United States Department of Agriculture

Natural Resources Conservation Service | Plant Guide

ANNUAL WILDRICE

Zizania aquatica L.

Plant Symbol = ZIAQ

A display of annual wildrice inflorescences. Photo courtesy of Sean McCandless.

Alternative Names

Common Names: annual wildrice; black rice; blackbird oats; Canadian rice; Indian oats; Indian rice; Indian wildrice; manomin; marsh oats; northern wildrice; water oats; wild oats; wildrice

Scientific Names: *Ceratochaete aquatica* (L.) Lunell; *Zizania aquatica* L.

Description

General: Annual wildrice is an annual grass native to the eastern US and most southern Canadian provinces (USDA-NRCS, 2021). It forms hairless roots that are straight and spongy at maturity but do not provide a strong anchoring system in the subaqueous soils where the species commonly occurs (Chambliss, 1940; Oelke, Elliot, Kernkamp, & Noetzel, 1973). They are naturally whitish in color but may appear rust colored if growing in sediment containing oxidized iron deposits (Oelke, Elliot, Kernkamp, & Noetzel, 1973). The species can range anywhere from 3-10 feet tall with primary stems simple or branching (Elias & Dykeman, 1990; Boyd, 1991). Plant height is impacted by water depth of the environment with individual plants growing in more shallow water of typically shorter stature than plants occurring in deeper water (Weir & Dale, 1960). It produces three distinct types of leaves: submerged, floating, and aerial. The long ribbonlike submerged leaves are produced first in mid-May in the northern range of the species (Weir & Dale, 1960). Seedlings emerge earlier in more southern regions with the initial leaves readily apparent by early April in the Mid-Atlantic region (Chambliss, 1940). The submerged leaves are followed by floating leaves a few weeks later that maintain buoyancy on the surface of the aquatic environment. The upright, ariel leaves are produced shortly after the formation of the floating leaves (Weir & Dale, 1960). The large, soft leaves range from 1-4 feet long and 1.5-2 inches wide (Gleason & Cronquist, 1963; Duncan & Duncan, 1987; Tiner, 1988; Elias & Dykeman, 1990). The mostly hairless leaves are frequently pubescent at the base and have sharp, finely toothed edges capable of breaking skin (Eleuterius, 1990; Silberhorn, 1999). The hydrology of the environment where an individual plant occurs also impacts the amounts of each type of leaf produced. A plant growing in a wet environment without standing water may produce only the upright, aerial type leaves while plants in deeper water will produce more submerged and floating leaves than plants in shallow water (Weir & Dale, 1960). The flowering period can range from May-October producing a terminal inflorescence from 4-24 inches long consisting of unisexual spikelets (Tiner, 2009). Female spikelets are erect on upper branches of the panicle while the male spikelets with six stamens per flower hang from the lower branches (Duncan & Duncan, 1987). Male flowers can range from reddish to purplish to straw colored (Eleuterius, 1990; Boyd, 1991). The panicle branches range from 6-8 inches long and are reddish or dark green and sometimes streaked with olive (Elias & Dykeman, 1990; Eleuterius, 1990). The inflorescence and spikelets develop upward from the base and the sex of individual spikelets is not discernable until later stages of development. Due to the structure of the inflorescence (female spikelets above male spikelets) and the timing of maturation of individually sexed spikelets (male flowers are usually still encased in a leaf sheath and do not bloom and discharge pollen until after female flowers on the same plant have bloomed and been successfully pollinated), self-pollination is rare. Female flowers are primarily wind pollinated by male flowers of nearby plants (Chambliss, 1940). Following pollination, mature seed is formed 10-14 days later in late summer or early fall (Weir & Dale, 1960; Elias & Dykeman, 1990). Upon seed maturity, the inflorescence becomes a bright yellow green and the female flowers form elongated mostly black but occasionally greenish or light to dark brown grains (Weir & Dale, 1960; Brown, 1979; Eleuterius, 1990; Silberhorn, 1999). The seeds are encased in papery goldish green glumes covered with bristly hairs and bristled at their tips (Chambliss, 1940; Lyle, 1997). The seed is narrow and cylindrical ranging about 0.5-1 inches long and 0.05-0.08 inches wide (Chambliss, 1940; Weir & Dale, 1960; Eleuterius, 1990). Seed maturation is indeterminate and shatters readily with minor agitation once mature (Brown, 1979). Seed may float for a short period but will typically sink to the water's bottom to find purchase in the subaqueous soil (Weir & Dale, 1960). Inflorescence branches are persistent after seed has shattered (Brown, 1979).

Distribution: Annual wildrice is most common in the Great Lakes Region and along the Atlantic coast of the US (Jenks, 1901; Martin & Uhler, 1939). Its native range encompasses most of the eastern two-thirds of US from Canada to Florida and west to Louisiana and the Rocky Mountains (Jenks, 1901; Tiner, 1988; Silberhorn, 1999). Its native range includes North Dakota, South Dakota, Nebraska, and Kansas (POWO, 2023). In Canada its native range stretches from Nova Scotia west to British Columbia (Tiner, 1988; USDA-NRCS, 2021). It is reported as introduced in California, Baltic States, Belarus, European Russia, and Ukraine (POWO, 2023).

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

Habitat: Annual wildrice prefers freshwater environments with water several inches up to 3 feet deep (Martin & Uhler, 1939). It occurs most frequently forming dense stands in quiet waters such as riverine tidal marshes, stream borders, tidal streams, sloughs, ponds, lakes, and lagoons (Martin & Uhler, 1939; Gleason & Cronquist, 1963; Prescott, 1969; Elias & Dykeman, 1990). It occurs in both fresh and brackish water habitats such as brackish river mouths, marshes, and bays (Brown, 1979; Tiner, 1988; Eleuterius, 1990; Boyd, 1991). It can occur in zones flooded regularly or irregularly but prefers tidal environments where water is circulated on a regular basis to avoid stagnant waters (Martin & Uhler, 1939; Tiner, 2009).

Annual wildrice generally grows in association with green arrow arum (*Peltandra virginica*), arrowleaf tearthumb (*Polygonum sagittatum*), pickerelweed (*Pontederia cordata*), sweetflag (*Acorus calamus*), smooth beggartick (*Bidens laevis*), yellow pond-lily (*Nuphar lutea*), broadleaf arrowhead (*Sagittaria latifolia*), rice cutgrass (*Leersia oryzoides*), big cordgrass (*Spartina cynosuroides*), common spikerush (*Eleocharis palustris*), sedges (*Carex* spp.), and smartweeds (*Polygonum* spp. and *Persicaria* spp.) (Chambliss, 1940; Silberhorn, 1999; MNFI, 2009; Nichols, 2014; Denis, 2015; Hosier, 2018). In deeper waters annual wildrice may grow within proximity of pondweeds (*Potamogeton* spp.), waterlilies (*Nymphaea* spp.), duckweeds (*Lemna* spp.), and American eelgrass (*Vallisneria americana*) (Tucker, Zanis, Emery, & Gibson, 2011). In more shallow water, small floating mannagrass (*Glyceria borealis*), watermilfoil (*Myriophyllum* spp.), water plantain (*Alisma* spp.), watercress (*Nasturtium officinale*), American bur-reed (*Sparganium americanum*), broadleaf cattails (*Typha* spp.), white arrow arum (*Peltandra sagittifolia*), and harlequin blueflag (*Iris versicolor*) are more closely associated species (Chambliss, 1940; MNFI, 2009). It may occur in association with smooth cordgrass (*Spartina alterniflora*) but where the two species coexist typically marks the upper threshold of salinity tolerance for annual wildrice (Martin & Uhler, 1939). In an environment such as a tidal river, chairmaker's bulrush (*Schoenoplectus americanus*) becomes a more closely associated species as the water salinity declines (Chambliss, 1940).

Adaptation

Annual wildrice is well adapted to saturated environments with wet soils that range in pH from 5-8 (Oelke, 1973; Eleuterius, 1990; USDA-NRCS, 2021). It is generally an emergent plant with the lower portion of the plant submerged and rooted in subaqueous soils of fine soft silts and deep mucks of at least 17 inches (Martin & Uhler, 1939; Fannucchi, 1983a; Eleuterius, 1990). It rarely establishes in soils with a high sand content (Fannucchi, 1983a). It can be grown in USDA hardiness zones 3a-9b and can behave as a perennial species in warmer climates (Duncan & Duncan, 1987; Tiner, 1988; Silberhorn, 1999; USDA-NRCS, 2021).

Annual wildrice has adaptive growth mechanisms that respond to water levels making it well adapted to grow in varying depths of water. Stevenson and Lee (1986) demonstrated these growth mechanisms in an experiment that increased the water depth plants were grown in from an initial depth of 17.7 inches to 23.6, 29.5, or 37.4 inches. No plant mortality was reported as plant heights increased with water depths.

Annual wildrice has a moderate fire tolerance and is intolerant of shaded environments (Davis, 1994; Thunhorst, 1993; USDA-NRCS, 2021). These two adaptations are related as burning prevents the encroachment of woody species that can eventually reduce the amount of available sunlight to understory plants (Bassett, 2004). Some important habitats where annual wildrice is a dominant species are dependent upon burning to maintain appropriate conditions for the plant to thrive. Prairie fens in the northern Midwest and marshy ecological edge areas between land and water in the Northern Alberta Boreal Forest are two examples of habitats that have been dependent on fire to prevent encroachment of woody species and maintain an open canopy providing sufficient sunlight (Bassett, 2004; Denis, 2015).

Annual wildrice has a moderate degree of tolerance for brackish waters. In tidal river environments along the Connecticut and Delaware rivers, it is reported to occur to salinity levels of 7.1 and 5.3 ppt respectively. Further inland, it only occurs in freshwater or slightly brackish environments (Martin & Uhler, 1939). Although the species shows some degree of saline tolerance, germination is severely hindered in saline water. Following a stratification period of 4 months in freshwater, Pihl, Grant, and Somers (1978) conducted germination trials using four treatment solutions: freshwater, 1/3 strength seawater, 2/3 strength seawater, and full-strength seawater. The resulting germination rates showed a steady reduction in germination as salinity levels were increased: 75, 5, 0, and 0% respectively.

Uses

Conservation Practices: Annual wildrice is a recommended species for wetland conservation projects. It is recommended for constructed wetlands, wetland restoration, and wetland enhancement projects (Thunhorst, 1992; Davis, 1994). Successful incorporation of annual wildrice in constructed wetlands has been documented and studies have shown that the species plays a role in water quality improvement by assisting with the removal of pollutants such as excess ammonia, nitrogen, and phosphorus (Ye & Li, 2009; Han et al., 2019; Qu et al., 2020).

If site conditions are appropriate and specific criteria for the conservation practice standard are met, annual wildrice could have beneficial applications for NRCS Conservation Practice Standards Conservation Cover (327), Stream Habitat Improvement and Management (395), Wildlife Habitat Planting (420), Wetland Wildlife Habitat Management (644), Wetland Restoration (657), Wetland Creation (658), and Wetland Enhancement (659).

Wildlife: The black grains produced by annual wildrice are a valuable food source and attractant for a wide variety of waterfowl, shorebirds, and songbirds (Martin, Zim, & Nelson, 1951; Brown, 1979). The attraction is so strong for waterfowl that annual wildrice plantings are recommended to draw waterfowl to areas where increased numbers are desired (Silberhorn, 1999). The grains are consumed by snow geese, common mallards, black ducks, baldpates, pintails, green-winged teals, blue-winged teals, wood ducks, redheads, ring-necked ducks, canvasbacks, greater scaup ducks, lesser scaup ducks, buffleheads, common coots, Virginia rails, soras, fish crows, bobolinks, eastern meadowlarks, red-winged blackbirds, rusty blackbirds, sharp-tailed sparrows, and song sparrows (Chambliss, 1940; Martin, Zim, & Nelson, 1951). In addition to providing a source of nutrition, dense stands of annual wildrice also provide quality nesting sites and cover for birds (Martin, Zim, & Nelson, 1951; Prescott, 1969). Wildlife habitat and sustenance provided by annual wildrice is of such great value that in Minnesota alone over 17 species listed as "species of greatest conservation need" depend on it to some degree for their survival and reproduction (Norrgard et al., 2008).

In an extensive study examining the food of game ducks in the US and Canada, Martin and Uhler (1939) reported that annual wildrice grains made up the ninth greatest percentage (1.95%) of diet by volume after analyzing the stomach contents of 7,998 ducks of 18 species from 247 locations. The importance of annual wildrice as a food source for ducks becomes even more apparent when the focus is shifted specifically to the study data from the native distribution range of annual wildrice, the eastern regions of the US and Canada. In these regions, annual wildrice constituted the third greatest percentage of diet by volume, 5.1 and 9.58% respectively. These percentages were determined after analyzing the stomach contents of 1,102 ducks of 15 species from 58 locations in the eastern US and 109 ducks of 13 species from 10 locations in eastern Canada.

In addition to the wildlife benefits annual wildrice provides to avian species, it is also consumed by muskrats and provides excellent habitat for construction of dens (Chambliss, 1940; Davis, 1994). Cattle, deer, and moose are reported to graze on the leaves and stalks (Chambliss, 1940; Davis, 1994). Decaying annual wildrice mulch from the previous year's growth provides food for a variety of fish and amphibians (Norrgard et al., 2008).

Warning: Grains may be susceptible to ergot (fungal) contamination which can be toxic if consumed.

Grains of annual wildrice may become infected with ergot, a fungal infection caused by the plant pathogen *Claviceps zizaniae* (Redhead, Corlett, & Lefebvre, 2008). Ergot infected grains can be purple, pink, or reddish and are usually enlarged but similar in shape to healthy grains. The infected grains can be deadly if consumed (Elias & Dykeman, 1990; Lyle, 1997).

Commercial crop: The edible grains are held in high regard and of great value to gourmet chefs and restaurateurs with reports of sometimes selling at a higher price per pound than filet mignon in New York (Brown, 1979; Hough, 1983; Timm & Slavin, 2014). The grain is commercially produced in greater quantities in the Great Lakes Region than anywhere else in the world; the grains are produced, harvested, and sold in Michigan, Wisconsin, Minnesota, and Canada (Prescott, 1969; Oelke, 1973; Brown, 1979; Timm & Slavin, 2014). A significant amount is also produced in California and Oregon (Timm & Slavin, 2014; Hauan, 2015). Annual wildrice is traditionally harvested from naturally occurring wild stands by canoe. Panicles with mature seed are held over the canoe and agitated with a stick to gather the grain. Because grain maturation is indeterminate, multiple harvests of the same stand are possible. Annual wildrice has been produced in managed paddies with hydrological controls similar to cranberry bogs. The plants are grown in standing water then the paddies are drained to allow mechanical harvest with a modified agricultural combine (Brown, 1979).

Ethnobotany
Annual wildrice is well documented as a historically important species to many Native American tribes' way of life as a form of subsistence and has been incorporated into religious ceremonies, social rituals, and oral traditions (MacCauley, 1884; Chambliss, 1940; Weir & Dale, 1960; Prescott, 1969; Wet & Oelke, 1978; Moerman, 1998; Tucker et al., 2011; USDA-NRCS, 2021).

Annual wildrice, commonly referred to as "manomin" by Native Americans, was an important grain food used by multiple Native American tribes (Chambliss, 1940; Wet & Oelke, 1978). It was a staple food and constituted an important element of the diets of the Chippewa, Dakota, Menominee, Meskwaki, Ojibwa, Omaha, Ponca, Thompson, and Winnebago Tribes (Wet & Oelke, 1978; Moerman, 1998). It was also commonly collected and consumed by the Potawatomi, Ottawa, Sauk, Fox, Maskotin, Kickapoo, Huron, Mississaqua, and Assiniboin Tribes (Wet & Oelke, 1978). Annual wildrice is also reported to have been harvested and consumed by the Seminole Tribe in Florida (MacCauley, 1884). The Menominee Tribe prepared the rice by seasoning with maple sugar after cooking in a broth of deer, pork, or butter (Jenks, 1901; Moerman, 1998). The Ojibwe Tribe has perhaps the most well documented history of use and various preparation methods of the native grain. The Ojibwe Tribe would commonly use annual wildrice to thicken the broth of venison, bear, fish, and fowl stews (Jenks, 1901). They would steam the rice and mix it with sugar and cream for breakfast (Moerman, 1998). It was used in waterfowl stuffing and to make gem cakes (Moerman, 1998). Hunters and fishermen of the Mississauga Native Americans, a branch of the Ojibwe Nation, would bring grain that had simply been parched as a convenient food to carry during expeditions. Ojibwe Native Americans from the Lake of the Woods area (at the border of Ontario, Canada and Minnesota, US) would prepare an annual wildrice soup that included blueberries (Jenks, 1901). The Sandy Lake Native Americans of the Ojibwe Tribe would season their rice by boiling it with rabbit excrement, a practice that was said to produce a luxury food (Jenks, 1901; Moerman, 1998).

Annual wildrice served as more than just sustenance to Native American tribes. The grain served as a commodity that was sold and traded for other goods by the Ojibwe and Thompson Tribes (Moerman, 1998). The Dakota Tribe used an annual wildrice dish seasoned with dried blueberries and presented on birch bark dishes during ceremonial banquets (Jenks, 1901). The harvest of annual wildrice was of such importance to the Native American way of life and traditions that many rice harvesting tribes named the moons of August, September, and/or October after the harvest of the grain. To the Ojibwe Tribe, the August or September moon was "Manoominike-giizis," "the moon of the gathering of wildrice" or "rice making moon" (Stickney, 1896; Jenks, 1901; WWU, 2022; Pitawanakwat, Sheldon, & Noodin, 2023). The Ottawa Tribe and the Menominee Tribe used different words in their languages to refer to the September moon, but both roughly translated to "wild-rice-gathering moon" or simply "rice moon" (Jenks, 1901; Hilger, 1960). The Potawatomi Tribe used the same word with the same meaning as the Ojibwe language, but for the late September and early October moon (Jenks, 1901). The Dakota Tribe used the words "Wasutuŋ Wi" and "Psiŋhnaketu Wi," which respectively meant "ripe rice moon" and "wildrice storing moon" to refer to the September and October moons (Jenks, 1901; Hocokata Ti, 2022).

Annual wildrice has been referred to as "food from the gods" and has been incorporated into Native American oral traditions (Chambliss, 1940; Weir & Dale, 1960; Wet & Oelke, 1978). The story of Wenibozho and his discovery of annual wildrice as a valuable source of food has been told for multiple generations by the Chippewa, Menominee, and other Native American tribes. The oral tradition tells the story of Wenibozho, a young boy who lived an easy life because of his indulgent grandmother providing all of his needs. When the grandmother realized Wenibozho had not learned the skills to be able to care for himself, she sent him on a journey to experience the hardships of hunger, thirst, and cold. After days of exhaustion and hunger challenged Wenibozho, plants began to speak to Wenibozho saying "sometimes they eat us." After trying several plants, Wenibozho discovered that the grain of annual wildrice had a pleasing taste and satisfied his hunger (Chambliss, 1940; Wet & Oelke, 1978). He asked the plants what they are called, and they replied "manomin" (Chambliss, 1940).

In modern times, annual wildrice is still of economic and social importance to Native American life (Prescott, 1969). It remains a source of valuable income to Native Americans in the US and Canada and a regular constituent of their diets (Weir & Dale, 1960). The edible grains are "prized by gourmets" (Hough, 1983). It is commercially harvested and sold in Michigan, Wisconsin, and Minnesota (Prescott, 1969). The majority of wildrice sold in the US is grown and harvested in Minnesota; Wisconsin also produces a smaller amount, and some is imported from Canada (Brown, 1979). Minnesota Department of Natural Resources requires a state wildrice harvesting license. However, members of federally recognized tribes located in Minnesota are deemed to have a license to harvest wildrice and are not required to purchase a state wildrice harvesting license (MNDNR, 2023).

The decline of annual wildrice populations compared to historic levels has been attributed to several causes: hydrology changes, herbivory by invasive species, competition with invasive plants, habitat loss, pollution, and watercraft wakes (Nelson, Owens, & Getsinger, 2003; Nichols, 2014; Trull, nd). Native American groups, US state and federal agencies, and non-governmental organizations such as the Minnesota and Wisconsin Departments of Natural Resources, the USDA Natural

Resources Conservation Service, the Great Lakes Indian Fish and Wildlife Commission, and the Nature Conservancy are all involved in efforts to conserve and restore annual wildrice populations (Tucker et al., 2011).

Status
Threatened or Endangered: Annual wildrice is not federally listed and has a global rank of "G5" or "Secure." By more specific regions, it is ranked as "S5", "S3", or "S2" meaning that it is not legally protected but ranges from "Secure" to "Vulnerable" to "Imperiled." In Canada it is ranked as "S3" in New Brunswick and Ontario. In the US it is ranked "S3" in Georgia, Illinois, and New York. Its rank ranges from "S3" to "S2" in Michigan (MNFI, 2009). It is ranked as "S2" in North Carolina, Ohio, Rhode Island, and South Dakota (Natureserve, 2022). It is listed as "Rare" in Pennsylvania (USDA-NRCS, 2021; PDCNR, 2022).

Wetland Indicator: Obligate (OBL) wetland plant for all regions in which it occurs (USACE, 2020).

Weedy or Invasive: Annual wildrice is not on any state or national invasive species lists (Wallace, 2018).

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
Prepare commercial grain production fields in advance of planting to ensure a clean, weed free seedbed conducive to seed to soil contact for improved establishment success. The production field must be level to allow an even standing water depth of 6-12 inches which may require dike construction. The selected field must have the capability to be flooded and drained to manage water levels with a quality water source within a pH range of 6.8-8.8 (Oelke, 1973). Broadcast apply seed to drained fields in the fall at a rate of 25-40 lb/ac and incorporate seed to a depth of 1-3 inches (Oelke, 1973; Hauan, 2015). Spring seeding into flooded fields is also a viable option but the seeding rate must be increased by 15-20% because the establishment rate is reduced due to seedlings floating prior to anchoring in the soil (Oelke, 1973). Fall seedings may be preferable to spring seedings as they allow for natural cold stratification of the seed resulting in higher germination rates (Hauan, 2015).

Appropriate site selection is especially critical for successful conservation planting establishments. Conservation planting sites should meet the criteria and ranges described in the habitat and adaptation sections of this plant guide. When considering seed sources, special consideration should be given to seed origin based on the intended establishment site. Tucker et al. (2011) demonstrated differences in plant responses to stresses caused by varied water depths from plants originating from isolated annual wildrice stands suggesting that environmental conditions of the seed source can impact overall plant performance and establishment success at a restoration site. Establish conservation plantings by broadcast applying seed in fall or early spring using similar rates and methods as for grain production field plantings (Martin & Uhler, 1939). Shade and competition for resources from other aquatic plants that develop earlier in the season can negatively affect and reduce establishment success. If the establishment site has heavy aquatic vegetation competition, control options should be considered to increase the likelihood of establishment success (Tucker et al., 2011).

Annual wildrice seed ranges from 11,340-14,065 seeds/lb (Fannucchi, 1983a; USDA-NRCS, 2021).

Management
Due to the indeterminate development of the seed and its tendency to readily shatter upon maturity, a significant amount of seed (500-1,000 lb/ac) can be lost prior to harvest and result in overly dense stands. If commercial grain production fields become too dense, lodging and reduced yields may occur. Thinning stands that have self-reseeded too heavily to the ideal rate of 5-6 plants/ft^2 in 6 inch wide rows with 2 feet between rows provides improved yields and reduced lodging (Oelke, 1973). Related to the indeterminate development of the seed and overly dense stands, the inverse problem of a stand thinning may occur if seed is harvested in a manner that does not allow self-reseeding, such as a single pass combine harvest prior to any substantial seed shattering. While combining greatly increases harvest efficiency over the non-mechanical methods used to harvest natural wild stands, it is so much more thorough that it may require the paddies to be reseeded annually (Brown, 1979).

Water level management is also important for grain production fields. Flood fields in early April and maintain a depth of 6-12 inches until they are drained to prepare for harvest when the grain begins to fill, usually in August (Oelke, 1973). Calm water and maintaining a consistent depth are of utmost importance 7-10 days after emergence when floating leaves develop and rest on the water surface. Changes in water depth during this period can uproot seedlings that have not yet developed a well anchored root system. Additionally, plant respiration may be negatively impacted if floating leaves become submerged due to increased water levels (Chambliss, 1940; Hauan, 2015). Plants may become more susceptible to lodging if the water depth is allowed to exceed 18 inches. Maintain a water depth of at least 6 inches to minimize weed pressure. Control other aquatic weeds (such as cattails) and incorporate remaining annual wildrice vegetation by rototilling following harvest (Oelke, 1973).

For grain production fields, base fertilization rates on soil test results. Contact your local agricultural extension for soil test analysis and fertilizer application recommendations prior to implementing a fertilization plan. Sufficient potassium availability protects from disease and encourages increased yields. If necessary, potassium can be applied in spring or autumn (Hauan, 2015). Nitrogen availability is also essential to maximize yields. Liquid formulations of ammonium nitrate, dry urea, and anhydrous ammonia are common sources of nitrogen for annual wildrice production and may be applied up to three times during the growing season (Hauan, 2015). However, excessive nitrogen applications can induce lodging (Oelke, 1973). Producers must pay special attention to water quality impacts due to excess nutrient runoff regarding all fertilizer applications, especially as the time to drain fields approaches (Hauan, 2015).

As a self-reseeding annual grass, little to no maintenance is necessary for conservation plantings established at an appropriate site. Ecological succession may lead to the encroachment of woody climax species that alter the environment reducing sunlight availability and making it uninhabitable for annual wildrice. Land managers can employ prescribed burns to control shade inducing species and maintain ideal conditions (Bassett, 2004; Denis, 2015).

Pests and Potential Problems
Annual wildrice is susceptible to several fungal infections caused by plant pathogens. Grains infected with ergot can be purple, pink, or reddish and are usually enlarged but similar in shape to healthy grains (Elias & Dykeman, 1990; Lyle, 1997 Redhead, Corlett, & Lefebvre, 2008). Infected grains are nonviable and poisonous making them no longer suitable for human consumption (Fannucchi, 1983a; Elias & Dykeman, 1990; Lyle, 1997). Culms may be infected by a smut fungus, *Ustilago esculenta* (Kealey, Kosikowski, & Gray, 1981). Manchurian wildrice (*Zizania latifolia*), a species closely related to native annual wildrice, has evolved with the smut fungus in East Asia to form a symbiotic relationship where the infected culms are harvested and consumed as a vegetable known as “gua sun” or “kah peh sung” (Terrell & Batra, 1982; Surendiran, Alsaif, Kapourchali, & Moghadasian, 2014; Yan et al., 2013). The fungal infection causes hypertrophic culms and reduces flowering therefore resulting in a decline in reproductive fitness (Terrell & Batra, 1982). Suppression of flowering and reproductive fitness is a more serious impairment to annual species such as annual wildrice than to a perennial species such as Manchurian wildrice. Therefore, Manchurian wildrice should not be introduced to annual wildrice native habitat (Terrell & Batra, 1982). Leaf blight and stem rot are additional diseases that may present a threat to annual wildrice (Oelke, 1973).

The wildrice worm feeds on developing grains. The wildrice midge feeds on leaves while they are still submerged under water. Both are major insect pests that may be responsible for substantial plant damage and reduced yields. Leafminers, stem maggots, and stem borers also feed on annual wildrice but the damage caused is usually negligible (Oelke, 1973).

Wildlife can pose a threat of significant damage to annual wildrice stands. Herbivory by resident Canada geese can cause a significant decline in annual wildrice stand density. Nichols (2014) reported a 78% reduction of stand density and a statistically significant reduction of plant height and panicle density due to resident Canada geese grazing in a study conducted in freshwater marshes along the Maurice River in New Jersey. Blackbirds have been reported to cause significant grain production losses (Oelke, 1973). Muskrats pose little risk to well established stands but can cause significant damage to recently established stands (Fannucchi, 1983b).

Annual wildrice does not compete well with exotic, invasive European common reed (*Phragmites australis* ssp. *australis*) and will most likely be overtaken in areas where the nonnative common reed has been introduced (Hosier, 2018).

Environmental Concerns
There are no known environmental concerns associated with annual wildrice.

Seeds and Plant Production
Approximate yields reported from unmanaged natural stands varies greatly from 50-500 lb/ac (Oelke, 1973; Norrgard et al., 2008). Managed commercial grain production fields can yield as much as 700 lb/ac (Oelke, 1973). Annual wildrice is reported to have significant fluctuations in yields even under controlled conditions (Forbes, 2008). The ideal time to harvest depends on field conditions, growing conditions that year, and harvest methods employed. The grain is usually harvested when approximately 33% has reached the hard dough stage and has turned brownish green or black; this usually occurs at the end of August or in September (Oelke, 1973; Hauan, 2015). Multiple pass harvest methods may last a period of 2-3 weeks (Chambliss, 1940). Annual wildrice harvested in the traditional manner by canoe with sticks sometimes referred to as flails, rods, or knockers allows for multiple harvests of the same stand (Brown, 1979; WIDNR, 2023). Several types of mechanized harvesting equipment can be used in drained commercial grain production fields. Picker-harvesters can be used to harvest the same field multiple times removing primarily only the mature grain with each harvest (Oelke, 1973). This allows a producer

to increase yields that would be lost due to a single harvest and the indeterminate seed maturation process of the species. Modified rice combines with fabricated reel arm and track extensions are also used to harvest commercial grain production fields (Oelke, 1973; Brown, 1979). Combines are operated at reduced reel speeds when harvesting annual wildrice (Oelke, 1973). If stands are harvested too completely or combined too early without allowing an opportunity for self-reseeding, stands may thin and require reseeding for future production (Brown, 1979).

Annual wildrice seed is recalcitrant and must be stored properly to be successfully stratified and to maintain viability. It must be stored wet and not allowed to dry to retain viability. It should be stored cold to delay germination and prevent fermentation (Chambliss, 1940). Seeds stored dry for 90 days resulted in a nearly complete loss of viability with a noticeable reduction of viability after 14 days of dry storage (Simpson, 1966). Stratify seed in an aquatic environment at 33.8-37.4 °F (1-3 °C) to achieve improved germination percentages and faster rates of germination. Stratified seed germinates readily when held at a constant temperature of 15-20 °C or with a daily alternating temperature between 59 and 86 °F (15 and 30 °C) (Simpson, 1966). Germination generally occurs in the natural environment when the soil reaches 39.9 °F (4.4 °C) (Forbes, 2008; Norrgard et al., 2008).

Annual wildrice seed typically has a dormancy period of about 6 months (Simpson, 1966). However, if conditions are not suitable for germination, seed can remain dormant for years (Forbes, 2008). Halstead and Vicario (1969) reported the discovery of viable seed that sat dormant in lake bottoms for several years in the Northern Saskatchewan region of Canada. Moyle (1967) reported viable seed from well-established stands that remained dormant for over 5 years. In trials examining seed dormancy, Cardwell, Oelke, and Elliott (1978) concluded that an impermeable pericarp was partly responsible for prolonged dormancy. Researchers punctured the pericarp of ungerminated seed collected from the soil of annual wildrice fields after they had been out of active production for 1 and 2 years. Germination rates of punctured seeds increased 33 and 79% respectively.

Cultivars, Improved, and Selected Materials (and area of origin)
These plant materials are not available from commercial sources.

Cultivars should be selected based on the local climate, resistance to local pests, and intended use. Consult with your local land grant university, local extension or local USDA NRCS office for recommendations on adapted cultivars for use in your area**.**

Literature Cited

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