SPECIES: Sorghum halepense

Choose from the following categories of information.

INTRODUCTORY

SPECIES: Sorghum halepense

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AUTHORSHIP AND CITATION:
Howard, Janet L. 2004. Sorghum halepense. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2007, September 24].

FEIS ABBREVIATION:
SORHAL

SYNONYMS:
None

NRCS PLANT CODE [190]:
SOHA

COMMON NAMES:
Johnson grass

johnson grass
Johnsongrass
johnsongrass

TAXONOMY:
The scientific name of Johnson grass is *Sorghum halepense* (L.) Pers. (Poaceae) [50,71,73,94,110,112,150,178,185,195,201,202,205,207]. *Sorghum* species are interfertile, and Johnson grass readily hybridizes with sorghum (*S. bicolor*) [11,71,73,207]. In the southern Great Plains and South, plants classified as Johnson grass may actually be stable Johnson grass × sorghum introgrades [73,183,207].

LIFE FORM:
Graminoid

FEDERAL LEGAL STATUS:
No special status

OTHER STATUS:
Twenty-four states in the U.S. and the province of Ontario in Canada have officially declared Johnson grass as a noxious or prohibited weed (as of 2004) [157,186,189]. Johnson grass is respectively listed as a Category 1 (highly invasive) and Category 2 (moderately invasive) species in the Southern and Eastern Regions of the U.S. Forest Service [187,188]. Planting Johnson grass is prohibited in the Southern Region [188].

DISTRIBUTION AND OCCURRENCE

SPECIES: Sorghum halepense

GENERAL DISTRIBUTION:
Johnson grass is native to the Mediterranean region of Europe and Africa, and possibly to Asia Minor. Worldwide, its range as a weed extends from 55° N to 45° S in latitude [97,129]. It was widely introduced in North America, Europe, Africa, and southwestern Asia [185], and was also introduced in Brazil, Argentina [156], and northern Australia [79]. In North America it occurs in southern Ontario; south through all the contiguous United States except Maine [73,110,207]; to the Rio Grande Delta region of Tamaulipas and the Cape region of Baja California Sur in Mexico [205]. Johnson grass also occurs in Hawaii and the Caribbean [110].

In the United States, Johnson grass was introduced in South Carolina from Turkey around 1830. William Johnson, whom the plant is named after, established Johnson grass along the Alabama River in the 1840s as a forage species, and Johnson grass spread rapidly across the South [14,150,171,183]. Johnson grass is now widely escaped from cultivation in much of the United States. It is most invasive in the Southeast, although it is widespread in central California and New Mexico [123,129,207]. Johnson grass is not persistent in the

Pacific Northwest, upper northern Great Plains, extreme northern portions of the Great Lake states, the Northeast [71,111,133,195], or in Arizona, Colorado, and Utah [112,201,202]. Plants database provides a state distributional map of Johnson grass.

Johnson grass occurrence is not well documented for all plant communities where it may occur. The following classification lists are not restrictive, but include plant communities where Johnson grass is a documented species.

ECOSYSTEMS [64]:
FRES10 White-red-jack pine
FRES11 Spruce-fir
FRES12 Longleaf-slash pine
FRES13 Loblolly-shortleaf pine
FRES14 Oak-pine
FRES15 Oak-hickory
FRES16 Oak-gum-cypress
FRES17 Elm-ash-cottonwood
FRES18 Maple-beech-birch
FRES28 Western hardwoods
FRES29 Sagebrush
FRES30 Desert shrub
FRES32 Texas savanna
FRES33 Southwestern shrubsteppe
FRES34 Chaparral-mountain shrub
FRES38 Plains grasslands
FRES39 Prairie
FRES41 Wet grasslands
FRES42 Annual grasslands

STATES/PROVINCES: (key to state/province abbreviations)

UNITED STATES

AL	AZ	AR	CA	CO	CT	DE	FL	GA	HI
ID	IL	IN	IA	KS	KY	LA	MD	MA	MI
MN	MS	MO	MT	NE	NV	NH	NJ	NM	NY
NC	ND	OH	OK	OR	PA	RI	SC	SD	TN
TX	UT	VT	VA	WA	WV	WI	WY	DC	PR
VI									

CANADA

ON

MEXICO

B.C.N.	B.C.S.	Tamps.

BLM PHYSIOGRAPHIC REGIONS [28]:
1 Northern Pacific Border
3 Southern Pacific Border
5 Columbia Plateau

6 Upper Basin and Range
7 Lower Basin and Range
8 Northern Rocky Mountains
9 Middle Rocky Mountains
10 Wyoming Basin
11 Southern Rocky Mountains
12 Colorado Plateau
13 Rocky Mountain Piedmont
14 Great Plains
15 Black Hills Uplift
16 Upper Missouri Basin and Broken Lands

KUCHLER [119] PLANT ASSOCIATIONS:
K009 Pine-cypress forest
K025 Alder-ash forest
K026 Oregon oakwoods
K027 Mesquite bosques
K028 Mosaic of K002 and K026
K030 California oakwoods
K032 Transition between K031 and K037
K033 Chaparral
K035 Coastal sagebrush
K036 Mosaic of K030 and K035
K038 Great Basin sagebrush
K039 Blackbrush
K040 Saltbush-greasewood
K041 Creosote bush
K042 Creosote bush-bur sage
K043 Paloverde-cactus shrub
K044 Creosote bush-tarbush
K045 Ceniza shrub
K047 Fescue-oatgrass
K048 California steppe
K049 Tule marshes
K050 Fescue-wheatgrass
K051 Wheatgrass-bluegrass
K053 Grama-galleta steppe
K054 Grama-tobosa prairie
K055 Sagebrush steppe
K056 Wheatgrass-needlegrass shrubsteppe
K057 Galleta-threeawn shrubsteppe
K058 Grama-tobosa shrubsteppe
K059 Trans-Pecos shrub savanna
K060 Mesquite savanna
K061 Mesquite-acacia savanna
K062 Mesquite-live oak savanna
K063 Foothills prairie
K064 Grama-needlegrass-wheatgrass
K065 Grama-buffalo grass
K066 Wheatgrass-needlegrass
K067 Wheatgrass-bluestem-needlegrass
K068 Wheatgrass-grama-buffalo grass

K069 Bluestem-grama prairie
K070 Sandsage-bluestem prairie
K072 Sea oats prairie
K073 Northern cordgrass prairie
K074 Bluestem prairie
K075 Nebraska Sandhills prairie
K076 Blackland prairie
K077 Bluestem-sacahuista prairie
K078 Southern cordgrass prairie
K079 Palmetto prairie
K080 Marl everglades
K081 Oak savanna
K082 Mosaic of K074 and K100
K083 Cedar glades
K084 Cross Timbers
K085 Mesquite-buffalo grass
K087 Mesquite-oak savanna
K088 Fayette prairie
K089 Black Belt
K090 Live oak-sea oats
K091 Cypress savanna
K092 Everglades
K099 Maple-basswood forest
K100 Oak-hickory forest
K101 Elm-ash forest
K102 Beech-maple forest
K103 Mixed mesophytic forest
K104 Appalachian oak forest
K106 Northern hardwoods
K109 Transition between K104 and K106
K110 Northeastern oak-pine forest
K111 Oak-hickory-pine
K112 Southern mixed forest
K113 Southern floodplain forest
K114 Pocosin
K115 Sand pine scrub
K116 Subtropical pine forest

SAF COVER TYPES [60]:
14 Northern pin oak
17 Pin cherry
18 Paper birch
24 Hemlock-yellow birch
25 Sugar maple-beech-yellow birch
26 Sugar maple-basswood
27 Sugar maple
28 Black cherry-maple
39 Black ash-American elm-red maple
40 Post oak-blackjack oak
42 Bur oak
43 Bear oak
44 Chestnut oak

45 Pitch pine
46 Eastern redcedar
50 Black locust
52 White oak-black oak-northern red oak
53 White oak
55 Northern red oak
57 Yellow-poplar
58 Yellow-poplar-eastern hemlock
59 Yellow-poplar-white oak-northern red oak
60 Beech-sugar maple
61 River birch-sycamore
62 Silver maple-American elm
63 Cottonwood
64 Sassafras-persimmon
65 Pin oak-sweetgum
68 Mesquite
69 Sand pine
70 Longleaf pine
71 Longleaf pine-scrub oak
72 Southern scrub oak
73 Southern redcedar
74 Cabbage palmetto
75 Shortleaf pine
76 Shortleaf pine-oak
80 Loblolly pine-shortleaf pine
81 Loblolly pine
82 Loblolly pine-hardwood
83 Longleaf pine-slash pine
84 Slash pine
85 Slash pine-hardwood
87 Sweetgum-yellow-poplar
88 Willow oak-water oak-diamondleaf (laurel) oak
89 Live oak
91 Swamp chestnut oak-cherrybark oak
92 Sweetgum-willow oak
93 Sugarberry-American elm-green ash
94 Sycamore-sweetgum-American elm
95 Black willow
96 Overcup oak-water hickory
97 Atlantic white-cedar
98 Pond pine
100 Pondcypress
101 Baldcypress
102 Baldcypress-tupelo
103 Water tupelo-swamp tupelo
104 Sweetbay-swamp tupelo-redbay
105 Tropical hardwoods
108 Red maple
109 Hawthorn
110 Black oak
111 South Florida slash pine
201 White spruce

202 White spruce-paper birch
221 Red alder
222 Black cottonwood-willow
233 Oregon white oak
235 Cottonwood-willow
236 Bur oak
242 Mesquite
246 California black oak
248 Knobcone pine
249 Canyon live oak
250 Blue oak-foothills pine
255 California coast live oak

SRM (RANGELAND) COVER TYPES [166]:
201 Blue oak woodland
202 Coast live oak woodland
203 Riparian woodland
204 North coastal shrub
205 Coastal sage shrub
206 Chamise chaparral
207 Scrub oak mixed chaparral
211 Creosote bush scrub
212 Blackbush
214 Coastal prairie
215 Valley grassland
217 Wetlands
314 Big sagebrush-bluebunch wheatgrass
315 Big sagebrush-Idaho fescue
316 Big sagebrush-rough fescue
401 Basin big sagebrush
403 Wyoming big sagebrush
413 Gambel oak
414 Salt desert shrub
418 Bigtooth maple
419 Bittercherry
421 Chokecherry-serviceberry-rose
422 Riparian
501 Saltbush-greasewood
502 Grama-galleta
505 Grama-tobosa shrub
506 Creosotebush-bursage
507 Palo verde-cactus
508 Creosotebush-tarbush
601 Bluestem prairie
602 Bluestem-prairie sandreed
603 Prairie sandreed-needlegrass
604 Bluestem-grama prairie
605 Sandsage prairie
606 Wheatgrass-bluestem-needlegrass
607 Wheatgrass-needlegrass
608 Wheatgrass-grama-needlegrass
609 Wheatgrass-grama

610 Wheatgrass
611 Blue grama-buffalo grass
612 Sagebrush-grass
614 Crested wheatgrass
615 Wheatgrass-saltgrass-grama
701 Alkali sacaton-tobosagrass
702 Black grama-alkali sacaton
703 Black grama-sideoats grama
704 Blue grama-western wheatgrass
705 Blue grama-galleta
706 Blue grama-sideoats grama
707 Blue grama-sideoats grama-black grama
708 Bluestem-dropseed
709 Bluestem-grama
710 Bluestem prairie
711 Bluestem-sacahuista prairie
712 Galleta-alkali sacaton
713 Grama-muhly-threeawn
714 Grama-bluestem
715 Grama-buffalo grass
716 Grama-feathergrass
717 Little bluestem-Indiangrass-Texas wintergrass
718 Mesquite-grama
719 Mesquite-liveoak-seacoast bluestem
720 Sand bluestem-little bluestem (dunes)
721 Sand bluestem-little bluestem (plains)
722 Sand sagebrush-mixed prairie
723 Sea oats
724 Sideoats grama-New Mexico feathergrass-winterfat
725 Vine mesquite-alkali sacaton
726 Cordgrass
727 Mesquite-buffalo grass
728 Mesquite-granjeno-acacia
729 Mesquite
731 Cross timbers-Oklahoma
732 Cross timbers-Texas (little bluestem-post oak)
734 Mesquite-oak
735 Sideoats grama-sumac-juniper
801 Savanna
802 Missouri prairie
803 Missouri glades
804 Tall fescue
805 Riparian
806 Gulf Coast salt marsh
807 Gulf Coast fresh marsh
808 Sand pine scrub
809 Mixed hardwood and pine
810 Longleaf pine-turkey oak hills
811 South Florida flatwoods
812 North Florida flatwoods
813 Cutthroat seeps
814 Cabbage palm flatwoods

815 Upland hardwood hammocks
816 Cabbage palm hammocks
817 Oak hammocks
819 Freshwater marsh and ponds
820 Everglades flatwoods
821 Pitcher plant bogs
822 Slough

HABITAT TYPES AND PLANT COMMUNITIES:
Johnson grass is most common in ecosystems with moist to mesic moisture regimes, including riparian [61,124], southern old-field [72,96], subtropical, and tropical [78,79] habitats.

Riparian and wetland associates:
A vegetation survey on the lower Rio Grande of Texas found Johnson grass was the most common herbaceous cover (34%) in Fremont cottonwood-Goodding willow (*Populus fremontii-Salix gooddingii*) communities, followed by docks (*Rumex* spp.) (32% cover). Saltcedar (*Tamarix chinensis*) and seepwillow (*Baccharis* spp.) were most common in the shrub layer [57]. On the Tensas River National Wildlife Refuge, Louisiana, Johnson grass is a dominant herbaceous species (8% cover) in winged elm-American elm-cedar elm-green ash (*Ulmus alata-U. americana-U. crassifolia-Fraxinus pennsylvanica*) woodlands. Other dominant herbs include purple loosestrife (*Lythrum salicaria*, 21% cover), trumpet creeper (*Campsis radicans*, 13% cover), and bushy bluestem (*Andropogon glomeratus*, 7% cover) [124].

Old fields:
On old bottomland fields of the Mississippi and Yazoo rivers, Mississippi, Johnson grass cover is greatest on silty-clay loams. Associated overstory species are Texas red oak (*Quercus texicana*), Shumard oak (*Q. shumardii*), and cherrybark oak (*Quercus pagoda*). Canada goldenrod (*Solidago canadensis*) is a common herbaceous associate [3]. In Oklahoma, Johnson grass dominates on bottomlands and old fields, associating with ragweed (*Ambrosia trifida*), Canadian horseweed (*Conyza canadensis*), and smooth sumac (*Rhus glabra*). Hoagland [96] provides a description of Johnson grass-dominated old-field communities in Oklahoma.

Southwest: Johnson grass was planted as a forage grass in wetland areas of the Southwest [4] and consequently has scattered, patchy occurrence on moist desert sites [36,42]. In western and southern Nevada, Johnson grass associates with blackbrush (*Coleogyne ramosissima*), sagebrush (*Artemisia* spp.), and shadscale (*Atriplex confertifolia*) [111].

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Sorghum halepense

Entire Johnson grass plant (left), and Johnson grass rhizomes and culm shoots (right). Photos Allan Kates, Virginia Polytechnic Institute (in [85]).

GENERAL BOTANICAL CHARACTERISTICS:
The following description of Johnson grass provides characteristics that may be relevant to fire ecology, and is not meant for identification. Keys for identification are available (e.g. [73,94,95,97,112,150,178,195]).

Morphology: Johnson grass is a nonnative, warm-season perennial [50,72,123,185,202]. It is usually rhizomatous, but is a highly variable species with many ecotypes [97]. It may grow as an annual in hot, arid climates and at the northern limits of its range [62,198,199]. Johnson grass rhizomes form a dense, tangled, tough sod [205]. Rhizomes serve as carbohydrate-storing and regeneration organs [6]. Most rhizomes occur in the top 7.9 inches (20 cm) of soil, although rhizomes in soft, deep soil may extend deeper [43,97]. Rhizomes vary in size from a few inches to several feet in length, and in thickness from 0.25 to 0.75 inch (6.4-19 mm) [87]. Leaves and aboveground stems (culms) are coarse [150]. Culms are 1.6 to 4.9 feet (0.5-1.5 m) tall. In flower, total plant height may reach 12 feet (3.7 m) [5]. The inflorescence is a 4- to 24-inch (10-60 cm) open panicle. Spikelets of *Sorghum*
species are paired: 1 is sessile and perfect; the other spikelet is pedicelled and staminate. Spikelets are 4 to 7 mm in length. There are about 35 to 350 spikelets per panicle, depending upon ecotype. Lemmas are cilate; they may be awnless or have short (1-15 mm), sometimes twisted awns that aid in seed dispersal [50,71,94,123,185,195,197,202]. Seeds are about 2 mm long [150].

Physiology:
Several physiological characteristics of Johnson grass aid in its spread. Mature Johnson grass plants are moderately drought resistant [6] and salt tolerant [208]. Johnson grass produces toxins (see Toxicity) that may be allelopathic [97,136,197].

RAUNKIAER [153] LIFE FORM:

Geophyte
Hemicryptophyte
Therophyte

REGENERATION PROCESSES:
Johnson grass reproduces from rhizomes and from seed [43,87,97].

Asexual regeneration:

Once a population is established, most population growth is from asexual regeneration by rhizomes [97]. Throughout most of its North American range, Johnson grass populations are strongly rhizomatous [50,72,123,185,202]. Some Johnson grass populations are weakly rhizomatous or nonrhizomatous, especially at the species' distributional limits [62,198,199]. Rhizome expression in Johnson grass is apparently controlled by multiple, dominant genes, resulting in variable degrees of rhizome development in both Johnson grass and its hybrids [210]. Extreme temperatures also inhibit Johnson grass' ability to produce rhizomes [86,176].

Rhizome development:

Johnson grass plants begin growing rhizomes in the seedling stage. Primary rhizomes are initiated at the 5-leaf stage, when plants are about a foot tall. Rhizome growth continues slowly until the 10-leaf stage, then accelerates greatly. Rhizomes are well developed by 6 to 7 weeks [6,102,126]. In a greenhouse experiment, Anderson and others [6] noted extensive rhizome development on 4.5-month-old plants, with over 5,200 rhizome nodes/plant [6].

In older plants, last-year or primary rhizomes produce new, secondary rhizomes in spring. Secondary rhizomes in turn produce tertiary rhizomes. Secondary and tertiary rhizome growth slows or stops around flowering, then resumes with seedhead development [127]. Rhizome production peaks at seed ripening [79,98], when a single plant may produce 200 to 300 feet (60-90 m) of rhizomes [128]. Secondary and tertiary rhizomes continue growth and carbohydrate accumulation until late fall, then go dormant over winter. Primary rhizomes die each fall. In spring, secondary and tertiary rhizomes become current-year primary rhizomes [4,43,81,87,97,102].

Rhizome sprouting: Small or broken rhizomes, especially secondaries, can form new plants [6,9,43,174]. Plows spread Johnson grass by breaking up, dispersing, and replanting rhizomes [3] (see Cultural control). Small rhizomes are more likely to sprout when shallowly buried, while large rhizomes are more likely to sprout when deeply buried. In the greenhouse, 3-inch (7.6-cm) rhizome sections sprouted best when planted less than 3 inches deep. Longer, 6-inch (15.2-cm) sections sprouted best when buried deeper than 3 inches ([39] and references therein). In a Mississippi field experiment, McWhorter [126,127] found that with shallow burial (≤ 2 inches (6 cm)), short rhizomes (< 3 inches (7.6 cm)) produced more sprouts than long rhizomes (6 inches (15.2 cm)). The opposite trend occurred when rhizomes were planted deeper than 2.4 inches (6 cm). Rhizomes usually grow to a depth of 10 to 20 inches (25-50 cm) [128]. Loose, sandy or loamy soils generally allow for best rhizome expansion [127]. Clay tends to inhibit rhizome expansion [87]; however, rhizomes may penetrate several feet down cracks in clay soil [127]. Deeply buried rhizomes that do not sprout cannot survive more than a year [4,81,97].

Rhizomes are somewhat drought-resistant, remaining viable after drying to 40% of initial harvest weight [6]. They are sensitive to extreme temperatures. In northern climates, rhizomes must be deeply buried in order to overwinter. In an Illinois field experiment, Johnson grass rhizomes did not survive winter temperatures less than 1.4 °F (-17 °C) unless buried 7.9 inches (20 cm) or more below ground [176]. In southern Ontario, rhizomes must be 10 inches (25 cm) or more inches below ground to overwinter ([86] and references therein).

Sexual regeneration:

Although growth of established populations is primarily through rhizomes, Johnson grass expands its distribution and establishes new populations through seed spread [97].

Breeding system: *Sorghum* species are mostly self-crossed, although some outcrossing occurs ([197] and references therein).

Pollination: Johnson grass is primarily self-pollinated [197]. Some pollination is effected by wind, especially when plants are ≤ 425 feet (130 m) apart [197,203].

Seed production: Johnson grass is a short-day plant, requiring 8 to 16 hours of daylight to flower [67,136]. It is a good seed producer under favorable growing conditions. A single plant may produce 80,000 or more seeds in 1 growing season [3,85]. Two seed crops may be produced under good conditions. In agricultural fields in Argentina, Johnson grass produced a large seed crop in early summer (Jan-Feb.; 60% of total seed production for the year) and a smaller seed crop in late summer-early fall (mid-March-early April; 40% of annual seed production) [67]. Johnson grass seed production is estimated at 90 gallons/acre (855 L/ha) on good sites in the South. Field trials in Mississippi showed mean seed production of 84 g/plant and 28,000 seeds/plant [128,197]. Resources are allocated to rhizomes at the expense of seeds under poor growing conditions [22,23].

Greenhouse trials using Johnson grass seed from the Northeast showed populations that grow and reproduce as annuals have faster growth rates, more rapid development, more and larger seeds, and fewer rhizomes compared to populations that sprout from overwintered rhizomes [199].

Seed dispersal: Wind, water, machinery, and animals disperse Johnson grass seed [3,66,85,86,183]. Spikelets are readily deciduous [202] and usually disperse as a unit beneath the parent plant [3,66,71,73]. Strong winds disperse seed longer distances. In Argentina, 28- to 31-mile/hr (45- to 50-km/hr) winds that occurred during May thunderstorms carried Johnson grass seed 2,950 to 3,300 feet (900-1,000 m) from parent plants [66]. Water has dispersed seed along many waterways of the United States [3,85,183]. Farming equipment also spreads seeds [66,85]. Viable Johnson grass seed is a common contaminant in hay, harvested crops, and commercial seed [3,143]. Johnson grass seed retains viability after passing through the digestive tracts of livestock [9,85,127]. The relative importance of agents that disperse Johnson grass seed is unclear [129].

Seed banking: Johnson grass builds up a soil seed bank [190]. The seeds are dormant and may remain viable for several years, although most soil-stored seeds germinate in their 1st or 2nd year [3,97,136]. In Mississippi, 1st-year stratified seed showed 82% viability in the field. After burial in the field for 2.5 years, the same seed lot showed 62% viability [54]. In California, 5-year-old buried seed showed ≥ 50% viability, but by age 6, viability dropped to 2% [121].

Germination:

Johnson grass has 2 mechanisms of dormancy: mechanical dormancy imposed by the seed hull and seedcoat, which requires weathering or scarification to break; and chemical dormancy, which requires oxygen to break [101]. Diurnal fluctuations in temperature, afterripening, or both are needed to overcome both types of dormancy [26,26,65,100,182]. Seed from water-stressed plants is generally less dormant than seed from amply watered plants [23]. Benech and others [25] present a model predicting loss of seed dormancy and consequent seedling emergence based on soil temperature.

Light improves germination rate with warm temperatures (> 93 °F (34 °C)) and inhibits germination with cold temperatures (< 72 °F (22 °C) [101]. In the greenhouse, Taylorson and McWhorter [182] found a 63% increase in germination rate for Johnson grass seed exposed to light vs. seeds kept in the dark. Deeply buried seed remains dormant for at least 7 years [85], but does not germinate [27,65,100]. Soil upheaval such as cultivation, which brings seed closer to the soil surface, usually increases germination rates [65,100]. In the greenhouse, best germination (60-75%) occurred with surface-scattered to shallowly buried (0-1.6 inches (0-4 cm)) seed. Less than 5% germination occurred with seed buried ≥ 3 inches (8 cm) below the soil surface [27]. Litter cover or shallow burial may aid germination in the field. Prostko and others [148] present a model to predict Johnson grass seedling emergence based upon temperature and seed burial depth.

Seedling establishment/growth:

Best establishment occurs on open, disturbed sites. Seed dispersed away from parent plants may show better establishment compared to seed falling beneath its parent. In an old field in Argentina, most Johnson grass seed fell near parent plants on undisturbed plots. Only 1% of seed beneath a parent plant established. On tilled plots mowed every 1-2 weeks by a corn (*Zea mays*) harvester, seed was carried 3 to 82 feet (1-25 m) from parent plants. Recruitment of those seed neared 100% [66]. On favorable sites, plants may produce 80 or more culms in their 1st year [3].

As a facultative annual, Johnson grass shows variable ability to regenerate from seed. Johnson grass annuals in rural-interface wildlands of southern Arizona rarely reproduce either from on-site seed or from rhizomes. Seed dispersed from adjacent agricultural lands provide continual sources of seed [62]. However, some populations in the northern portion of Johnson grass' range successfully reproduce from seed. In southern Ontario, northern Ohio, and northern New York, annual populations have larger leaves, inflorescences, and seeds compared to perennial Johnson grass populations [199].

Johnson grass seedlings may show faster 1st-year growth than plants started from rhizome fragments. On the Mississippi Delta near Stoneville, Mississippi, Johnson grass started from seed showed greater biomass and more rapid height gain than plants started from rhizome pieces. At flowering, seed plants were producing 0.75 to 3 feet (0.23-0.9 m) of new rhizome growth per day. Plant growth patterns were as follows (data are means) [126]:

Biomass and height of Johnson grass seedlings							
Date (1959)	Days after emergence	Green weight (g)				Height (in)	Rhizome length (ft)
		Leaves	Rhizomes	Roots	Seedhead		
May 20	20	12	2	3	----	12	----
May 27	27	190	30	30	----	23	<1
June 15	46	690	90	100	----	52	7
July 1	62	1990	750	220	180	74	35
Sept. 1	124	2950	5050	360	500	74	153
Sept. 29	152	3140	8070	430	680	74	212
Biomass and height of Johnson grass rhizome sprouts							
May 20	19	9	3	3	----	9	----
May 27	26	80	14	20	----	13	<1
June 3	33	530	100	40	----	30	1
June 15	45	610	110	130	----	47	5
June 19	49	590	310	160	9	70	9
June 24	54	950	220	160	74	72	14

SITE CHARACTERISTICS:
Johnson grass is most common on disturbed sites such as ditch banks, roadsides, fields, and "waste places" [94,112,150,201]. It occurs on all soil textures [87], with best growth occurring on silty bottomland soils [3,87]. On old bottomland fields of the Mississippi and Yazoo rivers, Mississippi, Johnson grass cover is greatest on silty-clay loams [3].

Moisture regime:

Although Johnson grass occurs in wet to dry habitats in its native range in southern Europe [185], in the United States it is generally restricted to wet or mesic sites [73,94,202]. It is most common in warm, humid southern climates that receive ample summer rainfall. Johnson grass is a facultative wetland species, frequently occurring on floodplains [18,19]. Johnson grass patches are often extensive along canals and irrigation ditches

[97]. In arid sites such as Organ Pipe Cactus National Monument, Arizona, Johnson grass establishes mostly in wet locations such as washes, drainages, and stream edges [62,179].

Elevational ranges of Johnson grass in several states are:

Arizona	below 6,000 ft (1,800 m) [112]
California	below 2,600 ft (800 m) [94]
Nevada	2,000-5,000 ft (600-1,500 m) [202]
New Mexico	3,500-6,000 ft (1,100-1,800 m) [123]
Utah	2,800-5,000 ft (850-1,500 m) [202]

SUCCESSIONAL STATUS:
Johnson grass is a pioneer species, and is often found on old fields [72], frequently inundated, or otherwise disturbed sites [72,84,170]. Johnson grass is not restricted to disturbed sites, however, as it invades undisturbed tallgrass and coastal prairies, savannas, and riparian zones [46,170]. In an Oklahoma study of succession in little bluestem (*Schizachyrium scoparium*) prairie, Johnson grass was most common in mid-successional seres, when other weeds and woody species were succeeding to tallgrass prairie species [46]. Johnson grass' aggressive spread through rhizomes may slow succession, especially in grassland ecosystems [170].

Old fields: Johnson grass is particularly common on old bottomland fields in the South [3,17,18]. Unlike most crop weeds, which tend to decrease in the absence of irrigation and fertilization, Johnson grass tends to persist on abandoned fields. For example, in Georgia it was prevalent in 1-, 4-, and 8-year-old fertilized crop fields, but was also prevalent in 8-year-old fallow fields [140].

Shade tolerance: Johnson grass requires open sites and does not persist under closed canopies [78,191]. In a honey mesquite (*Prosopis glandulosa*) Texas savanna, Johnson grass associated with Texas wintergrass (*Nassella lecotricha*) in open areas, but was not found under honey mesquite or other trees [191]. In Argentina grasslands, canopy removal increased Johnson grass germination and establishment compared to closed-canopy sites [25].

SEASONAL DEVELOPMENT:
Johnson grass plants generally die back in winter, growing back from primary rhizomes in spring [97,150]. Rhizomes start growth with spring temperatures above 60 °F (16 °C) [43,87,97]. Sprouts appear earlier in spring than seedlings [154]. After spring rhizome expansion, most summer growth occurs in aboveground organs until after flowering; then, most growth is reapportioned to rhizomes. In a greenhouse experiment, Rapp [152] found Johnson grass carbohydrate production peaked in aboveground tissues around 120 days after planting, and peaked in rhizomes around 300 days after planting.

Johnson grass produces seed about 2 months after initiation of spring rhizome expansion [152]. Even 1st-year Johnson grass plants are capable of quick flowering and seed set: Plants in Mississippi initiated flowers 46 days after seedling emergence [126]. Bridges and Chandler [35] present a model for predicting Johnson grass flowering under fluctuating field temperatures, with nitrogen fertilization, and with irrigation. Holshouser and Chandler [98,99] provide temperature-dependent models for predicting flowering, germination, rhizome bud break, and rhizome sprouting under field conditions.

The following table shows phenological development of Johnson grass in various states and regions:

Area	Growth stage	Period
Arizona		April-November [112]

Carolinas		May-October [150]
Florida		year-round [207]
Illinois	growth starting	late May-June [105]
	flowering	June-October [133]
	seed set	late July [105]
Kentucky	rhizomes expanding	early May-late June
	seedlings emerging	June [81]
Nevada	flowering	July-September [111]
New Mexico	flowering	June-October [123]
Oklahoma	seedlings emerging	late June [106]
Texas	flowering	May-November [50]
West Virginia		July-September [178]
Great Plains		June-October [73]
Southeast	culms expanding	mid-Feb-mid-May
	germinating	March-May [129]
Baja California	flowering	April-August [205]

FIRE ECOLOGY

SPECIES: Sorghum halepense

- FIRE ECOLOGY OR ADAPTATIONS
- POSTFIRE REGENERATION STRATEGY

FIRE ECOLOGY OR ADAPTATIONS:

Fire adaptations: Johnson grass survives fire by sprouting from rhizomes [72,87,141]. Variable rhizome depths to 7.9 inches (20 cm) or more below ground [43,97] ensure that Johnson grass survives even if fire damages or kills shallow rhizomes.

Little documentation is available on postfire regeneration of Johnson grass from seed. As a seed banking species that establishes in open, disturbed sites [72,84,170], it is likely that Johnson grass is capable of postfire seedling establishment. Information is needed on Johnson grass' ability to establish from seed after fire.

Fuels: Johnson [108] provides a model for estimating live:dead fuel ratios of Johnson grass. In Alabama wildlands, dry-matter biomass production of Johnson grass averaged 11.2 Mg/ha, more than most associated grasses [151]. Johnson grass litter reportedly remains on the ground through 1 or more growing seasons [105].

Fire regimes:

Johnson grass is well adapted to survive under all fire regimes (understory, mixed, and stand-replacement). As of this writing (2004), there is no published information on how Johnson grass interacts with North American fire regimes. In riparian and other areas where Johnson grass is highly productive, Johnson grass may promote fire spread by increasing fine fuel loads above historic levels. Studies are needed on the fire ecology of Johnson grass in North American.

The following table provides fire return intervals for plant communities and ecosystems where Johnson grass may be important. For further information, refer to the FEIS review on the dominant species listed below.

Community or Ecosystem	Dominant Species	Fire Return Interval Range (years)
maple-beech-birch	*Acer-Fagus-Betula*	> 1,000
silver maple-American elm	*A. saccharinum-Ulmus americana*	< 35 to 200
sugar maple	*A. saccharum*	> 1,000
sugar maple-basswood	*A. saccharum-Tilia americana*	> 1,000 [196]
California chaparral	*Adenostoma* and/or *Arctostaphylos* spp.	< 35 to < 100
bluestem prairie	*Andropogon gerardii* var. *gerardii-Schizachyrium scoparium*	< 10 [118,145]
Nebraska sandhills prairie	*A. gerardii* var. *paucipilus-S. scoparium*	< 10
bluestem-Sacahuista prairie	*A. littoralis-Spartina spartinae*	< 10 [145]
silver sagebrush steppe	*Artemisia cana*	5-45 [93,123,149]
sagebrush steppe	*A. tridentata/Pseudoroegneria spicata*	20-70 [145]
basin big sagebrush	*A. tridentata* var. *tridentata*	12-43 [161]
Wyoming big sagebrush	*A. tridentata* var. *wyomingensis*	10-70 (40**) [193,211]
coastal sagebrush	*A. californica*	< 35 to < 100
saltbush-greasewood	*Atriplex confertifolia-Sarcobatus vermiculatus*	< 35 to < 100
desert grasslands	*Bouteloua eriopoda* and/or *Pleuraphis mutica*	5-100 [145]
plains grasslands	*Bouteloua* spp.	< 35 [123,145]
blue grama-needle-and-thread grass-western wheatgrass	*B. gracilis-Hesperostipa comata-Pascopyrum smithii*	< 35 [123,145,160]
blue grama-buffalo grass	*B. gracilis-Buchloe dactyloides*	< 35 [123,145]
grama-galleta steppe	*Bouteloua gracilis-Pleuraphis jamesii*	< 35 to < 100
blue grama-tobosa prairie	*B. gracilis-P. mutica*	< 35 to < 100 [145]
sugarberry-America elm-green ash	*Celtis laevigata-Ulmus americana-Fraxinus pennsylvanica*	< 35 to 200 [196]
paloverde-cactus shrub	*Cercidium microphyllum/Opuntia* spp.	< 35 to < 100
blackbrush	*Coleogyne ramosissima*	< 35 to < 100
northern cordgrass prairie	*Distichlis spicata-Spartina* spp.	1-3 [145]
beech-sugar maple	*Fagus* spp.-*Acer saccharum*	> 1,000 [196]
California steppe	*Festuca-Danthonia* spp.	< 35 [145,177]
black ash	*Fraxinus nigra*	< 35 to 200 [196]
cedar glades	*Juniperus virginiana*	3-22 [80,145]
creosotebush	*Larrea tridentata*	< 35 to < 100
Ceniza shrub	*Larrea tridentata-Leucophyllum frutescens-Prosopis glandulosa*	< 35 [145]

yellow-poplar	*Liriodendron tulipifera*	< 35 [196]
Everglades	*Mariscus jamaicensis*	< 10 [135]
wheatgrass plains grasslands	*Pascopyrum smithii*	< 5-47+ [123,145,149]
pine-cypress forest	*Pinus-Cupressus* spp.	< 35 to 200 [10]
shortleaf pine	*P. echinata*	2-15
shortleaf pine-oak	*P. echinata-Quercus* spp.	< 10
slash pine	*P. elliottii*	3-8
slash pine-hardwood	*P. elliottii*-variable	< 35
sand pine	*P. elliottii* var. *elliottii*	25-45 [196]
South Florida slash pine	*P. elliottii* var. *densa*	1-5
longleaf-slash pine	*P. palustris-P. elliottii*	1-4 [135,196]
longleaf pine-scrub oak	*P. palustris-Quercus* spp.	6-10 [196]
pitch pine	*P. rigida*	6-25 [38,91]
pocosin	*P. serotina*	3-8
pond pine	*P. serotina*	3-8
loblolly pine	*P. taeda*	3-8
loblolly-shortleaf pine	*P. taeda-P. echinata*	10 to < 35
sycamore-sweetgum-American elm	*Platanus occidentalis-Liquidambar styraciflua-Ulmus americana*	< 35 to 200 [196]
galleta-threeawn shrubsteppe	*Pleuraphis jamesii-Aristida purpurea*	< 35 to < 100
eastern cottonwood	*Populus deltoides*	< 35 to 200 [145]
mesquite	*Prosopis glandulosa*	< 35 to < 100 [125,145]
mesquite-buffalo grass	*P. glandulosa-Buchloe dactyloides*	< 35
Texas savanna	*P. glandulosa* var. *glandulosa*	< 10 [145]
black cherry-sugar maple	*Prunus serotina-Acer saccharum*	> 1,000 [196]
California oakwoods	*Quercus* spp.	< 35 [10]
oak-hickory	*Quercus-Carya* spp.	< 35
northeastern oak-pine	*Quercus-Pinus* spp.	10 to < 35 [196]
oak-gum-cypress	*Quercus-Nyssa*-spp.-*Taxodium distichum*	35 to > 200 [135]
southeastern oak-pine	*Quercus-Pinus* spp.	< 10 [196]
coast live oak	*Q agrifolia*	2-75 [75]
white oak-black oak-northern red oak	*Q alba-Q. velutina-Q. rubra*	< 35 [196]
canyon live oak	*Q chrysolepis*	<35 to 200
blue oak-foothills pine	*Q douglasii-P. sabiniana*	<35 [10]
northern pin oak	*Q ellipsoidalis*	< 35 [196]
Oregon white oak	*Q garryana*	< 35 [10]
bear oak	*Q ilicifolia*	< 35 [196]

California black oak	*Q kelloggii*	5-30 [145]
bur oak	*Q macrocarpa*	< 10 [196]
oak savanna	*Q macrocarpa/Andropogon gerardii-Schizachyrium scoparium*	2-14 [145,196]
chestnut oak	*Q prinus*	3-8
northern red oak	*Q rubra*	10 to < 35
post oak-blackjack oak	*Q stellata-Q. marilandica*	< 10
black oak	*Q velutina*	< 35
live oak	*Q virginiana*	10 to< 100 [196]
interior live oak	*Q. wislizenii*	< 35 [10]
cabbage palmetto-slash pine	*Sabal palmetto-P. elliottii*	< 10 [135,196]
blackland prairie	*Schizachyrium scoparium-Nassella leucotricha*	< 10
Fayette prairie	*S. scoparium-Buchloe dactyloides*	< 10 [196]
little bluestem-grama prairie	*S. scoparium-Bouteloua* spp.	< 35
tule marshes	*Scirpus* and/or *Typha* spp.	< 35
southern cordgrass prairie	*Spartina alterniflora*	1-3 [145]
baldcypress	*Taxodium distichum* var. *distichum*	100 to > 300
pondcypress	*T. distichum* var. *nutans*	< 35 [135]
elm-ash-cottonwood	*Ulmus-Fraxinus-Populus* spp.	< 35 to 200 [53,196]

**mean

POSTFIRE REGENERATION STRATEGY [175]:
Rhizomatous herb, rhizome in soil

FIRE EFFECTS

SPECIES: Sorghum halepense

- IMMEDIATE FIRE EFFECT ON PLANT
- DISCUSSION AND QUALIFICATION OF FIRE EFFECT
- PLANT RESPONSE TO FIRE
- DISCUSSION AND QUALIFICATION OF PLANT RESPONSE
- FIRE MANAGEMENT CONSIDERATIONS

IMMEDIATE FIRE EFFECT ON PLANT:
Fire top-kills Johnson grass [72,87,194]. For example, an October 1986 wildfire killed aboveground portions of Johnson grass in a Rio Grande palmetto (*Sabal mexicana*)-honey mesquite grove in Texas. Johnson grass was sprouting from rhizomes by late December 1986 [194].

Very high temperatures kill Johnson grass seed. Soil-stored seed is protected from fire damage [132]. Fire scarification appears to have no effect on rate of seed germination. In the laboratory, there were no significant differences in rates of germination between unheated Johnson grass seed and seed heated to 200 °F (90 °C) and 400 °F (200 °C); mean germination rate was 52%. Mean germination rate dropped to 17% at 660 °F (350 °C) and 0% at 800 °F (430 °C) [132].

DISCUSSION AND QUALIFICATION OF FIRE EFFECT:
No further information is available on this topic.

PLANT RESPONSE TO FIRE:
Johnson grass sprouts from rhizomes after top-kill by fire [72,194], and fire may promote Johnson grass growth. Spring prescribed burning increased Johnson grass in a short-term study in Georgia. Old fields were burned on 5 March, 1970. In the 1970 postfire growing season (March-October), Johnson grass net productivity averaged 27.42 g/m² on burned plots and 0.20 g/m² on unburned control plots. Prescribed burning significantly (p=0.05) reduced the litter layer, and plants on burned plots showed increased spring nitrogen uptake compared to control plots [141]. Reduced litter and increased nitrogen uptake probably enhanced Johnson grass growth on burned plots.

Published information on postfire seedling establishment of Johnson grass is lacking. Studies are needed on the ability of Johnson grass to establish from seed in postfire environments.

DISCUSSION AND QUALIFICATION OF PLANT RESPONSE:
In Mississippi, burning or disking treatments to improve northern bobwhite habitat increased Johnson grass cover. Treatments were spring burning, winter burning, 1 fall disking, 2 fall diskings, 1 spring disking, 2 spring diskings, and an untreated control. Plots were remeasured at posttreatment year 1. There were no significant differences in Johnson grass cover among burned and disked treatments, but Johnson grass cover was significantly (p=0.023) greater on all treated plots (either burned or disked) compared to untreated control plots [74].

FIRE MANAGEMENT CONSIDERATIONS:
Fire may be a useful tool in controlling Johnson grass as long as it is used in conjunction with follow-up treatments to control rhizome sprouts. For example, restoration treatments in Kentucky successfully used a combination of spring burning and follow-up herbicide (imazapic) treatment to control nonnative Johnson grass, tall fescue (*Festuca arundinacea*), and hairy crabgrass (*Digitaria sanguinalis*) in remnant bluegrass (*Andropogon* spp.) stands [200]. Spring burning without further control treatments is not recommended for controlling Johnson grass, as it is likely to promote sprouting [170]. Few studies using fire to control Johnson grass have been attempted, so small-scale trials and caution are advised when using fire on Johnson grass. Research is needed on using fire to control Johnson grass.

Spot burning with a gas torch was once a widely practiced method of controlling patches of Johnson grass. It is rarely used today due to cost restraints [128], but may be useful in riparian or other areas where spot control is needed. In Arizona, a Johnson grass infestation along a canal bank was controlled by torching plants with a propane burner. Eleven burnings at 2-week intervals were required until postfire sprouting stopped. Johnson grass was absent from the site the following year [87].

Johnson grass was once used for postfire rehabilitation. For example, it was seeded in and successfully established after the 1960 Donner Ridge Fire near Truckee, California [89]. Current U.S. Forest Service regulations prohibit or recommend against planting Johnson grass on Forest Service lands [187,188].

MANAGEMENT CONSIDERATIONS

SPECIES: Sorghum halepense

- IMPORTANCE TO LIVESTOCK AND WILDLIFE
- OTHER USES

- IMPACTS AND CONTROL

IMPORTANCE TO LIVESTOCK AND WILDLIFE:
Although Johnson grass can be an undesirable species, it can also provide good forage for wildlife and livestock under most growing conditions [31,48,88,92].

Palatability/nutritional value: Johnson grass is moderately palatable and nutritious [48,50]. Deer make light to moderate use of Johnson grass [115,164], grazing all aboveground portions of the plant [48]. Rodents also graze Johnson grass. In honey mesquite (*Prosopis glandulosa* var. *glandulosa*) plains of Texas, Heerman's kangaroo rat and Great Basin pocket mouse used Johnson grass frequently (6.7% volume, 61% frequency; and 5.9% volume, 36% frequency, respectively) [2]. Quail, geese, and wild turkey consume Johnson grass seeds [31,48].

Although intolerant of heavy grazing, Johnson grass is a good pasture grass and makes fair-quality hay when cut in the boot stage [171,192]. Livestock make moderate to good use of fresh Johnson grass [88,92]. In a comparison of Texas range grasses, Johnson grass showed greatest in-vitro digestibility (45%-69%, depending on the digestion media) of 5 grasses tested [117]. Dairy cattle in Alabama showed good weight gain and milk production on Johnson grass pasture [88].

Nutritional content:
In a western Texas study, Johnson grass had highest summer crude protein content (13.2%) of 9 rangeland grasses. Spring, fall, and winter crude protein values were 6.62%, 8.06%, and 3.81%, respectively [37]. In a greenhouse study comparing relative mineral content of 15 grass species, Johnson grass scored significantly higher (p=0.1) in phosphorus content than other grass species. Cobalt, manganese, and copper contents were moderate compared to other grasses [29]. Energy value of Johnson grass grown in Texas was 3,900 kcal/g [137]; in India, seasonal fluctuation in energy value varied from 3,684 kcal/g in October to 4,578 kcal/g in April [168]. Nutritional content of fresh Johnson grass in eastern Texas was [63]:

Growth stage	No. samples	Protein (%)	Ether extract (%)	Crude fiber (%)	N-free extract (%)
young	6	9.22	2.28	28.51	42.35
bloom	3	5.43	1.87	30.00	43.19
mature	2	5.36	1.40	32.36	44.01

Seasonal changes in forage quality of Johnson grass on the Edwards Plateau of Texas were [104]:

Plant part	Date	Water (%)	Ash (%)	Cell wall (%)	P (%)	Protein (%)	Digestible organic matter (%)
leaves	5/24/73	71	10	55	0.38	15	73
leaves & stems	6/28/73	68	9	60	0.21	12	70
leaves	10/25/73	76	9	66	0.16	10	63

When harvested at its peak, Johnson grass makes fair-quality hay, similar to timothy (*Phleum pratense*) hay in nutrient content [147]. In a 1928 study in an Alabama coal mine, draft horses and mules were fed oat (*Avena sativa*) grain and either Johnson grass or timothy hay for 3 months. The equines maintained their weight on both diets under "moderate" workloads. The animals lost weight on both diets under "heavy" workloads, but lost less weight on timothy hay and grain compared to Johnson grass hay and grain (mean losses of 10.71 and 21.78 lbs., respectively). Digestible nutrient means were [76]:

	Total dry matter per	Digestible nutrients per 100 lbs.			
		Crude protein	Carbohydrates	Fat	Total

	100 lbs.				
Johnson grass hay	89.9	2.9	45.0	1.0	50.1
timothy hay	88.4	3.0	42.8	1.2	48.5

Toxicity: Johnson grass is generally a good forage grass [31,48,88,92]. However, at certain developmental stages or under some adverse environmental conditions, Johnson grass may form cyanogenetic glycosides that can poison livestock. Phenologically, Johnson grass is most toxic when leaves and culms are actively growing. Seedlings and sprouts generally have higher levels of glycosides than plants that have reached the flowering stage. Secondary growth, produced after mature plants are mowed or heavily grazed, can also have high levels of glycosides. Environmentally, Johnson grass is most toxic after drought, extreme heat, frost, or when plants are wet with dew or light rain. Glycoside levels can vary considerably among Johnson grass populations. Ruminants, especially cattle, are more susceptible to glycoside poisoning than monogastric herbivores like horses [158,174]. As well as fresh plants, hay cut when Johnson grass is young or experiencing adverse environmental conditions such as drought can also be toxic [40,82,134,171,171]. Livestock poisoning can be prevented by waiting until new growth is 15 to 18 inches tall (38-46 cm) tall after drought, or deferring grazing until plants have dried after frost [129].

Johnson grass may sequester selenium (or other elements that are toxic at high doses) when growing in soils with high concentrations of toxic elements. In the Dead Sea area of Jordan, for example, selenium concentrations in Johnson grass samples were high enough to poison livestock [1].

Prolonged consumption of fresh Johnson grass can cause nitrate poisoning in ungulates [40,174]. Most livestock can graze Johnson grass safely when plants are at least 18 inches (46 cm) tall [171].

Cover value: No information is available on this topic.

OTHER USES:
Although experts now recommend against planting Johnson grass due to its invasiveness, Johnson grass was once widely cultivated for forage and hay [178]. Johnson grass may have a future role in reclamation of radioactive soils. On the Oak Ridge National Laboratory, Tennessee, Johnson grass showed good ability to uptake and sequester ^{137}Cesium and ^{90}Strontium. Radioactive uptake was greatest in plants inoculated with *Glomus* spp. mycorrhizae [58,59].

IMPACTS AND CONTROL:
Impacts: Johnson grass is an important agricultural weed that causes serious economic losses [35,81,97,113]. Based upon its nearly worldwide distribution and adverse effect on the global economy, it is described as 1 of the world's worst weeds [97]. Johnson grass was recognized as 1 of the 6 most damaging weeds in the United States by the turn of the 20th Century, and was the 1st weed targeted by the U.S.D.A. for research on control methods [129]. Johnson grass causes millions of dollars in lost agricultural revenue annually in the United States [130]. For example, Johnson grass infestations reduce yields in Louisiana sugarcane (*Saccharum officinarum*) fields by 25-50% [129]. In 1 study, 7 tons/acre (16 t/ha) of Johnson grass rhizomes were produced on a Louisiana sugarcane field [87]. Johnson grass also impacts agricultural lands as an alternate host for many of crop-damaging insects, nematodes, fungi, and viruses [129]. It hosts sorghum midges [35,70,163], southwestern corn borers [12], corn leaf aphids [107], sugarcane borers [29], banks grass mites [69], sorghum downy mildew [30], and maize viruses [97,129,162].

Little is documented on Johnson grass' impact in wildlands, and further research is needed on how Johnson grass affects wildland habitats. Generalizations about Johnson grass must always be qualified because of numerous ecotypes [126]. Typically, Johnson grass is a good competitor for nutrient [97,197], space [104], and water [167] resources. It can outcompete associated species for water by extracting water from lower soil profiles (12 inches (30 cm) or more below ground) [106]. Johnson grass may also negatively impact plant community composition through its reputed allelopathy [97,136,197]. Cyanogenetic glycosides and other toxins in Johnson grass may inhibit germination and growth of associated plant species [97,136,197].

On many sites in the United States, Johnson grass is not invasive in undisturbed wildlands, although it may readily invade disturbed sites (Cox, as cited in [136]). Johnson grass is most invasive on moist sites in wet-temperate regions of the southeastern United States [72,73,136]. For example, Johnson grass and Canada thistle (*Cirsium arvense*) are listed as the 2 most invasive and expensive to control weeds on the Eastern Neck National Wildlife Refuge, Maryland [45]. Johnson grass interferes with conifer seedling establishment and growth on southern pinelands [51], and may interfere with cottonwood (*Populus* spp.) and willow (*Salix* spp.) establishment in riparian zones [172].

Johnson grass is not invasive on most sites in the Southwest. At the turn of the last century, Johnson grass was planted in southwestern arroyos and stream channels to stabilize soil [47]. It established on such wet and mesic sites, but failed to spread. Felger [62] reports Johnson grass as only weakly invasive in Organ Pipe Cactus National Monument, Arizona, where the arid climate restricts Johnson grass to roadsides and washes. Johnson grass may grow as an annual, without spreading, in arid southwestern wildlands. Nearby agricultural lands are continual seed sources [62].

Control:

Although considerable information is available on controlling Johnson grass in agricultural settings (e.g., see [9,81,85,128,181]), information on controlling Johnson grass in rangelands, natural areas, and other wildlands is lacking. The following information on Johnson grass control is extracted primarily from agricultural literature but may be applied to some wildland settings, particularly old fields. Research is needed on controlling Johnson grass in wildland settings [136].

Johnson grass control involves several steps: 1) preventing seed from ripening and dispersing, 2) killing seedlings, 3) killing existing rhizomes, and 4) preventing growth of new rhizomes [9,81,85,128,181]. Control is most effective before plants have developed 5 leaves [102]. Detailed Johnson grass control procedures and techniques are given in several publications [97,128,136].

Prevention:

The most efficient and effective method of managing invasive species such as Johnson grass is to prevent their invasion and spread [165]. Preventing the establishment of nonnative invasive plants in wildlands is achieved by maintaining native communities and conducting aggressive surveying, monitoring, and any needed control measures several times each year. Monitoring efforts are best concentrated on the most disturbed areas in a site, particularly along potential pathways for Johnson grass invasion: roadsides, waterways, and old fields. Large plant size makes monitoring Johnson grass relatively easy in summer, and yearly summer monitoring helps managers assess the effectiveness of control programs. As of this writing (2004), monitoring programs for Johnson grass are in their infancy. As potential contact sources, Newman [136] provides a list of managers who have started monitoring programs for Johnson grass on Natural Areas. The Center for Invasive Plant Management provides an online guide to noxious weed prevention practices.

Integrated management:

A combination of complementary control methods may be helpful for rapid and effective control of Johnson grass. Integrated management includes not only killing the target plant, but establishing desirable species and discouraging nonnative, invasive species over the long term. Johnson grass control is rarely successful with only 1 method of control [142], but a combination of control methods can be effective. For example, in a tallgrass restoration study on the Hear Wildlife Sanctuary, Texas, a combination of early fall glyphosate spraying followed by late fall tillage helped control nonnative grasses on a former Johnson grass-Bermuda grass (*Cynodon dactylon*) pasture. Early fall spraying targeted Johnson grass while it was still actively growing. After spraying, rhizomes brought to the soil surface by tilling 4 to 6 inches (10-15 cm) deep were killed by winter frost. Johnson grass showed 4.2% cover and 50% frequency 3 years after treatments. Only trace amounts of Bermuda grass were present [173].

Fire: See the Fire Management Considerations section of this summary.

Biological:
Biological control of Johnson grass is problematic, as known control agents that kill Johnson grass also kill crop grasses such as corn and sorghum [129,144,146]. As of this writing (2004), there are no biocontrol agents approved for Johnson grass [184]. Several biological agents are being tested for possible use. A smut (*Sphacelotheca holci*) has helped control Johnson grass in Louisiana croplands [131]. In Florida field trials, a mixture of native fungal pathogens controlled Johnson grass and other weedy grasses in citrus (*Citrus* spp.) groves [44].

Heavy grazing over 2 or more years reduces Johnson grass by depleting rhizome reserves [3,8,90]. Rhizome development is greatly reduced when plant height is kept below 12 to 15 inches (30.5-38 cm) [128]. Best control is offered when herbicide or winter plowing treatments follow grazing treatments [3]. For example, in an unpublished study at the Patagonia/Sonoita Creek Preserve, Arizona, cow and horse summer grazing reduced density of Johnson grass. After 4 years of summer grazing, Johnson grass stem density had decreased 75% compared to pretreatment levels. Plots were then sprayed in late spring with glyphosate. Posttreatment restoration plantings gave mixed results. One to two months after spraying, native bunchgrasses were transplanted onto the study sites. Broadleaf weeds invaded the study plots after Johnson grass density was reduced by the grazing and herbicide treatments. After mowing treatments to control the broadleaved weeds, native bunchgrasses on some test plots are showing good growth. Other plots have experienced Johnson grass reinvasion and pocket gopher herbivory, to the detriment of native bunchgrasses. Preserve managers are continuing weed control treatments to promote the native bunchgrasses [184].

Geese are sometimes used for Johnson grass control in croplands. Geese prefer young shoots, and do not graze Johnson grass over about 7 inches (18 cm) in height [9,87].

Chemical:
Herbicides may provide initial control of a new invasion or a severe infestation, but used alone, they are rarely a complete or long-term solution to invasive species management [41]. Herbicides are most effective on large infestations when incorporated into long-term management plans that include replacement of weeds with desirable species, careful land use management, and prevention of new infestations. Control with herbicides is temporary, as it does not change the conditions that allowed the invasion to occur in the 1st place (e.g. [212]). See The Nature Conservancy's Weed Control Methods Handbook for considerations on the use of herbicides in Natural Areas and detailed information on specific chemicals.

The most effective chemical control of Johnson grass involves using systematic herbicides that translocate the active chemicals to rhizomes [128]. A single application of herbicide generally does not control large infestations, and follow-up measures are needed for long-term control [170]. Johnson grass control can be obtained using glyphosate [7,21,105,128], phenoxy (e.g., 2,4-D, fluazifop), [109,116], or halogenated aliphatic (e.g., dalapon) herbicides [8,87,128]. Spot spraying with sodium chlorate [83,87] or dalapon has been effective for small infestations [154]. Spot control is not effective in the long term unless surrounding seed sources are also eliminated [105]. Experiments in agricultural fields in Argentina showed best control when the herbicide (dalapon) was applied when rhizome biomass was low. Ghersa and others [68] provide a model for predicting optimal spraying time based on minimum rhizome biomass. Although based on South American seasons, the model is easily adjustable for use in the northern hemisphere.

Postemergent herbicides are the most common method of Johnson grass control in agricultural systems, and are probably the best herbicide choice for wildland settings as well, since postemergent herbicides cause less damage to nontarget species. In a Maryland old-field study, foliar application of postemergence herbicide (DPX-V9360) was more effective in late-growth stages (> 5 leaves) than early-growth stages (< 5 leaves) when rhizomes had not fully expanded [139]. Rosales-Robles and others [159] discuss the relative effectiveness of several postemergent herbicides as influenced by application rate and Johnson grass growth stage. Application procedures for postemergent herbicides effective on Johnson grass are given in these publications: [20,52,120,209].

Ecotypes may show differential response to herbicides [129]. Populations in Kentucky and Mississippi show genetic resistance to fluazifop and other phenoxy herbicides [15,138,169]. Virginia populations have resistance to enzyme acetyl-coenzyme A carboxylase inhibitors [33]. In Greece, some populations show resistance to glyphosate [114].

Herbicide treatments greatly decreased Johnson grass cover in an Illinois bottomland old field. Restoration treatments included tillage, pre- or postemergent herbicide applications (sulfometuron or glyphosate, respectively), and green ash (*Fraxinus pennsylvanica*) plantings. Tillage had no significant impact on Johnson grass cover. Mean Johnson grass cover (%) was significantly lower after the 1st postspray year [77]:

Treatment	Year 1	Year 2	Year 3
No herbicide	27.4 by*	0.5 ax	0.01 ax
sulfometuron	1.2 ay	1.3 ay	0.01 ay
glyphosate	7.3 ay	2.4 ay	0.01 ay

*Columns followed by the same letter (a or b) are not significantly different. Rows followed by the same letter (x-z) are not significantly (p=0.05) different.

Cultural:

Little information is available on cultural methods of control for Johnson grass. An Arizona study using integrated pest management, including native bunchgrass plantings, showed some success in controlling Johnson grass (see grazing in the Biological control section above). Additional studies incorporating cultural control of Johnson grass are needed.

Physical/mechanical: Johnson grass can be controlled by tilling, mowing, and flooding [6,128,170]. Individual small plants or small clumps may be controlled by hand-pulling or solarization [13,55,170].

A consistent **tillage** program may provide effective control [6,43,81,126]. Unfortunately, tilling is not practical on most wildlands due to damage to desirable native plant species, uneven terrain, erosion, and cost constraints [105]. Tilling can be used on some sites such as bottomlands and old fields. Shallow plowing helps control Johnson grass by breaking up rhizome systems, exposing rhizomes to the sun or killing frosts, and depleting carbohydrate reserves [6,43,81,126]. Optimal plow depth is 8 to 12 inches (20-30 cm). Several treatments are needed in hot climates [87,102]. Killing sprouts early, before they form 5 leaves and start developing new rhizomes, gives best control [102]. First plowing is in spring (May), followed by similar plowings every 3 weeks (in rainy weather) to 6 weeks (in dry weather). New plants should reach more than 12 inches (30 cm) before plowing again [9]. In cold climates, Johnson grass is plowed in late October to expose rhizomes to frost [19]. An exposure of 24 or more hours to temperatures below 25 °F (- 4 °C) kills rhizomes [81,103,126,127]. A single plowing, or long intervals between plowings (≥ 4 years), is generally not effective because it stimulates growth [105,171], buries and protects rhizomes [43], and exposes deeply buried seeds to upper soil levels where they may germinate [65].

Because rhizomes may extend more than 20 inches (51 cm) below ground, cultivation alone may fail to kill Johnson grass rhizomes [43]. After plowing, close grazing or mowing (so that the grass stays < 12-15 inches (30-38 cm) tall) helps further reduce Johnson grass cover [87].

Even on old fields, tilling is a major soil disturbance that provides a favorable seedbed for pioneer species. Unless further rehabilitation efforts that include planting native herbaceous species are taken, it is likely that tilled fields will succeed to other invasive nonnatives.

Repeated, close **mowing** has the same inhibitory effect on growth as grazing [105,170]. In Mississippi, mowing seedlings 13 days after emergence killed them [126]. In an Alabama field experiment, multiple cuttings, starting when plants were 1 foot (cm) high, slowed Johnson grass rhizome development. At the end of the growing season, plots cut 8 times averaged 15 dry-weight oz (431 g) of Johnson grass top-growth and 0.3 dry-weight oz (10 g) of rhizomes. Plants cut only twice had 67 oz (1,909 g) top-growth and 26 oz (739 g) of rhizomes. Plots were 4 × 5 feet [180].

Flooding
for 3 to 6 weeks in early spring, before rhizomes sprout, can effectively control Johnson grass. Replacing open irrigation ditches with culverts or pipes helps prevent reinfestation [128].

Hand-pulling
Johnson grass usually leaves rhizome pieces behind in the soil, stimulating sprouting. It is not an effective control method unless all rhizomes are removed or new sprouts are controlled [105,170]. Best results are obtained in early spring when soil in moist and rhizomes are least likely to break [170].

Repeated **solarization**
treatments (using a clear polyethylene tarp to trap solar heat in the soil) can control small Johnson grass infestations [13].

Seeds: Solarization of moist soil at 140 °F to 150 °F (60-70 °C) for 7 days kills most Johnson grass seeds. Solarization of dry soil does not kill Johnson grass seed [55]. In Davis, California, soil watered and solarized for 9-12 weeks supported no Johnson grass. Untreated control plots showed 58% Johnson grass cover [56]. For established plants, 30 days of solarization kills most Johnson grass. Remaining plants have grown rhizomes through and above the landscape fabric, but rhizomes above the landscape fabric were easily removed by hand-pulling [122].

Composting Johnson grass seeds in cow manure for 3 days killed the seeds. Temperatures in the compost reached 120 °F (49 °C) [204]. Ensiling for 21 days also killed Johnson grass seed [213].

Sorghum halepense: References

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