SMOOTH CORDGRASS

Spartina alterniflora Loisel.

Plant Symbol = SPAL

Common Names: oystergrass; salt cane; salt cordgrass; saltmarsh cordgrass; saltwater cordgrass; smooth cordgrass

Scientific Names: *Spartina alterniflora* Loisel; *Spartina alterniflora* var. *glabra* (Muhl. ex Bigelow) Fernald; *Spartina alterniflora* var. pilosa (Merr.) Fernald; *Sporobolus alterniflorus* (Loisel.) P.M. Peterson & Saarela

Caution: This plant may become invasive - U.S. West Coast.

Figure 1: Smooth cordgrass (Spartina alterniflora).

Description

General: Smooth cordgrass is an herbaceous, native, warm season grass that forms dense vegetative colonies along shorelines and intertidal flats in coastal wetlands. Smooth cordgrass is a robust, rapidly spreading plant, tolerant to fluctuating water depths and salinity. Smooth cordgrass spreads primarily by vegetative propagation, producing new stems from an extensive system of long hollow rhizomes. Soft, spongy stems up to 0.5 inch in diameter emerge from the rhizomes. Plant height will vary according to site conditions, but generally will range from 24 to 72 inches. The flat leaf blades are typically 12 to 20 inches long, tapering to a long inward-rolled tip. In September and October, seedheads which are 10 to 12 inches long, emerge at the end of the stem. Each spike holds from 12 to 15 spikelets 2 or 3 inches in length. The flowers are wind pollinated.

Distribution: Generally, this species occurs in the coastal states along the U.S. It is commonly found growing on open coastal marshes between high and low tides from Newfoundland south to Florida and Texas (Bush and Houck, 2002). It is not native on the West Coast.

For current distribution, please consult the Plant Profile page for this species on the PLANTS Web site.

Habitat: Colonies tend to grow parallel to and continuous along shorelines; the width and thickness of a vegetative colony is controlled by a number of site-specific conditions such as plant competition, elevation, shoreline slope and frequency, depth, and duration of flooding. In southeastern swamps and salt marshes, smooth cordgrass commonly grows in association with black mangrove (*Avicennia germinans*), red mangrove (*Rhizophora mangle*), turtleweed (*Batis maritima*), saltgrass (*Distichlis spicata*), and needlegrass rush (*Juncus roemerianus*) (Penfound, 1952). In coastal New England, smooth cordgrass often borders and protects cobble beach plant communities composed of annual seepweed (*Suaeda linearis*), salt sandspurry (*Spergularia marina*), lavender thrift (*Limonium carolinianum*), and Virginia glasswort (*Salicornia depressa*). In Mid-Atlantic low salt marshes, smooth cordgrass often grows in association with saltmeadow rush (*Juncus gerardii*), salt meadow cordgrass (*Spartina patens*), perennial saltmarsh aster (*Aster tenuifolium*), Virginia saltmarsh mallow (*Kosteletzkya virginica*), and sweetscent (*Pluchea odorata*) (Collins and Anderson, 1994; Bruno and Kennedy, 2000). Commonly associated species in Mid-Atlantic high salt marshes include Jesuit's bark (*Iva frutescens*), eastern baccharis (*Baccharis halimifolia*), northern bayberry (*Morella pensylvanica*), big cordgrass (*Spartina cynosuroides*), sturdy bulrush (*Bolboschoenus robustus*), seaside goldenrod (*Solidago sempervirens*), coast cockspur grass (*Echinochloa walteri*), beaked spikerush (*Eleocharis rostellata*), spear saltbush (*Atriplex patula*), saltmarsh false foxglove (*Agalinis maritima*), and rose of Plymouth (*Sabatia stellaris*) (Collins and Anderson, 1994).

Adaptation

Smooth cordgrass is an intertidal brackish plant species that will tolerate fluctuating water levels. Aerenchyma formation is significantly increased in smooth cordgrass roots under flooded conditions which likely contributes to the species' adaptation to oxygen deficient environments via reduced metabolic oxygen requirements (Maricle and Lee, 2002; Maricle and Lee, 2007). Smooth cordgrass is described as a facultative halophyte; that is, it will tolerate salt, but salt is not a requirement for its growth. Smooth cordgrass establishes in freshwater; however, numerous field trials have demonstrated smooth cordgrass is difficult to establish and will not persist under freshwater field conditions. The ideal salinity range for establishing and growing smooth cordgrass is 8 to 33 parts per thousand or brackish to saline habitats. Smooth cordgrass establishes and persists in areas of elevated salinity (such as salt flats and tidal lagoons); however, plants in high saline habitats tend to be stubby and less robust, generally resulting in thinner and more open vegetative stands.

Smooth cordgrass is adapted to a wide range of soils from coarse sands to clays and mucks. Plant establishment and productivity appear to be superior on heavier mineral soils such as mucky clays, silty clays, silty clay loams, and fine sands. This grass occurs on sandy aerobic or anaerobic soils with pH ranging from 3.7 to 7.9. Soils with very high levels of organic matter pose structural problems and have proven to be problematic in establishing stands of smooth cordgrass (USDA-NRCS, 2018).

Uses

Coastal & Shoreline Restoration: Smooth cordgrass is a unique plant species when established properly and under applicable conditions has proven to provide significant erosion protection to shorelines, canal banks, and other areas of coastal wetland loss.

Smooth cordgrass is used primarily for erosion control along shorelines, canal banks, levees, and other areas of soil-water interface. In addition, smooth cordgrass is an effective soil stabilizer used on interior tidal mudflats, dredge-fill sites, and other areas of loose and unconsolidated soils associated with marsh restoration. When established in conjunction with shorelines, smooth cordgrass provides an effective buffer that dissipates energy, reduces shoreline scouring, and traps suspended sediments and other solids. Dense stands of smooth cordgrass are efficient users of available nutrients, producing significant amounts of organic matter. The cumulative effects of organic matter production, sediment trapping, and erosion control not only provide shoreline protection but also accelerate sediment accumulation and near-shore building (Broome, Woodhouse, and Seneca, 1974). Consequently, smooth cordgrass is a sustainable and renewable restoration resource, and when properly established and in the appropriate habitat, will persist and potentially remain effective indefinitely (Craft, Reader, Sacco, and Broome, 1999).

Smooth cordgrass will tolerate petroleum contaminated soils to a degree making it useful as a phytoremediation species. Lin and Mendelssohn (1998) demonstrated that smooth cordgrass can be successfully transplanted and established into an oil contaminated marsh setting with a soil oil concentration up to 250 mg/g. Their trials showed that fertilizer applications significantly increased plant biomass which may have contributed to the reported acceleration of oil degradation in the soil. Lindau et al. (1999) conducted in situ trials which supported the claims of smooth cordgrass tolerance for exposure to petroleum products. Additionally, their trials showed that smooth cordgrass was also tolerant of burning of applied crude oil. Given their findings, researchers suggested that under appropriate conditions burning could be considered as a viable, quick response oil spill remediation option for smooth cordgrass dominated wetlands to minimize oil migration.

Wildlife: Smooth cordgrass provides food and habitat to a variety of marsh, wetland, aquatic, and other wildlife species. Smooth cordgrass is a critical source of food for the federally threatened West Indian manatee (Zoodsma and Bratton, 1988). Manatees are protected under both the Endangered Species Act and the Marine Mammal Protection Act (USFWS, 2019). The greater snow goose frequently grazes on smooth cordgrass dominated coastal salt marshes from New Jersey to North Carolina during winter months (Lefebvre et al., 2017). The spring and summer diet of the feral horses of Shackleford Banks, North Carolina (Cape Lookout National Seashore, National Park Service) is substantially constituted (≈ 20%) of smooth cordgrass (Pratt-Phillips et al., 2011). Smooth cordgrass also provides shelter and a food source to nutria and muskrats (DeLaune, Nyman, and Patrick, 1994). Additionally, sheep, cattle, deer, rats, and rabbits have all been observed feeding on smooth cordgrass (Ranwell, 1961).

Ribbed mussels form facultative mutualistic relationships with smooth cordgrass in areas where the two species share habitats. Smooth cordgrass aboveground and belowground production is stimulated by physical and chemical effects of ribbed mussel presence resulting in increased grass height, biomass, and flowering. Mussels attach themselves to smooth cordgrass stems and roots via protein based byssal threads protecting the root mat from erosion and allowing further vegetative spread. As a byproduct of filter feeding, mussels deliver nitrogenous rich fecal material onto the smooth cordgrass root mat supplying additional nutrients (Bertness, 1984). Mussels have a documented benefit from the relationship in the form of increased individual weight gain and reduced mortality (Stiven and Kuenzler, 1979). A facultative mutualistic relationship between smooth cordgrass and the mud fiddler crab has also been documented. The formation of smooth cordgrass root mats in soft substrates provides structural support to create burrowing habitat for the fiddler crab. The burrowing activity increases soil drainage, soil oxidation-reduction potential, and belowground plant debris decomposition resulting in increased aboveground biomass production, stem height, flowering, and stem density (Bertness, 1985). The gastropod marsh periwinkle commonly grazes on smooth cordgrass and is thought to be an important factor in the process of decomposing standing dead plant biomass (Kemp, Newell, and Hopkinson, 1990). Smooth cordgrass provides marsh periwinkle a means of protection from excessive temperatures and escape from predation by crabs and conchs (Warren, 1985; McBride, Williams, and Henry, 1989).

Figure 2: Ribbed mussels and smooth cordgrass often form a symbiotic relationship where they share habitats.

Smooth cordgrass is a dominant species in critical habitat areas that act as the primary nursery grounds for commercially important fish and shellfish such as spot, Atlantic menhaden, flathead grey mullet, white mullet, brown shrimp, blue crab, and many other species (Weinstein, 1979). Smooth cordgrass is also the dominant species in important habitat for migratory and resident populations of waterfowl, shorebirds, and other marsh avian species including killdeer, least sandpiper, least tern, black skimmer, American oystercatcher, seaside sparrow, and many other species that share similar habitats (Gates, 1975; Melvin and Webb Jr., 1998).

Smooth cordgrass is the primary larval host plant for the Louisiana eyed silkmoth (Tuskes et al., 2019).

Forage: Smooth cordgrass is recognized as a historically important forage species for livestock producers along the central gulf coast when accessible (Ranwell, 1961). More recent research has demonstrated that up to 25% of dairy cattle diet could be augmented with smooth cordgrass forage, although it is reported to alter the taste and smell of milk and butter produced (Qin et al., 2016; Ranwell, 1961).

Ethnobotany

Smooth cordgrass was utilized as a food source by Native Americans in coastal areas of Virginia (LaRoche, 2007). Rousseau (1945) reported that the Iroquois used smooth cordgrass as a source of food and forage. Zent (2013) reports that smooth cordgrass is one of over 20 common marsh species used in the traditional craft of creole basket making, a craft initiated by African descent slaves. The baskets were highly valued to store rice and grains in southern states (Georgia, Florida, Alabama, and Mississippi). Inhabitants of coastal communities have traditionally used thatching made from smooth cordgrass to construct farmhouse roofs (Bandaranayake, 1998).

Status

Threatened or Endangered: No.

Wetland Indicator: OBL for all regions in which it occurs (USACE, 2018).

Weedy or Invasive: Smooth cordgrass is listed in California, Oregon, and Washington (CIPC, 2020; Kelch, 2020; WSNWCB, 2020; ODA, 2019).

This plant may become weedy or invasive in some regions or habitats and may displace desirable vegetation if not properly managed. Please consult with your local NRCS Field Office, Cooperative Extension Service office, state natural resource, or state agriculture department regarding its status and use.

Please consult the PLANTS Web site (http://plants.usda.gov/) and your state's Department of Natural Resources for this plant's current status (e.g., threatened or endangered species, state noxious status, and wetland indicator values).

Planting Guidelines

Site Selection: Of primary importance in site selection is that the site be intertidal. Smooth cordgrass is critically sensitive to reduced soil sulfides, a condition common to anaerobic and brackish marsh soils. Smooth cordgrass should not be planted outside of the tidal zone. Optimum water depths for establishing plants are 1 to 18 inches. Plantings in deeper water have been successful; however, plants are slow to anchor and vegetative cover is sparse. Consequently, plants are more prone to washout, and minimal shoreline protection is achieved.

There are a number of other site-specific elements to consider when working with smooth cordgrass. These conditions represent extremes and should be thoroughly investigated prior to committing to a significant project if any of these conditions occur.

•Soil load-bearing properties -- It is not uncommon for soils (especially in dredge deposit sites) to be fluid to the point that they physically will not support the weight of plants. This is an indicator of soils with a very high water-to-mineral ratio.

•High organic soils – Smooth cordgrass will not survive in soils with extremely high levels of organic matter. These soils are described as having very low bulk density and are problematic. When soil texture approaches the consistency of peat moss, there is potential for low plant survival.

•Poor water circulation – Smooth cordgrass is critically sensitive to sulfide accumulations and has a relatively low tolerance to sulfide toxicity.

•Shoreline configuration – Abrupt and steep cut-banks are indications of high wave energy and/or highly erodible soils. Special precautions may be required to keep transplants from dislodging prior to becoming established.

•Herbivore grazing – Smooth cordgrass is a favorite of numerous grazing animals. In areas of heavy nutria population, caging plants may be required to protect newly planted material.

•Smothering – Precautions should be taken when planting in areas of heavy floating debris. Both mechanical damage to the plants from surf-trash and smothering from water hyacinths are common.

If any of these conditions are present, consult with a wetland specialist for additional information and/or possible alternatives.

Planting: For planting purposes, two forms of vegetative plant materials are recommended: containerized and bare-root plugs. Both plant forms have shown to be equally successful in establishing plant stands when planted properly and on applicable sites. Commercially available sources of seed are rare or only available in limited quantities, and seeding is not a commonly recommended practice.

Smooth cordgrass can be produced in a number of container sizes; however, trade-gallons are the most widely used and most popular size. Trade-gallon containers have a higher per unit cost compared to smaller containers or bare-root plugs but provide the most reliable means of establishment. Trade-gallon plants have proven to be a highly successful transplant, especially along shorelines and other areas of high wave energy.

A trade-gallon will have 5 to 12 aerial stems, 18 to 24 inches in height. Smooth cordgrass produces new tillers (stems) and spreads almost entirely from rhizomes. Consequently, a well-developed root mass is critical to the survival and productivity of transplants.

Bare-root plugs are the most economical of the commercially available plant sizes. Per unit production costs are low and transportation costs are very low compared to container plants. Bare-root plugs are generally limited to planting sites with little or no energy exposure. Typical sites would include mudflats, sediment disposal areas, terraces, or other interior and protected sites. Bare-root plugs will not persist in high-energy environments because of their limited surface area. They tend to dislodge prior to establishing. Bare-root plugs have significantly less root mass than container plants, will suffer a higher level of transplant shock, and are slower to spread than container plants. However, if handled properly and used on an applicable site, bare-root plugs can be highly successful transplants.

Bare-root plugs typically consist of 3 stems 12 to 18 inches in height, and stems should remain attached at the root. Plugs should have a root mass of at least 2 inches in diameter at the root crown and 6 inches of root length.

When using fertilizer tablets with trade-gallon plants, push the tablet into the top 3 inches of the root ball immediately prior to or immediately after planting the transplant. The resulting hole should be pinched closed. For bare-root plugs, drop the tablet in the planting hole prior to inserting the plug.

A complete description (specification) for both trade-gallon container plants and bare-root plugs is available from the Natural Resources Conservation Service in Louisiana.

Planting Date: As a general rule, plant smooth cordgrass between April 1 to September 30. Some additional considerations include the following:

•Plant smooth cordgrass after the last frost date if there is a need to plant earlier, and available transplants are actively growing. In some areas this may be earlier than April 1.

•In interior marshes with poor water circulation, avoid planting between mid-July and the end of August. Elevated water temperatures are generally detrimental to new transplants; therefore, July and August plantings should be limited to lakes, bayous, and other areas of frequent tidal exchange.

•Late fall plantings in October and November have been successfully made in the past but should be limited to sites that are well protected and have minimal winter storm effect.

Shoreline Plantings: Shoreline plantings are typically planted as a single or double row parallel to the shoreline. Plant transplants at the mid-point between the high and low tide elevations. Plant spacing within the row will vary according to the size of the transplants and the rate at which full coverage is desired. Trade-gallons are generally planted on 5 to 8 foot centers and plugs on 2 to 3 foot centers. Under applicable site conditions, smooth cordgrass will spread laterally filling spaces between plants and will grow up to its highest elevation and down to its lowest elevation. It is not uncommon for smooth cordgrass to produce 8 to 10 feet of lateral spread in one growing season.

Depending on site conditions and the planting objective, two rows of smooth cordgrass are occasionally planted. A two-row planting will provide denser short-term coverage more quickly than a single-row planting. Plant two rows parallel to each other and about 5 feet apart using the same plant spacing within row as that of a single row. Plant the first row slightly above the mean tide elevation and the second row 5 feet below the first row. Stagger the plants on two rows so that plants alternate between spaces.

Interior Plantings: In addition to planting shorelines, smooth cordgrass can also be used along terraces, levees, across mudflats and dredge-fill sites. Design the planting configuration to provide maximum reduction in fetch lengths. Rows can be placed across shallow water exchange points to create a passive hydrologic barrier that will slow tidal exchange and trap suspended sediments. Planting large areas generally will require a significantly larger number of plants. Where applicable, plugs can be used and placed in a row-column configuration. The row and plant spacing can vary from a few feet to many, depending on the objective of the planting, the target rate for coverage, and available resources.

Planting Methods: Depending on the energy affecting the planting site, either containerized (for high impact sites) or bare root (for mild impact sites) plants can be utilized. Since most marsh sites are irregular and difficult to access, hand planting is the recommended planting method. When planting trade-gallons, transplants should be planted in a dug hole. Post-hole diggers, gas drills with modified bits, or any other methods of digging are satisfactory. The planting hole should be the same size or only slightly larger than the root-ball and deep enough so that the top of the root ball is flush or slightly below ground. The top of the root ball should not protrude above nor be more than 2 inches below normal ground. Tightly close the planting hole around the plant to prevent wobbling and ensure materials remain erect after planting.

Planting sites where high wave energy is a problem may require the addition of a plant anchor. A plant anchor consists of 0.25 inch mild steel re-bar bent into a crosier hook (candy-cane shape) and pushed down into the soil so that hook lays across the root ball, pinning it to the ground. Anchors are generally about 30 inches in overall length and will add to the cost of the planting. However, anchors are generally necessary at unusually problematic sites to prevent plants from washing out.

When planting bare-root plugs, holes need only be approximately 3 inches in diameter and deep enough to cover the roots. Any style of tool that will punch a hole this size such as a spade or dibble bar will work. Cupping the roots of the plug in hand and pushing down into the mud carefully will also work in more fluid soils. There are no plant anchors for plugs, and in practice, plugs should not be used at any site where wave energy is a factor. If site conditions are adequate, planting can be carried out with a mechanical, tractor drawn transplanter.

Direct Seeding: Although establishment via vegetative means is the widely accepted standard and most reliable option, direct seeding projects have been conducted and have demonstrated successful smooth cordgrass establishment at a reduced cost under appropriate conditions (Earhart and Garbish, 1983). Due to sparse and irregular seed production, it is critically important to have accurate and recent seed viability test results prior to planning a direct seeding establishment. Seed viability varies widely, and germination rates may range from 3.5% to over 80% depending on environmental conditions (Callaway and Josselyn, 1992; Biber and Caldwell, 2008; Hayasaka et al., 2020). Smooth cordgrass stands have been successfully established using a seeding rate of about 9 seeds/ft^2 or 2.24 lbs pure live seed (PLS)/acre (Earhart and Garbish, 1983; Broome et al., 1974). Broome et al. (1974) demonstrated that broadcasting and incorporating seed into the planting substrate to a depth of 0.4-1.6 inches was a more successful application method than hydromulching.

Small scale seeding trials in dredged sand material determined that smooth cordgrass could be successfully drill seeded in the upper third of the tidal range elevation. The wet seed was mixed with non-clumping cat litter to allow for seed flowability through the seed drill (Miller, Skaradek, and Alvarez, 2008). In lower energy environments a vegetatively planted buffer was not needed; however, in higher energy sites a planted buffer was needed in the lower portions of the tidal range to prevent seedlings from washing out. Generally, successfully seeded areas exhibited similar plant densities and cover as vegetatively planted areas within 2-3 full growing seasons after seeding (Miller, 2016).

Use of an airboat or hovercraft can be ideal for seeding large areas of mudflats and other areas inaccessible to land equipment. Broadcast the seed from a watercraft equipped with a drag chain to ensure the seed is incorporated with the substrate. This method is most successful where there is a shallow layer of water over the soil and where the seed is protected by the tidal wave action (Denbow et al., 1996). Aerial seeding is an alternative option for large-scale restoration efforts. In what was one of the largest known aerial seedings in salt marsh restoration efforts, the U.S. Fish and Wildlife Service (USFWS) aerially applied smooth cordgrass seed to expedite a 4,000-acre salt marsh restoration project (Leggett, 2016). USFWS (2020) personnel have reported rapid recolonization of native, salt marsh grasses and increased wildlife usage of the restored area following completion of the restoration project.

Direct seeding success is greatly impacted by the tide range. Greater success has been demonstrated in the upper portions of the tide range of direct seeded areas. Typically, the upper 20-50% of the range of naturally occurring stands for a specific area will produce the most consistent stands following direct seeding applications (Broome et al., 1974). Like vegetative establishment, the level of success of direct seeding is largely site dependent.

The reported number of seeds per pound varies widely with approximate counts ranging from 85,000 to 175,000 seeds per pound (Biber and Caldwell, 2008; USDA-NRCS, 2021).

Management

Smooth cordgrass stem and rhizome growth respond well to applications of well-balanced commercial fertilizers. High nitrogen slow-release fertilizer tablets may be used with container grown plants and bare root transplants.

Pests and Potential Problems

Rust disease has been reported to infect smooth cordgrass stands and can cause plant stress or death of the plant. The most severe impacts of a rust infestation result when the infestation occurs at the beginning of the growing season before the plant is able to reproduce. Damage from later infestations is less severe and somewhat mitigated naturally as rust spores are washed from new vegetative growth by tidal fluctuations (Denbow et al., 1996). Rust disease has been reported to infect smooth cordgrass in Connecticut, Delaware, Florida, Louisiana, Maine, Massachusetts, Mississippi, North Carolina, New Hampshire, Rhode Island, Vermont, and Virginia (Kaur, Knott, and Aime, 2010; Farr and Rossman, 2022). Although rare, smooth cordgrass has been reported to display ergot in New England and Gulf of Mexico coastal areas (Petry, 1968; Eleuterius, 1970). Flower beetles may limit seed production (Broome et al., 1974). Smooth cordgrass is host to a variety of stemborer insects that can contribute to the decline and death of stems in natural stands and nursery production operations (White, Adamski, Fine, and Richard, 2005; Gaeta and Kornis, 2011).

In areas with high populations of nutria and/or muskrats, herbivory could become problematic (DeLaune et al., 1994). New plantings may need to be protected from predation. Smith and Odum (1981) reported that monospecific stands of smooth cordgrass were most severely impacted in regard to percent cover and recovery of aboveground vegetation following grazing by snow geese when compared to two other coastal locations dominated by other coastal plant species; salt marsh hay and saltgrass were the dominant species at one location while sturdy bulrush dominated the other location.

Environmental Concerns

Smooth cordgrass is a native species critical to barrier island and wetland restoration along the U.S. Gulf and Atlantic coasts (Matthews and Minello, 1994). However, it is introduced into areas on the Pacific coast where it has become an aggressive invasive species. Smooth cordgrass is classified as an “A Listed” and “T-Designated” weed by the Oregon Department of Agriculture (ODA, 2020). Smooth cordgrass is classified as a “Class A Weed” by the Washington State Noxious Weed Control Board (WSNWCB, 2020). The California Invasive Plant Council and the California Department of Food and Agriculture designated smooth cordgrass as an invasive noxious weed (CIPC, 2020; Kelch, 2020).

Control

Please contact your local agricultural extension specialist or county weed specialist to learn what works best in your area and how to use it safely. Always read label and safety instructions for each control method. Trade names and control measures appear in this document only to provide specific information. USDA NRCS does not guarantee or warranty the products and control methods named, and other products may be equally effective.

In a review of smooth cordgrass control methods, Hedge et al. (2003) reported chemical treatment when plant height had reached 11.8-17.7 inches following a single mowing as the most effective form of control.

Chemical applications have been demonstrated as a viable means of smooth cordgrass control. Patten (2002) conducted trials that showed that imazapyr provided more consistent and complete control than glyphosate at a lower application rate. The trials also indicated that the efficacy of imazapyr applications was less affected by the length of time between application and tidal inundation than glyphosate applications.

Mowing has been demonstrated as a potential means of smooth cordgrass control. Efficacy of control increases with the number of treatments, reduced intervals between treatments, and smaller stand sizes. Mowing is more effective when used on smooth cordgrass growing in sandy or gravel substrates rather than a high organic matter soil. The primary limiting factor of mowing as a means of control is the associated cost for the number of repeated treatments required to achieve eradication of large stands (USFWS, 1997).

Other physical, nonchemical means of control include disking and rototilling. Hedge et al. (2003) reported that rototilling or disking is an effective means of control (greater than 90%) and provides improved results when conducted during winter trials rather than spring.

Caution: Use of biocontrol methods should only be conducted following satisfactory risk assessment trials for the intended area of use and with the approval of your local agricultural extension specialist or county weed specialist. Grevstad et al. (2003) conducted trials examining the potential use of a planthopper as a biocontrol. The trials indicated that the release of planthoppers posed no risk to nontarget plants in Washington State. The results showed reduced smooth cordgrass biomass and plant height in planthopper treated plots compared to control plots.

Regardless of control method, the strategy of implementation matters. Grevstad (2005) created a spatial model that simulated smooth cordgrass spread which was used to assess the efficacy of different control strategies. Grevstad's model predicted that controlling smaller outlying populations in the lower tide zone before controlling larger monospecific meadows (usually in the upper tide zone) would reduce the time and cost required to achieve eradication. Additionally, the model also predicted differences in the time and cost required to eradicate large smooth cordgrass meadows dependent upon the direction of control. The model showed it was more efficient to control in either a direction parallel to the shore or from the low tide edge towards the high tide edge rather than from the high tide edge towards the low tide edge.

Seeds and Plant Production

Smooth cordgrass is usually propagated by vegetative stem divisions. In nursery rows, plant smooth cordgrass 12 to 24 inches apart. Under ideal nursery conditions, each planting unit will establish stands containing 25 culms per square foot. Extensive weed control is essential to producing quality nursery grown plants. Plants propagated under nursery conditions are easily under cut and uplifted for distribution.

Smooth cordgrass is a poor seed producer. Although plants appear to produce a significant number of seeds, most seeds are empty, damaged, or sterile. Even so, the economic advantage of direct seeding a large area versus vegetative establishment creates demand for smooth cordgrass seed. Callaway and Josselyn (1992) reported an average production rate of 230 seeds/ft^2 from wild stands of smooth cordgrass. Large-scale, wild smooth cordgrass seed collections have been successfully conducted. Mechanical means to increase the efficiencies of collecting and cleaning the seed have been developed. During the seed collection phase of smooth cordgrass direct seeding trials, Broome et al. (1974) described the development and successful use of a mechanized seed harvester that could be operated in the marsh. Similar to a small plot harvester, the two wheeled, walk behind tractor used a sickle bar and reel to cut and collect seed heads. Simpler, although more physically laborious, methods of large scale, wild seed collections have also been successfully conducted using hand sickles to cut seedheads and collecting into large trash cans. Skaradek et al. (2006) reported the collection of over 400 lbs of clean seed with 99% viability collected by 15 individuals in a 2-week period using only hand tools (hand sickles, machetes, and pruning shears).

Handling and storage of the wild collected seed are important to achieve the high viability rates demonstrated by Skaradek et al. (2006). Their method recommended a 2-week after ripening period conducted in a weather protected environment with the total collected biomass spread on tarps to a depth of 12-15 inches and turned daily prior to cleaning. The cleaning process is expedited using mechanical equipment. Threshing to remove seed from the seedhead can be achieved using a small-scale threshing machine or, for larger collections, the use of a plot combine. Skaradek et al. (2007) conducted trials using a plot combine (Massey Ferguson, AGCO Corporation, Great Britain) as a large-scale threshing machine. Their trials concluded that the ideal combine settings to produce the highest quality seed output were:

Fan speed: 9

Cylinder speed: 7

Concave: 12

Air inlet: Full-Open

Adjustable sieves: 0.6 inch

The purity of the separated seed is further improved using standard seed cleaning equipment. Air and screen seed cleaners readily separate chafe from seed using a series of screen size changes. The recommended method is an initial scalping pass with a $^{9}/_{32}$ inch round hole screen and an additional pass with a slotted $^{3}/_{32}$ by $^{3}/_{4}$ inch screen (Skaradek et al., 2007).

Smooth cordgrass seed is recalcitrant and must be stored properly to be successfully stratified and to maintain viability. Cold, wet storage at 3-4ºC is recommended (Broome et al., 1974; Biber and Caldwell, 2008). Seed viability is improved with 1-4 months of cold, wet storage after which viability begins to decline until approaching or reaching 0% at about 11-12 months (Biber and Caldwell, 2008). In a series of germination experiments, Broome et al. (1974) demonstrated that storing smooth cordgrass seed frozen (wet or dry) reduced germination rates. It was also concluded that seed stored in saline (2.0-2.5%) water germinated at higher rates more often than seed stratified in fresh water. However, wet storage of seed presents the additional risk of unintended germination while in storage. Pihl et al. (1978) reported that up to 45% of seed stored in saline water at 4ºC had already germinated after 7 months storage.

Plugs can be produced from seed under appropriate conditions. A controlled environment will produce the most reliable results. Germination studies have shown success with a range of temperature thermoperiods. Success has been achieved applying minimum and maximum temperatures from 13-35ºC and thermoperiod durations in ratios between 7:17 hours to 12:12 hours (Broome et al., 1974; Pihl et al., 1978; Biber and Caldwell, 2008; Biber, n.d.). Although recommended temperature ranges and thermoperiods vary, studies indicate that temperature cycling is important and improves germination of smooth cordgrass seed (Mooring, Cooper, and Seneca, 1971; Pihl et al., 1978). Seed can be germinated in water and then transplanted or sown directly into containers with moist sand or peat. Most viable seed should germinate in 7-10 days (Broome et al., 1974; Biber n.d.). Seedlings should reach a height of 6 inches in about 3-4 months (Biber n.d.).

Cultivars, Improved, and Selected Materials (and area of origin)

'Vermilion' (LA) was released in 1989 by the USDA-NRCS Golden Meadow Plant Materials Center (Galliano, LA) for use in the Gulf of Mexico coastal areas. The Louisiana State University (LSU) Agricultural Center has released six cultivars of smooth cordgrass. The varieties 'Cameron', 'Terrebonne', and 'Jefferson' were released in 2012. The varieties 'Lafourche', 'St. Bernard', and 'Las Palomas' were released in 2013. Cameron originated from Cow Island in Cameron Parish, LA. Terrebonne was collected from Timbalier Island in Terrebonne Parish, LA. Seeds used to develop Jefferson were collected from the Barataria Waterway in Three Bayou Bay in Jefferson Parish, LA. Lafourche originated from Calumet Island in Lafourche Parish, LA. St. Bernard and Las Palomas were developed through an open pollination cross with plants collected from multiple sites in Texas and Louisiana. St. Bernard development began with plants produced from seeds collected in St. Bernard Parish, LA. Las Palomas development began with plants produced from seeds collected from Las Palomas Wildlife Management Area. All six LSU cultivars displayed faster recovery following transplanting, more abundant seed production, and greater germination rates than Vermilion (Knot, 2013).

Plant materials are generally obtained from two sources, a donor wetland site or commercial nurseries. The use of donor wetlands to obtain young plants will eventually affect the health and vigor of the donor stand regardless of the care taken in frequency, spacing, and location of plant removal. In addition, the removal of plant materials without the applicable permits may be in violation of standing state and federal regulations. Removing plant materials from donor stands is not recommended.

Nursery-grown stock is generally the most reliable and ecologically appropriate way to obtain plant materials. There are a number of commercial nurseries that produce and maintain smooth cordgrass transplants. Trade-gallon and vegetative plugs are the two most common sizes; however most nurseries will contract for other container sizes. Commercially available smooth cordgrass seed is rare but may be available on a contractual basis from select nurseries or seed suppliers.

Vegetative specifications should be used to tailor plant material quality and quantity to a specific project. These specifications should include acceptable sources, cultivars, ecotypes, plant size, stem height, container specifications, and extent of root development. In addition, other requirements such as climatic hardening, salt acclimation, and procedures for transportation and handling are commonly included.

Other sources of local ecotypes are available from commercial nurseries. A list of commercial wetland plant nurseries and assistance in developing plant material specifications is available from the Natural Resources Conservation Service Golden Meadow Plant Materials Center in Louisiana.

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