Forage Kochia

Its Compatibility and Potential Aggressiveness on Intermountain Rangelands

R.D. Harrison, N.J. Chatterton, B.L. Waldron, B.W. Davenport, A.J. Palazzo, W.H. Horton, and K.H. Asay

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The authors:

Harrison, Ronald Deane
Range Scientist, Utah State University, Logan UT, formerly State Resource Conservationist, USDA Natural Resource Conservation Service. 435-797-3066

Chatterton, N. Jerry
Research Leader, Plant Physiologist, USDA, Agricultural Research Service, Forage and Range Research, Logan, UT. 435-797-2249; E-mail njchatt@cc.usu.edu

Waldron, Blair L.
Plant Geneticist, USDA, Agricultural Research Service, Forage and Range Research, Logan, UT. 435-797-3073; E-mail blw@cc.usu.edu

Davenport, Burke W.
Rangeland Scientist, USDA, Agricultural Research Service, Forage and Range Research, Logan, UT. 435-797-3066; E-mail bdaven@cc.usu.edu

Palazzo, Anthony J.
Agronomist, U.S. Department of Defense, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH.
603-646-4374; E-mail apalazzo@cr102.crrel.usacc.army.mil

Horton, W. Howard
Rangeland Scientist, USDA, Agricultural Research Service, Forage and Range Research, Logan, UT. 435-797-3079; E-mail hhorton@cc.usu.edu

Asay, Kay H.
Plant Geneticist, USDA, Agricultural Research Service, Forage and Range Research, Logan, UT. 435-797-3069; E-mail khasay@cc.usu.edu

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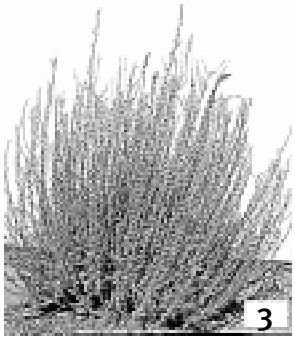
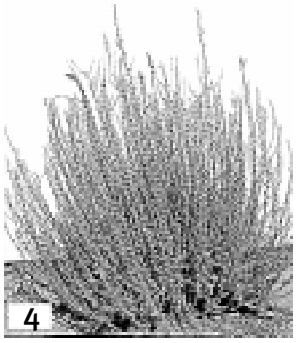




INTRODUCTION AND PURPOSE OF STUDY

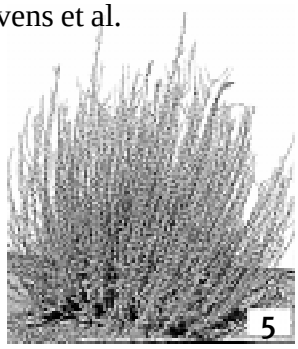
'Immigrant' forage kochia [*Kochia prostrata* ssp. *virescens*][1], a shrub, has been seeded on approximately 150,000 acres of rangeland in 10 western states. Forage kochia was transferred to the genus Bassia as *Bassia prostrata* (L.) (A. J. Scott 1978, USDA-ARS 1999). We opted to use *K. prostrata*. Many scientists and rangeland managers consider forage kochia a prime candidate for use in western range rehabilitation and fire prevention. However, some people are concerned that it will 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. Although some uncertainty is always associated with the introduction of new plants, only a few of the thousands of the purposefully introduced plants have become major problems (Williams, l980). This investigation was undertaken to examine Immigrant forage kochia's competitive ability, invasiveness and its potential effects on the biodiversity of native and introduced plant communities on semiarid rangelands.

During October 1999, two of the authors (Waldron, Harrison) participated in a forage kochia germplasm collection trip to Kazakhstan. They evaluated forage kochia's compatibility and aggressiveness in its native environment. See Discussion (p. 19) and Appendix E (p. 56).

Origin and History, Seed Physiology, Toxicity and Adaptation

Immigrant was released in the United States in 1984 (Stevens et al. 1984). Immigrant is native to the arid and semiarid regions of Central Eurasia (Larin 1956[2]; Keller and Bleak 1974; Plummer 1977[2]). The parental accession (PI 314929) of Immigrant, along with other accessions, was acquired on a trip to Russia by Wesley Keller and Perry Plummer in a search for plants to suppress halogeton [*Halogeton glomeratus*] on droughty and saline sites (J.A. Young 1999, USDA-ARS, Reno, NV, personal communication). Forage kochia seeds were obtained from the Perkalshy Arboretum, Stavropol, Russia, on 19 May 1966 and donated to the USDA-ARS Western Regional Plant Introduction Station, Pullman, WA. *K. prostrata* is a polyploid complex with diploid, tetraploid, and hexaploid forms. Immigrant, the only North American cultivar of the subsp. *virescens* (green-stem forage kochia) is a diploid with a chromosome number of 2n=18 (Pope and McArthur 1977; Herbel et al. 1981, McArthur et al. 1996). It was released for use as forage and soil erosion control on semi-desert and desert rangelands of the Intermountain West. During initial evaluations PI314929 outperformed other forage kochia accessions in longevity, forage production, palatability, nutritional quality, and competitiveness with annuals (Stevens et al. 1984; 1985).

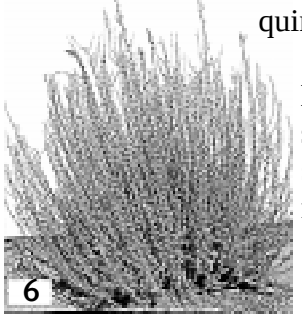
The first known Immigrant (PI 314929) planting in the US was made in l968. Keller and Bleak (1974) established PI 314929, along with a morphologically different accession (PI 358941), as seedlings in small plots in the foothills east of Logan, UT. The second planting of accession PI 314929 occurred in 1969 at the Great Basin Experiment



Station, Ephraim, UT (R. Stevens (retired) 1999, Utah Department of Wildlife Resources, personal communication). Several other plantings followed in the 1970's on mine spoils and disturbed roadsides in several western states (Plummer l977; Aldon and Pase 1981[2]; Stevens et al. 1981; Frischknecht and Ferguson 1984[2]; Ferguson and Frischknecht l985[2]; Pendelton et al. 1992; Blauer et al. 1993). After 16 years of testing by the USDA Forest Service (FS) Shrub Science Laboratory and the Utah Division of Wildlife Resources on sites in AZ, ID, NV, OR, and UT Immigrant was jointly released in March l984 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. In this publication we refer to the early plantings of PI 314929 as Immigrant although "Immigrant" was not released until later.

Forage kochia is a long-lived, semi-evergreen half shrub that averages 1 to 3 ft high at maturity. Individual plants may live 10-15 years (Balyan 1972[2]). It develops an extensive fibrous root system with a tap root that may extend to a depth of 16 ft (Prianshnikov 1976[2]). It does not tolerate flooding or soil with a water table (Balyan 1972). Most of the above ground annual biomass grows as stems from a low woody base (Romo and Haferkamp 1988). Total evapo-transpiration surface is often reduced by partial loss of leaves in the summer months (Rakhimova 1991[2]). In most environments the lower 1/3 of the plant maintains green leaves throughout the year while the seed stalk and the upper stems turn reddish brown and dry up after seed shatter (Stevens et al. 1984). In a study of forage kochia's salt tolerance, Francois (1976) found the yield of Immigrant was not reduced when grown in a soil salinity of 17.0 mmho/cm. In comparison, alfalfa yield is reduced to 50% at 12 mmoh/cm. Forage kochia tissue concentrations of Na and Cl may reach 50 to 85 meq/100 grams of dry matter, without showing any signs of injury.

Although the mode of reproduction in forage kochia has not been thoroughly studied, Balyan (1972) indicated that it is wind pollinated. Under favorable conditions it bears fruit during the establishment year (Plummer et al.1970[2]; Waller et al.1979; Stevens et al. 1984). Forage kochia is a prolific seed producer and full seed production generally occurs when plants are about three years old. Seeds ripen unevenly, even on the same raceme. The range in maturity of individual seeds may be up to 30 days (Balyan 1972). They ripen in late October and November (Prikhod'ko and Prikhod'ko 1977[2]); however, freezing temperatures hasten seed ripening. Forage kochia seeds (utricles) have 5 small wings and a diameter of approximately 2 mm. There are approximately 115,000 pure live seeds per lb (Stevens et al. 1996). Forage kochia seed germinates 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% or less moisture and stored at 36 to 50º F (2.2 to 10ºC) (Jorgensen & Davis 1984; S.G. Kitchen 1998, USDA-FS, Provo, UT, personal communication). Seeds planted in late fall may sprout without embedding. They normally germinate by late February and early March and may continue for 30 to 40 days (Balyan 1972). Some researchers (Baylan 1972, Stevens and Van Epps 1984, Waller et al.1983) have indicated that 4 to 6 months of cold temperatures are required to break seed dormancy.

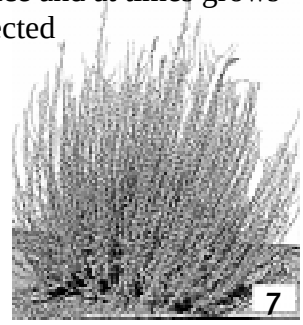


Haferkamp et al. (1990) reported that germination of Immigrant seeds was enhanced by imbibing seeds in a cold moist environment suboptimal for germination. Imbibed utricles germinated at a more rapid rate than freshly planted seed when temperatures were raised.

Some researchers have promoted forage kochia as a year-round grazing forage plant (Balyan 1972; Britton and Sneva 1977; Davis and Welch 1985; Utah State University 1994) that survives and, in fact, benefits from persistent grazing up to nearly 70-80% utilization (Balyan 1972, Herbel et al. 1981). Grazing in the spring is more detrimental than at other times. It should not be grazed to a stubble height of less than 2 in because heavy use reduces regrowth the following year (Keller and Bleak 1974; Stevens et al. 1984; M.R. Haferkamp 1998, USDA-ARS, Miles City, MT, personal communication). Immigrant has been used to improve the nutrient quality of range seedings (Otsyina et al. 1984) and may provide a valuable source of protein and carotene for grazing animals in seasons when grasses are dry and dormant. The protein content is relatively high, ranging from 9% in March to14% in August (Davis 1979). It presents no tannin or oxalate poisoning problems (Davis 1979). Plummer et al. (1970) and Krylova (1988) reported an average dry matter production of 1600 lbs/ac in hayfield-rangeland use. Although it tends to dampen the spread of wildfires, Immigrant will burn when surrounded by sufficient fuel, such as cheatgrass (*Bromus tectorum*). However, unlike many other shrubs including basin and Wyoming big sagebrush (*Artemisia tridentata),* it sprouts and regrows after burning (McArthur et al. 1990; Pellant 1990).

Immigrant has high ecological plasticity (Young et al. 1981; Krylova 1988) and is adapted to a variety of environmental conditions in the western United States. It has been successfully planted and continues to grow in numerous plant communities including gambel oak (*Quercus gambelii*), pinyon-juniper (*Pinus-Juniperus*), basin big sagebrush (*A.tridentata* subsp. *tridentata*), WY big sagebrush (*A.tridentata* subsp. *wyomingensis*), and salt desert shrub (*Atriplex-Scarcobatus species*) (McArthur et al. 1974 and 1990; Stevens et al. 1985; Romo and Haferkamp 1987). Immigrant does not survive in the Sonoran and southern portions of the Mojave Deserts but is vigorous in areas of the Mojave Desert that support *Artemisia* species (B. Munda 1998, NRCS, Tucson, AZ, personal communication; T. Simper 1998, NRCS, Cedar City, UT, personal communication).

Immigrant is well adapted to and has been successfully established on a wide range of soils including fine-to-coarse textured, shallow-to-deep, gravelly-to-stony and saline-to-alkaline. Some researchers indicate, however, that it grows best on heavy-textured soils (Balyan 1972; Francois 1976; Herbel et al.,1981; Stevens et al. 1984; USDA Soil Conservation Service 1984). Populations differ in preference or adaptation to ecological sites (E.D. McArthur 1999, USDA-FS, Provo, UT, personal communication). Immigrant grows well in basic soils but is not well adapted to neutral and acidic soils (Stevens et al.,1984). It is drought-hardy and capable of growing in areas with an annual precipitation of 5 to 27 in but appears to be best adapted to areas receiving 8 to 14 in (Frischknecht and Ferguson 1984; Stevens et al. 1985). Immigrant is cold-tolerant and persists in environments where temperatures range from -25 to 104º F (-32 to 40ºC) which includes USDA plant hardiness zones 4a-11. Seeds will germinate and survive in temperatures ranging from 50 to 86º F (10 to 30º C) (Young et al. 1981). Immigrant has moderate shade tolerance and at times grows as an understory to trees and taller shrubs. It does not appear to be affected by insect pests (Balyan 1972), but might be a host for lygus bugs (*Lygus desertinus*). Moore et al.(1982) noted that Lygus bugs were absent or in very low numbers in areas where Immigrant kochia was intermixed with other species. Immigrant can be controlled with 2,4-D herbicide (2,4-dichlorophenoxe acetic acid) (D.C. Ganskopp 1999, USDA-ARS, Burns, OR, personal communication).



Uses

Immigrant has been seeded to improve plant community diversity, esthetics, plant cover, species richness, forage for domestic livestock and wildlife, fire prevention, and soil stability. Specific examples of its use are listed below.

Renovation

1) Prevention of soil erosion, flooding, and for critical area stabilization including blow out areas (Stevens et al. 1984; Rasmussen et al. 1992; Horton, unpublished data,1998).
2) Ground cover on disturbed areas (Nemati 1986; Blauer et al.,1993).
3) Reclamation of disturbed mine sites (Howard et al. 1979[2]; Frischknecht and Ferguson 1984; Clements et al. 1997; Schuman 1999 ARS, Cheyenne, WY[2])
4) Stabilization of sand dunes (Krylova 1988),
5) Greenstrips that reduce wildfire size and/or spread (Pellant 1990; Monsen 1994; Clements et al. 1997),
6) Vegetative cover on saline and droughty areas (Larin 1956; Francois, l976; Blauer et al. 1976; McKell 1986; McFarland et al. 1990).

Forage and Habitat

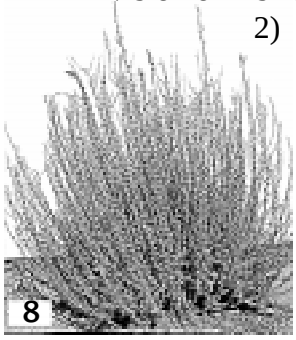
1) Forage for livestock and wildlife during normal and critical periods of forage deficiencies (Otsyina et al., l984; Gade and Provenza 1986; Kashkarov and Balyan 1989[3]; Bake 1997).
2) Food and cover for upland game birds, small mammals, reptiles, and insects (Stevens et al. 1985).
3) Increased fall and winter forage quality on sites dominated by perennial grasses (Stevens and McArthur 1990, Blauer et al. 1993).

Biodiversity

1) Beautification and stabilization of roadsides (Plummer 1970; Blauer et al. 1993).
2) Cover for inter-spaces among established perennial plants (Stevens and Van Epps 1984; Stevens et al. 1984; Clements et al. 1997).
3) Increased species richness and biodiversity and assist in the re-establishment of desired perennials (Blauer et al. 1993; Gutknecht 1996; Clements et al. 1997).

Others

1) Suppression or elimination of invasion of alien annual weeds like cheatgrass, halogeton, Russian thistle [*Salsola iberica*], and medusahead rye [*Taeniatherum caput-medusae*],(Van Epps and McKell 1983; McArthur et al. l990; Stevens and McArthur 1990; Monsen and Turnipseed 1990; Monsen 1994; Gutknecht 1996; Simper 1997, NRCS, Cedar, UT, personal communication; M. Turnipseed 1998, Division of Fish and Game, Caldwell, ID, personal communication).
2) Extract salts (sodium and chloride) from saline soils, (Larin 1956; Francois 1976, and McFarland et al. 1990).



Competition, Invasiveness, and Biodiversity

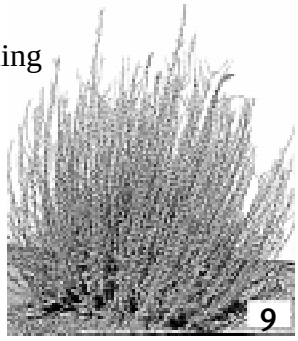
The competitive ability of a plant is a function of its genetics and tolerance to environmental conditions. Important considerations are geomorphology, slope, aspect, soil type, climate, salinity, human impacts, seed sources, and existing or competing vegetation. Together they determine the success a plant will have on a given site. 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 et al. 1996).

Immigrant 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 et al. 1985; Romo and Haferkamp 1987). The competitive advantage of Immigrant over annuals like cheatgrass, medusahead rye and halogeton is well documented (McArthur et al. 1990; Monsen and Turnipseed 1990; Stevens and McArthur 1990; K. Gray 1999, Nevada Division of Wildlife. Elko, NV, personal communication).

In its natural range in south central Eurasia forage kochia is commonly associated with grasses and *Artemisia* species and contributes significantly to plant biodiversity. It generally does not grow in pure stands in its native habitats in Eurasia (Plummer 1970; McArthur et al. 1974). In the US, Immigrant is best adapted within its ecological range where there is little competition from established perennial species. The Bureau of Land Management in Idaho has conducted numerous studies on the spread of Immigrant in several 1986 greenstrip seedings. They found that Immigrant has spread a few yards into disturbed areas beyond the original seeded boundaries in southwestern Idaho (M. Pellant 1998, BLM, Boise, ID, personal communication).

In 1990, Blauer et al. (1993) studied 12 test seedings of Immigrant that were planted in the mid l970's. The study sites had annual precipitation of 8 to 20 in. Slopes ranged from 0 to 64% at elevations of 5150 to 7320 ft. The soils were mainly mollisols with inclusions of aridisols and entisols. They concluded that Immigrant grows well in association with a variety of species, both native and introduced, annual and perennial, and herbaceous and woody. They noted that Immigrant was self-sustaining with new seedlings establishing on all sites. Immigrant competed well with species such as cheatgrass and halogeton that often provide severe competition to perennial species in disturbed areas. Established Immigrant plants were found 328 ft from the original seeded sites in natural and seeded pasture plant communities and on severely disturbed sites (Blauer et al. 1993). However, several researchers (Blauer et al. 1993, Stevens et al. 1985; Pendleton et al. 1992; Clements et al. 1997; Gray 1998, personal communication; Haferkamp 1998, personal communication), have concluded from studies in big sagebrush and desert shrub communities that Immigrant is not highly invasive and does not spread aggressively into healthy plant communities.

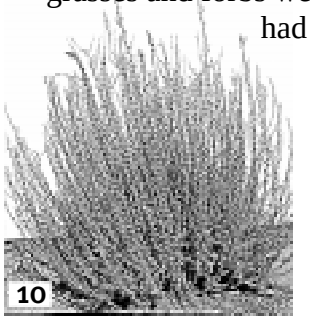
Immigrant recruitment is often found to be in the direction of prevailing winds but other factors are equally important. Although it becomes established in the interspaces of native plant communities, Immigrant does not reduce the density of established perennials and its encroachment is controlled in established plant communities (Stevens



and Van Epps.1984; Stevens et al. 1985). Frischknecht and Ferguson (1984) found forage kochia reduced the spread of weedy species on processed oil shale areas better than other chenopods. Clements et al. (1997), (C.D. Clements 1999, USDA-ARS, Reno, NV, personal communication) states, "In the sagebrush/bunch grass region of the Great Basin, forage kochia does not appear to be invasive." They found little to no spreading 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 et al. (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* and *Agropyron desertorum*], cheatgrass, and medusahead rye. A. DeBolt (1998, USDI BLM, Boise, ID, personal communication) indicated that pepperplant (*Lepidium davisii* and *L. papillienum*) species may suffer due to Immigrant's tendency to colonize saline and alkaline playas.

In the U.S., Immigrant has been recommended for seeding in a mixture with crested wheatgrass (McArthur et al. 1974; Monsen et al. 1990). Crested wheatgrass had increased production and vigor when grown with Immigrant at the Utah Agricultural Experiment Station near Nephi, UT (Otsyina et al. 1984). Provenza and Richards (1984) and Stevens (1992) reported Immigrant seedlings do not compete well with established crested wheatgrass plants. S.B. Monsen 1998 (USDA FS, Provo, UT, personal communication) and Haferkamp (1998, personal communication) reported that Immigrant does not readily reproduce in ungrazed stands of crested wheatgrass and Immigrant at Malta, ID, and Burns, OR, respectively. However, it persisted well in grazed stands of crested wheatgrass and Immigrant in both areas. At non-grazed nurseries established in 1970 at the Northern Great Basin Experimental Range Burns, OR, Immigrant is maintaining its presence through the establishment of young plants, although many older plants have died. Blauer et al. (1993) noted that in higher precipitation zones, Immigrant does not compete well in a closed herbaceous plant community. Stevens et al. (1985) reported that Immigrant competes with annuals by reducing plant density, foliage and seed production. Monsen (1998, personal communication) observed that Immigrant competes with itself in dense stands as evidenced by the death of numerous new seedlings that cover most of the open spaces between mature plants early in the season. Young seedlings of annuals such as cheatgrass die from Immigrant competition. Immigrant uses the available soil moisture before the annuals can become established.

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



MATERIALS AND METHODS

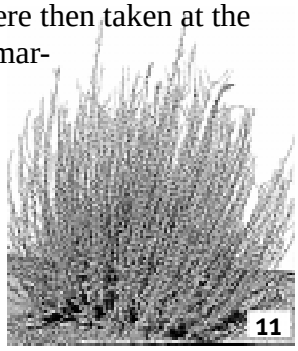
This study was designed to determine the planting success, biodiversity, spread and competitiveness of Immigrant on semiarid western rangelands. We assessed these responses of Immigrant under varied rangeland conditions in the Intermountain West using two approaches:

1) Questionnaires were sent 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 (Appendix A). Over 175 questionnaires were returned of which 151 identified forage kochia plantings. Information from the questionnaires and published reports was used to determine which plantings should be visited for on-site evaluation.

2) Site visits were made to representative seedings and/or transplantings of forage kochia throughout the west that were old enough to give some indication of long term responses.

On-site assessments were made, where possible, on all known Immigrant plantings that were unique or that were 10 years or older. More than 90 planting sites were visited and findings from 81 sites are presented in Table 1. Many of the selected sites were identified by personnel of the U.S. Forest Service; State Wildlife Resource Agencies in ID, NV, and UT; Bureau of Land Management in ID, NV, and UT; Natural Resource Conservation Service (NRCS) in ID and UT; and Agriculture Research Service in ID, MT, OR, UT and WY. Appendix B lists the forage kochia sites identified in the questionnaires and those where on-site evaluations were made.

Because of the large number of field sites, the line-intercept method (figure 2) was used to evaluate Immigrant spread and percent composition. Daubenmire (1959) states “that line interception is excellent for low shrubs” and is an efficient method that requires a minimum amount of field time. Transects were randomly located in plantings and a 100-foot tape 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 Immigrant into areas adjacent to the original planting and the maximum distance from the seeding’s edge that a single Immigrant plant had become established. These maximum distances were recorded. 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, random transects were then taken at the visually observed fringe. The fringe distance is defined as the visual marginal or peripheral threshold of Immigrant encroachment from the original seeded boundary. If no spread was observed, the fringe distance was recorded as zero. It should be noted that 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. Spreading data were not taken when seeding boundaries were unknown (Table 1).

Plant nomenclature generally follows "A Utah Flora" (Welsh et al.1993) and the "Intermountain Flora" for vascular plants (Cronquist 1977). However, nomenclature for the grasses follows Manual of Grasses for North America (M.E. Barkworth 1999, Utah State University, personal communication). Resource data, including precipitation, elevation, and some information on soils were obtained from the questionnaires, appropriate agency personnel, and published reports. NRCS soil surveys were used to obtain most soils data.

Statistical Analysis

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

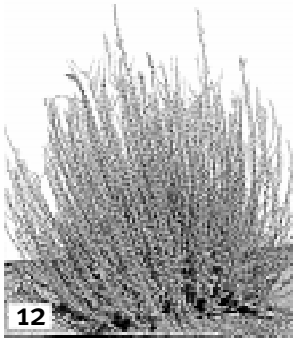
Questionnaire

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

On Site Assessment

All possible Pearson correlation coefficients (*r*) (SAS Institute, Inc. 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 were performed on independent variables to identify the best multiple regression model for the dependent variables. Independent variables that failed to maintain significance ($P<0.10$) were eliminated. Multiple regression was repeated using MAXR option of SAS 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 Immigrant spread and composition that is explained by the independent variables. 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 AND FINDINGS

Questionnaire Results

Returned questionnaires documented 151 forage kochia plantings by public agencies. Responses are summarized in Table 2 and the resulting information is presented in Appendix B. The most common intended uses of the plantings were grazing, weed control, wildlife habitat, erosion control, and greenstripping. Age of plantings ranged from 1 to 31 years and averaged 5.7 years. Immigrant was planted in a wide range of environments including the following: precipitation ranging from 5 to 20 in; 1600 ft to 7320 ft elevation; various soil types including coarse (gravelly), heavy (clay), light (sandy), medium (loamy), and saline or alkaline; and major vegetation types including salt desert shrub, desert shrub, WY big sagebrush, basin big sagebrush, pinyon-juniper, and mountain brush.

Summarization of responses to questions about planting method protocols showed that 92% were planted with a seed mix usually containing a wheatgrass component. Fifty-one percent of the plantings were made after fire, and 59% were planted on a prepared or disturbed seedbed. Planting methods included broadcast(aerial or ground), drilling, and transplanting.

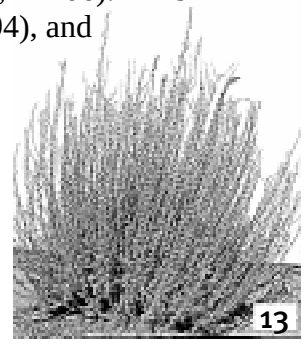
The field personnel were asked in the questionnaires to rate the seeding establishment success as excellent, good, fair, or poor. Of the 115 that responded, 62% reported good or excellent, 19% fair, and 19% poor establishment.

Responses concerning spread of Immigrant outside the initial planting areas were summarized as occurring or not occurring. In most cases these were general observations or the best recollection of the respondent. Of the 69 responses concerning Immigrant spread outside of the initial seeding boundary, 14 (20%) indicated that spread had occurred.

Questionnaire Correlations

Data from three locations in TX and two irrigated sites were not included in the correlation analysis because moisture levels at these sites were higher or had a different seasonal distribution than the normal adaptative range for Immigrant. Correlation analysis using data from the remaining questionnaires showed that no single environmental or planting-protocol factors were highly associated (r>0.60) with successful establishment of Immigrant or its spread. Correlations were based upon information from at least 40 plantings.

Correlations of a lower magnitude (r<0.60) included an association between successful establishment and seedbed preparation/disturbance (r=0.21, P=0.035, n=106). This finding is consistent with the results of Davis (1979), Page et al. (1994), and Stevens and McArthur (1990), and our own general observations. Factors such as precipitation, major vegetation type, soil type, fire, seeding method, and monoculture versus mixed species plantings were not associated with successful stand establishment. The lack of significant correlations between successful establishment and these



environmental variables associated with such a wide range of planting sites supports the belief that Immigrant is widely adapted to the semiarid conditions of the Intermountain West. Important variables, such as date of seeding, seeding rate, and quality and age of seed were not known and may have had a large impact on stand establishment. Also, establishment rating is subjective, especially in light of the varied backgrounds of the respondents, that the possibility of detecting correlations was probably reduced.

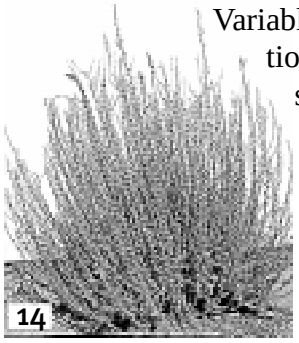
The reported recruitment or spread of Immigrant plants outside of the planting boundary was associated with medium textured soils (r=0.41, P=0.003, n=49) and drilled seeding (r=0.30, P=0.016, n=63). Neither of these correlations is easily explained. The subjectiveness of the questionnaire data on spread, combined with such a variable group of respondents, probably affected the possibility of detecting important associations. Based on the results of the questionnaire, few definitive conclusions could be made concerning the spread of Immigrant.

On-Site Assessment

Field surveys of seedings were primarily focused on 10-to 30-year old plantings. This is a short ecological time frame to determine Immigrant spread and competition in native and introduced plant communities. However, in view of the interest and continued use of Immigrant, we believe it is timely to evaluate the current status of the oldest plantings. Our conclusions are similar to those reported in the literature and summarized in the section "Competition, Invasiveness, and Biodiversity". The data and resource information for the on-site Immigrant planting evaluations are presented in Table 1. The greatest amount of spread (Table 1) was observed at the Dust Bowl seeding [sites 26 (Figure 2) and 33] at Clear Spot near Kanosh, UT. The maximum distance from the planting boundary to a single Immigrant plant was 3168 ft with a recruitment fringe of 185 ft. This site is unique because the area had severe degradation by fire and excessive wind erosion that removed 2 to 5 inches of topsoil. Fire and erosion had rendered the site and surrounding area entirely void of other vegetation prior to the plantings. A scatter plot confirmed this planting was a unique outlier (data were not consistent or it was extremely exaggerated when compared to other sites), therefore, we did not include it in the correlation or regression analysis.

Adaptation and Stand Composition Within Original Seeding

Percent composition of Immigrant within original seedings ranged from 2 to 91% with an average of 50% and median of 53%. Factors favorably associated with higher Immigrant composition include seeding date (r=0.24, P=0.065, n=58), medium textured soils (r=0.29, P=0.026, n=58), Immigrant planted as a monoculture (versus mixed planting) (r=0.43, P=0.001, n=58), prepared or disturbed seedbed (r=0.41, P=0.001, n=58), successful initial establishment (as reported in literature or questionnaire) (r=0.23, P=0.077, n=58), and predominantly annual competition (r=0.29, P=0.034, n=55). Variables associated with low Immigrant composition were higher precipitation (r=-0.24, P=0.068, n=58), pinyon-juniper and basin big sagebrush sites (r=-0.23, P=0.087, n=58 and r=-0.31, P=0.018, n=58, respectively), higher elevations (r=-0.25, P=0.057, n=58), planting after a fire (r=-0.28, P=0.058, n=58), coarse textured soils (r=-0.27, P=0.038, n=58) and predominantly perennial competition (r=-0.42, P=0.002, n=55).



The stepwise multiple regression prediction model explained 44% of the variation in Immigrant composition. It consisted of the following variables: mixed versus monoculture seeding, basin big sagebrush versus other vegetation types, disturbed versus undisturbed seedbeds, and elevation. Including all dependent variables in the regression model resulted in a maximum R^2 of 58%. Unexplained variation may be due to factors not determined such as quality of seed, seeding rate and date, or interactions among environmental variables.

Percent cheatgrass within the Immigrant planted area varied widely from 0% to 58%, with an average and median value of 9% and 2%, respectively. Percent cheatgrass outside the planted areas was greater than within the seeded areas. It ranged from 0% to 76%, resulting in an average and median of 28% and 25%, respectively. Usually, very little cheatgrass was observed within an Immigrant planting, as evidenced by the small median value (2%), strongly supporting the general belief that forage kochia out-competes cheatgrass. Furthermore, analysis using only sites where Immigrant was planted as a monoculture resulted in a negative correlation (r=-0.40, P=0.065, n=22) between Immigrant and cheatgrass percent composition.

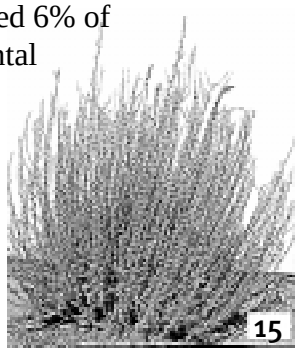
These results indicate that although Immigrant is widely adapted and can be established in many ecosystems, it establishes and grows best on disturbed sites at lower elevations where the competition consists mostly of annuals. Furthermore, Immigrant does not persist well in more productive ecosystems comprised of perennial plant communities, especially at higher elevations (e.g. basin and Wyoming big sagebrush, pinyon-juniper, and mountain brush sites). The significant correlation between increased Immigrant composition following monoculture planting, and the lack of a correlation between Immigrant composition and age of planting (Fig. 1) does not support notions that Immigrant is an aggressive competitor that through time will become the predominant vegetation when planted as a mixture or into existing perennial plant communities.

Recruitment From Original Planting

Maximum distance to a single plant. Reconnaissance surveys of the perimeters surrounding 62 Immigrant plantings found individual plants at 0 to 1265 ft from the seeding boundary. The mean and median distance 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 (Fig. 1).

No factors, including age of the seeding (Fig. 1), were significantly correlated with maximum distance to a single plant. However, a relationship was found between maximum distance and aerial broadcast seeding during preliminary analysis, but the dependant variable data were available for so few aerial seeded sites that an accurate conclusion could not be drawn. The best multiple regression model only explained 6% of the variation among sites, further indicating the evaluated environmental variables could not be used to predict this measure of spread.

Planting boundaries of aerial seedings are not well defined because Immigrant seed caught in wind gusts could easily be delivered to non-targeted areas allowing establishment outside the seeding bound-



ary. Other factors associated with this measure of Immigrant spread could be the occurrence of whirlwinds and/or amount of bare ground surrounding the planting area. The hypothesis that whirlwinds carried seed is highly possible because in many Immigrant plantings seed was not incorporated into the soil. Also, this is consistent with observations that Immigrant can recruit to a great distance at sites with high wind conditions and severely degraded perimeter areas as shown for sites 24, 26, and 27 (Table 1). Recruitment to distant perimeter areas may result from environmental conditions unrelated to the planting method.

Fringe of recruitment. Fringe distance, as defined in Materials and Methods is the 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.

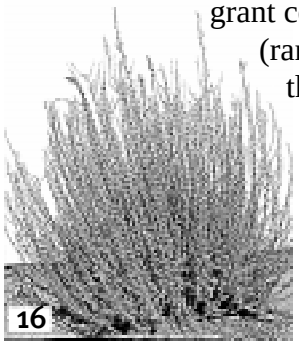
No independent environmental factors were highly correlated (r>0.50) with fringe distance. Variables associated at a lesser level (r<0.50) with wide fringe distances were medium texture soils (r=0.30, P=0.021, n=58) and salt desert shrub ecosystems (r=0.24, P=0.067, n=58). Narrow fringe distances were associated with pinyon-juniper sites (r=-0.21, P=0.100, n=58), fire before planting (r=-0.22, P=0.098, n=58), and increasing elevation (r=-0.22, P=0.090, n=58).

The best regression model, consisting of medium soil texture, elevation, and date of seeding, only explained 22% of variation in recruitment fringe distance. The maximum R^2 achievable using all estimated variables still only explained 48% of the variation. Unexplained variation may be due to factors that were not determined.

Preliminary analysis suggested that annual plant competition was associated with wide fringe distance. This is consistent with general belief. However, over all sites, we were not able to verify the impact of annual competition on this measure of spread. The significant association of fringe distance with salt desert shrub ecosystems agrees with our observations and those of others.

The extent of soil disturbances surrounding the planting area may be important in determining Immigrant spread. We had information on disturbance of the seeding area for most sites, but not about the disturbed border surrounding the planting. Our observations indicate soil disturbance is important to establishment and spread, and therefore, the extent of disturbance around the planting would be expected to have a large impact on the fringe distance.

Immigrant forage kochia composition at recruitment fringe. On the average Immigrant comprised only 6% of the vegetation at the defined recruitment fringe (range was 0 to 26%). The median value for Immigrant composition at the fringe was 4%. The most significant correlation found was with age of planting (r=0.40, P=0.002, n=58).



DISCUSSION AND SUMMARY

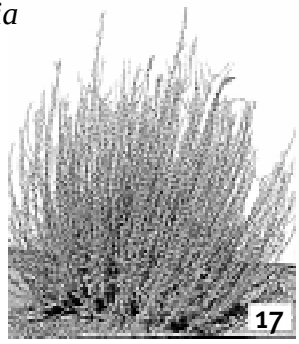
Our findings are in agreement with and generally confirm earlier published reports. Immigrant will naturally recruit, like most species, mainly into disturbed soils or in areas lacking competition from perennial vegetation, both within and outside the seeded area. Major factors that influence the distance a species will spread and its abundance are ecological adaptation, amount of soil disturbance, and plant competition from both annuals and perennials. Immigrant has a broad and diverse range of adaptability and therefore propagates itself in several western rangeland ecosystems. It is vigorous at elevations as low as 1600 ft at site 81 near Yakima, WA, and as high as 7,320 ft at site 10 in Salina Canyon near Salina, UT. Immigrant has been successfully planted in Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Texas, Utah, Washington and Wyoming.

At several sites we observed that the spread of Immigrant was generally less than 12 ft from the original seeding [see Table 1 and the following sites;13, 15, 23, 27, 37 (Figure 4), 39, 43, 47, 52, 53, 57, 58, 59 , 66, 69 (Figure 5), 73, 79, 80, and 81]. These sites are located in several different western states and ecosystems. We found very little spread at site 79 near Kuna, ID, however it was reported to have spread into small playas and slick spots (DeBolt 1998, personal communication).

Recruitment was noticeable on sites with an average annual precipitation of $\geq$ 18 in at site 1-Mouth of Green Canyon, Logan, UT; site 62-Texas Creek, Ririe, ID; and site 36-Clarkston, UT to sites with $\leq$ 6 in of rainfall at sites 21-North Site, Lake Side, UT; 23-Mapco Pipeline Plots, Bonanza, UT; and 34-Cedar Valley, Tooele County, UT. However, sites with high annual precipitation supported less Immigrant spread than those with lower annual precipitation. High precipitation zones may have more closed plant communities (high degree of plant competition) and less open spaces for Immigrant establishment than lower rainfall areas.

Immigrant establishes well in coarse, medium, and fine-textured soils including sandy, gravely, stony, clay, silt, and loam soils (Table 1). However, our analysis suggests that its establishment is favored by medium-textured soils. It recruited in droughty soils that had high concentrations of salts and alkali (Figures 6 and 7), including slick spots such as at site 21-North site, Lakeside, UT; site 24-White River Evacuation Creek, Bonanza, UT; and site 18-Mortenson, Ephraim, UT.

Immigrant has become established in the following vegetation types: gambel oak, maple (*Acer spp.*), pinyon-juniper, mountain big sagebrush (*Artemisia vaseyana*), basin big sagebrush, WY big sagebrush/bluebunch wheatgrass (*Pseudoroegneria spicata*), WY big sagebrush/Thurber's needlegrass (*Achnatherum thurberiana*), WY big sagebrush/galleta (*Hilaria jamesii*), shadscale, shadscale/indian ricegrass (*Achnatherum hymenoides*), black sagebrush (*Artemisia nova*), winterfat (*Kraschenninnikovia lanata*), falcate saltbush (*Atriplex falcata*), gardner saltbush (*Atriplex gardneri* Var.



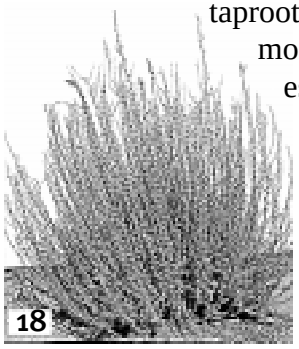
tridentata), black greasewood, and blackbrush (*Coleogyne ramosissima*) (Table 1). Immigrant has also become an understory plant in maple, serviceberry (*Amelanchier alnifolia*), snowberry (*Symphoricarpos longiflorus*), and rubber rabbitbrush (*Chrysothamnus nauseosus*) at site 2 - Snow Field Station (formerly Great Basin Experiment Station), Ephraim, UT; with oak at site 3 Steel Ranch, Mona, UT; with pinyon-juniper at site 17 - Great Basin Experimental Range, Ephraim, UT; and WY big sagebrush and black greasewood on several sites (Table 1) located in mountain, upland, semi-desert, and desert ecosystems.

Immigrant was found growing in association with many different species (Table 3). Sandberg bluegrass (*Poa secunda*) acts as an understory to Immigrant especially on shallow soils (Figure 2). Shadscale had spread into the 17-year-old test plot of Immigrant at site 20 (Lambert site at Lakeside, UT, Figure 8) and in contrast, Immigrant had not spread into the nearby control plot of shadscale. Shadscale was found vigorously growing with Immigrant on several sites (8, 12, 20, 24, 34, 46, 47, 53, 70, 71, and 72). Winterfat was found growing with Immigrant on several sites (26, 33, 34, 48, and 57) and had invaded into an Immigrant plot at site 57 [Trout Creek, near Jackpot, NV (Figure 9)]. Immigrant forms a close association with black greasewood on most of the black greasewood vegetation sites (Table 1, Figure 10). WY big sagebrush was found growing with Immigrant on the following sites (24, 27, 42, 46, 50, 51, 54, 55, 56, 61, 64, 65, 67, 74, 75, 76, and 78,). Simultaneous recruitment of juvenile WY big sagebrush and Immigrant plants was obvious at various sites (51, 54, 55, 61, and 76).

Although Immigrant recruitment is often related to the direction of the prevailing winds, other factors were more predominant on several sites [19, 20, 24, 26, 29, 33, 67, 68, 72 (Figure 12), 76 (Figure 11), and 78]. We conclude that soil disturbance, lack of vegetation competition, and open spaces near established Immigrant plants, are the most important conditions associated with successful recruitment.

Several factors including seeding success, presence of competing vegetation, and individual versus mixed seedings, determine the extent to which Immigrant plants dominate a planted site. On several evaluated sites, it made up 70% to 98% of the plant composition. It is interesting to note that at the White Rock-Fire Research Plots (Site 44) Immigrant exhibited less vigor and produced less foliage on areas seeded at 3 lb and 6 1b/acre than when seeded at 1 lb/acre.

In most years, Immigrant plants produce a large amount of viable seed. During the following spring numerous seedlings establish in adjacent open spaces. A large majority of these seedlings die before autumn primarily due to competition from adjacent mature plants and lack of soil moisture. In some situations Immigrant seedlings survive by forming a small rosette and then allocating significant energy into the growth of its taproot. Young seedlings can remain in this form until they receive adequate moisture. Through this process Immigrant competes with and prevents establishment of annuals and some perennials. Monsen (1998, personal communication) also made similar observations regarding Immigrant competing with cheatgrass (Figure 13). At a 25-year-old

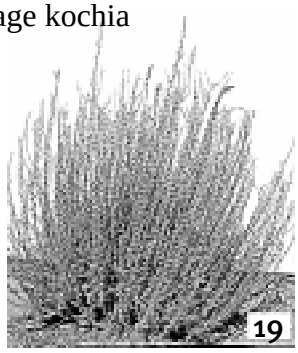


Immigrant planting (site 4 - Nine Mile Reservoir) several black sagebrush plants had died and very few juveniles had become established, however, several Immigrant juveniles were established (Figure 14). Immigrant was found in the interspaces between such plants as galleta and indian ricegrass (site 6 figure 15).

Immigrant is generally compatible with crested wheatgrass, and, in certain situations, it acts as a host plant to crested wheatgrass. On several sites [20, 26, 33, 44, 45, 46, and 76 (Figure 16)] crested wheatgrass was growing in the center of individual Immigrant plants. In some conditions, especially ungrazed areas in the WY big sagebrush vegetation type [sites 51, 66, and 76 (Figure 17)], Immigrant may give way to crested wheatgrass. The Malta, ID, sites 66 and 67 were the same except site 66 was ungrazed and site 67 was grazed. After 12 years, Immigrant made up 20% of the species composition at the ungrazed site and 80% at the grazed site. A better understanding of the relationship between forage kochia and crested wheatgrass is needed.

Long-term research would help determine Immigrant's competitive interaction with perennials in the WY big sagebrush, desert shrub (black sagebrush), and salt desert shrub (black greasewood) sites. Our observations suggest that over time native perennials such as shadscale, winterfat, WY big sagebrush, and western wheatgrass (*Pascopyrum smithii*) will re-establish themselves in stands of Immigrant. On many rangeland sites, resource managers are currently faced with the persistence of alien annuals such as cheatgrass and medusahead rye that result in degradation of the resource base through continued wild-fires and soil erosion. The establishment of Immigrant could help protect these environ-mental resources, yet allow native perennial communities to become re-established. Overall we conclude that Immigrant is widely adapted to the semi-desert environment of the Intermountain West. In the Great Basin, there are few perennial species with the broad adaptability and establishment attributes of Immigrant. On many evaluated sites biodiversity had been improved by the presence of Immigrant (Figures 6, 7, 9, 16). Clearly, Immigrant can be established in a wide range of areas and environmental condi-tions, and it will compete with annuals, especially 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 or that it will overcome estab-lished perennial plant communities.

Our evaluations in Kazakhstan and conclusions 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 aggressive-ness in the USA. Depending upon the site and associated species, the native perennial plant communities in Kazakhstan contained from 1 to 20% forage kochia. However, in disturbed areas along roadways, abandoned fields and farmsteads forage kochia made up from 15 to 60% of the plant community. Forage kochia was never observed to be dominant in the major plant communities com-prised sagebrush, saltbush, winterfat, crested and Siberian wheat-grass, and needlegrass. No where did we observe sites where forage kochia had invaded from disturbed sites into adjacent perennial plant communities on the Kazakhstan steppes.



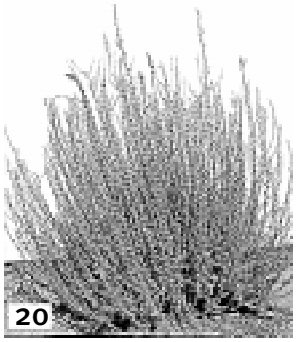
In many ways, our investigations show that not all introduced species are a threat to ecosystem balance or functions. This work helps to dispel some misconceptions about introductions of alien "foreign" species and shows that careful research can find the best adapted plants for range stabilization and productivity.

ENDNOTES

1. Authors of scientific names are listed in table 2.

2. Authors treat forage kochia species in general. We assume subspecies *virescens* (Immigrant) was included in treatise.

3. Reviews forage qualities of *K. prostrata* subspecies *grisea* which are similar to Immigrant.



TABLES AND FIGURES

Table 1. Site descriptions and field evaluations of Immigrant plantings.

Site Name and Location	Plant-ing Date	Ppt[1] in	Vegetation type	Soil[2]	Seed-bed[3]	Elev. ft	Seeding mix[4]	% comp in seeding[5]	Fringe[6] dist. ft	% comp fringe[7]	MD[8] ft	Immigrant Remarks
1. Mouth of Green Canyon; Logan, UT	1968	18	Wyoming (WY) big sagebrush, bluebunch wheatgrass	silt loam	yes	4690	single	IPD[9]	IPD	IPD	150	Slight encroachment into fence line and disturbed roadway area; associated with annuals and perennials
2. Snow College Field Station; Ephraim, UT	1969	11	basin big sagebrush	silty clay loam	yes	5580	single	IPD	IPD	IPD	550	Recruitment as understory into nearby lilac, maple, snowberry, and into fence line
3. Steel Ranch; Mona, UT	1972	18	pinion- juniper, gamble oak	cobbly loam	yes	5900	mixed	20	15	1	15	Understory to gambel oak; some spread into open areas along gravel road shoulders
4. Nine Mile Reservoir; Sterling, UT	1973	10	black sagebrush, WY big sagebrush	shale, silt loam	yes	5400	single	78	25	26	60	Recruitment into open spaces; significantly competed with black sagebrush; some dead black sagebrush plants
5. Redmond Junction; Redmond, UT	1974 1981 1982	10	WY big sagebrush, shadscale	silt loam	yes	5160	mixed	62	OPB[10]	OPB	OPB	Spread from original mixed planting of crested wheatgrass and Immigrant into highly disturbed areas
6. Redmond Road Cut, West and East Seeding; Redmond, UT	1974	9	WY big sagebrush, shadscale	cobbly clay, gravely sandy loam	yes	5150	single	83	OPB	OPB	0PB	Minor encroachment northeast from east seeding into interspaces of native species of galleta grass, green rabbitbrush, needle-and-thread grass
7. Sterling, West and East seeding; Sterling, UT	1974	12	WY big sagebrush	gravely silt loam	yes	5500	single	86 88	40 35	16 18	170 75	Dense Immigrant stand in both east and west original seedings; west seeding has moderate recruitment into northwest disturbed areas; east seeding recruited east into disturbed areas of intermediate wheatgrass
8. Salina Canyon I-70 Mile Post (mp) #57.8 ; Salina, UT	1974	12	shadscale	silt loam	yes	5670	single	75	25	20	110	Recruitment outside of 3 initial plots; associated with bluebunch wheatgrass, shadscale, and green rabbitbrush; south slope (SS)[11]
9. Salina Canyon I-70 mp #58; Salina, UT	1974	12	WY big sagebrush, indian ricegrass	stony loam	yes	5690	single	41	40	19	98	Slight spread into intermediate and crested wheatgrass plots; growing with indian ricegrass; (SS)
10. Salina Canyon I-70 mp #76; Salina, UT	1974	15	mountain brush, pinion- juniper	gravely loam	yes	7320	single	57	DAP[12]	DAP	DAP	Growing in crested wheatgrass seedings

Table 1. Site descriptions and field evaluations of Immigrant plantings. (continued)

Site Name and Location	Planting Date	Ppt[1] in	Vegetation type	Soil[2]	Seed-bed[3]	Elev. ft	Seeding mix[4]	% comp in seeding[5]	Fringe[6] dist. ft	% comp fringe[7]	MD[8] ft	Immigrant Remarks
11. Salina Canyon Mouth; Salina, UT	1975	11	shadscale, black greasewood	silty clay loam	yes	5300	single	65	OPB	OPB	OPB	Area has been highly disturbed
12. Salina Canyon I-70 mp #60; Salina, UT	1975	13	black greasewood, shadscale	silt loam	yes	5750	single	82	45	25	75	Dense stand of Immigrant; heavily recruited east of plot into black greasewood, shadscale and rubber rabbitbrush; some dead black greasewood, shadscale and rabbitbrush plants; (SS)
13. Salina Canyon I-70 mp #74; Salina, UT	1975	14	mountain brush, pinion-juniper	gravely sandy loam	yes	7220	single	UD[13]	0	0	0	Little spread; low vigor plants; (SS)
14. Nephi Canyon; Nephi, UT	1975	14	mountain brush, oak, birch leaf mahogany	shale, clay loam	no	5730	single	19	20	2	32	Little spread outside original planting; very low density; filled in some open spaces, recruited under birch leaf mahogany and rubber rabbitbrush; (SS)
15. South Salina; Salina, UT	1977	10	shadscale, black greasewood	silty clay loam	yes	5200	mixed	UD	DAP	DAP	DAP	Low density in planted strips of road cut; recruitment into black greasewood & 4-wing saltbush plots
16. First Planting; Rush Valley, UT	1977	10	falcate saltbush, winterfat, black greasewood	fine sandy loam	yes	5100	single	UD	25	3	30	Minor spread into interspaces of other species plots, in the fence line, and outside the fenced planting; Immigrant and black greasewood growing together as the dominant species
17. Great Basin Expt. Range; Ephraim, UT	1979	12	pinion-juniper, WY big sagebrush	stony fine sand	yes	5830	mixed	IPD	IPD	IPD	101	Moderate spread along road side in disturbed areas on west slope; associated with pinion-juniper and rubber rabbitbrush
18. R. Mortensen; Ephraim, UT	1979	11	black greasewood	alkaline	yes	5600	single	UD	DAP	DAP	50	Minor spread into black greasewood and Russian wildrye plots; competed strongly with halogeton
19. Headquarters Site; Lakeside, UT	1981	7	shadscale, winterfat	silt loam	yes	4300	single	70	10	3	35	Some recruitment to south and west in disturbed areas; Competes strongly with cheatgrass, halogeton and Russian thistle; the annuals comprise less than 8% of plant composition (PC)

Table 1. Site descriptions and field evaluations of Immigrant plantings. (continued)

Site Name and Location	Plant-ing Date	Ppt[1] in	Vegetation type	Soil[2]	Seed-bed[3]	Elev. ft	Seeding mix[4]	% comp in seeding[5]	Fringe[6] dist. ft	% comp fringe[7]	MD[8] ft	Immigrant Remarks
20. Lambert Site; Lakeside, UT	1981	8	shadscale	silt loam	yes	4400	single	80	25	3	40	Shadscale has recruited into original Immigrant plot; Immigrant has not recruited into shadscale control plots; it has recruited into disturbed area of other plots, fence line, roadway, and water drainage area
21. North Site ; Lakeside, UT	1981	6	black greasewood	saline, silt loam	yes	4270	single	76	20	1	50	Immigrant covers 38% of ground in original plots; minor recruitment into Russian wildrye plots. Immigrant competed strongly with cheatgrass and halogeton
22. Nephi Expt. Station; Nephi, UT	1981	15	basin big sagebrush	clay loam	yes	5000	mixed	7	DAP	DAP	DAP	Spread concentrated in fence line; compatible with crested wheatgrass, basin big sagebrush, 4-wing saltbush, Sainfoin, Senecio, and annual forbs
23. Mapco Pipeline Plots; Bonanza, UT	1981	6	black greasewood, WY big sagebrush	weathered process shale, silt loam	yes	5200	single	UD	5	1	10	Heavily grazed; several dead plants; few remaining Immigrant plants. Immigrant is the only surviving specie in the test which included Russian wildrye, crested wheatgrass, 4-wing saltbush, WY big sagebrush, and gray rabbitbrush
24. White River Evacuation Creek; Bonanza, UT	1982	7	black greasewood, shadscale, WY big sagebrush	silt loam, gravely silt loam	yes	5900	single	58	25	8	1265	Recruited south and east; heavy recruitment under black greasewood. Very few plants under WY big sagebrush; dead Immigrant and young black greasewood plants within plot; Immigrant 51% PC and cheatgrass 40% PC
25. South Manti; Manti, UT	1985	11	basin big sagebrush	silt loam	yes	5575	mixed	UD	30	15	75	Immigrant has moderate spread from scalped and seeded strips into the remaining basin big sagebrush rows
26. Clear Spot East[14]; Kanosh, UT	1987	7	shadscale, winterfat	silt loam	no	4725	single	98	50	8	3168	Moderate spread south into winterfat and crested wheatgrass plots; several winter-fat and Immigrant juveniles; major spread north in direction of prevailing winds into open areas; low vigor; competing with self

Table 1. Site descriptions and field evaluations of Immigrant plantings. (continued)

Site Name and Location	Planting Date	Ppt[1] in	Vegetation type	Soil[2]	Seed-bed[3]	Elev. ft	Seeding mix[4]	% comp in seeding[5]	Fringe[6] dist. ft	% comp fringe[7]	MD[8] ft	Immigrant Remarks
27. FS Upper Site; Rush Valley, UT	1988	14	WY big sagebrush, juniper	gravely loam, loam	yes	5274	single	UD	10	1	12	Minor recruitment northeast into fence line and disturbed areas mainly within plot, some of the original forage kochia plants are dying; gray stem kochia has spread more than Immigrant; cheatgrass and annual mustard are heavy competitors
28. FS Middle Site; Rush Valley, UT	1988	10	falcate saltbush, winterfat	fine sandy loam	yes	5100	single	65	30	15	85	Some recruitment within plots and northeast outside plots; gray stem kochia has greater density and has recruited farther than Immigrant to the south, north and east
29. FS Lower Site; Rush Valley, UT	1988	8	gardner saltbush	saline, silt loam	yes	5044	single	91	25	8	50	High density inside plot; a few plants have recruited outside of plot into basin saltbush to the north, south, and east; deep water table
30. Grantsville SCD; Grantsville, UT	1988 1989	11	shadscale, winterfat	loam	yes	4350	single	10	25	11	125	Minor recruitment 40 ft beyond plots with exception of water drainage area where it recruited 125 ft.; cheatgrass offered competition
31. Sandwash; Fruitland, UT	1988	10	WY big sagebrush, western wheatgrass	silt loam	yes	6740	single	UD	10	3	20	Increased within plot, very little spread outside of research planting; Immigrant has spread into Columbia needlegrass, needle-and-thread grass and winterfat plots. Kentucky bluegrass, indian ricegrass, and western wheatgrass have recruited into immigrant plots.
32. Davis Spring; Jensen, UT	1988	7	black greasewood, WY big sagebrush	saline silt loam	yes	5100	single	50	30	5	65	Immigrant is the only surviving seeded species; spread into other plots and outside of research area; understory to black greasewood
33. Clear Spot West[14]; Kanosh, UT	1988	7	shadscale, winterfat	silt loam	no	4725	single	98	90	8	1056	Spread east, west and north into disturbed open niches; low vigor; competing with self
34. Cedar Valley; Tooele County, UT	1988	6	shadscale, winterfat	silt loam	no	4800	mixed	22	OPB	OPB	OPB	Increased within seeding; high percent of cheatgrass; associated with sandberg bluegrass, shadscale, winterfat, globemallow, 4-wing saltbush, crested wheatgrass, & indian ricegrass.

Table 1. Site descriptions and field evaluations of Immigrant plantings. (continued)

Site Name and Location	Planting Date	Ppt[1] in	Vegetation type	Soil[2]	Seedbed[3]	Elev. ft	Seeding mix[4]	% comp in seeding[5]	Fringe[6] dist. ft	% comp fringe[7]	MD[8] ft	Immigrant Remarks
35. Negro Mag; Milford, UT	1988	10	galleta grass, WY big sagebrush	gravely sandy loam	no	5200	mixed	19	25	5	660	Associated with crested wheatgrass, galleta grass, needle-and-thread grass; some spread mainly in waterway 660 ft.
36. Clarkston; Clarkston, UT	1988	18	basin big sagebrush, basin wildrye	silt loam	yes	5350	single	UD	10	4	20	Poor vigor; several dead plants; juvenile plants have spread into crested wheatgrass and cicer milkvetch plots
37. Twist Canyon Plots; Sevier County, UT	1989	8	shadscale, winterfat	silty clay loam	yes	5250	single	UD	8	1	25	Very little spread, 12 plants had recruited outside of initial plots
38. White Rock-East Research Planting; Dugway, UT	1989	7	shadscale	fine sandy loam	yes	4700	mixed	58	OPB	OPB	OPB	Increased in grazed crested wheatgrass seeding
39. White Rock-Rydalch Junction; Dugway, UT	1989	7	WY big sagebrush, shadscale	gravely silt loam, fine sandy loam	yes	4800	mixed	62	5	2	10	Recruitment within seeding; some spread into cheatgrass, mustard and Russian thistle
40. Twist Canyon; Sevier County, UT	1990	8	WY big sagebrush	stony fine sand	yes	5280	mixed	53	OPB	OPB	OPB	Several crested wheatgrass juvenile plants have recruited into individual Immigrant plants
41. Big Wash; Myton, UT	1990	7	winterfat	silt loam	yes	5300	mixed	27	OPB	OPB	OPB	Natural spread in open spaces; heavily used by elk; associated with Russian wildrye, crested wheatgrass, and WY big sagebrush
42. Sandwash Fish & Game; Fruitland, UT	1991 1992 1995	10-14	pinion-juniper, basin and WY big sagebrush	silt loam, stony loam	yes	7000	mixed	26	OPB	OPB	OPB	Minor spread into open spaces mainly within seeded area; associated with intermediate and crested wheatgrass, alfalfa, cicer milkvetch, WY big sagebrush, basin wildrye, western wheatgrass, muttongrass
43. Upper ARS Plots; Dugway, UT	1991	7	shadscale	fine sandy loam, stony loam	yes	4800	single	21	5	2	10	Minor spread within other plots; little spread outside of research plots
44. White Rock-Fire Research Plots; Dugway, UT	1991 1992	7	shadscale, winterfat	fine sandy loam over gravel and sand	yes	4700	single	90	10	5	25	Minor spread into remaining cheatgrass strips; Immigrant competed with itself especially at the higher seeding rates; juvenile crested wheatgrass plants growing in center of mature Immigrant plants

Table 1. Site descriptions and field evaluations of Immigrant plantings. (continued)

Site Name and Location	Planting Date	Ppt[1] in	Vegetation type	Soil[2]	Seedbed[3]	Elev. ft	Seeding mix[4]	% comp in seeding[5]	Fringe[6] dist. ft	% comp fringe[7]	MD[8] ft	Immigrant Remarks
45. Lower ARS Plots; Dugway, UT	1992	7	shadscale, WY big sagebrush	sandy and fine sandy loam	yes	4675	single	58	20	1	50	Recruited within seeding; little spread outside of research plots
46. Dugway Base Planting; Dugway, UT	1992	7	shadscale, WY big sagebrush	fine sandy loam	yes	4700	mixed	76	20	1	25	Minor spread within seeding; very little spread outside of seeding; juvenile crested wheatgrass plants growing in center of mature Immigrant plants
47. Valcron; Myton, UT	1993	7	black sagebrush, fringed sagebrush	gravelly silt, shale	yes	5350	mixed	50	5	5	10	More shadscale and fringed sagebrush juveniles than Immigrant juveniles within seeding
48. Beryl; Beryl, UT	1993	8	winterfat, indian ricegrass	very fine sandy loam	no	5300	mixed	25	30	10	50	Minor recruitment into disturbed and open areas mainly east; winterfat juveniles recruiting in Immigrant seeding
49. Motoqua; Gunlock, UT	1994	12	Blackbrush, pinion-juniper	shallow gravelly sandy loam	no	4200	mixed	7	OPB	OPB	OPB	Summer precipitation and thermic temperature zone; transitional zone of Mojave Desert; associated with blackbrush, desert almond, indian rice grass, mountain big sagebrush and pinion-juniper
50. Milford Bench; Milford, UT	1994	9	WY big sagebrush, galleta grass	gravely sandy loam	yes	5200	mixed	20	5	2	15	Moderate spread into open areas; associated with galleta grass and WY big sagebrush
51. Headquarters Res. Plots, Squaw Butte Expt. Range; Burns, OR	1970 1971 1974	12	Bluebunch wheatgrass, basin and WY big sagebrush	loam, fine sandy loam	yes	4488	single	UD	20	10	50	Crested wheatgrass has recruited in forage kochia plots; several dead Immigrant plants; some recruitment of Immigrant juveniles; several WY big sagebrush juveniles
52. Range 14, Squaw Butte Ex. Range; Burns, OR	1982	12	Bluebunch wheatgrass, basin and WY big sagebrush	gravely loam	yes	4488	mixed	6	3	1	3	Little spread in fence line or surrounding areas; associated with crested wheatgrass; appears to be stable
53. Saddle Butte, Highway #205, Eastern Oregon Ag. Res. Center; Burns, OR	1982	10	Black greasewood, WY big sagebrush, shadscale	silty clay loam, moderate alkaline	yes	4116	single	UD	10	2	100	Black greasewood and shadscale juvenile recruitment into Immigrant plots; very little recruitment of Immigrant; some plants killed by 2,4-D spray

Table 1. Site descriptions and field evaluations of Immigrant plantings. (continued)

Site Name and Location	Plant-ing Date	Ppt[1] in	Vegetation type	Soil[2]	Seed-bed[3]	Elev. ft	Seeding mix[4]	% comp in seeding[5]	Fringe[6] dist. ft	% comp fringe[7]	MD[8] ft	Immigrant Remarks
54. Narrows, Eastern Oregon Ag. Res. Center; Burns, OR	1982	10	Black greasewood, WY big sagebrush	loam, moderate alkaline	yes	4116	single	UD	15	2	70	Several dead forage kochia plants; black greasewood and WY big sagebrush recruitment into Immigrant plots; kochia plants may have been killed by standing water or ice
55. Beacon Pit Mine; Battle Mountain, NV	1978	8	WY big sagebrush	mine spoil, stony loam	yes	5200	single	37	20	1	160	Very little spread outside of plots into open spaces; low density; associated with squirreltail, crested wheatgrass, 4-wing saltbush, rubber rabbitbrush
56. Paris Fire Rehab; Wells, NV	1986	8	WY big sagebrush, bluebunch wheatgrass	shallow loam	yes	6000	mixed	10	OPB	OPB	OPB	Slight recruitment mainly into open space in seeded area; associated with crested wheatgrass, WY big sagebrush, indian rice grass, great basin wildrye, and western wheatgrass
57. Trout Creek; Jackpot, NV	1987	13	Basin big sagebrush	loam	yes	5480	single	UD	5	1	5	Very little recruitment from original planting; recruitment of winterfat into Immigrant plot and individual plants
58. McDermit; Currie, NV	1987	8	Black sagebrush, indian rice grass	gravely loam	yes	5900	mixed	13	0	0	0	Little recruitment within, none outside of seeding
59. Trout Creek; Elko, NV	1988	10	Basin big sagebrush, bitterbrush	gravely loam	yes	5800	mixed	9	10	2	15	Slight recruitment within open spaces of roadway seeding
60. Phalen Fire Rehab; Wells, NV	1988	10	Pinion-juniper, WY big sagebrush	stony loam	no	6800	mixed	2	OPB	OPB	OPB	Recruited into open spaces within seeding; associated with bluebunch wheatgrass, sandberg bluegrass, WY big sagebrush, squirreltail
61. Bell Rapids; Hagerman, ID	1978 1979	11	Basin and WY big sagebrush, bluebunch wheatgrass	sandy loam	yes	3490	single	IPD	IPD	IPD	IPD	Some dead Immigrant plants; associated with western and crested wheatgrass, basin big sagebrush
62. Texas Creek Wildlife Mgt Area; Ririe, ID	1980 1981	18	Mountain big sagebrush, service berry, snowberry	stony silt loam, silt loam	yes	7100	mixed	31	15	1	30	Minor recruitment into disturbed gravel pit and other open spaces; associated with big bluegrass, milkvetch, alfalfa, snowberry, serviceberry, & mountain big sagebrush; west slope
63. Niagra Springs, River Bottoms; Wendell, ID	1984	11	black greasewood	fine sandy loam, blow sand	yes	3100	mixed	29	100	13	185	Recruited into understory of 4-wing saltbush and black greasewood.

Table 1. Site descriptions and field evaluations of Immigrant plantings. (continued)

Site Name and Location	Planting Date	Ppt[1] in	Vegetation type	Soil[2]	Seedbed[3]	Elev. ft	Seeding mix[4]	% comp in seeding[5]	Fringe[6] dist. ft	% comp fringe[7]	MD[8] ft	Immigrant Remarks
64. Niagra Springs, Tract G-1; Wendell, ID	1984	12	WY big sagebrush	stony fine sandy loam	yes	3400	single	42	OPB	OPB	OPB	Minor spread in disturbed areas; competed well with cheatgrass
65. North seeding, Tract G-10; Burley, ID	1985	10	WY big sage-brush, bluebunch wheatgrass	loam	yes	4175	mixed	71	40	6	100	Low vigor of Immigrant competed with itself; minor recruitment into WY big sagebrush native range
66. Skaggs Ranch, North Seeding; Malta, ID	1986	9	WY big sagebrush	silt loam	yes	4400	mixed	19	0	0	0	Dying out in ungrazed crested wheatgrass field; some recruitment in disturbed areas within seeding
67. Skaggs Ranch, South Seeding; Malta, ID	1986	9	WY big sagebrush	silt loam	yes	4400	mixed	53	50	4	125	Moderate recruitment throughout grazed crested wheatgrass and WY big sagebrush pasture; some spread east across highway into disturbed areas
68. RRMP Dr. Creek, I-84 mp #107; Hemmett, ID	1986	9	WY big sage-brush, thurbers needlegrass	silt loam	yes	3000	mixed	68	25	18	300	Recruited into disturbed areas west of seeding; East Slope – may have been seeded beyond green strip
69. Lockman I-84 mp #87; Mountain Home, ID	1986	9	WY big sagebrush, thurbers needlegrass	shallow gravely loam, silt loam	yes	3100	mixed	57	25	6	150	Little recruitment east from original seeding; Immigrant compatible with Sandberg bluegrass, especially on shallow gravelly soils; some spread on west side from original seeding
70. Disk Chain-Dorsey Butte; Grandview, ID	1986	7	shadscale, bud sage	silt loam	yes	2950	mixed	90	25	6	135	Several shadscale juveniles associated with Immigrant; little recruitment outside seedings
71. Dorsey Butte; Grandview, ID	1986	7	shadscale, bud sage	silt loam	yes	2950	mixed	UD	30	5	150	Associated with crested wheatgrass and 4-wing saltbush; little outside recruitment, mainly in disturbed areas of cheatgrass; recruitment into dry lake playa, associated with Davis pepperplant
72. Simco Road; Mt. Home, ID	1986	7	shadscale, bud sage	silt loam	yes	3000	mixed	86	OPB	OPB	OPB	Minor recruitment into open areas; associated with crested wheatgrass
73. East of Airport, Tract J-21; Jerome, ID	1987	9	WY big sagebrush	silt loam	yes	3900	mixed	75	0	0	0	Competed with itself; several dead seedlings and juvenile plants; some dead 4-wing saltbush plants
74. Orchard; Boise, ID	1987	10	WY big sage-brush, thurbers needlegrass	silt loam	yes	3130	single	80	25	1	75	High density within original plots; very competitive with annuals; spread into open areas of WY and silver sagebrush plots

Table 1. Site descriptions and field evaluations of Immigrant plantings. (continued)

Site Name and Location	Planting Date	Ppt[1] in	Vegetation type	Soil[2]	Seedbed[3]	Elev. ft	Seeding mix[4]	% comp in seeding[5]	Fringe[6] dist. ft	% comp fringe[7]	MD[8] ft	Immigrant Remarks
75. Niagra Springs, Tract J-18; Wendell, ID	1988	12	Basin and WY big sagebrush	fine sand, loamy sand	yes	3400	single	49	60	10	100	Some spread in open areas between WY big sagebrush plants
76. South of Airport, Tract J-10; Jerome, ID	1988	9	WY big sagebrush	silt loam	yes	3900	mixed	76	30	4	105	Spread north across highway #93; spread west in open areas and under WY big sagebrush; low vigor, competing with itself; crested wheatgrass growing in dead Immigrant plants
77. South seeding, Tract G-10; Burley, ID	1988	10	WY big sagebrush, bluebunch wheatgrass	loam	yes	4175	mixed	48	CD[15]	CD	CD	Immigrant and 4-wing saltbush established juveniles; some die off of 4-wing saltbush, Immigrant has more vigor in 4-wing saltbush mixed plantings than alone
78. Shoshone Wildlife; Shoshone, ID	1988	10	WY big sagebrush, sandberg bluegrass	loam	yes	4230	single	91	35	7	100	Minor spread into open areas to the west, north, and south of original seeding; Cheatgrass 8% PC in seeding
79. Swan Falls; Kuna, ID	1989	7	WY big sagebrush, bluebunch wheatgrass	silt loam	yes	2700	mixed	6	0	0	0	Recruitment within, none outside of seeded area; low density of Immigrant; recruitment into playas and slick spots
80. Fort Carson; Colo. Springs, CO	1994	11	Pinion-juniper	gravelly fine sand	yes	5570	single	UD	5	2	10	Slight spread from initial plots
81. Yakima Training Center; Yakima WA	1994	6	WY big sagebrush, sandberg bluegrass	gravelly silt loam	no	1600	single	UD	10	3	15	Slight spread from initial plots

1/ Average annual precipitation.
2/ Soil surface texture.
3/ Seedbed prepared or soil disturbed before planting.
4/ Planted as single specie(s) or as a mixture (m) with other species.
5/ Percent composition within original Immigrant planting.
6/ Distance from original Immigrant planting boundary to recruitment fringe area.
7/ Percent composition in fringe area.
8/ FD, furthest distance a single Immigrant plant was found from original planting boundary.
9/ IPD, initial planting disturbed or plowed out.
10/ OPB, original planting boundary unknown.
11/ Aspect is listed when it might influence Immigrant adaptability.
12/ DAP, Disturbed around boundary of original planting.
13/ UD, unable to determine, generally space plants, single row seedings.
14/ Blowout area, 2-3 inches of soil lost from wind erosion.
15/ CD, cultivated or disturbed on three sides; north seeding of Immigrant joins south seeding on north side.

Table 2: Summarization of responses received from Interagency forage kochia questionnaire.

	Range/Categories	No. of responses		Range/Categories	No. of responses
Date of Planting	1980 or before	6	**Site-vegetation**	Mountain Brush	3
	1981 to 1985	7		Pinyon – Juniper	8
	1986 to 1990	27		Wy. Big Sagebrush	46
	1991 to 1995	57		Basin Big Sagebrush	3
	After 1995	52		Desert Shrub	21
	Did not answer	2		Salt Desert Shrub	5
				Blackbrush	4
				Did not answer	61
Agencies involved[1]	BLM	127	**Planting Method**	Drill	44
	NRCS	16		Aerial broadcast	50
	State (wildlife div.)	12		Ground broadcast	45
	ARS	6		Transplant	6
	Universities	4		Did not answer	6
States with Plantings	Utah	44	**Soil Types**	Light	25
	Nevada	56		Heavy	8
	Idaho	36		Medium	59
	Texas	3		Coarse	30
	Arizona	8		Saline/alkaline	4
	Oregon	3		Did not answer	29
	Washington	1			
Precipitation (inches)	≤ 6	7	**Elevation (feet)**	< 3000	3
	7 to 8	18		3000 to 3999	4
	9 to 10	54		4000 to 4999	14
	11 to 12	17		5000 to 5999	16
	13 to 14	7		6000 to 6999	3
	≥ 15	5		≥ 7000	1
	Did not answer	43		Did not answer	110
Single or multiple species seeding	Monoculture	10	**Planted after fire**	Yes	75
	Mixture	116		No	71
	Did not answer	25		Did not answer	5
Associated plant competition	Annuals	81	**Stand (Success of establishment)**	Poor	22
	Perennials	32		Fair	22
	No competition	2		Good	47
	Did not answer	65		Excellent	24
				Did not answer	36
Seed bed prepared/ soil disturbed	Yes	85	**Spread/ recruited outside planting**	Yes	14
	No	59		No	55
	Did not answer	7		Did not answer	82

[1]More than one agency was involved with planting.

Table 3: Species found associated with Immigrant.

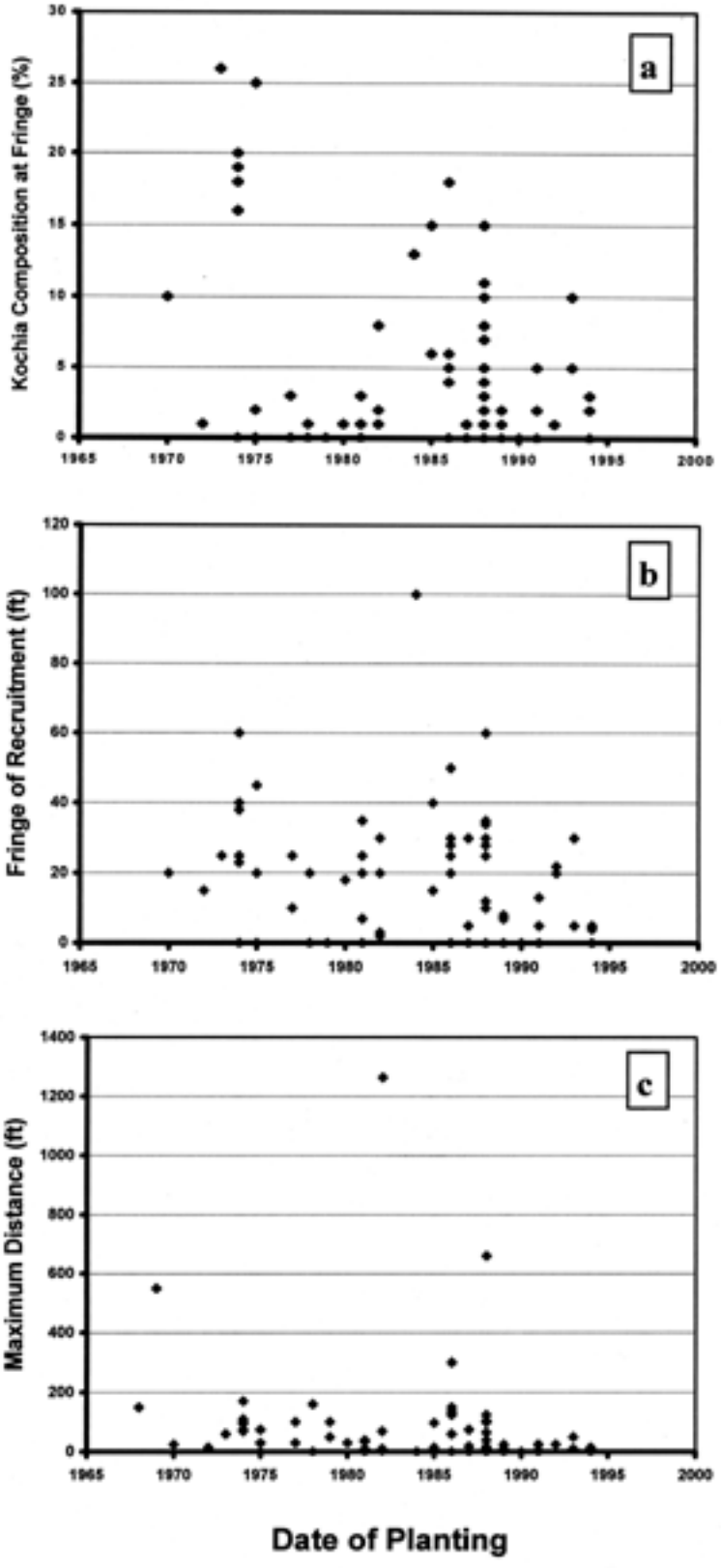
Lifeform	Origin	Commonly Used Names	Scientific Name
Forb	Introduced	Alfalfa	*Medicago sativa* L.
Forb	Introduced	Bur Buttercup	*Ranunculus testiculatus* Crantz
Forb	Introduced	Burnet	*Sanguisorba minor* Scop.
Forb	Introduced	Cicer milkvetch	*Astragalus cicer* L.
Forb	Introduced	Common Mustard	*Brassica campestris* L.
Forb	Introduced	Halogeton	*Halogeton glomeratus* (Bieb.) C. A. Mey
Forb	Introduced	Morning Glory	*Ipomoea purpurea* (L.) Roth
Forb	Introduced	Prickley Lettuce	*Lactuca serriola* L.
Forb	Introduced	Rush Skeleton Weed	*Chondrilla juncea* L.
Forb	Introduced	Russian Thistle	*Salsola iberica* Sennen & Pau
Forb	Introduced	Sainfoin	*Onobrychis viciifolia* Scop.
Forb	Introduced	Summer Cypress	*Kochia scoparia* (L.) Schrader
Forb	Introduced	Tansy Mustard	*Descurainia sophia* (L.) Webb in Engler & Prantl
Forb	Introduced	Tumble Mustard	*Sisymbrium altissimum* L.
Forb	Introduced	Yellow Salsify, Goatsbeard	*Tragopogon dubius* Scop.
Forb	Native	Aster	*Aster* spp.
Forb	Native	Common Globemallow	*Sphaeralcea coccinea* (Nutt.) Rydb.
Forb	Native	Daisy	*Erigeron* spp.
Forb	Native	Davis Pepperplant	*Lepidium davisii* Rollins
Forb	Native	Knotweed	*Polygonum aviculare* L.
Forb	Native	Lupine	*Lupinus caudatus* Kellogg
Forb	Native	Milkvetch	*Astragalus* spp.
Forb	Native	Papil Pepperplant	*Lepidium papilliferum* (L. F. Hend.) A. Nelson & J. F. Macbr.
Forb	Native	Penstemon	*Penstemon spp.*
Forb	Native	Prickley Pear Cactus	*Opuntia erinacea* Engelm. & Bigelow
Forb	Native	Senecio	*Senecio integerrimus* Nutt.
Forb	Native	Storks Bill	*Erodium cicutarium* (L.) L'Her. Ex Aiton
Forb	Native	Western Hawksbeard	*Crepis occidentalis* Nutt.
Forb	Native	Western Yarrow	*Achillea millefolium* L.
Forb	Native	Wild Onion	*Allium acuminatum* Hook.
Forb	Native	Yellow Sweetclover	*Melilotus officinalis* (L.) Pall.
Grass	Introduced	Bulbous Bluegrass	*Poa bulbosa* L.
Grass	Introduced	Cheatgrass	*Bromus tectorum* L.
Grass	Introduced	Crested Wheatgrass	*Agropyron cristatum* (L.) Gaertner and *A. desertorum* (Link) Schultes
Grass	Introduced	Intermediate Wheatgrass	*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey
Grass	Introduced	Kentucky Bluegrass	*Poa pratensis* L.
Grass	Introduced	Medusahead Rye	*Taeniatherum caput-medusae* (L.) Nevski
Grass	Introduced	Orchardgrass	*Dactylis glomerata* L.
Grass	Introduced	Red Brome	*Bromus rubens* L.
Grass	Introduced	Russian Wildrye	*Psathyrostachys juncea* (Fisch.) Nevski
Grass	Introduced	Siberian Wheatgrass	*Agropyron fragile* (Roth) P. Candargy
Grass	Introduced	Smooth Brome	*Bromus inermis* Leysser
Grass	Introduced	Tall Wheatgrass	*Thinopyrum ponticum* Z.-W. Liu & R. R.-C. Wang
Grass	Native	Big Bluegrass	*Poa ampla* Merr.
Grass	Native	Bluebunch Wheatgrass	*Pseudoroegneria spicata* (Pursh) A. Love
Grass	Native	Canby Bluegrass	*Poa secunda* subsp. *secunda* J. Presl
Grass	Native	Columbia Needlegrass	*Achnatherum lemmonii* (Basey) Barkworth

continued on next page

Table 3: Continued. . .

Lifeform	Origin	Commonly Used Names	Scientific Name
Grass	Native	Foxtail	*Hordeum jubatum* L.
Grass	Native	Galleta	*Pleuraphis jamesii* Torr.
Grass	Native	Great Basin Wildrye	*Leymus cinereus* (Scribn. & Merr.) A. Love
Grass	Native	Idaho Fescue	*Festuca idahoensis* Elmer
Grass	Native	Indian Ricegrass	*Achnatherum hymenoides* (Roem & Schult.) Barkworth
Grass	Native	Junegrass	*Koeleria macrantha* (Ledeb.) Schult.
Grass	Native	Muttongrass	*Poa fendleriana* (Steud.) Vasey
Grass	Native	Needle-and-Thread grass	*Hesperostipa comata* (Trin. & Rupr.) Barkworth.
Grass	Native	Nevada Bluegrass	*Poa nevadensis* Vasey ex Scribn.
Grass	Native	Oniongrass	*Melica bulbosa* Geyer ex Port. Coult
Grass	Native	Saltgrass	*Distichlis stricta* (Torr.) Rydb.
Grass	Native	Sand Dropseed	*Sporobolus cryptandrus* (Torr.) Gray
Grass	Native	Sandberg Bluegrass	*Poa secunda* Presl
Grass	Native	Squirreltail	*Elymus elymoides* (Raf.) Swezey
Grass	Native	Thickspike Wheatgrass	*Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould
Grass	Native	Thurbers Needlegrass	*Achnatherum thurberianum* (Piper) Barkworth
Grass	Native	Western Wheatgrass	*Pascopyrum smithii* (Rydb.) Barkworth & D.R. Dewey
Grasslike	Native	Sedge	*Carex* spp.
Moss	Native	Cryptogam (Lichen)	*Cryptogramma* spp.
Shrub	Introduced	Common Lilac	*Syringa vulgaris* L.
Shrub	Introduced	Forage Kochia	*Kochia prostrata* (L.) Schrad. var. *varescens* (Frenzl) Prat.
Shrub	Introduced	Gray Stem Forage Kochia	*Kochia prostrata* (L.) Schrad . var. *grisea* Prat.
Shrub	Native	Basin Big Sagebrush	*Artemisia tridentata* var. *tridentata* Nutt.
Shrub	Native	Blackbrush	*Coleogyne ramosissima* Torr.
Shrub	Native	Black Greasewood	*Sarcobatus vermiculatus* (Hook.) Torr.
Shrub	Native	Black Sagebrush	*Artemisia nova A.Nelson*
Shrub	Native	Bud Sagebrush	*Artemisia spinescens* D. D. Eaton
Shrub	Native	Desert Almond	*Prunus fasciculata (*Torr.) A. Gray
Shrub	Native	Falcata Saltbush	*Atriplex falcata* (M.E. Jones) Standl
Shrub	Native	Four-wing Saltbush	*Atriplex canescens* (Pursh) Nutt.
Shrub	Native	Fringed Sagebrush	*Artemisia frigida* Willid.
Shrub	Native	Green Rabbitbrush	*Chrysothamnus viscidiflorus* (Hook.) Nutt.
Shrub	Native	Horsebrush	*Tetradymia spinosa* Hook. & Arn.
Shrub	Native	Mormon Tea	*Ephedra viridis* Coville
Shrub	Native	Mountain Big Sagebrush	*Artemisia tridentata* Nutt. var. *vaseyana* (Rydb.) J. Boivin
Shrub	Native	Rubber Rabbitbrush	*Chrysothamnus nauseosus* (Pall.) Britton
Shrub	Native	Silver Sagebrush	*Artemisia cana* Pursh.
Shrub	Native	Shadscale	*Atriplex confertifolia* (Torr.) S. Watson
Shrub	Native	Snakeweed	*Gutierrezia sarothrae* (Pursh) Britton & Rusby
Shrub	Native	Snowberry	*Symphoricarpos longiflorus* A. Gray
Shrub	Native	Winterfat	*Krascheninnikovia lanata* (Pursh) A.D.J. Meeuse & Smit
Shrub	Native	Wyoming Big Sagebrush	*Artemisia tridentata* Nutt. var. *wyomingensis* (Beetle & A.M. Young) S.L. Welsh
Tree	Native	Birch-leaf Mountain Mohagany	*Cercocarpus montanus* Raf.
Tree	Native	Curl-leaf Mountain Mohagany	*Cercocarpus ledifolius* Nutt.
Tree	Native	Dixie Liveoak	*Quercus turbinella* Greene
Tree	Native	Gamble Oak	*Quercus gambelii* Nutt.
Tree	Native	Maple	*Acer* spp
Tree	Native	Pinyon Pine	*Pinus edulis* Engelm.
Tree	Native	Serviceberry	*Amelanchier alnifolia* (Nutt.) Nutt.
Tree	Native	Utah Juniper	*Juniperus osteosperma* (Torr.) Little

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



Field Photographs of Immigrant Forage Kochia

Figure 2: Immigrant and crested wheatgrass seeding at Lockman near Mountain Home, Idaho. Shallow stony loam site showing sandberg bluegrass providing high percent of ground cover. Center of picture shows tape used in field evaluation. (Site #69)

Figure 3: Eleven-year old Immigrant seeding showing recruitment into open areas of crested wheatgrass - Clear Spot blowout area near Kanosh, UT. (Site #26)

Figure 4: Nine-year old Immigrant test plot showing little spread at Twist Canyon research plots in Sevier County, near Salina, Utah. One plant was found 25 ft. from original planting. (Site #37)

Figure 5: East border of twelve-year old Immigrant and crested wheatgrass seeding at Lockman, near Moutain Home, Idaho. Immigrant had little spread on east side of seeding into cheatgrass. (Site #69)

Figure 6: Immigrant is the only surviving planted species at a Davis Spring research plot, planted in 1988, near Jensen, Utah. This greasewood-Wyoming big sagebrush site receives 7 in of rainfall and the soil is an akaline silt loam. (Site #32)

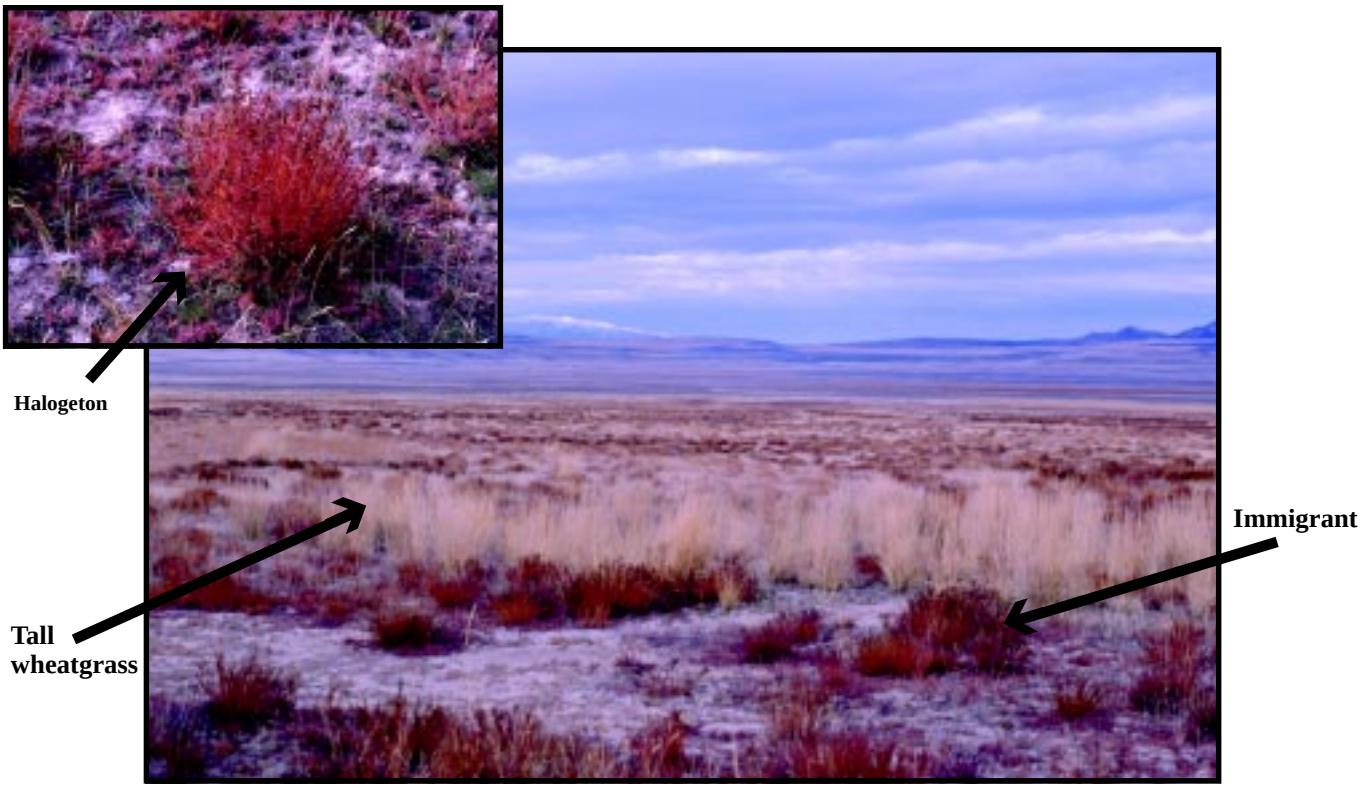


Figure 7: Tall wheatgrass and Immigrant seeding on a saline soil site. Part of the 4,000 acres on Robert Adams' seeding near Promontory, Utah. **Inset:** Immigrant is associated with western wheatgrass and has encroached into halogeton on a saline soil in the Adams' seeding.

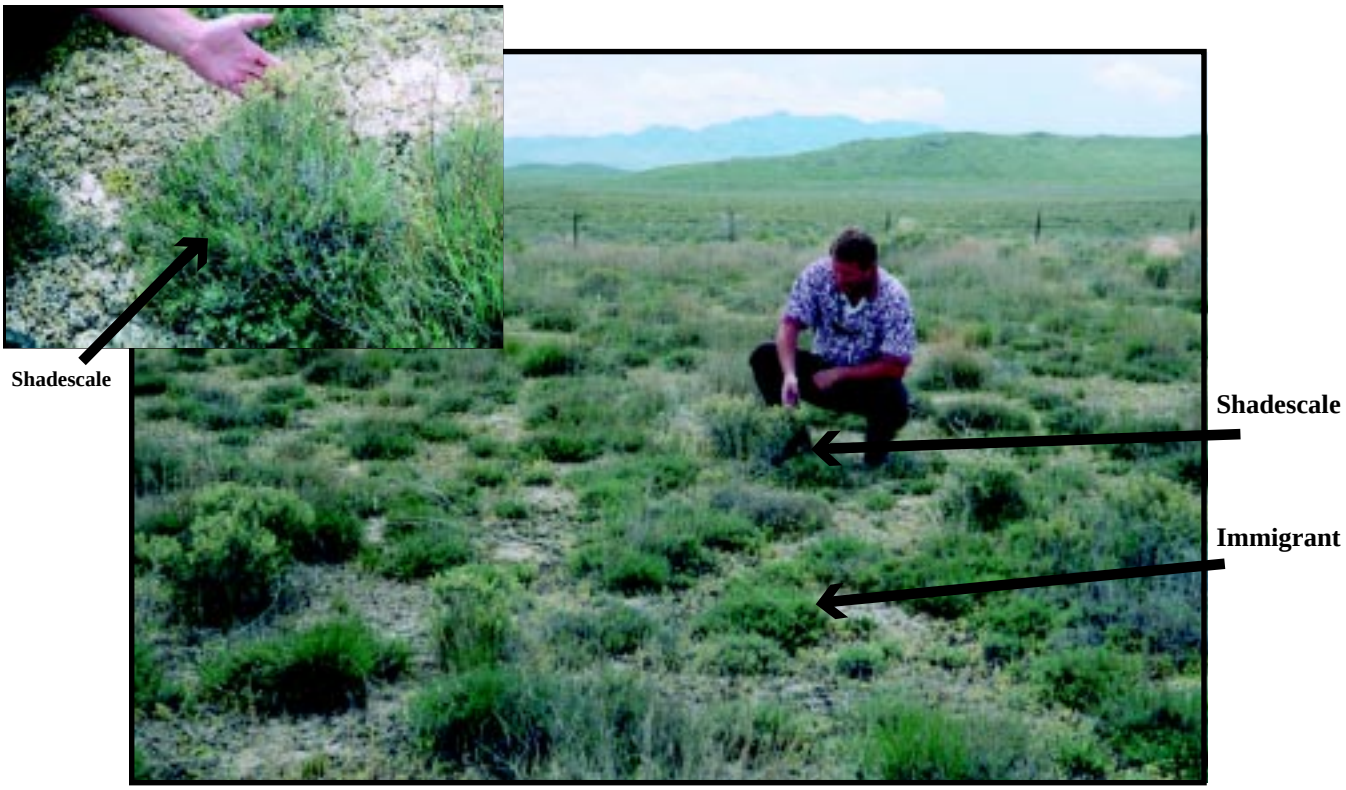


Figure 8: Shadescale has spread into a seventeen-year old test plot of Immigrant at Lambert site near Lakeside, Utah. In contrast, Immigrant had not spread into the adjoining shadescale plot. (Site #20)

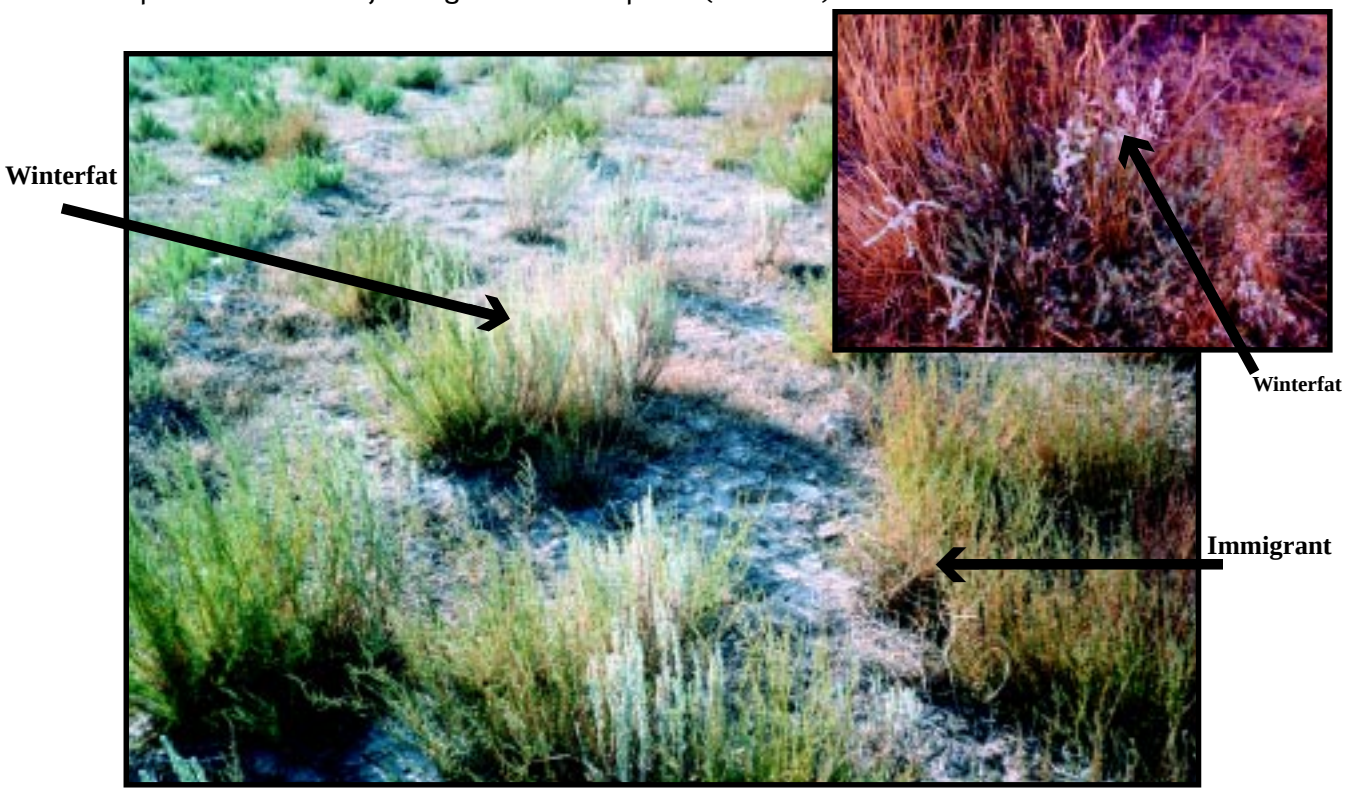


Figure 9: Winterfat and Immigrant growing together at the 1987 test plots at Clear Spot blowout area near Kanosh, Utah. **Inset:** Hatch winterfat invading an eleven- year old Immigrant plot at Trout Creek near Jackpot, Nevada. (Site #57)

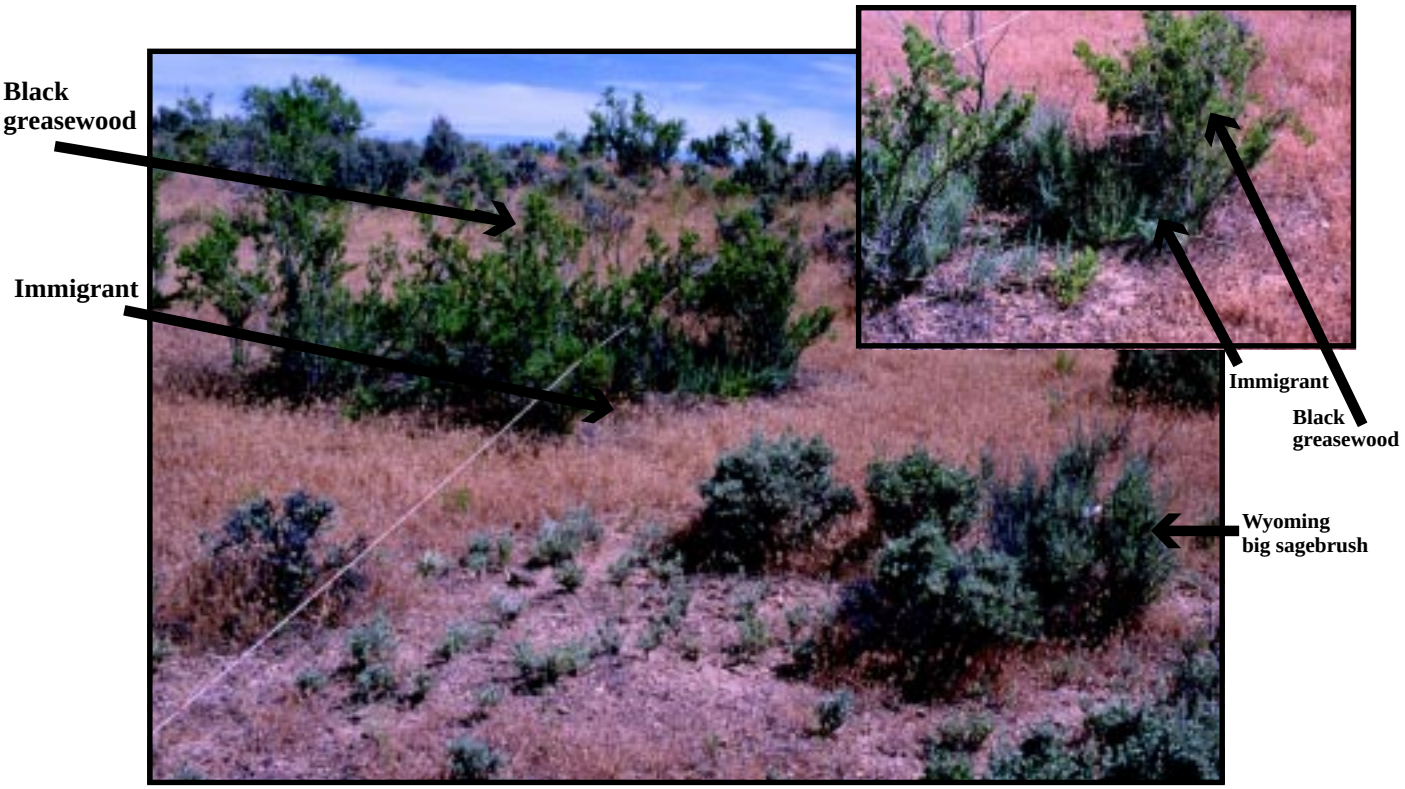


Figure 10: Biodiversity of black greasewood site. Black greasewood appears to favor establishment of Immigrant in the seventeen-year old seeding at White River Evacuation Creek near Bonanza, Utah. Note Wyoming big sagebrush with no Immigrant recruitment. (Site #24)

Figure 11: Eleven-year old Immigrant planting at Tract J-10, south of Jerome, Idaho airport. Immigrant recruitment into border of cheatgrass and mustard areas of native Wyoming big sagebrush native rangeland. (Site #73)

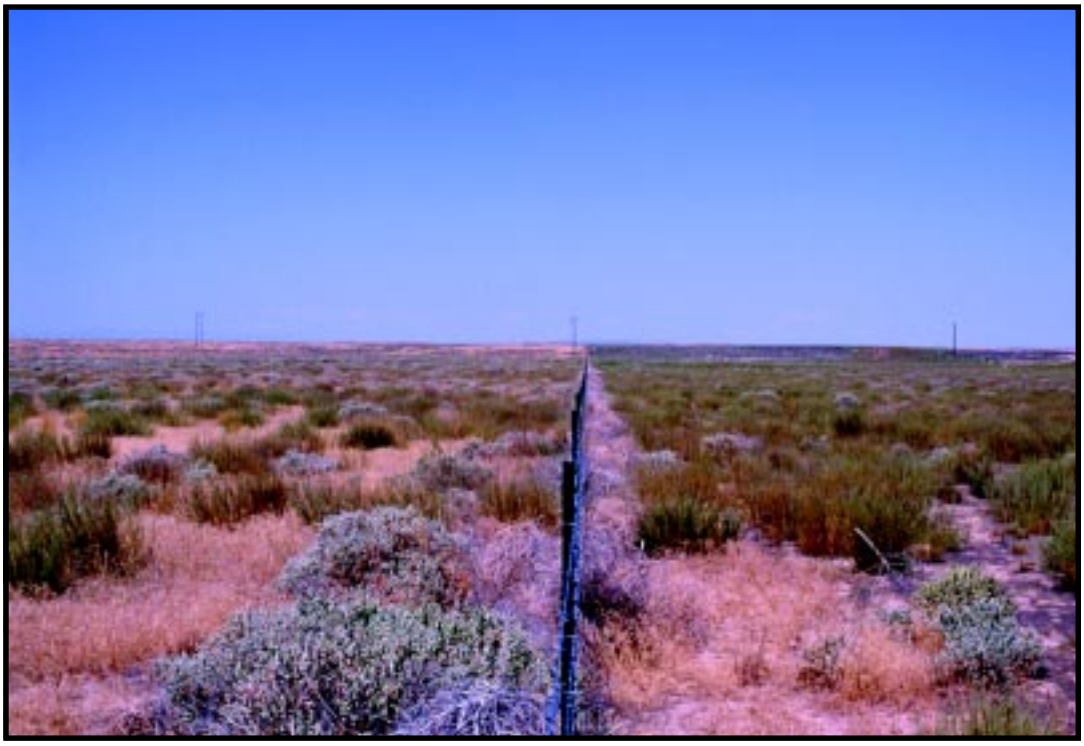


Figure 12: Recruitment of Immigrant and shadescale near twelve-year old Disk Chain seeding west of Moutain Home, Idaho. (Site #70)

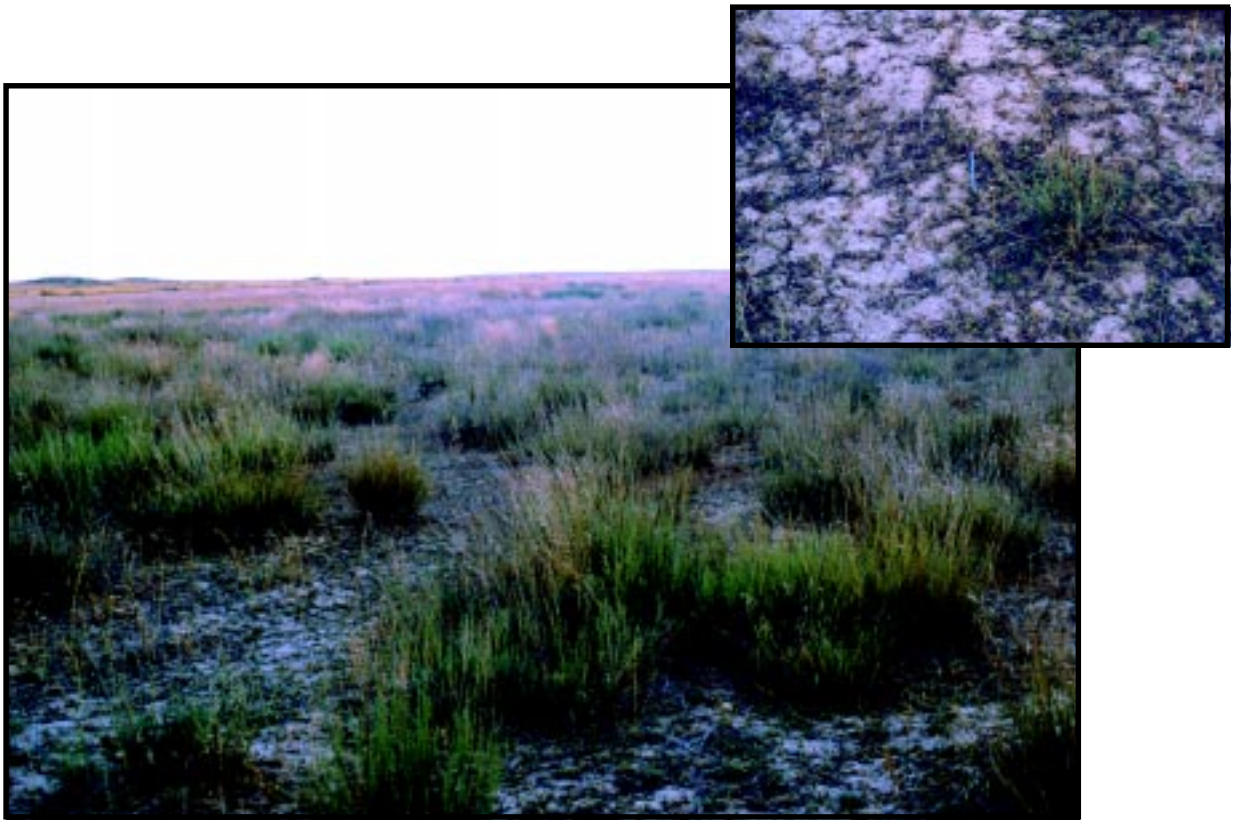


Figure 13: Immigrant competing with itself, numerous Immigrant seedlings become established each year but most die. Through this process, annuals, like cheatgrasss, are not able to become established in many Immigrant stands. Ten-year seeding near Shoshone Idaho. (Site #78)

Figure 14: Immigrant recruitment into a twenty-five year old planting at a black sagebrush site at Nine Mile Reservoir near Sterling, Utah. (Site #4)

Figure 15: Immigrant in association with galleta grass in a twentyfour-year old seeding at road cut near Redmond, Utah. **Inset:** Indian Ricegrass and Immigrant at the harsh site. (Site #6)

Figure 16: Crested wheatgrass juvenilles growing in individual Immigrant plants, Twist Canyon in Sevier County, near Salina, Utah. Eight-year old Immigrant and crested wheatgrass seeding. (Site #40) **Inset**: Six-year old planting, Dugway, Utah. (Site #44)

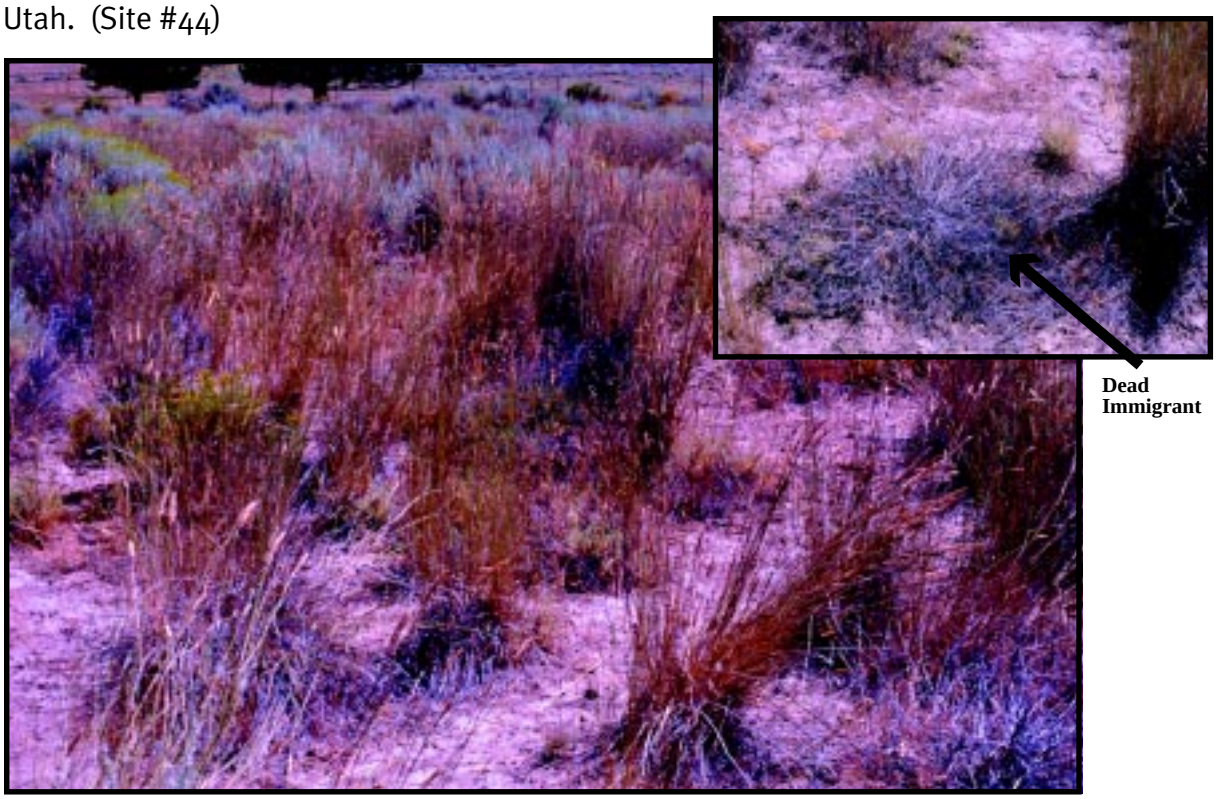
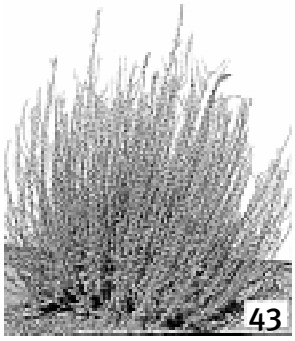
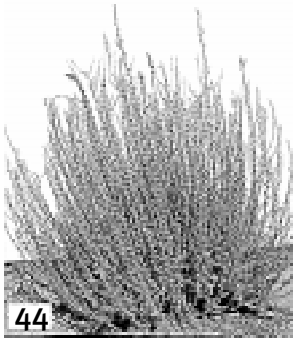


Figure 17: Encroachment of viscid rabbitbrush and crested wheatgrass in Immigrant seeding at the twentyeight-year old seeding, Squaw Butte Experimental Range near Burns, Oregon. (Site #70) **Inset:** Many dead Immigrant plants at this site.

ACKNOWLEDGMENTS

We appreciate the generous assistance from the many individuals who facilitated our field visits, answered questionnaires, and made recommendations for the study. This includes personnel from USDA Agriculture Research Service, Forest Service and Natural Resource Conservation Service, USDI Bureau of Land Management in AZ, ID, NV, OR, NM, UT, WA, and WY; State Divisions of Wildlife in ID, NV, and UT; and Brigham Young University, University of Idaho, Utah State University, the Utah Agricultural Experiment Station, Texas Agricultural Experiment Station, and Washington State University. A special thanks is given to individuals at the USDA Forest Shrub Sciences Laboratory in Provo, UT. This study was funded in part by the U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH.





APPENDICES

Appendix A: Questionnaire Sample

INTERAGENCY FORAGE KOCHIA SEEDING QUESTIONNAIRE
(Please Provide As Much Information as Possible by January 15 1998)

Date of seeding _____

Responsible Agency _____ Private Land Owner _____

Location _____ Name of Seeding _____

Section(s) _____ Range _____ and Township _____

Site Information - (ecological sites, soil, geology, climate, etc.)

Vegetation before seeding _____

Seeded immediately following a fire Yes _____ No _____

Seeding method: Drill _____ Broadcast _____ _____ Other_____
Ground Airplane

Seeding mixture (species and pounds per acre). _____ _____ _____

Seed (kind, source, etc.) _____

Condition of seedbed: _____ _____
prepared non-prepared

Uses made of seedings- Grazing _____, Erosion Control ____, Weed Control ____,
Green Stripping ____, Other (List) _____

Seeding results (Poor _____, Fair_____, Good _____, Excellent_____)

Competes well with: annuals _____ perennials _____

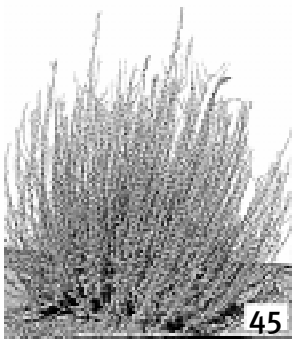
Spread from original seeding Yes___ No___ Distance _____

Information provided by _____

Address _____

Telephone _____

Please send Completed Questionnaire To:
R. Deane Harrison
USDA-ARS
Forage and Range Research Laboratory
Utah State University
Logan, UT 84322-6300
Telephone: (435)797-3066; FAX (435)797-3075



Appendix B. Listing and environmental description of all Immigrant plantings identified in questionnaires and/or on-site evaluations.

Site	Site Name[1]	Location	Quest.[2]	Agency[3]	Date[4]	Ppt. (in.)	Veget. Type[5]	Soil	Elev. (ft)	After Fire[6]	Planting Method[7]	Seed Mixture[8]	Seedbed prepared[9]	Stand[10]	Assoc. Plants[11]	Quest. Spread[12]
Locations used for on-Site Evaluations																
1.	Mouth of Green Canyon	Logan, UT	N	ARS	1968	18	WBS	Medium	4690	N	.	N	Y	.	.	.
2.	Snow College Field Station	Ephraim, UT	N	USFS	1969	11	BBS	heavy	5580	N	.	N	Y	.	.	.
3.	Steel Ranch	Mona, UT	N	UDWR	1972	18	MB	coarse	5900	N	.	Y	Y	G	ann. & per.	.
4.	Nine Mile Reservoir	Sterling, UT	N	USFS	1973	10	DS	medium	5400	N	broadcast	N	Y	G	annuals	.
5.	Redmond Junction	Redmond, UT	N	USFS	1974	10	DS	medium	5160	N	broadcast	Y	Y	G	annuals	.
6.	Redmond Road Cut, West and East Planting	Redmond, UT	N	USFS	1974	9	DS	coarse	5150	N	broadcast	N	Y	G	annuals	.
7.	Sterling - West Seeding	Sterling, UT	N	USFS	1974	12	WBS	coarse	5500	N	broadcast	N	Y	G	annuals	.
	Sterling - East Seeding	Sterling, UT	N	USFS	1974	12	WBS	coarse	5500	N	broadcast	N	Y	G	annuals	.
8.	Salina Canyon, I-70, mp# 57.8 (NS - SFS)	Salina, UT	N	USFS	1974	12	DS	medium	5670	N	.	N	Y	G	ann. & per.	.
9.	Salina Canyon, I-70, mp# 58 (NS - SFS)	Salina, UT	N	USFS	1974	12	WBS	coarse	5690	N	.	N	Y	G	ann. & per.	.
10.	Salina Canyon, I-70, mp# 76 (NS - SFS)	Salina, UT	N	USFS	1974	15	MB	coarse	7320	N	.	N	Y	F	ann. & per.	.
11.	Salina Canyon Mouth	Salina, UT	N	USFS	1975	11	SDS	heavy	5300	N	broadcast	Y	Y	G	annuals	.
12.	Salina Canyon, I-70, mp#60 (NS - SFS)	Salina, UT	N	USFS	1975	13	DS	medium	5750	N	.	N	Y	G	ann. & per.	.
13.	Salina Canyon, I-70, mp# 74 (NS - SFS)	Salina, UT	N	USFS	1975	14	MB	coarse	7220	N	.	N	Y	G	ann. & per.	.
14.	Nephi Canyon (SFS)	Nephi, UT	N	UDWR	1975	14	MB	coarse	5730	N	.	N	N	G	.	.
15.	South Salina	Salina, UT	N	USFS	1977	10	SDS	heavy	5200	N	.	Y	Y	G	ann. & per.	.
16.	First Planting Rush Valley	Rush Valley, UT	N	USFS	1977	10	SDS	medium	5100	N	trans	N	Y	G	ann. & per.	.
17.	Great Basin Expt. Range (WFS)	Ephraim, UT	N	UDWR	1979	12	PJ	light	5830	N	broadcast	Y	Y	G	annuals	.
18.	R. Mortenson	Ephraim, UT	N	UDWR	1979	11	SDS	heavy (saline)	5600	N	.	N	Y	G	ann. & per.	.
19.	Headquarters Site	Lakeside, UT	N	ARS	1981	7	DS	medium	4300	N	drill	N	Y	E	annuals	.
20.	Lambert Site	Lakeside, UT	N	ARS	1981	8	DS	medium	4400	N	.	N	Y	E	ann. & per.	.
21.	North Site	Lakeside, UT	N	ARS	1981	6	SDS	medium (saline)	4270	N	.	N	Y	F	annuals	.
22.	Nephi Experiment Station	Nephi, UT	N	USFS, UDWR	1981	15	BBS	heavy	5000	N	trans	Y	Y	G	per	.
23.	Mapco Pipeline Plots	Bonanza, UT	Y	BLM, Land Owner	1981	6	DS	coarse	5200	N	broadcast	N	Y	F	annuals	.
24.	White River Evacuation Creek	Bonanza, UT	N	BLM	1982	7	DS	medium	5900	N	.	N	Y	E	annuals	.
25.	South Manti	Manti, UT	N	USFS	1985	11	BBS	medium	5575	N	.	Y	Y	G	ann. & per.	.
26.	Clear Spot-East	Kanosh, UT	Y	ARS, NRCS, BLM	1987	7	DS	medium	4725	Y	drill	N	N	E	annuals	Y
27.	Upper Site (WFS)	Rush Valley, UT	N	USFS	1988	14	PJ	medium	5274	N	trans	N	Y	G	ann. & per.	.
28.	Middle Site	Rush Valley, UT	N	USFS	1988	10	DS	medium	5100	N	trans	N	Y	E	annuals	.

Appendix B. (continued)

Site	Site Name[1]	Location	Quest.[2]	Agency[3]	Date[4]	Ppt. (in.)	Veget. Type[5]	Soil	Elev. (ft)	After Fire[6]	Planting Method[7]	Seed Mixture[8]	Seedbed prepared[9]	Stand[10]	Assoc. Plants[11]	Quest. Spread[12]
29.	Lower Site	Rush Valley, UT	N	USFS	1988	8	SDS	medium (saline)	5044	N	trans	N	Y	F	ann. & per.	.
30.	Grantsville SCD	Grantsville, UT	Y	NRCS, GSCD	1988	11	DS	medium	4350	N	drill	N	Y	G	annuals	N
31.	Sandwash	Fruitland, UT	Y	NRCS	1988	10	WBS	medium	6740	N	drill	N	Y	G	ann. & per.	Y
32.	Davis Spring	Jensen, UT	N	ARS, USU, BLM	1988	7	SDS	medium (saline)	5100	N	.	N	Y	G	annuals	.
33.	Clear Spot-West	Kanosh, UT	Y	ARS, NRCS, BLM	1988	7	DS	medium	4725	Y	.	N	N	E	.	.
34.	Cedar Valley	Tooele County, UT	Y	BLM	1988	6	DS	medium	4800	Y	aerial	Y	N	F	per	.
35.	Negro Mag	Milford, UT	N	BLM	1988	10	WBS	coarse	5200	Y	aerial	Y	N	G	.	.
36.	Clarkston	Clarkston, UT	N	USU, ARS	1988	18	BBS	medium	5350	N	.	N	Y	G	ann. & per.	.
37.	Twist Canyon Plots	Sevier County, UT	N	BLM	1989	9	DS	heavy	5250	N	.	N	Y	G	ann. & per.	.
38.	White Rock-East Research Plots	Dugway, UT	N	ARS, USU, BLM	1989	7	DS	medium	4700	Y	.	Y	Y	E	.	.
39.	White Rock-Rydalch Junction	Dugway, UT	N	ARS, USU, BLM	1989	7	WBS	coarse	4800	Y	.	Y	Y	G	ann. & per.	.
40.	Twist Canyon Planting	Sevier County, UT	N	ARS, BLM	1990	8	WBS	coarse	5280	Y	drill	Y	Y	G	annuals	.
41.	Big Wash	Myton, UT	N	BLM	1990	7	DS	medium	5300	N	.	Y	Y	G	per	.
42.	Sandwash Fish & Game	Fruitland, UT	N	UDWR	1991	12	PJ	medium	7000	N	.	Y	Y	G	ann. & per.	.
43.	Upper ARS Plots	Dugway, UT	N	ARS, USA	1991	7	DS	medium	4800	Y	.	N	Y	G	annuals	.
44.	White Rock-Fire Research Plots	Dugway, UT	N	ARS, USU, BLM	1991	7	DS	coarse	4700	Y	broadcast	N	Y	E	annuals	.
45.	Lower ARS Plots	Dugway, UT	N	ARS, USA	1992	7	DS	light	4675	N	.	N	Y	G	annuals	.
46.	Dugway Base Planting	Dugway, UT	N	ARS, USA	1992	7	DS	medium	4700	N	drill	Y	Y	G	annuals	.
47.	Valcron	Myton, UT	N	BLM	1993	7	DS	coarse	5350	N	.	Y	Y	G	per	.
48.	Beryl	Beryl, UT	N	NRCS	1993	8	DS	medium	5300	N	drill	Y	N	F	ann. & per.	.
49.	Motoqua	Gunlock, UT	Y	BLM	1994	12	BB	coarse	4200	Y	aerial	Y	N	G	annuals	N
50.	Milford Bench	Milford, UT	Y	BLM	1994	9	WBS	coarse	5200	Y	.	Y	Y	E	annuals	.
51.	Headquarter Research Plots, Squaw Butte Expt. Range	Burns, OR	N	ARS	1970	12	WBS	medium	4488	N	.	N	Y	F	per	.
52.	Range 14, Squaw Butte Expt. Range	Burns, OR	N	ARS	1982	10	WBS	coarse	4488	N	.	Y	Y	G	per	.
53.	Saddle butte, Highway #205, Eastern Oregon Ag. Res. Center	Burns, OR	Y	ARS	1982	10	SDS	heavy (saline)	4116	N	.	N	Y	F	ann. & per.	.
54.	Narrows, Eastern Oregon Ag. Res. Center	Burns, OR	Y	ARS	1982	10	SDS	medium (saline)	4116	N	.	N	Y	F	ann. & per.	.
55.	Beacon Pit Mine	Battle Mt., NV	Y	BLM	1978	8	WBS	coarse	5200	N	.	N	Y	F	ann. & per.	.
56.	Paris Fire Rehab.	Wells, NV	Y	BLM	1986	8	WBS	coarse	6000	Y	broadcast	Y	Y	G	annuals	N
57.	Trout Creek (SS)	Jackpot, NV	Y	NRCS	1987	13	BBS	medium	5480	N	drill	N	Y	G	annuals	N
58.	McDermit	Currie, NV	Y	BLM	1987	8	DS	coarse	5900	Y	broadcast	Y	Y	G	ann. & per.	N
59.	Trout Creek	Elko, NV	N	BLM	1988	10	BBS	coarse	5800	N	.	Y	Y	F	ann. & per.	.
60.	Phalen Fire Rehab.	Wells, NV	Y	BLM	1988	11	PJ	coarse	6800	Y	broadcast	Y	N	G	per	N

Appendix B. (continued)

Site	Site Name[1]	Location	Quest.[2]	Agency[3]	Date[4]	Ppt. (in.)	Veget. Type[5]	Soil	Elev. (ft)	After Fire[6]	Planting Method[7]	Seed Mixture[8]	Seedbed prepared[9]	Stand[10]	Assoc. Plants[11]	Quest. Spread[12]
61.	Bell Rapids	Hagerman, ID	N	IDFG	1978	11	BBS	light	3490	N	drill	N	Y	G	annuals	.
62.	Texas Creek Wildlife Mgt Area (WS)	Ririe, ID	Y	IDFG	1980	18	MB	medium	7100	N	drill	Y	Y	E	per	Y
63.	Niagra Springs River Bottoms (SFS)	Wendell, ID	N	IDFG	1984	11	SDS	medium	3100	N	drill	Y	Y	G	annuals	.
64.	Niagra Springs Tract G-1	Wendell, ID	N	IDFG	1984	12	WBS	coarse	3400	N	drill	N	Y	G	annuals	.
65.	North Seeding Tract G-10	Burley, ID	Y	IDFG	1985	10	WBS	medium	4175	N	drill	Y	Y	E	ann. & per.	N
66.	Skaggs Ranch North Seeding	Malta, ID	N	USFS, BYU	1986	9	WBS	medium	4400	N	trans	Y	Y	G	per	.
67.	Skaggs Ranch South Seeding	Malta, ID	N	USFS, BYU	1986	9	WBS	medium	4400	N	drill	Y	Y	G	per	.
68.	RRMP Dr. Creek, I-84, mp#107, (ES)	Hemmett, ID	Y	BLM	1986	9	WBS	medium	3000	Y	drill	Y	Y	E	annuals	.
69.	Lockman, I-84, mp#87	Mountain Home, ID	Y	BLM	1986	9	WBS	coarse	3100	Y	drill	Y	Y	G	ann. & per.	.
70.	Disk Chain - Dorsey Butte	Grandview, ID	N	BLM	1986	7	DS	medium	2950	N	drill	Y	Y	G	ann. & per.	.
71.	Dorsey Butte	Grandview, ID	N	BLM	1986	7	DS	medium	2950	N	drill	Y	Y	E	annuals	.
72.	Simco Road	Mountain Home, ID	Y	BLM	1986	7	DS	medium	3000	N	drill	Y	Y	G	ann. & per.	.
73.	East of Airport Tract J-21	Jerome, ID	N	IDFG	1987	9	WBS	medium	3900	N	drill	Y	Y	G	annuals	.
74.	Orchard	Boise, ID	N	USFS	1987	10	WBS	medium	3130	N	.	N	Y	E	annuals	.
75.	Niagra Springs Tract J-18	Wendell, ID	N	IDFG	1988	12	BBS	medium	3400	N	drill	N	Y	G	annuals	.
76.	South of Airport Tract J-10	Jerome, ID	N	IDFG	1988	9	WBS	medium	3900	N	drill	Y	Y	G	annuals	.
77.	South Seeding Tract G-10	Burley, ID	N	IDFG	1988	10	WBS	medium	4175	N	drill	Y	Y	G	annuals	.
78.	Shoshone Wildlife	Shoshone, ID	Y	ARS	1988	10	WBS	medium	4230	N	broadcast	N	Y	E	annuals	N
79.	Swan Falls	Kuna, ID	Y	BLM	1989	10	WBS	medium	2700	N	drill	Y	Y	G	ann. & per.	.
80.	Fort Carson	Colo. Springs, CO	N	USA, ARS	1994	11	PJ	coarse	5570	N	broadcast	N	Y	F	annuals	.
81.	Yakima Training Center	Yakima, WA	N	USA, ARS	1994	6	WBS	coarse	1600	Y	broadcast	N	N	E	ann. & per.	.
Additional Sites Identified in Questionnaires																
82.	Central Ferry Research Farm	Central Ferry, WA	Y	ARS	1984	.	.	.	650	N	trans	Y	Y	.	.	N
83.	Big Wash Draw	Myton, UT	Y	BLM	.	.	.	.	.	N	broadcast	Y	Y	F	.	N
84.	Big Plains	Hillsdale, UT	Y	NRCS	1976	12	.	light	5500	N	drill	Y	Y	P	.	.
85.	Big Plains Irr.Trial	Hillsdale, UT	Y	NRCS	1977	20	.	light	5000	N	drill	Y	Y	F	.	Y
86.	Cliff Creek Davis Spring - Hwy 40 East	Jensen, UT	Y	BLM	1988	.	.	.	.	N	drill	.	Y	F	ann. & per.	Y
87.	Wells Draw	Myton, UT	Y	BLM	1988	.	.	.	.	N	drill	.	Y	P	.	N
88.	Aragagonite Toxic Waste	Tooele County, UT	N	Aragonite Co.	1992	7	DS	medium	.	N	drill	Y	Y	E	ann. & per.	.
89.	Meadow Spring Seeding	Lund, UT	Y	BLM	1992	.	.	medium	.	Y	drill	Y	Y	P	.	.
90.	North Sulpher	Garrison, UT	Y	BLM	1992	.	.	medium	.	Y	broadcast	Y	Y	G	annuals	N
91.	Three Mile Creek	Panguitch, UT	Y	BLM	1992	.	.	medium	.	Y	broadcast	Y	Y	G	annuals	.
92.	Bottom Fire Rehab.	Cove Fort - UT	Y	BLM	1993	.	.	light	.	Y	broadcast	Y	Y	E	ann. & per.	N
93.	Crickett Greenstripping	Filmore, UT	Y	BLM	1993	.	.	coarse	.	N	broadcast	.	N	P	.	N
94.	Rock House	Kanab, UT	Y	BLM	1993	.	.	light	.	Y	aerial	Y	N	P	.	.

Appendix B. (continued)

Site	Site Name[1]	Location	Quest.[2]	Agency[3]	Date[4]	Ppt. (in.)	Veget. Type[5]	Soil	Elev. (ft)	After Fire[6]	Planting Method[7]	Seed Mixture[8]	Seedbed prepared[9]	Stand[10]	Assoc. Plants[11]	Quest. Spread[12]
95.	Pahcoon #1	St. George, UT	Y	BLM	1993	.	.	.	.	Y	broadcast	Y	N	G	annuals	Y
96.	Dry Hollow Seeding	Antimony, UT	Y	BLM	1993	.	.	medium	.	Y	broadcast	Y	Y	G	annuals	.
97.	Black Rock Fire Rehab. Cove Fort, UT.	Millard County, UT	Y	BLM	1994	.	DS	.	.	Y	aerial	Y	Y	P	.	N
98.	Questar Pipeline- Junction Jesse Ewing	Vernal, UT	Y	BLM	1994	.	DS	.	.	N	broadcast	Y	Y	G	ann. & per.	N
99.	Post Hollow (SS Whiterock Rd.)	Tooele County, UT	Y	BLM	1994	.	DS	.	.	Y	broadcast	Y	N	F	annuals	.
100.	Inland Water line, Castle Peak Draw	Vernal, UT	Y	BLM	1995	.	DS	.	.	N	drill	.	Y	F	annuals	N
101.	Kitchen Canyon	Kanab, UT	Y	BLM	1995	.	.	light	5800	Y	aerial	.	Y	P	.	.
102.	Road and Oil Wel lRehab., Monument Butte -	Vernal, UT	Y	BLM	1995	.	DS	.	.	N	drill	.	Y	E	annuals	.
103.	Earthen Dam, Mouth of 5 Mile Canyon	Vernal, UT	Y	BLM	1995	.	.	.	.	N	broadcast	Y	Y	E	annuals	.
104.	Bracken Pond	Motoqua, UT	Y	BLM	1995	10	BB	coarse	.	Y	aerial	Y	N	P	.	N
105.	Marshall Well	Minersville, UT	Y	BLM	1995	14	PJ	heavy	.	Y	broadcast	Y	Y	G	annuals	.
106.	Plugged Oil Well Pad	Vernal, UT	Y	BLM	1996	.	DS	.	.	N	broadcast	.	Y	G	annuals	.
107.	North Narrows – Otter Creek HUA	Paiute County, UT	Y	NRCS, BLM	1996	.	.	coarse	.	.	drill	Y	Y	E	ann. & per.	Y
108.	Milford Pass and Pinnacle	Milford, UT	Y	BLM	1996	12	PJ	light	.	N	aerial	Y	Y	F	annuals	N
109.	Cedar Pockets	St George, UT	Y	BLM	1996	13	BB	coarse	.	Y	aerial	Y	Y	F	annuals	.
110.	Castledale Rehab. Project	Emery County, UT	Y	BLM	1997	9	SDS	coarse	.	N	drill	Y	Y	.	.	.
111.	Buckskin Wash Seeding (25 miles E of Kanab)	Kane County, UT	Y	BLM	1997	11	PJ	coarse	.	Y	drill	Y	N	P	.	.
112.	Honey Boy Aerial Seeding	Milford, UT	Y	BLM	1997	13	PJ	coarse	.	Y	aerial	Y	Y	G	.	N
113.	Cunningham	Beaver, UT	Y	BLM	1997	14	PJ	coarse	.	Y	aerial	Y	Y	G	.	N
114.	Twin Aerial Seeding	Beaver, UT	Y	BLM	1997	12	PJ	coarse	.	Y	aerial	Y	Y	E	.	N
115.	Black Ridge Drill & Aerial	Richfield, UT	Y	BLM	1997	9	WBS	light	.	Y	aerial	Y	N	.	ann. & per.	.
116.	Monticello	Monticello, UT	Y	NRCS	1997	.	.	.	.	N	drill	Y	Y	.	.	.
117.	Simpson Roundtop	Tooele County, UT	Y	BLM	1997	.	DS	.	.	N	aerial	.	N	.	.	.
118.	Swayback Knoll	Beaver, UT	Y	BLM	1998	.	.	light	.	N	drill	Y	Y	.	.	.
119.	Seaman Wash	Kanab, UT	Y	BLM	1998	11	.	light	.	Y	broadcast	Y	Y	.	.	.
120.	Pahcoon #2	St. George, UT	Y	BLM	1998	13	.	light	.	Y	aerial	Y	Y	.	.	.
121.	Ferguson Lease	Reagan County, TX	Y	TA E S	1984	.	.	heavy	.	N	trans	.	Y	G	ann. & per.	Y
122.	Shrub Observation Nursery	San Angelo, TX	Y	TA E S	1984	20	.	heavy	.	N	trans	.	Y	P	no	N
123.	Texas Range Station, Shrub Adapt. Nursery	TX	Y	TA E S	1988	20	.	heavy	.	N	trans	.	Y	E	ann. & per.	Y
124.	Vail Project	Vail, OR	Y	BLM	1992	9	.	light	.	N	drill	Y	Y	E	.	N
125.	Lone Tee Mine, Pumpernickle Valley	Ealcondo, NV	Y	BLM, ATSF	.	6	DS	medium	.	N	broadcast	Y	.	G	annuals	.
126.	Oasis Fire Rehab.	Big Springs Allot – NV	Y	BLM	1989	.	.	.	.	Y	broadcast	.	N	F	annuals	N
127.	Mud Springs	Elko County, NV	Y	BLM	1989	12	WBS	.	.	.	broadcast	Y	Y	G	annuals	N

Appendix B. (continued)

Site	Site Name[1]	Location	Quest.[2]	Agency[3]	Date[4]	Ppt. (in.)	Veget. Type[5]	Soil	Elev. (ft)	After Fire[6]	Planting Method[7]	Seed Mixture[8]	Seedbed prepared[9]	Stand[10]	Assoc. Plants[11]	Quest. Spread[12]
128.	Hycrott Mine Reclamation	Kamma mtns – NV	Y	BLM	1990	5	DS	coarse	.	N	broadcast	Y	Y	G	.	.
129.	Relief Cyn Mine	Packard Flat – NV	Y	BLM	1990	.	SDS	.	.	N	broadcast	Y	Y	F	annuals	.
130.	Midas EFR Seeding	Midas, NV	Y	BLM	1991	11	WBS	medium	.	Y	broadcast	Y	N	G	annuals	.
131.	Pinsum Mine	Osgood Mt., NV	Y	BLM	1991	9	WBS	medium	.	N	drill	.	Y	G	annuals	.
132.	Display Nursery	Paradise Valley – NV	Y	BLM	1991	6	DS	medium	.	N	drill	.	Y	G	.	.
133.	F-16 Crash Reclamation	Ely District – NV	Y	USAF, BLM	1991	9	DS	coarse	.	Y	broadcast	Y	Y	P	.	N
134.	Amax Mine Reclamation	Desert Valley – NV	Y	BLM	1992	6	DS	medium	.	N	broadcast	Y	Y	G	annuals	.
135.	Dunphy Hills Phase 1	Dunphy, NV	Y	NDOW, BLM, Newmont Gold Co.	1992	8	.	light	5000	N	.	Y	Y	E	annuals	N
136.	Little Humboldt Seeding	Midas, NV	Y	BLM	1993	9	.	medium	.	N	broadcast	.	N	P	.	.
137.	Evans Creek Seeding	Midas, NV	Y	BLM	1993	8	.	medium	.	N	broadcast	Y	N	P	.	.
138.	Willow Fire Rehab., Quinn River Valley	Orovada, NV	Y	BLM	1993	9	WBS	medium	.	Y	broadcast	Y	N	E	annuals	.
139.	Willow Fire Rehab., Quinn River Valley	Orovada, NV	Y	BLM	1993	9	WBS	medium	.	Y	drill	Y	N	E	annuals	.
140.	Willard Mine Reclamation	Humboldt Range – NV	Y	BLM	1993	.	DS	.	.	.	broadcast	.	Y	G	annuals	.
141.	Knoll Creek Seeding	Salmon River, NV	Y	BLM	1993	10	.	light	.	.	broadcast	Y	Y	G	.	N
142.	Dunphy Hills Seeding	Dunphy, NV	Y	Newmont Gold Co., BLM	1993	10	.	medium	.	N	broadcast	Y	Y	.	annuals	Y
143.	Roosters Comb-Phase1, Izzenhood	Battle Mtn., NV	Y	BLM, NDOW, Railroad	1993	8	.	light	4900	N	broadcast	Y	N	G	ann. & per.	N
144.	Newlands Expt. Stat. Seed Trial	Fallen, NV	Y	NRCS, NV state	1993	.	.	.	.	N	drill	Y	Y	G	annuals	Y
145.	Landen Seeding (22 Miles North Battle Mtn.)	Battle Mountain, NV	Y	BLM	1994	9	.	medium	.	N	broadcast	Y	N	.	.	.
146.	Moore Fire Rehab., Bloody Run Mountains	Winnemucca, NV	Y	BLM	1994	9	WBS	medium	.	Y	drill	Y	N	E	annuals	.
147.	Kimana Butte Greenstrip 375702	Paul, NV	Y	BLM	1994	10	WBS	coarse	.	N	aerial	Y	Y	.	.	.
148.	Roosters Comb-Phase2, Izzenhood	Battle Mtn., NV	Y	ATSF, NDOW, BLM	1994	8	.	light	4900	N	broadcast	Y	Y	G	ann. & per.	N
149.	Dunphy Hills-Phase 2	Dunphy, NV	Y	NDOW, Newmont Gold Co., BLM	1994	8	.	light	4900	N	broadcast	Y	Y	E	ann. & per.	N
150.	Moore Fire Rehab.	Bloody Run Mtns – NV	Y	BLM	1995	10	WBS	.	.	Y	aerial	Y	N	E	.	.
151.	Dunphy Hills-Phase 3	Dunphy, NV	Y	NDOW, Newmont Gold Co., BLM	1995	9	.	light	4900	N	broadcast	Y	Y	E	annuals	N

Appendix B. (continued)

Site	Site Name[1]	Location	Quest.[2]	Agency[3]	Date[4]	Ppt. (in.)	Veget. Type[5]	Soil	Elev. (ft)	After Fire[6]	Planting Method[7]	Seed Mixture[8]	Seedbed prepared[9]	Stand[10]	Assoc. Plants[11]	Quest. Spread[12]
152.	Frenchie Flat Aerial	Crecent Valley – NV	Y	BLM	1996	.	.	.	.	Y	aerial	.	N	P	annuals	N
153.	Kings Fire Rehab., Kings River Valley	Orovada, NV	Y	BLM	1996	9	WBS	medium	.	Y	aerial	Y	N	P	.	.
154.	Thacker Fire Rehab., Kings River Valley	Orovada, NV	Y	BLM	1996	8	WBS	medium	.	Y	aerial	Y	.	F	.	.
155.	Gold Quarry Complex	Carlin, NV	Y	BLM	1996	.	WBS	coarse	.	Y	aerial	Y	N	.	annuals	N
156.	NevadaLland & Resource (N of Battle Mtn, NV)	Battle Mountain, NV	Y	BLM	1996	.	.	medium	.	N	broadcast	Y	Y	F	.	N
157.	Gold Quarry Complex	Carlin, NV	Y	BLM	1996	10	.	coarse	.	Y	aerial	.	N	G	annuals	N
158.	Flat Creek Fire Rehab., Santa Rosa Mountain	Orovada, NV	Y	BLM	1996	.	.	.	.	Y	aerial	Y	N	.	.	.
159.	Three Mile Fire Rehab.	Santa Rosa Mountain – NV	Y	BLM	1996	11	WBS	medium	.	Y	aerial	Y	N	.	.	.
160.	Izzenhood Arial Fire Rehab.	Izzenhood – NV	Y	ATSF, NDOW, BLM	1996	9	WBS	coarse	5300	Y	aerial	Y	N	G	ann. & per.	N
161.	NW Izzenhood-Phase 1	Izzenhood – NV	Y	ATSF, NDOW, BLM	1996	8	.	light	5000	N	broadcast	Y	Y	E	annuals	N
162.	Kings River Rehab., Bilk Creek Mountains	Orovada, NV	Y	BLM	1997	11	BBS	medium	.	Y	aerial	Y	N	.	annuals	.
163.	Bloody Run Rire Rehab.	Winnemucca, NV	Y	BLM	1997	10	WBS	medium	.	Y	aerial	Y	N	.	.	.
164.	Division Canyon Seeding	Montello, NV	Y	BLM	1997	.	MB	light	.	Y	aerial	.	N	G	annuals	N
165.	Sentinel Fire Rehab., Montana Mts.	Orovada, NV	Y	BLM	1997	.	.	.	.	Y	drill	Y	.	.	.	.
166.	Dutch Flat Fire Rehab.	Osgoods & Hotspring mts., NV	Y	BLM	1997	.	BBS	.	.	.	aerial	Y	N	.	.	.
167.	Quinn Odell Fire Rehab.	Owyhee desert – NV	Y	BLM	1997	9	WBS	medium	.	Y	aerial	Y	.	G	.	.
168.	Palisade Aerial Seeding	Palisade, NV	Y	BLM	1997	12	.	coarse	.	Y	aerial	.	N	G	annuals	N
169.	Buffalo Fire Rehab., Pumpernickle Valley	Ealcondo, NV	Y	BLM	1997	6	.	medium	.	Y	drill	Y	.	P	.	.
170.	Buffalo Fire Rehab., Quinn River Valley	Orovada, NV	Y	BLM	1997	9	WBS	medium	.	Y	drill	Y	N	G	.	.
171.	Winnemucca Mtn Fire Rehab.	Winnemucca, NV	Y	BLM	1997	.	.	.	.	Y	aerial	Y	N	.	.	.
172.	NW Izzenhood-Phase II	Izzenhood – NV	Y	ATSF, NDOW, BLM	1997	8	.	light	5000	N	broadcast	Y	Y	.	.	.
173.	Bobs Flat 5800 Acres	Tuscurora River – NV	Y	NDOW, Newmont Gold Co., BLM	1997	10	.	coarse	5400	Y	aerial	Y	N	G	annuals	N
174.	Bobs Flat 5000 Acres	Immigrant, NV	Y	NDOW, Newmont Gold Co., BLM	1997	8	.	light	5250	N	broadcast	Y	Y	.	.	.
175.	Sentinel Fire Rehab. Quinn River Valley	Orovada, NV	Y	BLM	1997	9	.	medium	.	Y	drill	Y	.	.	.	.

Appendix B. (continued)

Site	Site Name[1]	Location	Quest.[2]	Agency[3]	Date[4]	Ppt. (in.)	Veget. Type[5]	Soil	Elev. (ft)	After Fire[6]	Planting Method[7]	Seed Mixture[8]	Seedbed prepared[9]	Stand[10]	Assoc. Plants[11]	Quest. Spread[12]
176.	Humboldt Fire Rehab., Snowstorm Mountains	Midas, NV	Y	BLM	1997	.	WBS	.	.	Y	aerial	Y	N	.	.	.
177.	Gal-Mesa Verde Coal Flood	Gallup, NM	N	USFS	1973	12	.	coarse	.	.	.	.	.	G	.	.
178.	Isolated Tract	Shoshone, ID	Y	BLM	1988	8	WBS	medium	.	N	drill	Y	N	E	ann. & per.	N
179.	Wildhorse Project 88	Deitrich, ID	Y	BLM	1988	10	WBS	medium	.	N	drill	.	Y	G	.	.
180.	Bray Lake	Bliss, ID	Y	BLM	1990	.	.	.	.	Y	aerial	.	N	G	ann. & per.	N
181.	Indian Springs Fire Rehab. - South Hills	Twin Falls, ID	Y	BLM	1990	12	WBS	medium	.	Y	drill	Y	N	F	.	N
182.	Wildhorse 90	Richfield, ID	Y	BLM	1990	10	WBS	medium	.	N	aerial	Y	Y	G	ann. & per.	.
183.	Halfway Lake Greenstrip 375595	Richfield, ID	Y	BLM	1991	10	.	coarse	.	N	drill	Y	Y	F	.	.
184.	Timmerman Hill Supplemental	Shoshone, ID	Y	BLM	1991	10	WBS	medium	.	N	drill	Y	Y	G	ann. & per.	.
185.	Wildhorse 91	Richfield, ID	Y	BLM	1991	10	WBS	medium	.	N	aerial	Y	Y	G	ann. & per.	.
186.	Thorn Creek Fire Rehab.	Shoshone, ID	Y	BLM	1991	.	WBS	.	.	Y	aerial	Y	N	G	ann. & per.	N
187.	LA Sharp Expt. Station	Malta, ID	Y	Univ. of Id.	1991	.	.	medium	.	N	broadcast	Y	Y	G	ann. & per.	Y
188.	Hawley Fire Rehab.	Minidoka, ID	Y	BLM	1992	10	WBS	medium	.	Y	broadcast	Y	N	F	.	N
189.	Cassia Gulch	Bliss, ID	Y	BLM	1992	9	WBS	medium	.	Y	aerial	Y	Y	.	annuals	.
190.	Burley North	Burley, ID	Y	BLM	1993	10	WBS	medium	.	N	broadcast	Y	N	P	.	N
191.	Black Ridge Fire Rehab.	Richfield, ID	Y	BLM	1993	10	WBS	medium	.	Y	aerial	Y	N	G	ann. & per.	.
192.	Coffee Point Inter-Cen	Aberdeen, ID	Y	NRCS, BLM	1994	.	.	.	.	N	drill	.	Y	F	.	N
193.	Poen	Kuna, ID	Y	BLM	1994	9	WBS	medium	.	Y	drill	Y	N	.	annuals	.
194.	Squaw Creek	Mountain Home, ID	Y	BLM	1995	9	WBS	light	.	Y	aerial	Y	.	.	annuals	.
195.	Poen	Kuna, ID	Y	BLM	1995	9	WBS	medium	.	Y	aerial	Y	Y	.	annuals	.
196.	Alkali	Shoshone, ID	Y	BLM	1996	10	WBS	heavy	.	Y	drill	Y	N	.	annuals	.
197.	Camp 1 Fire Rehab	Dietrich, ID	Y	BLM	1996	10	WBS	medium	.	Y	aerial	Y	N	P	.	Y
198.	Laidlow Fire Rehab	Richfield, ID	Y	BLM	1996	10	.	coarse	.	Y	aerial	Y	N	P	.	.
199.	Initial Point	Kuna, ID	Y	BLM	1996	8	WBS	medium	.	Y	aerial	Y	Y	.	annuals	.
200.	Canal Fire Rehab.	Wendell, ID	Y	BLM	1996	10	.	light	.	Y	aerial	Y	N	.	.	.
201.	Indian Allotment Fire Rehab.	Bliss, ID	Y	BLM	1996	10	.	medium	.	Y	aerial	Y	N	F	ann. & per.	N
202.	Rattlesnake	Mountain Home, ID	Y	BLM	1997	9	WBS	medium	.	Y	aerial	Y	Y	.	annuals	.
203.	Cove	Bruneau, ID	Y	BLM	1997	8	WBS	medium	.	Y	aerial	Y	N	.	annuals	.
204.	Queens Crown Fire Rehab.	Carey, ID	Y	BLM	1997	16	MB	medium	.	Y	aerial	Y	N	.	.	.
205.	Santa Rita Expt. Range	Tucson, AZ	Y	NRCS	1975	11	.	light	3000	N	drill	Y	N	.	.	N
206.	Kochia Ecotype Eval.	Tuscon, AZ	Y	NRCS	1977	11	.	light	2200	N	trans	Y	Y	F	.	N
207.	Sulpher Springs Valley	Douglas, AZ	Y	Land owner	1987	12	.	coarse	.	N	drill	.	Y	P	.	N
208.	Kaibab-Paiute Field	Fredonia, AZ	Y	NRCS	1994	10	.	heavy	4600	N	drill	.	N	P	no	N
209.	Jefters Plot	Holbrook, AZ	Y	NRCS	1994	9	DS	medium (saline)	5230	N	trans	Y	N	P	.	N
210.	Dutchman/Cottonwood	Arizona strip – AZ	Y	BLM	1996	.	BB	coarse	.	N	drill	Y	N	.	.	.
211.	Irrigated Kochia-Seed Production	Woodruff, AZ	Y	NRCS	1996	9	SDS	heavy (saline)	5000	N	broadcast	Y	Y	E	.	Y
212.	Shoebuckle, Sullivan Tank Allotment	Arizona Strip – AZ	Y	BLM	1997	14	PJ	coarse	.	N	aerial	Y	N	.	.	.

Appendix B. (continued)

1/ Abbreviations used in Site name/description: I=Interstate Highway, mp#=mile post number, SFS=south facing slope, WSF=west facing slope, NS=north side, SS=south side, WS=west side, and ES=east side.
2/ Location identified by questionnaire (Y=yes, N=no).
3/ Agency responsible for establishment (ARS=USDA Agricultural Research Service, USFS=USDA Forest Service, UDWR=Utah Div. of Wildlife Resources, BLM=USDI Bureau of Land Management, NRCS= USDA Natural Resources Conservation Service (formerly Soil Conservation Service), GSCD=Grantsville Soil Conservation District, USU=Utah State Univ., USA=United States Army, IDFG=Idaho Dept. of Fish and Game, BYU=Brigham Young Univ., Texas Ag. Expt. Stat.=Texas Agriculture Experiment Station, USAF=United States Air Force, NDOW=Nevada Division of Wildlife, and ATSF=Atchison, Topeka, and Santa Fe Railroad).
4/ Year of establishment.
5/ Vegetative Site description (MB=Mountain Brush, PJ=Pinyon-Juniper, WBS=Wyoming Big Sagebrush, BBS=Basin Big Sagebrush, DS=Desert Shrub, SDS=Salt Desert Shrub, and BB=Blackbrush).
6/ Established after fire (Y=yes, N=no).
7/ Planting method (broadcast=ground broadcast, aerial=aerial broadcast, drill=drilled, and trans=transplanted).
8/ Seeded as a mixture versus monoculture (Y=mix, N=monoculture).
9/ Seedbed prepared or soil disturbed before establishment (Y=yes, N=no).
10/ Establishment success [rated as poor (P), fair (F), good (G), or excellent (E)].
11/ Growth habit of primary competitive vegetation.
12/ Spread as reported by questionnaire responses (Y=yes, N=no).

Appendix C: Immigrant Seeding Recommendations

Based on a review of the literature, personal communications with researchers and land managers, and on the expertise of the authors we make the following recommendations:

Timing:

Planting Immigrant on rangelands is recommended in late fall or early winter when surface moisture is present. Excellent seedling establishment occurs following broadcasting of seeds in winter months on snow or just prior to snowfall. Spring sowing generally gives negative results.

Planting Methods:

Immigrant is successfully seeded by broadcasting or drilling and by transplanting. The best results are often obtained by broadcasting current years seed on the top of disturbed soil during winter months with or without covering the seed. Aerial broadcasting from an altitude of 165-230 ft with a wind velocity of less than 13 ft per second are recommended. Two flights may be necessary to get proper coverage. In some instances successful stands have been established on undisturbed soil. Immigrant establishes best when pressed onto the soil surface of seedbeds rather than buried in the soil. Immigrant seed should not be drilled deeper than 1/8 in. Alternate row seeding may increase Immigrant's longevity when planted with crested wheatgrass.

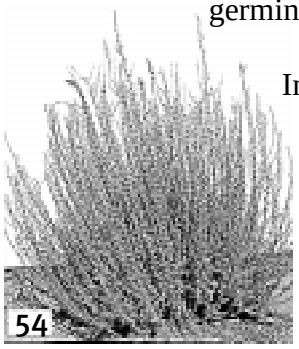
Seedbed Preparation and Site Condition:

A clean, weed-free seedbed improves the likelihood of seeding success. In order to obtain a successful stand, it is usually necessary to reduce or eliminate competition prior to seeding. Competition from annuals like cheatgrass often reduces or prevents seedling establishment. Cheatgrass can be controlled with chemicals or through disking prior to the phenological plant boot development stage.

Excellent stands are obtained when seeding is done on burned areas followed by mild soil treatment such as culti-packing. Success is also obtained following a burn with no soil treatment. The poorest results are obtained on sites that receive no treatment. Adding nitrogen will increase germination.

Seed Characteristics/Concerns:

Forage kochia seeds are dormant immediately after harvest and require a period of 4 to 6 months to break dormancy. There is no known successful method to eliminate or shorten this after harvest ripening period. However, germination may be enhanced by imbibing in a cold-moist environment. No after ripening or cool moist pretreatment requirements is needed for seeds to germinate in the spring a few months following harvest. Seeds may germinate over a 30- to 40-day period and will sprout without embedding.



Immigrant seed loses its viability rapidly, generally within 5-7 months, if not properly stored, therefore, one should plant current year seed when possible. It is also important to have a current germination test. However, seed that has been properly dried to 7% moisture or less, and

stored at 36 to 50ºF (2.2 to 10ºC) in air tight containers may retain up to 55% germination 3 years after storage.

Poor stand establishment has been associated with low seed viability, seeds are too small, unprepared seedbeds, competition from already established vegetation including annuals like cheatgrass, planting too deep, improper time of seeding or unsuitable environments. Seed cleaning and sizing to remove small seeds and then planting only the larger mature seeds increases percent germination and seedling establishment. The viability of seeds, survival rate of plants and finally the yield of forage kochia will depend upon the weight and size of the seed.

Seeding Rates:

For rangeland seeding we recommend 1/4 lb to 1 lb per acre of Immigrant in a mixture of grasses, forbs and other shrubs. If a mixture of grasses, forbs and Immigrant are desired, the grasses and forbs should generally be drilled and the Immigrant broadcast. There are approximately 115,000 pure live seeds per lb. One would target 400 to 1200 plants per acre. When planting Immigrant, as a single species (monoculture) for green stripping, we recommend 3 lbs per acre. A study at White Rock, near Dugway, UT, showed the 3 lbs per acre seeding rate, produced much less fuel and had a greater ground cover than when planted at 1 lb per acre.

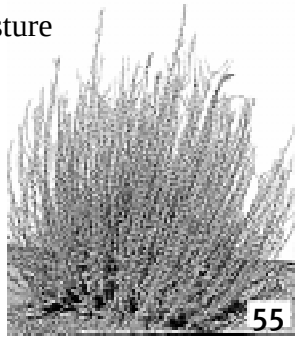
When Immigrant is planted for seed production, seeds should be broadcast at a rate of 1 lb (pure live seed) per acre and transplants should be planted 1 ft apart in 3 ft rows. Spring planting may be problematic and is only recommended if irrigation is available.

Appendix D: Recommendation for Harvesting and Storing Immigrant Seed

Immigrant is a prolific seed producer and when growing conditions are optimum it may bear seed the first year. Plants are generally in full seed production at 3 years of age. Seed is usually harvested in late October and November after a heavy frost. However, seed bearing plants can be cut and swathed prior to frost and allowed to dry.

Depending on environmental conditions, Immigrant may produce a large amount of seed under rangeland conditions. When grown under cultivation and irrigation at the Snow-field Station, Ephraim, UT, Immigrant produced an average of 1532 lbs per acre clean seed over an 8 year period. Seed production generally tapers off when Immigrant plants become 5 or 6 years old. The application of nitrogen greatly increases seed production.

Seed should be reduced to 7% or less moisture, placed in air and moisture tight containers, and stored in cold storage 36 to 50ºF (2.2 to 10ºC). The viability of properly stored Immigrant seed may have up to 55% germination after 3 years. However, seed stored in open containers in an area with fluctuating temperatures loses most of its viability in 5-7 months.



Appendix E: Forage Kochia Germplasm Collection Expedition to Russia and Kazakhstan (October 2-28, 1999)

U.S. Participants:

Blair L. Waldron - Research Geneticist, USDA - Agricultural Research Service, Logan, Utah U.S.A.

R. Deane Harrison - Range Scientist, Utah State University, Logan, Utah

Russia and Kazakhstan Participants:

Nicolai Dzyubenko - Head of Forage Crops Research, N. I. Vavilov Research Institute of Plant Industry, St. Petersburg, Russia

Sergey Alexanian - Director of Foreign Relations, N. I. Vavilov Research Institute of Plant Industry, St. Petersburg, Russia

Sergey Shuvalov - Assist. Director and Interpetor, Foreign Relations Department, N. I. Vavilov Rearch Institute of Plant Industry, St. Petersburg, Russia

Auskhan Khusainov - Director, Aral Sea Experiment Station for Plant Genetic Resources, Chelkar, Kazakhstan

Purpose of Trip

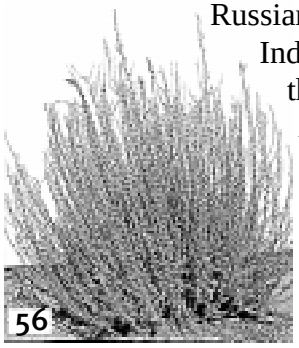
1. To expand the U. S. germplasm base of forage kochia (*Kochia prostrata*).

2. To make a collection of forage kochia ecotypes which would have the potential to be used in the development of a valuable summer, fall and winter forage. Private landowners have recently taken an interest in utilizing forage kochia for livestock forage, however, Immigrant, the only North American forage kochia cultivar, has limited winter use because of its low stature.

3. To develop contacts and improve interactions for germplasm exchange and related agricultural research with scientists and administrators associated with N. I. Vavilov Institute of Plant Industry at St Petersburg, Russia and the Aral Experimental Station of Genetic Resources of Plants at Chelkar, Kazakhstan.

Collection Details

Forage kochia germplasm was collected on 64 sites in Kazakhstan. The collection area included the area from Chelkar in the south to Karabutak in the north and Irgiz in the east. These areas are in the Clay and Sand Deserts which includes the Brown Desert Steppe, Light Chestnut Steppe, Degraded Solonetz and Solonetz (Atlas of Agriculture of the USSR. 1960. Chief management for geodesy and cartography. Moscow, Russia [In Russian.]) According to scientists from the N. I. Vavilov Institute of Plant Industry these areas have the highest concentration of forage kochia in the former Soviet Union. Plant associations include the following: *Agropyron - Stipa - Artemisia*; *Artemisia terrae-albae*; *Artemisia terrae-albae - Krascheninnikovia* (*Ceratoides*); *Artemisia - Salsola - Kochia*; *Atriplex- Anabasis -Artemisia*; *Artemisia - Anabasis*; and

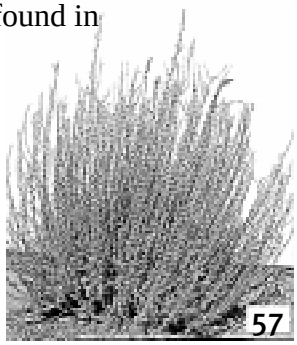


Anabasis. Soil surface textures found included sands, fine sands, sandy loam, sandy clay loam, silt loam, clay loam, clay, and gravelly and cobbley. Most soils in the Clay Desert had a clay loam or clay subsoil and were generally saline and alkaline. The Solonetz sites had extremely high concentrations of alkali and salt. The subsoil in the Sandy Desert was mainly sand to fine sand. Elevations ranged from 250 feet near the city of Irghiz to 1000 feet above sea level north of Karabutak. Annual precipitation, averaged over 14 to 43 years, list Chelkar receiving 6 to 9 inches, Irgiz receiving 6 to 8 inches, and Karabutak receiving 10 to 12 inches (Climate of the U.S.S.R. 1968. No. 18. Part H. Kazakhstan SSR. Air humidity, precipitation, snow cover. Leningrad, Russia [In Russian]; Agricultural management in the Aktyubinsk region. 1958. Kazgosizdat. Alma-Ata, Kazakhstan [In Russian]). Average air and soil surface temperatures at Chelkar are 41.9º F and 46.4º F, respectively; at Irghiz 41.5º F and 44.6º F, respectively; and at Karabutak 37.3º F and 41.0º F, respectively (Climate of the U.S.S.R. 1968. No. 18. Part H. Kazakhstan SSR. Air humidity, precipitation, snow cover. Leningrad, Russia [In Russian.])

Two hundred and forty-six germplasm collections were made involving the following species: forage kochia (*Kochia prostrata*) - 192 collections; winterfat (*Krascheninnikovia* [*Ceratoides] papposa*) - 13 collections; saltbush (*Atriplex cana*) - 8 collections; camphorosma (*Camphorosma lessingii*) - 10 collections; Anabasis (*Anabasis salsa*) - 1 collection; yellow flower alfalfa (*Medicago falcata*) - 3 collections; giant wildrye (*Leymus* [*Elymus*] *giganta*) - 2 collections; spreading wildrye (*Elymus angustiafolia*) - 7 collections; siberian wheatgrass (*Agropyron fragile*) - 7 collections; crested wheatgrass (*Agropyron desertorum*) - 2 collections; and needlegrass (*Stipa sareptana*) - 1 collection.

Species associated with forage kochia but not collected include: FORBS - Yarrow (*Achillea micrantha*), annual chenopod, annual kochia (*Kochia laniflora* and *Kochia scoparia*), knapweed (*Centaurea picris* and other *sp.*, knotweed (*Polygonum sp.*), buckwheat (*Eriogonum sp.*), fisheye (*Ceratocarpus arenarius*), russian thistle (*Salsola iberica*), and locoweed (*Astragalus sp.*) ; SHRUBS - *Artemisia austriaca*, *Artemisia arenaria*, *Artemisia terrae-albae*, *Salsola orientalis*, winterfat (*Krascheninnikovia* [*Ceratoides*] *ewersmanniana*), *Ephreda sp.*, and *Haloxylon aphyllum*; GRASSES - *Bromus inermi*, *Poa sp.*, *Festuca ovina* and other *Festuca sp.*, *Stipa capillata*, reedgrass (*Calamagrostis sp.*), redtop (*Agrostis sp.*), orchardgrass (*Dactylis glomerata*), saltgrass (*Distichlis sp.*), tall wheatgrass (*Thinopyrum ponticum*), *Elymus sp.*, *Leymus sp.*, quackgrass (*Elytrigia repens*), foxtail (*Hordeum sp.*), and junegrass (*Koeleria sp.*).

Forage kochia on average made up 6% of the perennial plant composition on native steppe sites ranging from 1 to 20%. The percent composition depended on the site and associated species. For example lower percentages of forage kochia were found on the *Agropyron - Stipa - Artemisia*, *Artemisia terrae- albae*, and *Artemisia - Krascheninnikovia* (*Ceratoides*) sites while higher percentages were found in the *Artemisia - Salsola - Kochia*, and *Atriplex - Anabasis - Artemisia* sites. Overall, *Artemisia terrae-albae* was the dominant species throughout the native steppe area. Forage kochia made up a higher percentage of the plant composition in disturbed areas along road shoulders, abandoned fields, and farmsteads where a high percent of



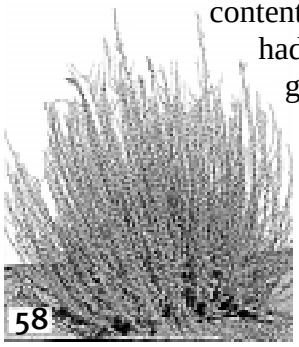
annuals were growing. On these sites forage kochia ranged from 15 to 60%, and averaged 32% of the plant composition.

As indicated above forage kochia made up a small percentage of the perennial plant communities. No where on the Kazakhstan steppes did we observe forage kochia as a dominant component of communities comprised of sagebrush, winterfat, saltbush, Anabasis, crested and siberian wheatgrass, and needlegrass. Instead, forage kochia complimented the biodiversity of such communities. In addition, we did not observe forage kochia invading from disturbed sites into the surrounding perennial plant communities.

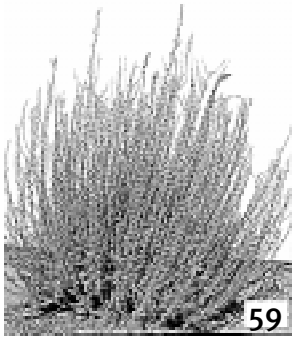
The forage kochia germplasm collected was mainly the glabrous and red-green stem forage kochia (*Kochia prostrata ssp. virescens*), however, some of the forms were gray with heavy pubescence on the leaves and stems and were classified as *ssp. grisea*. Other forms were in-between the red-green stem and the gray stem subspecies which suggests that the two subspecies may hybridize. This was confirmed in our discussions with Dr. Dzyubenko and Mr. Khusainov, whose combined experience with forage kochia expands over 20 years. Seed was collected by bulking seed from plants with similar morphological characteristics found at the same site. The morphological characteristics included: Height - one to three feet; Seeds - small and large, and few to numerous; Branches or tillers - few to numerous, and basal or high on the stem; Leaves - mostly basal or throughout the stems and branches; Stems - diameter - fine (about 1/16 in.) or thick stems (about 1/4 in.), color - red, yellowish-green, or gray; leaves, branches and stem - glabrous or pubescent.

Our Russian colleagues said they are not aware of any forage kochia genetics or breeding programs in Russia or Kazakhstan. Earlier cytogenetics work in the former U.S.S.R. has documented diploid, tetraploid, hexaploid, and octoploid forage kochia types, and naturally occurring aneuploids resulting from hybridization between ploidy levels. In addition, these scientists suggest that the two subspecies of *virescens* and *grisea*, which are frequently recognized in North American literature, are not well defined and in their native habitat readily hybridize with each other resulting in morphological types intermediate between the subspecies. The possibility of inter-ploidy and inter-subspecies hybridization may partially explain why we observed a large amount of variation within forage kochia populations at many collection sites.

Through our observations and discussions with scientists from Russia and Kazakhstan, we gathered some notes concerning the use and value of forage kochia in Kazakhstan. Forage kochia is an important part of the plant composition throughout the northern Kazakhstan steppe. It had been heavily to moderately grazed on most of the collection sites. It was often selectively grazed indicating high palatibility and/or high nutritional content. It is estimated that the number of grazing animals on the steppe had dropped by 10 fold since the breakup of the Soviet Union, thus greatly reducing grazing pressure allowing us to collect seed even in grazed areas. The grazing/browsing animals in order of their magnitude were cattle, sheep and goats, horses, camels, and antelope. We observed utilization of forage kochia by cattle, sheep and goats, and



horses, and assumed that camels and antelope were also grazing the forage kochia. We observed large areas of the native steppe that had been mowed and hayed for winter feed. Forage kochia comprised 1 to 20% of that feed (as indicated above in the discussion on species composition) with *Artemisia terrae-alba* being the major component and *Stipa sp.* and *Agropyron fragile* making up lesser components. Even though forage kochia made up a low percentage of the overall biomass in the hay, we assumed that its high nutritional value (high protein) made it an important component in overwintering livestock. We did not observe solid stands of forage kochia or areas where it had been seeded, and in fact we only saw one attempt to improve the steppe by seeding of any improved forage species - in which case crested wheatgrass was planted. However, Dr. Dzyubenko and Mr. Khusainov told us that 20,000 ha of forage kochia have been planted in southern Kazakhstan. That area is used for grazing sheep in late fall and early spring to flush the ewes and increase the number of live births.



LITERATURE CITED

Aldon, E.F., and C.P. Pase. 1981. Plant species adaptability on mine spoils, in the southwest: A case study. Res. Note RM 398. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Allen, R.S. 1985. Studies on seed performance of five arid landscape species. Provo, UT. Brigham Young University. PhD. Thesis.

Balyan, G.A. 1972. Prostrate summer cypress and its culture in Kirghizia. Isdatel'stvo, Frunze, Kirghizistan. (Translated from Russian, 1979). Nat. Tech. Info. Ser TT77-59026.

Bake, E. 1997. Bobs flat wildlife enhancement project. Mining and Wildlife. Habitat Bureau, Nevada Division of Wildlife. Reno, NV.

Blauer, A.C., E.D. McArthur, R. Stevens, and S.D. Nelson. 1993. Evaluation of roadside stabilization and beautification plantings in south-central UT. Research Paper INT-462, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Blauer, A.C., A.P. Plummer, E.D. McArthur, R. Stevens, and B.C. Guinta. 1976. Characteristics and hybridization of important intermountain shrubs. II. Chenopod family. Res. Pap. INT-77, Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Britton, A.C., and F.A. Sneva. 1977. Production and chemical attributes of *Kochia prostrata*. Denver, CO: Abstracts of papers, 30th Annual Meeting Society for Range Management.

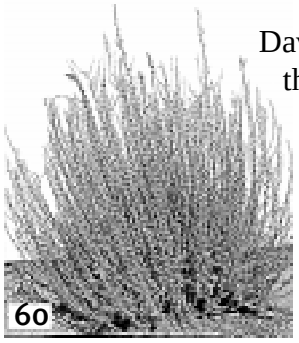
Clements, C.D., K.J. Gray, and J.A. Young. 1997. Forage kochia: To seed or not to seed. Rangelands 19(4):29-31.

Cronquist, A., A.H. Holmgren, N.H. Holmgren, J.L. Reveal, P.K. Holmgren. 1977. Intermountain Flora, Vascular Plants of the Intermountain West, U.S.A. Columbia University Press, V 6.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33:43-64.

Davis, A.M. 1979. Forage quality of prostrate kochia compared with three browse species. Agronomy Journal 71:822-824.

Davis, J.N., and B.L. Welch. 1985. Winter preference, nutritive value and other range use characteristics of *Kochia prostrata* (L.) Schrad. Great Basin Naturalist 45:778-783.



Francois, L.E., 1976. Salt tolerance of prostrate summer cypress (*Kochia prostrata*). Agronomy Journal. 68:455-456.

Frischknecht, N.C., and R.B. Ferguson. 1984. Performance of chenopodiaceae species on processed oil shale. In: Tiedemann, A.R., E.D. McArthur, H.C. Stutz, R. Stevens, and K.L. Johnson, and compilers. Proceedings-symposium on the biology of *Atriplex* and related chenopods, May 2-6, 1983, Provo, UT. Gen Tech. Rep. INT-172: 293-297, Ogden UT. U.S. Department of Agriculture, Forest Service, Forest and Range Experiment Station.

Ferguson, R.B., and N.C. Frischknecht. 1985. Reclamation on Utah's energy and Alton coal fields: Techniques and plant materials, Research paper INT-335, U.S. Department of Agriculture, Forest Service, Intermountain Range Experiment Station.

Gade, A.E., and F.D. Provenza. 1986. Nutrition of sheep grazing crested wheatgrass versus crested wheatgrass-shrub pastures during winter. Journal of Range Management. 39:527-530.

Gutknecht, K. 1996. Forage kochia thrives and is well-behaved. Utah Science 57:17-19. Available at http://agx.usu.edu/agx/UtahSci/USSpr96NET/kochia.html

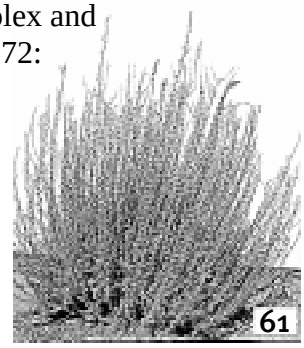
Haferkamp, M.R., C.C. Ganskopp, K.L. Marietta, and B.W. Knapp. 1990. Environmental influences on germination of utricles and seedling establishment of "Immigrant" forage kochia. Journal of Range Management 43:518-522.

Harrison, R.D., N.J. Chatterton, R.J. Page, M. Curto, K.H. Asay, K.B. Jensen, and W.H. Horton. 1996. Competition, biodiversity, invasion, and wildlife usage of selected introduced grasses in the Columbia and Great Basins. Utah State University, Agriculture Experiment Station Research Report 155. Available at http://agx.usu.edu/agx/ResearchReports/USDAREPORT/toc.html.

Herbel, C.H., R.R. Barnes, H.F. Heady, and L.N. Purdy. 1981. Range research in the Soviet Union. Rangelands 3:61-63.

Howard, G.S., F. Rauzi, and G.E. Schuman. 1979. Woody plant trials at six mine reclamation sites in Wyoming and Colorado. Production Research Dpt 177. U.S. Department of Agriculture Science and Education Administration, U.S. Government Printing Office, Washington, D.C.

Jorgensen, K.R., and J.N. Davis. 1984. A technique for retaining seed viability in *Kochia prostrata* seed. In: Tiedemann, A.R., E.D. McAurthur, H.C. Stutz, R. Stevens, and K.L. Johnson, compilers. Proceedings-symposium on the biology of Atriplex and related chenopods, May 2-6, 1983, Provo, UT. Gen Tech. Rep. INT-172: 293-297, Ogden UT. U.S. Department of Agriculture, Forest Service, Forest and Range Experiment Station.



Kashkarov, A.A., and G.A. Balyan. 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, D.C.).

Keller, W., and A.T. Bleak. 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, D.C.).

Larin, I.V. 1956. Pasture economy and meadow cultivation p. 168-170. Translated to English, 1962, and published by Israel Program for Scientific Translation, Jerusalem.

McArthur, E.D., A.C. Blauer, and R. Stevens. 1990. Forage kochia competition with cheatgrass in central UT. In: McArthur, E. Durant; Romney, Evan M.; Smith, Stanley D.; Tueller, Paul T., compilers. Proceedings- symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; April 5-7, 1989; Las Vegas, NV, Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 351 p.

McArthur, E.D., B.C. Guinta, and A.P. Plummer. 1974. Shrubs for restoration of depleted ranges and disturbed areas. Utah Science 35:28-33.

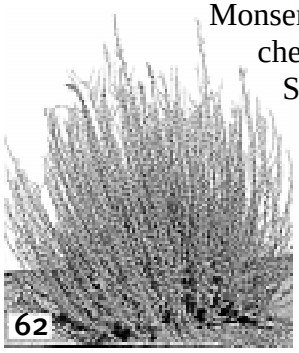
McArthur, E. D., S. C. Sanderson, and J. N. Davis. 1996. Adaptation of forage kochia accessions in environmental gradient in Park Valley, UT. Arid Soil Research and Rehabilitation 10:125-130.

McFarland, M.L., D.N. Ueckert, S. Hartmann, and F.M. Hans. 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. and Kitchen, S. G., compilers, Proceedings-Ecology and Management of Annual Rangelands. General Technical Report INT-GTR-313: 363-373. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Monsen, S.B., and D. Turnipseed. 1990. Seeding forage kochia onto cheatgrass-infested In: McArthur, E. Durant; Romney, Evan M.; Smith, Stanley D.; Tueller, Paul T., compilers. Proceedings- symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; April 5-7 1989; Las Vegas, NV, Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 351 p.



Monsen, S.B., J.F. Vallentine, and K.H. Hoopes. 1990. Seasonal dietary selection by beef cattle grazing mixed crested wheatgrass-forage kochia pastures. Proceedings, Western Section, American Society of Animal Science, 41:300-303.

Moore, T.B., R. Stevens, and E.D. McArthur. 1982. Preliminary study of some insects associated with rangeland shrubs with emphasis on *Kochia prostrata*. Journal of Range Management. 35:128-130.

Nemati, N. 1986. Pasture improvement and management in arid zones of Iran. Journal of Arid Environments, 11:27-35.

Otsyina, R., C.M. McKell, J. Malechek, and G. Van Epps. 1984. Potential of *Atriplex* and other chenopods for increasing range productivity for fall-winter grazing use. In: Tiedemann, A.R., E.D. McAurthur, H.C. Stutz, R. Stevens, and K.L. Johnson, compilers. Proceedings-symposium on the biology of *Atriplex* and related chenopods, May 2-6, 1983, Provo, UT. Gen Tech. Rep. INT-172: 293-297, Ogden UT. U.S. Department of Agriculture, Forest Service, Forest and Range Experiment Station.

Page, R. J., V.P. Rasmussen, W.H. Horton, R.L. Newhall, D.E. Wilson, G.W. Kidd, and T.C. Roberts, Jr. 1994. White Rocks Road Immigrant forage kochia trial seedings, Rangelands 16(4):167-168.

Pellant, M. 1990. The cheatgrass-wildfire cycle- are there any solutions? In: McArthur, E. Durant; Romney, Evan M.; Smith, Stanley D.; Tueller, Paul T., compilers. Proceedings- symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; April 5-7, 1989; Las Vegas, NV, Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 351 p.

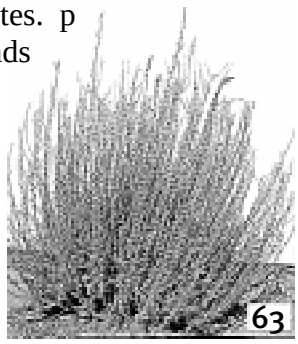
Pendleton, R.L., N.C. Frischknecht, and E.D. McArthur. 1992. Long-term survival of 20 selected plant accessions in a Rush Valley, UT, planting. Research Note INT-403, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Plummer, A.P. 1970. Plants for revegetation of roadcuts and other disturbed or eroded areas. Range Improvement Notes; 15(1):1-8. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region.

Plummer, A.P., D.R. Christensen, R. Stevens, and K.R. Jorgensen. 1970. Highlights, results, and accomplishments of home range restoration studies. Utah State Div. Fish and Game, Pub. 70-3.

Plummer, A.P. 1977. Revegetation of disturbed Intermountain area sites. p 302-339. In: Thames, J. L., ed. Reclamation and use of disturbed lands in the Southwest. Tucson, AZ: University of Arizona Press.

Pope, C.L., and E.D. McArthur. 1977. IOPB chromosome number report. In: Chenopodiaceae. Taxon 26:109.



Prianshnikov, S. 1976. Improvement and national utilization of semidesert and desert pastures of Kazath, U.S.S.R. The introduction of wild-growing fodder plants, Alma Ata, U.S.S.R.

Prikhod'ko, N.D., and S.Y.A. Prikhod'ko. 1977. Introduction of *Kochia prostrata* into pasture in the Kopet-Dug Foothills. Proble Osvo Pastyn; 3:67-70.

Provenza, F. D., and J. H. Richards. 1984. Interseeding crested wheatgrass ranges. Utah Science 45: 73-77.

Rasmussen, V.P., W.H. Horton, R.J. Page, R.L. Newhall. 1992. Summary of BLM Rangeland (desert-ecosystem) plantings. 1987-1990. Unpublished report on file at: Cooperative Extension Service, Utah State University.

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., and M.R. Haferkamp. 1987. Forage kochia germination response to temperature, water stress and specific ions. Agronomy Journal 79:27-30.

Romo, J.T., and M.R. Haferkamp. 1988. Comparative water relations in *Artemisia tridentata* nutt. subsp. wyomingensis and *Kochia prostrata* (L.) Schrad. Journal of Arid Environment 15:53-64.

SAS Institute, Inc. 1989. SAS/STAT User's Guide, Version 6, Fourth Edition, Volume 2, Cary, NC.

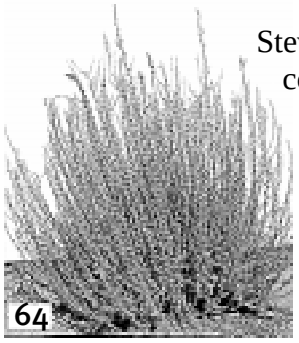
Stevens, A. R. 1992. Establishment and distribution of forage kochia seedlings within crested wheatgrass stands. Provo, UT. Brigham Young University. Masters Thesis.

Stevens, R., K.R. Jorgensen, E.D. McArthur, and J.N. Davis. 1985. "Immigrant" forage kochia. Rangelands 7:22-23.

Stevens, R., K.R. Jorgenson, E.D. McArthur, S.B. Monson, J.N. Davis, and J.R. George. 1984. Naming and release of Immigrant forage kochia for commercial production and marketing of seed. 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. Wildlife Restoration Project, W-82-R.

Stevens, R., K.R. Jorgenson, S.A. Young, and S.B. Monsen. 1996. Forb and shrub seed production guide for UT. Utah State University Extension AG 501, 51 p.

Stevens, R. and E.D. McArthur. 1990. "Immigrant" forage kochia competition with halogeton following various seeding techniques. In: McArthur, E. Durant; Romney, Evan M.; Smith, Stanley D.; Tueller,



Paul T., compilers. Proceedings- symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; April 5-7, 1989; Las Vegas, NV, Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 351 p.

Stevens, R., W.L. Moden, Jr., and D.W. McKenzie. 1981. Interseeding transplanting shrubs and forbs into grass communities. Rangelands 3(2):55-58.

Stevens, R., and G.A. Van Epps. 1984. Seeding techniques to improve establishment of *Kochia prostrata* and other chenopods. In: Tiedemann, A.R., E.D. McAurthur, H.C. Stutz, R. Stevens, and K.L. Johnson, compilers. Proceedings- symposium on the biology of *Atriplex* and related chenopods, May 2-6, 1983, Provo, UT. Gen Tech. Rep. INT-172: 293-297, Ogden UT. U.S. Department of Agriculture, Forest Service, Forest and Range Experiment Station.

USDA-ARS. 1999. National Genetic Resources Program. Germplasm Resources Information Network - (GRIN). [Online Database] National Germplasm Resources Laboratory, Beltsville, MD. Available: www.ars-grin.gov/cgi-bin/npgs/html/econ.pl.

USDA Soil Conservation Service. 1984. Management and Uses of 'Immigrant' forage kochia - *Kochia prostrata* (L.) Schrad, ID-7-N-2000-429.

Utah State University. 1994. Forage Kochia holds ground against cheatgrass, erosion. Utah Science: 55: 10-11.

Van Epps, G. A. & C. M. McKell. 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., K.K. Schmidt, J.L. Stubbendieck, C.M. Button, and F.A. Sneva. 1979. Effect of harvest data and drying procedures on germination of *Kochia prostrata* (L.) Schrad. p. 8-10. In: 1979 Progress Report. Research in Rangeland Management. Oregon Special Report 549, Corvallis, OR: Oregon State University Agricultural Experiment Station.

Waller, S. S., C. M. Britton, D. K. Schmidt, J. Stubbendieck, and F. A. Sneva. 1983. Germination characteristics of two varieties of *Kochia prostrata* (L.) Schrad. Journal of Range Management 36:242-245.

Welsh, S.L., N.D. Atwood, S. Goodrich, and L.C. Higgins. 1993. A Utah Flora, 2nd ed. Brigham Young University Print Services, Provo, UT.

Williams, M.C. 1980. Purposefully introduced plants that have become noxious or poisonous weeds. Weed Science 28:300-305.

Young, J.A., R.A. Evans, R. Stevens, and R.L. Everett. 1981. Germination of *Kochia prostrata* seed. Agronomy Journal 73:957-961.