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Development of Native Plant Materials for Coastal Dune Revegetation in the Pacific Northwest: Final Report

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INTRODUCTION

Dune grasslands that occur along the Pacific Coast are a globally endangered vegetation community (Pickart, 2008). A long history of dune stabilization through the intentional introduction of several non-native plant species has dramatically altered much of this ecosystem. Along the Oregon, Washington, and Northern California coast, European beachgrass (*Ammophila arenaria)*, a species introduced for dune stabilization, is widespread and can form nearly monotypic stands, outcompeting most native vegetation. Such alterations have had a significant impact on plant and wildlife communities. A negative correlation was found between *A. arenaria* presence and species diversity on 34 beaches along the Pacific Coast (Barbour et al., 1976). Other species introduced for dune stabilization purposes include Scotch broom (*Cytisus scoparius*), American beach grass (*Ammophila breviligulata*), and tree lupine (*Lupinus arboreus*). These species also displace native vegetation on dunes, though in foredunes *A. arenaria* is usually the dominant introduced species in Oregon and Northern California and *A. breviligulata* is usually the dominant introduced species along portions of the Washington coast (Seabloom & Wiedemann, 1994).

For these reasons and others, the Oregon Conservation Strategy (OCS) (2016), an overarching state strategy for conserving fish and wildlife, lists coastal dunes as one of eleven focal habitats in the state. The OCS includes several strategy species that inhabit coastal dunes. These are all rare species with different federal and state designations. The Western snowy plover (*Charadrius alexandrinus nivosus*) is a Federal and Oregon State Threatened bird species. The streaked horned lark (*Eremophila alpestris strigata*) is a Federal Threatened and Oregon State Sensitive bird species that is found in dune habitats in Washington and British Columbia. There are also three plant species in coastal dunes listed as strategy species. Pink sand verbena (*Abronia umbellata)* is a federal species of concern and endangered in Oregon. Silvery phacelia *(Phacelia argentea)* is a federally and Oregon state threatened species. Wolf's evening primrose (*Oenothera wolfii)* is a federal species of concern and Oregon state threatened species. Oregon lists one other obligate dune species as endangered, seaside gilia (*Gilia millefoliata*).

The widespread establishment of introduced grass species (both *A. arenaria* and *A. breviligulata*) has resulted in significant loss of active nesting areas and a decline in populations of the Western snowy plover. These *Ammophila* species capture and stabilize sand more effectively than do the native dune plant species, leading to the formation of dunes of a steeper topography than those dominated by native grasses and forbs (US Fish and Wildlife Service, 2007).

In Oregon, much of the ocean shore, including adjacent publicly owned dunes, is administered as a State Recreation Area by the Oregon Parks and Recreation Department (OPRD) (OPRD, 2020). Sand dunes are also privately owned along portions of Oregon's coast. OPRD regulates ocean shore activities, including dune sand alterations. Sand alterations occur for a variety of reasons, including view-shed enhancement, construction of shoreline protective structures, beach access ways, dune grading and other removal and fill activities, routing of pipelines and cables, natural product removal, and others (OPRD, 2005). After sand alterations, OPRD recommends revegetating graded sand dunes with European beachgrass and currently does not offer an alternate recommendation for dune revegetation that utilizes native plant species. However, little is known about the germination, propagation, and introduction of native dune plant species in the Pacific Northwest. Occasionally, the native American dune grass (*Leymus mollis*) is used, but lack of availability, both in the wild and in commercial nurseries, limits this. Other native plant species are rarely used in dune restorations, largely a result of lack of knowledge of appropriate introduction methods and lack of plant material availability. In a search of nurseries providing native plant species in the Pacific Northwest, three nurseries were found to provide the primary native grass of

foredunes, *Leymus mollis*, and only one nursery provided an additional selection of dune-specific species. In the case of this nursery, five additional species were offered. Documented propagation knowledge and plant materials for some more generalist species that also inhabit dunes, such as yarrow (*Achillea millefolium*), do exist. Considering the expressed demand for coastal dune restoration and stabilization, the development of a body of knowledge regarding propagation and cultural requirements of native dune species is expected to provide an opportunity for commercial nurseries and the native seed production industry in Oregon.

In 2005, OPRD published an Ocean Shores Management Plan that defines goals for shore management in Oregon. The highest priority natural resources goal listed in the plan was to implement the U.S. Fish and Wildlife Service's Habitat Conservation Plan for the Western snowy plover (USFWS, 2007). Included in this restoration plan are restoration prescriptions to remove introduced beachgrasses and revegetate using native plant species. Also included in OPRDs natural resource management goals for the ocean shore is work with stakeholders, including resource agencies, to protect plant species known to occur in open sandy habitats.

This project addresses needs outlined in NRCS's regional plant materials needs assessment. First, NRCS identified the need for guidance on mix recommendations for pollinator habitat in endangered Oregon silverspot butterfly (OSB) and native coastal meadow sites. A significant portion of the historic range of the OSB covers stabilized dune meadows with very little mineral soil development. Native plants found in such sites include several species that also occur on foredunes. To date, pollinator habitat management efforts at such sites have had limited success; one limitation has been the understanding and availability of an appropriate suite of native plant materials. The development of knowledge about the growth and planting requirements of native dune flora is a necessary precursor to developing the availability of plant materials to support pollinator habitat in OSB and native coastal stabilized dune sites. Second, NRCS identified the need for information on plants for pollinators by ecoregion in Western Washington. The information developed in this study would apply to the Coastal Lowland ecoregion. Lastly, NRCS identified the need for information on pollinator plants for cranberry production areas of southwest Oregon. Cranberries are grown in sandy substrates, and therefore the development of knowledge about native dune pollinator species addresses this need.

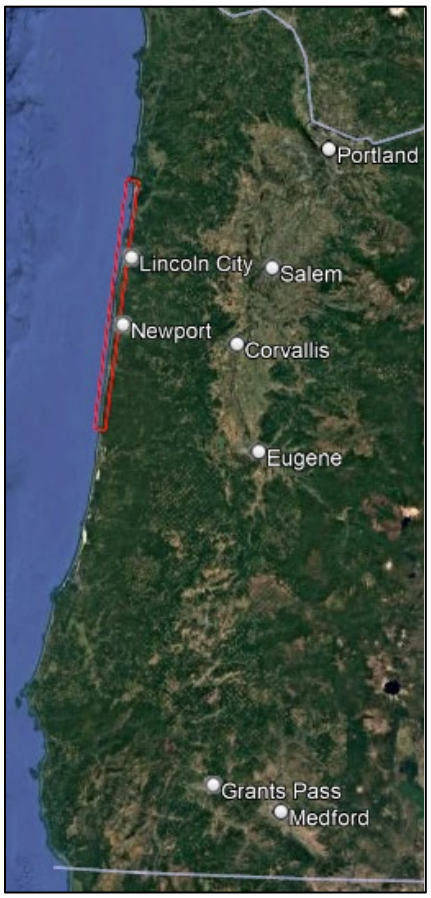

Figure 1: Primary wild seed collection region in Oregon (outlined in red). A small number of wild seed collections were made outside of this area.

In addition to wildlife habitat and native plant community restoration, restoration of coastal dunes is important for dune stabilization to protect coastal communities. Vegetated dunes minimize blowing sand and protect communities from storm surges and sea level rise. Stabilized dunes are a necessary buffer in the face of climate change and the expected increase in storm turbulence.

These needs and goals suggest that development of propagation and revegetation protocols for native dune species is critically important information. This study focused on developing this

body of knowledge so that dune plant materials may become more widely available and successfully established in their native habitats. This process will support numerous natural resource management aims and will create opportunities for commercial nurseries to provide plant materials for dune restoration.

MATERIALS AND METHODS

Wild seed collection

Seeds and propagules of Pacific Northwest native dune flora were gathered from wild populations and provided by partners. Wild seed collection by PMC staff occurred in summer-fall of 2021-2024. Quantities and locations are reported in the results section. Seed collection sites were largely located from Tillamook Head south to Heceta Head in Oregon, with a small number lying outside this range (Figure 1).

Seed counts

The number of seeds per pound for each species were determined by counting and weighing three samples of 100 seeds per species. The number of seeds per pound was rounded to the nearest 100. For some species, counts were determined for different scenarios (i.e. wild seed, production seed). Some species are particularly challenging to extract from their fruiting structures. In these cases, the number of fruits per pound was determined.

Germination studies

Prior propagation knowledge and plant life history was used to determine germination pre-treatments to explore. Germination trials were initiated in January 2021, December 2021, August 2022, December 2023, and October 2024. For most species, germination pre-treatments included mechanical scarification and different periods of moist stratification. Mechanical scarification was performed by placing seeds in a pneumatic scarification drum (Westrup Inc., Sioux Falls, South Dakota) lined with sandpaper and treating the seeds with pressurized air until initial signs of seed coat damage appeared. Duration of scarification treatment varied by species. Moist stratification included cold (4˚C) periods of differing durations or alternating durations of cold and warm (12 hours with light at 20˚C and 12 hours without light at 10˚C).

Treatments in a 2024 trial on *Abronia latifolia* were unique to that species. They included soaking for 24 hours in 3 concentrations of gibberellic acid (500, 1000, 1500 ppm) and liquid ethephon (Monterey brand florel growth regulator at 0.66mL/1L distilled water). Treatments in a 2022 trial on *Fragaria chiloensis* were unique to that species and included a comparison of germination of seed cleaned with two different extraction methods. The first treatment involved mashing the fresh fruits, allowing the fleshy material to decompose for seven days, washing off the achenes, and drying to yield clean seed. The second involved putting fresh fruits in a blender with taped blades and water for 30 seconds, pouring the resulting solution through a screen, washing the remaining flesh off the achenes, and drying to yield clean seed.

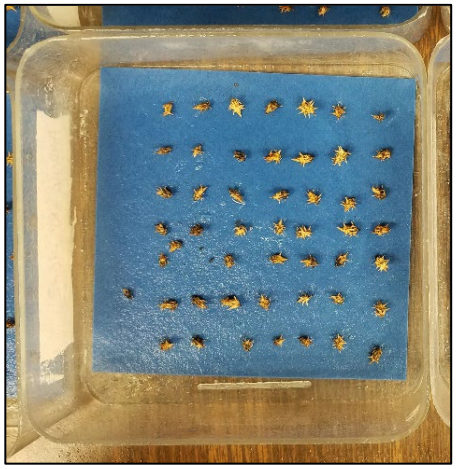

Figure 2: One replicate in a germination trial with Ambrosia chamissonis.

The blender cleaning method served as a type of scarification treatment.

For most species, 3 reps of 50 seeds each per treatment were evaluated. However, seed quantity limitations for some species required using less seeds per replicate, less replicates, or less treatments. Each replicate was placed on blue blotter paper in a clear germination box, and seeds were moistened with distilled water. After pre-treatment, germination boxes were placed in a growth chamber (Hoffman Manufacturing Inc., Corvallis, OR) with 12-hour 20˚C light and 12-hour 10˚C dark cycles. Germinated seeds (defined by the presence of a visibly emerged radicle) were counted weekly for three weeks. *Fragaria chiloensis* was an exception, where germinants were counted weekly for 12 weeks. For all species, if seeds germinated prior to the completion of a pre-treatment, that pre-treatment was eliminated from analysis (ex: germinating in the warm treatment during a 4 weeks warm followed by 4 weeks cold moist stratification treatment).

Data was analyzed within a species and treatment date across all treatments. A Shapiro-Wilk test was used to test for normality. One-way analysis of variance (ANOVA) and Tukey's pairwise comparisons were used to determine significance.

Container production

Three different assessments of container production requirements were performed. In January through April of 2021, 10" D40 containers (Stuewe and Sons, Tangent, OR) of six species were sown. Species included *Carex macrocephala, Polygonum paronychia, Glehnia leiocarpa, Abronia latifolia, Calystegia soldanella,* and *Lathyrus japonicus*. Two different substrates were used: 1) Pro-Mix (Premier Tech, Quakertown, PA) high porosity potting soil and 2) 1 part washed river sand to 2 parts Pro-mix high porosity potting soil. Containers for each species were filled with each of the two mixes. The number of containers varied by species from 26 to 260 and was determined by seed availability. On July 22, 2021, once container plants were well established, the number of surviving plants by species and substrate type were counted.

Figure 3: Container production trials of mixed native dune species at the Corvallis Plant Materials Center.

In a second container production trial, 15 species were sown on July 26, 2023, in three different container types all filled with Pro-Mix high porosity potting soil. Container types included 1) 2" plugs in 72 cell liner trays (volume 3.6 in^3 per cell), 2) 5.5" Ray Leach Stubby cells (6.5 in^3 per cell), and 3) 10" D40 (40 in^3 per cell). Species requiring cold-stratification were placed in a walk-in cooler at 4˚C for the appropriate period and then placed outside in a shade house. All other species were placed in the shade house directly after sowing. Prior to the first frost, plants were moved on October 27 to a heated

greenhouse to continue their growth. Starting in December, 3 individuals per container type within each species were removed from their containers and root growth was evaluated. When all three plants were rooted to the point where they held the potting media together well and could be easily transplanted, they were considered filled. Days to fill were monitored weekly until all container types and species were filled.

In a third container production trial, live *Honckenya peploides* stems were collected from a natural population on October 4, 2020. The following day, 15 propagules were placed in each of 5 treatments into 15”x15”x5” nursery trays of pure beach sand. The 5 treatments were 1) stems with all leaves intact, cut end buried 3cm; 2) stems with 3cm of leaves stripped, cut end buried 3cm; 3) stems with all leaves stripped and entire stem buried horizontally 1cm under the surface; 4) leaves only on surface; and 5) leaves only with cut end lightly buried. On May 1, 2021, the number of established plants per treatment were counted.

Figure 4: Vegetative propagation trial of Honckenya peploides*. Stems with leaves intact are buried 3cm in beach sand.*

Seed production

Seed amplification was trialed for 26 species between October 2020 and October 2025 in farm fields located at the Corvallis Plant Materials Center (45.625260, -123.214172). Soil types are Willamette and Amity silt loams on 0 to 3 percent slopes (USDA Soil Survey). While these species exist at least partially if not entirely on coastal sands in their native habitats, commercial seed production in Oregon occurs largely in inland valleys on developed soils, and understanding the ability of these species to grow and produce seed under these circumstances has practical, applied restoration value.

Methods for seed production varied by species. Initial evaluation plantings of approximately 20 plants were performed for some species that were expected to grow poorly in this site’s soil and climate conditions due to their total restriction to coastal sands in their natural habitat. All other species were planted in greater numbers. Larger plantings up to 1000 individuals were performed for species expected to perform better or those with a wider natural habitat range.

Planting season, supplemental irrigation, and plant spacing were chosen by species. In some cases, multiple approaches were taken by species. Seed production protocols were written for 15 species that performed sufficiently well in our seed amplification environment. The remaining species did not perform adequately and will require different approaches for plant material production.

RESULTS

Wild seed collection

In total, 20.1kg of wild seed was collected for 106 unique accessions from 26 different sites. Totals by species are listed in Table 1. Many of these accessions were used for germination, container, and seed production trials.

Table 1: Wild seed collection totals for the years 2021-2024, Oregon coastal dune species.

Species	Collection Years	# of sites	Total # collections	Cleaned quantity (g)
Abronia latifolia	2022, 2023	2	2	2,461
Ambrosia chamissonis	2021	2	2	386
Anaphalis margaritacea	2023	1	1	3.8
Angelica hendersonii	2021, 2023, 2024	4	5	623
Angelica lucida	2021, 2023, 2024	5	10	600
Armeria maritima	2021, 2022, 2023	4	8	5.3
Calystegia soldanella	2021, 2023	4	5	4.3
Cardionema ramosissimum	2021	2	2	6
Carex macrocephala	2022, 2023, 2024	1	3	5,047
Carex macrocephala **(perigynia removed)**	2023	1	1	1,135
Carex pansa	2024	1	1	114
Erigeron glaucus	2022, 2023	2	2	3.1
Gamochaeta ustulata	2021	2	2	2.1
Gilia millefoliata	2023	3	3	0.79
Glehnia leiocarpa	2021, 2022, 2023, 2024	2	5	544
Grindelia stricta	2021	3	3	237
Juncus breweri	2021	3	3	107
Lathyrus japonicus	2021, 2023	2	3	6,846
Lathyrus littoralis	2021, 2022, 2023	4	8	240
Leymus mollis	2021, 2022	5	8	271
Lupinus littoralis	2021	4	4	16
Nuttallanthus texanus	2022	1	1	0.04
Poa macrantha	2024	1	1	90
Polygonum paronychia	2021	1	1	2.6
Potentilla anserina	2023	1	1	3.4
Rumex crassus	2021	6	6	113
Rumex occidentalis	2021	1	1	4
Rumex persicarioides	2021	2	2	47
Solidago spathulata	2024	1	1	296
Tanacetum bipinnatum	2024	1	1	46
Vicia nigricans var. gigantea	2021, 2023	5	10	851

Seed counts

Table 2 shows seeds per pound for 28 species. In several cases, further details are offered with the species name.

Germination studies

Selected results of germination trials are presented in Table 3, including recommended germination pre-treatments based on results of these trials and in some cases, results of other informal trials with the species. Complete germination trial results including statistical analyses, seed sources and collection dates, and trial initiation dates can be found in Appendix 1.

Species requiring no pre-treatment to stimulate germination include *Gamochaeta ustulata*, *Juncus breweri*, and *Poa macrantha.* Species requiring scarification but no stratification include *Calystegia soldanella* and four legume family species: *Lathyrus japonicus, Lathyrus littoralis, Lupinus littoralis,* and *Vicia nigricans* var. *gigantea.* Species requiring no scarification but varying lengths of cold-moist stratification include *Angelica hendersonii*, *Cardionema ramosissimum*, *Gilia millefoliata, Glehnia leiocarpa*, *Grindelia stricta, Leymus mollis, Nuttallanthus texanus, Polygonum paronychia,* and *Rumex crassus.* Species requiring warm-moist stratification prior to a period of cold-moist stratification include *Angelica lucida* and *Rumex persicarioides.* Species requiring scarification

Table 2: Seeds per pound for 27 native dune species and 1 non-dune coastal species.

Species	seeds/lb
Abronia latifolia (fruits)	24,100
Abronia umbellata (fruits)	46,000
Ambrosia chamissonis (fruits)	86,600
Angelica hendersonii (fruits)	43,800
Angelica lucida (fruits)	73,500
Armeria maritima (achenes only, wild)	899,000
Armeria maritima (achenes only, irrigated production seed)	591,000
Armeria maritima (with floral bracts attached, irrigated production seed)	260,000
Calystegia soldanella (only 81 seeds available)	7,200
Cardionema ramosissimum	805,400
Carex macrocephala (with periginia)	30,500
Carex macrocephala (achenes only)	59,000
Erigeron glaucus	2,500,000
Fragaria chiloensis	928,000
Gamochaeta ustulata	1,490,200
Gilia millefoliata (wild seed)	1,162,100
Gilia millefoliata (production seed)	957,800
Glehnia littoralis (fruits)	16,800
Grindelia stricta	170,500
Helenium bolanderi	598,900
Lathyrus japonicus	14,700
Lathyrus littoralis	5,800
Leymus mollis	51,200
Lupinus littoralis	61,700
Nuttallanthus texanus	19,739,100
Poa macrantha (with lemma and palea)	182,700
Poa macrantha (caryopses only)	251,400
Polygonum paronychia	131,700
Rumex persicarioides	1,429,200
Rumex crassus	460,600
Sanicula arctopoides	61,100
Tanacetum bipinnatum	929,700
Vicia nigricans* var. *gigantea	5,200

followed by varying lengths of cold-moist stratification include *Ambrosia chamissonis* and *Carex macrocephala.* Results for *Abronia latifolia* were inconclusive but suggest that soaking naked seeds in liquid ethephon may support improved germination; further investigation is necessary.

Table 3: Plant species, treatment leading to the highest germination rate, and germination recommendation summary. Where indicated, scarification was mechanical with the use of sandpaper; exceptions are noted. Stratification treatments are listed by number of weeks in a 4˚C (cold = C) or 20˚C (warm = W) environment. scar = scarification, strat = stratification, CMS = cold moist stratification, WMS = warm moist stratification, $^{\varphi}$ = scarification treatment: complete removal of seed from fruiting structure/bracts

Species	Treatment(s) with highest germination rate: mean germination %	Germination Recommendation Summary
Abronia latifolia	Scar$^{\Phi}$, liquid ethephon, 0C: 44%	Remove seed from fruit husk and soak in liquid ethephon, no strat; requires further investigation to determine additional stratification requirement
Ambrosia chamissonis	Scar, 8C: 18%	Scar not aggressive enough; in informal trials, aggressive mechanical scar and 8 weeks CMS resulted in over 70% germination
Angelica hendersonii	Fresh seed and 16C: 59%	Minimum 12 weeks CMS; viability maintained after a year but seed dead after 3 years
Angelica lucida	Fresh seed and 4W16C: 67%	4 weeks WMS followed by minimum 12 weeks CMS; viability maintained after a year but seed dead after 3 years
Calystegia soldanella	Scar, 0C: 100%	Scar, no strat
Cardionema ramosissimum	4C: 93%	4 weeks CMS
Carex macrocephala	Scar$^{\Phi}$, 8C: 67%	Scar, 8 weeks CMS with naked achenes
Gamochaeta ustulata	4C: 61%	No pre-treatment necessary (similar germination rate to 4C)
Gilia millefoliata	3C: 66%	3 weeks CMS
Glehnia leiocarpa	4W16C: 71%	12 weeks CMS or 4 weeks WMS followed by 16 weeks CMS; results differ between different trials with same species
Grindelia stricta	8C: 64%	4 weeks CMS (similar germination rate to 8C)
Helenium bolanderi	0C: 80%	No pre-treatment necessary
Juncus breweri	4C: 91%	No pre-treatment necessary (similar germination rate to 4C)
Lathyrus japonicus	Scar, 0C and 4C: 100%	Scar, no strat
Lathyrus littoralis	Scar, 4C: 80%	Scar, no strat (similar germination rate to 4C)
Leymus mollis	4W4C: 82%	4 weeks CMS
Lupinus littoralis	Scar, 4C: 96%	Scar, no strat (similar germination rate to 4C)

Species	Treatment(s) with highest germination rate: mean germination %	Germination Recommendation Summary
Nuttallanthus texanus	4C: 16%	Inconclusive, germination rate low in all treatments (other trials showed high germination with 8 weeks of natural outdoor strat Nov-Jan)
Poa macrantha	Scar$^{\phi}$, 0C: 98%	No pre-treatment necessary (similar germination rate to scar)
Polygonum paronychia	12C and 16C: 75%	8 weeks CMS (similar germination rate to 12C and 16C)
Rumex crassus	8C and 4W4C: 91%	4 weeks CMS (similar germination rate to 8C and 4W4C)
Rumex persicarioides	4W4C: 95%	4 weeks WMS followed by 4 weeks CMS (some seed lots have germinated significantly in greenhouse trials without any pre-treatment)
Vicia nigricans* var. *gigantea	Scar, 4C: 87%	Scar, no strat (similar germination rate to 4C)

Container production

In the 2021 container trial of six different species, rates of establishment ranged from 14% to 100% (Table 4). *Glehnia leiocarpa* had the lowest rate of establishment at about 14% in both media treatments.

Table 2: Percent establishment in containers of six native dune species. Each container was planted with one germinated seed.

	High Porosity Pro-Mix (HP)			1/3 Sand, 2/3 HP		
Species	**# sown**	**# established**	**% establish-ment**	**# sown**	**# established**	**% establish-ment**
Carex macrocephala	120	85	70.8	140	119	85
Polygonum paronychia	37	35	94.6	20	15	75
Glehnia leiocarpa	43	6	14.0	56	8	14.3
Abronia latifolia	20	11	55.0	20	6	30
Calystegia soldanella	22	20	90.9	4	4	100
Lathyrus japonicus	180	180	100.0	80	80	100

Lathyrus japonicus had the highest rate of establishment at 100% in both media treatments. Species with an establishment rate of more than 10% higher in HP soil than in the sand mix were *Polygonum paronychia* and *Abronia latifolia.* The only species with an establishment rate more than 10% higher in the sand mix than in the pure HP soil was *Carex macrocephala*. Given these results and the significant added weight and therefore practical challenge of container cultivation in sand, it does not appear merited to mix sand into potting soil for container production of any of these species.

In the 2023 trial of 15 species in 3 different container sizes, days to fill ranged from 97 days for a 2" plug of *Armeria maritima* to 253 days for a 10" plug of *Lathyrus japonicus* (Table 5). It is likely that some of the faster growing species such as *Festuca ammobia, Grindelia stricta, Rumex crassus,* and *Rumex persicarioides* would more rapidly fill a 2" plug than all other species, but these assessments were not included. Note that days to fill does not include the stratification period.

In the assessment of vegetative propagation methods for *Honckenya peploides*, all three treatments that utilized the stems of the plant established at a rate of 100%. Both treatments that used leaves only and no stems established at a rate of 0%.

Table 5: Days to fill in 3 plug sizes of 15 native dune species.

Species	2" plug, 72-cell tray	5.5" stubby	10" D40
Armeria maritima	97	159	181
Calystegia soldanella	139	240	NA
Erigeron glaucus	139	223	223
Festuca ammobia	NA	139	177
Grindelia stricta	NA	111	111
Juncus breweri	154	194	223
Lathyrus japonicus	139	177	253
Lathyrus littoralis	139	253	NA
Poa macrantha	NA	139	194
Polygonum paronychia	149	149	195
Rumex persicarioides	NA	111	149
Rumex crassus	NA	111	126
Solidago spathulata	NA	139	194
Tanacetum bipinnatum	NA	139	194
Vicia nigricans* var. *gigantea	139	154	223

Seed production

In-field seed production was attempted for 26 species. Results varied by species from death of all plants within two months of transplanting to significant vegetative growth and seed production.

No individuals of the following species survived for more than two months after containers were planted into field conditions: *Abronia latifolia, Glehnia leiocarpa*, and *Lathyrus littoralis*.

Survival for Vicia nigricans var. gigantea was less than 5% one year after planting the two times field establishment was attempted. The first attempt started with 346 plants and the second attempt started with 150.

Figure 5: Vegetative propagation trial of Honckenya peploides. *On the left, plants resulted from buried leafless stems. On the right, zero plants established from both leaf-only treatments.*

Figure 6: (Left) Lathyrus japonicus *growing vigorously in its first year. Rows of* Deschampsia cespitosa *are planted on either side to act as a living trellis. (Right)* Leymus mollis *in its fourth year.*

Four species grew vegetatively in our fields but had low to no flowering and/or produced only a small quantity of seed. *Carex macrocephala* survived and grew vegetatively when planted in fall or spring planted with irrigation, but it spread very little rhizomatously, flowered at a low rate, and produced less than 1lb/acre of seed in its third year. *Calystegia soldanella* grew actively vegetatively for four years and survived tillage when we attempted to remove the plants but did not produce any flowers. A patch of 313 plants of *Leymus mollis* from 5 different populations produced 20 or less inflorescences per year in its second, third, and fourth years of growth, with a yield of 2.5 lb/acre of clean seed in the final year. *Juncus breweri* had high survival, grew, and flowered but did not spread nor produce detectable seed after 3 years.

After 3-5 years of trials, three species showed signs of seed production potential. but we did not adequately determine seed production methods. These are *Fragaria chiloensis*, *Lathyrus japonicus*, and *Poa macrantha*. *Fragaria chiloensis* flowered abundantly most years but seed yields were too low in all four years to be an economically viable candidate. *Lathyrus japonicus* survived for two years when planted in a monoculture. When planted in a biculture with *Deschampsia cespitosa* (serving as a living trellis), survival and flowering were high, but developing seeds were eaten out of the pods by rodents. *Poa macrantha* grew vegetatively and many plants flowered but is dioecious and in our third year with

the species we determined the field to be more than 80% male. Future trials with more appropriate sex ratios may lead to better production.

A total of 15 species produced an agronomically significant quantity of seed when grown in field conditions. These are *Ambrosia chamissonis, Angelica hendersonii, Angelica lucida, Armeria maritima, Cardionema ramosissimum, Erigeron glaucus, Gamochaeta ustulata, Gilia millefoliata, Grindelia stricta, Helenium bolanderi, Lupinus littoralis, Nuttallanthus texanus, Polygonum paronychia, Rumex crassus,* and *Rumex persicarioides.* Complete seed production protocols for these species can be found in Appendix 2, except for *Angelica lucida*, which is referenced in the *A. hendersonii* protocol.

Seed production totals and extrapolated yields for all species are in Table 6.

*Table 3: Seed production totals, field sizes, and extrapolated yields for all species and years. Most production was done in the ground in a field setting, but some were done in containers. Exceptions are noted as follows: * 10" D40 containers, ** gallon pots, ***2" 72 cell liner trays, ****raised sand boxes*

Species	Year	Field Age (Years)	Quantity (g)	Field Size (ft^2)	Extrapolated yield (lb/ac)
Ambrosia chamissonis	2023	1	418	168	239
Ambrosia chamissonis	2024	2	2,270	100	2178
Angelica hendersonii	2024	2	28	80	34
Angelica hendersonii	2025	3	142	80	170
Angelica lucida	2025	2	54	80	65
Armeria maritima	2024	2 Fields: 1 and 2	296	600	47
Armeria maritima	2025	2	1060	1000	101
Cardionema ramosissimum	2023	2	270	328	79
Cardionema ramosissimum	2024	3	484	328	142
Carex macrocephala	2024	3	0.72	400	0.17
Erigeron glaucus	2023	1	150	120	120
Erigeron glaucus	2024	2	738	120	590
Erigeron glaucus	2024	1	44	1800	2
Erigeron glaucus	2025	2	5,857	1800	312
Fragaria chiloensis	2021	1	5.3	1800	0.3
Fragaria chiloensis	2022	2	45.41	1800	2.4
Fragaria chiloensis	2023	3	0.61	1800	0.03
Fragaria chiloensis	2024	4	3.28	1800	0.2
Gamochaeta ustulata	2022	1	21	232	8
Gamochaeta ustulata	2023	2	33	232	13
Gamochaeta ustulata	2024	3	96	232	40
Gilia millefoliata	2024	1	289	20****	1386
Gilia millefoliata	2024	1	467	40*	1120
Gilia millefoliata	2025	1	13,665	1615	812
Grindelia stricta	2023	1	1,937	1200	155
Grindelia stricta	2024	2	5,857	1200	468
Helenium bolanderi	2024	1	70	300	22

Species	Year	Field Age (Years)	Quantity (g)	Field Size (ft^2)	Extrapolated yield (lb/ac)
Helenium bolanderi	2025	2	1,453	300	465
Lathyrus japonicus	2022	1	134	520	25
Lathyrus japonicus	2023	2	15	520	3
Leymus mollis	2024	2 Fields: 2 and 4	16.2	620	2.5
Lupinus littoralis	2023	1	205	400	49
Lupinus littoralis	2024	1	58	410	14
Nuttallanthus texanus	2023	1	1.80	10**	17
Nuttallanthus texanus	2024	1	3.60	10**	35
Nuttallanthus texanus	2025	1	2,996	873	329
Poa macrantha	2023	2	7.70	640	1.2
Poa macrantha	2024	3	62	640	9
Poa macrantha	2025	2	10.0	660	1.45
Polygonum paronychia	2022	1	160	208	74
Polygonum paronychia	2023	2	322	208	149
Polygonum paronychia	2024	3	152	208	70
Polygonum paronychia	2025	4	179	208	83
Rumex crassus	2023	1	762	960	76
Rumex crassus	2024	2	4,994	960	499
Rumex crassus	2025	3	3,087	960	309
Rumex persicarioides	2022	1	62	20*	298
Rumex persicarioides	2023	1	99	235	40
Rumex persicarioides	2024	1	53	20*	254
Rumex persicarioides	2024	1	57	20***	273
Rumex persicarioides	2025	1	999	1020	94

DISCUSSION AND CONCLUSIONS

Appropriate pathways for plant material production are species specific and depend on several factors. Figure 7 can be used as a guide to make informed choices about plant material forms for use in restoration. Clear answers to these questions require experience with the species. This study was intended to answer questions on Figure 7 related to plant performance in a farm/nursery. As a broader dune restoration community in Oregon, we currently know little about the establishment from seed directly on restoration sites of many of these species. Varying restoration site conditions may also generate different answers related to plant establishment on site, making answers to these questions not only species-specific, but site-condition specific as well. Species-specific plant material production recommendations are summarized in Table 7.

Due to the difference between native dune habitat restoration site conditions and those found in most nurseries and seed production farms, some native dune species may be particularly appropriate for establishment of significant populations on natural or restored sites that will then subsequently be used as collection sites for seed or vegetative propagules to support restoration at additional locations. We refer to this as "wild farming." This may be particularly true for species seemingly obligated to the shifting coastal sands on foredunes such as *Abronia latifolia*.

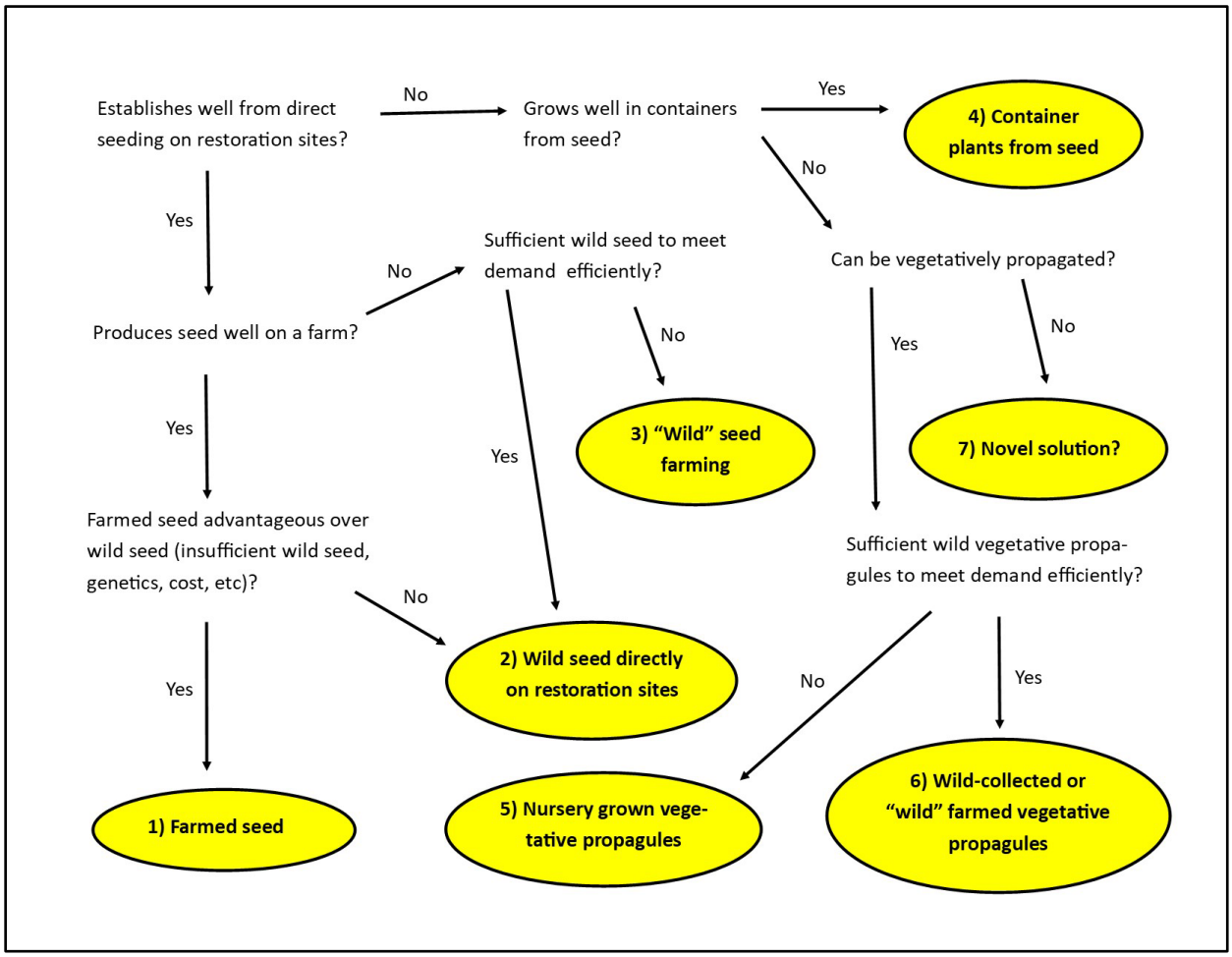

Figure 7: Plant material production decision flowchart. "Wild" farming refers to installing a heavy representation of a target plant species on a natural or restored site and using the resulting population for the collection of propagules to support restoration elsewhere.

Species-specific plant materials production recommendations

Abronia latifolia (yellow sand-verbena) – A poor candidate for seed production in inland valleys. This species appears to establish adequately from direct seeding in foredune restoration. Large wild populations may be able to support seed collection for use directly on restoration sites or for plug production in cases where direct seeding is less successful. Natural populations or restoration sites can be augmented to serve as collection sites to provide seed for use on other restoration sites.

Ambrosia chamissonis (beach bur-sage) – A sufficiently successful producer of seed in our soils in Corvallis (see Appendix for seed production protocol). It is likely important that soils are adequately well-drained to minimize loss due to crown/root rot. This species appears to establish adequately from direct seeding in foredune restoration. This is also a good candidate for wild seed farming because seed harvest methods are the same on a farm and in the wild.

Angelica hendersonii (Henderson's angelica) -- A sufficiently successful producer of seed in in our soils in Corvallis (see Appendix for seed production protocol). Direct seeding success on restoration sites is unknown. Seed is short-lived (1-2 years) and wild populations are potentially large enough to support wild seed use directly on restoration sites. This is a likely candidate for wild seed farming because of ease of hand harvest of seed.

Angelica lucida (seawatch) – This species has produced seed less successfully in Corvallis than has *A. hendersonii,* suggesting it may be a marginally successful seed producer in inland valleys. Direct seeding success on restoration sites is unknown. Seed is short-lived (1-2 years) and wild populations are potentially large-enough to support wild seed use directly on restoration sites. This is a likely candidate for wild seed farming because of ease of hand harvest of seed.

Armeria maritima (sea thrift) -- A sufficiently successful producer of seed in our soils in Corvallis (see Appendix for seed production protocol). Direct seeding success on restoration sites is unknown, making it unclear if direct seeding or container plant introduction are appropriate introduction methods.

Table 4: Summary of plant material production pathway recommendations. Definitions of plant material pathways are as follows: 1) Farmed seed -- seed produced in an agricultural setting; assumes that the species establishes adequately from direct seeding on a restoration site and that direct seeding is preferred over container plantings; 2) Wild collected seed used directly on restoration sites – seed collected from a naturally occurring population is used directly on a restoration site; assumes that the species establishes adequately from direct seeding on a restoration site, that direct seeding is preferred over container plantings, and that wild populations are of an adequate size to support seed collection for this purpose; 3) Wild seed farming – collection of seed from a population of plants that was established on a restoration site or in a natural area for the purpose of seed harvest to support restoration on other sites; assumes that the species establishes adequately from direct seeding on a restoration site and that direct seeding is preferred over container plantings; 4) Container plants from seed – the planting of nursery-grown container plants on a restoration site; assumes that the species does not establish well from direct seeding on a restoration site; 5) Nursery grown vegetative propagules – the use of vegetative propagules produced in a nursery or farm setting; 6) Wild-collected or wild-farmed vegetative propagules – the use of vegetative propagules that are collected directly from a wild population or a population that was established on restoration site or natural area for the purpose of providing plant materials to support restoration on other sites.

	1 Farmed Seed	2 Wild collected seed used directly on restoration sites	3 Wild seed farming	4 Container plants from seed	5 Nursery grown vegetative propagules	6 Wild-collected or wild-farmed vegetative propagules
Abronia latifolia		X	X	X		
Ambrosia chamissonis	X	X	X			
Angelica hendersonii	X	X	X	X		
Angelica lucida	X	X	X	X		
Armeria maritima	X			X		

	1 Farmed Seed	2 Wild collected seed used directly on restoration sites	3 Wild seed farming	4 Container plants from seed	5 Nursery grown vegetative propagules	6 Wild-collected or wild-farmed vegetative propagules
Calystegia soldanella					X	X
Cardionema ramosissimum	X	X	X	X		
Carex macrocephala		X	X	X	X	X
Erigeron glaucus	X			X		
Fragaria chiloensis					X	X
Gamochaeta ustulata	X					
Gilia millefoliata	X					
Glehnia leiocarpa			X	X		
Grindelia stricta	X	X		X		
Helenium bolanderi	X			X		
Honckenya peploides					X	X
Juncus breweri		X	X	X	X	X
Lathyrus japonicus	X	X	X	X		
Lathyrus littoralis			X	X		
Leymus mollis					X	X
Lupinus littoralis	X	X	X	X		
Nuttallanthus texanus	X					
Poa macrantha	X		X	X	X	X
Polygonum paronychia	X	X	X	X		
Rumex crassus	X		X	X		
Rumex persicarioides	X					
Vicia nigricans* var. *gigantea		X	X	X		

Calystegia soldanella (coast morning-glory) -- A poor candidate for seed production in all locations because plants are highly prostrate, produce few flowers, and each flower produces few seeds. Further experimentation with vegetative propagation is required to inform appropriate restoration plant material forms. A possible method of introduction is through nursery-grown, wild-farmed, or wild-collected vegetative propagules.

Cardionema ramosissimum (sandcarpet) -- A sufficiently successful producer of seed in our soils in Corvallis (see Appendix for seed production protocol). This species can be abundant on disturbed coastal sands. In a seed production environment, hand harvest is necessary due to the highly prostrate growth form, suggesting that wild seed collection or wild farming could be an equally efficient production method as compared to farm-based seed production.

Carex macrocephala (big-head sedge) – Has not successfully produced seed in a field setting in Corvallis. This species may require coastal sands for successful seed production. If densely cultivated for seed production on sand, it is unknown if plants will hold their seed heads high enough to facilitate mechanical harvest. Large quantities can be collected efficiently by hand in large wild populations to support direct-seeding on restoration sites.

Erigeron glaucus (seaside daisy) – A successful producer of seed in our soils in Corvallis (see Appendix for seed production protocol). This species has been established from direct seeding in a coastal meadow, but results from direct seeding in a dune environment are unknown.

Fragaria chiloensis (beach strawberry) – Seed production in Corvallis has been low and irregular. The labor cost associated with producing the seed in our trials was estimated at over $3500/lb. Restoration plant materials are most likely to come from vegetative propagules produced in a nursery, wild-farmed, or from wild-harvest. Further development of on-farm seed production potential could focus on the relationship between genetic diversity of foundation stock and resulting seed yield.

Figure 8: Fragaria chiloensis *grew aggressively and flowered abundantly, but yields were low, resulting in high-cost seed.*

Gamochaeta ustulata (purple cudweed) – A successful producer of seed in our soils in Corvallis (see Appendix for seed production protocol). This plant is often an annual, making restoration site introduction by plug more challenging. Success from direct seeding on dune restoration sites is unknown.

Gilia millefoliata (dark-eyed gilia) – A very successful producer of seed in our soils in Corvallis (see Appendix for seed production protocol). As an annual that grows on sand with a low density of other vegetation, introduction by direct seeding is most likely to be the most successful introduction method.

Glehnia leiocarpa (beach silvertop) -- A poor candidate for seed production in inland valleys. Establishment success from direct seeding on restoration sites is unknown. Due to this species' restriction to coastal sands and poor seed retention, wild seed farming is likely an appropriate pathway for producing adequate seed for other restoration sites, either for container production or, if successful, direct seeding.

Grindelia stricta (coastal gumweed) -- A very successful producer of seed in our soils in Corvallis (see Appendix for seed production protocol). Establishment success from direct seeding on dune restoration sites is unknown. However, this species self-sowed abundantly in our Corvallis seed production field, suggesting its potential to successfully establish from direct seeding on restoration sites.

Helenium bolanderi (coast sneezeweed) – A successful producer of seed in our soils in Corvallis (see Appendix for seed production protocol). Establishment from direct seeding on restoration sites is unknown. This is the only species in this study that is not known to occur in dune habitats.

Honckenya peploides (seaside sandwort) – Seed production was not attempted for this species because it appears to produce little seed and is highly restricted to coastal sands. Vegetative propagation has been

successful by shallowly burying stem cuttings. This is a good candidate for wild farming or nursery production of vegetative propagules.

Juncus breweri (Brewer's rush) – Poor seed producer in our soils in Corvallis. Establishment from direct seeding on restoration sites is unknown. This species has potential to be grown for seed amplification on coastal sands and because of flowering height and adequate seed retention, it may be able to be mechanically harvested. Wild seed or vegetative propagule farming could be considered but would not likely come with the efficiencies associated with mechanical harvest.

Lathyrus japonicus (beach pea) – This species was a poor producer of seed in Corvallis, but more assessments are merited. Grown alone, this species lays on the ground and ripens indeterminately, making mechanical harvest challenging. Grown with a companion that serves as a living trellis (we used *Deschampisa cespitosa* and *Bromus sitchensis*; *D. cespitosa* was superior), plants could likely be swathed at the height of ripeness. There are also large natural populations of this species, and we were able to harvest and clean 1lb of wild seed per hour of labor from wild populations. As such, on farm seed amplification may be unnecessary, and seed needs may possibly be met with wild seed collection or wild seed farming.

Figure 9: Lathryus japonicus *can be found growing in large stands on the lee side of foredunes in association with* Leymus mollis *and* Ammophila arenaria*, making efficient wild collection of significant seed quantities possible.*

Lathyrus littoralis (gray beach pea) -- A poor candidate for seed production in inland valleys. Early results from trial seedings suggest the potential for this species to establish from direct seeding on dune restoration sites, but more investigation is needed. Many wild populations in Oregon are small and exhibit signs of inbreeding. Plants in container production can exhibit low vigor. This species will likely require a coastal sand-based seed production environment, either in a controlled setting or though wild-farming.

Leymus mollis (American dunegrass) – This species grew successfully vegetatively in Corvallis and spread rhizomatously but flowered at a very low rate. *L. mollis* is not known to produce significant seed in most circumstances in its natural habitat. This species will likely require sand-based vegetative propagation to produce ample plant material for ecological restoration. This could be through wild-harvest, wild-farming, or nursery production of vegetative propagules.

Lupinus littoralis (seashore lupine) – Farm based seed production fields of this species are not long lived if done in inland valleys due to crown/root rot diseases (see Appendix for seed production protocol). However, in its natural habitat, this species can produce significant seed, and it is known to establish

sufficiently well from direct seeding on restoration sites. Due to indeterminate ripening, poor seed retention, and a low growth habit, mechanical harvest is not likely to be successful with this species, suggesting that wild-harvest and wild seed farming may be successful plant material pathways. If root/crown rot diseases and rodent consumption of seed can be managed successfully and a large percentage of seeds harvested, this species may be an adequate farm-based seed production candidate.

Nuttallanthus texanus (large flowered blue toadflax) -- A very successful producer of seed in our soils in Corvallis (see Appendix for seed production protocol). We have no direct experience with establishing this species from direct seeding on dune restoration sites, but this species does self-sow abundantly and establish successfully in containers in our nursery, suggesting its potential to do so on restoration sites.

Figure 10: Despite sometimes significant flowering in wild populations of Poa macrantha, seed fill is commonly low making collection of large amounts of seed challenging.

Poa macrantha (seashore bluegrass) – Further development is necessary to determine appropriate plant material pathways for this species. Plants grow successfully vegetatively in our fields in Corvallis, but we have found the ratio of male to female plants to be high (over 80% male) and the seed production low. Future efforts will use vegetative propagation to increase the ratio of females to males. We are not aware of how this species performs from direct seeding in a dune restoration setting. If a successful farm-based seed production protocol is not developed, wild farming of seed or vegetative propagules is a likely pathway.

Polygonum paronychia (beach knotweed) -- A successful producer of seed in our soils in Corvallis (see Appendix for seed production protocol). Establishment from direct seeding on restoration sites is unknown. Its near continuous flowering for most of the year and hiding of ripe seed behind bracts makes the optimal timing of seed harvest challenging.

Rumex crassus (willow dock) -- A successful producer of seed in our soils in Corvallis (see Appendix for seed production protocol). Establishment from direct seeding on restoration sites is unknown. Prostrate growth habitat makes hand harvest necessary, indicating that wild seed farming is a possible pathway to produce restoration plant materials.

Rumex persicarioides (seashore dock) -- A successful producer of seed in our soils in Corvallis (see Appendix for seed production protocol). Establishment from direct seeding on restoration sites is unknown. This species requires significant supplemental irrigation to support ample vegetative growth, flowering, and seed production. Not a likely candidate for successful wild seed farming because of its high water need.

Vicia nigricans var. gigantea (giant vetch) – Very poor establishment from plugs in two separate locations on our farm in Corvallis, including when planted between two rows of *Deschampsia cespitosa* that was intended to function as a living trellis. Establishment from direct seeding on restoration sites is unknown.

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APPENDIX 1: COMPLETE GERMINATION TRIAL DATA

Plant species and mean germination percentage by germination pre-treatment. Each treatment by species represents 3 replicates of 50 seeds each; exceptions are noted. Where indicated, scarification was mechanical with the use of sandpaper; exceptions are noted. Stratification treatments are listed by number of weeks in a 4˚C (cold = C) or 20˚C (warm = W) environment. Superscript letters indicate pre-treatment significance groups within that species and initiation date. scar = scarification, strat = stratification, CMS = cold moist stratification, WMS = warm moist stratification, E = Ethephon, GA = Gibberellic acid, * 1 rep with 20 seeds, * 1 rep with 25 seeds each, **3 reps with 25 seeds each, $^{\phi}$ scarification treatment: complete removal of seed from fruiting structure/bracts

Species	Scarified?	Stratification Tx (weeks in warm or cold): Mean germination percentage	Statistical summary	Seed Source	Seed Collection Date	Date Trial Initiated
Abronia latifolia	Yes$^{\phi}$	0C: 0%^{B} 2C: 0%^{B} 4C: 0%^{B} 8C: 9%^{AB} 4W4C: 14%^{A}	p strat = 0.012	Bayshore (Waldport)	8/28/2020	1/13/2021
Abronia latifolia*	Yes$^{\phi}$	0C: 0% **0C/E: 44%** 0C/GA500: 4% 0C/GA750: 24% 0C/GA1500: 16%	N/A	Bayshore (Waldport)	2020	12/19/2024
		0C: 8% 0C/E: 16% 0C/GA500: 0% 0C/GA750: 0% 0C/GA1500: 0%		Bob Straub State Park	2023	
Ambrosia chamissonis	Yes	0C: 0%^{B} 4C: 12%^{AB} **8C: 18%^{A}** 12C: 15%^{AB} 4W4C: 6%^{AB}	p strat = 0.022	Lost Creek	9/10/2021	12/1/2021
Angelica hendersonii	No	OC: 0%^{B} 4C: 0%^{B} 8C: 9%^{B} 12C: 21%^{A} 4W4C: 0%^{B} 4W8C: 7%^{B} 4W12C: 23%^{A}	p strat = 0.000	Bob Creek	10/22/2021	12/1/2021
		12C: 47%^{A} **16C: 59%^{A}**	p year = 0.000, p strat = 0.646	PMC G1 (G0 from Bob Creek)	2024	10/16/2024
		12C: 43%^{A} 16C: 39%^{A}		Bob Creek	2023	
		12C: 0%^{B} 16C: 0%^{B}			2021	
Angelica lucida	No	0C: 0%^{B} 4C: 0%^{B} 8C: 0%^{B} 12C: 1%^{B} 4W4C: 0%^{B} 4W8C: 5%^{B} 4W12C: 20%^{A}	p strat = 0.001	Hwy 101 at Otter Crest	8/13/2021	12/1/2021
		4W12C: 54%^{A} **4W16C: 67%^{A}**	p year = 0.000, p strat = 0.005, p strat*year = 0.044	Rocky Creek/Lost Creek Mix	2024	10/16/2024
		4W12C: 29%^{B} 4W16C: 55%^{A}		Rocky Creek	2023	
		4W12C: 0%^{C} 4W16C: 0%^{C}			2021	
Calystegia soldanella*	Yes	**0C: 100%** 2C: 90% 4C: 55%	N/A	Winema Beach	10/2/2020	1/13/2021

Species	Scarified?	Stratification Tx (weeks in warm or cold): Mean germination percentage	Statistical summary	Seed Source	Seed Collection Date	Date Trial Initiated
Cardionema ramosissimum	No	0C: 49%^{B} **4C: 93%^{A}** 8C: 89%^{A}	p strat = 0.006	Whalen Island	8/18/2021	12/1/2021
Carex macrocephala	Yes	0C: 0%^{C} 2C: 0%^{C} 4C: 12%^{BC} 8C: 17%^{B} 4W4C: 0%^{C}	p scar = 0.000, p strat = 0.000, p strat*scar = 0.000	Winema Beach	10/2/2020	1/13/2021
	No	0C: 0%^{C} 2C: 0%^{C} 4C: 0%^{C} 8C: 0%^{C} 4W4C: 2%^{C}				
	Yes$^{\phi}$	0C: 0%^{C} 2C: 17%^{B} 4C: 21%^{B} **8C: 67%^{A}** 4W4C: 0%^{C}				
Gamochaeta ustulata	No	0C: 57%^{A} **4C: 61%^{A}** 8C: 57%^{A}	p strat = 0.851	Rocky Creek State Scenic Viewpoint	2021	12/1/2021
Gilia millefoliata	No	0C: 0%^{B} **3C: 66%^{A}** 4W4C: 0%^{B}	p strat = 0.000	Crissey Field, Pistol River, Storm Ranch	2023	12/1/2023
Glehnia leiocarpa***	No	0C: 0%^{C} 2C: 0%^{C} 4C: 1%^{C} 8C: 9%^{BC} 12C: 69%^{A} 4W4C: 12%^{BC} 4C4W4C: 31%^{B}	p strat = 0.000	Sand Lake Research Natural Area	10/2/2020	1/13/2021
Glehnia leiocarpa		12C: 49%^{B} 16C: 51%^{B} 4W12C: 53%^{AB} **4W16C: 71%^{A}**	p strat = 0.021		2024	10/16/2024
Grindelia stricta	No	0C: 2%^{B} 4C: 58%^{A} **8C: 64%^{A}** 4W4C: 55%^{A}	p strat = 0.006	Bob Straub State Park	10/20/2021	12/1/2021
Helenium bolanderi	No	**0C: 80%** (4C, 8C, 4W4C initiated but not completed because of rapid germination without pre-treatment)	N/A	Otter Point, Blacklock Point, Cape Blanco	2023	12/1/2023
Juncus breweri	No	0C: 83%^{A} **4C: 91%^{A}** 8C: 89%^{A}	p strat = 0.619	Driftwood Beach	8/13/2021	12/1/2021
Lathyrus japonicus	Yes	**0C: 100%^{A}** 2C: 98%^{A} **4C: 100%^{A}** 8C: 98%^{A}	p scar = 0.000, p strat = 0.358, p scar*strat = 0.194	Yaquina Bay State Park	8/28/2020	1/13/2021
	No	0C: 4%^{B} 2C: 5%^{B} 4C: 5%^{B} 8C: 4%^{B}				
Lathyrus littoralis***	Yes	0C: 71%^{A} **4C: 80%^{A}**	p strat = 0.020, p scar = 0.000, p strat*scar = 0.174	South Beach State Park	7/8/2021	12/1/2021
	No	0C: 0%^{B} 4C: 3%^{B} 4W4C: 25%^{B}			7/8/2021	12/1/2021

Species	Scarified?	Stratification Tx (weeks in warm or cold): Mean germination percentage	Statistical summary	Seed Source	Seed Collection Date	Date Trial Initiated
Leymus mollis	Yes	0C: 33%^{C} 4C: 31%^{C} 8C: 54%^{B}	p strat = 0.000, p scar = 0.000, p strat*scar = 0.000	Whalen Island	7/16/2021	12/1/2021
	No	0C: 1%^{D} 4C: 74%^{A} 8C: 78%^{A} **4W4C: 82%^{A}**				
Lupinus littoralis	Yes	0C: 89%^{A} **4C: 96%^{A}**	p strat = 0.178, p scar = 0.000, p strat*scar = 0.242	South Beach State Park	7/9/2021	12/1/2021
	No	0C: 25%^{B} 4C: 29%^{B}				
Nuttalanthus texanus	No	0C: 0%^{A} **4C: 16%^{A}** 8C: 5%^{A} 4W4C: 0%^{A}	p strat = 0.055	PMC G1 production (G0 Crissey Field)	2023	12/1/2023
Poa macrantha	Yes$^{\phi}$	**0C: 98%^{A}** 2C: 96%^{A} 4C: 97%^{A}	p strat = 0.017, p scar = 0.000, p strat*scar = 0.036	Heceta Beach	9/11/2020	1/13/2021
	No	0C: 90%^{A} 2C: 69%^{B} 4C: 72%^{B}				
Polygonum paronychia	Yes	0C: 3%^{AB} 4C: 24%^{A}	p strat = 0.004, p scar = 0.647, p strat*scar = 0.947	Horsfall	7/29/2020	1/13/2021
	No	0C: 0%^{B} 4C: 22%^{AB}				
		8C: 71%^{A} **12C: 75%^{A} 16C: 75%^{A}**	p strat = 0.500	Yaquina Bay State Park	8/13/2021	12/1/2021
Rumex crassus	No	0C: 1%^{B} 4C: 88%^{A} **8C: 91%^{A} 4W4C: 91%^{A}**	p strat = 0.000	Rock Creek	7/30/2021	12/1/2021
Rumex persicarioides	No	0C: 2%^{C} 4C: 22%^{B} 8C: 23%^{B} **4W4C: 95%^{A}**	p strat = 0.000	Driftwood Beach	9/10/2021	12/1/2021
Vicia nigricans* var. *gigantea	Yes	0C: 73%^{A} **4C: 87%^{A}**	p strat = 0.878, p scar = 0.000, p strat*scar = 0.287	Sand Lake Recreation Area	7/16/2021	12/1/2021
Vicia nigricans* var. *gigantea	No	0C: 11%^{B} 4C: 5%^{B}				

APPENDIX 2: SEED PRODUCTION PROTOCOLS

Ambrosia chamissonis
beach bur-sage

Life form: perennial forb

Pollination: Wind pollinated.

Ease of agronomic seed increase: Moderate. Plants are prostrate and require hand-harvest. Fruits are ornamented with spines. Seed requires very aggressive scarification to stimulate germination.

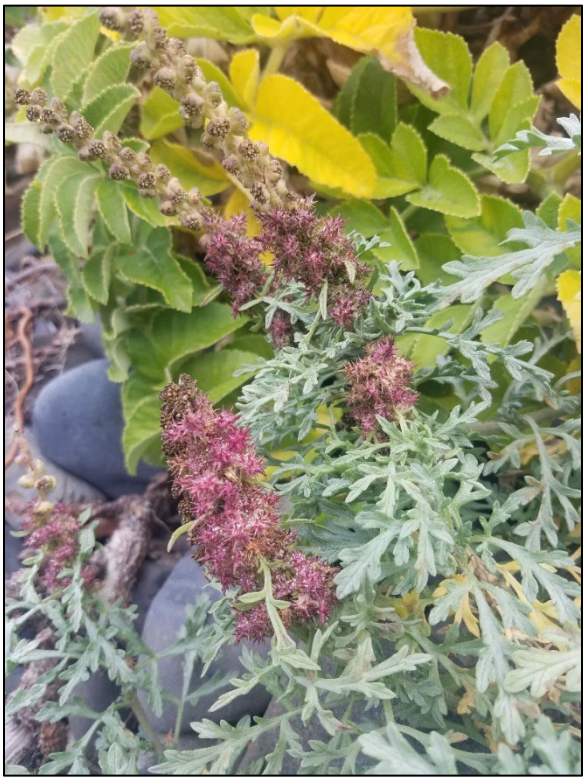
Native distribution/habitat: Coastal dunes, cobble beaches, and bluffs from the northern end of the Alaskan panhandle south to Baja California Sur in Mexico.

Ease of wild seed collection: Moderate; ripe fruits hold for a few weeks on the plant and whole inflorescences can be cut. In Oregon, populations tend to be small, and fruits contain only a single seed, limiting the potential to collect sufficient wild seed. Fruits are spiny and should be handled gently.

Seeds per pound: 87,000 fruits; seeds are difficult to remove from the bur

Establishment: Seeds exhibit two kinds of dormancy. Fruits require very aggressive mechanical scarification. After scarification, maximum germination is achieved with 8 weeks of cold-moist stratification. Seedlings grow slowly for about the first two months and then can grow rapidly after that. Production fields should be established with plugs. Plants are prostrate and grow large, covering areas over 10ft^2 per plant. Closer planting distances in the field does not appear to encourage plants to hold their inflorescences higher off the ground. We have planted on 2 ft x 2 ft spacing and plants will entirely cover the ground in their second year. Plants flower and produce seed in their first year.

Establishment rating: High from plugs. Plants do not need supplemental irrigation if fields are planted very early in the spring/late winter. We have also planted fields from 10" plugs in late fall and these plants have been very drought tolerant.



Fertilization: Plants have been fertilized with 50lbs/acre of a nitrogen-dominant granular fertilizer and have appeared healthy and productive.

Weed control: In the first year when plants are small, weeds can be controlled with spot spraying, mechanical methods, and hand

weeding. Plants go entirely dormant in the winter, allowing opportunities for dormant season control. When spaced as suggested, plants will entirely cover the ground in the second year, reducing weed management to hand weeding.

Pests: No insect pests have been observed on this species, but in our fine-textured soils in Corvallis, we have lost approximately 10% of the field annually to root/collar rot.

Harvest: Because plants are highly prostrate and the tops of inflorescences tend to be no higher than 6-8" above the ground, hand harvest has been used. Ripe fruits hold on the plant for several weeks but also ripen indeterminately. Maximum yields will be achieved with two harvests. All stems on a plant can be lifted and cut at about 6" from the collar, speeding up harvest, though this method will yield more material to thresh. Inflorescences can be cut individually, but this process significantly increases harvest time.

Post-harvest residue management: The quantity of remaining residue will be determined by harvest method. Plants go entirely dormant in the winter and remaining plant residue largely breaks down by the following spring in biologically active soils. Because plants are prostrate, very low mowing would be required to break up the remaining residue, but this risks crown damage. As such, we have not performed post-harvest mowing.

Seed cleaning: Dried plant material can be threshed in a brush machine and then cleaned in an air screen machine. Fruits are large and high rates of purity can generally be achieved.

Average yields/stand longevity: Yields vary widely based on field age and timing of harvest. First year fields may yield 200 lbs/acre, while more established fields optimally timed for harvest may yield more than 2000 lbs/acre. Our field has lived for four years, but with decline due to root/collar rot, approximately 50% of the original plants are present.

Remarks: There are two varieties of this species found in Oregon, var. *bipinnatisecta* and var. *chamissonis*. They are distinguished by leaf morphology and can be found growing together in mixed stands along with forms with intermediate leaf morphology. Plants in our production fields were of both varieties and no effort was made to separate them.

Angelica hendersonii
Henderson's angelica

Life form: long-lived perennial forb

Pollination: This plant hosts a veritable pollinator party! Small bees, bumblebees, wasps, beetles, ants, and butterflies are commonly seen visiting its pollen and nectar-rich flowers. Anise swallowtails caterpillars are frequent summer residents in its foliage and have been observed to eat as much as half the foliage on a plant when in high concentration.

Ease of agronomic seed increase: Moderate; establishment is good from plugs, but plants take three years to reach full production. Seeds hold well on the umbel to facilitate harvest.

Native distribution/habitat: Coastal dunes, bluffs, and meadows from NW Washington south to San Francisco Bay area. Generally found within a short distance of the ocean's salt spray and is not usually found more than a few hundred meters inland.

Ease of wild seed collection: Easy; a single umbel produces up to 100s of large seeds and can be harvested easily with hand-clippers. Plants are easy to relocate in the wild for harvest, though one must distinguish between this species and *Angelica lucida* when collecting. *A. lucida* ripens much earlier and has glabrous bottom leaf surfaces, whereas *A. hendersonii* ripens in the late summer/early fall and has wooly bottom leaf surfaces. For both *Angelicas*, harvests are likely to be the same on a farm as in the wild (unless fields are large), making wild harvesting from large populations a possible method to meet seed needs, depending on population size and distribution. However, due to the late ripening (September to October) of *A. hendersonii* in the wild and its proximity to ocean mist, significant mold is commonly observed on ripening seeds. When grown for seed in the Willamette Valley, mold is not observed on ripe seed, suggesting a possible advantage to seed farmed in an inland environment.

Seeds per pound: 44,000, seed is highly variable in size; *A. lucida* has 73,000 seeds per pound and is similarly variable in size

Establishment: Despite this species living very close to the ocean in the wild, it grows well in unirrigated conditions in Willamette Valley clay and silt-dominated soils. Seeds require 12 weeks of cold-moist stratification to relieve dormancy, and seedlings grow at a moderate rate thereafter. Seedlings can be grown in short plugs (2" deep) but have better root development in deeper containers. Plant plugs on 2'x2' spacing to allow adequate space as plants can get rather large when mature. Closer spacings may limit weed growth but could compromise plant performance and seed production.

Establishment rating: High from plugs. This species doesn't generally get very large in the

first year, and a subset of the plants will bloom in the second year, reaching full production in the third year. Plants seem very drought tolerant and resistant to pests.

Fertilization: Fertilization should occur in early to mid-spring when plants are in the active vegetative growth phase. Either a balanced fertilizer or a nitrogen-dominant fertilizer can be used depending on your soil tests. 50 lbs/acre of nitrogen has been effective at promoting healthy

vegetative growth.

Weed control: As with other long-lived perennials, weed control is particularly important in the first year. Wider plant spacing and small young plants means more area requiring weed management. Cultivation and spot spraying can be used between plants, and plants are entirely dormant in the winter, offering non-selective dormant season weed control opportunities that can be timed to occur just prior to *Angelica* emergence. Plants get quite large by year three and will occupy most of the space available to weeds, reducing the need for weeding.

Pests: None observed. Mold can be a concern on ripening seeds if rains and warmth coincide with harvest, but when grown for seed in the Willamette Valley, harvest generally occurs before the end of summer.

Harvest: Small to medium plots can be harvested easily by hand by cutting entire umbels. Seed ripens indeterminately but tends to hold well on the umbel. Inflorescences are held at variable heights, adding challenge to any mechanical harvest method. Direct combining or seed stripping may be options for large fields, but we have not tried this.

Post-harvest residue management: Fields can be mowed after plants are entirely dormant in the early fall. This will help recycle nutrients in plant tissues and create opportunities for dormant-season weed control.

Seed cleaning: Seed can be highly variable in size within a single harvest and even within a single umbel. As your acceptable seed size range gets wider, more inert material will be present in the final seed lot. Dried umbels can be run through a brush machine, but some seeds are large enough that no meaningful separation will usually occur during the brushing process. An air screen machine can then be used to remove inert material. If excessive inert material exists in the seed lot, it can be broken into a few smaller fractions by screening, the fractions cleaned of inert material separately, and then the cleaner seed recombined. Some seeds will be removed from the pericarp in the brushing process, and aggressive brushing can remove a significant percentage of it if the seed lot is very dry. It is not necessary to remove the pericarp for effective germination to occur.

Average yields/stand longevity: Our small field yielded approximately 170 lbs/acre in the third year; this could yield more as plants continue to mature. As a long-lived perennial, we have not seen the decline of plants in production yet.

Remarks: Seed production of *Angelica lucida,* seawatch, is very similar in many respects. One primary difference is that this species requires four weeks of warm stratification prior to a 12-week cold-stratification period to stimulate germination, whereas *A. hendersonii* does not

require the initial warm period. Seed ripening is earlier in the season with *A. lucida*, but it has not performed as well in the Willamette Valley for seed production as has *A. hendersonii*, yielding 65 lbs/acre. *A. lucida* appears less drought tolerant than *A. hendersonii* when in seed production in the Willamette Valley, requiring supplemental water to thrive. We have seen a 50% establishment rate from small plugs for *A. lucida*.

Armeria maritima
sea thrift

Life form: perennial forb

Pollination: Solitary bees, honeybees, bumblebees, and several species of flies all visit this species. Sea thrift is generally considered to be self-incompatible, though some level of self-compatibility may exist under some circumstances.

Ease of agronomic seed increase: Moderate to difficult; fields establish well from plugs and plants flower in the first year, but we have observed low levels of seed fill in both wild populations and seed production fields. Seeds can be difficult to remove from the dried flower, leading to two different viable separations when cleaning.

Native distribution/habitat: Native distribution is confounded by taxonomic issues, as there appears to be some disagreement among authorities about subspecies classification. *Armeria maritima* has subspecies that occur in Alaska and through much of Canada east to Ontario. The species also occurs along the Pacific Coast as far south as California's Channel Islands. It is often found along bluffs and dunes on the Pacific Coast and can be found in inland prairies and dunes elsewhere in its range.

Ease of wild seed collection: Moderate; seeds are well retained on the plant, often for several months and late into the fall, giving a wide window for seed collection. It can be difficult to assess how much filled seed is on an inflorescence. As such, wild collection generally requires collecting and hoping there's seed in there, as it can also be difficult to extract seeds from the papery floral bracts by hand in the field.

Seeds per pound: 899,000 (seed only, wild-collected); 591,000 (seed only, irrigated production field); 260,000 (seed within floral bract, irrigated production field)

Establishment: This species requires 4-6 weeks of cold-moist stratification to overcome dormancy. Seedlings grow slowly at first. Production fields should be established with plugs. Plants grow in a pincushion shape and do not spread laterally. 1ft x 1ft space gives adequate room. This species can be grown for seed successfully in inland valleys (i.e. Willamette Valley in Oregon) on silt and clay loam soils.

Establishment rating: High from plugs. Plants have shown greater soggy winter soil resilience than expected.

Fertilization: Plants are responsive to fertilization. 50lbs/acre of nitrogen, either as a

nitrogen-specific or a balanced fertilizer, can support healthy growth.

Weed control: Plants when mature stay tightly bunched and do not spread, providing ample opportunity for mechanical and hand weeding or spot spraying between plants. It is common for weeds to establish within *Armeria* mounds, and tap rooted weeds can be difficult to manage in this scenario.

Pests: None have been observed.

Harvest: Plants mature over a long period of time, but ripe seeds tend to hold well on the plant. Hand harvest works on small plots, and a seed stripper can be used on larger fields. It is common for a seed stripper to remove seed on one side of the inflorescence, but not on the other, requiring fields to be harvested in both directions to maximize harvest. In most cases, immature flowers are not damaged with the seed stripper. Inflorescences may also be variable in height, leading to some harvest being missed above or below the seed stripper head.

Post-harvest residue management: There is little requirement for any post-harvest residue management. All leaves of this species stay tightly bunched in the pincushion shape at the base. Fields can be mowed after the final harvest of the season to reduce the presence of dead peduncles, but care should be taken not to mow too low, as mature plants can be damaged.

Seed cleaning: Removal of mature seeds from the papery floral bracts that surround a single seed can be challenging. Plant material must be very dry. An aggressive brush machine will remove many but not most of these seeds, and an air screen machine can be used to clean the seed to acceptable purity. However, to maximize seed retention, there may be two seed lots once cleaned. One will contain clean seeds, and the other will contain seeds that are still stuck within the floral bracts. We have not been successful at removing these seeds from the floral bracts without damaging a significant percentage of the remaining seeds.

Average yields/stand longevity: Up to 100 lbs/acre, though seed cleaning can be challenging and therefore some of this quantity will likely contain more inert matter than is generally preferred, including seed that may not be able to be extracted from the floral bracts. Plants can be short-lived if grown in poor conditions but are long-lived perennials if grown under optimal conditions.

Remarks: According to Oregon Flora Project, there are two subspecies known in Oregon. Ssp. californica is native and ssp. maritima is exotic and naturalized. The native subspecies has stigmas with small bumps on it. The exotic subspecies has stigmas of two forms, either with bumps or smooth.

Cardionema ramosissimum
sandcarpet, sandmat

Life form: low-growing perennial forb

Pollination: Flowers are small and not showy, suggesting pollination is likely performed by small insects. We observed some small bees visiting the flowers.

Ease of agronomic seed increase: Difficult; this species is only a few inches tall and grows below the cut height for all mechanical harvesting tools. Sepals and fruits are spiny and will draw blood; good gloves are required. Seed matures indeterminately along the stem, but fruits with ripe seed tend to hold onto the plant until most seed is ripe. Harvest must be done by hand by cutting nearly entire plants, leading to a large volume of spiny material to manage that often has significant amounts of dirt adhering to it. There is only one seed per fruit.

Native distribution/habitat: This species has a long range, inhabiting coastal sands on beaches, dunes, and bluffs from Washington south to Chile. It is also found in the Andes Mountains. Found commonly in disturbed areas.

Ease of wild seed collection: Moderate and potentially painful; plants are well-armored, and gloves are necessary. Areas between plants in wild populations often contain dispersed fruits that stick to your knees when you get on the ground to collect seed. Seed can be collected by cutting branches, or by cutting nearly whole plants.

Seeds per pound: 805,000

Establishment: Seeds are dormant and require four weeks of cold-moist stratification to stimulate germination. Seed fields can be established from plugs one foot between plants in row and 2 feet between rows. Plants grow quickly and expand to cover up to about a square foot per plant.

Establishment rating: Easy from plugs. Plants grow readily in our Willamette Valley clay and silt dominated soils and appear very tolerant to drought. No supplemental irrigation is necessary.

Fertilization: Responsive to light fertilization, but because plants are low-growing, it is particularly important to control weeds adequately prior to fertilization.

Weed control: Mechanical weeding and spot spraying can be used between plants, especially between rows. Depending on spacing, plants may grow together in row, requiring hand weeding. It can be difficult to remove perennial weeds that are established within the mounds of sandcarpet plants.

Pests: None observed.

Harvest: Because plants are prostrate and seed ripens indeterminately, seed can be hand harvested by cutting near entire plants. Do not cut lower than the point at which side branches initiate, as this can hamper regrowth the next year. To harvest, gather the branches of an entire plant and use clippers or a rice knife to cut

through the base of all the side branches, leaving approximately 1-2" at the base of the side branches for regrowth. Only one harvest per year is required as early ripening fruits tend to remain on the plant long enough for the later maturing fruits to be ready. Some seeds may be lost in the process. Plants may not yield sufficient seed in their first year to merit harvest.

Post-harvest residue management: Because nearly whole plants are harvested, there is no residue management requirement after harvest.

Seed cleaning: After drying, nearly entire plants can be run through a brush machine. Choose a mantle that will allow seed to pass through. With this approach, many of the spines will not pass through the mantle, reducing volume and handling risk for subsequent steps. Seeds can be easily separated from the remaining material with an air screen machine that has good air control. Depending on your soil type and harvest cut height, there may be significant dirt mixed with the seed after screening and air treatment. As necessary, the remaining material can be run through a brush machine again on a less aggressive setting (to minimize the risk of destroying the seed) to pulverize remaining dirt particles and then passed through an air screen machine again to remove the pulverized dirt. Some soil types can also be removed with a magnet.

Average yields/stand longevity: 80-140 lbs/acre. Plants are perennial and will continue to produce for several years, even when cut back close to the primary stem for harvest.

Remarks: Did we say spiny? This plant is also aptly called "tread lightly" in some places.

Erigeron glaucus
seaside fleabane, seaside daisy

Life form: perennial forb

Pollination: This self-compatible species provides both nectar and pollen and is attractive to many insects including butterflies and bees.

Ease of agronomic seed increase: Moderate; plants are vigorous and establish well under dryland or irrigated conditions, but seed is attached to a pappus that dehisces readily from the flower head once mature.

Native distribution/habitat: Coastal dunes, bluffs, and grasslands from the Columbia River in Oregon south to Los Angeles County, California. Rarely found above 500m elevation.

Ease of wild seed collection: Moderate; seeds mature over the course of several weeks and dehisce from the flower heads in the wind.

Seeds per pound: 2,500,000

Establishment: Seeds are not dormant and germinate readily in the warmth of a greenhouse or outside in the fall or spring. Seedlings grow slowly initially, making establishment of seed production fields from direct seeding challenging. Fields should be established from plugs. Plants can become large if given adequate space but spacing to facilitate mechanical harvest on larger fields is important. 1 ft x 1 ft spacing will create a dense patch where plant

canopies grow together, causing the flower heads on the edges of each row to be held higher off the ground. Some plants will flower in their first year, and the first significant harvest will occur in year 2. This species can be grown for seed successfully in inland valleys (i.e. Willamette Valley in Oregon) on silt and clay loam soils.

Establishment rating: High from plugs. Plants grow rapidly if irrigated in the first summer, but establishment under dryland conditions from late-March to early-April planted greenhouse grown plugs is also successful.

Fertilization: Plants are responsive to fertilization, but so are weeds. Do not fertilize small plants unless weeds are well controlled.

Weed control: Mechanical and hand weeding can be performed on this species, and spot spraying can be used when fields are young and there is adequate space between plants. Once the plants create a dense continuous canopy, hand weeding will be required. There are no herbicides labeled for use on this species being grown for seed production.

Pests: No pests have been observed on this species in seed production fields.

Harvest: Seeds are attached to a pappus that disperses on the wind shortly after ripening. Mature seeds will remain on the flower head for several days or even weeks if there is little wind

but will soon dehisce from the flower head and fall onto the ground or vegetation. Small fields can be harvested with a shop-vac. Seeds will not be sucked from the flower heads unless they are mature. Large fields can be harvested with a seed stripper with minimal damage to immature seeds and flowers. With either harvest method, several harvests will be required to maximize yield. If growing a larger field and using a seed stripper, it is important to modify plant spacing to allow for repeated harvest equipment access without requiring driving over a significant percentage of plants during each harvest.

Post-harvest residue management: It can be helpful to mow seed production fields in the fall to eliminate old flowering stalks so that less inert material is harvested in the following year.

Seed cleaning: With either harvest method described above, harvested material will be largely composed of seeds and pappus, with a smaller quantity of flower receptacles, stems, and petals. Seeds must be threshed to remove the pappus; a brush machine can be used for this process. Threshing may grind the pappus into fluff, and seed lots must then be cleaned of large amounts of light fluff. An air screen machine without a top screen and a blank bottom screen can be used to remove the majority of the light pappus material, though the material may need to be run through the machine several times to do so adequately. After air treatment, the remaining material can be run through a screen to remove small and large inert material. Seed lots can be cleaned to high purity with this method.

Average yields/stand longevity: Up to 300 lbs/acre for large fields harvested with a brush machine; up to 600 lbs/acre for smaller plots regularly harvested with a shop vac with very minimal seed loss. Some plants will flower in the first year and harvest will likely not be merited unless fields are small or seed is highly desired. The first significant harvest will occur in the second year. Plants are long-lived, though we don't know how long they will remain adequately productive for seed.

Remarks: Plants are very drought tolerant. When grown in the Willamette Valley where freezing winter temperatures are common, leaves will freeze, and plants may be reduced to thickened stems. Plants will resprout from nodes on these stems in the spring. When grown in areas without regular freezing temperatures, this plant may remain evergreen through the winter.

Gamochaeta ustulata
purple cudweed

Life form: annual, biennial, or perennial forb

Pollination: Likely pollinated by small insects, though no information specific to this species could be found.

Ease of agronomic seed increase: Difficult; seed is easy to germinate, and seedlings grow readily but plants are small, low to the ground, and seed ripens indeterminately over a long period and flies away in the wind virtually as soon as it is ripe.

Native distribution/habitat: Mostly on the west side of the Cascades from Vancouver Island, British Columbia south to Southern California. Found in dry disturbed areas, grasslands, bluffs, dunes, riverbanks, and some forests.

Ease of wild seed collection: Difficult; seeds are attached to a pappus and take flight quickly upon maturation. Seed should be collected when the tips of the pappus turn brown and before the flower opens for dispersal.

Seeds per pound: 1,490,000

Establishment: Seeds are non-dormant and germinate readily in warmth (70F). Seeds are small and as such it is difficult to seed an appropriate number of seeds per cell in a plug tray; thinning will be necessary. Plugs can be planted out in late March/early April once temperatures have begun to warm. Plants will grow rapidly after this but generally will remain small. One foot by one foot spacing is sufficient, and it may be acceptable to plant even closer in row. It may be possible to establish a field from direct seeding in the fall, but seeds should be sown early when soil temperatures are still warm to give an adequate opportunity to germinate. When direct sown, seedlings will grow slowly through the winter.

Establishment rating: High from plugs. Because of the annual, biennial, or perennial nature of this species, fields may need annual augmentation to remain full. Seedlings will self-recruit in the field.

Fertilization: Does not appear necessary, as this plant often grows in disturbed, low-nutrient environments. However, plants will become larger if fertilized.

Weed control: Because plants grow slowly in cold weather and remain small when mature, successful weed control is of increased importance. Mechanical methods and spot spraying can be used between rows.

Pests: None observed.

Harvest: Small fields can be hand harvested at the timing suggested for wild seed collection. If you wait for the flowers to open and the dry pappus to be exposed, in most cases it will be too late because the seeds disperse quickly. Hand harvest can be targeted on a per inflorescence basis. It is possible that a seed stripper could be used on a larger field, but this has not been attempted. Low plant height may limit success with mechanical harvest.

Post-harvest residue management: If grown as an annual, residue can be mowed and incorporated after harvest. If managed for more than a year, fields can be mowed or left as is after harvest; plants are small and do not produce significant residue.

Seed cleaning: Seeds are light and when dry and still attached to the pappus can fly away with any wind disturbance. Be sure to dry seeds in a low to no wind environment, as any disturbance will cause a mass of pappus to fly into your face. The pappus can be removed from the seed with a brush machine, and this will result in a mass of fluff with small seeds mixed throughout. A mantle with small holes should be used to allow the stems and larger pieces to be removed. An air screen machine with good air control (such as a Clipper Office Tester) can then be used without a top screen and with a blank bottom screen to remove the fluff. Multiple passes may be required. After this, a screen can be used to remove material larger than the seed.

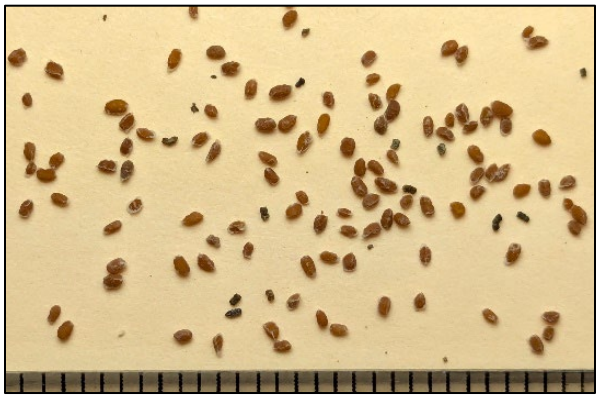
Average yields/stand longevity: 8-40 lbs/acre. Plants vary in longevity, so a full stand will only last one year. Self-recruitment from seed may be adequate to maintain a dense stand in subsequent years. Otherwise, fields will need to be augmented either by direct seeding or with plugs.

Gilia millefoliata
dark-eyed gilia, many-leaf gilia

Life form: winter annual forb

Pollination: Little is known about the pollination requirements of this species. Many small solitary bees have been observed visiting plants in seed production fields. A related species, *Gilia capitata*, is known to have self-incompatible as well as partially self-compatible ecotypes.[1]

Ease of agronomic seed increase: Moderate; seeds mature over a period of several weeks and shatter from the capsules as they mature, falling to the ground. Planting in holes on weed cloth can significantly increase yields. In cultivation, plants can be significantly larger than in the wild.



Native distribution/habitat: This species is restricted to coastal sands from Lincoln County (historic) south to the San Francisco Bay area. In Oregon, existing populations occur south of Bandon. It is considered rare throughout its range; listed as Endangered in Oregon, Imperiled in California, and is a Federal Species of Concern.

Ease of wild seed collection: Moderate to difficult; wild plants tend to be small to diminutive, often having only a single flowering stem and few flowers. Ripe seed may be retained in the capsule briefly but will shatter with agitation. The seed collection window may last several weeks because seeds ripen indeterminately. Seed should be collected shortly after ripening. Small plants or plants on hotter or drier sites will produce seed earlier.

Seeds per pound: 1,162,000 (wild seed); 958,000 (production seed)

Establishment: When growing in non-coastal seed production sites, establish from plugs and outplant in late March/early April on 1 ft x 1 ft spacing. To do so, sow seeds in flats on approximately January 1 and place outside or in a cooler for stratification for 2-3 weeks to relieve seed dormancy. Seeds will not germinate without this brief cold treatment. After stratification, place flats in a warm greenhouse (70F days/60F nights); germination is rapid and even with fresh seeds. Seedling thinning may be necessary. Small plugs (2.5 in^3) can be ready for transplanting in 8-10 weeks if grown at the listed temperatures, longer if grown in cooler conditions. Field grown plants that are established at the timing listed here will likely not need supplemental irrigation. Caution is recommended with supplemental irrigation as plants can be susceptible to powdery mildew. This species can be grown for seed successfully in inland valleys (i.e. Willamette Valley in Oregon) on silt and clay loam soils.

Establishment rating: Easy from greenhouse-grown plugs in the Willamette Valley. Seed production fields may be able to be established from direct seeding on coastal sites. Seedling vigor is high, and development is rapid once spring temperatures warm. Leaves present at transplant may die but new leaves will likely form in a few weeks after transplanting.

Fertilization: Plants are highly responsive to nitrogen fertilization and will become leggy and floppy if fertilized excessively. Plants will grow in low-fertility conditions but will not produce as much seed.

Weed control: Plants should be grown in fields with minimal weed pressure. If grown in holes on weed cloth, weeding should be done by hand. It is particularly important to remove weed species with similarly-sized seeds. If grown without weed cloth, cultivation can be done between rows of plants when young. There are no herbicides labeled for use on this species.

Pests: Second year self-seeded plants in containers and sand boxes appear highly susceptible to powdery mildew, which can be significant enough to kill the plants and severely limit seed production.

Harvest: When grown on weed cloth, plants should be harvested when all or nearly all plant material is brown. Herbage is sticky-glandular, and early harvest can leave a gooey residue on tools/machinery. Depending on field size, plants can be direct-combined or hand cut. Seeds remaining on weed cloth can be vacuumed or swept. In a trial at the Corvallis Plant Materials Center, 46% of seed was harvested by direct combining, and 54% of seed was vacuumed off the weed cloth. The trial highlighted how much seed will be lost if plants are not grown on weed cloth.

Post-harvest residue management: As an annual species that appears susceptible to powdery mildew in the second year of seed production, field locations will likely need to be rotated from year to year. As a result, residue can be mowed and/or tilled in after harvest.

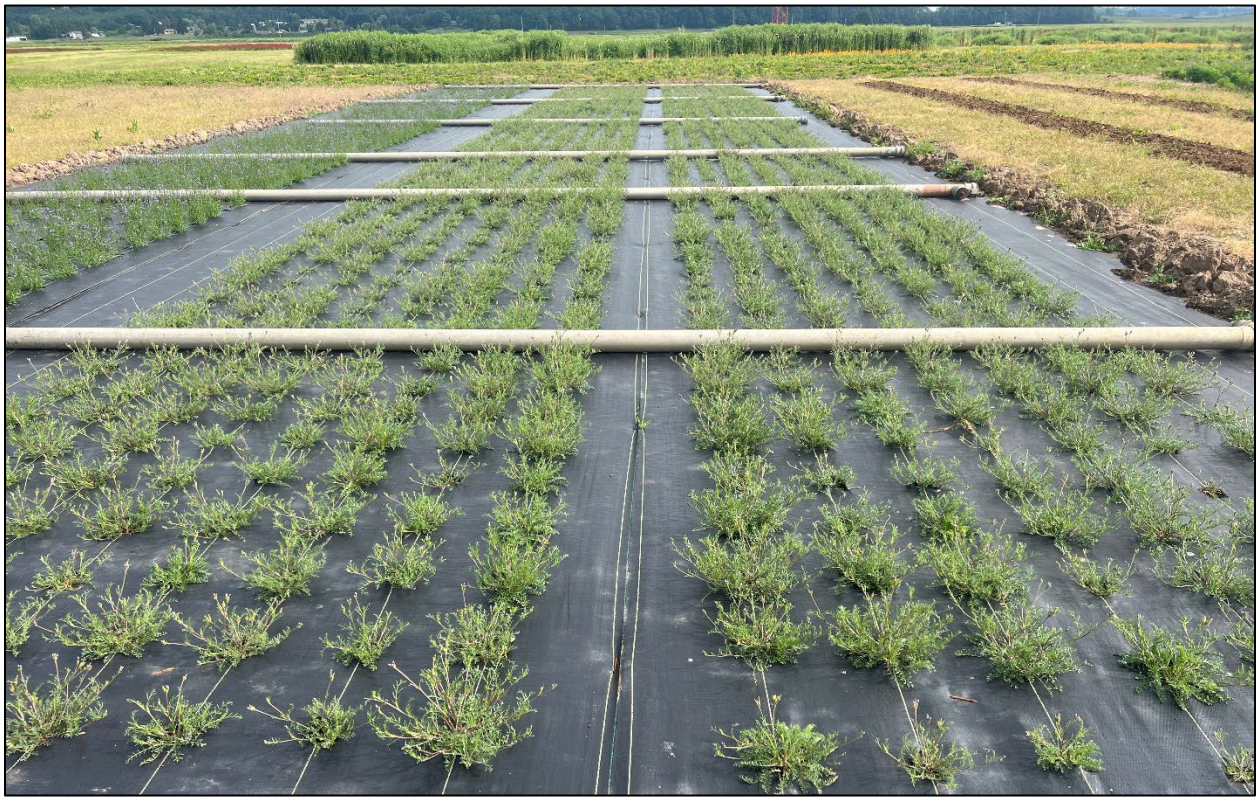
Seed cleaning: If direct-combined, seed can be cleaned with an air-screen machine to remove capsules and small inert matter. Seed collected from weed cloth may contain some dirt. A brush machine can be used to grind the dirt to powder, and then an air separator or air screen machine used to remove the dirt. Small pieces of leaves that remain, if concerning, can mostly be removed with an indent cylinder, though it may not be necessary to do so.

Average yields/stand longevity: Up to 800 pounds per acre when grown on weed cloth and fertilized. Production will be significantly reduced if grown without weed cloth or grown without fertilizer on low-fertility soils. Production is higher in containers when plants are well fertilized (yields up to 1400 lbs/acre), but labor requirements will be higher, and plants are more susceptible to powdery mildew development because of the increased irrigation requirement.

Remarks: Seeds exude a mucilage when wet that can glue seeds to whatever surface they are on. If rain is expected when significant seeds are sitting on weed cloth, but plants are not ready to harvest, it may be valuable to do an early vacuum or sweep of the shattered seed.

References:

[1] Grant, Verne (1954) "Genetic and Taxonomic Studies in Gilia: VI. Interspecific Relationships in the Leafy stemmed Gilias," Aliso: A Journal of Systematic and Floristic Botany: Vol. 3: Iss. 1, Article 4. Available at: https://scholarship.claremont.edu/aliso/vol3/iss1/4



Grindelia stricta
coastal gumweed, Oregon gumweed

Life form: perennial forb

Pollination: Pollinated by bumblebees, bees, butterflies, and beetles. A high diversity of solitary bees visits this species in our production fields. Like some other *Grindelia* species, this species may be self-incompatible and therefore requires these pollinators to set seed.

Ease of agronomic seed increase: Easy; plants grow rapidly and flower after their first winter. Seed is well retained on the flower heads.

Native distribution/habitat: Salt marshes, tidal mudflats, bluffs, meadows, and sand dunes from Southern California north to coastal British Columbia. Taxonomic treatments vary as to how they handle species in this genus across different habitats. As such, this range and habitat list may contain inaccuracies.

Ease of wild seed collection: Easy; seeds within a flowering head generally ripen evenly and are retained for a period of several weeks.

Seeds per pound: 171,000

Establishment: Seeds are dormant and require four weeks cold-moist stratification to relieve dormancy and stimulate germination. Seedlings grow rapidly. It is recommended to start fields from plugs. One foot in row spacing and two feet between rows will allow plants sufficient room to grow while minimizing space for weed

establishment. Direct sowing could be accomplished with fall sowing but weed management will need to be fastidious to support seedling establishment. Plants require one year of vernalization to flower. Fields from fall-planted plugs will flower and produce seeds the next year, while spring planted plugs will not flower until the next year after that (see last picture). Seedlings will readily establish in the field from seed that shatters on the ground. This species can be grown for seed successfully in inland valleys (i.e. Willamette Valley in Oregon) on silt and clay loam soils.

Establishment rating: Easy from plugs. Seedling vigor is high and healthy greenhouse-grown plugs will grow rapidly if outplanted when moisture is adequate and soil temperatures are beginning to warm in the late-winter/early spring.

Fertilization: Plants are very responsive to fertilizer and benefit from a nitrogen-based application, or from a balanced fertilizer, depending on your soil.

Weed control: Plants are vigorous and grow large in the first year, especially when planted in fall. This will reduce weed establishment through competition. Before plants grow laterally in the spring and fill all in-row space, weeds can be managed through cultivation, spot-spraying, or hand methods. Once the plants grow into the in-row spaces, hand weeding or spot spraying can be used. In years following harvest, this species may establish from shattered seed at a very high

rate, necessitating control to reduce self-competition.

Pests: We have found tortricid caterpillars (potentially genus *Eucosma*) feeding on the developing seeds and causing significant seed loss. Fruit flies, likely genus *Goedenia*, feed in mature flower heads of gumweed plants and have been observed to damage flowers. Weevils, likely family Curculionidae, have also been found in the seed heads.

Harvest: Seeds are retained for a few weeks on the dry flower heads after they reach maturity. Maturation occurs over the course of a few weeks, but only one harvest pass is necessary to collect most of the ripe seed. Leaves are fleshy and moist when seed is ripe and remaining unripe seed heads will exude latex, so direct combining is not recommended. Harvest can be achieved using a modified swather to harvest and collect seed and some vegetative material. This mass can be dried on tarps and then run through a stationary combine to thresh. Depending on in-row spacing and the value of remaining seed in the field, seed heads on low lateral branches below swather cut height can be hand harvested afterwards. In-field swathing and combining with a pick-up header could be achieved in large fields but with a greater amount of seed loss as compared to direct collection with a modified swather.

Post-harvest residue management: Fields can be flail mowed at two inches to eliminate standing residue and hasten the recycling of plant nutrients.

Seed cleaning: After threshing, seed can be cleaned to adequate on an air screen machine. Depending on purity requirements, air will need to be adjusted to remove unfilled and damaged seed. Plants are susceptible to larval damage and damage rates can sometimes be high.

Average yields/stand longevity: 150-470 lbs/acre. Stand longevity is unknown but this species is suspected to be a short-lived perennial.

Remarks: Plants bloom late in the summer and are visited by a high diversity of solitary bees and other pollinators. Growth in seedling stage is very rapid compared to most other forbs found in dune ecosystems.

Helenium bolanderi
coast sneezeweed

Life form: perennial forb

Pollination: This species appears to be very attractive to many species of bees and butterflies. *Helenium* species produce both nectar and pollen. This species is likely self-incompatible, as are most other Aster family species and other members of the genus *Helenium*.

Ease of agronomic seed increase: Moderate; plants are not very drought tolerant when young and benefit from supplemental irrigation. Plants flower and produce seed in the first year but can be susceptible to significant leafhopper damage. Seed ripens indeterminately and shatters shortly after ripening, requiring several harvests to maximize seed production.

Native distribution/habitat: Coastal bluffs, meadows, thickets, bogs, and seeps from Coos County Oregon south to Sonoma County California. Not exclusively coastal.

Ease of wild seed collection: Moderate; seeds ripen indeterminately, extending the wild seed collection season across several weeks. Heads with mature seeds can be cut or seeds can be stripped from the head in the field. Seeds may shatter in heat and wind shortly after ripening.

Seeds per pound: 599,000

Establishment: Seeds are non-dormant and germinate readily with warmth. We have only established a field with plugs, but direct seeding could be successful if weeds are well controlled, ample foundation seed is available, and seeding is performed in early fall or in spring when temperatures are warm. When growing plugs, seeds germinate readily, and seedlings grow rapidly. Plugs can be planted in early spring once temperatures have started to warm. One foot in-row spacing and two feet between rows allows room for plants to grow large. Plugs may not perform well in the first year without supplemental irrigation. This species can be grown for seed successfully in inland valleys (i.e. Willamette Valley in Oregon) on silt and clay loam soils.

Establishment rating: High if adequate moisture is provided to young plants.

Fertilization: Plants are responsive to fertilizer and benefit from a nitrogen-based application or, depending on your soil, a balanced fertilizer.

Weed control: Fields can be cultivated or spot-sprayed when plants are small. As plants grow, when planted one foot apart, they are likely to grow together in row, and areas between rows

may continue to require cultivation, hand hoeing, or spot spraying for weed management.

Pests: Leaf hoppers have been present in large numbers in our production field and appear to be the primary cause of the significant yellow leaf stippling and some small necroses observed throughout the field. This damage has been present in all production years, but yields have remained adequate. It appears that the leaf hoppers cause some minimal damage to the disc flowers as well.

Harvest: Because of the long seed ripening period and short seed retention period in the summer heat of inland valleys, mature seed must be harvested several times in one summer to maximize seed production. Small fields may require up to a weekly hand harvest for more than a one-month period. Larger fields can be harvested with seed strippers though some ray flower petals may be damaged in the process.

Post-harvest residue management: Fields can be flail-mowed at two inches or higher after harvest to reduce standing material and recycle plant nutrients.

Seed cleaning: Most harvested seeds will still have dried flower parts attached to them. A brush machine can be used to separate the remaining petals from the achenes. An air screen machine can be used to remove inert material and unfilled seed. As necessary, an air column separator or other winnowing tool can be used to remove remaining inert material not removed by the air screen machine.

Average yields/stand longevity: 20 lbs/acre in the first year after plug planting and 465 lbs/acre in the second year. Yields may be reduced if mechanically harvested. Plants can remain productive for several years.

Remarks: Contrary to what is suggested by the common name, the pollen of this species is not known to cause sneezing or other hay fever symptoms. The common name instead refers to one of the plant's known uses as a snuff to purposefully induce sneezing when crushed.

Lupinus littoralis
seashore lupine

Life form: perennial forb

Pollination: Perennial lupines are generally outcrossing and require pollination for successful seed set. Bumblebees are common visitors of many lupine species, including seashore lupine.

Ease of agronomic seed increase: Difficult; seashore lupine plugs can be finicky and can stall in their growth. When successfully grown as plugs, plants can grow rapidly upon transplanting. Their form is highly prostrate, inflorescences ripen indeterminately, and pods explosively shatter when mature. It can be difficult to find a large percentage of the maturing pods to hand harvest among the low-growing vegetation. Plants can be grown on weed cloth to collect shattered seed, but voles consume the seed and find more than ample cover under the plants' dense, overlapping canopy. We have not found this species to regrow adequately in year two in the Willamette Valley, as it appears susceptible to disease in moist winters and our fine textured soils, though it flowers well and produces seed in year one.

Native distribution/habitat: Coastal sands from Haida Gwaii, British Columbia south to Monterey Bay, California.

Ease of wild seed collection: Moderate; pollination bags can be placed over

inflorescences after pods begin to grow to maximize seed collection and broaden the harvest window. These bags can be collected once pods have shattered. Alternatively, seed collection can occur by clipping an entire inflorescence once the bottom pod(s) have ripened. Some of the upper pods on the inflorescence will after-ripen and explode when ripe, so hand harvested material should be dried with a cover over it that allows for air flow but restricts the seeds from leaping away. Some natural sites host large populations.

Seeds per pound: 62,000

Establishment: Seeds require scarification but no stratification to stimulate germination. Seeds germinate readily, but seedlings sometimes appear challenged by an interruption in nutrient availability; be certain to provide regular light fertigation so they don't stall in their growth. Small plug cells ($1.5cm^3$) can sometimes grow healthy plugs but are more prone to slow growth than larger plugs. Transplant in early spring on 1-2 foot in row spacing with 2 feet between rows. Closer in row spacing may better support plants to hold their inflorescences high, facilitating easier harvest.

Establishment rating: Medium, plugs appear prone to nutrient deficiencies and can stall in growth when transplanted. Transplanting actively growing plugs and fertilizing shortly thereafter can improve establishment. When

grown on weed cloth, transplants appear to be more susceptible to disease and slug damage.

Fertilization: See Establishment and Establishment Rating sections about the importance of fertilization. We have inoculated seeds with a lupine-specific bacterial symbiont prior to sowing and have not observed any benefit.

Weed control: Weeds can best be managed with mechanical and hand methods, and with spot spraying, especially when young as the field is establishing. Plants will grow together and cover the entire field, reducing weed control efforts to hand methods and possibly spot herbicide applications. Most plants mostly go dormant in the winter, though we have observed a few plants with some green leaves that time of year.

Pests: We observed many plants dying from a root/collar rot disease in the first year when grown on weed cloth. In Corvallis, fields without weed cloth have died in the spring of the second year, also from a root/collar disease. This plant does not seem well adapted to seed production on fine-textured or poorly drained soils. Plants grown near Olympia, WA on coarse-textured glacial till soils have in general also succumbed to root/collar rot diseases in the winter at two years of age.

Harvest: Fruits shatter when ripe and shoot their seed away from the mother plant. For small plots, inflorescences can be hand harvested when the bottom pod on a single inflorescence turns brown. Lay harvested material on a tarp and cover with a breathable material (screen, shadecloth, etc.). Seed in some of the pods higher on the inflorescence will after-ripen. Plants can also be grown on weed cloth, allowed to shatter entirely, and the seed removed by sweeping or with shop vacs.

Post-harvest residue management: Plants should be mowed once dormant to reduce dead material and recycle plant nutrients.

Seed cleaning: If hand harvested, once material is dry, most seeds should have been removed from the pods, and no threshing process should be needed. Most seed lots, including those that are harvested of weed cloth, can be cleaned to high purity with the use of an air screen machine.

Average yields/stand longevity: Approximately 100 lbs/acre in the second year. First year harvests may be up to 50 lbs/acre. Plants have not persisted in inland valleys and should not be relied upon for more than one or two harvest years under these circumstances.

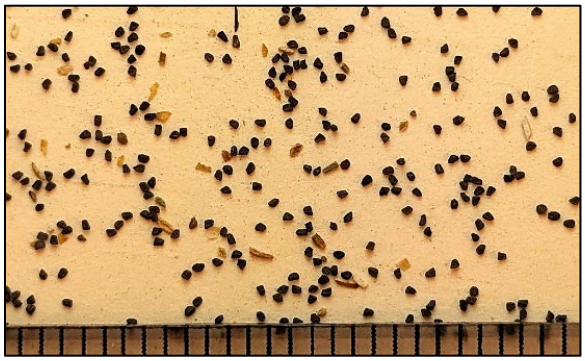
Remarks: Lupines may hybridize if they are grown near other lupine species that flower at the same time. *Lupinus littoralis* is known to hybridize with *L. rivularis* and *L. arboreus* in the wild. Wild seed collection sites should be chosen carefully.

Nuttallanthus texanus
large-flowered blue toadflax

Life form: annual or biennial forb

Pollination: Produces both closed and open flowers, suggesting that both self-pollinating and pollinator-mediated outcrossing occur.

Ease of agronomic seed increase: Moderate. Our controlled trials have not clarified exact germination requirements, but we have achieved sufficient germination through natural stratification outdoors. Plants are small and initially grow slowly. Seeds shatter when ripe and fall to the ground, requiring ground cloth to collect shattered seed. Seeds are extremely small.



Native distribution/habitat: The northern extent of the range includes parts of British Columbia east to Saskatchewan. This species is found south to California and east through most of the continental US (excluding the Upper Midwest and Northeast US). Considered rare in several parts of its range, including British Columbia, Alberta, Washington, Montana, Wyoming, and Nebraska. Found in dunes and meadows along the Oregon Coast.

Ease of wild seed collection: Moderate; plants are often diminutive in their natural habitats along the Oregon Coast and may have only a few flowers per plant. Dry capsules are held upright when they split so it is possible for seeds to be retained for several weeks, but any agitation to the plant can cause the seed to fall to the ground, narrowing the seed collection window.

Seeds per pound: 19,739,000. So tiny!

Establishment: Because of the miniscule seed, cold-stratification requirement, and slow initial growth rate, seed production fields should initially be started with plugs. Controlled trials have produced very low germination rates, but seeds have successfully germinated in adequate quantities with 8 weeks of natural cold-stratification outdoors in Corvallis between November and January. After this amount of stratification, plants can be brought into a heated greenhouse to produce a well-rooted 2" plug in 8-12 weeks. Trays that stayed outside all winter did not result in successful establishment, indicating that young seedlings are sensitive to temperatures in the mid-20s. Plants branch from the base early in their development, making thinning challenging if delayed. As such, seedlings should be thinned at the cotyledon or first true leaf stage prior to the initiation of basal branching. Plants can self-recruit from seed well, making subsequent years of field establishment easier.

Establishment rating: High from plugs. Seedling vigor is initially low, but transplants survive well,

and plants can continue to grow vegetatively after flower initiation.

Fertilization: Plants are responsive to balanced fertilizer and can become much larger in cultivation than in their natural habitat if fertilizer is applied.

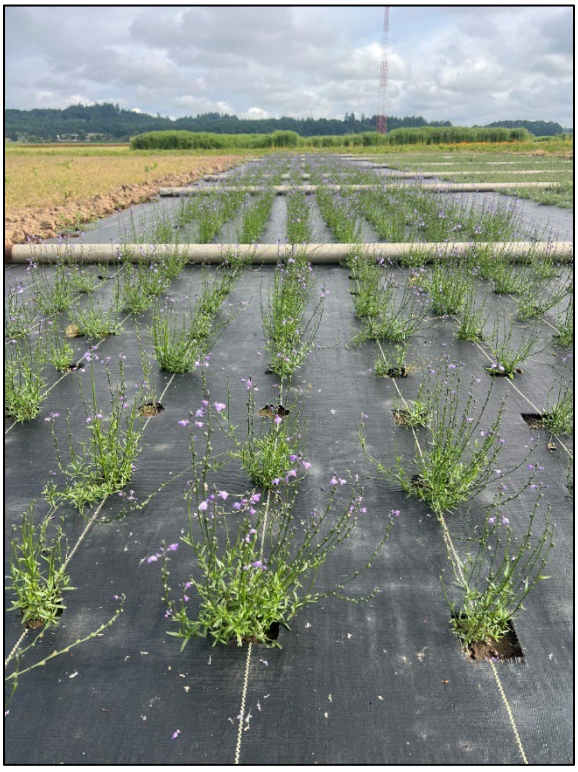
Weed control: Because of low initial seedling vigor, it is especially important to put transplants into a clean field space with low weed pressure. If weed fabric is used as a passive seed collector, weed management will be simplified and reduced to hand weeding around the plants in the holes in the weed fabric. If fields are allowed to self-sow for subsequent years of production, fall weeds should be managed prior to *Nuttallanthus* seed germination and toward the end of the cold-stratification period. A common field weed in Corvallis, *Spergularia rubra*, has similarly colored and sized seeds that can be challenging to clean out, making it particularly important to remove in seed production fields.

Pests: None observed.

Harvest: Capsules ripen unevenly, and seed can shatter upon ripening; harvests will be maximized if this species is grown on weed cloth. Plants should be allowed to ripen fully. Whole plants can be hand cut at the base (not pulled as this method can cause significant dirt contamination in the seed lot collected off the weed cloth). Shattered seeds can be swept or vacuumed. Seeds that shatter on the bare ground in the holes in the weed cloth should be vacuumed separately as this fraction of the harvest can contain much more dirt (and potentially weed seed) than the fraction vacuumed directly from the weed cloth. Caution should be exercised to make sure that the tiny seeds are retained in the harvest process and not lost through any process involving air (i.e. vacuums, combine, etc.). If grown on weed cloth, it is useful to use a leaf blower to clean off the cloth prior to seed shatter to minimize dirt contamination in the final seed lot.

Post-harvest residue management: Post-harvest residue management is not likely to be necessary because plants are generally hand cut and removed from the field in the harvest process. If necessary, residue can be mowed.

Seed cleaning: To streamline cleaning effort, hand harvested whole plants can be shaken or whacked with a stick while on a tarp to encourage plants to drop any remaining seed. Whole plants can also be threshed with a brush machine or other threshing device and the seed further cleaned with an air screen machine, but this may add significant effort for minimal seed gain, as seed falls readily from the capsules. In



any cleaning step involving air, it is important that air be set at minimum initially because of the lilliputian seed of this species. Seed vacuumed off weed cloth may contain dirt that is difficult to remove.

Average yields/stand longevity: Expected yields are up to 330 lbs/acre if grown on weed cloth and all shattered seed is collected (that's over 6.5 billion seeds!). Because plants are relatively small, we have observed up to 40% of the seed fall in the small hole in the weed cloth that the plant is rooted in. Yields will be much lower if grown without weed cloth. Most plants will not reemerge for a second year, so fields should be treated as annual.

Polygonum paronychia
beach knotweed

Life form: perennial woody sub-shrub

Pollination: At the Corvallis Plant Materials Center, we have observed bees and flies visiting this species.

Ease of agronomic seed increase: Moderate; this species can be found in flower for much of the year, and seeds mature over a period of several months but hold moderately well on the plant. It can be difficult to determine the correct timing to maximize seed harvest, and multiple harvests are laborious.

Native distribution/habitat: Sandy coastal habitats including beaches, dunes, and scrub from Vancouver Island south to San Luis Obispo County, California.

Ease of wild seed collection: Moderate; the extended seed ripening period means that some seed may fall to the ground prior to collection, but it gives a wide window of opportunity to collect seed.

Seeds per pound: 132,000

Establishment: Seeds require 8 weeks of cold-moist stratification to stimulate germination, and emergence can take up to 30 days. Seedlings grow slowly initially and are prone to becoming leggy and floppy. As a result of these factors, direct seeding is not recommended, and field establishment from plugs is recommended. If leggy, plugs can be cut back to simplify transplanting. This species can be grown for seed successfully in inland valleys (i.e. Willamette Valley in Oregon) on silt and clay loam soils.

Establishment rating: Moderate; plants generally survive well after outplanting, but some may die the first summer if they experience drought stress. Established plants are drought tolerant.

Fertilization: Plants are tolerant of low-nutrient environments but are more productive when fertilized.

Weed control: Because plants grow slowly and can be leggy in the first year, weed control is particularly important during the establishment phase. Once established, fields can be weeded largely with hand or mechanical methods. There are no herbicides labeled for use on this species when grown for seed.

Pests: None have been observed.

Harvest: Seeds are covered with a papery bract, making determining the quantity of ripe seed available on an individual plant basis difficult without rubbing the flower material in your hands. As such, performing selective hand harvest is challenging. Our harvest method is

nearly whole plant harvest by hand. A modified swather may also be used, though care should be taken to harvest above the point where primary branches come off the main woody stem. If cut lower and through the main stem, resprouting will likely be compromised. Selective harvest with a seed stripper may be possible, but we have not attempted it. In Corvallis we have harvested several years in mid-November, and plants are still in bloom at this time.

Post-harvest residue management: If whole or nearly whole plants are harvested, there will be little remaining residue on the field to manage.

Seed cleaning: Harvested material should be threshed to release seeds from the inflorescence. Plant material quantity will be significant if whole or nearly-whole plants are harvested. An air screen machine can then be used to remove much of the inert material. Because leaves are small and linear, if leaf material is harvested, it will be difficult to remove all dried leaf material from the seed lot. An indent cylinder or air column separator can be used to some success, but seed lots resulting from whole harvested plants are likely to still contain inert plant matter.

Average yields/stand longevity: 70-150 pounds per acre. This species appears to be long-lived.

Remarks: Contrary to our expectations, this species regrows well after being cut for harvest, and harvest in subsequent years does not appear to be reduced.

Rumex crassus
willow dock

Life form: perennial forb

Pollination: Like other *Rumex* species, this species is likely wind-pollinated.

Ease of agronomic seed increase: Moderate; this species is easy to establish but most branches grow prostrate below the cutting height of harvesting machines, and the seed ripens indeterminately and shatters in hot weather shortly after ripening.

Native distribution/habitat: Grows on sandy and cobbly beaches and on dunes along most of the Pacific coast of the United States from Northern Washinton to Southern California.

Ease of wild seed collection: In its native coastal environment, ripe seed holds on the plant longer than when grown for seed production in inland valleys that get hotter in the summer. This allows for a longer window of wild seed collection. Each plant can produce a significant amount of seed and adequate seed for a modestly sized production field can be hand collected easily.

Seeds per pound: 461,000

Establishment: Seeds are dormant and require four weeks of cold-moist stratification to initiate germination. Production fields are best established with plugs. Seedlings grow rapidly at first and will flower and produce seed in their first year. We have planted plugs on one foot in-

row spacing with two feet between rows, but this may not be optimal. Plants are largely prostrate, and most seed heads are held too low for mechanical harvest. It is possible that planting at a higher density will encourage plants to grow more vertically than they would otherwise, better facilitating mechanical harvest. This species can be grown for seed successfully in inland valleys (i.e. Willamette Valley in Oregon) on silt and clay loam soils.

Establishment rating: High if weeds are well managed in the early stages of establishment.

Fertilization: Plants are very responsive to fertilizer and benefit from a nitrogen-based application, or from a balanced fertilizer, depending on your soil.

Weed control: New fields planted from plugs provide a window of opportunity for weed management before the plants grow laterally. Before this rapid lateral growth, fields can be cultivated or spot-sprayed between rows to manage weeds. Once lateral growth eliminates in-row spacing, it will be difficult to use hoes or tractor-mounted cultivators, and hand-weeding will likely be necessary.

Pests: None observed.

Harvest: Because of its prostrate growth, mechanical harvest is challenging. Seed also ripens indeterminately and shatters quickly in the summer heat of inland valleys, so we have performed multiple hand harvests per year to maximize seed harvest. A minimum of two hand

harvests will likely be required, and seed harvest quantity can be increased with more frequent hand harvests. Weed fabric would simplify weed management and maximize harvest, but it is not known if this species would thrive in the elevated temperatures when growing on weed fabric.

Post-harvest residue management: Flail mowing after the final harvest of the year will help minimize standing dead vegetation, simplifying harvests in subsequent years. Much of the vegetative growth will be prostrate, and care should be taken not to mow too low as subsequent vegetative growth could be hampered.

Seed cleaning: After harvest, plant material will likely need to be aggressively threshed to remove the dried tepals and corky appendages (tuberculate callosity in botany speak) that surround the seed. A brush machine can be used for this, but care should be used as excessively aggressive brushing can destroy the seeds, and insufficient brushing will fail to remove the inert material from the seed. If using a brush machine, it is best to use a mantle sized to allow the seed to fall through, but with holes small enough to minimize passage of seed that are still retaining their tepas and appendages. After brushing, an air screen machine can be used to achieve a relatively high purity lot. If necessary, further conditioning can be done with an air column separator or an indent cylinder depending on the inert material to be removed.

Average yields/stand longevity: Up to 500 lbs/acre in the second year and beyond. First year harvests are lower (80 lbs/acre). Yields will likely vary widely based on harvest timing. Plants are long-lived and can be expected to produce seed for several years.

Rumex persicarioides
seashore dock

Life form: annual forb, occasionally a biennial

Pollination: Like other members of the genus *Rumex,* this species is likely wind-pollenated.

Ease of agronomic seed increase: Moderate if irrigated. This species is not tolerant of dry conditions. Plants are short and ripen indeterminately, requiring hand harvest.

Native distribution/habitat: It is difficult to determine the range of this species as it appears there is taxonomic confusion around it. Oregon Flora Project indicates a range as limited as Vancouver Island south to the San Francisco Bay, with a near exclusively coastal distribution. USDA Plants indicates a broader range and habitat and considers this name to be a synonym of *Rumex maritimus*, an introduced species. In Oregon, *R. persicarioides* is usually found at the upper high tide line in moist sand or cobble and is one of the species found lowest in elevation on the beach.

Ease of wild seed collection: Easy if adequate populations can be found.

Seeds per pound: 1,429,000

Establishment: Germination can be tricky, as some seed lots require 4 weeks warm-moist stratification followed by 4 weeks cold-stratification to stimulate significant germination, while other seed lots germinate

readily without pre-treatment. Seedlings grow quickly after germination and readily fill a small plug cell in 12 weeks. It is important not to let transplants begin flowering while in plug trays, as this will significantly hamper their subsequent vegetative growth and seed production. Transplant in late winter/early spring into the ground on 1ft x 1ft spacing maximum. Transplants could likely be planted as close as 6 inches apart in all directions. Regular irrigation will significantly increase yields.

Establishment rating: Medium; germination is tricky, and plants must be transplanted before flower initiation. Irrigation is required for adequate yields.

Fertilization: Plants respond positively to balanced fertilizer application.

Weed control: Transplants should be planted into a weed-free field. On close spacing, hoeing and spot spraying with a shield can be effective weed control. If spaced wider, cultivation and spot spraying can be used for weed control. Active irrigation will stimulate summer weeds in fields of this species, so repeated weeding will likely be necessary.

Pests: None observed.

Harvest: With heavy watering, this species grows taller and may reach the height appropriate for harvest with a modified swather. In this case, some seed would be harvested prior to maturity because of indeterminate ripening. Smaller fields or fields with shorter plants can be selectively hand harvested twice to maximize collection of mature seed.

Post-harvest residue management: Very little residue is left after harvest as whole plants are generally harvested.

Seed cleaning: Hand harvested material can be run through a standing combine or aggressively threshed in a brush machine with a mantle with small openings. In the threshing process, it is necessary to remove the dried tepals and corky appendages (tuberculate callosity) that surround the seed. In this species, the corky appendages are particularly large and block the view of most of the sepal except for the elongated marginal teeth. If seeds are not adequately threshed and many remain within the tepals, more inert

material is likely to remain in the seed lot. After threshing, multiple passes through an air screen machine will remove most of the inert material. Final conditioning in an indent cylinder or air column separator can remove most of the remaining inert material.

Average yields/stand longevity: 40-100lbs/acre when grown under field conditions. Seed fields will only be productive for one year and need to be replanted annually.