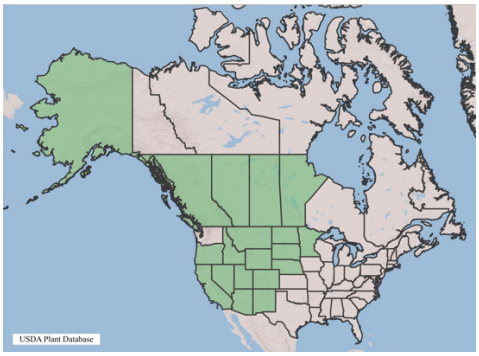
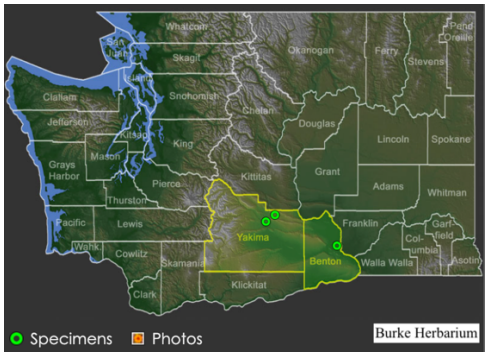
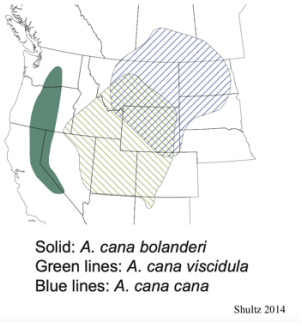
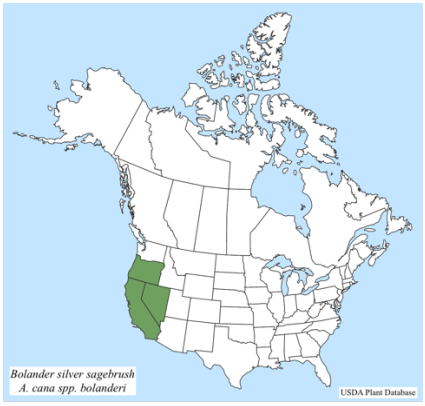
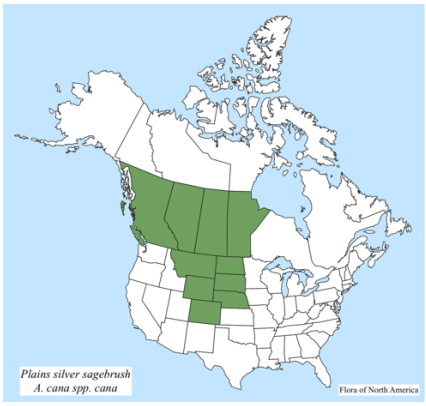
Plant Propagation Protocol for *Artemisia cana*
ESRM 412 – Native Plant Production
URL: https://courses.washington.edu/esrm412/protocols/2023/ARCA13.pdf

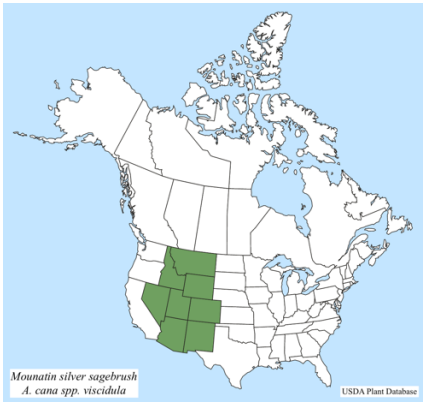












TAXONOMY	
Plant Family	
Scientific Name	Asteraceae
Common Name	Sunflower
Species Scientific Name	
Scientific Name	*Artemisia cana* Pursh
Varieties	
Sub-species	Based on differences in morphology and ploidy level[2,14,17]: *Artemisia cana* Pursh spp. *bolanderi* (Gray) G.H. Ward "Bolander silver sagebrush"[30,39] *Artemisia cana* Pursh ssp. *cana* "Plains silver sagebrush" [30,39] *Artemisia cana* Pursh ssp. *viscidula* (Osterh.) Beetle "Mountain silver sagebrush" [30,39]
Cultivar	

Common Synonym(s)	*Artemisia cana* *Seriphidium canum* (Pursh) W. A. Weber[30, 39] *Artemisia cana* spp. *bolanderi:* *Artemisia bolanderi* A. Gray[30, 39] *Artemisia tridentata* Nutt. ssp. *bolanderi* (A. Gray) H.M. Hall & Clem.[30, 39] *Artemisia tridentata* Nutt. var. *bolanderi* (A. Gray) McMinn[30, 39] *Artemisia cana* ssp. *cana*: *Artemisia cana* Pursh var. *cana*[30, 39] *Artemisia cana* ssp. *viscidula*: *Artemisia argilosa* Beetle[30, 39] *Artemisia cana* Pursh var. *viscidula* Osterh.[30, 39]
Common Name(s)	Silver sagebrush[11,39], Coaltown Sagebrush[18], Dwarf Sagebrush[11,18] Hoary Sagebrush[11,18], Silvery Sagebrush[18], Sticky sagebrush[11], Silver wormwood[11]
Species Code (as per USDA Plants database)	ARCO13
GENERAL INFORMATION	
Geographical range	Silver sagebrush is widely distributed across over 53,221 mi^2 (137,800 km^2) of the western North America[2]. It occurs from southern British Columbia east to southwestern Manitoba and south to Minnesota, Nebraska, northern New Mexico and Arizona, and southern California[12,14,30]. It is the second mostly widely distributed sagebrush species after big sagebrush[2]. Silver sagebrush is most common in the northern Great Plains, Rocky Mountain, and Intermountain regions[14]. It is relatively uncommon in the Great Basin[14,25] and is rare in Utah, British Columbia, Manitoba, and Washington state[14]. From British Columbia to California

	including in Washington state, it occurs east of the Cascades crest[10]. ***A. cana* ssp. *bolanderi*** is primarily distributed west the of continental divide[30] and occurs disjunct from the other two subspecies[12,15,14,22,25]. This subspecies occurs from north-central Oregon in montane meadows of the Ochoco and Blue mountains, to the eastern slope of the Cascade Range[14] south through the mountainous regions and eastern edge of the Great Basin to Inyo and Tulare counties, in California, and east to Humboldt and Washoe counties, Nevada[4]. In Washington state it occurs east of the Cascades crest in Yakima County[10]. ***A. cana* ssp. *cana*** dominant over 34 million acres of its' range, primarily distributed east of continental divide[30] from southern British Columbia east to southwestern Manitoba and south to western Nebraska, eastern Colorado, central Wyoming, and south-central Montana[12,14,38]. Widely distributed in the northern Great Plains and common in Saskatchewan and becoming increasingly sparse to the south except along watercourses and bottomlands, where it may be locally abundant[14,22]. Outlying populations occur in west-central Colorado, the Dakotas, Wyoming, northwestern Nebraska, and northern Colorado[4,12]. ***A. cana* ssp. *viscidula*** is the most abundant of the three subspecies and primarily distributed west of continental divide[30] from central Idaho and western Montana east to central Colorado, south to northeastern New Mexico and north-central Arizona, and west to central Nevada and eastern[12,14,22,25,38] and is concentrated in

	Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming[30]. Distributions of **ssp. *cana*** and **spp. *viscidula*** overlap in eastern Idaho, western Montana, across Wyoming, and in north-central Colorado[14].
Ecological distribution	Rocky, open grasslands, floodplains[18], meadows, forest openings, woodlands, riparian areas, bottomlands, shrub steppe from low to middle elevations in the mountains[10]. Ideal habitat is meadows and along streams in areas of lingering snowpack and seasonal high-water tables[30]. These areas are usually found along edges of aspen and conifer forests in the mountainous regions throughout the Rocky Mountains and east of the Sierra Nevada at elevations above 7,000 feet. Generally prefers moister sites, near streams, meadows and at higher mountain elevations, but some ecotypes grow on much drier sites[32]. Tolerant of high water tables and periodic flooding, and is often found in wet-to-upland transitional habitats[17]. Widely distributed but occurs in smaller, more isolated stands than big sagebrush (*A. tridentata*)[11]. **<u>Ecosystems</u>**[9] Elm-ash-cottonwood Douglas-fir Ponderosa pine Sagebrush Desert shrub Chaparral-mountain shrub Mountain grasslands Mountain meadows Plains grasslands Grows best in rocky, moist sites with deep loamy or sandy soils[1] but can tolerate dry soils[18]. Preferring moister,

	colder soils than other sagebrush species[17], and are common on transitional wet-to-dryland sites where soils dry by late summer[14]. Occurs on a wide range of soil textures[17], and is adapted to all soil textures except dense clays[33]. Best growth occurs on well-drained, coarse-textured, alluvial soils that are moist in the upper 6 inches (20 cm) of the soil profile[14,37]. Parent materials include sandstones, shales, and granites and soil textures include clay, silt, loam, sand, and gravel[12,14,36]. Can tolerate pH range of 5.2-9.0 and can tolerate weak acid, and moderately salt or alkali soils[32,] but is intolerant of strongly saline and calcareous soils[26]. ***A. cana* ssp. *bolanderi*** (occurs in meadows, stream banks, and basins at middle elevations from 7,500–9,000-feet elevations[4,10] and is found on soils that are more clayey, poorly drained[30], and usually more alkaline than ssp. *viscidula*. It is common on pluvial lakebeds, internally drained basins with alkaline soils, and in snow catchments with granitic soils[14]. These soils usually have standing water on them for several weeks in the spring and is classified as a major indicator shrub for riparian zones in central Oregon[4,14]. ***A. cana* ssp. *viscidula***[4] occurs on a wide range of soil textures except clay[11], and usually occupies rich loam soils usually derived from limestone that are deep and have slower draining characteristics than common for big sage brush (*A. tridentata*)). It is often in mountain meadows, along streams, or in depressions with late-lying snows. ***A. cana* ssp. *cana***[4]

	Found in areas with summer rain, in deep loamy soils[4]. Grows in both sparse and dense stands of well-watered, well-drained-to-imperfectly-drained, deep loamy, or sandy soils of prairies, stream sides, drainage ways, alluvial flats, terraces of valley bottoms and upland soils in valleys[4]. Its mostly shallow root system finds an optimum environment in soils where the upper six inches are moist or where coarse materials are found throughout the soil profile. These soils are usually lower in nitrogen, phosphorus, potassium, cation exchange capacity, and organic matter than those associated with Big sagebrush (*A. tridentata var. tridentata).* *A. cana* provides valuable forage for deer, bison, elk, pronghorn, bighorn sheep and sage-grouse[17] and habitat for a variety of ground-nesting and ground-feeding birds[39]. The areas between the sagebrush shrubs are favored by elk and especially by deer for bedding, as they provide abundant forage and hiding cover below 1 m.
Climate and elevation range	2,000 to 11,000 ft. (600-3350m)[17] USDA Zone 4-10 Although *A. cana* requires hot, dry climatic conditions and full sun, it also requires more moisture than most sagebrush species[14]. Its' distributed in areas that receive between 9 – 12 inches minimum precipitation (dry-ecotypes) and 14 – 16 in (moist-ecotypes)[32] and have a water table within 3 feet (1m) of the soil surface[14]. Has very low shade tolerance and requires full sun for seed establishment[26].

Local habitat and abundance	In the early 2000's, The Nature Conservancy ranked silver sagebrush communities of the Great Plains as regionally endangered[14]. Communities in Nevada were also state ranked as SP (having potential for being threatened or vulnerable but needing further reporting or documentation). Composition of silver sagebrush communities is variable across the species' broad geographical range[14]. The communities are often compositionally and structurally simple, but are sometimes diverse, especially in riparian zones. *A. cana* may allelopathically inhibit germination of some herbaceous species, as well as its own seed[14]. Aqueous extracts leaves reduced germination of 6 mixed-grass species, including *A. cana*. Laboratory results using extracts do not necessarily indicate allelopathy under field conditions; however, a field study of plant species distributional patterns in western North Dakota suggests that some forb species are more likely to associate beneath or nearby silver sagebrush canopies. Other species, especially bunchgrasses, tend to segregate away from silver sagebrush. Possible allelopathy and its effects on plant community composition and structure, need further investigation. **Ecosystems characterized by *A. cana* and its associations**[14]: Silver sagebrush/basin wildrye (*Leymus cinereus*) Silver sagebrush/mountain big sagebrush/Cusick's bluegrass (*Poa cusickii*) Silver sagebrush/Fendler bluegrass (*P. fendleriana*), Silver

	sagebrush/Sandberg bluegrass (*P. secunda*) **Plant Community Associations**[8,14,16] Western ponderosa forest Douglas-fir forest Eastern ponderosa forest Mountain-mahogany-oak scrub Great Basin sagebrush Saltbush-greasewood Sagebrush steppe Wheatgrass-needlegrass shrub steppe Foothills prairie Montane meadows Tall forb community Aspen woodland Riparian Sandsage prairie Fescue grassland **Tall Woody Cover Associations**[8,14] Aspen, Cottonwood, Rocky Mountain juniper, Black cottonwood-willow, Pacific Douglas-fir, Cottonwood-willow, Interior ponderosa pine, Western juniper, Gambel oak **Rangeland Cover Associations**[8,14,16] (Kulcher, Eyre, Howard) Bluebunch wheatgrass Idaho fescue Green fescue Western juniper/big sagebrush/bluebunch wheatgrass Bluebunch wheatgrass-blue grama Bluebunch wheatgrass-Sandberg bluegrass Bluebunch wheatgrass-western wheatgrass Idaho fescue-bluebunch wheatgrass Idaho fescue-Richardson needlegrass Idaho fescue-slender wheatgrass Idaho fescue-threadleaf sedge Idaho fescue-tufted hairgrass Idaho fescue-western wheatgrass Needle-and-thread-blue grama

	Rough fescue-bluebunch wheatgrass Rough fescue-Idaho fescue Tufted hairgrass-sedge Big sagebrush-bluebunch wheatgrass Big sagebrush-Idaho fescue Big sagebrush-rough fescue Black sagebrush-bluebunch wheatgrass Black sagebrush-Idaho fescue Shrubby cinquefoil-rough fescue Threetip sagebrush-Idaho fescue Basin big sagebrush Mountain big sagebrush Wyoming big sagebrush Threetip sagebrush Black sagebrush Low sagebrush Stiff sagebrush Other sagebrush types Bluestem-grama prairie Crested wheatgrass Wheatgrass-bluegrass Wheatgrass-bluestem-needlegrass Wheatgrass-needlegrass Wheatgrass-grama-needlegrass Wheatgrass-grama-buffalo grass Wheatgrass-saltgrass-grama Wheatgrass-grama Wheatgrass Blue grama-buffalo grass Blue grama-western wheatgrass Sagebrush-grass Fescue-wheatgrass Grama-buffalo grass Grama-needlegrass-wheatgrass ***A. cana* ssp. *bolanderi***[14]: Consistent associates include Cusick's bluegrass () and western yarrow (*Achillea millefolium*). In the Toiyabe National Forest of west-central Nevada and east-central California are co-dominated by Douglas' sedge (*Carex douglasii*) and/or Baltic rush (*Juncus balticus*). In California communities are known to be co-dominated by mat muhly (*Muhlenbergia richardsonis*) in

	Lassen County and co-occuring with with mountain big sagebrush, Nebraska sedge (*Carex nebrascensis*), and tufted hairgrass (*Deschampsia cespitosa*) in Plumas County. Co-occurs with mat muhly communities near seasonal ponds in central Oregon, expanding and contracting with changing water levels. In meadows of the Ochoco and Blue mountains, co-dominates with big sagebrush. ***A. cana* ssp. cana**[14]: Associates with a few other shrub species, bunchgrasses and other graminoid species, usually in low diversity communities, in the Great plains regions such as the Badlands of North Dakota. In Saskatchewan co-dominates sandhill prairies with the blue grama-green needlegrass (*Bouteloua gracilis-Nassella viridula*) association. Dominates mesic mountain steppes communities in the northwestern portion of its range, often mixed with Wyoming big sagebrush (*A. tridentata* var. *wyomingensis*). Occurs in western wheatgrass-Idaho fescue (*Pascopyrum smithii-Festuca idahoensis*) and bluebunch wheatgrass *(Pseudoroegneria spicata)*-Idaho fescue mountain grasslands and in black greasewood (*Sarcobatus vermiculatus*) communities, upslope from black cottonwood (*Populus balsamifera* ssp. *trichocarpa*) floodplains, may codominate with willow (*Salix*) species on meandering drainages, and can dominate understories of open narrowleaf cottonwood (*Populus angustifolia*) stands. In the shortgrass prairie, such as the Badlands of North Dakota, it occurs on or upslope from floodplains where it co-dominates with western wheatgrass, green needlegrass,

	prairie sandreed (*Calamovilfa longifolia*), and/or blue grama, and has been found in assocaiteation with western snowberry (*Symphoricarpos occidentalis*) and western wheatgrass in bottomlands of these areas. Only woody sagebrush species known to grow in association with basin wildrye in eastern Wyoming. Threated by invasion from Japanese brome (*Bromus japonicus*) and cheatgrass (*B. tectorum*). ***A. cana* ssp. *viscidula*[14]:** Typically occurs in steppe vegetation communities, and species diversity and productivity can be great, especially when bordering riparian zones and moist mountain meadows. In Wyoming and Montana it is widely associated with tufted hairgrass and Idaho fescue, and co-dominated with Idaho fescue communities in moraines and landslides at higher elevation (> 7,000 ft. (2,000 m)) sites. Lower-elevation sites in Wyoming may be dominated by bluegrasses (*Poa* spp.) and bromes (*Bromus* spp.). Shrubby cinquefoil (*Dasiphora floribunda*) is a common associate in mountain communities, and is the only shrub constant associate of the *A. cana* spp. *viscidula*/Thurber fescue (*F. thurberi*) steppes of Colorado and *A. cana* spp. *viscidula* /Idaho fescue steppes of central and eastern Idaho. Is dominant in mountain grasslands on clay soils of central Idaho, where it forms the "Camas Prairie" association with common camas (*Camassia quamash*). In Northern Utah and southern Idaho co-dominates with tufted hairgrass, sheep fescue (*F. ovina*), and Kentucky bluegrass (*P. pratensis*). Merges into the understory of open quaking aspen-Rocky Mountain Douglas-fir

	(*Pseudotsuga menziesii* var. *glauca*) parklands in the Northern great plains. In eastern Oregon associates with Douglas' sedge and Cusick's bluegrass and merges into upland mountain big sagebrush and streamside Kentucky bluegrass or sedge (*Carex* spp.) communities. In Nevada occurs in steppes co-dominated by slender wheatgrass (*Elymus trachycaulus*), Idaho fescue, beardless wildrye (*Leymus triticoides)*, sedges, and Baltic rush.
Plant strategy type / successional stage	*A. cana* is deciduous, growing in sites that are wet or seasonally waterlogged, and distinguishing it clearly from the evergreen Big sagebrush[30]. It can withstands high water table and periodic flooding[11], but is still drought tolerant[18] with a rhizomatous taproot that grows down almost 3 times the height of the plant[1]. Many of the sites where *A. cana* is dominant have a moderately-high water table and are earlier seral stages of some higher-elevation riparian willow shrublands[39]. *A. cana* is less susceptible to fire mortality than other sagebrush species, as rhizomes readily sprout after fire and other disturbances[17]. A strong sprouting response from buried organs increases *A. cana's* ability to survive flood, ice scour, drought, and even severe fire damage[35,36]. Enlargement of colonies via sprouting and layering is nearly the sole method of silver sagebrush regeneration in the absence of disturbance; both seedlings and sprouts may occur on disturbed sites.

	A. cana occurs in early to late stages of succession[2,14,27]. Sometimes forming a stable community, especially in steppes systems, and sometimes succeeded to quaking aspen. Prefers open sites, and is intolerant of all but light shade, will grow on newly exposed soils and can survive fire, browsing, and short periods of flooding disturbance[14]. May invade overgrazed mountain meadows. *A. cana* is moderately palatable to livestock and fair to good palatability to wildlife, especially during winter[11]. **Hybridization[14]:** *A. cana* readily hybridizes with other woody sagebrush species (*Artemisia* subgenus *Tridentatae*) including threetip sagebrush (*A. tripartita*), big sagebrush (*A. tridentata*)[23,24] and low sagebrush (*A. arbuscula*)[2,33]. Silver sagebrush × mountain big sagebrush (*A. t.* ssp. *vaseyana*) and silver sagebrush × Lahontan sagebrush (*A. a.* ssp. *longicaulis*) hybrids form stable, self-reproducing populations that some authorities classify as distinct taxonomic entities (snowfield sagebrush (*A. spiciformis* Osterh.) and coaltown sagebrush (*A. argilosa* Beetle), respectively)[2,20,21,24,31]. Sagebrush hybrids are important ecologically as well as evolutionarily, often tolerating a broader range of ecological conditions than either parent[21]. *A. cana* intra-taxa also hybridize with each other, although spp. *bolander* is geographically isolated from the other two subspecies and does not do so naturally[2,6,20] while spp. *cana* does not hybridize with other species in the subgenus Tr*identatae*[14].

Plant characteristics  Great Basin Seed  Steve Madson	*A. cana* is a subshrub to a shrub (L&H seeds)[40] with semiwoody to woody stems[14]. Plants generally range from 1.3 to 3.3 feet (0.4-1 m) in height, with mature plants maximum heigh 4-5ft[14,32]. Densely branched from base[31]. Plants on upland sites tend to be smaller than plants on bottomlands and other moist sites[14]. The lanceolate leaves are thin and narrow, ranging from 0.8 to 3.5 inches (2-9 cm) in length. Plants with lobed leaves are probably showing introgression with big sagebrush[2]. Vegetative shoots are light brown to gray-green, woody, somewhat pliable, leafy, persistently canescent to glabrescent. evergreen and perennial[14,31]. Floral shoots are annual but somewhat persistent after drying[14]. The inflorescence is a panicle of perfect disc flowers and the fruit is a small (~ 2.5 × 1 mm), sticky-walled cypsela bearing a single, tiny seed. Blooms July-September[10] and sets seed in the fall[11]. Pollen is mostly spread by wind[14] although visitation by bees, beetles, and flies regularly indicate insect-mediated pollination probably occurs[14,22]. At time of dispersal, the involucre bracts spread and release the ripe fruits. The single seed remains contained within the fruit, which falls beneath or slightly downwind of the parent plant. Some long-distance dispersal probably occurs when the sticky fruits adhere to passing animals[14]. Wind and water also disperse seed away from the parent plant[2,14,35]. Fruits that fall on crusted snow may be moved long distances by wind. Sagebrush seeds float, and water currents may also carry seeds considerable distances[14].

	The root system consists of a taproot with lateral roots and deeply rooted individuals can have deep taproots without much lateral branching in upper soil layers[5,14]. Rhizomatous with rhizomes generally located within a few inches of the soil surface[14]. And can be serval times in length the above ground height of the plant. Although classified as evergreen, silver sagebrush sheds many of its leaves in winter, retaining a few until spring regrowth[14]. Leaves may drop early in response to drought. Infrataxa are morphologically distinguished by plant height and relative leaf size, color, and hairiness of herbage, however, distinctions are not clear-cut, and there is considerable overlap in the subspecies' characteristics[14]. Keys for distinguishing silver sagebrush infrataxa[2,31]. ***A. cana* ssp. *bolanderi*** has highly variable morphology, ranging from short to tall plants with narrow or broad leaves[30]. An erect or spreading, much-branched, and rounded shrub growing 8–24 inches tall[4]. Leaves of this subspecies are linear, 0.4-1.2 inches long, 0.04-0.1 inches wide, entire to divided at the tip, leaves green to gray-green and more gray-white and hairy than ssp. viscidula[30]. Stems felty-tomentose. Flowering occurs from August to September with seed ripening in October and November. ***A. cana* ssp. cana** is taller and bushier than the other two subspecies[30]. An erect, rounded, and freely branched shrub 3–5 feet tall with densely hairy

	white to yellowish young bark, which becomes brown with age[4]. Leaves of the vegetative branches are large, linear, and entire or, rarely, with one or two irregular teeth or lobes. They are only 0.06–0.4 inches wide and 0.75–3.25 inches long. They are densely covered with a silky pubescence and emit a pungent turpentine odor when crushed. Flowering heads are usually arranged into dense, leafy panicles, which bloom in September, with seed ripening during October and November[30]. ***A. cana* ssp. *viscidula***[30] is an erect, thickly branched shrub generally not more than 3.3 feet tall. Inconsistent with its common name, it is not silver in appearance. Leaves are deciduous, dark green, simple and entire, linear, and often with prominent unequal lobes 0.06–0.2 inches wide, up to 2.75 inches long, and often crowded in dark-green clusters[30]. It is distinctive in the late summer and fall by its somewhat sticky (viscid) yellow-green or gray ephemeral leaves[30]. On the vegetative branches leaves are smaller and darker green than those of ssp. *cana* and darker green than *A. tridentata* var. *vaseyana*[4], with which it often grows. Usually restricted to wet meadows and stream banks, it is distinguished from ssp. *bolanderi* geography and by its darker green foliage and sparsely (rather than densely) tomentose or glabrous stems. Flowering occurs from August to September with seed ripening in October and November[4]. Flowering occurs from August to September with seed ripening in October and November.

	Breeding[14]**:** *A. cana's p*erfect flowers are uniformly fertile. Most breeding is accomplished by outcrossing, although some selfing occurs. DNA studies of plains silver sagebrush showed evidence of interpopulation outcrossing, but differences in genetic diversity among populations were not great as large population sizes and wind-effected pollination tend to minimize between-population differences.
PROPAGATION DETAILS	
Ecotype	Seed transfer guidelines first call for the selection of appropriate species and sometimes an associated species mix for a target planting location based on the geographic distribution or seed zone for each species[19]. Within each species, additional considerations are made for appropriate subspecies based on elevation and moisture gradients. Elevation transfers are more liberal for moving seed sources down in elevation than up in elevation. Adopting seed transfer guidelines, partnered with monitoring the frequency of seed crops (every 1 to 4 y), will benefit seed procurement activities, management of genetic diversity, and encouraging successful planting programs.
Propagation Goal	Plants, Seeds
Propagation Method	Seed
Product Type	Seed + Plugs
Stock Type	
Time to Grow	Will begin producing seed after three to four years[3,14].
Target Specifications	
Propagule Collection Instructions	Seed is collected in late fall from October through November via hand stripping or clipping leader growth with seed head using a handheld cutter[3,34].

	Early winter (November or December), seeds are collected by stripping the flowerheads of mature shrubs into a large paper bag[29].
Propagule Processing/Propagule Characteristics	850,000 and 2,200,000 seeds per pound[3,4,32]. Sagebrush species tend to have high fruit set, seed set although *A. cana* has an 18% lower rate of seed production than big sagebrush[14,12].
Pre-Planting Propagule Treatments	**Cleaning:** Seeds can be cleaned using a mechanical flail (60 seconds), clipper, or seed blower[34]. Place seed into a Forsberg's Gravity Separators for a brief period, then run through a Clipper air cleaner with a number 1/18 screen on the top, a blank screen on the bottom, and air speed is set at low[3]. Continue on entire process until desired seed cleanness is achieved. **Dormancy Treatment:** Best germination occurs when seeds are retained on the parent plant long enough to experience cold temperatures (Walton). Optimum germination appears to occur with persistently cool soil temperatures. Eddleman[7] obtained better (73%) and faster germination from stratified, year-old seed than from unstratified 2-month-old seed (26% germination) in a laboratory. Harvey[12] found when sown in the greenhouse, seeds showed 93% germination at 68 °F (20 °C) and 97% germination at 59 °F (15 °C). Romo[27] found best germination occurred with stratification (≥ 28 days' duration) around 50 °F (10 °C), with the temperature range for germination 41-77 °F (5-25 °C). Exposure to relatively high temperatures) prior to planting resulted in loss of seed viability[14].

Growing Area Preparation / Annual Practices for Perennial Crops	Ensure the seed bed is weed free[3].
Establishment Phase Details	Seeds can be planted in fall on top of rough surface to 1/8 inch deep[4], or seeded in spring with a belt seeder at a shallow (less than 1cm) planting depth[3]. Germination rates are best for seed planted 2.5 mm below the soil surface, and no germination occurs in seed more than 7.5 mm below the soil surface[14]. Seeds sown on the soil surface germinated readily but were highly susceptible to desiccation[12]. Provide limited irrigation through germination and periodically throughout growing season until plants are established[3]. High seed production and germination rates help offset the genus' generally low rate of seedling establishment[14]. Spring-sown seed showed significantly better emergence than fall-sown seed, which was more likely to be killed by fungi or drastic fluctuations in temperature[14,27]. Some seeds that failed to germinate within the 1st year were still viable, and the authors suggest that silver sagebrush may have a small soil seed bank reserve on safe sites[27]. Seed germinates with or without light[14,34] over a wide range of temperatures but are aided by light[34]. Seeds can be planted directly into peat plugs by pressing seed onto of each moist plug[29].
Length of Establishment Phase	mid-March to mid-June 50% germination energy in 2-6 days[34].
Active Growth Phase	Seedlings require open ground that is free from competition[12,27] making

	establishment challenging in undisturbed to lightly disturbed, mature stands and naturally occurs on soils disturbed by animal burrowing or tilling[12,14,27]. Although seed production is high, few plants survive the germination and seedling stages[37]. Seedling mortality is greatest in the 1st year, and tends to level out after that[13,37]. Harvey[12] found that up to a critical mass, seedling establishment and growth rates of seedlings increased with increasing weight of their originating seeds. However, plants from seeds weighting ≥ 0.57 mg showed poor germination, and growth of seedlings from the heaviest seeds was slow. Romo[27] found that only 5-6% of silver sagebrush seed produced seedlings, but 85% of seedlings that survived their 1st year also survived their 2nd. Drought is the primary cause of seedling death a seedlings require moist soil for establishment and growth and naturally likely take advantage e of years of above-average precipitation[35,36]. Acclimated seedlings are cold-hardy and researchers suggested that seedlings germinating early in spring may show better winter survivorship than later-germinating seedlings, as older seedlings that have gradually acclimated to cooling temperatures have had more time to develop protection from freezing by lignifying cell walls and expanding twig buds[13]. Plants in field must be watered and kept in moist conditions during first year as they develop a tap root[29]. Once taproot

	is developed, will become drought tolerant during second year.
Length of Active Growth Phase	March-June
Hardening Phase	Once risk of frost has past (spring) plants in pots may be moved outside[29]. Once plant roots being to stick out of peat plugs, transfer to pots[29]. Once plant roots begin to stick out of pot, transfer plants into field.
Length of Hardening Phase	May-October
Harvesting, Storage and Shipping	Seed can be hand collected or clipped from the plant October through November[3]. After cleaning, seed is stored in a burlap sack at room temperature[3].
Length of Storage	Store the seeds in a dry place with the bag partially open to facilitate drying[29]. Seed can be stored for at least 15 years and remain viable[3]. Silver sagebrush seed retains its ability to geminate when stored under cool, dry conditions, but looses germinative capacity rapidly when exposed to unfavorable conditions. Seed in Montana, stored at room temperature for 2 years, and sown in the greenhouse showed 51% and 64% germination on filter paper (without and with fungicide treatment, respectively)[14].
Guidelines for Outplanting / Performance on Typical Sites	s relatively easy during the spring and summer from containerized material and bare root (spring only). Avoid winter and late fall transplanting. (native intermounatins)
Other Comments	Can be susceptible to foliar and root pathogens such as Powdery Mildew and Fusarium root rot. Check for aphids especially in the early spring[26]. Tolerates moderate fertilization but does not tolerate salt[26].

PROPAGATION DETAILS	
Ecotype	
Propagation Goal	Plants
Propagation Method	Vegetative Cloning is silver sagebrush's most common method of reproduction[27,35]. Sprouts from roots[2,12,14, 20,25], rhizome[14,20], root crown[2,14,25,28,33]. Has the ability to layer[2,12,14]. Propagation through hardwood cuttings[12].
Product Type	Plants (bareroot/plug) + Propagules (cuttings)
Stock Type	
Time to Grow	
Target Specifications	
Propagule Collection Instructions	
Propagule Processing/Propagule Characteristics	
Pre-Planting Propagule Treatments	
Growing Area Preparation / Annual Practices for Perennial Crops	Hardwood cutting: Rooting substrate is 50:25:15:10 sand: vermiculite: peat:perlite[28].
Establishment Phase Details	Collect 6 in (15 cm) cuttings of stems, strip leaves off bottom 1½ in (4 cm) of stem, dip base in rooting hormone. stick cutting in rooting substrate and place under an intermittent mist system[28]. This system had a reported result of 87% rooting.
Length of Establishment Phase	
Active Growth Phase	
Length of Active Growth Phase	
Hardening Phase	
Length of Hardening Phase	
Harvesting, Storage and Shipping	
Length of Storage	
Guidelines for Outplanting / Performance on Typical Sites	
Other Comments	.ssp. *cana* particularly spreads extensively by rhizomes and is easy to transplant[4]. *A. cana* can be pruned and tends to regrow lusher. Tolerates hedging[26].

	Soil texture may affect ability to clone: the only sites where plants established from seed outnumbered those originating from rhizomes were those with very gravelly or very clayey soils[12]. Similarly, another Montana study of plains silver sagebrush regeneration found plants started from seed outnumbered cloned plants only on sites with clay pans underlaid with gravel.
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Protocol Author	Maya Kahn-Abrams
Date Protocol Created or Updated	May 28, 2023

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