

Forage Kochia: Friend or Foe

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Abstract—Perennial forage kochia (*Kochia prostrata*) is a half-shrub valuable for reclamation, fire breaks, and livestock and wildlife forage on semiarid and saline rangelands. Interest is mounting about this species, but some are concerned that it will become an invader of perennial communities. Only one cultivar (Immigrant) has been released in the United States. Eighty-one forage kochia plantings (mainly Immigrant) were evaluated to document forage kochia's adaptation and spread. Ecological descriptions were taken for each site and multiple regression analyses were done to determine prediction equations for recruitment outside the original plantings. Our results indicated that forage kochia is well adapted to a wide range of semiarid and arid rangelands, but is not an aggressive spreader. However, it may recruit into playas, slick spots, and disturbed and/or degraded areas. The fringe of recruitment, defined as the marginal recruitment threshold, ranged from 0 to 100 ft with a mean and median distance of 20 ft. Regression only explained 22 percent of fringe threshold variation and consisted of the following factors: medium textured soils, lower elevation, and age of seeding. Unexplained variation may be due to factors not determined, such as the disturbed peripheral area surrounding each planting.

Introduction

"Immigrant" forage kochia [*Kochia prostrata* ssp. *virescens*], a half-shrub, has been seeded on over 200,000 acres of rangeland in 10 western states. Many scientists and rangeland managers consider forage kochia a prime candidate for western range rehabilitation and fire prevention. However, others are concerned about its potential to invade and suppress or eliminate native plant populations. Many are concerned that because forage kochia is an introduced species it may spread vigorously throughout western rangelands. We conclude that these concerns are largely unfounded. This investigation was undertaken to examine Immigrant forage kochia's competitive ability, invasiveness and potential effects on bio-diversity of native and introduced plant communities on semiarid rangelands.

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During October 1999, two of the authors (Waldron and Harrison) participated in a forage kochia germplasm collection trip to Kazakhstan. They evaluated forage kochia's compatibility and aggressiveness in its native environment on 64 sites.

Immigrant forage kochia was released in the United States in 1984 (Stevens and others 1984). Immigrant is native to the arid and semiarid regions of Central Eurasia (Larin 1956; Keller and Bleak 1974; Plummer 1974). The parental accession (PI314929) of Immigrant, along with other accessions, was acquired in May 1966 in a search for plants to suppress halogeton [*Halogeton glomeratus*] on droughty and saline sites. Immigrant, the only North American cultivar of the ssp. *virescens* (green-stem forage kochia) is a diploid with a chromosome number of $2n = 18$ (Pope and McArthur 1977; Herbel and others 1981).

The first known Immigrant (PI 314929) planting in the U.S. was made in 1968 by Keller and Bleak (1974). Immigrant was jointly released in March 1984 by the USDA Forest Service, USDA Soil Conservation Service, the Utah Division of Wildlife Resources and the Idaho, Nevada, Oregon, and Utah Agriculture Experiment Stations.

Forage kochia is a long-lived, semi-evergreen half shrub that averages 1 to 3 ft high at maturity. Individual plants may live 10 to 15 years (Balyan 1972). It develops an extensive fibrous root system with a tap root that may extend to a depth of 16 ft (Prianshnikov 1976). It does not tolerate flooding or soil with a water table (Balyan 1972).

Seeds ripen in October and November (Prihod'ko and Prihod'ko 1977), however, freezing temperatures hasten seed ripening. There are approximately 115,000 pure live seeds per lb (Stevens and others 1996). Forage kochia seeds germinate well for 6 to 8 months after harvest. It may maintain good germinability for up to 3 years if seed is properly dried to 7 percent or less moisture and stored at 36 to 50 °F (2.2 to 10 °C) (Jorgensen and Davis 1984).

Immigrant is widely adapted and has been successfully established on a range of soils including fine-to-coarse textured, shallow-to-deep, gravelly-to-stony and saline-to-alkaline and in numerous plant communities from mountain to desert shrub.

Uses

Immigrant has been seeded to improve plant community diversity, esthetics, plant cover, species richness, forage for domestic livestock and wildlife, fire prevention, and improved soil stability. Specific examples of its use are to (1) prevent accelerated soil erosion, flooding, and critical

area treatment including blowout areas (Stevens and others 1984; Rassmussen and others 1992; Horton, unpublished data 1998); (2) supply livestock and wildlife forage during normal and critical periods (Otsyina and others 1983; Gade and Provenza 1986; Kashkarov and Balyan 1989; Bake 1997); (3) provide food and cover for upland game birds, small mammals, reptiles, and insects (Stevens and others 1985); (4) readily provide ground cover on disturbed areas (Nemati 1986; Blauer and others 1993); (5) suppress or eliminate alien invasion of annual weeds like cheatgrass (*Bromus tectorum*), halogeton [*Halogeton glomeratus*], Russian thistle [*Salsola pestifer*], and medusahead rye [*Taeniarum (Elymus) caput-medusae*], (Van Epps and McKell 1983; McArthur and others 1990; Stevens and McArthur 1990; Monsen and Turnipseed 1990; Monsen 1994; Gutknecht 1996; Simper, personal communication, NRCS, Cedar City, UT, 1997; Turnipseed, personal communication, Idaho Fish and Game, Caldwell, ID, 1998); (6) reclamation of disturbed mine sites (Howard and others 1976; Frishchnecht and Ferguson 1984; Clements and others 1997); (7) beautify and stabilize road sides (Plummer 1970; Blauer and others 1993); (8) stabilize sand dunes (Krylova 1988); (9) increase species richness and biodiversity and assist in the reestablishment of desired perennials (Blauer and others 1993; Gutknecht 1996; Clements and others 1997); (10) provide green strips that suppress or prevent wild fires (Pellant 1990; Monsen 1994; Clements and others 1997); and (11) extract salts (sodium and chloride) from saline soils (Larin 1956; Francois 1976).

Competition, Invasiveness, and Biodiversity

Expression of a plant's competitive ability is a function of environmental and site conditions. Important environmental considerations are geomorphology, slope, aspect, soil type, climate, salinity, human impacts, seed sources, and existing or competing vegetation. All plants, both native and introduced, spread and compete in environments where they are best adapted and where there is little or no competition by other species for resources (Harrison and others 1996).

Immigrant forage kochia appears to have a competitive advantage over many other species in the cool shrub steppe because of its temporal and spatial capacity for water uptake (Romo and Haferkamp 1987). Under some conditions it can rapidly deplete soil moisture and become established in the presence of annual and perennial competitors (Keller and Bleak 1974; Van Epps and McKell 1983; Stevens and others 1985; Romo and Haferkamp 1987). The competitive advantage of Immigrant on disturbed sites over annuals like cheatgrass and halogeton is well documented (McArthur and others 1990; Monsen and Turnipseed 1990).

In its natural range in south-central Eurasia forage kochia is commonly associated with grasses and *Artemisia* species and contributes significantly to plant biodiversity. We concur with others that it generally does not grow in pure stands in its native habitats in Eurasia (Plummer 1970; McArthur and others 1974). In the U.S., Immigrant forage kochia appears to be best adapted within its ecological range when there is little competition from established perennial species.

The Bureau of Land Management in Idaho found that Immigrant has spread a few meters in disturbed areas beyond the original seeded boundaries on several 1986 greenstrip seedings (M. Pellant, BLM, personal communication, Boise, ID, 1998). Several researchers (Blauer and others 1993; Stevens and others 1985; Pendleton and others 1992; Clements and others 1997; K. Gray, personal communication, Nevada Division of Wildlife, Elko, NV, 1998; M. Haferkamp, personal communication, USDA-ARS, Miles City, MT, 1998) have concluded from studies in the big sagebrush and desert shrub communities that Immigrant is not highly invasive and does not spread aggressively into healthy plant communities.

Clements and others (1997), (C. D. Clements, personal communication, USDA-ARS, Reno, NV, 1999) states, "In the sagebrush/bunch grass region of the Great Basin, forage kochia does not appear to be invasive." They found little to no movement outside of 17 established seedings ranging from 2 to 17 years old. They concluded that "areas must be reduced to bare soil before it successfully invades." Stevens and others (1984) reported that Immigrant out competes many annuals, fills in the inter spaces between perennials, and establishes well when co-seeded with other perennials. They noted its recruitment into a black greasewood [*Sarcobatus vermiculatus*]-shadscale [*Atriplex confertifolia*]-halogeton community, and into introduced plant communities of intermediate wheatgrass [*Thinopyrum intermedium*], crested wheatgrass [*Agropyron cristatum*], cheatgrass, and medusahead rye. A. DeBolt (personal communication, USDI BLM, Boise, ID, 1998) indicated that pepper plants (*Lepidium davisii* and *papillienum*) species may suffer due to Immigrant's tendency to colonize on saline and alkaline playas. Blauer and others (1993) noted that in higher precipitation zones, Immigrant does not compete well in a closed herbaceous plant community.

In 1998, Clements (personal communication, 1999) found in Immigrant seedings that the density of cheatgrass declined and that native species numbers were seven times greater than in adjacent unburned stands. Clements and others (1997) concluded that native plants will become established in Immigrant seedings if fires are infrequent. They reported the spread of Wyoming big sagebrush, thickspike wheatgrass [*Elymus lanceolatus*], native bunch grasses and forbs was common in the fourth growing season of a stand of Immigrant, which had first suppressed cheatgrass.

Materials and Methods

This study was designed to determine planting success, biodiversity, spread, and competition of Immigrant forage kochia on semiarid western rangelands. In our attempt to assess the responses of Immigrant to the varied rangeland conditions into which it has been seeded in the Intermountain West we: (1) sent questionnaires to personnel at state and national resource agencies and researchers at universities and other institutions who were, or had been, involved with forage kochia research; (2) visited representative seedings and/or transplantings throughout the West that were old enough to give some indication of long term responses. We received over 151 questionnaire responses

describing forage kochia plantings. Information from the questionnaires and published reports was used to determine which plantings should be visited for further evaluation.

Onsite assessments were made, where possible, to all known Immigrant plantings that were unique or that were 10 years or older. More than 90 planting sites were visited and data was collected from 81 sites.

Because of the large number of field sites, the line-intercept method was used to evaluate Immigrant spread and percent composition. Transects were randomly located in plantings and a 100-foot tape was laid parallel to the original planting. Individual species, litter, bare ground and rocks were recorded. Percent plant composition was calculated for each species as the percentage of the total vegetation comprised by that species. A visual reconnaissance survey was made to assess the spread of forage kochia into fringe areas adjacent to the original planting, and the maximum distance from the seeding's edge where a single Immigrant plant had become established was recorded. The fringe distance was defined as the visual marginal or peripheral threshold of Immigrant encroachment from the original seeded boundary. In many instances, recruitment away from the seeding occurred in a pattern of fingers or pockets. At such sites a transect was taken within the finger or pocket at the visually observed threshold area of recruitment. If spread appeared to be mainly uniform around the planting then random transects were taken at the visually observed fringe. If no spread was observed then the fringe distance was recorded as zero. It should be noted the evaluation areas for each site were randomly selected and may not completely represent the entire planted area. Planting boundaries were shown to us by field personnel. Recruitment data were not taken when original seeding boundaries were unknown.

Statistical Analysis

Independent variables were treated as continuous (for example, elevation, precipitation, and so forth), interval categorical (for example, results = poor, fair, good, or excellent), or dichotomous categorical (yes or no) for correlation and regression analysis.

Questionnaire

Information obtained from the questionnaires was subjected to correlation analysis using SAS software (1989) to search for significant ($P < 0.10$) associations between independent environmental factors and the perceived degree of success in establishment and recruitment of forage kochia outside the planting area.

Onsite Assessment

All possible correlation coefficients (r) (SAS 1989) were calculated between dependent variables (maximum distance to a single plant, fringe of recruitment, percent Immigrant composition at the fringe, percent Immigrant

composition inside original seeding) and independent environmental variables as determined by site visits or from the questionnaires and published literature.

Stepwise multiple regression procedures (SAS 1989) were performed on independent variables to identify the best multiple regression model for the dependent variables. Independent variables that failed to maintain significance were eliminated. Multiple regression was repeated using the MAXR option of SAS (1989) to determine the maximum R^2 obtainable using the independent variables estimated. The resulting R^2 from these multiple regression models is indicative of the proportion of total variation in forage kochia spread and composition explained by the independent variables. It is possible that interactions between independent factors may have significantly increased the predictive power of the regression models, but because of degree-of-freedom limitations and complexity of interpretation, we did not test interactions. Planting-method variables were not included in the stepwise regression procedures because of the limited number of sites for which that information was known.

Results

Adaptation and Stand Composition Within Original Seeding

Percent composition of Immigrant within original seedings ranged from 2 to 91 percent with an average of 50 percent and median of 53 percent. Factors favorably associated with higher Immigrant composition included seeding date, medium textured soils, Immigrant planted with no other species, prepared or disturbed seedbed, successful initial establishment, and predominantly annual competition (table 1). Stepwise regression analysis resulted in an R^2 of 44 percent (table 1). Including all independent variables in the regression model resulted in a maximum R^2 of 58 percent. Unexplained variation may be due to factors not determined such as quality of seed, seeding rate and date, or interactions among environmental variables.

Fringe of Recruitment

Fringe distance, or marginal or peripheral recruitment threshold, ranged from 0 to 100 ft. The mean and median were both 20 ft. These small values for the mean and median strongly suggest that in most environments, Immigrant is not an aggressive competitor with native or established vegetation. The best regression model, consisting of medium soil texture, elevation, and date of seeding, only explained 22 percent of variation in recruitment fringe distance (table 1). Even though date of planting was included in the multiple regression model, the plot of planting date versus fringe suggests a very weak association between the two (fig. 1). The maximum R^2 achievable using all estimated variables still only explained 48 percent of the variation. Unexplained variation may be due to factors that were not determined such as variations in annual precipitation during the life of the seeding.

Table 1—Correlation coefficients and associated P-value, P-value from stepwise multiple regression, and R² for multiple regression model for ecosite variables associated (P ≤0.10) with percent forage kochia composition within seeding and fringe of forage recruitment outside of planting (58 sites included in analysis).

Variable	r	P-value (individual)	P-value (mult. reg.)
Forage kochia percent within seeding			
Monoculture seeding	0.43	0.001	0.001
Disturbed seedbed	0.41	0.001	0.020
Perennial competition	-0.42	0.002	.
Medium textured soils	0.29	0.026	.
Annual competition	0.29	0.034	.
Coarse textured soils	-0.27	0.038	.
Elevation	-0.25	0.057	0.018
Fire before planting	-0.28	0.058	.
Seeding date	0.24	0.065	.
Precipitation	-0.24	0.068	.
Successful establishment	0.23	0.077	.
Pinyon-juniper ecosystem	-0.23	0.087	.
Basin big sagebrush ecosystem	-0.23	0.087	0.010
			R ² = 44 percent
Fringe of forage kochia recruitment			
Medium textured soils	0.30	0.021	0.018
Salt desert shrub ecosystem	0.24	0.067	.
Elevation	-0.22	0.090	0.4
Fire before planting	-0.22	0.098	.
Pinyon-juniper ecosystem	-0.21	0.100	.
Age of planting	.	.	0.063
			R ² = 22 percent

Maximum Distance From Seeding to a Single Plant

Reconnaissance surveys of the perimeters surrounding 62 Immigrant plantings found individual plants at 0 to 1,265 ft from the seeding boundary. The mean and median distances were 93 ft and 50 ft, respectively. These numbers indicate that although individual plants were found at a considerable distance from the boundary at a few sites, the furthest single immigrant plant at half the sites was 50 feet or less from the original planting. The best multiple regression model only explained 6 percent of the variation among sites, further indicating the evaluated environmental variables could not be used to predict this measure of spread. No ecosite variables were significantly correlated with maximum distance to single forage kochia plants.

Immigrant Forage Kochia Composition at Recruitment Fringe

On average Immigrant comprised only 6 percent of the vegetation at the defined recruitment fringe (range was 0 to 26 percent). The median value for immigrant composition at the fringe was 4 percent. The most significant correlation found was with age of planting.

From the low R² values for these measures of recruitment it is obvious that unknown factors are important in determining the extent of forage kochia recruitment. Our observations suggest that the extent of severe soil disturbance around the planting may have a large impact on the recruitment.

Discussion and Summary

The complete report of this study can be found at (Harrison and others 2000). Our findings are in agreement with and generally confirm reports in literature. Immigrant will naturally recruit, like the majority of plants, mainly in disturbed soil or in areas lacking vegetation, especially perennial vegetation, both within and outside its seeding area. The major elements that influence the distance and amount a species will spread are its ecological adaptation, amount of soil disturbance, and plant competition from both annuals and perennials. Immigrant kochia has a broad diverse adaptability and therefore propagates itself in several western rangeland plant communities.

Sites with high annual precipitation supported less kochia spread than those with lower annual precipitation. High precipitation zones may have more closed plant communities and less open spaces for kochia establishment than lower rainfall areas. Immigrant establishes well in course, medium, and fine textured soils including sandy, gravely, stony, clay, silt, and loam soils.

Long-term research is needed to determine Immigrant's competitive interaction with perennials in the Wyoming big sagebrush, desert shrub (black sagebrush and shadescale), and salt desert shrub sites. Our observations suggest that over time native perennials, such as shadscale, winterfat, Wyoming big sagebrush, thickspike wheatgrass and western wheatgrass [*Pascopyrum Smithii*] may reestablish themselves in stands of Immigrant forage kochia. In many instances, resource managers are currently faced with the persistence of alien annuals such as cheatgrass and

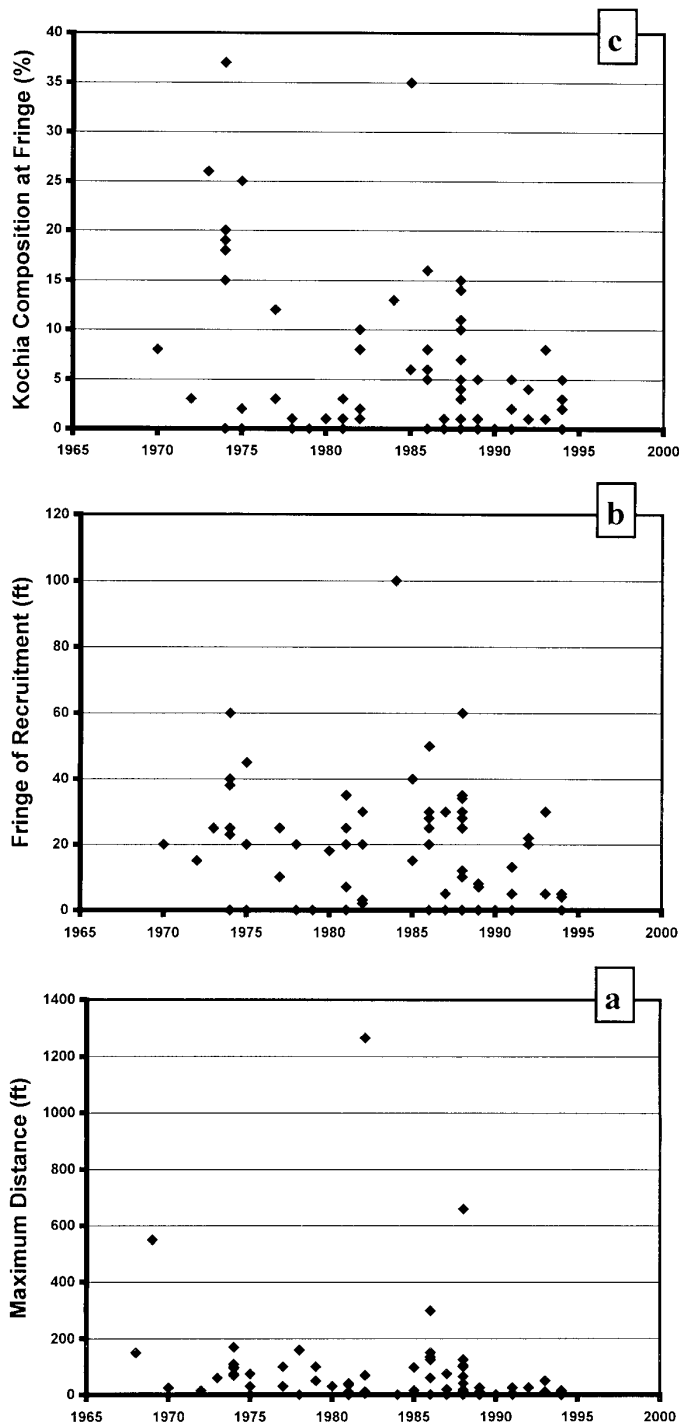


Figure 1—Date of forage kochia planting plotted against (a) maximum distance to a single kochia plant outside the planting boundary, (b) the fringe (threshold) of spread outside the planting boundary, and (c) the percent composition of forage kochia at the fringe. These graphs show that date of planting is not associated with distance of forage kochia spread.

medusahead rye that result in increased frequency of wild-fires and degradation of the resource base through soil erosion. The establishment of Immigrant forage kochia helps protect these environmental resources and allows native perennial communities to become re-established. On many evaluated sites, biodiversity has been improved by the presence of Immigrant. Clearly, Immigrant can be established in a wide range of areas and environmental conditions. It successfully competes with annuals, such as cheatgrass, halogeton, Medusahead rye, and tumble mustard (*Sisymbrium altissimum*). Although Immigrant may spread into disturbed and bare areas, especially on sites with minimal productivity, low elevation, low precipitation, and saline/alkaline soils, including playas and slick spots, we found little evidence that Immigrant is an aggressive spreader in established perennial plant communities.

Our conclusions from evaluations in Kazakhstan and discussions with Russian and Kazakhstan scientists concerning the spread of forage kochia into native perennial plant communities are in full agreement with our assessments of its adaptation and aggressiveness in the U.S.A. Depending on the site and associated species, native perennial plant communities in Kazakhstan contained from 1 to 20 percent forage kochia. However, in disturbed areas along roadways, abandoned fields, and farmsteads, forage kochia made up from 15 to 60 percent of the plant community. Forage kochia was never observed to be the dominant species in the major plant communities comprised of sagebrush, saltbush, winterfat, crested and siberian wheat-grasses, and needlegrass. Nowhere did we observe sites where forage kochia had invaded from disturbed sites into adjacent perennial plant communities on the Kazakhstan steppes.

References

- Balyan, G. A. 1972. Prostrate summer cypress and its culture in Kirghizia. *Isdatel'stvo, Frunze, Kirghizistan*. (Translated from Russian, 1979). National Technical Information Service TT77-59026.
- Bake, E. 1997. Bobs Flat wildlife enhancement project. Reno, NV: Nevada Division of Wildlife, Habitat Bureau, Mining and Wildlife.
- Blauer, A. C.; McArthur, E. D.; Stevens, R.; Nelson, S. D. 1993. Evaluation of roadside stabilization and beautification plantings in south-central Utah. Res. Pap. INT-462. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 65 p.
- Clements, C. K.; Gray, K. J.; Young, J. A. 1997. Forage kochia: to seed or not to seed. *Rangelands*. 19(4): 29–31.
- Francois, L. E., 1976. Salt tolerance of prostrate summer cypress (*Kochia prostrata*). *Agronomy Journal*. 68: 455–456.
- Frishchkecht, N. C.; Ferguson, R. B. 1984. Performance of Chenopodiaceae species on processed oil shale. In: Tiedemann, A. R.; McArthur, E. D.; Stutz, H. C.; Stevens, R.; Johnson, K. L., comps. Proceedings—symposium on the biology of Atriplex and related chenopods; 1983 May 2–6; Provo, UT. Gen Tech. Rep. INT-172. Ogden UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 293–297.
- Gade, A. E.; Provenza, F. D. 1986. Nutrition of sheep grazing crested wheatgrass versus crested wheatgrass-shrub pastures during winter. *Journal of Range Management*. 39(6): 527–530.
- Gutknecht, K. 1996. Forage kochia thrives—and is well-behaved (Online). Available at http://ext.usu.edu/agx/Utah_percent_20Sci/USSpr96NET/kochia.html (verified 23 Jan. 1998)

- Harrison, R. D.; Chatterton, N. J.; Page, R. J.; McCurto, M.; Asay, K. H.; Jensen, K. B.; Horton, W. H. 1996. Competition, biodiversity, invasion, and wildlife usage of selected introduced grasses in the Columbia and Great Basin. Res. Rep. 155. Logan, UT: Utah State University, Agriculture Experiment Station. 84 p.
- Harrison, R. D.; Chatterton, N. J.; Waldron, B. L.; Davenport, B. W.; Palazzo, A. J.; Horton, W. H.; Asay, K. H. 2000. Forage kochia—its compatibility and potential aggressiveness on Intermountain rangelands. Res. Rep. 162. Logan, UT: Utah State University, Utah Agricultural Experiment Station. 66 p. Available on-line: <http://agx.usu.edu/agx/ResearchReports/KOCHIA/kochia.html> (verified 20 Oct. 2000).
- Herbel, C. H.; Barnes, R. R.; Heady, H. F.; Purdy, L. N. 1981. Range research in the Soviet Union. Rangelands. 3: 61–63.
- Howard, G. S.; Rauzi, F.; Schuman, G. E. 1976. Woody plant trials at six mine reclamation sites in Wyoming and Colorado. EPA-IAG-DS-E763. Environmental Protection Agency, Science and Education Administration, Federal Research Interagency Agreement.
- Jorgensen, K. R.; Davis, J. N. 1984. A technique for retaining seed viability in *Kochia prostrata* seed. In: Tiedemann, A. R.; McArthur, E. D.; Stutz, H. C.; Stevens, R.; Johnson, K. L., comps. Proceedings—symposium on the biology of Atriplex and related chenopods; 1983 May 2–6; Provo, UT. Gen Tech. Rep. INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 166–167.
- Kashkarov, A. A.; Balyan, G. A. 1989. Raising productivity of pastures in the rocky deserts of Kirghizia. Problems of Desert Development. (4): 100–104. (English translation edition of Problemy osvoeniya Pustyn'. U.S. Department of Agriculture and National Science Foundation, Washington, DC).
- Keller, W.; Bleak, A. T. 1974. *Kochia prostrata*: a shrub for western ranges? Utah Science. 35: 24–25.
- Krylova, N. P. 1988. Foreign experience in introducing *Kochia prostrata*. Problems of Desert Development. (6): 11–18. (English translation edition of Problemy Osvoeniya Pustyn'. U.S. Department of Agriculture and National Science Foundation, Washington, DC).
- Larin, I. V. 1956. Pasture economy and meadow cultivation. Translated to English, 1962, and published by Israel Program for Scientific Translation, Jerusalem: 168–170.
- McArthur, E. D.; Blauer, A. C.; Stevens, R. 1990. Forage kochia competition with cheatgrass in central Utah. In: McArthur, E. D.; Romney, E. M.; Smith, S. D.; Tueller, P. T.; comps. Proceedings—symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5–7; Las Vegas, NV. Gen Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 56–65.
- McArthur, E. D.; Guinta, B. C.; Plummer, A. P. 1974. Shrubs for restoration of depleted ranges and disturbed areas. Utah Science. 35: 28–33.
- McFarland, M. L.; Veckent, D. N.; Hartmann, S.; Hans, F. M. 1990. Transplant shrubs for revegetation of salt-affected soils. Landscape and Urban Planning. 19: 377–381.
- McKell, C. M. 1986. Propagation and establishment of plants on arid saline land. Reclamation Revegetation Research. 5: 363–375.
- Monsen, S. B. 1994. Selection of plants for fire suppression on semiarid sites. In: Monsen, S. B.; Kitchen, S. G., comps. Proceedings—Ecology and management of annual rangelands; 1992 May 18–21; Boise, ID. Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 363–373.
- Monsen, S. B.; Turnipseed, D. 1990. Seeding forage kochia onto cheatgrass-infested rangelands. In: McArthur, E. D.; Romney, E. M.; Smith, S. D.; Tueller, P. T.; comps. Proceedings—symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5–7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 66–71.
- Nemati, N. 1986. Pasture improvement and management in arid zones of Iran. Journal of Arid Environments. 11: 27–35.
- Otsyina, R.; McKell, C. M.; Malenchek, J.; Van Epps, G. 1983. Potential of Atriplex and other chenopods for increasing range productivity for fall-winter grazing use. In: Tiedemann, A. R.; McArthur, E. D.; Stutz, H. C.; Stevens, R.; Johnson, K. L., comps. Proceedings—symposium on the biology of Atriplex and related chenopods; 1983 May 2–6, Provo, UT. Gen Tech. Rep. INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 215–219.
- Pellant, M. 1990. The cheatgrass-wildfire cycle—are there any solutions? In: McArthur, E. D.; Romney, E. M.; Smith, S. D.; Tueller, P. T.; comps. Proceedings—symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5–7; Las Vegas, NV. Gen Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 11–18.
- Pendleton, R. L.; Frischknecht, N. C.; McArthur, E. D. 1992. Long-term survival of 20 selected plant accessions in a Rush Valley, Utah, planting. Res. Note INT-403. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 7 p.
- Plummer, A. P. 1970. Plants for revegetation of roadcuts and other disturbed or eroded areas. Range Improvement Notes. 15(1). Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region: 1–8.
- Plummer, A. P.; Christensen, D. R.; Stevens, R.; Jorgensen, K. R. 1970. Highlights, results, and accomplishments of home range restoration studies. Publ. 70-3. Salt Lake City, UT: Utah State Division of Fish and Game.
- Plummer, A. P. 1974. Oldman wormwood to stabilize disturbed areas. Utah Science. 35: 28–33.
- Pope, C. L.; McArthur, E. D. 1977. IOPB chromosome number report, Chenopodiaceae. Taxon. 26: 109.
- Prianshnikov, S. 1976. Improvement and national utilization of semidesert and desert pastures of Kazakh, U.S.S.R—the introduction of wild-growing fodder plants. Almaata, U.S.S.R.
- Prikhod'ko, N. D.; Prikhod'ko, S. Y. A. 1977. Introduction of *Kochia prostrata* into pasture in the Kopet-Dug Foothills. Proble Osvo Pastyn. 3: 67–70.
- Rasmussen, V. P.; Horton, W. H.; Page, R. J.; Newhall, R. L. 1992. Summary of BLM rangeland (desert-ecosystem) plantings 1987–1990. Unpublished report on file at: Cooperative Extension Service, Utah State University, Logan, UT.
- Rakhimova, T. 1991. Systematic investigations into adaptation of plants to xerothermic conditions of arid zones. Soviet Journal of Ecology. 22: 166–171.
- Romo, J. T.; Haferkamp, M. R. 1987. Forage kochia germination response to temperature, water stress and specific ions. Agronomy Journal. 79: 27–30.
- Stevens, R.; Jorgensen, K. R.; McArthur, E. D.; Davis, J. N. 1985. “Immigrant” forage kochia. Rangelands. 7: 22–23.
- Stevens, R.; Jorgensen, K. R.; McArthur, E. D.; Monson, S. B.; Davis, J. N.; George, J. R. 1984. Naming and release of Immigrant forage kochia for commercial production and marketing of seed. Wildlife Restoration Project, W-82-R. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, U.S. Department of Agriculture, NRCS, and Utah State Division of Wildlife Resources.
- Stevens, R.; Jorgensen, K. R.; Young, S. A.; Monsen, S. B. 1996. Forb and shrub seed production guide for Utah. AG 501. Logan, UT: Utah State University Extension Service. 51 p.
- Stevens, R.; McArthur, E. D. 1990. “Immigrant” forage kochia competition with halogeton following various seeding techniques. In: McArthur, E. D.; Romney, E. M.; Smith, S. D.; Tueller, P. T., comps. Proceedings—symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5–7; Las Vegas, NV. Gen Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 175–180.
- Van Epps, G. A.; McKell, C. M. 1983. Effect of weedy annuals on the survival and growth of transplants under arid conditions. Journal of Range Management. 36: 266–369.
- Waller, S. S.; Schmidt, K. K.; Stubbendieck, J. L.; Button, C. M.; Sneva, F. A. 1979. Effect of harvest data and drying procedures on germination of *Kochia prostrata* (L.) Schrad. In: 1979 Progress Report, Research in Rangeland Management. Oregon Special Report 549. Corvallis, OR: Oregon State University Agricultural Experiment Station: 8–10.