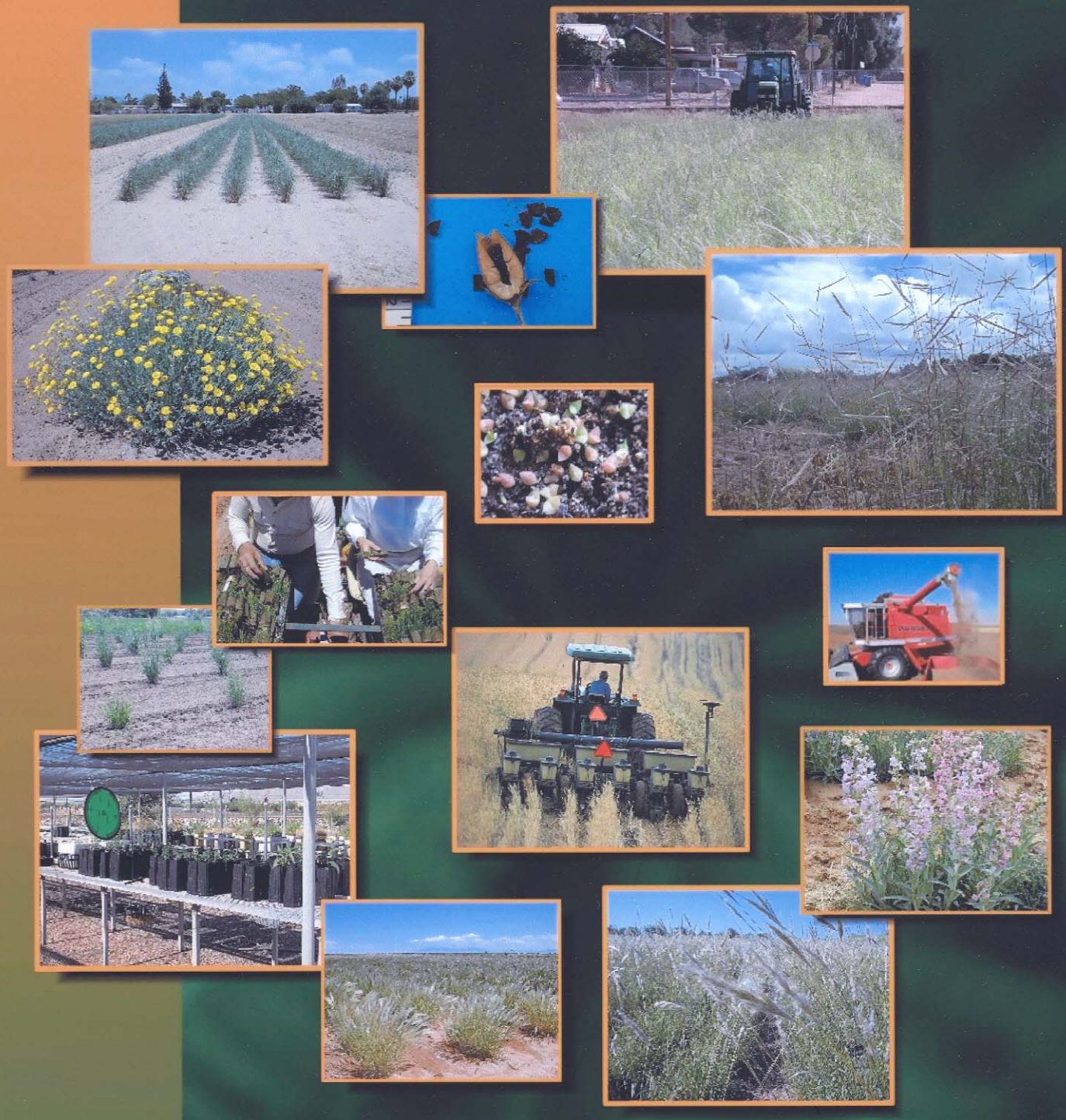

Native Seed Production

Tucson Plant Materials Center
in cooperation with
Coronado Resource Conservation and Development Area, Inc.

United States Department of Agriculture
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Introduction

During the late 1800's and early 1900's scientists and land users in southern Arizona began to pursue management practices to improve vegetative cover, increase forage production and reduce erosion. Early research on the Santa Rita Experimental Range found native plants to be more ecologically suitable to the Sonoran desert than the exotic species. However, by the 1930's the emphasis had shifted to the use of introduced species. These exotic species were planted extensively throughout southern Arizona. These species have spread aggressively wherever they were planted and have resulted in reductions in plant and animal diversity.

Over the past 20 years, interest has again turned to revegetating with native plant species. Revegetation along highway and pipeline right-of-ways, to reclaim mines and on a range of disturbed sites to reduce erosion and to reintroduce habitat is done almost exclusively with native plants. Native plants are also showing up in urban settings for aesthetic purposes as well as their low maintenance requirements. Desert shrubs, cacti and grasslands dominate the native vegetation in the Sonoran desert of Southern Arizona. This area consists of a diverse landscape with large areas of arid and semi-arid desert terrain.

What is a Native Plant?
Native or indigenous plants occur naturally in a particular region without direct or indirect human actions. These species are well adapted to local soil, rainfall and temperature conditions, and are tolerant to many insects and diseases. Native plants have evolved in concurrence with other biota in the area, to form a complex network of relationships. These plants are the basis of our native ecosystems.

Why Not Plant More Natives?

The explanations for not planting more natives are many and varied, but the following are the more common:

1) *Forage production* - a native plant's most important attribute is the ability to survive under harsh conditions. Consequently, deep and extensive root systems are more important than forage production. The exotic species may produce more forage, however it is often of a lesser quality.

2) *Seed production* – most native plants are guarded seed producers. The long-term survival of these species requires that more energy go into survival than into seed production. However, research into production of

natives has shown that with adequate moisture and fertility the seed yield of natives can be quite good.

3) *Seed shatter* - seed shatter can be an important advantage for native plants because it insures the dissemination of their seed. This trait can make seed hard to harvest. The development of new harvesting equipment has allowed for the harvest of native seed without excessive shattering.

4) *Seed quality* – seed quality refers to the ability of a plant to germinate and develop into a vigorous plant. Seed dormancy is often considered a negative seed attribute, however this is true only for initial establishment. Dormancy provides an advantage for the native plant seed by enabling it to survive in the soil over winter or for several years until growth conditions are ideal.

5) *Seedling vigor* – seedling vigor is normally measured on the above ground growth of the plant, but most native plants spend much of their first growing season putting down deep root systems to insure long-term survival, rather than expending energy on above ground vegetative growth.

Because of these perceived disadvantages, native seed production is only a small percent of the billion dollar grass seed industry in North America. Regardless of their inadequacies, native plants have a long list of attributes that make them outstanding conservation plants. These advantages including superior longevity, low input requirements, ecological diversity, wildlife habitat and the biggest advantage of all, thousands of years of adaptation to the environment of southern Arizona.

Native Plants are Specialty Crops

The production of native plant seed can be a challenge for the grower even though he/she may have experience with conventional agricultural crops. Native plants grown for seed production should be considered specialty crops. They require specific management and cultural practices to ensure success. Seed production of native plants, forbs, shrubs and trees can offer an opportunity for dedicated producers to develop a profitable enterprise. However, production of native conservation seed requires a long-term commitment. Unlike conventional crops such as wheat, cotton, and alfalfa, seed of conservation plants have

no real dollar value until sold to a seed distributor or to the end user. Individuals considering seed production as a farm enterprise should first determine species that are in demand and have a marketing strategy or production contract in place when the seed field is established.

SEED CERTIFICATION

Seed certification ensures high quality seed is distributed to seed growers and users. Certification protects the genetic identity of seed providing the user with a known pedigree and high germination and purity standards. This is achieved using Foundation (Generation 1) or Registered (Generation 2) seed, isolation of seed production fields, field inspection, and seed testing-analysis by certified seed laboratories under the jurisdiction of the state seed certification agency.

Seed producers should consider the production of certified seed. If a seed producer is not well established, certified seed may be more readily marketable. USDA-Natural Resources Conservation Service - Plant Materials Centers (PMCs), Agricultural Research Service (ARS) and others produce Foundation seed. Foundation seed is available to individuals through state crop improvement associations. Individuals in southern Arizona may purchase Tucson PMC foundation seed through the Arizona Crop Improvement Association or Los Lunas, NM PMC foundation seed through the New Mexico Crop Improvement Association. Registered and certified seed is available through local seed dealers and producers. Foundation seed must be planted to qualify for production of registered seed. Foundation or Registered seed must be planted to qualify for certified production. Certified seed cannot be used to produce any other class of certified seed. Certified seed can only produce common or uncertified seed. Producers of certified seed must comply with the rules of their state seed certification program; in Arizona, certification is managed by the Arizona Crop Improvement Association.

Alternative Plant Releases for Pedigreed (Certified) and Commercial Production

Most U.S. certified seed production utilizes the conventional certified seed classification system for native seed (i.e. breeders, foundation, registered and certified). However, an alternative certification system is available and is beginning to be used for native seed production. This alternative system allows

certification within four classes: source identified, selected, tested and cultivar. Native seed may be bought and sold with one of these four designations.

Source Identified: Seeds or plants from a naturally growing population occupying a known or defined geographic area. It has been through no selection or testing. Seeds for commercial sale may be collected directly from the wild stand or grown under cultivated conditions. This agronomically produced material should strive to be representative of the entire germplasm of the wild stand and have undergone no selection during the initial collection. This requires the collector to be diligent in taking a representative sample. Source identified seed may be certified by the seed certifying agency of the source state.

Selected: Seeds or plants shall be the progeny of phenotypically selected plants of untested parents. The seeds or plants will be produced to ensure genetic purity and identity from either natural stands or seed production areas. Selection may or may not be conducted on the selected material; if no selection is conducted, the plant material may be eligible for a "natural" designation on the certification label. Progeny of this material may produce offspring that are diverse and dissimilar from the parents.

Tested: Seeds or plants shall be the progeny of plants whose parentage has been tested and has proven genetic superiority or possesses distinctive traits for which the heritability is stable, as defined by the certifying agency. This material has been through additional testing on more than one generation on multiple sites. Replicated plots are used to verify performance and heritability of desirable traits. Selection may or may not be conducted on the selected material; if no selection is conducted, the plant material may be eligible for a "natural" designation on the certification label.

Cultivar: This plant material has been through replicated testing at multiple sites over two or more generations. This material is clearly distinguished by documented characteristics and when reproduced it will retain these characteristics. Testing has proven and documented the heritability of traits, performance and the range of adaptation.

The traditional seed classification system in the U.S. only recognized the cultivar seed class for both native and introduced plants and allowed the following seed increase generations: breeder, foundation, registered and certified. With the new classes the seed increase designations for the cultivar class

remain the same, but for the source identified, selected and tested classes, the seed increase generations are designated as Generation 1 (G1), Generation 2 (G2), etc.

General Principles of Native Seed Production

Selection and Preparation

Seed producers should consider only those species and varieties that are adapted to their area. It is also advisable to grow those varieties in greatest demand by land managers or the seed trade.

First time seed producers should select varieties that establish easily, have high seed yield potential, exhibit the least difficulty in maintaining row culture (bunch plants), and present the least difficulty in culture, establishment and management, seed harvesting, conditioning and storage.

Site Selection

Success in the establishment and maintenance of plants for seed production is closely correlated with soil type, slope, moisture regimes and other site factors. For consistently high production, choose the best land available and match the soil and site with the species to be grown. The best soils for growing native seed are well-drained sandy loams, loams, or silt loams, all of which allow for easy cultivation and the maintenance of optimal soil moisture conditions. Many native species will tolerate poorer soil conditions, but seed production potential can be limited. If the field is to meet seed certification standards, it must be isolated from other cultivars or native plants of the same species and it should not have produced a seed crop of the same species during the past two years.

Seed production fields should be as weed free as possible, especially from noxious weeds such as silverleaf nightshade, morning glory, bindweed, tumbleweeds, Bermuda grass, etc. Each state maintains a noxious weed list; the weeds on this list must be controlled. State seed certifying agencies may reject whole fields that are infested with plants on the state noxious weed list. Annual plants are always problematic in seed production fields. If the field is not clean, do not plant. Many weeds can be controlled in conjunction with seed production but this is not the way to start a production field. Fields must be adapted to irrigation without ponding or excessive erosion. Soil erosion by water can be a serious problem when producing seed in wide row spacing on rolling land. Select a level to gently sloping site for growing varieties in wide rows or plant on the contour to reduce soil erosion between rows. Rills and gullying between rows make harvesting very difficult. Runoff water from

heavy rains can carry seed from adjacent fields or field margins to another field, creating the potential for serious cross species contamination. Seed production fields must be located to avoid contamination by other species.

Site Preparation

Control measures to reduce or eliminate undesirable vegetation should be planned during site preparation and well in advance of seeding. It is essential to control competing vegetation before attempting to establish plants.

Inadequate weed suppression leads to more seeding failures than any other single factor. Fields that have not been tilled recently and contain annual or perennial weeds may require one or more years of intensive cultivation, herbicide treatment or both. If only tillage is used, numerous operations may be required. Selective herbicides are available and should be evaluated as alternatives to tillage.

Seedbed Preparation

Final seedbed preparation typically involves both shallow tillage and packing to produce a finely granulated, yet firm seedbed. Packing is essential to insure good soil to seed contact, and with the exception of heavy clay soils, it is difficult to over pack a seedbed. A good rule of thumb is that in an ideal seedbed a footprint will be no deeper than one-quarter inch. A firm seedbed facilitates the capillary movement of moisture to the seed and developing seedling. Allow the seedbed to set for a period following tillage and packing. Failure to provide a firm seedbed often results in non-uniform emergence and uneven stands which reduce seed production potential and encourage weed infestation.

One of the best ways to insure an ideal seedbed is to precede the seeding year by a season or partial season of summer fallow. Fallowing not only provides a firmly packed, finely granulated seedbed, but also allows full recharge of the soil moisture profile, enhances nutrient availability, allows rapid soil warming in the spring and reduces weed problems. Summer fallowing is not recommended on light soils that are prone to wind erosion or on steep slopes subject to water erosion.

With the development of zero and reduced tillage seeding equipment, it is becoming more common to plant native plants into standing cereal stubble. A major cause of establishment failures with slow establishing native plants is weed competition, especially annual weeds. Growing a cereal crop the

previous year provides a good opportunity for weed control. Planting the following spring with reduced or zero tillage, preceded by the application of a nonselective herbicide (e.g. glyphosate), usually results in excellent weed control. It is essential that surface residue be thinly and evenly distributed over the field to prevent uneven emergence of the small, non-vigorous grass seedlings.

Planting Dates

In irrigated fields, planting in August or September produce the best stands for seed production of most plants in southern Arizona. At the Tucson PMC, late summer (August and September) plantings are vigorous and have less weed problems. However, a spring planting may yield more seed in the first year after planting than late summer or early fall planting dates.

The most critical question when deciding on a planting date is, "Is there sufficient moisture for germination, emergence and seedling establishment?" Even with irrigation to supply water as needed, high temperature and windy conditions can quickly desiccate young seedlings.

Seeding Rate

Seeding equipment is no longer a major restriction in growing native plants. Equipment now available delivers seed at an accurate, uniform rate, places the seed at the proper depth and firms the soil around the seed. A seeding rate of 25 to 30 pure live seeds (PLS) per lineal foot (2 to 2.5 seeds per inch) of row provides a solid, uniform row of plants for species with less than 500,000 seeds per pound. Species with greater than 500,000 seeds per pound should be seeded at approximately 50 PLS per lineal foot (4 seeds per inch). Lower seeding rates may be recommended, however these rates may not provide good weed competition within the row or protect the planting from external factors (climate, etc.) which often limit establishment success. Enough seed must be planted to insure that the row is solid by the end of the second growing season. Since germination percentage for many native grass seed lots is below 80 per cent, seeding rates must be based on a pure live seed (PLS).

Broadcast seeding: Traditionally native seed producers have not used solid seeding. Recently, however, some producers have been successful using this approach in native grass seed fields. When solid seeding the seeding rate is increased. It is essential to follow the seeder with a harrow or packer to increase seed to soil contact. The greatest

limitation for solid seeding is providing adequate weed control without cultivation given that the number of herbicides registered for use on native plants is limited.

Seeding Depth

Native seed needs to be shallow seeded. Increasing the seeding depth reduces the percent emergence. The recommended seeding depths range from one quarter to one inch. Native plants evolved under a system without cultivation. There was little opportunity for soil incorporation and the mechanisms of germination and emergence developed without this influence. Shallow seeding becomes critical. It also allows leaf area to form quickly and prevents seed reserves from being exhausted as the seedling stretches for the soil surface.

The range in seeding depths is influenced by soil type and structure. Germination and emergence in heavier soils is more difficult due to increased bulk density of the soil and seeds should be planted in the one quarter to one-half inch range. The seeding rate may increase in lighter soils to one inch to insure adequate soil moisture for germination, emergence, and establishment. A seeding depth of one inch or greater will lead to non-uniform emergence and difficulties in both establishment and weed control. Seeding depth is also influenced by seed size, with smaller seeds planted shallower.

Soil to seed contact is the most essential element in establishing a productive field.

Row Spacing

Row spacing for native seed production generally ranges from 30 to 48 inches. Determining the ideal row spacing depends on a number of factors including:

1) the potential for inter-row cultivation

2) the plants growth type

3) irrigated or dryland production

4) planting equipment available.

Most native plants will yield higher in wider rows, compared to narrow rows and solid stands. Additionally, if the species being grown is for pedigreed seed, then wider rows makes it easier to rogue off types, to remove volunteer plants and to control weeds with inter row cultivation.

Plants, forbs and shrubs tend to react differently to wide row spacing versus solid or narrow row spacing. Wide row spacing generally produces higher seed yields over a longer time period. Row plantings require less seed per acre for desired stand establishment, and cultivation for weed control is possible when compared to a solid planting. Few herbicides are available and

labeled for forage seed crops. Undesirable or off-type plants can be identified and rogued from the field easier and volunteer plants from shattered seed or tillering from rhizomes can be controlled more effectively when planted in rows.

Fertilization

During Establishment: Fertilization is often not required or recommended for native plant establishment. The macronutrients phosphorus (P), potassium (K), and sulfur (S) are essential for development of the root system, but generally are not required unless a soil test indicates low levels. Since phosphorus does not move well within the soil profile, the recommendation is to incorporate enough P to last for 3 years. Applications of nitrogen are not recommended because nitrogen often tends to benefit annual grass and broadleaf weeds more than the slower growing native perennials. The safest seed placed fertilizer is pure phosphorus (0-46-0), some producers add low nitrogen fertilizer mixtures (11-48-0 or 11-51-0). Side-dressing or deep banding is an option during the first cultivation when using inter-row cultivation. Many new seed drills are designed to allow the application of fertilizer in side or deep bands, preventing fertilizer to seed contact. Another option is to apply 20 to 30 lbs/acre (22 to 34 kg/ha) of nitrogen at the 2 to 3 leaf stage. Applying more than 10 lbs/acre of actual N or K_20 with the seed may cause injury to seedlings.

Established stands: Typically, nitrogen rates for established stands range from 60 to 100 lbs/acre for irrigated fields. Excess N will promote lodging. Fertilizer applied to established stands can be side or deep banded between rows, normally 4 to 6 inches (10 to 15 cm) off center to ensure that roots have access to the immobile or less mobile nutrients being added.

The primary season for nitrogen application is in the late fall or in the early spring. If a seed stand is planted on a coarse textured soil where N leaching is possible, N fertilizer will be more efficient if applications are equally split between the late fall and early spring.

Weed Control

Weed control in native species can be difficult. In the seedling stage, many natives tend to be poor competitors. Little, if any, information is available on native plant herbicide tolerance, and there are few herbicides currently registered for use on natives. The limited acreage of natives has meant that little emphasis has been placed on the evaluation for herbicide tolerance.

Thus, the selection of a relatively weed free field and the control of weeds in crop during the year prior to the establishment is essential to reduce potential weed problems throughout the life of the native stand. Use of certified seed will dramatically reduce the chances of planting weed seed with the natives, thereby reducing the amount of competition within the row and further reducing the potential for future problems. It is essential to select fields and seed lots that contain no problem weeds. Practices such as zero tillage and low N fertility during early establishment will help suppress weed growth and competitiveness. Controlling perennial weeds in areas surrounding the seed field will also help reduce the weed pressure within the field.

The methods of weed control that are currently available to native seed producers are: mechanical control, herbicides and roguing.

1. *Mechanical Weed Control*

   Mechanical control involves the use of cultivation equipment to uproot weeds. Various forms of inter-row cultivation equipment are available including shovels, sweeps and rotary tillers. Inter-row cultivation can take place as soon as the rows of the plants are visible. Cultivation should be no closer than 1 to 1-1/2 inches to the row, so as not to disturb the seedlings. Cultivators can be equipped with row shields to prevent covering the seedlings with soil. Care must be taken to ensure that the emerging tillers are not cut off or buried by soil. Inter-row cultivation is also a valuable weed control practice on established stands. Cultivation should be shallow, ideally one to two inches deep, as cultivating too deep may cut off the fibrous roots of the native plants. Another benefit of inter-row cultivation is the restriction of rhizome growth in certain species. Restricting this growth keeps the seed production field from becoming sod bound. Mowing is another form of mechanical weed control. Mowing is especially effective where annual weeds are a problem. Annual weeds are killed when mowed at the proper stage of maturity and the perennial seedlings not only survive, but clipping usually encourages growth. It is essential to wait until the annual weeds are at an early seed head stage before mowing. If annual weeds are mowed too soon and the

growing point remains below mowing height, they often produce new tillers that grow close to the soil surface and create even greater competition than before mowing.

2. *Herbicides for Weed Control*

Herbicide application in seedling fields can sometimes begin as early as the 1 to 2 leaf stage. A delay in application can pose a problem because the efficiency of control decreases as the size of the weeds increase. Producers may use a nonselective herbicide like Roundup (glyphosate) before or immediately after seeding, but timing is critical to allow control of rapidly emerging weed species before the seedlings emerge. Another method of enhancing weed control in seedling stands is to charcoal band with the seed. A pre-emergent herbicide is then applied prior to emergence. The charcoal band, approximately 3 inches (7.5 cm) wide, is applied directly over the seed. It absorbs and neutralizes subsequent herbicide applications, thereby protecting the developing seedling. This method is being used with some of the higher valued perennial crops grown in the northwestern U.S.

On established fields, application of most other herbicides is recommended during the vegetative period when the plant is rapidly growing, but before it has reached the boot stage. Wicking or wiping with nonselective herbicides like Roundup (glyphosate) requires a height differential between the weeds and the crop in order to be effective. Wicking is effective on short species.

Registration of herbicides for use on native seed crops will not take place unless there is a concerted effort from producer groups to promote minor use registration. Trade names used in this document are solely to provide specific information. Mention of a trade name does not constitute a guarantee or endorsement.

Always check with appropriate state agencies for usage requirements of any pesticides.

3. *Roguing for Weed Control and Seed Purity*

Roguing is the physical removal of off-type plants of the same species,

plants of different species and weeds from a seed production field. Roguing is the most laborious and time consuming method of weed control. It is done by removing the plants either by hand or spot spraying the weeds with a nonselective herbicide. The removal of off-type plants and plants of other species is an important component in the production of pedigreed (certified) seed. Contamination of a pedigreed (certified) seed field by off-type plants results in the loss of genetic purity. Seed of other species or other cultivars in the harvested seed may result in the harvested seed lot being rejected for pedigreed (certified) status. Often there is zero tolerance for many weeds or even other crop kinds.

Wide row spacings will facilitate roguing by providing easier identification of undesirable plants and easier movement within the field.

Plants removed by hand, should be removed from the field to reduce the possibility of contamination during harvest. Chemical roguing may be accomplished using a nonselective herbicide to spray out individual weeds, other species and off-type plants. Chemical roguing is best accomplished prior to seed production because immature or nonviable seed will also lead to a downgrading of the seed lot.

Diseases and Insects on Native Plants

Little information is available on disease and insect damage of native plants. What is available is based on the observations of researchers in the field. The natural environment for most native plants is in mixed stands. This reduces the chance of inoculum buildup that is necessary for severe disease and insect infestations. The planting of the native plants in monoculture for seed production encourages the development of disease and insect problems.

Much more research and field observation is needed to control diseases and insect pests on native plants.

Seed Harvest

Time of harvest varies for each species. The timing of harvest for native plants also depends on their origin. Because of the short day photoperiod response of most native plants, plant material brought from southern regions will flower later when

moved northward.

Seed Maturity

Seed maturity varies among and within species. Seed maturity occurs over a period of time lasting from a few days to several weeks. The time from flowering (pollination) to mature seed takes 30 days or more. Wet, cool weather increases the number of days to maturity while dry, hot weather decreases the time to maturity. All plants go though the same stages of maturity; milk, soft dough, medium dough, hard dough and vitreous or mature. Seed harvested at the milk or soft dough stages usually shrivel when cured and show poor germination. Seed harvested at the hard dough to mature seed stage generally have the highest germination and greatest longevity in storage. Swathing at the medium dough stage may be used with shatter prone species, allowing the seed to mature for several days in the swath.

A major limiting factor for seed production of many native plants is a tendency for seed to shatter before or during harvest. Most plants do not hold seed long after maturity. Timing of harvest is critical for species prone to shattering. Successful growers inspect seed fields often to determine when the majority of seed are ripe. Compromise is often required in deciding when to harvest. The challenge is to harvest before shattering, but to wait for seed maturity to avoid yield losses from immature seed. There is a fine line between viable seed that will germinate and immature shriveled seed that is worthless.

Practical Harvesting Guidelines:

1. *Harvest when most of the seed is at the medium- to hard-dough stage or the mature seed stage. Thumbnail test: At the hard-dough stage, firm thumbnail pressure will be required to produce an imprint on the kernel.*
2. *The seed heads of most native plants ripen from the top down, a stand is ready to harvest when the tips of the seed heads begin to shatter.*
3. *If seed shatters when striking the seed head firmly against the palm, the grass seed stand is ready to combine.*
4. *Seed that shatters readily or are overly mature should be harvested during the early morning hours when the relative humidity is generally higher.*

Harvesting Techniques

***Direct combining*:** The advantage of direct combining is that the necessary equipment is available on many farms. It is the method of choice for short stature plants. The seed is harvested mature, but because there may be a range of maturity within a seed field, post harvest seed drying may be required. This operation requires less harvest time, when compared to swathing and then combining. The major risk with direct combining is that

the crop is left longer in the field, increasing the risk of crop loss due to inclement weather and/or seed shatter. Seed yields may be less than with swathing due to indeterminate ripening patterns.

Swathing and Combining is a rapid field operation because foliage is cured prior to combining. Retrieving the swath from the field may present problems. This occurs when swaths are small with short, sparse stubble or swaths have been rained on and become imbedded in the stubble. Seed quality declines when the swath has been rained on. There are many excellent pickup attachments on the market for combines.

Stripper Headers provide a new harvesting option. While these headers are costly, they are good for plants that do not have uniform maturity, for those with light and fluffy seeds or with long awns or seed pubescence. The header strips mature seed from the plant, leaving immature seed still attached. This allows the harvest operation to be repeated, resulting in a higher yield potential. This method does not work well for all plants. To be efficient, seed should be concentrated at a uniform height.

Timing of harvest is dependent on the harvest method. Swathing can begin when the seed is in the medium to hard dough stage, whereas direct combining requires seed in the hard dough to mature seed stage. Plants with high shatter potential should be swathed. The decision to either direct combine or swath will also depend on the amount of biomass produced. Harvesting is best when the humidity is low and temperature high. These conditions ensure separation of the seed from the head and reduce the need for post harvest drying. These conditions also cause the greatest amount of seed shattering. Seed should be threshed at 20 to 30 per cent moisture. Combines must be properly adjusted and carefully monitored to prevent physical damage or loss of seed. There is a delicate compromise between cylinder speed and concave setting to completely thresh seed without damage when using traditional combines.

Residue Management and Renovation

Residue should be removed after harvest to reduce disease pressure from stubble borne diseases and to shading of the crowns. Native plants require periodic renovation in order to maintain optimum vigor. Burning, grazing and haying are all methods used to rejuvenate native plants. Burning is extremely effective in completely removing crop residue. Grazing and haying are also

effective, however the residue must be removed without damaging the plants.

Chemical gapping is a less used renovation option. Strips are chemically removed, allowing room for new tiller initiation and growth from the remaining rows. Seed yield of rangeland blue grama has been increased 100% by using chemical gapping.

Every seed harvest contains contaminants such as weed seed, other crop seed and inert material such as stems, leaves and immature and broken seed. Depending on the harvest method, inert material can make up over 50 per cent of the bulk material received from the field. Impurities are separated from the seed based on physical properties such as size, weight, surface texture and shape. The greatest concern is weed seed with physical characteristics similar to the desired seed. The best, easiest and most economical way to produce clean seed is to keep the field weed free. Good cultural and management practices including spray programs, crop rotation, inter-row cultivation and rouging, minimize many serious weed and contaminant problems.

PROCESSING NATIVE SEED

Seed Cleaners and Separators

Seed cleaning machines use the physical properties of seed to separate the desirable from the undesirable. These machines can be used singly or in combination. The choice of machines and their sequence in processing depends on the seed being cleaned, the quantity of weed seed, contaminants in the mixture and the purity requirements. Following are brief descriptions of machines commonly used in a seed cleaning plant.

The Air-Screen Cleaner is the primary machine in a seed cleaning plant. It makes seed separations based on the physical properties of size, shape and density. There are many makes and models of air-screen cleaners. They rang from the small, one fan, single screen machine to the large, multiple fan, six or eight screen machine. Screens for these machines are manufactured with many sizes and shapes of openings. The typical air-screen cleaner found in a seed cleaning plant is a four screen machine located beneath a seed hopper. Seed flows by gravity from the hopper into a feeder that meters the seed mixture into an airstream, which removes the light chaffy material. The remaining seed is uniformly distributed over the top screens. The top screen removes large material, the second screen grades or sizes the seed, the third screen scalps the seed more closely and the fourth

screen performs a final grading. This finely graded seed is then passed through an airstream, which drops the plump, heavy seed, while blowing out light seed and chaff.

The Horizontal Screen Cylinder sizes products by width or thickness and is similar to a grader. Material introduced to the rotating cylinder either passes through the perforations or is discharged from the tail end.

Indent Disc and Indent Cylinder Separators cleans seed that have been size graded by width and thickness and can be further separated based on length differences. Length separators are of two general types the indent disk and the indent cylinder both use the principle of lifting short seeds from a mixture with an indentation that is too shallow to accommodate long seeds. The disc separator consists of a series of indented discs that revolve together on a horizontal shaft. As the discs revolve, the recessed pockets in the disks lift out the short seeds and reject the longer seeds. Indent cylinders use centrifugal force and length differences to lift material and make a length sizing separation. The indent cylinder consists of a rotating, horizontal cylinder and a movable, horizontal seriating trough. Seed is passed through the rotating cylinder, short seed is lifted from the seed mixture by indentations on the inside of the cylinder and dropped into an adjustable trough.

Specific Gravity Separators classify material according to density or specific gravity. Particles of the same size, but different densities, and particles of different size and same densities can be separated. The mixture to be separated is metered at a uniform rate to the back of the deck. The slant of the deck and its oscillating motion move the seed over the deck. Air forced through the porous deck causes the material to stratify in layers of different densities. Heavy material is moved uphill and light material downhill. Movable splitters divide the material into different density fractions.

Air Separators divide materials according to their terminal velocities. Air velocity through the machine can be adjusted by regulating the fan air intake. All products with a terminal velocity less than the air velocity will be lifted. Materials with the same terminal velocity as the air will float and objects with a higher terminal velocity will fall against the airflow. With adequate control of airflow and feed rate, precise separations can be made.

Velvet Roll Separator is a special seed cleaning machine that divides material by

differences in surface texture and shape. It consists primarily of pairs of velvet covered rollers placed side by side in contact with one another and set at an angle. The rolls rotate outwardly in opposite directions and have an adjustable shield above them. A seed mixture to be separated is fed onto the rolls at the upper end so that seed travels down the incline formed by the rolls. Rough coated seeds, sharp pointed seeds and broken seeds catch in the velvet and are thrown against the shield, which deflects them back to the roll. They bounce back and forth until they are worked over the roll and out of the mixture. Smooth coated seeds spin, work their way down the incline, and are discharged.

Seed Precleaning

Many seed lots are conditioned or precleaned before they enter the seed cleaning line. The primary machines used are scalpers, debearders, hammermills and huller scarifiers.

Scalping is a rough cleaning operation that screens off foreign material larger than the crop seed. The scalped material typically contains stems, green leaves, weed seeds, insects and trash. Removing this large bulk of waste early will reduce later handling and storage and improve cleaning efficiency. In addition, removal of trash and high moisture green material will lower drying costs and permit safer storage. There are many types and sizes of scalpers available. The most common is a simple two screen machine that removes large stems and leaves quickly and provides for the removal of inert material by basic air separation. The greatest benefits from a scalper come when it is the first machine used when seed comes in from the field.

Seed Conditioning

Many seed lots can be cleaned directly after scalping, while others may require further conditioning. A seed lot may contain untraced seed in the form of pods, heads, clusters or doubles. In addition, many native plants have hulls, awns, beards and/or pubescence. To minimize seed loss, unthreshed units must be broken down to single seeds, and awns should be removed for proper separation in the cleaning process.

The debearder consists of a horizontal beater assembly that rotates inside a steel drum. The beater is made up of a shaft with projecting arms that are pitched to move the seed through the drum. Stationary posts, adjustable for clearance with the arms, protrude inward from the drum to prevent

the seed from turning with the beater. This machine causes a vigorous rubbing of seeds, pods, heads and doubles against the arms, posts and each other. The time that seeds remain in the unit is varied by regulating a weighted discharge gate. The severity of action is controlled by exposure time, beater speed and clearance between beater arms and posts. Another type of debearder utilizes a cylinder made of exchangeable wire mesh and sets of beaters and brushes. An auger system moves the seed to the cylinder. The paddles and brush are pitched to move the seed through the cylinder. Debearding is accomplished by the action of the seed rubbing together and against the inside of the wire mesh cylinder.

The hammermill uses many finger-like hammers rotating inside a section of perforated metal screen. Seeds processed in the mill are subjected to vigorous beating or rolling action between the hammers and perforated screen that removes appendages and forces the seed through the screen holes. Results will depend on hammer speed, size of screen openings, feed rate and crop condition. Too large a screen will cause an excess amount of inert material and high percentage of awns not removed. Too small a screen will cause excess damage to the seed, decrease capacity and increase the length of the operation. When the speed is too fast, the seed is mutilated or cracked. When the speed is too slow, the awns are not completely removed.

Hullers and Scarifiers are used after scalping and sometimes debearding when many kinds of seeds can be cleaned without further conditioning. However, certain legumes and plants may require hulling, scarifying or both. Hulling is the removal of an outer coat or husk to improve the seeds cleaning characteristics or its planting qualities. With the husk removed, the seed is more readily handled in both cleaning and planting equipment, and in some cases, husks are impermeable to water and thus prevent germination. In scarification, the seed coat itself is scratched or ruptured. Hullers and scarifiers usually abrade the seeds between two rubber faced surfaces or against roughened surfaces like sandpaper or carborundum. Some kinds of seed lose viability quickly after being hulled or scarified; therefore this should be delayed until shortly before planting time.

Seed Storage

The stage of maturity at harvest will affect seed viability and longevity. Seed that is too wet for immediate storage can be slowly dried with warm air, bringing the moisture

down to 15 per cent before storage. Care must be taken not to use air temperatures above 108^0 F to dry the seed. Doing so will cause reduced viability or the death of the seed. To maintain viability, native seed should be stored in bulk at 10 to 12 per cent moisture and in bags at 12 to 15 per cent moisture. Seed with a long dormancy period, may require a period in storage of 14 to 18 months in order to completely break dormancy. When environmental conditions are not controlled during storage, these native plants will reach their maximum germination 2 to 3 years following harvest and maintain a high level of viability for 3 to 6 years. Seed should be stored under carefully controlled environmental conditions to maintain viability over long periods. To maintain existing viability, seed has to be stored cool and with low relative humidity. The rule of thumb is that the sum of the air temperature and relative humidity should be less than 100 to provide a suitable long-term storage environment.

FUTURE POTENTIAL

Much of the current market for native seed is through contract seed production or bulk purchase by end users, such as government agencies, wildlife organizations, mining companies and highway departments. The remainder is through the sale of smaller quantities of seed to the public for small scale plantings and even for ornamental purposes. The price of seed is dependent upon the species. The price of seed is determined by the ease of production and the demand for the seed. The production of common seed (seed harvested from natural sites or seed produced from noncultivar sources) is still prevalent for most species.

In general, the quality of native seed has been below the standards set for introduced forage plants. The adoption of the pedigree (certified) seed production system for native seed is being encouraged and will hopefully have the effect of increasing seed quality. Increasing the quality of native seed should also increase the ease of establishment and therefore increase demand.

The greening of the public has led to an increased demand for native plant material. The reclamation of marginal agricultural lands has become more prevalent as sustainability of the agricultural land base has increased in importance. These factors should help to provide a steady market demand for native seed.

Market opportunities for expansion of the native seed industry need to be explored. Increasing the use of native plants in

mainstream agriculture (e.g. pastures and rangelands) would increase the demand for seed. Recent investigations into the use of native plants for energy production may also increase demand for some native plants.

Expanding the native seed market into the urban market may increase seed demand. Native plants for turf plantings are being evaluated by many turfgrass breeding companies and at several research institutions. Both warm and cool season plants are being investigated for their performance under low turf maintenance conditions, as well as for their seed production potential.

At present, the native seed production industry is relatively small. The quantity of seed that is required to meet the North American demand for some species can be produced by a single producer on limited acreage. Many current producers have entered the industry through their own interest in preserving native materials and habitats. The growth of the industry will depend upon an increase in the demand for seed and the willingness of the present producers to share their knowledge, much of which has been independently acquired. The amount of research focused on native seed production will depend largely upon funding from the native seed industry. A coordinated effort is needed to link producers, extension agents and researchers in order to accumulate, organize and disseminate any available information as well as to identify areas of priority for future research.

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Seed Production Guidelines

Arizona Cottontop (*Digitaria californica*)

SEED WEIGHT: 615,000/lb.

SEEDING RATE: (Pure Live Seed)
30 seed per linear foot of row

38 in. spacing = 0.7 lb/acre
24 in. spacing = 1.1 lb/acre

ROW SPACING: 24 to 38”

***Note**: Narrower row spacing may be used forfeiting inter-row cultivation, but seed yields and stand longevity may be reduced.*

PLANTING DATE: Late Summer (August) to early fall (September)

WEED CONTROL:

During Establishment: Plant in a field where weeds have been controlled by summer fallow or a broad spectrum herbicide during the previous 1 to 2 years. Wait until the 3 to 5 leaf stage before applying herbicides and then use low rates.

Established Stand: Herbicides labeled for seed production, such as 2,4-D and various preemergents. Hand rouging and cultivation.

Note: Always apply pesticides according to the label.

FERTILIZATION:

During Establishment: Not recommended

Established Stand: Apply nitrogen at 40 to 60 lbs/acre. Apply phosphorus and potassium according to soil test results

IRRIGATION:

During Establishment: Apply enough water to get stand established. Keep soil surface moist to avoid crusting. Bring soil moisture to field capacity in late fall.

Established Stand: Bring soil moisture to field capacity in late fall. Irrigate in spring through the boot stage if rainfall does not provide sufficient moisture for continued plant growth. (soil moisture should be about 50% of field capacity). Irrigation should be avoided during flowering (pollination), but good soil moisture is essential during seed development. Irrigation is not usually necessary during seed ripening.

*Note: **Never** allow plants to be moisture stressed while flowering or while immature seed heads are forming*

HARVEST:

Average Date in Tucson, AZ: Arizona cottontop produces multiple crops per year. The first harvest may be as early as June

Lodging: None

Stripping: Preferred method

Stage: hard dough to mature seed

Brush Speed: 350 to 400 rpm

Direct Combine: not advisable due to the forage being green at time of seed maturity

Swathing/Windrowing: Unknown

SEED PROCESSING:	Seed may need to dry after harvest. Seed is then processed with a brush machine to remove fluffy material and then processed through an air screen cleaner.
EXPECTED PRODUCTIVE STAND LIFE:	10 to 15 years if soil fertility is maintained
ADDITIONAL COMMENTS:	Arizona cottontop will produce multiple seed crops each year. After seed harvest the forage is mowed, fertilizer applied and irrigated. Plant at the Tucson Plant Materials Center will produce another seed crop in 6 to 8 weeks.

Cane Bluestem (Beardgrass) (*Bothriochloa barbinodis*)

SEED WEIGHT: 754,000/lb.

SEEDING RATE: (Pure Live Seed)
30 seed per linear foot of row

38 in. spacing = 0.5 lb/acre
24 in. spacing = 0.9 lb/acre

ROW SPACING: 24 to 38”

***Note**: Narrower row spacing may be used forfeiting inter-row cultivation, but seed yields and stand longevity may be reduced.*

PLANTING DATE: Late Summer (August) to early fall (September)

WEED CONTROL:

During Establishment: Plant in a field where weeds have been controlled by summer fallow or a broad spectrum herbicide during the previous 1 to 2 years. Wait until the 3 to 5 leaf stage before applying herbicides and then use low rates.

Established Stand: Herbicides labeled for seed production, such as 2,4-D and various preemergents. Hand rouging and cultivation.

Note: Always apply pesticides according to the label.

FERTILIZATION:

During Establishment: Not recommended

Established Stand: Apply nitrogen at 40 to 60 lbs/acre. Apply phosphorus and potassium according to soil test results

IRRIGATION:

During Establishment: Apply enough water to get stand established. Keep soil surface moist to avoid crusting. Bring soil moisture to field capacity in late fall.

Established Stand: Bring soil moisture to field capacity in late fall. Irrigate in spring through the boot stage if rainfall does not provide sufficient moisture for continued plant growth. (soil moisture should be about 50% of field capacity). Irrigation should be avoided during flowering (pollination), but good soil moisture is essential during seed development. Irrigation is not usually necessary during seed ripening.

*Note: **Never** allow plants to be moisture stressed while flowering or while immature seed heads are forming*

HARVEST:

Average Date in Tucson, AZ: July to August

Lodging: Moderate

Stripping: Preferred method

Stage: hard dough to mature seed

Brush Speed: 250 to 300 rpm

Direct Combine: not applicable due to forage being green at harvest

Swathing/Windrowing: satisfactory

SEED PROCESSING:	Seed may need to dry after harvest. Seed is then processed with a brush machine to remove fluffy material and then processed through an air screen cleaner.
EXPECTED PRODUCTIVE STAND LIFE:	10 to 15 years if soil fertility is maintained
ADDITIONAL COMMENTS:	Cane Bluestem will produce multiple crops per year in Tucson, AZ. Forage height may cause problems when harvesting, to reduce height at harvest mow the grass early in the season, when it begins to flower.

Plains Bristlegrass (*Setaria macrostachya*)

SEED WEIGHT: 293,000/lb.

SEEDING RATE: (Pure Live Seed)
30 seed per linear foot of row

38 in. spacing = 1.4 lb/acre
24 in. spacing = 2.2 lb/acre

ROW SPACING: 24 to 38”

***Note**: Narrower row spacing may be used forfeiting inter-row cultivation, but seed yields and stand longevity may be reduced.*

PLANTING DATE: Late Summer (August) to early fall (September)

WEED CONTROL:

During Establishment: Plant in a field where weeds have been controlled by summer fallow or a broad spectrum herbicide during the previous 1 to 2 years. Wait until the 3 to 5 leaf stage before applying herbicides and then use low rates.

Established Stand: Herbicides labeled for seed production, such as 2,4-D and various preemergents. Hand rouging and cultivation.

Note: Always apply pesticides according to the label.

FERTILIZATION:

During Establishment: Not recommended

Established Stand: Apply nitrogen at 40 to 60 lbs/acre. Apply phosphorus and potassium according to soil test results

IRRIGATION:

During Establishment: Apply enough water to get stand established. Keep soil surface moist to avoid crusting. Bring soil moisture to field capacity in late fall.

Established Stand: Bring soil moisture to field capacity in late fall. Irrigate in spring through the boot stage if rainfall does not provide sufficient moisture for continued plant growth. (soil moisture should be about 50% of field capacity). Irrigation should be avoided during flowering (pollination), but good soil moisture is essential during seed development. Irrigation is not usually necessary during seed ripening.

*Note: **Never** allow plants to be moisture stressed while flowering or while immature seed heads are Forming*

HARVEST:

Average Date in Tucson, AZ: late fall

Lodging: None

Stripping: satisfactory

Stage: hard dough to mature seed

Brush Speed: 300 to 400 rpm

Direct Combine: preferred method

Swathing/Windrowing: unknown

SEED PROCESSING:	Seed may need to dry after harvest. Seed may need to be processed with a brush machine or a hammermill. Basic cleaning is through an air screen cleaner.
EXPECTED PRODUCTIVE STAND LIFE:	10 to 15 years if soil fertility is maintained
ADDITIONAL COMMENTS:	Germination of Plains Bristlegrass may be increased by pre-chilling. Therefore, in planting a production field it may be beneficial to plant in early winter for a natural chilling of seed. If seed is planted in the winter irrigation will need to be applied if there is no winter precipitation.

Purple Threeawn (*Aristida purpurea*)

SEED WEIGHT: 250,000/lb.

SEEDING RATE: (Pure Live Seed)
30 seed per linear foot of row

38 in. spacing = 1.6 lb/acre
24 in. spacing = 2.6 lb/acre

ROW SPACING: 24 to 38”

***Note**: Narrower row spacing may be used forfeiting inter-row cultivation, but seed yields and stand longevity may be reduced.*

PLANTING DATE: Late Summer (August) to early fall (September)

WEED CONTROL:

During Establishment: Plant in a field where weeds have been controlled by summer fallow or a broad spectrum herbicide during the previous 1 to 2 years. Wait until the 3 to 5 leaf stage before applying herbicides and then use low rates.

Established Stand: Herbicides labeled for seed production, such as 2,4-D and various preemergents. Hand rouging and cultivation.

Note: Always apply pesticides according to the label.

FERTILIZATION:

During Establishment: Not recommended

Established Stand: Apply nitrogen at 40 to 60 lbs/acre. Apply phosphorus and potassium according to soil test results

IRRIGATION:

During Establishment: Apply enough water to get stand established. Keep soil surface moist to avoid crusting. Bring soil moisture to field capacity in late fall.

Established Stand: Bring soil moisture to field capacity in late fall. Irrigate in spring through the boot stage if rainfall does not provide sufficient moisture for continued plant growth. (soil moisture should be about 50% of field capacity). Irrigation should be avoided during flowering (pollination), but good soil moisture is essential during seed development. Irrigation is not usually necessary during seed ripening.

*Note: **Never** allow plants to be moisture stressed while flowering or while immature seed heads are forming*

HARVEST:

Average Date in Tucson, AZ: May to July

Lodging: Moderate

Stripping: Preferred method

Stage: hard dough to mature seed

Brush Speed: 200 to 250 rpm

Direct Combine: satisfactory

Swathing/Windrowing: satisfactory

SEED PROCESSING:	Seed may need to dry after harvest. Conditioning following harvest consists of hammermilling at moderate speed to remove awns, followed by air-screen separator. Care is needed to avoid damaging the seed while removing the awn.
EXPECTED PRODUCTIVE STAND LIFE:	10 to 15 years if soil fertility is maintained
ADDITIONAL COMMENTS:	Purple threeawn has awns that make it difficult to broadcast or drill seed. Awned seed can be easily hydroseeded. De-awing the seed would improve seeding options, but may reduce seed quality. A seed drill would need a fluffy seed agitator and large drop tubes to seed purple threeawn.

Spike Dropseed (*Sporobolus contractus*)

SEED WEIGHT: 1,750,000/lb.

SEEDING RATE: (Pure Live Seed)
30 seed per linear foot of row

38 in. spacing = 0.25 lb/acre
24 in. spacing = 0.37 lb/acre

ROW SPACING: 24 to 38”

***Note**: Narrower row spacing may be used forfeiting inter-row cultivation, but seed yields and stand longevity may be reduced.*

PLANTING DATE: Late Summer (August) to early fall (September)

WEED CONTROL:

During Establishment: Plant in a field where weeds have been controlled by summer fallow or a broad spectrum herbicide during the previous 1 to 2 years. Wait until the 3 to 5 leaf stage before applying herbicides and then use low rates.

Established Stand: Herbicides labeled for seed production, such as 2,4-D and various preemergents. Hand rouging and cultivation.

Note: Always apply pesticides according to the label.

FERTILIZATION:

During Establishment: Not recommended

Established Stand: Apply nitrogen at 40 to 60 lbs/acre. Apply phosphorus and potassium according to soil test results

IRRIGATION:

During Establishment: Apply enough water to get stand established. Keep soil surface moist to avoid crusting. Bring soil moisture to field capacity in late fall.

Established Stand: Bring soil moisture to field capacity in late fall. Irrigate in spring through the boot stage if rainfall does not provide sufficient moisture for continued plant growth. (soil moisture should be about 50% of field capacity). Irrigation should be avoided during flowering (pollination), but good soil moisture is essential during seed development. Irrigation is not usually necessary during seed ripening.

*Note: **Never** allow plants to be moisture stressed while flowering or while immature seed heads are forming*

HARVEST:

Average Date in Tucson, AZ: late September to October

Lodging: Moderate

Stripping: Satisfactory

Stage: hard dough to mature seed

Brush Speed: 350 to 400 rpm

Direct Combine: Preferred

Swathing/Windrowing: Unknown

SEED PROCESSING:	Seed may need to dry after harvest. Seed is then processed through an air screen cleaner.
EXPECTED PRODUCTIVE STAND LIFE:	10 to 15 years if soil fertility is maintained
ADDITIONAL COMMENTS:	Seed of spike dropseed ripens indeterminately, however most of the seed spike is enclosed in a sheath that will protects the seed from shattering. Harvest may be delayed until the plant is dormant in the fall without severe seed loss.

Tanglehead (*Heteropogon contortus*)

SEED WEIGHT: 181,000/lb.

SEEDING RATE: (Pure Live Seed)
30 seed per linear foot of row

38 in. spacing = 2.3 lb/acre
24 in. spacing = 3.6 lb/acre

ROW SPACING: 24 to 38”

***Note**: Narrower row spacing may be used forfeiting inter-row cultivation, but seed yields and stand longevity may be reduced.*

PLANTING DATE: Late Summer (August) to early fall (September)

WEED CONTROL:

During Establishment: Plant in a field where weeds have been controlled by summer fallow or a broad spectrum herbicide during the previous 1 to 2 years. Wait until the 3 to 5 leaf stage before applying herbicides and then use low rates.

Established Stand: Herbicides labeled for seed production, such as 2,4-D and various preemergents. Hand rouging and cultivation.

Note: Always apply pesticides according to the label.

FERTILIZATION:

During Establishment: Not recommended

Established Stand: Apply nitrogen at 40 to 60 lbs/acre. Apply phosphorus and potassium according to soil test results

IRRIGATION:

During Establishment: Apply enough water to get stand established. Keep soil surface moist to avoid crusting. Bring soil moisture to field capacity in late fall.

Established Stand: Bring soil moisture to field capacity in late fall. Irrigate in spring through the boot stage if rainfall does not provide sufficient moisture for continued plant growth. (soil moisture should be about 50% of field capacity). Irrigation should be avoided during flowering (pollination), but good soil moisture is essential during seed development. Irrigation is not usually necessary during seed ripening.

*Note: **Never** allow plants to be moisture stressed while flowering or while immature seed heads are forming*

HARVEST:

Average Date in Tucson, AZ: Tanglehead produces multiple crops per year. The first harvest may be as early as June.

Lodging: Moderate

Stripping: Preferred method

Stage: hard dough to mature seed

Brush Speed: 200 to 250 rpm

Direct Combine: not advisable due to the forage being green at time of seed maturity

Swathing/Windrowing: Unknown

SEED PROCESSING:	Seed may need to dry after harvest. Conditioning following harvest consists of hammermilling with a 1/8 screen at moderate speed, followed by air-screen separator. Seed storage life is approximately four years.
EXPECTED PRODUCTIVE STAND LIFE:	10 to 15 years if soil fertility is maintained
ADDITIONAL COMMENTS:	Tanglehead is difficult to harvest and clean. Hand-stripping is the most effective way to harvest seed. Because of the difficulty in cleaning seed, it may be easier to bail the material when seed is ripe. The seed may be planted on conservation sites by spreading the seed containing straw and incorporating it into the soil.

Appendix I
Helpful Calculations

Pure Live Seed

$$\frac{\text{\% purity} \times \text{\% germination}}{100}$$

Calibrating Seeding Equipment (Wheel Turn and Catch Method)

This method is used to calibrate equipment before going to the field.

1. Measure the circumference of the drive wheel of the planter.

   Circumference = diameter of a circle X 3.1416

2. Determine the number or revolutions of the wheel to collect seed from 0.1 acre.

   $$\frac{(43{,}560/\text{drill width}) \ / \ 10}{\text{(wheel circumference)}}$$

   example: 8ft drill and wheel circumference of 7 feet requires 77.8 revolutions to equal 0.1 acre

   43,560/8 = 5,445

   5,445/10 = 544.5

   544.5/7 = 77.8

3. Put seed in the drill and elevate the drive wheel so it can be turned by hand when the drill is engaged

4. Collect seeds from each opening while turning the wheel the required number of revolutions.

5. Calculation: seed weight (lb) X 10 = lb/acre

Seeding Density (seed/ft) Equation

Seed/ft X sq. ft in acre/ number of seed in a pound

For planting in rows sq. ft/acre is calculated:

38 in row spacing = 43,560/3.16 = 13,784 ft of planted area in 1 acre

24 in row spacing = 43560/2 = 21,780 ft of planted area in 1 acre

example: 5 acres seeded at 30 seed/foot at 24 in. row spacing of species with 300,000 seed per

30 X 21,780 = 653,400 seed/acre

lb of seed/acre = 653,400/300,000 = 2.18 lb/acre