California Seed Strategy

Prepared by:
California Native Plant Society
April 17, 2023
Table of Contents

Acknowledgements ....................................................................................................................................... 1
Introduction .................................................................................................................................................. 1
Scope ............................................................................................................................................................. 2
Goal 1: Identify Seed Needs, and Ensure the Reliable Availability of Genetically Appropriate Seed ........... 3
    Background ............................................................................................................................................... 3
    Objective 1.1: Match supply of genetically appropriate seed with demand ............................................ 3
    Objective 1.2: Increase funding and predictability for native seed supply. ............................................. 3
    Objective 1.3: Create policy to support California Seed Strategy work ................................................... 5
    Objective 1.4: Create incentives to support California Seed Strategy work ............................................. 6
    Objective 1.5: Create staffing to support California Seed Strategy work ................................................. 7
Goal 2: Compile Information and Conduct Research to Provide Genetically Appropriate Seed and to
        Improve Technology for Native Seed Production and Ecosystem Restoration ............................................ 9
    Background ................................................................................................................................................... 9
    Objective 2.1: Refine and improve use of seed zones and transfer guidelines for current and projected
                  future conditions...................................................................................................................................... 9
    Objective 2.2: Improve use of species-specific information of seed collection, processing, storage, and
                  production protocols for restoration species. ........................................................................................ 10
    Objective 2.4: Improve plant establishment, species interactions, and ecological restoration success
                  through shared seeding plans................................................................................................................ 12
    Objective 2.5: Develop or modify monitoring techniques, and investigate long-term restoration
                  impacts and outcomes for adaptive management. ................................................................................ 13
Goal 3: Develop Tools that Enable Managers to Make Timely, Informed Seeding Decisions for Ecological
        Restoration .................................................................................................................................................. 15
    Objective 3.1: Develop Training Materials and Programs for Practitioners, Producers, and
                  Stakeholders on the Use of Genetically Appropriate Seed for Restoration ....................................... 15
    Objective 3.2: Develop Native Seed Source Availability Data and Tools for Accessing the Data ............ 16
    Objective 3.3: Build on Ecological Assessments and Disturbance Data, and Provide Training that will
                  Allow Managers to Anticipate Needs and Establish Spatially Explicit Contingency Strategies .......... 17
Goal 4: Develop Strategies for Internal and External Communication ....................................................... 18
    Objective 4.1: Conduct Education and Outreach through the Seed Strategy Network ............................ 18
    Objective 4.2: Report Progress, Recognize Achievements, and Revise Strategy .................................... 18
Priority Near-Term Actions Summary ......................................................................................................... 20
References .................................................................................................................................................. 21
List of Frequently Used Abbreviations ........................................................................................................ 24
Acknowledgements

The California Seed Strategy Steering Committee met numerous times from June 2022 to May 2023 to help see this plan to completion and ensured the plan was measurable, achievable, relevant, and effective. The Steering Committee includes Christina Lund (Bureau of Land Management), Brent Johnson (National Park Service), Brenda Lanini (California Department of Food and Agriculture), Mark McLoughlin (CDFA), Raffica LaRosa (California Department of Fish and Wildlife), Hillary Sardiñas (CDFW), Julea Shaw (CDFW), Cristin Walters (CDFW), Lusetta Sims (United States Forest Service). Additional contributions by the California Crop Improvement Association (CCIA), PMC, etc.

Work funded by BLM grant # L21AC10512-00

Additional reviewers and contributors include Arlee Montalvo.
Introduction

The California Floristic Province is one of 36 global biodiversity hotspots; complex variation in climate, topography and geology make it home to more native plant species than any other state in the United States, with a third of those being endemic. Floral diversity also assembles as a range of vegetation types in California, from wildflower-rich oak woodlands and grasslands, to the tallest and oldest conifers, to fire-dependent coastal sage scrub and chaparral. Northeastern portions of the state represent the Great Basin Floristic Province, and southeastern California are part of the Desert Province. While we understand that plants arrange themselves without respect to political boundaries, this plan is generally constrained to the boundaries of the State of California with some regional work extending into neighboring states where floristics or other factors dictate.

California’s diversity owes not only to the factors noted above, but also to fire, originally from stewardship by California’s Indigenous peoples and some lightning-caused blazes. Over a century of fire suppression, land mismanagement, and climate change have contributed to fires getting larger and more severe. Native seeds are often used post-fire to combat erosion and invasive species, but native seed is not always available or seen as desirable. In addition, we are in the United Nations Decade of Restoration (2021-2030), where dams are coming down and habitat is being restored. Now more than ever, we need appropriate native seed to restore the California landscape with ecological integrity.

California is embarking on ambitious plans to provide resilience in a changing world: adapt to a warming climate, provide resilience to drought and extreme wildfire, and ensure that all residents benefit from a healthy environment. Efforts such as 30 x 30 and other climate and biodiversity responses under Governor Newsom’s Executive Order N-82-20 place California squarely as a global leader. For these efforts to be successful, the state must invest in core infrastructure necessary to support the growing demand for native plant seed.

Restoration activities return habitats degraded from human use, wildfires, and other means to a biodiverse community. In turn, these restored habitats are more resilient to future disturbances and can create a more steady demand for seeds, as opposed to supply and demand driven by bursts of emergency needs with very short windows of funding. However, much of the native seed use in restoration does come from post-fire emergency funding, which leaves little room for planning and creates an unstable market for producers. Furthermore, as California experiences more erratic weather due to climate change, producers see the need for appropriately locally sourced seed is increasing and that the current seed production system and infrastructure are not going to adequately handle the anticipated increase in demand.

As noted in David Festa and Karina Mudd’s Strengthening the Native Plant Supply for California’s Central Valley, “Historically driven by the boom-and-bust cycles of government demand, the native seed market is uncertain and volatile, which burdens producers with large amounts of risk.” One of the seed companies stated that, “We believe the demand for native plants will outstrip current combined capacity of all growers in the state to supply both the necessary volume and diversity of ecotypes that will be required. This supply shortage has the potential to create major delays and cost overruns in projects requiring native plants.” Another was more specific about the concern, “We anticipate the demand for local native seed will grow as more habitat enhancement projects come down the pipeline...we fear that without a local seed source established, these projects will have to resort to non-
local seeds that won't be as well-adapted to the local conditions. We're trying to build up our seed supplies for such projects.”

Seed collection, production, and sales are happening throughout the state with varying scopes and scales. In researching who is collecting, growing, and storing California native seeds we encountered individuals who contract collect, collectives who are working on ways to better plan for their region, small companies that do only local contracts, and large suppliers that have warehouses and capacity for large scale growing. Each of these pieces plays an integral role in the current industry, and they all had ideas about the current shortcomings and needs for long-term planning.

In addition to infrastructure needed to increase availability of native seeds for restoration, standards and guidelines need to be set for each stage of the process to preserve local genetics and biodiversity. Despite good intentions of habitat restoration, we risk unintentional harm to the rich biodiversity of California if restoration practitioners do not have genetically appropriate seed available to use. We risk tampering with locally adapted genetic plant populations if we use seeds sourced from a distant location with different environmental conditions (Knapp and Rice 2006). If seed increase operations are not standardized, we risk selection of certain traits (Schoen and Brown 2001; Dyer et al. 2016) that can “swamp” out the local diversity (Holl et al. 2022; Johnson et al. 2017).

A central group that leads work under this strategy, including compiling and disseminating information, convening meetings, and maintaining communications between members is necessary to the strategy’s success. To this point, it has been the California Native Plant Society connecting with agencies and others; CNPS could continue this work but regardless it should be an organization committed to providing scientific information to practitioners and the public, and without financial stake in the restoration seed production pipeline.

Scope
The California Seed Strategy was created as a roadmap to increase the availability of native seed for habitat restoration in California and intended as a stepped-down, state-specific version of the National Native Seed Strategy. The California Seed Strategy is made up of four goals: 1) identify the state’s seed needs, 2) identify research needs to define “genetically appropriate seed,” 3) develop decision making tools for seed users, and 4) communicate the Strategy across the state. The vision of the California Seed Strategy, like the National and Nevada Seed Strategies that have set a precedent, is to get the right seed, in the right place, at the right time.

As indicated above, the California Seed Strategy applies to seed collected, grown, and applied as part of habitat restoration, at various scales, and inclusive of emergency responses such as post-wildfire or -flood seeding. Species-specific rare plant seed collection and long-term conservation storage and seedbanking (ex situ conservation), while essential to biodiversity preservation, is outside the scope of this plan.
Goal 1: Identify Seed Needs, and Ensure the Reliable Availability of Genetically Appropriate Seed

Background
Nationally, the need for genetically appropriate native seed outstrips supply; California is no different. In truth, California’s tremendous floral diversity makes production of a biodiverse mixture of local native seed even more of a challenge. Emergency needs are a large portion of demand and are limited to two years post-fire or other disasters and do not allow for opportunities such as seed bulking to increase stock. Stable funding sources and long-term contracts are needed for adequate native seed restoration planning. There needs to be collaboration between landowners to increase availability, which will require standards in practice across agencies. Additional seed producers, seed certifiers and additional personnel are needed to meet demand.

Objective 1.1: Match supply of genetically appropriate seed with demand
Although California has an active community focused on promoting the use of native seeds, these discussions highlight the challenging gap between the current capacity and the long-term need. To reliably supply the restoration needs of public lands throughout California there needs to be investment and systemic change.

Action 1.1.1: Conduct a full assessment of the current seed industry in California to understand what is needed.
Surveying seed producers and other partners throughout California and surrounding states and reviewing any past assessments or research is needed to understand current capacity and what is needed to provide a stable seed market for the future. Assessment should include small and large producers, cooperatives, councils, and collectives and Tribal, federal, state, private, and NGO landowners.

A 2022 California Native Plant Society (CNPS) survey of seed growers and sellers (20 recipients, six respondents) collected information on the 10 most requested native plant species and then compared it to the 10 most supplied species from the inventory of each seller. The scope of this survey was limited to California native plant seed sellers and did not include sellers of non-native seeds. Responses were received from around the state from a range of grower types: from those that only collected for contract grows and kept little seed inventory on hand to seed producers with over 1 million pounds in inventory. By analyzing the data collected, the survey identified that 13% of the species most frequently requested were not supplied by the sellers, and 23% of the time were unavailable or not available in sufficient quantity, indicating a potential gap in the market for these species and a communications gap in the planning for which seeds to harvest and grow for upcoming restoration efforts. The top species requested (mode: 3) were Bromus carinatus, Elymus glaucus, Festuca microstachys [sic], Lupinus bicolor, and Stipa pulchra. The top species supplied (mode: 3) were Asclepias fascicularis and Eschscholzia californica.

Objective 1.2: Increase funding and predictability for native seed supply.
Perhaps the largest barrier in increasing reliable supply of seed is proper prior planning and funding for large projects. Often contracts and orders are reactionary rather than proactive. In order to assure
quality, regionally appropriate native seeds available in the needed locations, changing the contract structure and improving forecasting and communication would allow producers to scale up accordingly.

**Action 1.2.1: Change contracting structure to reduce risks to producers.**

Having more flexible, long-term contracts would allow producers to grow and store large amounts with assurance that there will be buyers for these species. From the National Academies of Sciences, Engineering, and Medicine 2023 Final Report “An Assessment of Native Seed Needs and the Capacity for Their Supply:”

In 2018, the BLM’s Plant Conservation and Restoration Program began to address the issues of communication, timeframe, and availability of stock seeds using a native seed Indefinite Delivery-Indefinite Quantity (IDIQ) production contract with suppliers to have them grow and increase native seed types from seed transfer zones not readily available on the commercial market. Although seed production IDIQ contracts are not a new financial instrument, the focus on seed production by seed transfer zone is a new approach for BLM. The seed given to suppliers for increase came from the Seeds of Success (SOS) program initiated by the BLM in 2001. To secure the genetic diversity of native plants, BLM partnered with six non-federal seed banks (SOS Partners) to store native seed collected from numerous seed zones across different ecoregions...in the western United States. Although the quantities being increased are small and the funding for the new program is modest, the IDIQ approach is a significantly new approach to meeting seed needs.

**Action 1.2.2: Create more stable funding sources.**

Restoration work that is not time-constrained would allow for contracting lead time to build regional seed stock that can be repurposed in emergency situations. The timeframes of both grant-based restoration funding and disaster recovery funding are too short for contract lead times, so stable regional funding for restoration could serve multiple purposes. A way to forecast need is to provide reliable funding for restoration matched with regionally forecasted disaster likelihood; this is discussed more in Objective 3.3.

**Action 1.2.3: Work with federal and state lawmakers to budget reliable funding.**

State funding from initiatives such as climate change and wildfire resiliency, biodiversity and 30x30 support restoration and can also be leveraged to create a more stable demand for native seed.

A new Farm Bill can help on the agricultural side, as native seed may be considered a small market crop. Crop transitions from nonnative crops with high water needs are also needed to support the Sustainable Groundwater Management Act, and with appropriate guidance these lands can be maintained in agricultural production by moving to native seed production.

A relatively small investment of $3 million in 2018 to the California Plant Rescue doubled their pre-funding collections in five years; while the scale of restoration needs is orders of magnitude larger, the application of funding to an organized coalition with clear goals can do great things to advance biodiversity protection and restoration.
Objective 1.3: Create policy to support California Seed Strategy work
Seed growers and users cannot improve biodiversity and integrity of native seeds without a means to inform and incentivize standard guidelines. There needs to be a means to identify seed source and a mode to share seed across jurisdictional boundaries, while adhering to ecological boundaries.

Action 1.3.1: Set a minimum standard for use of native seeds.
Develop clear guidelines for use by the seed industry and public and private agencies around where and what specificity of native seed is required: what it means to be local, whether out-of-state genetics ‘count’ as California native, minimum seed zones and transfer guidelines, and how many generations can be produced in a farming environment before stock must be refreshed from wild seed. These should be required for state-funded habitat restoration work to ensure success and biodiversity preservation.

The USFS and NPS have policies where native and genetically appropriate plants are first choice in revegetation (USFS 2005; NPS 2006), including post-fire seeding (USFS 2003; NPS 2019). Although federal guidelines suggest native seed be used in restoration work, these guidelines are not always followed—particularly when foresters, range managers, or contracting personnel are in charge of seed procurement.

Various agencies are using different seed zones throughout the state of California. The Federal Highway Administration uses Environmental Protection Agency Level 3 ecoregions (USDOT 2017). The NPS generally uses watershed and sub-watershed level seed zones (personal communication, A. Williams 2022). Creating transfer guidelines that will help hold multiple agencies to the same standard within the state of California will help collaboration amongst seed growers and users.

Species-specific genetic seed zones should be used when information is available. For species without genetic seed zones, ecoregions with similar geology, climate, soil, hydrology, vegetation and other geographic features can direct seed zones and transfer guidelines (Erickson and Halford 2020).

Action 1.3.2: Expand capacity for native seed certification.
Develop a state policy that regulates source-identified native seed. Without knowing the source of seed, seed zones, transfer guidelines, and other protocols protecting genetic integrity cannot be followed. California Department of Food and Agriculture (CDFA) does not currently have statutory authority to regulate native seed as it does other types of seed. Regulations requiring native seed for restoration, preferring source identification and growing location, recognizing the California Crop Improvement Association (CCIA) as a seed certifier, and incentivizing local native seed would bolster seed markets and allow CDFA to regulate them. CCIA requires testing at a lab using Association of Official Seed Certifying Agencies (AOSCA) rules for seed quality, yield, genetic purity, weeds, and other elements. Implementing CCIA certification of native seeds will help increase the efficacy, quality, and integrity of ecological restoration in California. Additional training may be needed to bring more seed testing labs up to specifications for native seeds, as identification and germination testing are dissimilar to most crops. See Action 2.3.7 for more information.
Action 1.3.3: Work with agencies to re-evaluate seed collection policies.

Work with agency leaders and policymakers to re-examine policies around seed collection on state-owned lands, which can limit access to diverse source populations. Having permitting or agreements in place is a useful step, as some public lands devoted to biodiversity protection (fish and wildlife or parks in particular) may prohibit the collection of for use outside of department property boundaries. Federal agencies have increased their use of Seeds of Success contractors to wild-collect seed for use on federal lands, either directly or for increase and later application. State and local lands, as well as others who wish to take part in such a partnership, could participate in a parallel partnership or explore participating in the Seeds of Success program.

Action 1.3.4: Establish the stewardship of native seed as a public good.

An investment from the state is necessary to ensure that seed sourced for restoration from and for public lands remains a public good, and that information generated from these activities will be available to bring new producers into the market to address growing need for seed around the state.

Other states have used their land-grant universities to function as the group to centralize wildland collection, genetic testing, and releasing of ecotypes to growers for increase and contract fulfillment.

Objective 1.4: Create incentives to support California Seed Strategy work

Due to the financial burden for native seed producers to transition to Source Identified seed (SI) and CCIA certified seed, there is little incentive to do so. Furthermore, it would be detrimental to create legislation without financial support and technical production protocols to assist native seed producers in improving production practices.

Action 1.4.1: Fund the transition to SI and CCIA certified native seed and needed ecotypes.

Currently, SI and seed certification is not required in the state of California (California Seed Law) and the capital required for seed producers to obtain SI and CCIA certification is a major barrier. Cultivating a new species is a huge risk requiring trial and error. By providing a financial incentive, native seed producers will be more able to transition to SI and CCIA certified seed. In addition, there needs to be incentive to diversify and create small hyperlocal crops as large workhorse crops would be safer for producers. Funding opportunities should be inclusive and accessible to producers big and small, and any state funding should require protocols developed be made available through publicly accessible websites.

Similarly, source-identified seed requires documentation and personnel to collect and verify species, location, and growing conditions of native seed. CCIA has indicated their current annual maximum is 50 certifications, well under the location and species diversity necessary to meet needs. Other states’ AOSCA groups have determined that Seeds of Success data collection methods are sufficient or equivalent to the data collection requirements and do not require additional certification. Having this for California would allow CCIA to focus on growers, and limit the travel and number of visits. Alternatively, start-up funding for certification of additional wildland collections will be needed.

Funding should be awarded equitably across producer demographics, with set-asides or targets for underrepresented groups. Tribes are the original stewards of native plants, and many are continuing their collection, growing, and stewardship of native plant populations through applying cultural practices or starting native plant nurseries. A block grant, administered with the assistance of the
Bureau of Indian Affairs and/or the Intertribal Agriculture Council, should be set up to support current efforts and provide additional opportunity for California Indigenous peoples in this area.

**Objective 1.5: Create staffing to support California Seed Strategy work**

Increasing production, certification, and use of native seed will require an increase in staffing to support this seed strategy work.

**Action 1.5.1: Ensure that restoration seeding decisions are made by a restoration specialist, botanist, or someone with similar expertise.**

Both USFS and BLM should have restoration seeding decisions under the purview of a botanist/restorationist at either the regional or national level. State, private, Tribal, NGO and other landowners should have someone qualified to make restoration seeding decisions.

**Action 1.5.2: Create additional positions in Cooperative Extension or NRCS to support native seed producers.**

Bringing additional producers online and certifying wild collections and subsequent generations in production will require investing in knowledgeable individuals. Other states have cooperative extension personnel to support native seed farming, and particularly if California desires to repurpose or restore millions of acres and transition agricultural lands with higher water needs, then having farmer-trusted expertise in UC-ANR or NRCS personnel to support them will be a necessity.

**Action 1.5.3: Work with land management partners to expand capacity for native seed bulking and grow outs.**

While outside a ‘seed’ strategy, both USFS and California Department of Forestry and Fire Protection (CAL FIRE) nurseries should be requested or required to grow woody non-conifer species for restoration, in addition to providing more space to seed bulking grows. Other states also have their UC equivalent institutions participating in seed collection and foundation stock storage and maintenance, seed growing, including propagation testing, genetic and other research, and this work could be reliably expanded and supported in California, in addition to needed investments in the federal Plant Materials Center.

More facilities that can bulk native plant seed and develop new stocks of a variety of locally appropriate genetically diverse plant species are needed. Few national parks and forests in California have their own native plant nurseries, and those that do focus more on growing out plants rather than bulking native seed. USFS\(^1\) and its California sister agency CAL FIRE primarily produce conifers for forest reforestation, with limited nursery space for other plants, including forbs and grasses. The USDA Plant Materials Center in California does not have the capacity to provide the level of assistance needed to support work on native seed. With recent federal investments supporting work under the National Native Seed Strategy, several federal agencies are bringing on Seeds of Success contractors to California to make wild collections of seed that might be used as foundation seed for bulking. Collections are stored in the BLM’s National Seed Warehouse system (Ely, NV; Boise, ID; Twin Falls, ID), and other agencies may buy from the warehouses.

---

\(^1\) California is USFS Region 5, and served by the Placerville Nursery but Northern California national forests may also use the Bend, OR Seed Extractory in Region 6.
Action 1.5.4: Support regional collaboration.

The state of California contains portions of three Floristic Provinces and 13 Level III ecoregions. Bioregions such as these are useful for delineating seed transfers and population genetics, but we also acknowledge each agency has its own way of organizing regions. Jepson Regions (e.g., northwest (NW), Sierra Nevada (SN)) loosely correspond to many agency’s regions as well, and would be useful geographic subdivisions for regional collaboratives involving agencies, Tribes, producers, researchers and other interested landowners and nonprofit organizations. Regional hubs are also a potential way for locally sourced seed and regional seed banks to be developed, which will increase guaranteed availability and quality. Climate-controlled storage, seed cleaning equipment, and growing equipment are large investments for individual producers. Regional assessments of infrastructure to process and store seed will show where investments are needed to increase capacity, either through state or federal investment or through grower cooperatives or another association.

The 2023 National Academies report (National Academies of Sciences, Engineering, and Medicine 2023) contains thorough recommendations around a structure similar to the National Interagency Fire Center that would bring cross-agency coordination to the level needed.

Several regional collaboratives are already active in California around seed collection and growing, from the Mojave Desert to Orange County, Seed L.A. and the Mattole Restoration Council. The Mojave Desert Native Plant Program was started by the BLM and is an excellent ecoregional model for collaboration, from priority species selection to coordinated collection, research, and implementation.
Goal 2: Compile Information and Conduct Research to Provide Genetically Appropriate Seed and to Improve Technology for Native Seed Production and Ecosystem Restoration

Background

To improve availability of genetically appropriate seed for restoration practitioners in California, more research and technology needs to be developed. The following objectives will address guidelines, research and technology needs for each step of the native seed production process including seed zones, seed transfer, collection, processing, storage, seed increase, testing and certifications within the state of California. Furthermore, guidelines, research and technology needed for seeding methods and monitoring of restoration sites will be addressed.

Objective 2.1: Refine and improve use of seed zones and transfer guidelines for current and projected future conditions.

Seed transfer guidelines inform how far plant material can be transferred from point of origin to the project with minimal risk of maladaptation. Genetic variation is important to maintain for populations to be able to adapt to stresses and climates (Armstrong et al. 2017). The following actions address ways to improve and develop seed zone and transfer guidelines within California.

Action 2.1.1: Provide information around already established seed zones and transfer guidelines by California species and bioregion.

Both RNGR and SER databases provide some level of information, but this can be mirrored or augmented to make information more accessible for California seed users and producers to improve practices of native seed use in restoration. Seed zones were first established for trees, but are more recently being developed for grasses, forbs and shrub species commonly used in revegetation (Bower et al. 2014). The product can include related research that helps determine seed zone and transfer criteria for target species. Seed zones should be established by species and bioregion. This could be an expansion of the existing seed selection tool. We recommend a state-specific website is compiled and maintained for this information; see Goal 4 for more information.

Action 2.1.2: Conduct research on species that need seed zone and transfer guidelines developed for bioregions in California.

After compiling information on established California seed zones and transfer guidelines, research can be conducted by characterizing genetic variation of species used in restoration that do not have genetic seed zone and transfer guidelines established. This information will help native seed users and producers improve the integrity, quality, and success of ecological restoration.

Research should be prioritized not only based on commonly used species, but also developing recommendations around situations where extra caution should be practiced around using local-only seed stock. Prioritization could include species with evidence of local adaptation within seed zones, life history traits with low potential for gene flow, ploidy variation, hybridization, and taxonomic uncertainty. Some of these species might receive subzones or exclusion zones (Ward et al. 2008).
Some species are genetic generalists and can tolerate a wide range of environmental gradients and movement, whereas other species are genetic specialists and are adapted to local conditions and regions (Johnson et al. 2010). This information can be obtained through genetic testing and/or common garden experiments and can be used to create appropriate seed zones and transfer guidelines.

**Objective 2.2: Improve use of species-specific information of seed collection, processing, storage, and production protocols for restoration species.**

Providing easily accessible information on seed collection, processing, storage, germination, and harvesting will help improve efficacy of native seed production and therefore increase availability of native seeds. Unlike agricultural species, native species each have different dormancy and germination traits. In addition, different species seed traits require different storage, processing and harvesting techniques. This makes native seed production far more complex and challenging than crop plants. Information on species specific production protocols should be made readily available to seed producers and users and knowledge gaps should be filled by additional research. Information should be open access, draw from existing protocols when available, and have a process for vetting; the Plant Materials Center in Corvallis has a Native Seed Production Guide for the Pacific Northwest that can serve as an example or starting point. The following actions address ways to improve access to information on the multiple stages of seed production. We recommend a state-specific website is compiled and maintained for this information; see Goal 4 for more information.

**Action 2.2.1: Compile best management practices to limit pests and pathogens during collection and production.**

Best management practices exist for seed production to limit movement and spread of pathogens and invasive species via contaminated seed and equipment. These include training to ensure the correct species is being collected, material on or near the ground or from diseased plants is not collected; people, tools and equipment are inspected and cleaned between sites; and drying is done to avoid pathogens while preserving seed viability.

**Action 2.2.2: Compile information on established species-specific seed processing.**

Proper processing is important to ensure seed is clean and healthy for optimal propagation success and greater storage longevity. Seed processing, or seed cleaning, removes seed from fruit (threshing) and chaff (winnowing). California Botanic Garden has a comprehensive guidebook on seed processing by species and family (Wall and Macdonald 2009). RNGR has a database of species-specific processing protocols. The USFS has a manual on woody plant seed processing (Bonner and Karrflat 2008). Additional reference material should be sought out and centralized for greater availability and use. Producers and researchers can use these resources for taxonomic and physiologically similar species, as well as contribute additional information to a centralized database.

**Action 2.2.3: Compile information on species-specific seed storage.**

Short term storage is important to hold seed until the restoration site is ready and the timing is right. Long-term storage is important for conservation banking. Without proper seed storage, seed viability can be lost and precious seed wasted. Seed storage protocols vary by species, seed type (orthodox, recalcitrant, or intermediate), and storage timeframe (short or long term). Proper seed moisture content and temperatures differ between species, seed type and storage timeframe. California Botanic Garden
(Wall 2009), SER (Pedrini and Dixon 2020) and other scientific research (De Vitis et al. 2020; Walters et al. 2018; Walters 2015; Walters et al. 2007) have guidelines on species-specific seed storage. SER has a new Seed Information Database (SID) for species-specific seed storage information and RNGR has species-specific storage protocols included in their database as well. Producers and researchers can use these resources for taxonomic and physiologically similar species, as well as contribute additional information to a centralized database.

**Action 2.2.4: Compile information on species-specific germination protocols.**

Understanding seed dormancy, germinability and viability is important for production planning. Most native plant species have some form of dormancy, and while it may have its advantages in the wild, slow or erratic germination poses challenges in seed production. Understanding species-specific germination protocols can improve native seed production. Seed treatments can be done to synchronize and break seed dormancy to aid in production (Kildisheva et al. 2020). Understanding germination rates and viability of seed lots is important to plan seeding rates. Emery (1988) has seed propagation protocols for California native plants. RNGR and SER have species-specific germination protocols. Producers and researchers can use these resources for taxonomic, physiologic, and geographically similar species, as well as contribute additional information to a centralized database.

Germination rules (methods) for most native species do not exist under AOSCA. ISTA also has few rules for native species. Additionally, most Registered Seed Technologists (RST) are not very familiar with native seed identification so having centralized materials available, workshops and training may be necessary to have sufficient laboratories and trained RST to provide a laboratory report for a native seed lot. A current list of labs trained in these methods should be presented with other useful information on the seed strategy website.

**Action 2.2.5: Establish guidelines for native seed production.**

Native seed increase/production is a critical step to maintain genetic integrity and increase availability of native seed for ecological restoration. Guidelines include the number of generations seed can be produced from the wild collection, how to prevent hybridization, how to prevent unintentional selection of traits, among others (Conrady et al. 2023; Pedrini and Dixon 2020; Dyer et al. 2016). One novel production method to maintain diversity is the Diversity Enhancement Block, where collection populations within a species are sown in different block in the production field to observe any differences (Ward et al. 2008). Furthermore, the amount of seed required for production and average annual yields differ between species (USDOT 2017). Having these best practices available will assist producers in adopting these practices and seed users in project planning.

**Action 2.2.6: Compile information on seed increase field maintenance.**

To assist producers in field production, field maintenance information should be gathered and made available in a centralized location. Helpful field maintenance information includes site preparation (weed control, soil seed bed), and establishment (timing of seeding, irrigation, seed vs. transplants, weed control, fertilization, and pest and disease management) (NRCS n.d.).

**Action 2.2.7: Compile information on seed harvesting.**

With many other aspects of seed production, seed harvesting of native species is far more challenging than crop plants, especially when genetic diversity is preserved with best practices preventing
unintentional selection. Harvesting techniques for native species vary depending on location, seed traits, the scale of the operation, frequency of harvest, and volume of seed harvested. Pedrini et al. (2020b) includes information on different harvest equipment and techniques based on these factors. The NRCS Plant Material Center in Corvallis, OR has a native plant production guidebook for the Pacific Northwest that includes information on different harvest equipment and pros and cons of each, as well as species-specific harvest recommendations (NRCS n.d.). RGNR has species-specific harvest methods. Producers can use these resources for taxonomic, physiologic, and geographically similar species, as well as contribute additional information to a centralized database.

Action 2.3.7: Conduct research on species-specific seed processing, storage and germination for native species that lack technical guidelines.

Filling in knowledge gaps on species-specific seed processing, storage, germination, and harvest will assist seed producers in expanding the number of species available and the quantity of each species available. Information should be shared on a centralized open-access location and have a process for vetting.

Objective 2.4: Improve plant establishment, species interactions, and ecological restoration success through shared seeding plans.

After all the efforts of seed collection to production harvest, successful establishment at the restoration site is crucial. A seeding plan includes site preparation, seed mix and sowing rates, maintenance, monitoring, and communication, and are all important to the success of current and future restoration projects (Shaw et al. 2020). Seeding plans will vary by objective and habitat type (Stromberg et al. 2007; Griggs 2009; Jackson et al. 2015; UCANR 2017; USDOT 2017). Numerous factors influence plant establishment and success of ecological restoration including seed stock, water availability, hydrology, soils, weather, solar radiation, competing vegetation and more (USDOT 2017). Providing information to restoration practitioners on limiting factors affecting plant establishment will help increase the success rate of ecological restoration and maintain a steady demand for native seed. Information should be provided by bioregion.

Action 2.4.1: Compile and share site preparation strategies based on initial assessment to improve plant establishment and community diversity.

An initial assessment of the site including disturbance history, invasive species levels, level of degradation, soil erosion or compaction, slope and aspect, and existing vegetation will identify barriers to plant establishment (USDOT 2017). Site preparation measures such as weeding, and tilling can help mitigate these barriers to plant establishment. Compiling and sharing information of various site preparation measures used in the field will aid land managers in selecting the appropriate actions to facilitate successful plant establishment. Information should be categorized by bioregion and elements of initial assessment.

Action 2.4.2: Compile and share workhorse seed mixes, sowing rates and sowing techniques by objective, habitat type and bioregion that improve plant establishment and community diversity.

Diverse seed mixes are better than single species, although some quick growing annuals can outcompete slow growing perennials (UCANR 2017; USDOT 2017). Establishing workhorse seed mixes of species that perform well together over a broad range will help increase availability of native seed and increase successful plant establishment. Seed mixes should be established by objective, habitat type,
and seed zone. Caution should be taken to not decrease genetic diversity through the use of workhorse seed mixes. While we want lots of seed that does well at reaching our ecological restoration goals, we also need to use small batches of local genetics to preserve genetic diversity. Finding the most genetically diverse seed mixes that are practical to produce will be key.

Sowing rates depend on the composition of the seed mix and germination rates, although there are general rules of thumb based on functional group, seed characteristics and seeding technique (Stromberg et al. 2007; Jackson et al. 2015; UCANR 2017). Sowing techniques and timing should maximize seed to soil contact, optimize soil moisture and provide thermal insulation. Sowing is usually best done in the fall and techniques depend on seed and site conditions. Information on sowing techniques such as broadcast, drilling, hydroseeding, composting and mulching will help land managers select the appropriate sowing technique to facilitate successful plant establishment and community diversity.

Information should be shared in a centralized location and organized by bioregion and other site characteristics amongst restoration practitioners to learn from each other’s successes and failures. This will help improve success rates of restoration and help stabilize the demand for native seeds.

**Action 2.4.3: Compile and share maintenance strategies to ensure successful plant establishment.**

Pre- and post-seeding weed control and other maintenance measures are critical to the success of plant establishment. Compiling and sharing information on proper maintenance techniques and timing will help land managers choose the correct maintenance action and anticipate maintenance time into their initial plans.

**Objective 2.5: Develop or modify monitoring techniques, and investigate long-term restoration impacts and outcomes for adaptive management.**

Monitoring is critical for adaptive management and often a project requirement, yet information from monitoring is largely unavailable. Compiling and analyzing monitoring data helps inform if restoration actions are successful, and if not, what changes need to be made, including steps in the seed production process. Improving and standardizing monitoring techniques and increasing information sharing will help advance the field of ecological restoration by learning from previous restoration projects, improve restoration success, and help stabilize demand for native seed.

**Action 2.5.1: Develop or modify monitoring techniques.**

Monitoring techniques should be developed based on objective, habitat type, statistics, and economic feasibility. Monitoring should be conducted for multiple years before and after restoration and/or a reference site to compare baseline conditions to desired future conditions. Monitoring criteria should be selected (cover, density, survival) to determine restoration and seeding success. Results from monitoring should be used to determine whether current native seed production and restoration strategies are successful, detrimental, or neutral and if changes should be made to the native seed production process or restoration strategies to better reach restoration goals.

The most comprehensive guide to monitoring is Elizinga et al. (1998).
Action 2.5.2: Conduct long-term monitoring and share information gained from long-term monitoring.

Long-term monitoring should be conducted at native seeding site and data should be shared amongst the restoration community. Practitioners should use and contribute to existing ecological restoration database to aid other practitioners in restoration decision making based on best available science. The Society for Ecological Restoration has a database: Restoration Resource Center Resource Database (serrrc.org).

Action 2.5.3: Use monitoring information to improve native seed use in ecological restoration.

Results from monitoring can shed light on various aspects of the seed production process and may inform a need to make changes. For example, results from monitoring may indicate a need to change the seed zone for a species, or seeding rate, etc. Metrics and strategies should be created for how to adapt management given a set of conditions we see on the ground instead of having to create on the fly.
Goal 3: Develop Tools that Enable Managers to Make Timely, Informed Seeding Decisions for Ecological Restoration

Objective 3.1: Develop Training Materials and Programs for Practitioners, Producers, and Stakeholders on the Use of Genetically Appropriate Seed for Restoration

A shared set of protocols and best practices around all phases of the process—selection, collection, propagation and growing, harvest and storage, planning, seeding, and monitoring—will ensure participants have similar knowledge and expectations and the ability to make decisions about getting the right seed in the right place at the right time.

Action 3.1: Integrate and Deliver Research and Information to Support Restoration Project Development and Implementation.

Research suggested in Goal 2 will need to be disseminated to practitioners in multiple ways. Synthesis of existing guidelines and protocols should be available and downloadable in a central website for the California Seed Strategy, and verbal summaries of essential information delivered in an engaging training format. The needed work may be placed broadly into three priority categories:

- Identify existing restoration guidelines and tools, and highlight needed protocols and resources to support restoration project development.
- Develop a template for reporting, metrics for tracking restoration project development
- Develop science delivery tools, such as websites and trainings.

While federal agencies and grantors may have their own reporting templates, a fairly standard broad set of metrics for restoration project tracking will help reduce duplication of effort and allow for more meaningful summaries of statewide progress. California Department of Fish and Wildlife (CDFW) is working on trainings and metrics, and should be resourced such that they can help lead this work as the stewards of the state’s natural heritage.

As noted in Action 2.1.1, a database of seed transfer guidelines will help ensure producers can offer the right seed for particular purposes, and restorationists can request seed that meets their needs. Seed collection protocols also vary slightly by purpose, with those for rare species differing slightly from those for more common species. Seed collection guidelines have been established by California Botanic Garden (Wall 2009), Society of Ecological Restoration (Pedrini et al 2020b), Bureau of Land Management (BLM 2021), US Department of Transportation (USDOT 2017), and in research (Armstrong et al. 2007; Espeland et al. 2017). These guidelines address the number of individuals to collect from, the number of collection sites within a seed zone to collect, how to avoid damaging a population, the number of seed to collect, and various methods to capture genetic diversity and avoid unintentional selection. RNGR has a database of species-specific collection protocols. Other results of research can be compiled and incorporated into the website and trainings.

Shared trainings for restoration practitioners and seed collection will have aspects that are transferable statewide, others that are regional or species-specific in nature, and others that are agency-specific. Transferable aspects of trainings can be held remotely, in concert with materials available on a website, allowing participants from around the state easy access to ongoing education. For online training, closed captioning and translation to as many languages as possible should be considered for accessibility. In
person training can be held in various parts of the state to allow broad access with regionally specific information, and training materials at least should be available in Spanish. Multiple agencies can collaborate on an in-person training to reduce costs, and have a breakout session or separate day that covers agency-specific information.

A sample of potential trainings by participants:

- **Seed collection**
  - Target species identification
  - Methods for seed collection team to ensure the genetic diversity within species is collected
  - Train-the-trainer seed collection program to make sure each person leading teams has been trained on the proper protocol for making high quality collections while having the least possible impact on wild plant populations
  - How to document collections: digital mapping and photos, paper datasheets and maps, herbarium specimen collection, and any matrilineal or other genetic separation needs and coding
  - Tools, techniques, and capacity building for seed collection; germination; and establishment of native plant communities

- **Land Managers**
  - Use of seed menus and other tools for land managers
  - Restoration planning: site assessment, species and seed selection, site preparation including weed control, installation/planting, goals and monitoring
  - Contracting and procurement (agency-specific, but should also cover lead time for contract growing and what to look for in seed testing and labeling)

- **Business owners**
  - Navigating the Federal procurement system, including their contracting criteria. The training and materials will encourage new entrants into the seed industry, as well as simplify the process for existing seed producers.
  - Permitting and documenting collections of wildland seed

- **General**
  - Promote and strengthen professional standards in all activities devoted to the use of genetically appropriate seed and ecological restoration
  - Seed certification - how and why

**Objective 3.2: Develop Native Seed Source Availability Data and Tools for Accessing the Data**

An inventory database of seed that identifies the type, province, location, quantity, and other characteristics of the seeds available throughout the state would allow purchasers to find appropriate seed. Often when there is not enough of a particular type of seed available to meet a contract, the agency or seller will supplement with something similar, but not what is called for in the specifications. However, a database of seeds would allow sellers and buyers to coordinate in order to best meet those contract specification.
Action 3.2: Invest in development of an inventory database.
Several existing websites currently list nurseries with seed available, and species lists as well: Institute for Applied Ecology, Calscape, Calflora and others. No current site provides functionality for producers to list inventory in such a way that source, amount available, and price could be shown in addition to taxon name. This could be tied to grower knowledge infrastructure, seed transfer zones, or other aspects useful to the overall seed strategy, such as protocols and training videos.

Objective 3.3: Build on Ecological Assessments and Disturbance Data, and Provide Training that will Allow Managers to Anticipate Needs and EstablishSpatially Explicit Contingency Strategies
As mentioned previously, better forecasting of where restoration is or may be needed will allow for proactive seed collection and growing, as well as potentially reduce the need for seed if land management can make areas more resilient to disturbances. Fire and fuels management has seen intense investment and growth over the past decade, and some of these tools are suitable for use in forecasting seed needs. Three broad categories of work can help with better prioritization and targeting of restoration work:

● Identify existing ecological assessments and disturbance data
  ○ GIS, remote sensing, climate-based modeling
● Develop/use tools based on existing data to help forecast needs with climate change, disturbances such as wildfire and flooding
● Building upon existing research, data, and tools, provide training to managers that will ensure their restoration projects prioritize strategies within the context of climate change and disturbances.

Action 3.3.1: Assess existing tools for suitability.
Tools such as Planscape focus on where interventions can reduce fire intensity, but also overlay biodiversity information and fire, climate, and other data. California’s 30x30 effort has compiled climate, biodiversity, and other layers at their CA Nature site. CNPS has highlighted Important Plant Areas throughout the state, which may help prioritize areas around which to restore. Each of these tools was built for a purpose other than forecasting restoration needs, so a determination should be made as to whether using one or more of these, building upon them, or creating a separate tool or training would be the proper choice.

Action 3.3.2: Train managers in forecasting.
After assessing existing information, a training module on best practices for assessing lands for restoration and cross-referencing with potential severe disturbances should be prepared.
Goal 4: Develop Strategies for Internal and External Communication

To successfully promote and encourage adoption of the California Native Seed Strategy, broad collaboration and engagement across agencies, stakeholders, and partners is needed. The communication strategy should target specific players in the industry, including specific agencies, producers, sellers, and other relevant stakeholders. Prioritizing feedback, creating a framework for evaluation and reporting of success of the Strategy will ensure it remains relevant as needs and effectiveness evolve over time.

Objective 4.1: Conduct Education and Outreach through the Seed Strategy Network

Nationally, communication and coordination work of the National Native Seed Strategy is led by the Plant Conservation Alliance Network (PCA), a public-private collaboration among 17 federal agency members and more than 400 non-federal cooperators sharing the same goal of protecting native plants by ensuring that native plant populations and their communities are maintained, enhanced, and restored. The California Seed Strategy’s steering committee of federal and nonprofit organizations are represented within the PCA, but California’s size and complexity necessitates its own structure for more localized, frequent and targeted communication. Regional nodes feeding to a coordinating group will allow for two-way communication, ensuring broad standards are met and successes (or learning opportunities) are shared.

Developing and implementing a communications plan successfully communicating the Strategy not only to a specific target audience, but to the wider public is key. A website with information should be partnered with targeted messaging to agencies, legislators and decisionmakers, producers, and the public.

Action 4.1.1: Distribute and implement the Strategy across partners and regions, and provide feedback mechanisms.

A point person or group should ideally be tasked with coordinating the steering committee/central convening group and hosting or maintaining regional groups. This should include having meetings on a monthly basis for the first year of implementation, and re-evaluating the meeting schedule afterwards. The point person or group could also coordinate trainings and other work under the strategy.

Action 4.1.2: Develop a Strategy website to organize information.

A California Seed Strategy website is key to providing information on all aspects of seed production and organizing regional groups, and as a way to introduce new partners to the work.

Action 4.1.3: Develop a communications plan.

A good communications plan will identify key target audiences, and the messages that motivate them to action or support, as well as what messengers they trust to deliver this type of information.

Objective 4.2: Report Progress, Recognize Achievements, and Revise Strategy

This strategy offers a suite of objectives, actions and recommendations for realizing a California Seed Strategy. A key part of any strategy is a way to measure progress toward goals, involve new partners and keep participants engaged, and revise the strategy as needed. A monitoring and improvement plan would involve developing and implementing a way to track metrics of success with the Strategy. Each objective and action would have one or more key metrics, how they will be measured, and how
frequently. After an appropriate interval, the steering committee should review and revise the Strategy accordingly, ideally tracking and making small adjustments annually to start and then every 5 years for major revisions.

**Action 4.2.1: Create agreed-upon metrics to measure progress.**

Regional groups and the steering committee should create metrics useful for measuring progress toward the goals, such as the following:

- Partners participating in the strategy (attendance at meetings, sign-ups on website)
- Interaction with website (page views, resource downloads)
- Resources available on website (by category)
- Actions completed (from strategy)
- Partner surveys

**Action 4.2.2: Review and revise strategy.**

Annual reviews of progress can help target additional actions. The strategy should be reviewed and revised by the five-year mark.
Priority Near-Term Actions Summary
Because actions under many of the objectives overlap, and some near-term actions are necessary to complete others, a brief summary is presented here.

<table>
<thead>
<tr>
<th>Action</th>
<th>Recommended Responsible Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate regional groups</td>
<td>CNPS</td>
</tr>
<tr>
<td>Create website and compile/add resources</td>
<td>CNPS</td>
</tr>
<tr>
<td>Research and create decision support tools for land managers</td>
<td>National Seed Strategy</td>
</tr>
<tr>
<td>Fund collection of additional ecotypes for use and bulking by multiple growers</td>
<td>WCB, Federal agencies</td>
</tr>
<tr>
<td>Coordinate bringing on additional growers</td>
<td>UC Cooperative Extension or NRCS</td>
</tr>
</tbody>
</table>
References


https://ucanr.edu/sites/Jackson_Lab/files/215941.pdf

https://www.fs.usda.gov/treesearch/pubs/37836


http://dx.doi.org/10.1111/j.1526-100X.1996.tb00101.x


https://doi.org/10.1525/california/9780520252202.003.0021


**List of Frequently Used Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAL FIRE</td>
<td>California Department of Forestry and Fire Protection</td>
</tr>
<tr>
<td>CCIA</td>
<td>California Crop Improvement Association</td>
</tr>
<tr>
<td>CDFA</td>
<td>California Department of Food and Agriculture</td>
</tr>
<tr>
<td>CDFW</td>
<td>California Department of Fish and Wildlife</td>
</tr>
<tr>
<td>CNPS</td>
<td>California Native Plant Society</td>
</tr>
<tr>
<td>NPS</td>
<td>National Park Service</td>
</tr>
<tr>
<td>NRCS</td>
<td>Natural Resource Conservation Science</td>
</tr>
<tr>
<td>RNGR</td>
<td>Reforestation, Nurseries, and Genetic Resources</td>
</tr>
<tr>
<td>SER</td>
<td>Society for Ecological Restoration</td>
</tr>
<tr>
<td>SI</td>
<td>Source Identified</td>
</tr>
<tr>
<td>UC</td>
<td>University of California</td>
</tr>
<tr>
<td>UC-ANR</td>
<td>University of California Agriculture and Natural Resources</td>
</tr>
<tr>
<td>USDA</td>
<td>United States Department of Agriculture</td>
</tr>
<tr>
<td>USFS</td>
<td>United States Forest Service</td>
</tr>
</tbody>
</table>