Seed Technology for *Carex* and *Juncus* Species of the Intermountain Region[1]

Emerenciana G. Hurd and Nancy L. Shaw[2]

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Abstract. --Seed technology is being developed for common sedges (Carex spp.) and rushes (Juncus spp.) of the Intermountain Region to evaluate the feasibility of propagating container stock from seed as well as from vegetative material. Germination requirements vary among species. Pretreatments are being developed to enhance germination of common intermountain species.

INTRODUCTION

Approximately 105 Carex (sedge) and 23 Juncus (rush) species are native to the Intermountain Region (Cronquist and others 1977). About two-thirds of the Carex and all of the Juncus species are associated with riparian or wetland habitats. A number of these are dominant or associated species in one or more of the riparian community types described for National Forest lands in this region (Jensen and Tuhy 1982, Manning and Pagett 1989, Pagett and others 1989, Youngblood and others 1985). A few have status as sensitive species.

Due in part to the taxonomic complexity of these two genera, most species have received little study. However, recent emphasis on rehabilitation and management of degraded riparian and wetland habitats in the Western United States has highlighted the critical role Carex and Juncus species play in stream stabilization and community dynamics as well as their ability to provide wildlife habitat and forage for grazing animals.

Successful use of Carex and Juncus species in riparian revegetation efforts requires an improved understanding of the ecology of each species and development of technology for their propagation and establishment. Although planting sod plugs or rhizomes provides a reliable means of establishing most grasslike species (Martin and Uhler 1939, Ratliff 1985), suitable vegetative material is not always readily available, and in some cases its harvest may result in environmental damage. Logistics of rhizome or plant collection and storage and possible contamination of collections with weedy species present additional problems. Thus, under some circumstances, seed propagation of nursery stock might be a preferred approach.

The objective of this paper is to discuss seed technology being developed for important Intermountain Carex and Juncus species and to review literature describing germination requirements for individual species.

TAXONOMY, ECOLOGY, AND REVEGETATION VALUES

Several publications provide information on the taxonomy, distribution, habitat requirements, growth habit, palatability, and spreading characteristics of major Intermountain Carex and Juncus species (Cronquist and others 1977, Hansen and others 1988a, b, Hermann 1970, 1975, Hitchcock and others 1969, Lewis 1958, Welsh and others 1987). Platts and others (1987) outlined revegetation values. Studies describing aspects of seed biology, seed technology, natural seedling establishment, and revegetation technology for Intermountain Carex and Juncus species are scarce. Pertinent literature is reviewed in table 1.

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[2] Emerenciana G. Hurd and Nancy L. Shaw are Botanists, Intermountain Research Station, Forest Service, U.S. Department of Agriculture, stationed at the Forestry Sciences Laboratory, Boise, Idaho 83702.

Table 1.--Review of literature pertaining to germination requirements of common Intermountain *Carex* and *Juncus* species.

Species	Seed source	Storage Conditions/ pretreatment	Incubation Conditions	Total germination	References
Carex aquatilis Water sedge	Wyoming		15-21/21-26°C, natural light. 60 days.	Low germination. Viability not determined.	Johnson and others (1965)
	Uniat, AK		22°C, constant light or dark.	2.7% (light), 0.0% (dark).	Bliss (1958)
	Medicine Bow Mountains, WY		22°C, constant light or dark.	0.0% (light), 0.0% (dark).	Bliss (1958)
	Soil seed bank, Arctic Coastal Plain, AK	Soil stratified at 2°C for 6 mo. (1981).	20-30°C, natural light. 4 mo. incubation.	107 seedlings/m^2 of soil surface.	Ebersole (1989
		Soil stored at -18°C for 3 mo. (1983).	20-30°C, natural light plus supplemental light after 2.5 mo., 7 mo. total.	267 seedlings/m^2 of soil surface.	Ebersole (1989
				Common emergent from soil seed bank or disturbances.	Ebersole (1989
Carex lanuginosa Woolly sedge		Immersed in water or stored dry in glass jars at room temperature for 60 mo.	20/30°C (12 hrs/12 hrs), light at 30°C, 28 days.	3 mo. storage: water 60%, dry 1%. 60 mo. storage: water 48%, dry 10%.	Comes and others (1978)
Carex microptera Small-winged sedge	Wyoming	Control; 1, 7, or 30 day stratification at 2-7°C; or 24 hr. leaching in tap water	15-21/21-26°C, natural light, 60 days. Controls incubated in distilled water, 0.2% KNO_3, or soil leachate.	58% (30-day stratification), 69 to 83% (all other treatments).	Johnson and others (1965)
	Montana,	Stratify at 2 to 4°C for 3 days.	20/30°C (16/8 hrs), blotters moistened with 0.2% KNO_3.	100% (based on viable achenes).	Wiesner and others (1967)
Carex nebraskensis Nebraska sedge	Wyoming	Control; 1, 7, or 30-day stratification at 2-7°C.	See *C. microptera*.	5% (30-day stratification), 13 to 36% (all other treatments).	Johnson and others (1965)
Carex pachystachya Chamisso sedge	Montana	Stratify at 2-4°C for 3 days.	See *C. microptera*.	4% (26 days), 92% (77 days) (based on viable achenes).	Wiesner and others (1967)
Carex rostrata Beaked sedge	Wyoming			Low germination. Viability not determined.	Johnson and others (1965)
Carex subfusca Pond sedge	Wyoming	Control; 1, 7, or 30 day stratification at 2-7°C; or 24 hr. leaching in tap water.	See *C. microptera*	100% (1-day stratification) 0% (30-day stratification) 83 to 93% (all other treatments) Viability not determined.	Johnson and others (1965)
Juncus articulatus Jointed rush	New York	Water, 1-3°C, 2, 5, or 7 months, dark.	13-16/18-21°C, natural light.	46 0(2 mo.) 96 (5 mo.) 97 (7 mo.)	Muenscher (193
	United Kingdom	Dry, 5°C	2°C fluctuation required for 50% of maximum germination recorded.		Thompson and Grime (1983)
Juncus effusus Soft rush	United Kingdom		Surface seed in field. Requires light. Seedlings sensitive to drying, competition, and mechanical disturbances.		Lazenby (1955)
	United Kingdom	Dry, 5°C	2°C fluctuatation required for 50% of maximum germination recorded. Absolute requirement for light.		Thompson and Grime (1983)
	New York	Water 7 years, frozen twice.		Some germination.	Shull (1914)
Juncus tenuis Slender rush	Ohio	Seedbank, saline zones.	13-34°C, 16 hrs., light.	Effective. Germinates response to reduced salinity.	Ungar and Riehl (1980)

MORPHOLOGY

Carex

Sedges are perennial plants with stems arising singly, few together, or in clumps from creeping rhizomes. Stems are solid and triangular to terete in cross section. Most species are monoecious; a few are dioecious. The inflorescence, borne on a reproductive culm (fig. 1), consists of single or multiple spikes and may be staminate, pistillate, androgynous (staminate flowers borne above the pistillate flowers), or gynecandrous (pistillate flowers borne above the staroinate flowers) (fig. 2). Each flower is subtended by a scale. The perianth is lacking. Staminate flowers consist of two or three stamens. Pistillate flowers consist of a single pistil enveloped in the saclike perigynium, a specialized foliar structure. The two or three stigmas are exserted through an opening at the apex of the perigynium. The fruit is an achene that develops within the persistent perigynium (Cronquist and others 1977). Achenes are covered with a tough, leathery pericarp that ranges from light brown to nearly black. Achenes developing from ovaries with two stigmas are lens-shaped, while those developing from ovaries with three stigmas are triangular. The seed consists primarily of thick endosperm with a small embryo at the basal end (Lee 1952).

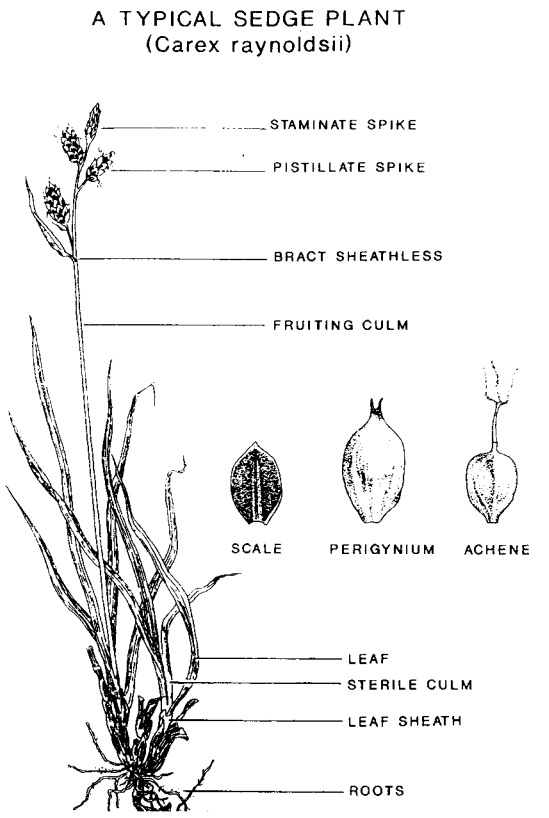


Figure 1--Morphology of a typical sedge plant (Carex raynoldsii) (modified from Lewis 1958).

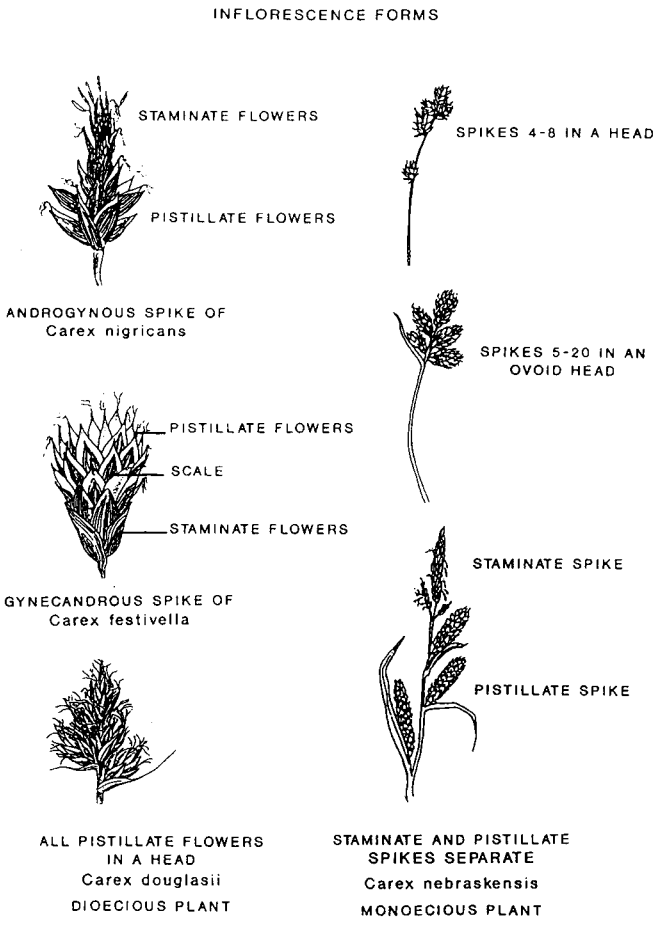
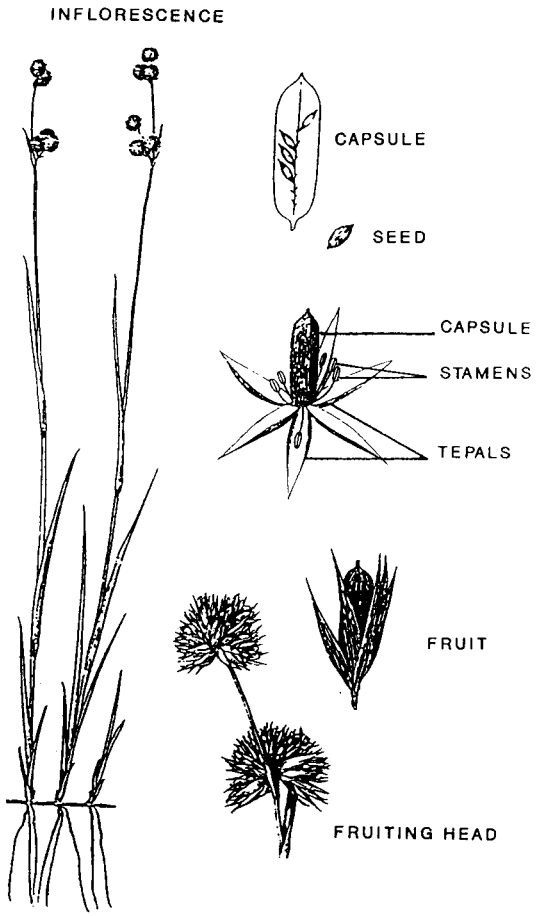


Figure 2--Inflorescence types of Carex species (modified from Lewis 1958).

Juncus

Rushes are grasslike annual or perennial herbs. Stems are solitary, few together, or caespitose, arising from rhizomes. They may be compressed or terete. Terete stems are sometimes hollow and may have transverse septae. Reproductive culms are terminated by inflorescences ranging from open panicles to headlike structures (fig. 3). Flowers are perfect with six membranous, scalelike, greenish to brownish tepals in two whorls, six or sometimes three stamens, and a single pistil with three stigmas. The fruit is a loculicidal capsule with three locules bearing numerous tiny seeds (Hermann 1975, Welsh and others 1987). Seeds vary from elongate and spindle-shaped to nearly spherical (Cronquist and others 1977). Seed color ranges from yellowish-gold to gray or dark brown. The rudimentary embryo is embedded in endosperm near the basal end of the seed. Seeds are dispersed when the capsule opens at maturity.



Juncus ensifolius

Figure 3--Morphology of a typical rush plant (Juncus ensifolius) (modified from Hermann 1975).

HARVESTING

Most Carex achenes and Juncus seeds are harvested between mid-June and early October with maturation date and duration of the harvest period varying considerably with species, altitude, soil moisture, and local weather conditions. Several factors must be considered in selecting collection sites:

1. Seed transfer guidelines have not been established for Carex or Juncus species. Until such information becomes available, seed or vegetative material should be harvested at sites similar to the proposed planting site.
2. It may be necessary to search for a stand or portion of a stand where mature achenes or seeds of acceptable quality occur in sufficient quantity to meet collecting objectives. For species that rapidly disperse their achenes or seeds at maturity, only a portion of the stand may be available for collection on a given date.
3. If single species collections are required, it may be necessary to locate a monotypic stand or take care to avoid collecting unwanted but similar appearing species growing in mixed stands. Germination requirements vary considerably among species. Thus, it is best to harvest and store collections of different species separately for nursery production.
4. Heads of palatable species may be grazed by livestock or wildlife.
5. Attacks by insects and fungal diseases are not uncommon. Infested stands should be avoided.

Tables 2 and 3 contain harvesting dates and recommendations for a number of common Carex and Juncus species derived from our work, primarily in southern Idaho and eastern Oregon. Within inflorescences, fruits of both genera generally ripen fairly uniformly. Perigynia fill of Carex species with thin, light-colored perigynia can easily be determined with a hand lens or dissecting microscope (table 2). For species with thick or dark-colored perigynia, fill is estimated by pressing the perigynia between the thumb and index finger. Both perigynia and achene fill may be highly variable in some species such as C. rostrata. Numerous empty perigynia occur in some C. nebrascensis and C, lanuginosa collections.

It may be necessary to examine capsules of Juncus species with a hand lens or to shake intact or crushed capsules over a light-colored surface to determine whether capsules have begun opening and seeds have dispersed. Color of mature fruits varies with species and ranges from green or straw-colored to dark brown. It is not uncommon for all capsules of some Juncus populations to be insect infested.

Both Carex and Juncus species may be harvested by clipping inflorescences. Some Carex species are more rapidly collected by hand-stripping achenes from inflorescences (table 2). If Juncus capsules are open, simply shake the seeds into a container. Attaching a collection bag or other container to a belt or shoulder strap frees both hands for harvesting. Gloves, clippers, and waterproof boots are essential collecting equipment.

Achenes, inflorescences, and associated material harvested from wetlands generally have a high moisture content and poor storage potential. Thus, immediate drying in the field may be required. Overheating and warm, damp conditions conducive to development of mold must be avoided. Collections should be labeled carefully with location and a detailed site description. A voucher specimen of a typical plant should be collected, labeled, pressed, and accurately identified. A sharp digging tool will be needed for extracting roots and rhizomes.

Table 2.--Achene harvesting technology for selected Intermountain *Carex* species.

Species	Common name	Achene harvesting period	Determination of perigynia fill[1]	Harvest method[2]	Ease of collection[3]	Achene weight[4]	Special considerations[5]
						-millions/kg-	
Carex amplifolia	Big-leaf sedge	Aug.-Sept.	1,2 (Good fill common)	Clip	2-3	1.2	Large plants. Stout and coarse stems. Plants may be scattered.
Carex aquatilis	Water sedge	Aug.-Sept.	1,2	Clip	2-3	3.0	Check perigynia fill. Often dense stand.
Carex douglasii	Douglas sedge	July-Aug.	1,2	Clip/ strip	3-4	2.5	Inflorescence small. Plants dioecious. Perigynia fill may be low. Low growing, scattered plants.
Carex lanuginosa	Woolly sedge	July-Sept.	1	Clip/ strip	3-4	1.2	Check perigynia fill. Achenes sometimes smut infested. Plants may be scattered.
Carex lenticularis	Lens sedge	July-Sept.	1 (Good fill common)	Clip/ strip	1-2	3.0	Perigynia disarticulate readily when mature. Plants form large clumps.
Carex microptera	Small-winged sedge	June-Sept.	1,2	Clip/ strip	4-5	3.2	Inflorescences small. Check perigynia fill. Plants may be scattered.
Carex nebrascensis	Nebraska sedge	Aug.-Sept.	1,2	Clip	2-3	2.7	Check fill. Large plants with stout stems. Plants may be scattered.
Carex pachystachya	Chamisso sedge	June-Aug.	1,2	Strip	3-4	1.6	Small inflorescences. Achenes disarticulate readily when mature.
Carex praegracilis	Silver sedge	June-Sept.	1,2	Clip/ strip	4-5	1.9	Small inflorescences. Low growing, scattered plants.
Carex rostrata	Beaked sedge	Aug.-Sept.	1	Clip	2-3	1.3	Plants large with stout stems. Perigynia fill may be low. Achenes sometimes smut infested. Plants may be scattered.
Carex sheldonii	Sheldon's sedge	Aug.-Sept.	1	Clip	2-3	1.1	Pergynia fill may be low. Achenes sometimes smut infested. Plants sometimes scattered.
Carex simulata	Shortbeaked sedge	July-Sept.	1,2	Clip/ strip	4-5	3.1	Small inflorescences. Plants often scattered.
Carex stipata	Prickly sedge	July-Sept.	1 (Good fill common)	Clip/ strip	1-2	1.3	Large inflorescences. Achenes disarticulate readily when mature. Dense stand or scattered.
Carex subfusca	Pond sedge	July-Sept.	2	Clip/ strip	4-5	4.4	Heads small. Plants may be scattered. Perigynia disarticulate readily when mature.
Carex vesicaria	Blister sedge	Aug.-Sept.	1	Clip	2-3	1.6	Check seed fill. Plants scattered to densely clustered.
Carex vulpinoidea	Fox sedge	July-Sept.	2 (Good fill common)	Clip/ strip	1-2	2.6 2.9[6]	Large inflorescences. Achenes disarticulate readily when mature. Plants may be scattered.

[1]Field methods to test for presence of achene within perigynia:
1 - Press perigynia between fingers.
2 - Examine perigynia with hand lens.
[2]Clip - several inflorescences may be clipped at once.
Strip - hand strip achenes from inflorescences.
[3]Prompt collection is required for those species with achenes that disarticulate readily at maturity.
[4]Authors' data, based on one or two conditioned collections. Weights include achenes and perigynia.
[5]Scoring: 1=achenes easily harvested. 5=achenes difficult to harvest.
[6]Swingle (1939)

Table 3.--Seed harvesting and testing technology for selected Intermountain *Juncus* species.

Species	Common name	Seed harvesting period	Ease of harvest[1]	Seed weight[2]	Harvesting considerations	Viability testing considerations
				-millions/kg-		
Juncus articulatus	Jointed rush	Aug.-Sept.	3	64	Inflorescence small. Stems loosely clustered.	
Juncus balticus	Baltic rush	Aug.-Sept.	5	32	Inflorescence small. Number of seeds/inflorescence varies considerably among populations. Seeds sometimes insect infested. Plant density highly variable. Plants scattered.	Clear seeds with lactophenol. Seeds produce mucilage when imbibed.
Juncus bufonius	Toad rush	July-Aug.	3-5	58 67[3]	Inflorescence and plants small. Capsules open soon after seed maturation. Flowers solitary.	
Juncus effusus	Soft rush	Aug.-Sept.	1	96	Large inflorescences. Capsules open soon after seed maturation. Large clump-forming plants.	Seeds produce mucilage when imbibed.
Juncus ensifolius	Dagger rush	Aug.-Sept.	3	152	Inflorescence size variable. Capsules open soon after seed maturation. Plants may be scattered.	
Juncus howellii	Howell's rush	July-Sept.	1-2	79	Capsules open soon after seed maturation. Seeds sometimes insect infested.	
Juncus tenuis	Slender rush	July-Sept.	1-2	113	Capsules open early. Plants sometimes clump-forming.	Seeds produce mucilage when imbibed.
Juncus torreyi	Torrey's rush	Aug.-Sept.	2	81 83[4]	Large inflorescences. Capsule only partially dehiscent. Some seeds remain within capsules overwinter. Plants may be scattered.	

[1]Code: 1=easily harvested; ...5=difficult to harvest.
[2]Authors' data, based on 1 or 2 conditioned seedlots
[3]Stevens (1932)
[4]Stevens (1932)

CONDITIONING

Drying and cleaning Carex achenes and Juncus seeds is fairly simple and basically the same for all species of each genus. Harvested Carex collections must be thoroughly air-dried in a warm, dry, well-ventilated area by spreading seeds, fruits, or inflorescences in a thin layer over a fine screen. Drying inflorescences outdoors may not be possible unless screens are also placed over the material to prevent it from blowing away.

Small lots of dried Carex achenes can be separated from inflorescences by hand stripping, by rubbing them with the palm of the hand, or by using a rubbing board. It is not necessary to separate the perigynia from the achenes. Care should be taken to avoid damaging achenes. Chaff can be removed using sieves (sizes 12 to 18 are useful) or an air-screen cleaner. Purity may be further improved using a seed blower. Techniques and equipment used for cleaning grass seed can be used for larger Carex lots.

Fruiting culms of Juncus are best dried upright in large buckets. Juncus capsules open during the drying process. Seeds can then be shaken into a container and separated from chaff using a fine screen (0.3 to 0.6 mm openings).

STORAGE

We have limited information regarding the effect of storage conditions on germinability, dormancy, afterripening, vigor, or longevity of Carex achenes or Juncus seeds (Amen and Bonde 1964, Bliss 1958, Comes and others 1978, Muenscher 1936, Schmid 1984). Seeds of species in both genera are known to survive for long periods in soil seed banks (Ebersole 1989, Hill and Stevens 1981, Jerling 1983). Viability of species included in our studies (listed in tables 2 and 3) did not decline after 14 to 17 months of storage in sealed containers at room temperature. Moisture content of these collections ranged from 6 to 8 percent.

SEED QUALITY

Purity

With careful cleaning it is possible to remove many empty or poorly developed achenes and seeds from Carex and Juncus collections. Most Carex collections can be cleaned to purities in excess of 90 percent using a seed blower or by hand winnowing. Empty perigynia are included with pure seed when calculating purity of Carex collections. Purity of Juncus collections is improved by avoiding inflorescences contaminated with dirt, mud, or disease. Shaking seeds from open capsules directly into a container without first crushing the capsules also yields greater purity.

Fill

Fill of Carex perigynia and achenes, and Juncus seeds may vary considerably among collections. Carex achenes must **be sliced open to** determine fill. Empty **Juncus seeds are collapsed** and therefore easily **recognized when viewed under** a microscope.

Achene and Seed Weight

Few values have been reported in the literature (tables 2,3). Our data are based on one or two conditioned central and **southern Idaho** collections for each species. Variability within species has not been examined.

Viability

Viability tests are used to evaluate achene and seed quality because standardized germination tests for individual Carex and Juncus species have not been developed. High viability seedlots may be obtained if healthy, mature fruits and seeds are selected for harvest and collections are carefully conditioned. Viability may be tested using the following equipment and procedures:

I. Materials and Equipment

Watchglasses, filter paper (Whatman 5.5 cm diameter, white), razor blade (new, single edge), TZ solution (1$ 2,3,5-triphenyl tetrazolium chloride), distilled water, teasing needle (fine point), Kimwipes, dissecting microscope, fine point bamboo strip, antistatic spray, glass plate.

II. Procedure for Carex

A. Preconditioning
1. Label watchglasses, line with filter paper.
2. Place Carex achenes (with perigynia intact) in each watchglass; add distilled water to cover.
3. Presoak 12 hours at 25°C.

B. Preparation for sectioning:
1. Lift one side of filter paper and blot excess water from watchglass.
2. Transfer filter paper with achenes to glass plate on microscope stage.

C. Sectioning
Carex achenes may be sectioned lengthwise, crosswise, or by removing a superficial slice (fig. 4). We have found the first two methods easiest and most effective. None require perigynia removal.
1. Lengthwise section
Hold perigynium in place with forceps or index finger of one hand and slice away 1/4 of the tissue

along one long side of the achene with a sharp razor blade (fig. 4). Place achene with embryo intact in TZ solution.

2. Cross section
   Hold basal portion of perigynium in place with forceps or index finger of one hand. Slice away and discard upper half of achene. Place lower half (containing the embryo) in TZ solution.
3. Superficial slice
   Hold basal portion of perigynium in place with forceps or index finger of one hand. Carefully slice through achene from midsection to the base, exposing, but not injuring the embryo. Place embryo portion in TZ solution.

D. Staining
   Soak sectioned achenes in TZ solution for 4 to 6 hours at 33 to 38°C or overnight at 25 to 30°C. If achenes float, fold the filter paper in half over them.

E. Reading (evaluation of staining)
1. Blot excess TZ solution. Transfer filter paper with achenes to microscope stage.
2. If achenes were prepared by lengthwise or crosswise sectioning, use needles to tease out the embryo or cut achene lengthwise through the center of the embryo (fig. 4).
3. If achenes were prepared by superficial sectioning, embryos can be read in place.
4. Viable embryos are firm and stain uniformly red or pink (fig. 4). Embryos are considered nonviable if they were unstained, lightly stained, or darkly stained and flaccid. Firm, well stained immature embryos are considered viable while those staining lightly are regarded nonviable.

III. Procedure for Juncus

The tiny seeds of Juncus (0.25 to 0.50 mm in length) are difficult to handle due to static electricity. The problem can be minimized by placing them on a glass plate sprayed with an antistatic product and manipulating them with a bamboo probe, also sprayed with an antistatic product.

A. Preconditioning - as described for Carex.

B. Preparation for sectioning - as described for Carex.

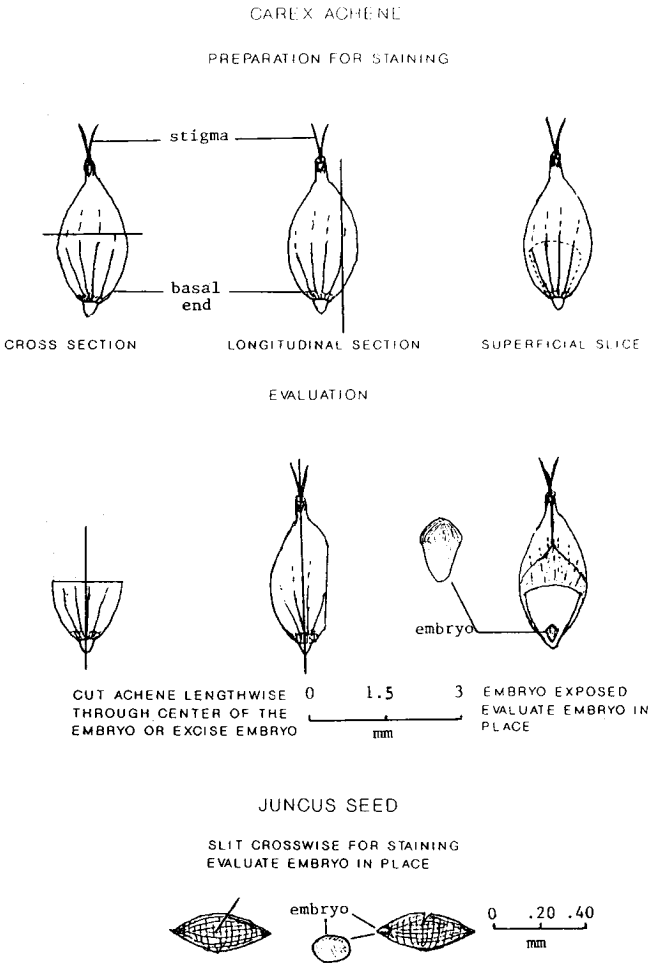


Figure 4--Viability testing procedures for Carex achenes and Juncus seeds--sectioning techniques for staining and evaluation.

C. Sectioning
1. With a sharp corner edge of a razor blade, make a small slit across the seed without bisecting it (fig. 4). If the seed is bisected, it is often difficult to determine which of the two halves contains the embryo.
2. Blot excess liquid from filter paper by placing it on blotter or Kimwipe, then fold it like an envelope making sure seeds are in the middle.
3. Place folded filter paper in a dry watchglass and add enough TZ solution to cover.

D. Staining
   Soak sectioned seeds in TZ solution for 4 to 8 hours at 33 to 38°C or overnight at 25 to 30°C.

E. Reading (evaluation of stain)

1. Transfer the folded filter paper to the microscope stage, unfold and read.
2. Stained embryos of most species can easily be read without excision. Viable embryos are firm and stain uniformly red or pink. Unstained, slightly stained or darkly stained and flaccid embryos are considered nonviable.
3. Opaque seedcoats of some species such as Juncus balticus are cleared by soaking them in lacotphenol for 12 hours at 30oC (table 3). Some Juncus seeds are difficult to handle as they produce mucilage when moistened (table 3). Adding water to the filter paper will reduce sticking.

GERMINATION

Germination requirements for common Carex and Juncus species of the Intermountain Region are summarized in table 1. Light and alternating temperatures are common requirements for both genera. Fungal development is a common problem with many Carex collections. Thus, it may be necessary to treat achenes with a fungicide prior to pretreatment or incubation. Juncus seeds and germinants are barely visible to the unaided eye. Thus, a hand lens or dissecting microscope is essential for conducting germination tests. Static electricity problems encountered with Juncus seeds can be minimized using procedures described under viability testing.

Based on our experience, seed propagation is operationally possible for fresh seed lots of nondormant species such as Carex lenticularis, _C. subfusca, or Juncus articulatus and for those that respond positively to cold pretreatment (30 days at 3-5oC) such as _C. amplifolia, _C. nebrascensis, _J. effusus, and _J. ensifolius. We are presently developing germination pretreatments for species that do not respond to stratification.

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