of rapidly establishing shrubs (such as fourwing saltbush and winterfat) in combination with slower establishing shrubs at high seeding rates along with low seeding rates of grasses may be the better long-term approach to soil stabilization and an effective land use. On north-facing slopes a more appropriate seed mixture may include a higher seeding rate of grasses and forbs compared to shrubs to ensure good grass establishment. The use of irrigation on

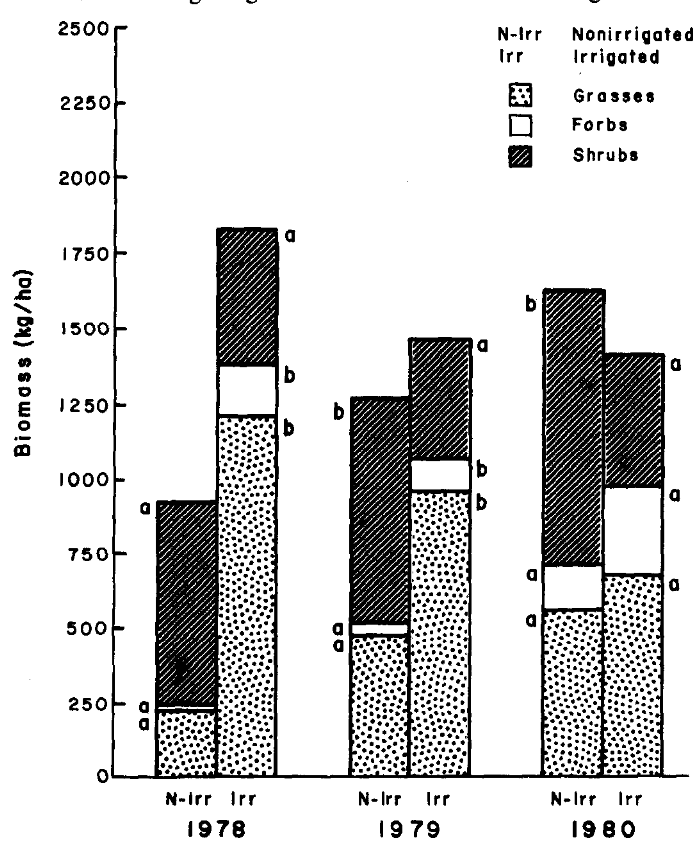

Fig. 1. *Mean biomass of seeded grasses, forbs, and shrubs for 1978, 1979, and 1980 on irrigated and nonirrigated plots. Means with different letters within year and life form are significantly different (p<0.10).*

Table 1. Seeding mixtures and rates used on the revegetation techniques study.

Common name	Scientific name	Seeding rate PLS (kg/ha) Life Form Ratio 1	Life Form Ratio 2
Mixture 1-Combination (native and introduced) species			
1. Crested wheatgrass 'Nordan'	*Agropyron desertorum*	1.1	0.6
2. Siberian wheatgrass	*A. sibiricum*	1.1	0.6
3. Thickspike wheatgrass 'Critana'	*A. dasystachyum*	1.1	0.6
4. Streambank wheatgrass 'Sodar'	*A. riparium*	1.1	0.6
5. Slender wheatgrass	*A. trachycaulum*	1.1	0.6
6. Meadow brome 'Regar'	*Bromus biebersteinii*	1.1	0.6
7. Indian ricegrass	*Oryzopsis hymenoides*	1.1	0.6
8. Green needlegrass	*Stipa viridula*	1.1	0.6
9. Hard fescue 'Durar'	*Festuca ovina duriuscula*	0.6	0.3
10. Yellow sweetclover 'Madrid'	*Melilotus officinalis*	0.6	0.3
11. Sweetvetch	*Hedysarum boreale*	1.1	0.6
12. Globemallow	*Sphaeralcea monroana*	0.6	0.6
13. Lewis flax	*Linum lewisii*	0.6	0.6
14. Arrowleaf balsamroot	*Balsamorhiza sagittata*	1.1	0.6
15. Fourwing saltbush	*Atriplex canescens*	1.1	4.5
16. Stansbury cliffrose	*Cowania mexicana stansburiana*	1.1	3.4
17. Winterfat	*Ceratoides lanata*	1.1	2.2
18. Green ephedra	*Ephedra viridis*	1.1	2.2
	Total	17.8	20.1
Mixture 2—Native species			
1. Western wheatgrass 'Rosana'	*Agropyron smithii*	1.1	0.6
2. Streambank wheatgrass 'Sodar'	*A. riparium*	1.1	0.6
3. Bearded bluebunch wheatgrass	*A. spicatum*	1.1	0.6
4. Indian ricegrass	*Oryzopsis hymenoides*	1.1	0.6
5. Green needlegrass	*Stipa viridula*	1.1	0.6
6. Big bluegrass 'Shermans'	*Poa ampla*	1.1	0.6
7. Alkali sacaton	*Sporobolus airoides*	0.6	0.3
8. Globemallow	*Sphaeralcea munroana*	0.6	0.3
9. Sweetvetch	*Hedysarum boreale*	1.1	0.6
10. Palmer penstemon	*Penstemon palmeri*	0.6	0.3
11. Stansbury cliffrose	*Cowania mexicana stansburiana*	2.2	4.5
12. Green ephedra	*Ephedra viridis*	1.1	3.4
13. Fourwing saltbush	*Atriplex canescens*	1.1	3.4
14. Winterfat	*Ceratoides lanata*	1.1	2.2
15. Antelope bitterbrush	*Purshia tridentata*	1.1	3.4
	Total	16.1	22.0
Mixture 3—Introduced species			
1. Crested wheatgrass 'Nordan'	*Agropyron desertorum*	1.1	0.6
2. Siberian wheatgrass	*A. sibiricum*	1.1	0.6
3. Tall wheatgrass 'Jose'	*A. elongatum*	1.1	0.6
4. Pubescent wheatgrass 'Luna'	*A. trichophorum*	1.1	0.6
5. Intermediate wheatgrass 'Oahe'	*A. intermedium*	1.1	0.6
6. Smooth brome 'Manchar'	*Bromus inermis*	1.1	0.6
7. Meadow brome 'Regar'	*B. biebersteinii*	1.1	0.6
8. Russian wildrye 'Vinal'	*Elymus junceus*	1.1	0.6
9. Alfalfa 'Ladak'	*Medicago sativa*	0.6	0.3
10. Yellow sweetclover 'Madrid'	*Melilotus officinalis*	0.6	0.3
11. Cicer milkvetch 'Lutana'	*Astragalus cicer*	0.6	0.6
12. Sainfoin	*Onobrychis viciaefolia*	0.6	0.6
13. Bouncing bet	*Saponaria officinalis*	1.1	1.1
14. Small burnet	*Sanguisorba minor*	1.1	1.1
15. Siberian peashrub	*Caragana arborescens*	1.1	4.5
16. Russian olive	*Elaeagnus angustifolia*	2.2	4.5
	Total	16.7	17.8

these sites would increase grass production for the first 2 to 3 years, but this gain may be rapidly lost after this period of time as indicated in the present study.

Effects of Fertilizer

Aboveground biomass of seeded grases was significantly greater on fertilized plots compared to unfertilized plots in 1978 regardless of irrigation (Fig. 2). However, fertilization was more effective on irrigated plots compared to nonirrigated plots. Also, grass biomass was generally greater on fertilized plots in 1979 and 1980 under irrigated conditions, although this increase was not statistically significant. Depuit and Coenenberg (1979) found that fertilizer was effective in significantly increasing grass biomass compared to unfertilized grasses 3 years after application. Shrub competition may have reduced grass biomass on fertilized plots in this study.

Aboveground biomass of seeded forbs was not affected by fertilization (Fig. 2). A study in Montana showed that forbs did not respond to fertilizer treatments when seeded with more competitive grass species (Depuit and Coenenberg 1979). Russell et al. (1965) found that N application decreased the percentage of legumes found in hay meadows in Nebraska. They also reported that P increased legume composition. The lack of response by forbs in this study may be partially caused by increased grass competition from the application of N negating any forb produc-

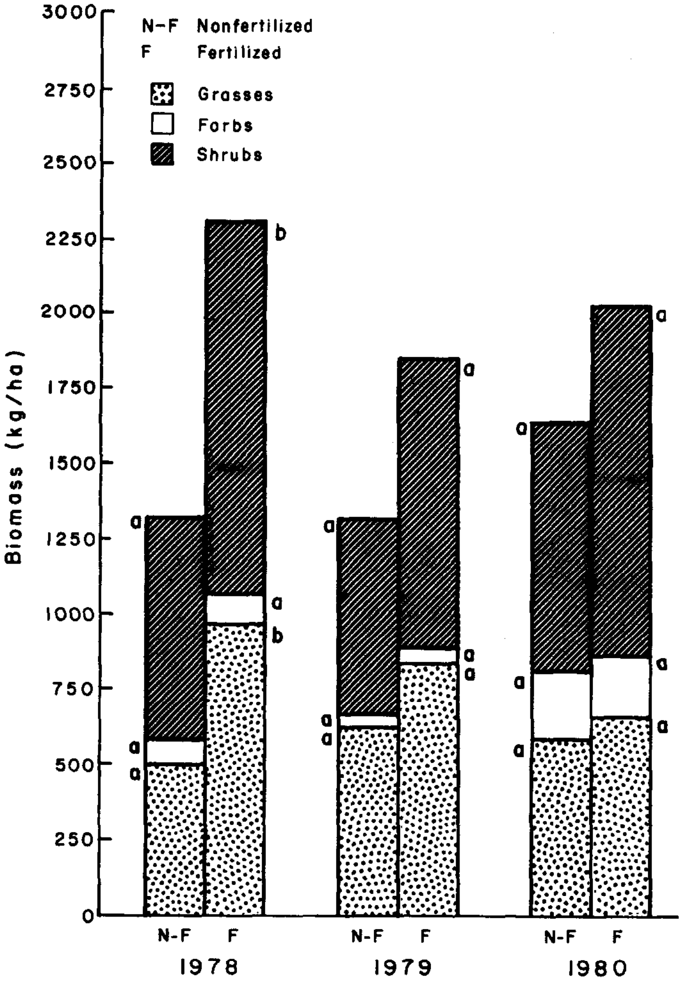

Fig. 2. *Mean biomass of grasses, forbs, and shrubs in 1978, 1979, and 1980 on fertilized and nonfertilized plots. Means with different letters within year and life form are significantly different ($p<0.10$).*

tion increases in response to the phosphorus applications. In addition, vegetation often does not display increased production to fertilizer under drought conditions (Vallentine 1971, Bauer et al. 1966, Smika et al. 1961). Therefore, poor forb establishment and production could be expected on fertilized plots.

Forb densities were low (3 to 4 plants/m^2) because of low competitive ability of northern sweetvetch *(Hedysarum boreale)*, Palmer penstemon *(Penstemon palmeri)*, Lewis flax *(Linum lewisii)*, small burnet *(Sanguisorba minor)*, bouncing bet *(Saponaria officinalis)*, sainfoin *(Onobrychis viciaefolia)*, and arrowleaf balsamroot *(Balsamorhiza saggitata)* in the seedling stage. Other revegetation studies in the Piceance Basin by Berg et al. (1979), Herron et al. (1980), and Harbert and Berg (1978) also reported low establishment of similar forbs in complex grass-forb-shrub mixtures.

Fertilization significantly increased shrub production in 1978 (Fig. 2). Greater production was also seen in 1979 and 1980 on fertilized plots, but this was not statistically significant. However, fertilization significantly increased shrub cover in 1980 on nonirrigated plots. Shrub cover was 28% on fertilized-nonirrigated plots compared to 14% on unfertilized-nonirrigated plots. Draves and Berg (1978) found that seeded shrubs were not significantly affected by fertilization in mountain shrub communities of Colorado because of grass competition. The lack of shrub response to fertilization on irrigated plots corresponds to the findings of Draves and Berg (1978), and the hypothesis of grass competition overriding fertilization effects was demonstrated in this study.

Effects of Seed Mixture

Seed mixture affected the establishment of grasses and forbs but not shrubs. Aboveground grass biomass was greatest in the introduced mixture and lowest in the native mixture under irrigated and nonirrigated treatments in 1978 and 1979 (Fig. 3). The greater grass biomass of the introduced mixture can be attributed to faster growth and greater vigor of introduced compared to native grasses. In addition, introduced shrubs failed to become established from seed. Consequently, grass growth in the introduced mixture was not restricted by shrub competition for space or moisture. The aboveground production of grasses in the native mixture in 1980 was similar to grass production in the introduced mixture on irrigated plots. Although native grasses generally have slower growth and lower production potential than introduced grasses, the production potential appears to be similar for this site. In addition, it appears that 4 to 5 growing seasons may be necessary for native species to reach their potential production on semiarid sites. The consistently low grass production of native and combination mixtures on nonirrigated plots through 1980 was attributed to the poor establishment of green needlegrass *(Stipa viridula)*, Indian ricegrass, hard fescue *(Festuca ovina duriuscula)*, alkali sacaton *(Sporobolus airoides)*, and big bluegrass *(Poa ampla)*.

Forb density and biomass were greatest in the introduced mixture compared to the combination and native mixtures in 1978, 1979, and 1980 on irrigated and nonirrigated plots (Fig. 3). Alfalfa and cicer milkvetch were robust plants in 1979 and 1980. Consequently, these species accounted for the differences in forb response among seed mixtures. Shrub biomass was generally greater in the native mixture compared to biomass in the combination mixture, although the difference was not statistically significant (Fig. 3). The greater biomass exhibited by shrubs in the native mixture may be attributed to the lower vigor of native grasses (e.g., green needlegrass, Indian ricegrass, big bluegrass, and alkali sacaton) compared to grasses and forbs in the combination mixture (e.g., crested wheatgrass, thickspike wheatgrass *(Agropyron dasystachyum)*, and yellow sweetclover *(Melilotus officinalis)* the first two growing seasons. The similarity of shrub production between the native and combination mixtures the third and fourth growing seasons can be attributed to the similarity of grasses and forbs (Table 1) used and their production in these mixtures (Fig. 3).

The combination mixture of both native and introduced species provided greater grass cover and production compared to the native mixture in 1978 and 1979. The high production was attributed to slender wheatgrass *(A. trachycaulum)*, crested wheatgrass, and meadow brome *(Bromus biebersteinii)*. Only slender wheatgrass was a native species. These three species declined by 1980 to become subdominant (crested wheatgrass) or of lesser importance (slender wheatgrass and meadow brome). Streambank wheatgrass production increased in 1980 from 1979 levels to partially compensate for the reduction of the introduced species in the combination seed mixture. Grass biomass in the combination mixture was therefore equivalent to biomass in the native mixture (which did not exhibit as great a decline in production). The rapid grass establishment and production of the combination mixture may make this mixture superior to the native mixture on steep slopes where rapid establishment is critical for soil erosion control. Also, the increase of the native species component (i.e., streambank wheatgrass, winterfat, and fourwing saltbush) appears to make the combination seed mixture as potentially suitable as the native mixture for long-term soil stabilization and grazing use. Similarly, native forbs including globemallow *(Sphaeralcea munroana)* and Lewis flax *(Linum lewisii)* had greater biomass the fourth growing season compared to previous growing seasons.

Effects of Life Form Ratios

The high grass-forb seeding rate (Life Form Ratio 1) resulted in grass densities of 44 plants/m^2 compared to densities of 38 plants/m^2 with the low grass-forb seeding rate (Life Form Ratio 2). Similarly, grass and forb biomass was greater on Life Form Ratio 1 plots compared to Life Form Ratio 2 plots in 1978 through 1980 (Fig. 4). The biomass increases for the different life forms, while not significant, indicate that composition changes will occur in the plant community when seeding rates among life forms are altered. Other studies in the Piceance Basin have shown that varying seeding rates among life forms will change life form composition in favor of grasses at the expense of forbs (Rio Blanco Oil Shale Company 1980). Other work by Depuit and Coenenberg (1980) in Montana reported that increased seeding rates will generally reduce the cover of less competitive species. Also, competition between species will create large variation in species responses; thus statistical significance is difficult to achieve. Cook et al. (1967) found that less competitive grasses did not benefit as greatly from increased seeding rates as did competitive grasses in seeding trials in central Utah.

Changes in life form ratios did not significantly affect shrub biomass or cover (Fig. 4). However, Life Form Ratio 2 (shrubs seeded at a higher rate than grasses and forbs) produced consistently greater shrub biomass than did Life Form Ratio 1 (grasses and forbs seeded at a higher rate than shrubs).

This study and other studies on seeding rates indicate that successional plant expression will change with variations of seeding rate. However, these changes will not be proportional to the change in seeding rate and is a reflection of such factors as competition, characteristics of each species (including drought tolerance at different phenological stages, rate of growth, potential size and production, and germination percent and rate). Therefore, great care needs to be taken in formulating seed mixtures and ratios to achieve a balanced community of grasses, forbs, and shrubs that fit the land use requirements. This may require more innovative techniques rather than a standard agronomic approach. Similarly, variations in the outcome of stand establishment should be expected because of differences in site characteristics and weather parameters.

Conclusions

Irrigation shortened the time required for grasses and forbs to establish and reach high production levels. However, this gain was only short term; therefore, irrigation should be considered only if there is a need for rapid establishment of these life forms under environmental conditions similar to those in this study. Shrubs were not as easily established, and production was reduced with irrigation. Similarly, fertilizer aided early grass and shrub production but reduced forb production. If greater production of shrubs or forbs is required for diversity or wildlife needs of cover and food, then rapid production of grasses may need to be sacrificed by limiting the use of irrigation or fertilizer to ensure forb and shrub establishment and growth. Similarly, sacrificing forb and shrub production to achieve rapid grass production may be required on sites particularly susceptible to erosion.

The success of the 3 seed mixtures used in this study demonstrates that a wide selection of species is available for revegetation in the semiarid west. Therefore, flexibility exists in selection of species according to their utility (e.g., soil stabilizing agent, wildlife habitat, or livestock forage). However, some species were not successfully established in sufficient quantities to be considered important components of the seeded communities. Arrowleaf bal-

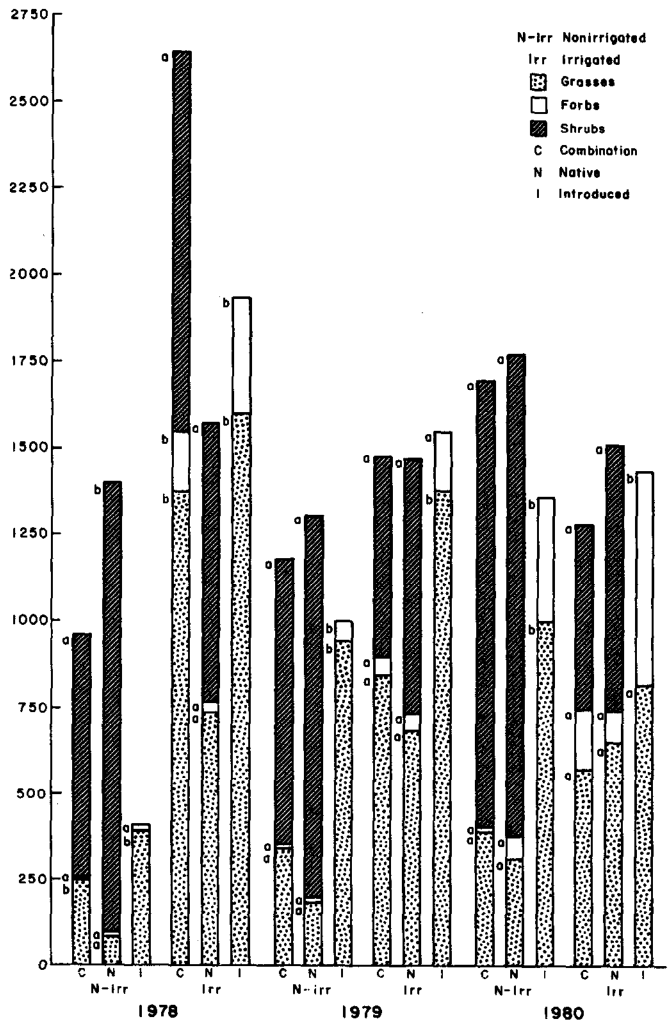

Fig. 3. *Mean biomass of grasses, forbs, and shrubs on irrigated and nonirrigated plots for combination, native and introduced seeded mixtures in 1978, 1979, and 1980. Means with different letters within year and life form are significantly different (p<0.10).*

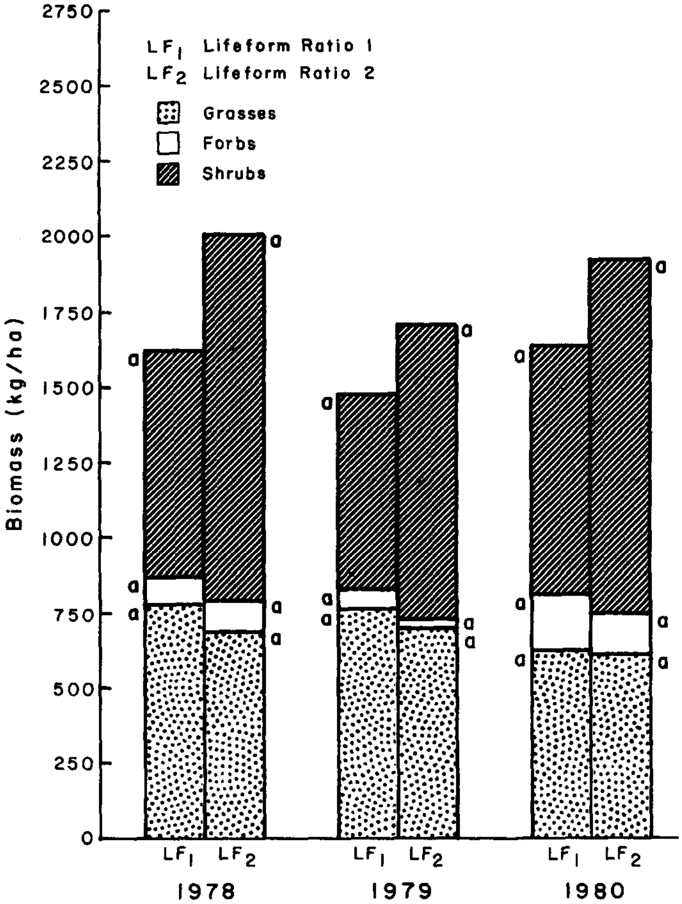

Fig. 4. *Mean biomass of grasses, forbs, and shrubs for seeding Life Form Ratios 1 and 2 in 1978, 1979, and 1980. Means with different letters within year and life form are significantly different* ($p<0.10$).

samroot *(Balsamorhiza sagittata)*, sainfoin *(Onobrychis viciaefolia)*, bouncing bet *(Saponaria officinalis)*, small burnet *(Sanguisorba minor)*, cliffrose *(Cowania mexicana)*, green ephedra *(Ephedra viridis)*, bitterbrush *(Purshia tridentata)*, Siberian peashrub *(Caragana arborescens)*, and Russian olive *(Elaeagnus angustifolia)* were forb and shrub species that did not have satisfactory establishment rates in these mixtures. Grass species that did not perform well in this study included hard fescue, big bluegrass, and alkali sacaton. These species should not be disregarded as future reclamation species but demonstrates the need for improvement of establishment techniques. Also, some species or groups of species may serve as important food components for some wildlife species although they do not compose a large percent of the vegetation composition.

Altering the life form ratio within a seeding mixture will certainly affect the composition of the established community. However, the ratio among the life forms of the established plants may not be in direct proportion to that found in the original seed mixture. Other factors such as competition, rate of growth, drought tolerance, and climatic conditions will influence the ultimate plant expression.

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