Barbwire Russian Thistle Seed Germination

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Abstract

Barbwire Russian thistle (*Salsola paulsenii*) is the dominant species of severely degraded plant communities in the most arid portions of the Great Basin. The seed germination of this alien annual plant was compared with that of common Russian thistle (*S. iberica*). In general, the two species of *Salsola* have similar germination characteristics. However, there were important differences that apparently favor barbwire Russian thistle in arid environments. These advantages were (a) less restrictive after-ripening requirements that allow some germination at a broader range of temperature sooner after maturity, (b) more rapid germination at low temperatures during the first 10 days of incubation, and (c) dehiscence of seeds without the necessity of the plants uprooting and tumbling.

Barbwire Russian thistle (*Salsola paulsenii*) has only scant coverage in range management literature because only recently has it been widely recognized in the western United States as a separate species from Russian thistle (*S. iberica*).

Russian thistle is one of the most widely occurring alien annuals in western North America. This weed was first introduced into the United States in 1873 or 1874 in flax (*Linum sp.*) seed brought from Russia and sown near Scotland, South Dakota (Stevens 1943; Robbins et al. 1952). Several Canadian provinces and 16 western states of the United States were infested by 1895. Russian thistle now infests all of the western portion of North America.

Barbwire Russian thistle is native to southeastern Russia and central Asia (Allen 1964). It was probably introduced to the far western United States sometime between 1891-1913 (Beatley 1973). Coville (1893) did not collect barbwire Russian thistle in his extensive botanical explorations on the Death Valley Expedition of 1891. Alice Eastwood, the noted California botanist, collected barbwire Russian thistle near Barstow, California in 1913 (Beatley 1973). Barbwire Russian thistle occurs in California, Nevada, and Utah (Munz 1968; Anonymous 1969).

We do not know exactly when barbwire Russian thistle invaded the Carson Desert of northwestern Nevada. During the 1960's Beatley (1971) established that there were distinct taxonomic entities of Russian thistle in the southern Great Basin. Publication of Beatley's work stimulated our interest and

observation in the Carson Desert and we observed what appeared to be the last stages of replacement of Russian thistle by barbwire Russian thistle in the desert rangeland communities of the area. Such replacement has not occurred in many ruderal communities or in areas of irrigated, intensive agriculture.

Previous studies (Young and Evans 1972; Evans and Young 1972) have enumerated many of the seed and seedbed ecology characteristics of Russian thistle. The purpose of this investigation was to conduct similar comparative studies of the seed and seedbed ecology of barbwire Russian thistle.

Methods

We collected seeds from numerous populations of barbwire Russian thistle growing in degraded plant communities in the northern Carson Desert. Collections were made in November of 1974, 1975, and 1976. Entire plants were pulled before the mature seeds started to fall and after initial post-harvest drying the seeds were hand threshed, cleaned, and stored in paper bags until moisture equilibrium was reached. Further storage, until germination tests were conducted, was at room temperature in the laboratory.

The potential vegetation and soils of the northern Carson Desert have been enumerated by Billings (1945). The area where we collected seeds was first degraded by bands of sheep near the wool and lamb shipping-point at Wadsworth, Nev., and later by cattle on and adjacent to the Pyramid Lake Indian Reservation. The degraded plant communities were invaded first by Russian thistle and during the 1940's by halogeton (*Halogeton glomeratus*). Extensive control measures for halogeton killed native shrubs in this area.

In all germination tests, four replications of 100 seeds each were arranged in dark germinators in a randomized block design. Seeds were placed on nontoxic germination paper in petri dishes for testing. Seeds were considered germinated when the seedlings uncoiled and the hypocotyl arch had risen. Incubation time was 4 weeks with weekly germination counts. In one test, germinating seeds were counted daily.

Germination tests were conducted at the time of seed harvest and 1,3,5, and 6 months after harvest. Constant incubation temperatures were −6, −4, −2, 0,2,5 and through 45°C and 5°-C increments. Alternating temperature regimes consisted of 16 hours in each 24-hr period at each lower constant temperature, and 8 hr at all possible higher temperatures. For example 0°C was alternated with 2,5,10, 15, 20, 25, 30, 35, 40, and 45°C, but 40°C was alternated with 45°C only.

To directly compare the rate of germination of barbwire Russian thistle and Russian thistle we incubated 4-month old seed of both species at 2, 5, 10, 15, 20, 25, 30, 35, and 40°C and counted germination daily through 1 week. The Russian thistle seeds were

collected from an agricultural field at Reno, Nevada.

We placed seeds of barbwire Russian thistle on the surface, or buried them 0.5, and 1, 2, 3, 4, or 5 cm deep in a sandy soil in beds prepared in the greenhouse. The soil was obtained from a barbwire Russian thistle community in the Carson Desert and was compacted in the beds to approximate the bulk densities of field profiles. In addition to the soil burial, we also placed seeds on the soil surface and covered them with 1 cm of annual grass litter, or sprinkled the seeds on the top of the litter. The seedbeds were kept moist with a mist nozzle. Emerging seedlings were counted daily.

We prepared aqueous solutions of −4, −6, −8, −10, −12, and −16 bars osmotic potential by dissolving appropriate amounts of polyethylene glycol or NaCl in distilled water. Both of these materials produce reduced osmotic potentials; however, the NaCl solutions often are toxic to germinating seedlings even though they have been used in many studies, while properly prepared polyethylene glycol solutions subject the seeds only to differences in moisture stress. Seeds of barbwire Russian thistle and Russian thistle that were 6 months old were incubated at 15°C in the reduced osmotic potentials. The seeds were arranged in plastic boxes with the osmotic solutions using the procedures described by Young et al. (1968). The procedure involves placing seeds in a matrix of ground styrofoam with the solutions at different osmotic potentials.

To determine the dispersal pattern and germinability of barbwire Russian thistle seeds we collected 120 soil samples 5 by 10 cm in surface area and 2.5 cm deep from a barbwire Russian thistle community in the Carson Desert. Samples were collected in December 1974 and 1975 after most of the seeds had fallen from the plant. Samples were collected at the stem base, 0.1, 0.5, and 1.0 m from the stem in each cardinal direction. The number of germinable seeds was determined by standard bioassay techniques in the greenhouse (Young et al. 1969).

We collected 100 soil samples from a barbwire Russian thistle community in the Carson Desert in May 1974 and 1975. Each soil sample was $300\ cm^2$ in surface area and 2.5 cm deep. Considerable germination had occurred by the time the samples were collected; seedlings were removed. To determine the germinability of seeds remaining in the soil after the initial field germination, we divided each sample into six subsamples for different bioassay treatments. Seeds in the bioassay were kept wet with (a) control (tap water), (b) aqueous solutions of 1.0 mM potassium nitrate (KNO_3), (c) 0.1 mM KNO_3, (d) 0.01 mM KNO_3, (e) 0.28 mM gibberellic acid (GA_3), (f) 0.56 mM GA_3, or (g) the combination of 0.56 mM GA_3 and 0.1 mM KNO_3. The procedures and concentration of germination enhancement additives were suggested by previous studies by Evans and Young (1975).

Table 1. Germination (%) at constant and alternating temperatures of barbwire Russian thistle seeds 1 month (December) and 6 months (May) after harvest. Means for 1974, 1975, and 1976.[a]

Cold period temperature 16 hr °C	1 month after harvest — Warm period temperature 8 hr °C										
	0	2	5	10	15	20	25	30	35	40	45
−6	0	0	0	0	0	0	0	0	0	0	0
−4	0	0	0	0	0	0	0	0	0	0	0
−2	0	0	0	0	0	6c	0	0	0	0	0
0	0	16a-c	24a-c	20a-c	18a-c	37a	20a-c	27a-c	7c	0	0
2		24a-c	26a-c	32ab	32ab	19a-c	22a-c	27a-c	22a-c	11bc	0
5			20a-c	32ab	25a-c	19a-c	20a-c	18a-c	14bc	3c	0
10				12bc	12bc	27a-c	20a-c	18a-c	20a-c	0	0
15					8c	11bc	25a-c	6c	6c	0	0
20						15bc	6c	0	0	0	0
25						10c	6c	0	0	0	0
30							6c	0	0	0	0
35								0	0	0	0
40									0	0	0
45										0	

Cold period temperature 16 hr °C	6 months after harvest — Warm period temperature 8 hr °C										
	0	2	5	10	15	20	25	30	35	40	45
−6	0	0	0	0	0	0	0	0	0	0	0
−4	0	0	0	8no	2no	16L-o	0	0	0	0	0
−2	0	8no	18L-o	22L-n	68e-g	81a-f	48h-j	24k-n	0	0	0
0	61g-i	73c-g	88a-d	87a-e	86a-e	78a-g	79a-g	70d-g	63f-i	29j-m	0
2		93ab	89ad	91ab	85a-c	88a-d	90a-c	78a-g	84a-e	30j-l	2o
5			94a	87a-e	94a	91ab	76a-g	86a-e	70d-g	29j-m	0
10				74b-g	80af	89a-d	80a-f	84a-e	88a-d	25k-n	12L-o
15					88a-d	79a-g	85a-e	93ab	87a-e	30j-l	10m-o
20						75b-g	81a-f	81a-f	88a-d	86a-e	8no
25							80a-f	71d-g	85a-e	43i-k	10m-o
30								62f-i	61g-i	26k-n	6no
35									75b-g	17L-o	2no
40										43ik	20
45											0

[a] Means followed by the same letter are not significantly different at the 0.01 level of probability as determined by Duncan's multiple range test. For readers convenience, means not significantly lower than the maximum, our definition of optimum, are underlined.

Results

Temperatures for Germination

Barbwire Russian thistle seeds germinated soon after harvest, but the optimum germination [defined as germination not statistically ($P=0.01$) lower than the maximum] was rather low (Table 1). Seeds germinated at a range of temperatures from -2 to 30°C. Maximum germination was below 40% and there was little difference in germination among the cold and cool-temperature regimes.

Afterripening

The germinability of barbwire Russian thistle seeds increased over the winter, as measured by both the temperature regimes support germination and the percentage of germination at given temperatures (Table 1). This increase in germinability fits the concept of afterripening (Mayer and Poljakoff-Mayber 1963), in which germination increased with storage time after harvest and is relatively independent of storage conditions. By 6 months after harvest the number of temperature regimes that supported germination had almost doubled and average germination had increased from 18% to 60% at the temperatures where some germination occurred. The mean of all temperatures, including those where no germination occurred, increased from 8% to 44% when the afterripening was satisfied. The average optimum for germination had increased from 23% to 85%. This increase in germination occurred gradually during the winter after harvest (data for intermediate test not shown).

By early in the spring following maturity, barbwire Russian thistle seeds germinated with no limitations by seedbed temperature. Some germinated at practically all temperature combinations that would prevail in seedbeds in the *Artemisia/grasslands* (Evans et al. 1970).

Comparison with Russian Thistle

The pattern of limited germination immediately after harvest and gradually increasing germination during the winter is similar in both barbwire Russian thistle and Russian thistle (Young and Evans 1972). Barbwire Russian thistle seeds generally mature in October, a month earlier than common Russian thistle seeds; however, some overlap in maturation may occur. In December, barbwire Russian thistle seeds germinated in 35% more temperature regimes (Table 1) than Russian thistle seeds did (Young and Evans 1972). However, overall germination was lower because the additional germination of barbwire Russian thistle was mainly at cold to very cold temperatures where percentage germination was relatively low.

To compare directly the rate of germination of barbwire Russian thistle and Russian thistle we conducted an experiment in March 1974. March is the time of the earliest germination of barbwire Russian thistle in communities of the Carson Desert. Barbwire Russian thistle seeds had a decided advantage in rate of germination at incubation temperatures below 30°C for the first 5 to 7 days (Table 2). After the first day the shorter the incubation time during the first week the greater the advantage to barbwire Russian thistle. Wallace et al. (1968) stressed that one of the most important factors in the establishment of Russian thistle was rapid germination. After germination has begun, the radicle must elongate, enter the soil, and start supplying moisture before the seedling desiccates in the typically harsh environment of the seedbeds where this species grows.

Table 3. Emergence (%) of barbwire Russian thistle seedlings from various planting depths (cm) in a sandy soil and on top of or beneath 0.5 cm of annual grass litter.[a]

Planting depth cm	Emergence %
Bare soil surface	36b
0.5	93a
1.0	90a
2.0	90a
3.0	82a
4.0	32b
5.0	8c
Under 0.5 cm litter	93a
On surface of 0.5 cm litter	32b

[a] Means followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's multiple range test.

Emergence

Barbwire Russian thistle seeds germinated on the surface of a bare seedbed, but the germination there was low, only slightly more than one-third (39%) of that under minimum soil coverage (Table 4). Litter coverage of seeds compensates for lack of soil coverage. The emergence of barbwire Russian thistle in a sandy soil was not significantly ($P=0.01$) reduced until burial was greater than 3 cm.

Germination under Low Osmotic Potentials

Russian thistle seeds are noted for relatively high germination under very low osmotic potentials (Young and Evans 1972). Considering the barbwire Russian thistle has replaced Russian thistle in what are generally known as "salt desert" plant communities, one would expect that barbwire Russian thistle could also germinate under greatly reduced osmotic potentials. However, the expected results were not obtained when seeds of both species were compared with reduced osmotic potential created with polyethylene glycol (Table 5). When the osmotic

Table 2. Greater (+), less (−) or equal (=) germination (%) of barbwire Russian thistle seeds compared to Russian thistle for 1 through 7 days incubation at 2 through 40 °C. Test run in March 1974, 4 months after harvest. Zeros indicate no germination by either species.

Incubation temperature (°C)	Days of incubation						
	1	2	3	4	5	6	7
2	0	0	=	=	+29	+25	+32
5	0	0	+60	+72	+76	+47	+38
10	0	−98	+91	+80	+54	+28	+18
15	+93	+96	+83	+35	+32	+15	+9
20	+90	+96	+79	+49	+30	+13	+10
25	+69	+62	+44	+28	+7	−22	−24
30	−32	+78	+59	+17	+9	+4	−7
35	−17	+62	+47	+54	+49	+23	+29
40	−89	+46	+30	+22	+5	+5	=

Table 4. Germination (%) of barbwire Russian thistle and Russian thistle seeds in reduced osmotic potential created with polyethylene glycol or NaCl.[a]

Osmotic potential −bars	Barbwire Russian thistle		Russian thistle	
	Polyethelene glycol	NaCl	Polyethylene glycol	NaCl
0	93a	93a	95a	95a
4	58cd	48c-e	95a	68bc
6	53c-e	50c-e	89ab	54c-e
8	38d-g	28f-g	66bc	46c-f
12	33d-g	20g-h	64bc	33d-g
16	16gh	2b	55cd	24f-h

[a] Means followed by the same letter are not significantly different at the 0.01 level of probability as determined by Duncan's multiple range test.

Table 5. Emergence of barbwire Russian thistle seedings with and without potassium nitrate (KNO_3) and/or gibberellic acid (GA_3) added to soil samples collected from the northern Carson Desert and tested in the greenhouse.[a]

Treatments	Seedlings/m^2
Control	60d
KNO_3 1.0 mM	140bc
KNO_3 0.1 mM	200a
KNO_3 0.01 mM	100cd
GA_3 0.27 mM	130bc
GA_3 0.56 mM	110bcd
KNO_3 0.1 mM plus GA_3 0.56 mM	160ab

[a] Means followed by the same letter are not significantly different at the 0.01 level of probability as determined by Duncan's multiple range test.

potential was reduced with NaCl, germination of the two species was not significantly ($P=0.01$) different. In interpreting these data, one should be aware that (a) not all soils in the Carson and associated salt deserts have surfaces that are high in soluble salts (Billings 1945) and (b) many studies have shown an inverse relation between germinability under low osmotic potentials and the ability to persist and grow under these conditions (e.g. McGinnies 1960).

Dispersal of seeds

During the late fall and early winter period when barbwire Russian thistle seeds have fallen, most of the seeds are located under the canopies of the still rooted plants (Fig. 1). This indicates that barbwire Russian thistle seeds disperse without the plants being uprooted and tumbling. In this characteristic barbwire Russian thistle is in sharp contrast to Russian thistle (Evans and Young 1972). Russian thistle plants, in western Nevada, must tumble before the seeds are dispersed. Ecotypes of Russian thistle with self-dispersing seeds have been reported in mid-western United States (personal communication F. Wertman, Control Seed Laboratory, Hopkins, Minn.). When both species grow in the same community, barbwire Russian
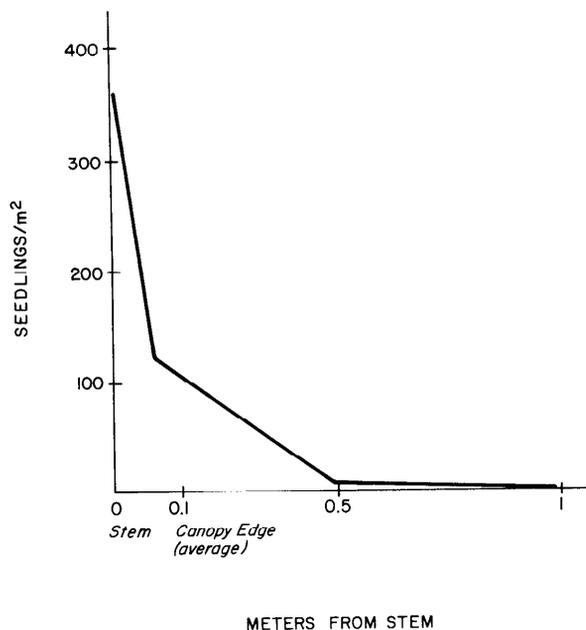
Fig. 1. *Germinable seeds of barbwire Russian thistle per m^2 of soil at selected distances from the stem of mature plants. Values are means for samples taken in the four cardinal directions and in 2 years (1974 and 1975). Samples were tested in greenhouse.*

thistle seeds may be dispersed and lying on the soil and available for germination before midwinter storms uproot and tumble Russian thistle plants to disperse their seeds.

Enchancing Germination

Field observations in the Carson Desert indicated most seeds of barbwire Russian thistle germinated in the early spring. To determine the germinability of the remaining barbwire Russian thistle seeds, we treated bioassay samples from field seedbeds with a source of nitrate (as KNO_3) and gibberellin (GA_3), the two substances known to greatly enhance germination of some seeds (Mayer and Poljakoff-Mayber 1963; Evans and Young 1975). The addition of 0.1 mM KNO_3 greatly enhanced germination (Table 6). The addition of GA_3 also enhanced germination, but not as much. The soils of the Carson Desert are characteristically deficient in available nitrate-N. Any microenvironmental condition that favored nitrification and therefore accumulation of nitrate apparently would favor the germination of barbwire Russian thistle.

Discussion

Interpretation of the comparative seed ecology of barbwire Russian thistle and Russian thistle is aided by the knowledge that the species have been reported to hybridize freely (Beatley 1973). Where populations of both species integrate, hybrid swarms showing varying degrees of introgression are common. We carefully avoided collected seeds from populations of either species that exhibited great morphologic variability. Despite the occasional hybridization between the species they usually occupy distinct habitats and they have been shown to be physiologically different and morphologically dissimilar (Beatley 1972).

As would be expected of two closely allied species the seed germination of both is relatively similar; but there are subtle and not-so-subtle differences between them. The most important differences that imply an advantage for barbwire Russian thistle are: (a) less restrictive afterripening requirements which allow some germination at more temperatures and sooner after maturity; (b) more rapid germination at low temperatures during the first few days of incubation; and (c) dehiscence of seeds without the necessity of the plants uprooting and tumbling.

The relatively low germination of barbwire Russian thistle under reduced osmotic potentials may be a competitive advantage in disguise. There may be an inverse relation between germinability under osmotic stress and persistence in such environments.

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