'Immigrant' Forage Kochia (*Kochia prostrata*) Seed Germination as Affected by Storage Conditions

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Abstract—'Immigrant' forage kochia (*Kochia prostrata*) is an introduced semi-evergreen subshrub planted as a forage and reclamation plant on western cold deserts. Currently, seed demand is high; however, effective use of forage kochia seed is complicated by its short shelf-life. Delaying harvest until seeds are mature, typically from mid-October to mid-November, should ensure that seeds have good germination characteristics and will be better able to withstand storage. To preserve maximum dormancy and the delayed and desynchronized germination rate found in fresh seeds, storage with a low seed water content (2 to 6%) is critical; low temperature (2 °C) storage is also important.

Forage kochia (*Kochia prostrata*) is the only introduced subshrub species to have a variety released as a forage crop in the United States (Horton and others 1994). It is native to arid and semiarid regions of central Eurasia where it is valuable for forage (Balyan 1972). On native sites, it is often associated with crested wheatgrass (*Agropyron cristatum*) and Eurasian sagebrush species (*Artemisia* spp.) and grows on alkaline, stony, and sandy steppes, deserts, plains, and mountains (McArthur and others 1974). Forage kochia was first introduced to the United States from Russia during the early 1960's (Keller and Bleak 1974).

Many accessions of forage kochia have since been tested as potential forage and reclamation plants for western rangelands (Keller and Bleak 1974; Stevens and others 1985). A named variety of forage kochia, 'Immigrant', was released in 1985 for forage and erosion control on greasewood-shadscale (*Sarcobatus vermiculatus-Atriplex confertifolia*), sagebrush-grass, and pinyon-juniper (*Pinus* spp.-*Juniperus* spp.) rangelands of the Intermountain West (Stevens and others 1985). Most commercially available seed is used in reclamation, primarily for post-burn seedings on cheatgrass-dominated rangelands (Horton and others 1994). Most seedings currently use the Immigrant variety.

Due to its many uses and unusual range of adaptability, demand for Immigrant forage kochia seeds is generally high. Fresh forage kochia seeds should be planted in late fall or winter for best establishment (Haferkamp and others 1990; Monsen and Kitchen 1994). Many times, however, buyers have planted year-old seeds and have experienced low seeding success. Haferkamp and others (1990) had poor stand establishment using year-old seeds and attributed it to a loss in seed vigor or viability. Their data suggests that seeds may have experienced changes in germination timing mechanisms, such as dormancy and germination rate. Several factors may contribute to changes in these mechanisms.

One factor is the short shelf-life of seeds, especially under uncontrolled storage conditions (Balyan 1972; Jorgensen and Davis 1984; Keller and Bleak 1974). To maximize seeding success and return of dollars spent, it is essential to understand changes in germination characteristics over time, seed storage requirements, and seed longevity (Stevens and Jorgensen 1994).

An additional factor that may contribute to changes in seed germination characteristics is early harvest. Forage kochia seeds may not ripen until October or November (Moghaddam 1978). Seed growers may be motivated to harvest the seeds before snow falls. However, germination controls may not be in place until later in seed development (Waller and others 1983). Thus, when seeds are not fully matured at harvest, they may not have the germination timing mechanisms that would help them survive, especially after being stored.

Another important consideration is the environment in which the seeds mature. Environmental conditions, including temperature, length of growing season, photoperiod, light quality, soil nutrients, soil moisture, and position on the plant may significantly affect germination characteristics (Baskin and Baskin 1973).

Afterripening

Two germination timing mechanisms that prevent germination at inappropriate times are dormancy and slow germination rates (Meyer and Monsen 1991). Afterripening, which occurs over time, results in reduced dormancy and increased germination rate (Meyer and others 1997). An afterripening requirement in forage kochia seeds allows for emergence when better conditions for seedling survival are encountered. Afterripening of forage kochia seeds, when harvested, may occur in as little as a few weeks at room temperature or over a longer period in cold storage (Balyan 1972; Kitchen and Monsen, in press).

Dormancy is a delay mechanism in seeds that prevents premature germination in conditions that might prove to

In: McArthur, E. Durant; Ostler, W. Kent; Wambolt, Carl L., comps. 1999. Proceedings: shrubland ecotones; 1998 August 12–14; Ephraim, UT. Proc. RMRS-P-00. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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be unsuitable for establishment (Meyer and Monsen 1991). Seed dormancy is associated with species from unpredictable environments (Meyer and Monsen 1992), which is the case in arid rangelands where rainfall tends to be highly variable. A large fraction of fresh Immigrant forage kochia seeds remain dormant until late winter or early spring (Balyan 1972). Preserving dormancy in forage kochia seeds becomes especially important when seeds are stored for use in years following initial growth season. If fully afterripened seeds are seeded in the fall or winter, they may germinate too quickly, leading to poor overall stand establishment (Kitchen and Monsen, in press).

Slow germination rate is also important for seeds of species from unpredictable environments. Meyer and Monsen (1991) found that for big sagebrush (*Artemisia tridentata*) slow germination rate may have been almost as effective as dormancy in preventing precocious emergence of seeds. Overall, fresh forage kochia seeds have a delayed and desynchronized germination rate, which should allow for some portion of the seeds to germinate when good conditions for seedling survival occur (Monsen and Kitchen 1994). Forage kochia seeds that have afterripened have a more rapid and synchronized germination rate (Haferkamp and others 1990; Kitchen and Monsen, in press). This again may be detrimental when planting year-old seeds in the fall or winter, as they may germinate under adverse conditions. Cold temperature (2 °C) germination tests are useful in studying germination rate and synchronization because they more closely resemble field conditions when seedling emergence is likely to occur. Differences in germination rate are also magnified at lower temperatures (McArthur and others 1987; Meyer and Monsen 1991).

Objective

Our objective was to examine the effects of harvest date (an index of seed maturity), maternal growth environment (wildland or irrigated), and storage conditions (temperature, seed water content, and duration) on dormancy and cold temperature germination rate of Immigrant forage kochia seeds. These factors influence the seeding success of Immigrant on western rangelands.

Methods

Seed Collection Sites (Growth Environments)

Fruits (hereafter referred to as seeds) were collected from two sites (Romo and Haferkamp 1987). The first was a USDI Bureau of Land Management wildland site, located approximately 11 km north of Dugway, Tooele County, Utah. Soil is a deep, well-drained Timpie silt loam, and annual precipitation is 13 to 20 cm. Several hundred mature Immigrant forage kochia plants are present. The second site was an irrigated field managed by Stevenson Intermountain Seed Company near Manti, Sanpete County, Utah, where certified Immigrant forage kochia seed is grown commercially. The soil is a Sigurd gravely loam (Soil Conservation Service 1981); the crop is irrigated as needed to maximize production.

Seed Harvest

Seeds were harvested from both sites in fall 1996 on October 4, October 18, November 1, and November 15. Twenty plants were selected at each site to represent within-population variation. Seeds were hand-stripped on each collection date and air-dried for 3 to 10 days. Empty and immature fruits, fruit fragments, leaves, and small stems were removed using Seedburo Equipment Company's K (2 /64"), U (4 /64"), and A (12/64") Rounds.

Storage Treatments

A subsample (3-20 g) of each fresh seed lot was dried to 0% moisture in a drying oven. This sublot was used as a reference in calculating seed water content to obtain the desired water contents for storage. The remaining fresh seeds were then divided evenly into sublots to provide a complete factorial arrangement of storage treatments [four seed maturity levels (harvested on Oct. 4, Oct. 18, Nov. 1, and Nov. 15) x two growth environments (wildland and irrigated sites) x three storage temperatures (fresh seed with no storage, cold storage at 2 °C, and warm storage at 25 °C) x three seed water contents during storage (fresh seed with no storage, low seed water content at 2 to 6%, and high seed water content at 12 to 16%) x four storage duration periods (0, 4, 8, and 12 months)]. Each of these sublots was weighed and stored in a plastic vial. Each group of vials was placed in a sealed plastic bag and a cardboard box.

Germination Tests

Tests for dormancy and cold temperature germination rate were performed on each seed lot, when fresh and after treatments. Each test included four replications of 25 seeds from each seed lot. Seeds were placed in 100 x 15 mm plastic petri dishes on two 1-mm thick blotters (Anchor Paper) saturated with tap water. To retain moisture, petri dishes were randomized, stacked, and placed in plastic bags. To ensure even light treatment for all dishes, a blank dish with two blotters was placed on the top of each stack. Blotters were resaturated as needed during the germination tests. Petri dishes were randomly arranged in a germination chamber and rearranged after weekly counts. Germination was defined as 5+ mm radicle emergence.

Dormancy Test—To determine dormancy of each seed lot, seeds were incubated in a controlled environment chamber in a 12 hour diurnal photoperiod at 10 and 20 °C. Every 7 days, for a period of 4 weeks, the number of seeds in each dish that had germinated were counted and removed. After 28 days, firmness of ungerminated seeds in each dish was determined using a cut test to examine the tissue of the seeds (Association of Official Seed Analysts 1988). Dormant seeds were defined as firm seeds that did not germinate within 28 days.

Cold Temperature Germination Rate Test—To estimate cold temperature germination rate of each seed lot, seeds were incubated at 2 °C for 16 weeks, during which time germinated seeds were counted and removed weekly. Following the chilling period, seeds were incubated in a germination chamber in 12 hour diurnal photoperiods at

10 and 20 °C for an additional week for a final germination count. The results of this test confirmed the dormancy analysis of firm seeds completed in the above test.

Statistical Analysis

Germination percentage (firm seed basis) was calculated for each replication of the dormancy test. Germination rate (days to 50% germination) was calculated for each replication of the cold temperature germination test. The germination percentages were arcsine transformed prior to analysis to normalize the data. A factorial analysis of variance appropriate to the completely randomized experimental design was used to determine significance of treatments and interactions (SAS 1998). Mean separation was completed using the Student-Newman-Keuls means comparison test.

Results and Discussion

Effects of seed maturity, growth environment, and storage conditions on dormancy and cold temperature germination rate of Immigrant forage kochia seeds were highly significant ($p < 0.01$). Fresh seed viability and treatment effects on seed viability were also assessed for each seed lot. Mean viability for fresh seeds from the first harvest was low (17%). The dormancy and cold temperature germination rate data from that harvest is suspect because it is based on few viable seeds of questionable vigor. Viability of fresh seeds from the last three harvests was high (88%); thus, in all following results only data from the last three harvest dates are included.

Dormancy

Means of percent germination (firm seed basis) for harvest date x seed water content x storage temperature x storage length are found in table 1. Differences in dormancy associated with storage temperature, seed water content, and harvest date were highly significant ($p < 0.01$). Fresh seeds from the last three harvest dates were highly dormant (12% germination). Low seed water content in storage, especially when the seeds were stored at a cold temperature, allowed for the greatest preservation of dormancy (67% germination over all storage periods). Low water content when seeds were stored at a warm temperature yielded seeds that were less dormant (79% germination overall). Seeds stored with a high water content in the cold retained little dormancy (90% germination overall). Seeds stored with a high water content at a warm temperature were only 4% viable, so dormancy results were not reliable. None of the storage conditions used preserved dormancy in forage kochia seeds at the level observed in fresh seeds. Allen (1985) noted that no successful method for avoiding afterripening of forage kochia seeds had been developed; however, other work suggests that at subzero storage temperatures, dormancy can be preserved (Kitchen, unpublished data).

Dormancy, as previously discussed, may be environmentally cued, and in this study, there were differences in the dormancy patterns of seeds depending on growth environment and seed maturity. This resulted in a significant interaction between site and harvest date for percent germination ($p < 0.05$). Seeds from the irrigated growth environment and the wildland environment responded similarly to treatments, differing only in magnitude. The irrigated growth environment yielded less dormant seeds than the wildland site over all harvest dates (67 and 55% germination, respectively). However, an irrigated environment for commercially growing seeds is able to produce a much greater volume of seeds, a benefit that greatly outweighs possible effects on seed dormancy.

The interaction of seed maturity and length of storage was highly significant for percent germination ($p < 0.01$) (table 1). Seeds from the first harvest responded differently to storage than seeds from later harvests; however, as previously

Table 1—Means of percent germination (firm seed basis) for 'Immigrant' forage kochia seeds incubated in a 12 hour diurnal photoperiod at 10 and 20 °C for 28 days. Seeds were collected from a wildland site and an irrigated site in central Utah on four harvest dates in fall 1996 and tested for dormancy when fresh and after storage treatments. Due to low viability (13%) of seed from the first harvest, percent germination is shown only for seed from the last three harvests. High and low seed water contents were 12 to 16%, and 2 to 6%, respectively. Cold temperature storage was 2 °C, and warm storage temperature was 25 °C. Numbers in parentheses are standard errors.

			Storage length					
	Seed		4 months		8 months		12 months	
Harvest	water	Fresh	Storage temperature					
date	content	seed	Cold	Warm	Cold	Warm	Cold	Warm
			Percent germination					
Oct. 18	High		80 (5)	68 (16)	69 (5)	88 (6)	98 (2)	58 (18)
	Low		49 (8)	65 (8)	36 (6)	53 (5)	96 (2)	98 (1)
		10 (2)						
Nov. 1	High		88 (4)	—	86 (4)	—	99 (1)	—
	Low		57 (6)	72 (7)	39 (6)	76 (5)	98 (1)	100 (0)
		6 (1)						
Nov. 15	High		92 (3)	—	96 (2)	13 (13)	99 (1)	—
	Low		73 (5)	81 (6)	46 (4)	70 (7)	96 (1)	100 (0)
		20 (3)						

mentioned 83% of the seeds began as nonviable, so differences were viewed with caution. Seeds from the other three harvests responded to storage in a similar pattern but differed in magnitude, with seeds from the third and fourth harvests retaining slightly more of their dormancy (55 and 60% germination, respectively) than seeds from the second harvest (67% germination). Seeds that mature and disperse early may be more dormant than later developing seeds. Germination characteristics are driven by the genetics of each plant but are also influenced by the maternal environment. Late-ripening seeds may mature under a different environment than early-ripening seeds. Thus, seeds retained on the plant that were collected on the fourth harvest date may have experienced changes that caused more of them to germinate. Meyer (unpublished data) has results that indicate this happening with rubber rabbitbrush (*Chrysothamnus nauseosus*), another fall-ripening species. The differing environmental conditions each subset of seeds experienced may explain the differences in their levels of dormancy or rate of afterripening.

A fivefold increase (from 12 to 60%) in germinating seeds from the last three harvests occurred after 4 months in storage, which was the greatest loss of dormancy in any of the storage periods (table 1). From 4 to 8 months of storage, no major changes in dormancy occurred; however, by 12 months storage a majority of dormancy had been lost (79% germination overall), as the seeds were mostly afterripened by then. Afterripened forage kochia seeds, used for seeding in late fall or early winter, may experience premature germination resulting in poor stand establishment. Thus, any measure, e.g., storage with low seed water content in a cold temperature, which can delay afterripening may improve seeding success of Immigrant forage kochia.

Cold Temperature Germination Rate

Means of cold temperature germination rates (days to 50% germination) for harvest date x seed water content x storage temperature x storage length are found in table 2. An interaction between level of seed water content and length of storage was highly significant for cold temperature germination rate ($p < 0.01$). All seeds germinated more rapidly over time in storage as they afterripened; however, seeds stored with a low water content germinated more slowly than seeds stored with a high water content (46 and 12 days to 50% germination overall, respectively) (fig. 1). Low seed water content in storage resulted in a steady increase in germination rate (decrease in days to 50% germination) over time, which may be the result of steady afterripening of the seeds. However, high seed water content in storage caused a considerable increase in germination rate after just the first 4 months of storage, suggesting afterripening was accelerated with a high seed water content. Storage with a low seed water content delayed afterripening, which may again benefit seeding success with stored forage kochia seeds. Because germination rates for all seeds were greatly shortened over time in storage, this reaffirms that the storage methods used were not highly effective in retarding afterripening of Immigrant forage kochia seeds. However, seeds stored for more than 3 years at 2 °C have been able to delay germination sufficiently for successful stand establishment (Kitchen and Monsen, in press).

Differences in cold temperature germination rates resulted in a highly significant interaction between storage temperature and levels of seed water content ($p < 0.01$). Fresh seeds overall germinated slowly, taking 110 days to reach 50% germination (fig. 2). Low seed water content and

Table 2—Means of germination rate (days to 50% germination) for Immigrant forage kochia seeds incubated at 2 °C for 16 weeks, followed by 1 week incubated in 12 hour diurnal photoperiods at 10 and 20 °C. Seeds were collected from a wildland site and an irrigated site in central Utah on four harvest dates in fall 1996 and tested for cold temperature germination rate when fresh and after storage treatments. Germination rates are shown only for seeds from the last three harvests, due to low viability (13%) of seed from the first harvest. High and low seed water contents were 12 to 16%, and 2 to 6%, respectively. Cold temperature storage was 2 °C, and warm storage temperature was 25 °C. Numbers in parentheses are standard errors.

			Storage length					
	Seed		4 months		8 months		12 months	
Harvest	water	Fresh	Storage temperature					
date	content	seed	Cold	Warm	Cold	Warm	Cold	Warm
			Days to 50% germination at 2 °C					
Oct. 18	High		40 (3)	39 (10)	18 (1)	15 (6)	13 (5)	6 (6)
	Low		112 (2)	72 (3)	50 (2)	41 (3)	21 (1)	12 (4)
		116 (1)						
Nov. 1	High		22 (2)	—	10 (3)	—	12 (3)	—
	Low		95 (3)	46 (3)	47 (4)	23 (2)	19 (2)	—
		115 (1)						
Nov. 15	High		24 (3)	—	4 (3)	—	8 (3)	—
	Low		85 (2)	60 (3)	63 (4)	35 (2)	42 (4)	11 (4)
		98 (3)						

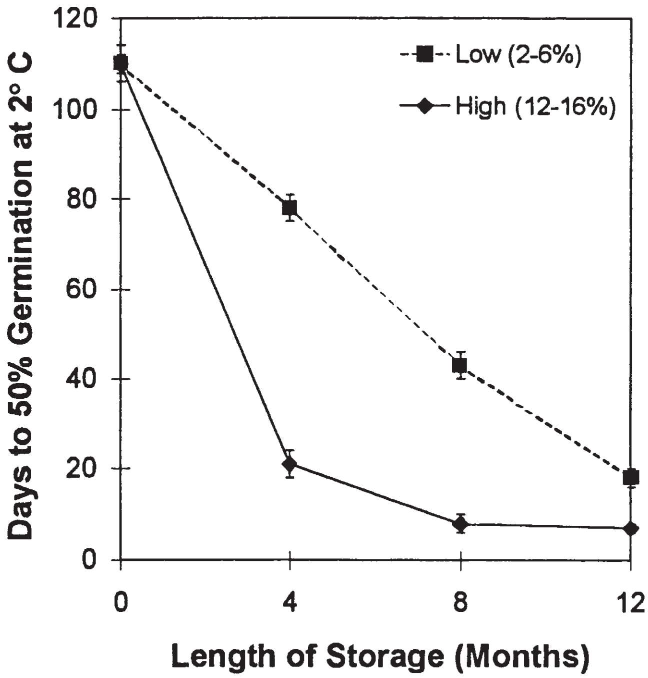

Figure 1—Cold temperature (2 °C) germination rate (days to 50% germination) of 'Immigrant' forage kochia seeds with two seed water content levels (high at 12 to 16% and low at 2 to 6%) shown over length of storage (0, 4, 8, and 12 months). This two-way interaction was significant at $p < 0.01$. For means at 0 months of storage, $n = 32$, and for all other means, $n = 64$.

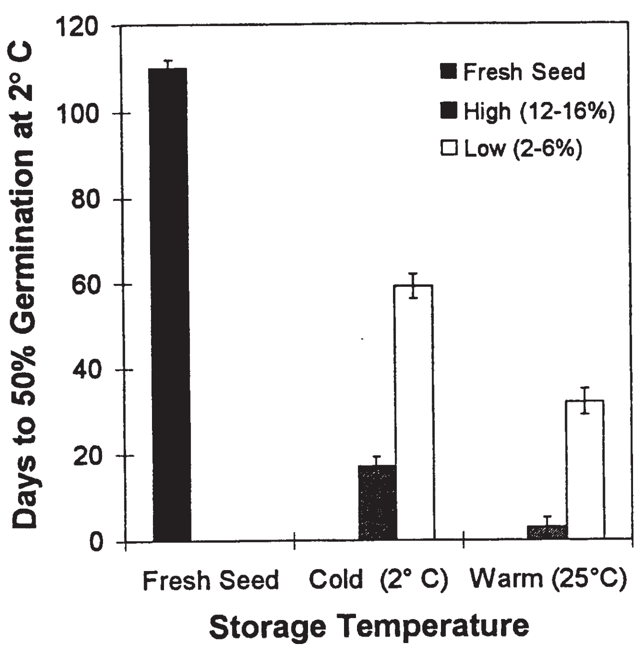

Figure 2—Cold temperature (2 °C) germination rate (days to 50% germination) of 'Immigrant' forage kochia seeds with three seed water content levels (fresh seeds with no storage, high at 12 to 16%, and low at 2 to 6%) and three storage temperatures (fresh seeds with no storage, cold at 2 °C, and warm at 25 °C). This two-way interaction was significant at $p < 0.01$. For means of fresh seeds, $n = 32$, and for all other means, $n = 96$.

cold temperature storage treatments maintained the slowest germination rate (59 days to 50% germination) compared to other storage treatments. Low seed water content and warm temperature storage retained the next slowest germination rate (32 days to 50% germination). High seed water content for both cold and warm temperature storage yielded much more rapid germination rates (17 and 3 days to 50% germination, respectively). Thus, storage with a low seed water content, along with storage at a cold temperature, will benefit in maintaining a slower, desynchronized germination rate in stored forage kochia seeds.

Seeds from the two growth environments responded differently in germination rates as seeds matured ($p < 0.01$) (table 2). The wildland site yielded seeds with a slower germination rate than the irrigated site (37 and 33 days to 50% germination overall, respectively). This difference, again, is outweighed by the high volume of seeds generated in a commercial seed production setting. Also, the germination rate pattern of seeds from the last three harvests was again similar and only differed slightly in magnitude. Once more, differences in afterripening rate of seeds may have resulted from the differing environmental conditions seeds from each harvest experienced.

Conclusions

Forage kochia seeds should not be stored in the same manner as most range plant seeds. Some seed companies store Immigrant seeds in a breathable polypropylene bag on a shelf in a warehouse where annual temperatures may fluctuate from 7 to 38 °C. Forage kochia seeds can be expected to afterripen quickly if stored in that manner, even if only for a short time. To preserve maximum dormancy and to maintain the most delayed and desynchronized germination rate, storage with a low seed water content (2 to 6%) is critical; storing seeds at a low temperature (2 °C) is the next priority. Aside from ensuring seed viability, seed maturity had little effect on the rate of afterripening. As the use of forage kochia increases on western rangelands, these recommendations will aid in obtaining the best possible seeding success when using stored Immigrant forage kochia seeds.

References

Allen, P. S. 1985. Studies on seed performance of five arid landscape species. Provo, UT: Brigham Young University. 111 p. Thesis.

Association of Official Seed Analysts. 1988. Rules for testing seeds. Lansing, MI: Stone Printing Company. 6(2): 1-36.

Balyan, G. A. 1972. Prostrate summer cypress and its culture in Kirghizia. Frunze, USSR: Isdatel'stovo "Kyrgyzstan" (Translated from Russian; U.S. Department of Commerce, TT77-59206, 1979.). 296 p.

Baskin, J. M.; Baskin, C. C. 1973. Plant population differences in dormancy and germination characteristics of seeds: heredity or environment?. American Midland Naturalist. 90: 493-498.

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

Horton, H. H.; Monsen, S. B.; Newhall, R. L.; Stevens, R. 1994. Forage kochia holds ground against cheatgrass, erosion. Utah Science. 55: 10-11.

Jorgensen, K. R.; Davis, J. N. 1984. A technique for retaining seed viability in *Kochia prostrata* (L.) Schrad. In: Tiedemann, A. R.; McArthur, E. D.; Stutz, H. C.; Stevens, R.; Johnson, K. L., comps.

Proceedings: symposium on the biology of *Atriplex* and related chenopods; 1983 May 2-6; Provo, UT. Gen. Tech. Rep. INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 166-167.

Keller,W.; Bleak, A. T. 1974. *Kochia prostrata*: a shrub for western ranges?. Utah Science. 35: 24-25.

Kitchen, S. G. Unpublished data on file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Shrub Sciences Laboratory, Provo, UT.

Kitchen, S. G.; Monsen, S. B. [In press]. *Kochia* Roth. In: Seeds of woody plants of the United States. U.S. Department of Agriculture, Forest Service.

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

McArthur, E. D.; Meyer, S. E.; Weber, D. J. 1987. Germination rate at low temperature: rubber rabbitbrush population differences. Journal of Range Management. 40: 530-533.

Meyer, S. E. Unpublished data on file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Shrub Sciences Laboratory, Provo, UT.

Meyer, S. E.; Allen, P. S.; Beckstead, J. 1997. Seed germination regulation in *Bromus tectorum* (Poaceae) and its ecological significance. OIKOS. 78: 475-485.

Meyer, S. E.; Monsen, S. B. 1991. Habitat-correlated variation in mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) seed germination patterns. Ecology. 72: 739-742.

Meyer, S. E.; Monsen, S. B. 1992. Big sagebrush germination patterns: subspecies and population differences. Journal of Range Management. 45: 87-93.

Moghaddam, M. R. 1978. *Kochia prostrata*—a plant material for range improvement in arid and semiarid regions. Rangeman's Journal. 5: 153-154.

Monsen, S. B.; Kitchen, S. G. 1994. Annual report—summary report of progress related to Interagency Agreement No. ID910 between USDI, Idaho Bureau of Land Management and USDA, Forest Service, Intermountain Research Station. Provo, UT: USDA, Forest Service, Intermountain Research Station, Shrub Sciences Laboratory. 45 p.

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

SAS.1998. SAS user's guide. SAS Institute. Cary, NC.

Soil Conservation Service. 1981. Soil survey of Sanpete Valley Area, Utah. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service. 179 p.

Stevens, R.; Jorgensen, K. R. 1994. Rangeland species germination through 25 and up to 40 years of warehouse storage. In: Monsen, S. B.; Kitchen, S. G., comps. Proceedings: ecology and management of annual rangelands; 1992 May 18-21; Boise, ID. Gen. Tech. Rep. INT-GTR-313. Odgen, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 257-265.

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

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