Ericaceae—Heath family

Kalmia latifolia L.

mountain-laurel

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Synonyms. *Kalmia latifolia* var. *laevipes* Fern.

Other common names. Broad-leaved laurel, calico-bush, spoonwood, ivy, mountain ivy, big-leaved ivy, ivy-bush, laurel-leaves, and calmoun.

Growth habit and occurrence. The genus *Kalmia* L. consists of about 6 species of evergreen or deciduous shrubs native to North America and Cuba (LHBH 1976). Of these species, mountain-laurel—*Kalmia latifolia* L.—has for a number of reasons attracted the most attention. Mountain-laurel is a broad-leaved, evergreen shrub that is dense and symmetrical when young but develops an open, loose habit with age (Dirr 1990). Typically, the shrub reaches a height and spread of 1.5 to 2 m. However, heights of 4.6 to 9 m have been reported (Bridwell 1994; Dirr 1990). The species has a wide range, from coastal Maine to northwestern Florida, primarily along the Appalachian Mountain range, westward to Louisiana and northward into southern Ohio and Indiana (Fernald 1950; Jaynes 1997). This range includes USDA Hardiness Zones 4 to 9 (Dirr 1990). Mountain-laurel is often found in rocky or gravelly woods and clearings, typically on acid or sterile soils (Fernald 1950). A common associate of mountain-laurel in the mountainous regions of the southern United States is rosebay rhododendron—*Rhododendron maximum* L. Together, these 2 species form almost impenetrable thickets, sometimes known locally as "laurel slicks" or "rhododendron hells" (Olson and Barnes 1974).

Use. Mountain-laurel is an excellent ornamental shrub for shady borders and for naturalizing (Dirr 1990). As an understory shrub, it effectively prevents water runoff and soil erosion (Jaynes 1997). Clumps and thickets of mountain-laurel are a haven for wildlife, providing year-round cover and protection (Jaynes 1997). Practical considerations aside, Rehder (1986) has described mountain-laurel as one of the most beautiful American flowering shrubs. In addition to the value of the species as a landscape plant, the foliage is also used in Christmas decorations and the fine-grained and durable wood is used for making pipes and other items (Jaynes 1997). Unfortunately, the foliage of mountain-laurel is poisonous and caution should be exercised when planting in a landscape utilized by young children or grazing animals (Jaynes 1997; Mabberley 1993).

Geographic races and hybrids. Five races of mountain-laurel have been identified:

- *Kalmia latifolia* f. *angustata* Rehd.
- *Kalmia latifolia* f. *fuscata* (Rehd.) Rehd.
- *Kalmia latifolia* f. *myrtifolia* (Bosse) K. Koch.
- *Kalmia latifolia* f. *obtusata* (Rehd.) Rehd.
- *Kalmia latifolia* f. *polypetala* (Nickolsen) Beissner, Schelle, & Zabel.

There are 4 interspecific crosses that produce progeny:

- *K. polifolia* Wangenh. × *K. latifolia*—reciprocal cross did not result in seed set (Jaynes 1997)
- *K. latifolia* × *K. hirsuta* Walt.—reciprocal cross also set seed (Jaynes 1997)
- *K. angustifolia* L. × *K. latlifolia*—reciprocal cross did not result in seed set (Jaynes 1997)
- *K. polifolia* × *K. microphylla* (Hook.) A. Heller—reciprocal cross also set seed (Jaynes 1997)

There is also 1 intergeneric cross known to produce progeny:

- *K. latifolia* × *Rhododendron williamsianum* Rehd. & Wils.—putative hybrid (Jaynes 1997)

Flowering and fruiting. Mountain-laurel typically flowers between April and June, depending on local climate (Radford and others 1968). Floral color ranges from white to a deep rose with purple markings (Dirr 1990). There have been many cultivar selections across this color spectrum

(Jaynes 1997). An individual shrub commonly has hundreds of terminal inflorescences (corymbs), each with 50 to 300 flowers (Rathcke and Real 1993). Flower size also varies with different forms and cultivars of the species, but the normal diameter ranges from 2 to 2.5 cm (Dirr 1990). Flowers have an unusual pollination mechanism, with 10 anthers held in pouches along the inside of the corolla (Mabberley 1993). When pollen is ripe, a visiting insect—typically a bumble bee (*Bombus ternarius* Say)— triggers the release of the anthers (Rathcke and Real 1993). The pollen is then cast over the insect so that cross pollination can occur with the next flower of mountain-laurel visited by the insect. Typically, mountain-laurel is considered to be a non-selfing species (Fryxell 1957; Jaynes 1997). A recent study by Rathcke and Real (1993) suggested that certain populations of mountain-laurel may be able to self-fertilize in the absence of pollinators. Autogamy seems most likely to have evolved for reproductive assurance under competition for pollinator service (Rathcke and Real 1993). The fruit is a brown, 5-valved, globular dehiscent capsule about 6 mm in diameter, borne in clusters, that matures in September and October (Radford and others 1968) (figure 1).

Collection of fruits and seed extraction. Once seed capsules have turned brown and dried, seeds are mature and ready for harvest. Harvested capsules should be placed in a coin envelope, paper bag, or small vented container and allowed to dry for an additional 2 to 4 weeks at about 21 °C. Capsules will then open, and their seeds can be shaken loose (Blazich 1996; Jaynes 1997). The seeds are cleaned by gently shaking them down a creased sheet of paper (Jaynes 1997). Seeds will move down the paper faster than the chaff. This process should be repeated several times until clean seeds are separated. If the capsules are collected prematurely, they will not dehisce and must be crushed. This treatment results in large amounts of debris that can be removed effectively by sieving. Viable seeds can also be separated from chaff and empty seeds by using an air-column blower or by placing crushed capsules in water and allowing viable seeds to sink (Jaynes 1997). Seeds of mountain-laurel are extremely small, with cleaned pure seeds averaging 50,000/g (1.4 million/oz) (Jaynes 1997). Each seed is about 1 mm long and 0.3 mm wide, with a ribbed or striated surface (figures 2 and 3).

Storage. Seeds of mountain-laurel can remain viable for several years when stored at room temperature (Glenn and others 1998; Wyman 1953). However, longevity of seeds can be extended greatly (up to 15 years) if seeds are stored at 4.4 °C (Jaynes 1997). When dried to a moisture content of 5%, seeds have been stored successfully for 4 years at –18 or 4 °C with no loss in viability (Glenn and others 1998). Storage under these conditions suggests that the species is orthodox in storage behavior, and that viability can be maintained for extremely long periods of time.

Pretreatments and germination tests. After harvest, there is no inhibiting dormancy, and seeds germinate readily with no pretreatment necessary (Fordham 1960; Jaynes 1997). However, stratification (moist-prechilling) for 8 weeks or soaking seeds overnight in 200 ppm gibberellic acid may increase germination (Jaynes 1997). Seeds of mountain-laurel require light for germination (Jaynes 1971; Malek and others 1989). Malek and others (1989) conducted a 30-day germination study of seeds from a native popula-

Figure 1—*Kalmia latifolia*, mountain-laurel: cluster of capsules (**top**) and a single capsule (**bottom**).

Figure 2—*Kalmia latifolia*, mountain-laurel: seeds.

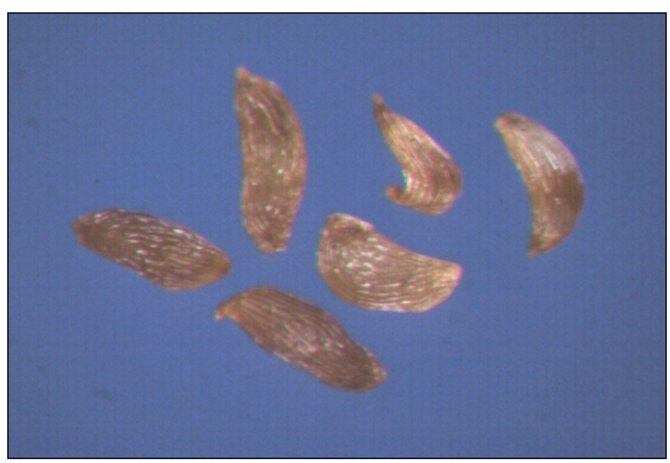
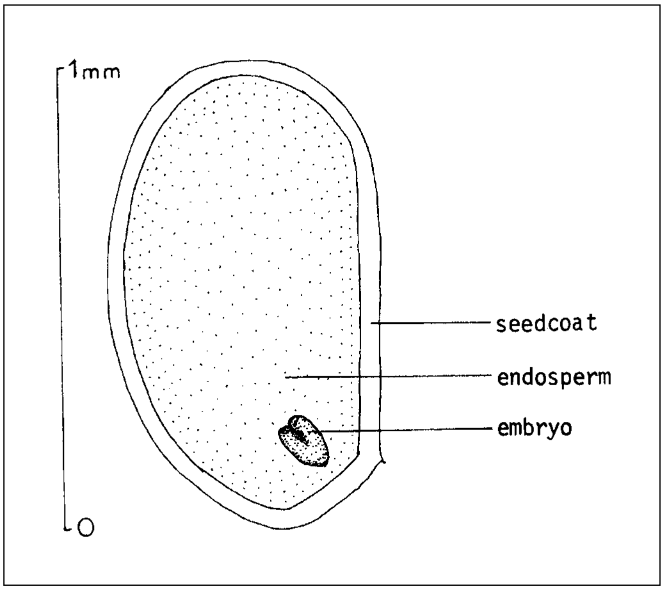


Figure 3—*Kalmia latifolia*, mountain-laurel: longitudinal section of a seed.



tion growing in Avery County, North Carolina. Seeds were germinated at 25 °C or an 8/16-hour thermoperiod of 25/15 °C with daily photoperiods of 0, $^1/_2$ hour, $^1/_2$ hour twice daily, 1 hour, or 2, 4, 8, 12, or 24 hours. The cool-white fluorescent lamps used as the light source provided a photosynthetic photon flux (400 to 700 nm) of 42 μmol/m^2/sec (3.2 klux). For both temperatures, no germination occurred during the 30-day test period for seeds not subjected to light. At 25 °C, increasing the length of the photoperiod increased germination, with germination of 82 and 90% occurring by day 27 for the 12- and 24-hour photoperiods, respectively. The alternating temperature of 25/15 °C enhanced germination when light was limiting. At this temperature, germination ≥ 87% occurred by day 24 for photoperiods ≥ 8 hours. There are no test methods prescribed for official testing of this species.

Nursery practice. Seeds should be sown directly on peat, placed under lights, and maintained at 24 °C (Dirr 1990). Other media can also be used (Jaynes 1997). Initial seedling growth is very slow (Dirr and Heuser 1987; Weinberg 1984), although Malek and others (1992) reported that seedling growth can be optimized under long-day conditions with 9/15-hour day/night temperatures of 22 to 26/22 °C. To stimulate seedling growth further, the ambient atmosphere can be supplemented with 2,000 ppm carbon dioxide (Jaynes 1997). Seedlings should be transplanted 2 to 6 months after germination into pots with a medium consisting of 70 liters (2 bu) peat, 35 liters (1 bu) perlite, 17 liters ($^1/_2$ bu) coarse sand, and 15 to 30 g (0.5 to 1 oz) hydrated lime and fertilized every 3 weeks with a 20-20-20 ($N:P_2O_5:K_2O$) water-soluble fertilizer at a rate of 1.2 g/liter (0.04 oz/1.06 qt) (Jaynes 1997).

Traditionally, mountain-laurel has been propagated vegetatively by layering, grafting, and stem cuttings. However, there has been limited success with vegetative propagation by stem cuttings and results appear to be genotype specific (Dirr and Heuser 1987). On the other hand, micropropagation (tissue culture) has proven very successful and has led to wide availability of outstanding selections and hybrids of the species (Lloyd and McCown 1980).

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Araliaceae—Ginseng family

Kalopanax septemlobus (Thunb. ex A. Murr.) Koidz.

castor-aralia

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Synonym. *K. pictus* (Nakai).

Growth habit, occurrence, and use. The genus *Kalopanax* comprises 1 species of deciduous, small to medium-sized tree that is native to China, Japan, eastern Russia, and Korea (LHBH 1976; Ohashi 1994). Castor-aralia—*K. septemlobus* (Thunb. ex A. Murr.) Koidz.—was introduced in 1865 and has been used primarily for ornamental purposes, as a shade tree yielding a tropical effect in USDA Hardiness Zones 4 to 7 (Dirr 1990; Hillier 1991; Krüssmann 1984; van Gelderen and others 1994; Wijnands 1990). It is a valuable tree in China (Zhao and others 1987) and the wood may be suitable for bentwood, carving, and some interior use (KRRT 1987). The dried bark has been used as a medicine in China for various ailments (Sano and others 1991). Analysis of the nutrient content of leaves of castor-aralia showed plentiful levels of calcium, magnesium, zinc, iron, and beta-carotene, making it a potential food source of high nutritive value (Liu and others 1998). Phytochemical investigations have allowed the isolation and characterization of saponin and phenolic compounds (Porzel and others 1992; Sano and others 1991; Shao and others 1989, 1990; Sun and others 1990) that are reported to show preventive activity against stress-induced changes in mice.

Castor-aralia is an upright, oval-rounded tree that can obtain heights of 24.4 to 27.4 m in the wild, but under cultivation practices usually 12.2 to 18.3 m (Dirr 1990). The branches are coarse, stout, and bear numerous broad-based prickles (Dirr 1990; Hillier 1991). The leaves are quite variable—but somewhat similar in shape to sweetgum, *Liquidambar styraciflua* L.—changing to yellow or red in the fall (Dirr 1990). Another variety—*K. septemlobus* var. *maximowiczii* (Van Houtte) Hand.-Mazz.—has leaves that are deeply lobed (5–7) and incised to beneath the middle of the blade (Krüssmann 1984).

Flowering and fruiting. The perfect, white flowers, which bloom in July to early August (sometimes as early as May in parts of Japan), are produced in numerous umbels, forming large terminal panicles that measure 30.5 to 61 cm across (Dirr 1990; Hillier 1991; Rudolf 1974). The fruits are globose drupes about 0.4 cm wide with a persistent style (bluish black in color) that contains 2 flat seeds (Dirr 1990; Krüssmann 1984). The fruits, which ripen in September–October, have a fleshy coat and are relished by birds (Dirr 1990; Dirr and Heuser 1987).

Collection of fruits; extraction, cleaning, and storage of seeds. The fruits are harvested by hand or shaken onto canvas as they ripen in September–October (Rudolf 1974). Fruits should be run through a macerator with water to extract the seeds (figure 1). Although more recent information was not attainable, Sins (1925, cited by Rudolf 1974) reported that about 3.6 to 4.5 kg (8 to 10 lb) of clean seeds can be obtained from 45.4 kg (100 lb) of fresh fruits. The number of cleaned seeds per weight was 220,000/kg (99,790/lb) (Satoo 1992). The seeds (figure 2) have small embryos and contain endosperm tissue (Rudolf 1974). Reports indicate that seeds can be kept satisfactorily for 1 year under ordinary storage conditions (Sins 1925, cited by Rudolf 1974). However, the use of sealed containers kept at 0 to 5 °C is suggested for longer storage periods.

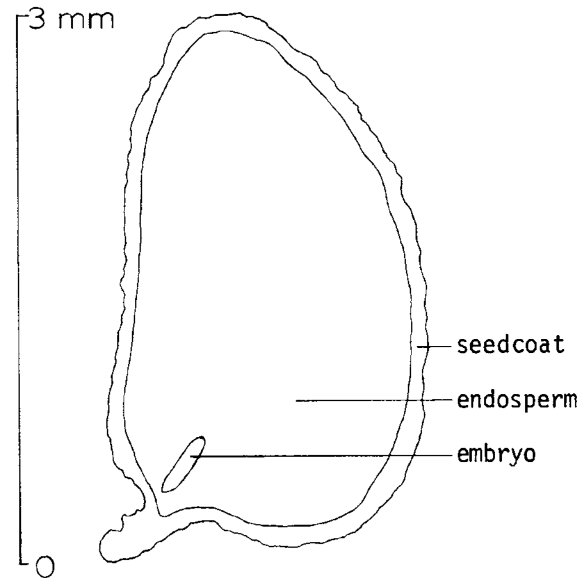
Figure 1—*Kalopanax septemlobus*, castor-aralia: cleaned seed extracted from the fleshy fruit.

Pregermination treatments. Under natural conditions, castor-aralia seeds require a 2-year germination period (Sato 1998). Dormancy of the seed is caused by neutral (coumarin) and acid (abscisic) inhibitors present in the seedcoat and endosperm, and by an impermeable seedcoat (Dirr 1990; Huang 1987a&b). Warm temperatures of 15 to 25 °C for 3 to 5 months followed by cold stratification at 0 to 5 °C for 2 to 3 months will overcome seed dormancy and give reasonable germination (Dirr and Heuser 1987; Huang 1986, 1987b; Sato 1998; Xu and Han 1988). Soaking the seeds in sulfuric acid for 30 minutes will substitute for the warm stratification period (Dirr and Heuser 1987; Rudolf 1974).

Germination tests. Tests in germinators or sand flats for 60 days is suggested (Rudolf 1974).

Nursery practice and seedling care. Fresh seeds that have been cleaned and dried can be sown in the fall but will not germinate for 2 years (Dirr and Heuser 1987; Satoo 1992). Stratified seeds should be sown in the spring (Rudolf 1974). The seeds should be sown in well-prepared beds at a rate of 1,760 to 3,300/m^2 (164 to 307/ft^2) to give 200 to 300 seedlings/m^2 (19 to 28/ft^2) (Satoo 1992). Castor-aralia can be propagated by root cuttings (Dirr and Heuser 1987; Macdonald 1986). Root cuttings, 7.6 to 10.2 cm (3 to 4 inches) in length, should be dug soon after frost and then placed upright (proximal end) in a medium kept in a cool greenhouse with bottom heat (Dirr and Heuser 1987). Stem cuttings are difficult, if not impossible, to root from mature trees (Dirr and Heuser 1987).

Figure 2—*Kalopanax septemlobus*, castor-aralia: longitudinal section through a seed.



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Chenopodiaceae—Goosefoot family

Kochia Roth

kochia

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Growth habit, occurrence, and use. Two woody-based non-rhizomatous sub-shrub species of kochias are found in the western United States. The widely distributed native, gray molly, and its introduced and closely related counterpart (Blackwell and others 1978), forage kochia, are found in salt-desert, sagebrush, pinyon–juniper, and dry mountain brush communities (table 1). Erect to steeply ascending annual stems growing from a woody base and long-lived prostrate branches attain heights of 5 to 50 cm for gray molly (Welch and others 1987) and 10 to 100 cm for forage kochia (Baylan 1972).

Each species provides nutritious winter forage for livestock (Baylan 1972; Blauer and others 1976). Variability in preference by livestock (Shishkin 1936) and mule deer (*Odocoileus hemionis*) (Davis and Welch 1985) has been observed among ecotypes of forage kochia.

Both species have potential for use in revegetation of saline and alkaline soils on arid and semi-arid sites (Blauer and others 1976; Clarke and West 1969; Francois 1976; Romo and Haferkamp 1987) and forage kochia has been used successfully in stabilizing mine spoils (Frischknecht and Ferguson 1984). Perhaps the greatest potential use of forage kochia is in providing cover and forage on degraded western cold-deserts (McArthur and others 1974; Monsen and Turnipseed 1990; Pendleton and others 1992). Where established, it effectively competes with weeds such as halogeton (*Halogeton glomeratus* (Bieb.) C.A. Mey.) and cheatgrass (*Bromus tectorum* L.) (Blauer and others 1993; McArthur and others 1990). Natural spread of forage kochia from seeds can be rapid where perennial cover is lacking. The high water content of stems and leaves during summer months and crown sprouting capacity make this species especially desirable for desert landscapes prone to high fire frequencies (Kitchen and Monsen 1999).

Geographic races and hybrids. Blackwell and others (1978) concluded that the random variation in pubescence in gray molly did not justify dissection of this species to subspecies level. Conversely, forage kochia is a complex species represented by 3 known ploidy levels (2X, 4X, and 6X) (Pope and McArthur 1977) and extensive phenotypic variation in plant stature, stem color and diameter, leaf size and pubescence, growing season, and adaptability to soils (Baylan 1972). Numerous regional ecotypes have been grouped into as many as 4 species; however, a single species with 2 subspecies—*virescens* (Frenzl) Prat. (green-stem) and *grisea* Prat. (gray-stem and highly variable)—is the most commonly accepted (Baylan 1972).

About 40 accessions of forage kochia have been introduced to the United States, primarily for evaluation as candidates for revegetation of disturbed arid and semi-arid regions in the western United States (Kitchen and Monsen 1999). To date, a single cultivar, 'Immigrant' (2X, ssp.

Table 1—*Kochia,* kochia: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
***K. americana* S. Wats.** *K. vestita* (S. Wats.) Rydb. *K. americana* var. *vestita* S. Wats.	**gray molly,** green molly	Oregon to Montana S to California, Arizona, & New Mexico
***K. prostrata* (L.) Schrad.** *K. suffruticulosa* Lessing *Salsola prostrata* L.	**forage kochia,** prostrate kochia, summer-cypress, prostrate summer-cypress	Deserts, steppes, & mtns of Central Asia, W to the Mediterranean Basin, & E to Manchuria; naturalized in W North America

Sources: Shishkin (1936), Welsh and others (1987).

virescens), has resulted from this research (Stevens and others 1995). 'Immigrant' has been planted on several thousand acres in Utah, Idaho, and surrounding states. Small plantings of other accessions (ssp. *grisea*) also exist (Blauer and others 1993; McArthur and others 1990; Monsen and Kitchen 1995; Monsen and Turnipseed 1990).

Flowering and fruiting. Kochia flowering structures are described as one to several, mostly perfect, inconspicuous, sessile flowers occurring in axils of foliose bracts (Welsh and others 1987). Stems are potentially floriferous throughout (Blackwell and others 1978). Flowering is indeterminate from May to August for gray molly and from July to September for forage kochia (Shishkin 1936). The fruit is a 1-seeded utricle that is enclosed in a thin, fragile perianth (figure 1). The perianth is horizontally winged at maturity. Perianth pubescence for forage kochia is highly variable (Baylan 1972). Seeds are oval to orbicular in shape and 1 to 2 mm in diameter. The embryo is bent into roughly the shape of a horseshoe, a common configuration for this family (figure 2).

Fruit collection and cleaning. Fruits of forage kochia ripen from September to November (Baylan 1972) whereas those of gray molly are generally ripe by mid-October. Fruits are easily dislodged when fully ripened and dry. They are hand-harvested by stripping individual stems or by beating seeds into a hand-held hopper with a badminton racket or similar device. Mechanical harvest techniques for forage kochia seeds include mowing stems just before fruits are ready to shatter, drying, and combining. Vehicle-mounted mechanical sweepers are also used to harvest fully ripened fruits from solid stands (Stevenson 1995). Although harvesting the fruits before the seeds are fully ripened can reduce losses to shattering, it also results in lower seed viability percentages (Waller and others 1983).

Figure 1—*Kochia prostrata*, forage kochia: fruits in perianth.

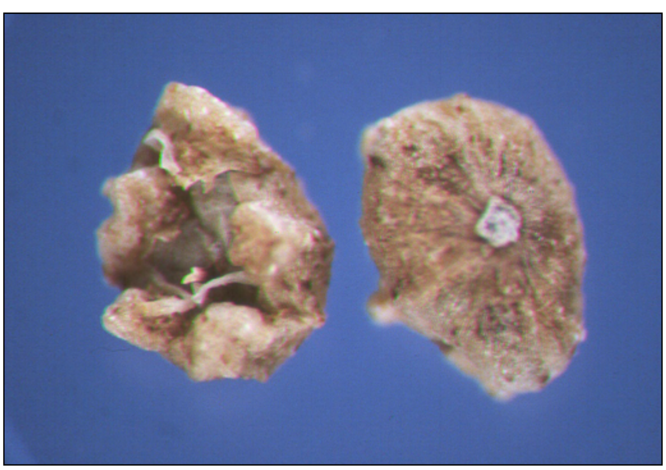
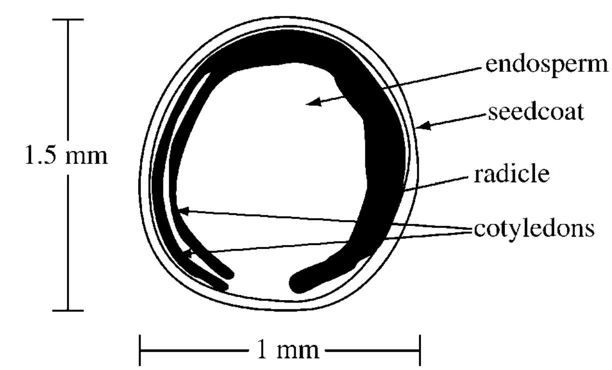


Figure 2—*Kochia prostrata*, forage kochia: longitudinal section through a seed.



The cleaning process removes empty fruits and fragments of fruits, leaves, and small stems using a barley debearder and multi-screened fanning mill (air-screen cleaner). Attainable purities for 'Immigrant' forage kochia depend upon harvest method and experience (Stevenson 1995). Hand-picked lots can usually be cleaned to at least 90% purity. Purities for lots harvested with mechanical harvesters are slightly lower (80 to 85%), whereas the combine method seldom produces purities greater than 70%. High-purity lots contain from 500,000 to 1,000,000 seeds/kg (225,000 to 450,000/lb) (Kitchen and Monsen 1999).

Storage. Kochia seeds are orthodox in storage behavior, but they are short-lived when storage temperatures are above 5 °C and seed moisture content is not controlled (Jorgensen and Davis 1984). Significant losses in forage kochia seed viability have been reported as early as 2 months after harvest (Baylan 1972); however, losses usually do not occur during the first 6 months of storage. Young and others (1981) reported viabilities of 18 to 34% for lots representing 13 accessions after 4 years of warehouse storage. Seed moisture contents above 7 to 8% and warm storage temperatures accelerate seed mortality. Baylan (1972) attributed this to loss of limited seed reserves through accelerated respiration rates. Storage life can be extended by drying seeds to between 4 and 8% water content and storing them in sealed containers at cool (< 5 °C) temperatures (Kitchen and Monsen 1999).

Seed germination and testing. Initial dormancy (0 to 75%) and rate of after-ripening of forage kochia seeds varies among ecotypes and years of harvest (Kitchen and Monsen 1999). After-ripening requires from 0 to 12 months at room temperature and longer in cold storage (Baylan 1972; Kitchen and Monsen 1999). Germination of recently harvested seeds is enhanced by fluorescent light and moist chilling. Germination of after-ripened or chilled seeds occurs across a wide range of temperatures and osmotic potentials (Young and others 1981; Romo and Haferkamp 1987). Germination rate at near freezing temperatures (2 °C) for recently harvested seeds is asynchronous within accessions and highly variable among ecotypes. Mean germination time shortens as seeds after-ripen (table 2). Field studies have demonstrated that when after-ripened seeds (with a rapid, synchronized germination rate) are sown in late fall/early winter, premature germination results in poor stand establishment (Kitchen and Monsen 1999). Haferkamp and others (1990) attributed poor establishment from 1-year-old forage kochia seeds to loss of seed viability and/or vigor. Their data show that in germination tests of laboratory-stored seeds, germination rate had greatly increased for 1-year-old seed when compared to the same lots tested fresh. This suggests that the poor establishment that they observed for 1-year-old seeds may have been related, at least in part, to change in germination rate, as has been observed by Kitchen and Monsen (1999) and Stewart and others (1999). Kitchen and Monsen (1995) also observed that seeds stored for more than 2 years at refrigerated and frozen temperatures retain full viability and are able to delay germination sufficiently for successful stand establishment.

Germinating gray molly seeds tolerate higher salinity levels than do seeds of many halophytic forage plants (Clarke and West 1969). In limited germination trials conducted on a single lot of fresh gray molly seeds, the level of initial dormancy was 26% and the cold temperature germination rate was comparable to that of fresh lots of forage kochia seeds (Monsen and Kitchen 1999).

Seed viability can be difficult to determine from tetrazolium chloride staining due to interference of embryonic chlorophyll. Independent laboratory tests for the same seed lot often produce variable results. Laboratory germination tests are also sometimes inconsistent due to difficulty with seedling normality classification. Dormant healthy seeds germinate normally and rapidly after the seedcoat is pierced.

Nursery and field practice. Forage kochia transplants are easily grown as bareroot and container stock from non-dormant seeds. For best results, seeds should be sown in growth medium 4 to 6 mm ($^1/_8$ to $^1/_4$ in) deep. Germinants are susceptible to fungal root pathogens, dictating clean greenhouse culture techniques. Transplant survival from early spring planting is commonly 90% or higher using standard practices (Monsen and Kitchen 1995).

Seeding should be conducted in the fall or early winter for best establishment from direct seeding on non-irrigated untreated sites (Haferkamp and others 1990). Proper seeding rate varies from 0.5 to 4.5 kg/ha (0.5 to 4.0 lb/acre) (pure live seeds) depending on species mix, site conditions, and seeding method. Successful spring plantings have been reported using after-ripened seeds (Monsen and Turnipseed 1990). Irrigated fields can be sown during summer months. Seed placement at or near the soil surface is critical for successful establishment (Baylan 1972; Stevens and Van Epps 1984). Satisfactory stands have been achieved from broadcasting seeds on the soil surface or on snow with little or no seed-bed preparation (Kitchen and Monsen 1999).

Table 2—*Kochia prostrata,* forage kochia: mean germination times as affected by temperature of dry storage

	Mean germination times (days to 50% germination)			
Accession*	**Fresh**	**20 °C**	**2 °C**	**–5°C**
314929†	72 a	11 b	60 a	67 a
343101	51 a	12 b	46 a	55 a
356818	53 a	14 b	51 a	58 a
356826	108 a	11 c	86 b	90 b
358941	81 a	12 c	63 b	76 a
Mean	71 a	12 b	61 a	69 a

Source: Kitchen and Monsen (1999).
Note: Within an accession, means followed by the same letter are not significantly different at the P <0.05 level. Five accessions of forage kochia were germinated at 2 °C after 24 months of dry storage at 20, 2, or –5 °C; controls were freshly collected seeds.
* Accession numbers are plant introduction (PI) numbers assigned by the USDA Natural Resource Conservation Service's Plant Materials Center in Pullman, Washington.
† 'Immigrant'.

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K

Sapindaceae—Soapberry family

Koelreuteria paniculata Laxm.

panicled golden raintree

Charles H. Michler and Paul O. Rudolf

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Growth habit, occurrence, and use. Native to China, Korea, and Japan, the panicled golden raintree—also called pride-of-India, China tree, and varnish tree—is a small deciduous tree ranging from 5 to 11 m tall that has been cultivated since 1763, chiefly for ornamental purposes (Rehder 1940).

Flowering and fruiting. The irregular (or apparently polygamous) yellow flowers occur in broad, loose, terminal panicles and bloom from July to September (Krüssmann 1960; Ohwi 1965; Plouvier 1946). The fruits are bladdery, triangular, 3-celled capsules about 3 to 5 cm long (figure 1); when they ripen in September and October they change from a reddish color to brown. Within the papery walls of ripe fruit are 3 round, black seeds (figure 2) (Rehder 1940; Rudolf 1974). The seeds are naturally dispersed from fall to the next spring (Pammel and King 1930). Good seedcrops are borne almost annually (Rudolf 1974).

Collection of fruits; extraction and storage of seeds. Capsules should be collected from trees in September and October for extraction and cleaning the seeds. The yield from 46 kg (100 lb) of fruits is about 32 kg (72 lb) of cleaned seeds (Plouvier 1946). Cleaned seeds per weight ranged from 5,700 to 7,700/kg (2,600 to 3,500/lb), and averaged 6,394/kg (2,900/lb) for 3 samples. Four samples of commercial seedlots averaged 99% in purity and 95% in soundness (Rudolf 1974; Swingle 1939; Zentsch and Kaul 1968). One sample that was stored in fruit jars with loosely fastened lids and exposed to temperatures ranging from about 4 to 32 °C showed 50% germination at the end of 10 years (Toumey 1921).

Figure 1—*Koelreuteria paniculata*, panicled golden raintree: capsules (**top**) and seeds (**bottom**).

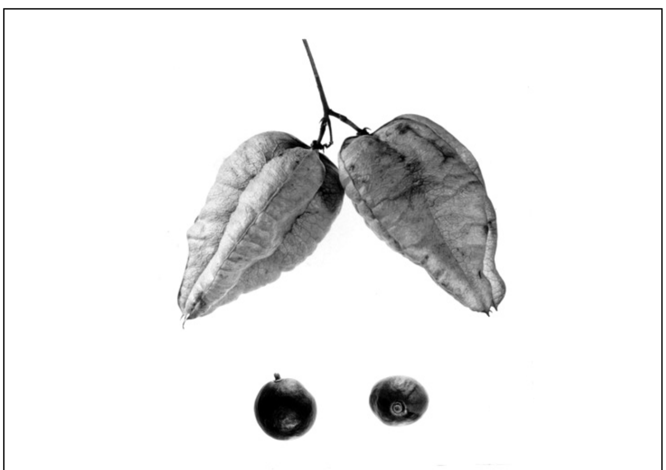
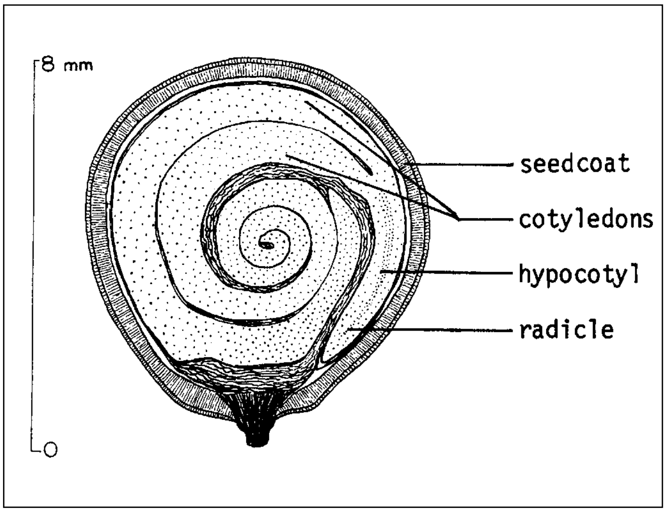


Figure 2—*Koelreuteria paniculata*, panicled golden raintree: longitudinal section through a seed.



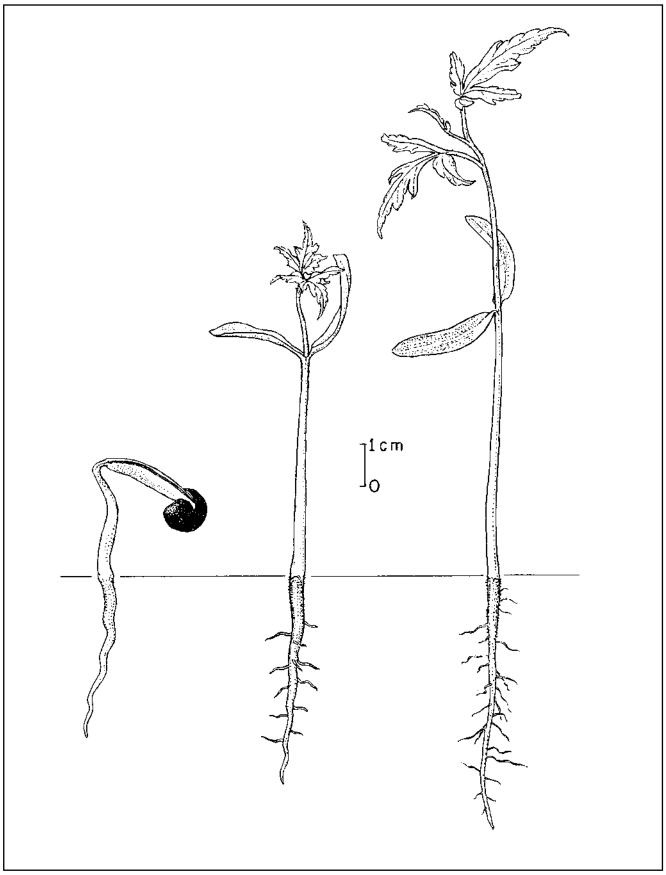
Pregermination treatments. Dormancy in seeds appears to be caused by an impermeable seedcoat and possibly by an internal condition of the embryo. In a series of tests, soaking seeds in sulfuric acid for 1 hour plus 90 days of stratification in moist sand at 4.5 °C gave the best results (Rudolf 1974). In another series of tests, mechanically scarified seeds germinated promptly and well (Zentsch and Kaul 1968). Mechanical scarification followed by stratification for 90 days produced complete germination in 9.7 days (Garner 1979; Garner and Lewis 1980). Seed exposure to an electromagnetic field of 100 gauss for 4.3 seconds increased germination after scarification from 56 to 97% (Maronek 1975).

Germination tests. Germination is epigeal (figure 3). Germination should be tested in sand flats or germinators for 5 to 10 days at 20 (night) to 30 °C (day), using 200 to 400 seeds that were acid treated and then stratified for each test. One test of untreated seeds gave a germination rate of only 2% in 29 days, whereas seeds of the same sample gave 52% after the acid plus stratification treatment recommended above (Rudolf 1974). In another test, 74% of untreated seeds germinated in 54 days, compared with 91% of mechanically scarified seeds in 23 days (Zentsch and Kaul 1968). Official seed testing agencies recommend tetrazolium staining for germination tests of panicled golden raintree. The suggested procedure is to soak the seeds in water for 18 hours, then remove the seedcoat before staining for 24 hours at 30 °C in a 1% solution (ISTA 1993).

Nursery practice. Untreated seeds may be sown in the fall and scarified seeds can be sown in the spring (some seedlots may require stratification after scarification) and covered with 6 to 13 mm ($^1/_4$ to $^1/_2$ in) of soil. Seedlots sown immediately after collection in fall usually give reasonably good results (Swingle 1939). A target bed density is about 300 to 315 seedlings/m^2 (30/ft^2). Tree survival is about 70% (Jack 1969). Seedlings should be lifted as 2+0 stock (Jack 1969).

This species should be planted only in sunny locations, but it is not particular as to soil type (Bailey 1939). It may also be propagated by layers, cuttings, or root cuttings (Bailey 1939).

Figure 3—*Koelreuteria paniculata*, panicled golden raintree: seedling development at 1, 3, and 5 days after germination.



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Chenopodiaceae—Goosefoot family

Krascheninnikovia lanata (Pursh) A.D.J. Meeuse & Smit

winterfat

D. Terrance Booth

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Synonyms. *Eurotia lanata* (Pursh) Moq., *Ceratoides lanata* J.T. Howell, *Diotis lanata Pursh*; see appended notes on nomenclature.

Other common names. white-sage.

Growth habit, occurrence, and use. Winterfat is a sub-shrub that in early spring appears as small bunches of new leaves closely joined to dead-looking low stems that have new shoots arising from woody bases. By late summer, the shrub's attractive foliage is 20 to 80 cm high and often crowned with dense clusters of handsome, white, fruiting bracts. The leaves can grow to 5 cm and are narrow and entire, with strongly revolute margins. Leaves and herbaceous stems have short white hairs that give the plant its characteristic gray-green color and its *Eurotia* synonym (from the Greek *euros,* meaning mold).

Winterfat habitats are characterized by drought and temperature extremes. It grows in scattered clusters or uniform stands on dry plains, foothills, and mountains from western Nebraska and Texas to California and from northern Mexico to the prairie provinces and the Yukon Territory of Canada, north to the vicinity of Lake Kluane, Alaska (Coupland 1950; Hulten 1968; Stevens and others 1977; Welsh 1974). In the Great Basin, winterfat occupies thousands of hectares in pure stands and may be found at elevations from the lower Sonoran zone to ridges over 3,048 m in elevation (Stevens and others 1977). Soils supporting winterfat are low in sodium and other soluble salts but often high in carbonates of calcium and magnesium; soil textures vary from clays to sandy and rocky loams (Nelson 1962; Stevens and others 1977).

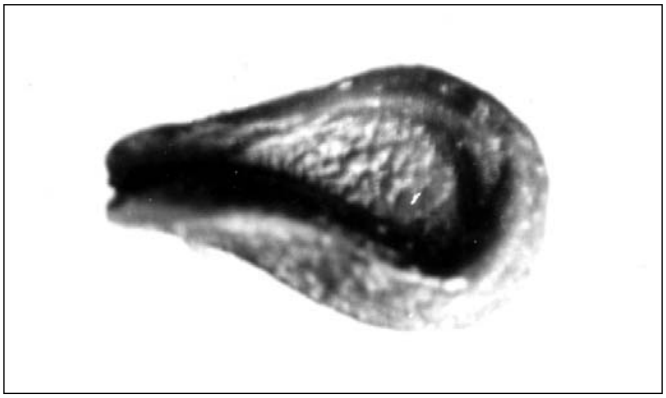
Native stands are highly valued as forage for livestock and wildlife (Asay 1959; Jones and Barclay 1972; Nelson 1905; Plummer and others 1968), but many have been depleted or destroyed by abusive grazing or by wildfire in combination with the invasion of exotic annual grasses. Winterfat is regularly used in re-vegetating disturbed lands, has value as an ornamental, and is recommended for reseeding to restore depleted western rangelands and for providing waterfowl nesting cover on the Canadian prairies. It was first cultivated in 1895 (Springfield 1974b). Notable progress has been made in seed handling and seeding methods so that disturbed lands sown with winterfat regularly develop healthy stands.

Ecotypic variation. Winterfat displays strong ecotypic variation that appears to account for the range of habitats occupied by the species. This variation must be considered when collecting seeds for a particular environment or use (Bai and others 1997b; Plummer and others 1968; Workman and West 1969). Seed quality and seedling vigor differ by collection (Booth 1992; Moyer and Lang 1976; Springfield 1968a), with some differences appearing as adaptive compromise between seed quality and the demands of stressful environments (Booth 1990a; Booth and Haferkcamp 1995). The selection of high-vigor lines may be possible (Riedl and others 1964), but studies are needed to understand genetic and environmental interactions with seed quality and cultivar adaptability.

Flowering and fruiting. Flowers are small, gray-green, and inconspicuous and are likely cross-pollinated by wind (Riedl and others 1964). The plants are dioecious or monoecious. Flowers bloom from June to August, depending on elevation and weather. Staminate flowers have a 4-parted calyx with 4 exerted stamens. Pistillate flowers have 2 styles emerging from between 2 united bracts. At maturity the bracts have formed fluffy white diaspores (seed-containing dispersal units) that decorate the fruiting spikes and function in seed dispersal, embryo protection, and in promoting the establishment and survival of the seedling (Booth 1988, 1990b). Bract hairs are 2 to 8 mm long in spreading tufts (figure 1). Each pair of bracts enclose an indehiscent, pubescent, 1-seeded fruit (utricle) (figure 2). The seedcoat is thin and transparent and is most easily discerned on naked imbibed or germinating seeds. Diaspores disperse in the fall or winter and collect in aggregations on the soil surface (figure 3). Plants may produce seeds the first

Figure 1—*Krascheninnikovia lanata*, winterfat: fruiting spike.

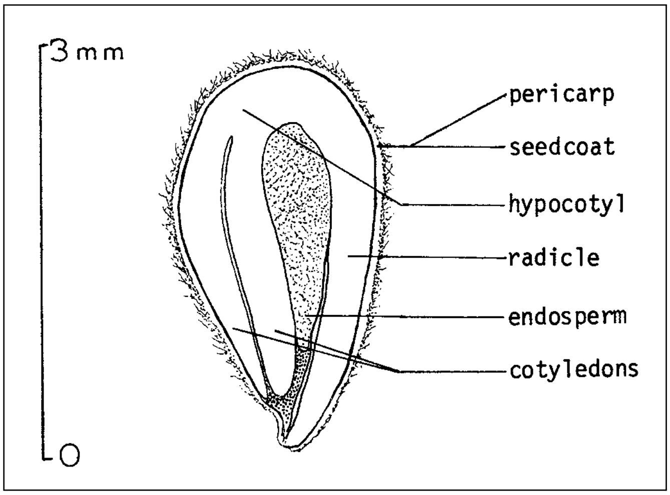
Figure 2—*Krascheninnikovia lanata*, winterfat: cleaned seed.



year and produce abundant crops annually (table 1). A 10-year-old stand has produced 78 to 90 kg/ha (70 to 80 lb/ac) of "fruit" (diaspores) (Springfield 1974b). Good seed quality depends on the mother plant's maintaining transpiration rates during seed and diaspore development (Booth 1990a).

Seed collection and storage. Seeds are harvested by stripping the diaspores from the bushes or by cutting and drying the fruiting spikes. Harvest time is mid-September in Saskatchewan (Romo 1995) to mid-October or early November at lower latitudes (Strickler 1956; Wasser 1945; Wilson 1931). Mechanized harvest methods have been tried (Springfield 1974b), but most collectors have found it more efficient to hand-harvest. However, Majerus (2003) described harvesting winterfat seeds with a combine. Dry diaspores should be stored without threshing or other processing to prevent accelerated aging. Harvested material will contain unfilled diaspores, but there are no practical methods for separating these from the germinable diaspores (Allen and others 1987). Percentage diaspore fill may be determined by threshing small samples. This is quickly done using equipment described by Booth and Griffith (1984).

Figure 3—*Krascheninnikovia lanata*, winterfat: sectional schematic of diaspore (seed).



Winterfat seeds are orthodox in storage behavior but their viability decreases after 6 to 12 months at ambient conditions (Hilton 1941; Springfield 1968a,b; Wilson 1931). Viability is maintained longer when seeds are stored in sealed containers at 4 to 5 °C (Springfield 1968c, 1973, 1974a), but seedling vigor will continue to decrease (Booth and others 1999). To maintain seedling vigor during long-term storage (more than 6 months), winterfat diaspores should be held at –20 °C.

Germination. Diaspores germinate naturally during cold or cool weather. Seeds imbibe readily, and the rate and total weight gain vary by temperature (Bai and others 1999; Booth and McDonald 1994) and by oxygen concentration (Booth 1992). Holding imbibed diaspores at 0 to 5 °C will improve germination, germination rate, and seedling vigor of most seed lots (Booth 1992; Booth and Schuman 1983; Strickler 1956) though the vigor of fresh seeds (4 months after harvest) is unlikely to be affected by imbibition temperature (Bai and others 1998a; Booth and others 1999). Winterfat's capability to germinate at freezing temperatures is well documented (Booth 1987b; Hilton 1941; Wilson 1931; Woodmansee and Potter 1971) and is reported to allow winterfat to establish in stressful environments (Springfield 1968a; Workman and West 1967). Dettori and others (1984) measured germination of threshed seeds of 3 collections, including an Asian species, at 55 temperature combinations ranging from 0/0 to 40/40 °C. Germination occurred over a wide range of temperatures. but the optimum germination occurred most frequently at 0 to 5 °C alternating with 15 to 20°C. Allen and others (1987) noted evidence of increased mold growth with alternating temperatures and temperatures above 15 °C.

Table 1— *Krascheninnikovia lanata,* winterfat: diaspore weights by source and harvest year

Source	Collections	Years harvested	Diaspores/weight Mean* /g	/oz	Range /g	/oz
Colorado	3	1982, 84, 94	147	5.2	137–203	4.8–7.1
New Mexico	3	1984	231	8.1	208–270	7.3–9.5
Nevada	1	1983	175	6.2	175	6.2
Saskatchewan	1	1994	147	5.2	147	5.2
Utah	2	1982, 84	212	7.5	167–257	5.9–9.0
Wyoming	2	1994	177	6.2	173–181	6.1–6.4
Total	12	—	—	—	—	—

Sources: Allen and others (1987), Booth (1994).
* Mean + SD = 198 + 15.ß
† 'Immigrant'.

Germination is most suitably tested by imbibing diaspores at 0 to 5 °C for 4 or 5 days followed by incubation at 15 °C. A longer cold treatment, 6 to 15 days, may increase the germination rate and seedling vigor for some seedlots, especially those that are less than 3 months or more than 12 months after harvest. Seeds less than 3 months from harvest may require after-ripening (Springfield 1972). Germination is not affected by light (Hilton 1941) and is rapid at warm temperatures.

Nursery and field practice. In the past, it was considered important to thresh the seed from the diaspore to simplify seeding with mechanized equipment (Springfield 1974b). However, that practice is no longer recommended because the bracts aid in seedling establishment, and threshing damages the seeds (Booth 1984, 1989a&b, 1990b; Booth and Schuman 1983). Broadcasting diaspores results in good establishment in depressions, in litter, and in protected sites (Stevens and others 1977). Diaspores can also be sown with a cultipacker (Luke and Monsen 1984), with a hydroseeder (Pellant and Reichert 1984), as pelleted diaspores, and in seed tapes (Booth 1987a&b). Use of the cased-hole punch seeder (Booth 1995) is effective and allows diaspores to be sown through fabric mulch. Natural establishment occurs with cool temperatures and high surface moisture and with a mat of diaspores on the soil surface (figure 3) (Booth 1987b, 1989a, 1990b; Gasto 1969; Wilson 1931; Woodmansee and Potter 1971). Fall-seeding is recommended (Zabek and Romo 1998). Under-snow germination produces vigorous seedlings and contributes to seeding success. Winterfat seeds and seedlings can show freeze-tolerance (Bai and others 1997a; Booth 1987b, 1989a; Hilton 1941; Stricker 1956; Woodmansee and Potter 1971), but reduced germination or loss of seedlings can also occur (Bai and others 1997b; Booth 1989a; Hodgkinson 1975; Stevens and others 1977). Ecotype, imbibition temperature, conditioning, and stage of growth are factors influencing seed and seedling freeze-tolerance (Bai and others 1997b; Booth 1989a; Hodgkinson 1975).

Winterfat can be transplanted as container-grown or bareroot plants. Shaw and Monsen (1984) recommended beds producing bareroot seedlings contain 167 to 222 seedlings/m^2 (15 to 20/ft^2). These should be lifted as 1+0 stock in the spring before they break dormancy. Shaw and Monsen (1984) found that 93% of mechanically transplanted seedlings were alive after 5 growing seasons when these recommendations were followed.

Notes on nomenclature. The type specimen for winterfat was collected by the Lewis and Clark expedition "On the banks of the Missouri River, in open prairies" and was described as *Diotis lanata* by Pursh in 1814 (Pursh 1814). Moquin-Tendon (1840) placed the species in the genus *Eurotia* (Adanson 1763) and listed as synonyms *Diotis, Axyris* (Linnaeus 1753), *Ceratoides* (Gagnebin 1755), and *Krascheninnikovia* (Gueldenstaedt 1772). For more than 2 centuries, botanical authors followed Adanson or Meyer's emended interpretation of Adanson's description in major botanical works and in numerous papers dealing with winterfat description, value, management, ecology, and culture (Meyer 1933, as cited by Howell 1971). In 1964, Ball reapplied the name *Krascheninnikovia* (Tutin and others 1964). Subsequently, Howell (1971) applied *Ceratoides* to *E. lanata*, and Meeuse and Smit (1971) joined Tutin and others in using *Krascheninnikovia*. Chu, in his Flora of China, has also choosen to use *Krascheninnikovia* (Stutz 1995). A 1976 attempt by the Russian Grubov to conserve (retain the use of) the name *Eurotia* was rejected (Brummitt 1978).

Although the International Code of Botanical Nomenclature was changed to allow such action, *Eurotia* was unfortunately not re-submitted for conservation (Wiersema 2000). North American authors have shown a disinclination to accept the procedural name change and some have continued to publish using the name *Eurotia*.

K. lanata has 1 subspecies, *subspinosa,* in southern Arizona (Kearny and Peebles 1960; Munz and Keck 1968) and 1 released cultivar, 'Hatch' (Stevens and Monsen 1988). Losina-Losinskaja (1930) defines 5 Eurasian species and Chu defines 7 (Stutz 1995).

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