Ventenata dubia

2017

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Abstract—Ventenata is a nonnative, annual grass that is invasive in parts of the Pacific Northwest. A review of the literature and observational evidence shows that its establishment and spread is greatest in Palouse prairie and sagebrush communities and in previously barren scablands. It also occurs in low-elevation ponderosa pine stands. Ventenata tends to dry out earlier than associated perennial grasses and remains highly flammable throughout the fire season. When growing in dense patches, it increases horizontal continuity of fine fuels and increases risk of fire spread in plant communities that historically had discontinuous fuels. On previously barren scablands, for example, ventenata promotes fire spread to adjacent Palouse prairie and ponderosa pine communities. Palouse prairies, sagebrush steppes, and scablands of the Inland Northwest are especially vulnerable to invasive grass/fire cycles fueled by ventenata. Research is underway to better understand the impacts of ventenata invasion on fuel structure and fire behavior and to test the feasibility of using prescribed fire in combination with other control methods to reduce ventenata cover on invaded wildlands.

Figure 1—Ventenata clump in a ponderosa pine stand. Creative Commons photo by Matt Lavin.

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INTRODUCTION

FEIS ABBREVIATION

VENDUB

COMMON NAMES

ventenata
North Africa grass
North African wiregrass
softbearded oat grass
ventenatagrass
wiregrass

TAXONOMY

The scientific name of ventenata is *Ventenata dubia* (Leers) Coss. (Poaceae). It is the only *Ventenata* species found in North America [5, 7, 40, 51, 62, 112].
See table A for a complete list of common and scientific names of plant species discussed in this synthesis and links to FEIS Species Reviews.

SYNONYMS

Avena dubia Leers
Ventenata avenacea Koeler (cited in [112])
Ventenata dubia Coss. & Durieu [107]

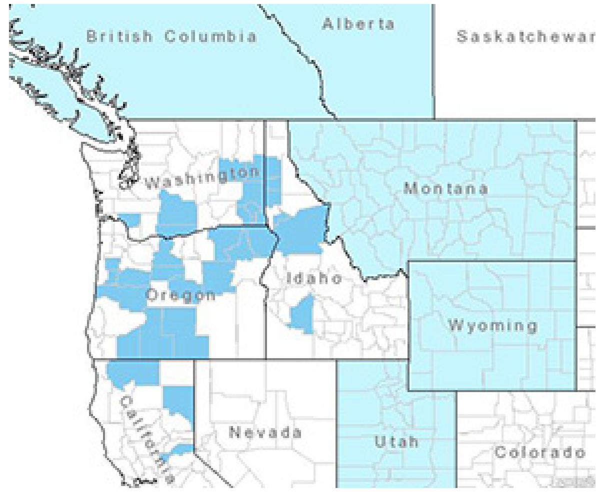
LIFE FORM

Graminoid

DISTRIBUTION AND PLANT COMMUNITIES

GENERAL DISTRIBUTION

Ventenata is native to the Mediterranean region of North Africa, southern Europe, and western Asia and to central Europe [5, 40, 102]. Although invasive in parts of North America, it is rare [48, 69, 87] or extirpated [87] in parts of its native range in Europe. Distribution of ventenata is spreading outside its native range in Asia. It was first collected in Iran [48] and Japan [68] in the early 2000s.
Ventenata is nonnative in North America. In the West, it occurs from British Columbia and Saskatchewan south to northern California and northern Utah. In the Great Lakes and Northeast, it occurs from Ontario to New Brunswick and south to east-central Wisconsin and New York [112].

	
Figure 2a—State and province distribution of ventenata.	Figure 2b—Countywide distribution of ventenata in the Pacific Northwest.
Maps courtesy of USDA, NRCS. 2016. The PLANTS Database. National Plant Data Team, Greensboro, NC. [2015, October 21] [112].	

Ventenata is invasive in many parts of the Pacific Northwest [82, 95] (figure 2b). It was first identified in Washington in 1952 [9] and had spread to Idaho by 1957. It was noted as "abundant" in canyon grasslands of west-central Idaho [108] and was present throughout the Pacific Northwest by the mid-1980s [18]. In 2001, its annual rate of spread in the Pacific Northwest was estimated at 3 million acres (1.2 million ha)/year (National Invasive Species Council 2001, cited in [87]). It is most prevalent in the Inland Northwest (eastern Oregon, eastern Washington, and northern Idaho). As of 2016, it was well established in eastern Washington [51, 82] and western Idaho, especially in croplands, pasturelands, and Palouse prairies [7, 82]. It was less common in California, northern Utah [77], western Montana [82], and Wyoming [77, 82], and it was incidental in the Great Lakes and Northeast [82].

States and provinces [62, 77, 112]
United States: CA, ID, MT, OH, OR, NY, ME, UT, WA, WI, WY
Canada: AB, BC, NB, ON, QC, SK

SITE CHARACTERISTICS AND PLANT COMMUNITIES

Site Characteristics
Ventenata typically grows in open, disturbed areas and along roadsides. It is most common on dry sites [5] such as scablands [128] and is classified as an obligate upland species in the Columbia Basin of Washington [31]. However, it is not limited to dry sites [18]. For example, ventenata grows in moist swales on the Malheur National Forest, Oregon [105]. Best growth is on sites that are inundated in early spring but dry out by late spring [80, 91, 102]. Ventenata may initially establish on moist sites and then spread to drier sites. From 2008 to 2010, it spread from moist, low drainages and springs onto dry, shallow, Palouse prairie scablands across the Inland Northwest [18].

Ventenata grows in clays and clay-loams that are often shallow and rocky [18, 57, 102] and on loess soils deposited on plateaus [10]. Basalt is a common parent material for soils in which ventenata grows [10, 56]. In Idaho fescue-onespike oatgrass associations of the Ochoco and other ranges of the Blue

Mountains, for example, it grows in shallow soils overlying basalt. Such dry grasslands are considered highly invasible to ventenata. In the northern Blue Mountains, ventenata dominates disturbed Mima mounds (distinct domes of topsoil surrounded by shallow, rocky soils) overlying basalt. In bluebunch wheatgrass-Sandberg bluegrass-bighead clover associations of the Blue Mountains, it occurs on southwesterly aspects in very gravelly loam overlying very gravelly clay [57].

Topography in Palouse prairies with ventenata ranges from flat to slopes of about 50°. Most terrain is gentle [10]. Ventenata is most common on south- and west-facing slopes [80, 102] but grows on all aspects [91].

Ventenata occurs from near sea level to midelevations (0-6,000 feet (1,800 m)) in the western United States [9, 91, 102]. It tolerates higher elevations than cheatgrass [66]. It is reported from 30 to 5,900 feet (10-1,800 m) in the Pacific Northwest [91] and from 1,600 to 4,900 feet (500-1,500 m) in California [5]. Ventenata occurs from 3,900 to 4,900 feet (1,200-1,500 m) in its native range [54].

The climate of the Pacific Northwest is moderate where ventenata is invasive (area shown in figure 2b). Winters and early springs are cool and wet; summers are hot and dry. Most precipitation falls as rain [10]. Annual precipitation in ventenata-invaded areas of the Pacific Northwest ranges from 14 to 44 inches (350-1,120 mm)/year [5, 18, 93]. On the Columbia Plateau, infestation rates are highest in the intermediate (12-18 inches (300-450 mm)) to high (19-24 inches (480-600 mm)) precipitation zones, where dry croplands interface with Palouse prairies and ponderosa pine savannas [94].

Plant Communities

__Pacific Northwest__: Ventenata is invasive in Palouse prairie and sagebrush steppe communities. It occurs but is less common in riparian red-osier dogwood and other riparian shrub communities [38, 74, 82, 94]. It also grows in ponderosa pine savannas and woodlands [2, 3, 47] and western juniper woodlands [64]. In savannas and woodlands, it occurs in low-elevation, open to lightly-shaded areas, especially in disturbed areas [47, 64]. In agricultural systems, it invades pastures, hayfields, and croplands. It is particularly invasive in timothy hayfields [9, 38].

Figure 3—Ventenata in Palouse prairie steppe of eastern Washington. Wikimedia Commons photo by Matt Lavin.

Ventenata is rapidly spreading into and becoming dominant in grassland and sagebrush communities, including those where cheatgrass and/or medusahead was formerly dominant [6, 18, 85, 123]. It is well established in many bluebunch wheatgrass-Idaho fescue and other Palouse prairie communities of the Inland Northwest [53]. Grasslands in which ventenata occurs include:

- In Asotin County, Washington, it codominates a onespike oatgrass-bulbous bluegrass association. It has infested over 90% of that association [114].
- In the northern Blue Mountains, ventenata occurs in Idaho fescue-bluebunch wheatgrass-arrowleaf balsamroot associations. It dominates Idaho fescue-prairie Junegrass associations on disturbed Mima mounds [57].
- In the central and southern Blue and Ochoco mountains, ventenata is a component of antelope bitterbrush/Idaho fescue-bluebunch wheatgrass, Idaho fescue-onespike oatgrass, bluebunch wheatgrass-Sandberg bluegrass-largehead clover, onespike oatgrass-Wasatch desertparsley, and Idaho fescue-bluebunch wheatgrass associations [57].
- In northern Idaho, it has established and spread in bluebunch wheatgrass-Idaho fescue [2, 3] and Idaho fescue-prairie Junegrass communities [69].

Limited research suggests that Palouse prairie-sagebrush steppes and ponderosa pine savannas have high invasibility for ventenata. On 3 sites in the Wallowa Mountains of northeastern Oregon, ventenata and medusahead had highest abundance rankings (% of total canopy cover) among all plant species present on grass-shrubland sites ($P < 0.001$). Ventenata was most abundant on gently-sloped (<20%) benchlands within fenced cattle rangelands. Historically, Idaho fescue and bluebunch wheatgrass dominated the benchlands. Ventenata was consistently present in grassland-shrub steppes and open forests, with mean frequency in June and July ranging from 49% to 54%. It was one of the most frequent nonnative herbs in open ponderosa pine-Douglas-fir/common snowberry/elk sedge communities, although it was most frequent on roadsides (table 1) [2, 3].

Table 1—Frequency of ventenata in the Wallowa Mountains [3].

Site	Frequency[a] (%)
Roadside	45
Grassland-shrub steppe	28
Open ponderosa pine	16
Closed mixed-conifer forest	0
Subalpine fir-Engelmann spruce	0

[a]Presence on 2 m^2 quadrats.

Ventenata importance increases with livestock grazing. Throughout the Blue Mountains, it has established in western wheatgrass-bulbous bluegrass communities that are heavily grazed or otherwise disturbed. In the central and southern Blue and Ochoco mountains, it dominated low sagebrush/Idaho fescue-bluebunch wheatgrass and other bunchgrass-steppe communities that were overgrazed. Researchers noted that on plots where ventenata dominated, bluebunch wheatgrass cover was <5% and Idaho fescue was either absent or present only as relict individuals. In Idaho fescue-prairie Junegrass communities in the northern Blue Mountains, grazing was considered the primary disturbance responsible for increases in ventenata and other nonnative annual grasses. Cover of native perennial bunchgrasses was <5% on severely disturbed sites but >50% on sites in good condition [57].

Although ventenata grows and is invasive in sagebrush steppe (Williams 2016 personal communication [123]), its habitat preferences in sagebrush communities were not well documented as of 2016. On the Ochoco National Forest, anecdotal evidence suggests that it is more common in Wyoming big sagebrush than in mountain big sagebrush communities, likely because soils are more shallow in Wyoming big sagebrush communities (Hallmark 2016 personal communication [46]). It is a component of low sagebrush/Idaho fescue-bluebunch wheatgrass associations of the southern and central Blue and Ochoco mountains [57].

Other areas: In the Willamette Valley, Oregon, ventenata is a component of Oregon white oak/Pacific poison-oak/California oatgrass-blue wildrye communities [19].

In Modoc County, California, medusahead dominated or codominated in Sandberg bluegrass alliances. Ventenata and cheatgrass were present as associates [117].

In its native regions, ventenata occurs in bunchgrass and dry shrub-bunchgrass steppes [36].

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

GENERAL BOTANICAL CHARACTERISITCS

Botanical Description

Figure 4—Ventenata has an open, sparse form. Creative Commons photo by Matt Lavin.

This description covers characteristics that may be relevant to fire ecology and is not meant for identification. Identification keys are available (e.g., [26, 51]).

Ventenata is an annual grass. It typically grows from 6 to 18 inches (15-46 cm) tall [102, 120], although some plants reach 29.5 inches (74.9 cm) [120]. It has an open form, with a few stems (culms) that branch only at the root crown. Stems are spreading and often droopy, with a stiff, wiry texture [77, 80, 102]. Leaves are rolled lengthwise or folded [80]. Roots are shallow, from 1 to 2 inches (2.5-5 cm) deep [37, 38, 91].

The inflorescence is an open, spreading to drooping, pyramid-shaped panicle up to 16 inches (41 cm) long. The spikelets contain 3 to 4 florets. Florets are bisexual except for the lowest, which is usually staminate. Awns are long: up to 1 inch (2.5 cm) [38]. Awns on bisexual florets bend and twist as they mature [5, 7, 51, 120], while the awn on the staminate floret remains straight [120]. Identification can be tricky because the staminate floret tends to remain after the bisexual florets have broken off; at that stage, ventenata resembles oat species [26]. The fruit is a caryopsis [7, 51].

Raunkiaer Life Form
Therophyte [96]

SEASONAL DEVELOPMENT
Ventenata is a winter annual [9, 38, 102, 120]: it germinates in fall, is dormant over winter, resumes growth in spring, and dies in late summer. Germination occurs when fall temperatures are moderate to high [9, 38, 102], usually after the first fall rain [69]. Early spring and later growth is slower than that of associated nonnative annual grasses. On sites across eastern Oregon, eastern Washington, and northern Idaho, ventenata remained in the 2- to 3-leaf stage until mid-May, when stems elongated [94] (table 2). Ventenata flowers in spring [93] and produces seedheads from May through August, depending on location. Its seeds mature 1 month later than seeds of cheatgrass and other annual bromes [18, 77, 94, 102]. Ventenata dries out earlier in the season than native perennial bunchgrasses but later than associated nonnative annual grasses [67]. Seed shatter and plant death occur in July or August, when awns bend and twist (figure 6) [9, 80, 102, 121]. Soil drying generally induces seed maturation [91] and plant death. In the Wallowa Mountains, dry ventenata plants were slower to decompose than associated grasses that had dried [2].

Figure 5—Nodes turn reddish-black in late spring, when flowers are developing. Photo by Pamela Scheinost, USDA NRCS Pullman Plant Materials Center.

Ventenata shows distinct color changes as it develops. Plants are bright green in early spring [102, 121]. Nodes turn reddish- to purplish-black in late spring (figure 5) [80, 121]. Plants become distinctly shiny when flowering and developing seedheads [37, 102], then turn silvery-green before they dry and senesce [121]. They senesce and turn tan when soil dries, usually in late summer [102, 121].

Table 2—Phenological development of ventenata in 3 areas.

Area	Stage
California	flowers June-September [5]
	spring growth begins May-June [102, 121]
	nodes turn reddish-black May-June [80, 121]
Pacific Northwest	flowers mid-June-July [51, 94]
	seed matures June-early July [94, 102, 121]
	plants die June-August [102, 121]
	flowers May-August
Northwestern Idaho	plants die July [69]

Wallace and others [118] provide a model to predict seedling emergence, stem elongation, and flowering stages of ventenata on Conservation Reserve Program lands, rangelands, and timothy hayfields of the Inland Northwest.

REGENERATION PROCESSES

Because it is an annual, ventenata reproduces only from seed [120].

Pollination and Breeding System

Information on pollination and the breeding system of ventenata was not found in English-language literature. Most grasses are wind-pollinated [70], although a few are self- [61] or insect-pollinated [28, 70].

Seed Production

Ventenata produces from 15 to 35 [18, 91, 102] or 50 [9] seeds per plant.

Seed Dispersal

Unless otherwise dispersed, seeds drop near the parent plant when ripe [37, 38]. The bent, twisted awns easily catch onto fur, feathers, clothing, and machinery. Ventenata seeds often disperse along roadways and other travel corridors [69, 80, 102]. For example, along the U.S. State Highway 95 right-of-way in Latah County, Idaho, ventenata was nearly always present in exposed soil [69]. Seeds also disperse as a contaminant in hay [82, 102, 118]. The awns unwind and "self-bury" or drill into soil [91, 120]. Moisture accelerates unwinding of awns and drilling of seeds into soil [91].

Figure 6—Upper florets with bent, spiraling awns (center) that have broken away from the spikelets (outside). Creative Commons photo by Matt Lavin.

Seed Banking

Ventenata has a short-term soil seed bank [98]. In field tests near Pullman, Washington, most seeds (81%) were viable after 1 month of burial at 0.8 to 3 inches (2-8 cm) deep. Burial depth did not greatly affect viability of ventenata seed, but germination rates were slightly higher for seeds buried 0.8 inch (2 cm, 82% germination) than for seeds buried 3 inches deep (8 cm, 79% germination) ($P < 0.05$) [118, 119].

Oregon State University's Agricultural Extension Service [18] reports that most ventenata seeds (85%) germinate in their first year. In field tests in northeastern Oregon, eastern Washington, and northern Idaho, most seeds were viable for <18 months, but a few seeds (0.1%) remained viable for up to 2 years [94]. Near Pullman, germination of buried seeds dropped to <1% after 6 months and to 0% after 4 years [118, 119].

Germination
Ventenata seed germinates with moderate to high fall temperatures (50-82° F (10-28° C)) and goes dormant with cool temperatures [9, 18, 94, 102]. Stratification is required; fresh ventenata seed is apparently not germinable. Warm fall temperatures induce germination. In the laboratory, seeds in dry storage required at least 30 days of warm stratification before germination. Germination rates were highest after 90 days of warm stratification (23% at 30 days and 71% at 90 days) [118]. Optimum range for ventenata germination in the laboratory was 64° to 84° F (18-29° C) [85, 118].

Cold fall temperatures (vernalization) induce seed dormancy [91]. In the laboratory, prechilling greatly reduced germination rates of ventenata (about 30% with chilling vs. 85% without) [18, 118]. It took 30 to 90 days to break dormancy in the laboratory. After that, ventenata germinated at a wide range of temperatures (48-84° F (9-29° C)) [118].

In the field, ventenata germinates about 2 weeks later than cheatgrass [91, 93]. In the laboratory, it took an average of 15 days for ventenata to achieve 75% germination. This was slower than the mean time required for cheatgrass germination (5 days) but faster than the mean time required for medusahead germination (18 days) [85].

Seedling Establishment and Plant Growth
Ventenata is most likely to establish on bare, dry soils (Site Characteristics), probably because it outcompetes other grasses on such sites (Impacts). Overgrazing or other disturbances that that expose bare soil favor ventenata establishment [57].

Even though ventenata is adapted to dry soils, its establishment may increase in wet years and on sites with litter [89, 94, 120]. In a 2-year field study in northeastern Oregon and northern Idaho, spring seedling recruitment was higher in 2012, when annual precipitation was high, than in 2013, when it was low. Potted ventenata seeds showed 50% mean emergence across sites and years [94]. In a related, 2-year common garden study near Pullman, ventenata emergence and survivorship differed across years. In the first year, emergence and survival rates were higher when ventenata was growing in thick layers (0.3-0.6 oz. (10-20 g)) of litter than when growing in thin layers (0.2 oz. (5 g)) of litter. Similarly, emergence and survival rates were higher when ventenata was growing in thin layers of litter than with no litter [118, 119]. In second-year plantings, emergence and survival of ventenata were similar with thick and thin layers of litter, and greater than emergence and survival of ventenata with no litter ($P < 0.05$ for all variables) [118]. The authors suggested that emergence and survivorship were greater with litter because it lowers soil temperature, helps retain soil moisture, and reduces the number of days in which the upper soil layer is frozen [118, 119].

Vegetative Regeneration
Ventenata produces one to few tillers during its single growing season. Tillers generally resprout if cut before soil dries [91].

SUCCESSIONAL STATUS
Ventenata establishes on open sites [30, 82]. It tolerates partial shade but is not prevalent there (Hallmark 2016 personal communication [46]). It establishes well on bare soils and is common after soil disturbances. Ventenata may replace perennial bunchgrasses [91] or other annual nonnative grasses [6, 85, 123] on disturbed sites. Disturbances favoring ventenata establishment and spread include heavy gazing [57], fire [30, 82], frost heaving, flooding, and construction. It is especially prevalent on overgrazed sites [82] and on roadsides. Along the Highway 95 corridor in northern Idaho, sites with

exposed soil "always had ventenata and annual bromes" [69]. Ventenata also grows on scablands that were undisturbed but bare prior to its establishment (Hallmark 2016 personal communication [46]).

FIRE EFFECTS AND MANAGEMENT

FIRE EFFECTS

Immediate Fire Effects on Plant

As of 2016, there was no published information on the immediate effect of fire on ventenata. During the fire season, ventenata has typically already dried out (Seasonal Development) and dispersed its seeds. Early-season fire may top-kill ventenata, although it may not burn well when green. Fire probably kills some seeds, especially if they have not yet shattered. However, grass fires are flashy and of low severity [63, 127]; typically, grass seeds buried in soil survive such flashy, low-severity fires [27]. For example, enough cheatgrass [126] and medusahead [76, 103] seeds survive fire to populate the next generation. Because ventenata self-buries its seeds, it is even more likely that enough viable ventenata seeds remain in the soil seed bank for ventenata to persist on burned sites.

Postfire Regeneration Strategy

Ground residual colonizer (on site, initial community)
Initial off-site colonizer (off site, initial community)
Secondary colonizer (on- or off-site seed sources) [106]

FIRE ADAPTATIONS AND PLANT RESPONSE TO FIRE

Effects of fire on ventenata are uncertain and require further study. Fire creates openings that favor ventenata germination and establishment [30, 120, 121]. However, limited studies suggest that low-severity fire may help control ventenata [72]. Because litter may increase ventenata germination and establishment, fire that removes litter may help reduce ventenata germination and survivorship [73]. Since ventenata establishes in openings and disturbed sites (Successional Status), it may be favored in postfire environments. It is known to establish from soil-stored seed [37, 38, 98] and seed dispersed from off-site [80, 102] after other disturbances (Regeneration Processes) such as road building [68].

As of 2016, only 2 studies were available on ventenata's response to fire, so it is unclear how fire affects its postfire abundance. One documented ventenata's postfire responses in a ponderosa pine community [128] and the other in a Palouse prairie community [30].

Ponderosa Pine

In the northern Blue Mountains of Oregon, ventenata established in low numbers after thinning and/or prescribed fire in a ponderosa pine-Douglas-fir/common snowberry community. Treatments were thinning from below in summer 1998, a mid-September prescribed fire in 2000, or both. Ventenata was not present on untreated control plots before treatments but was present in trace amounts (<3% cover) on treated plots in 2004 (postfire year 4). Among 3 nonnative annual grasses present on treated plots (ventenata, cheatgrass, and Japanese brome), only cheatgrass was present in more than trace amounts, with 3.8% cover on thinned and burned plots. However, all 3 nonnative annuals were considered significant indicators of thinned and burned treatments (table 3) [128].

Table 3—Mean percent frequency and cover of nonnative annual grasses 6 years after thinning and 4 years after follow-up prescribed fire in the northern Blue Mountains of Oregon [128].

Species	Frequency (Cover) by treatment			
	Unburned control (%)	Thinned (%)	Burned (%)	Thinned and burned (%)
Ventenata	Not present	1 (0.3)	18 (1.8)	25 (1.3) indicator value = 12.8, *P*= 0.002 [a]
Cheatgrass	18 (0.9)	28 (3.7)	51 (2.9)	55 (3.8) indicator value= 24.6, *P* = 0.006
Japanese brome	21 (0.7)	11 (0.5)	30 (2.4)	38 (1.5) indicator value = 15.1, *P* = 0.027

[a]Significance of species' associations with thinned and burned treatment.

The authors concluded that because cover of the nonnative annual grasses was <3% on burned plots in postfire year 4 and cover of other nonnative herbs was even less, "invasion and expansion of nonnative species was occurring slowly if at all" on burn-only plots. However, they cautioned that "continued monitoring will be required to assess the long-term effects of this treatment on non-native species establishment", especially in areas that were recently thinned and burned [128]. See the FEIS Research Project Summary of the Youngblood et al. [78, 128] study for detailed information.

Palouse Prairie

Ventenata abundance may be higher when fire and other disturbances interact than with fire alone. Preliminary results from a study on the Turnbull National Wildlife Refuge, eastern Washington, showed ventenata density and cover were greater on plots that had both high pocket gopher activity and prescribed fire than on plots with only high pocket gopher activity or only prescribed fire. Treatment plots were located on a Mima mound prairie with a large population of northern pocket gophers [30]. Historically, Idaho fescue-Pennsylvania sedge-hoary fringe-moss [35] and Idaho fescue-prairie Junegrass associations [57] dominated Mima mound prairies. Ventenata had invaded the prairie prior to the 2012 study and was the dominant grass, although cheatgrass was also present. In postfire year 1, total cover of nonnative invasive annual grasses was twice as great on plots that had either northern pocket gophers or the prescribed fire treatment compared to control plots (unburned plots without northern pocket gophers). Total cover of nonnative invasive annual grasses was 5 times greater on plots that had both northern pocket gophers and prescribed fire than on control plots. Ventenata density was 3 times greater on plots with both northern pocket gophers and prescribed fire compared to control plots [30]. The same study found richness of nonnative plant species was significantly greater on plots with prescribed fire than other treatments, while richness of native plant species was significantly lower (figures 7a and 7b) [29, 30]. The authors concluded that prescribed fire should be used with caution in areas with nonnative invasive annual grasses because interactive effects of prescribed fire and other disturbances are likely to result in increased abundance of nonnative annuals grasses at the expense of native herbaceous species [30].

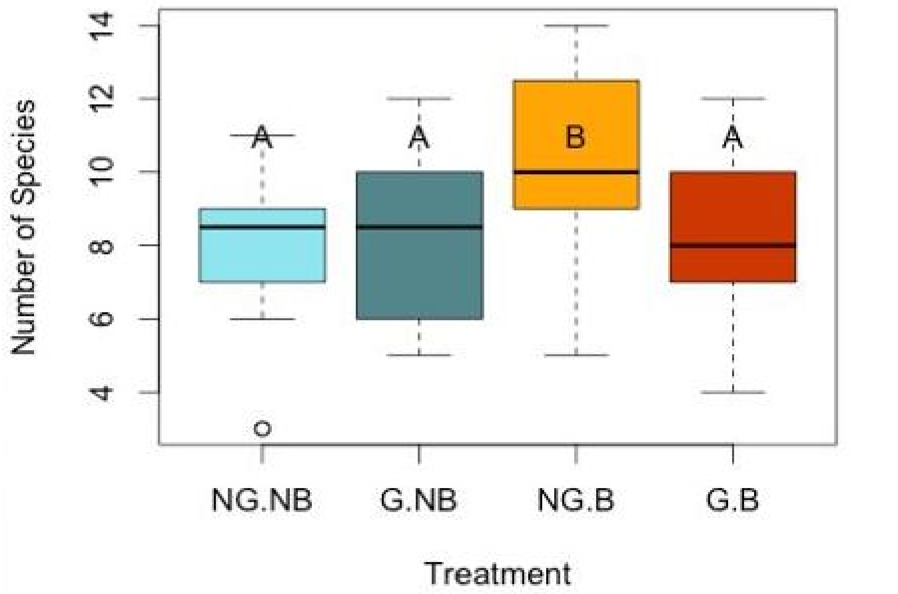


Figure 7a—Richness of nonnative plant species by treatment.

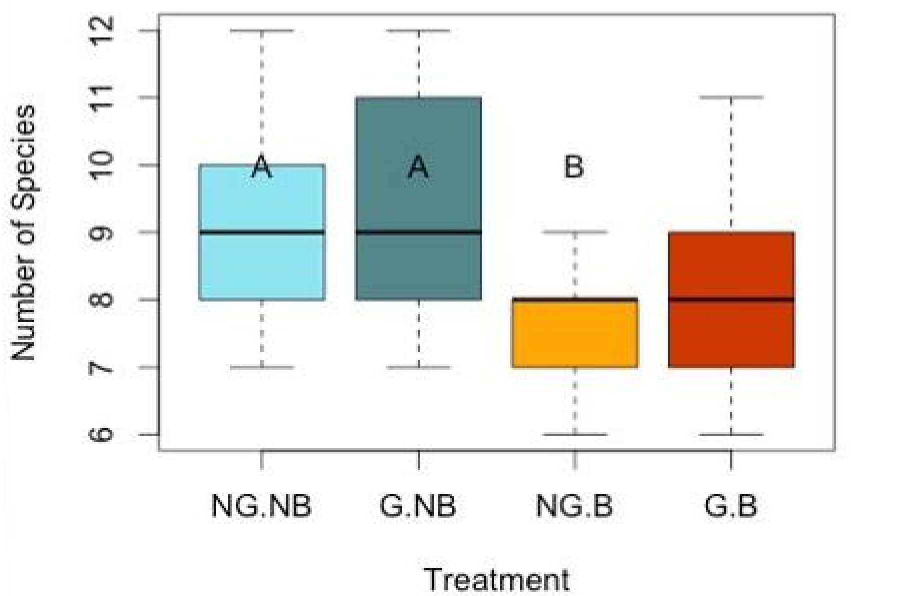


Figure 7b—Richness of native plant species by treatment.

NG = no gopher, G = gophers present, NB = no burn, B = burn. Boxes with different letters are statistically different at $P = 0.05$. $N = 20$ plots/treatment (80-m² plots) [29, 30]. Figures by Kimberly Cook, used with permission.

FUELS AND FIRE REGIMES

Fuels

When present in dense patches, ventenata increases horizontal continuity of fine fuels and increases risk of fire spread in areas that historically had discontinuous fuels [37, 38, 66]. It is dry and remains highly flammable throughout the fire season [38, 67] and is relatively persistent after senescence. Dry ventenata stalks and litter decay more slowly than stalks and litter of most associated grasses [2, 38], likely due to ventenata's relatively high silica content when dry (2.7%) [38].

Figure 8—Continuous, dry ventenata in a big sagebrush stand. Creative Commons photo by Matt Lavin.

Figure 9—Patchy, dry ventenata in a ponderosa pine stand. Creative Commons photo by Matt Lavin.

Species that alter the disturbance regime of a site are those that are functionally different from the rest of the species in a community (review by D'Antonio [32]). When there are no native species with fuel characteristics functionally similar to those of the invader, the invader can alter fire frequency [32, 43]. Because ventenata forms more continuous fuels than perennial grasses, ventenata-invaded Palouse prairies and sagebrush steppes of the Pacific Northwest are vulnerable to altered fire regimes in which fires become more frequent, native perennial bunchgrasses and shrubs less abundant, and ventenata increasingly abundant with each fire [57, 92]. Such annual grass-fire cycles tend to be self-promoting: frequent fire reduces postfire regeneration of native grasses and shrubs and further promotes dominance of nonnative annual grasses [13, 32, 33]. Because most sagebrush species cannot sprout after fire and recover slowly from on-and off-site seed sources (e.g., [83, 125]), sagebrushes are especially vulnerable to increases in fire frequency [11, 21].

Fire Regimes

Historical Fire Regimes: Palouse prairies and ponderosa pine savannas historically had frequent fires. In Palouse prairies of the Inland Northwest, historical mean fire-return intervals ranged from about 10 [58] to 30 years [22]. Ponderosa pine savannas and woodlands had mostly low- to moderate-severity surface fires, with mean fire-return intervals ranging from about 10 years to 31 years [42, 49, 60].

Historical fire-return intervals probably varied widely in sagebrush communities, depending on site and plant community composition. Fuels were often limited and discontinuous [21]. Fires were less frequent in sagebrush than in Palouse prairie and ponderosa pine communities; most fires were patchy but some were stand replacing. Estimates of historical fire-return intervals in Wyoming big sagebrush communities range from about 50 [124] to 350 years [20]. Estimates of historical fire frequency in low sagebrush communities range from 100 [79] to 425 [4] years.

See these FEIS publications for further information on historical fire regimes in plant communities in which ventenata is sometimes invasive:

- Fire regimes of northwestern montane and foothill grassland communities
- Fire regimes of Columbia Plateau grasslands and steppe
- Fire regimes of conifer communities in the Blue Mountains
- Fire regimes of basin big sagebrush and Wyoming big sagebrush communities
- Fire regimes of mountain big sagebrush communities
- Fire regimes of mixed dwarf sagebrush

Find further fire regime information for plant communities in which this species may occur by entering "ventenata" in the FEIS home page under "Find Fire Regimes".

Impacts on Historical Fire Regimes: Spatial arrangement of fuels across the landscape is a major driver of wildland fire behavior, and ventenata increases fuel continuity and resultant fire spread [66]. As of 2016, however, the extent to which ventenata might alter historical fire regimes of Palouse prairie, sagebrush steppe, and ponderosa pine savannas of the Pacific Northwest was uncertain [82]. As a flashy fuel, ventenata did not appear to increase fire severity in ponderosa pine savannas and woodlands during the 2015 wildfires on the Ochoco National Forest; however, it did increase fuel continuity and fire spread (Romero 2016 personal communication [99]).

Ventenata is altering fuel structure, increasing fuel loads, and promoting fire spread in some Palouse prairie scabland-ponderosa pine woodland mosaics and some sagebrush steppe communities of the

Inland Northwest. Before ponderosa pine savannas and woodlands became infested with nonnative annual grasses, they were interspersed with open Palouse prairies that had discontinuous surface fuels and with scablands that had either no fuels or extremely sparse surface fuels consisting of short-statured herbs [57, 67]. During firefighting, these open areas have been used as firebreaks and firefighter safety zones because they do not carry fire well [67]. Scablands in particular slow fire spread. On ventenata-invaded scablands, however, ventenata's flashy fuels can rapidly carry fire into adjacent grasslands and woodlands ([66], Romero 2016 personal communication [99]).

During the 2015 wildfires on the Ochoco National Forest, firefighters observed rapid spread of fires that were fueled by dry ventenata [67]. For example, ventenata contributed to fuel continuity and fire spread during the 2015 Corner Creek Fire. Prior to the wildfire, ventenata had established on previously barren scabland ridges in a ponderosa pine-Palouse prairie mosaic. Fire managers and firefighters noted that ridges had converted from firebreaks to areas that were "quite receptive to fire" due to presence of ventenata, and firefighters witnessed rapid fire spread from ventenata-infested scablands into ponderosa pine woodlands. Fire severity was lower on timbered sites that had been thinned and burned 1 or 2 years previously than on similar untreated sites (Hallmark 2016 personal communication [46]); however, on invaded sites, ventenata "may have negated some of the advantage" of fuel treatments. The Incident Commander stated that the "treated areas almost always reduced fire behavior, but where there was ventenata it didn't matter, the fire just ran through the ventenata and kept going" [47]. Because the wildfire occurred so soon after treatments, it was unclear whether thinning and prescribed fire affected ventenata abundance. Anecdotal evidence suggests that ventenata cover had not increased in postfire year 1 (Hallmark 2016 personal communication [46]).

FIRE MANAGEMENT CONSIDERATIONS

Preventing invasive plants from establishing in weed-free burned areas is the most effective and least costly management method. This may be accomplished through early detection and eradication, careful monitoring and follow-up, and limiting dispersal of invasive plant propagules into burned areas. General recommendations for preventing postfire establishment and spread of invasive plants include [1, 12, 41, 113]:

- Incorporate the cost of weed prevention and management into fire rehabilitation plans.
- Acquire restoration funding.
- Include weed prevention education in wildland fire training.
- Minimize soil disturbance and vegetation removal during fire suppression and rehabilitation activities.
- Minimize the use of retardants that may alter soil nutrient availability, such as those containing nitrogen and phosphorus.
- Avoid areas dominated by high priority invasive plants when locating firelines, monitoring camps, staging areas, and helibases.
- Clean equipment and vehicles prior to entering burned areas.
- Regulate or prevent human and livestock entry into burned areas until desirable site vegetation has recovered sufficiently to resist invasion by undesirable vegetation.
- Monitor burned areas and areas of significant disturbance or traffic from management activity.
- Detect weeds early and eradicate before vegetative spread and/or seed dispersal.
- Eradicate small patches and contain or control large infestations within or adjacent to the burned area.
- Avoid use of fertilizers in postfire rehabilitation and restoration.

- Use only certified weed-free seed mixes when revegetation is necessary.

For detailed information, see the following publications: [1, 12, 41].

While fire may help reduce ventenata populations when combined with other control methods [17, 18, 120], as of 2016, prescribed fire alone was not recommended to control ventenata [102, 121]. There are too many uncertainties regarding fire effects on plant communities with ventenata infestations, and only one study [73] has investigated using prescribed fire to control ventenata. Even if fire does reduce ventenata cover temporarily, other nonnative annual grasses may establish in ventenata's place without follow-up control measures [69]. The Washington State Noxious Weed Control Board recommends planting and seeding of native herbaceous species after fire or other treatments to control ventenata [120].

On Conservation Reserve Program land near Troy, Idaho, an integrated management study examined control of ventenata on Palouse prairie and found prescribed fire followed by herbicide application reduced ventenata abundance in the short term [73]. Ventenata, orchardgrass, Japanese brome, meadow foxtail, and tall annual willowherb comprised 75% of total plant community composition before treatments. Treatments included fall or spring prescribed burning (figure 10); spring sickle mowing and removing vegetation; spring rotary mowing with resulting litter left in place; fall fertilizing (46-62-45); and fall application of sulfosulfuron herbicide (table 4). Treatment efficacy was evaluated at high (>50% ventenata cover) and low (<25% ventenata cover) levels of ventenata infestation [73].

Figure 10—Burn treatments on Conservation Reserve Program land near Troy, Idaho. Photos by permission of Timothy Prather, Invasive Plant Biology Lab, Department of Plant Science, College of Agricultural and Life Sciences, University of Idaho.

Two years after treatments, most plots with integrated treatments had lower ventenata cover and biomass than control plots. Plots with either prescribed fire or herbicide treatments had less ventenata cover and biomass than the control, but ventenata cover and biomass were least when herbicide was applied after prescribed fire (tables 4 and 5). On plots with high ventenata cover, fall and spring prescribed burning followed by herbicide controlled ventenata cover better than other treatments (table 4) [73].

Table 4—Foliar cover and biomass of ventenata 2 years after treatments in a Palouse prairie with high ventenata cover (>50%). *P*-values are a pairwise comparison of each treatment to the control [73].

Treatment	Foliar cover (%, SE 6.1)		Biomass (kg/ha, SE 5)	
	Mean[a]	*P*-value	Mean	*P*-value
fall Rx fire + fall sulfosulfuron	10.20 a	0.0005	6.50 a	0.0003
spring Rx fire + fall sulfosulfuron	12.80 ab	0.001	4.30 a	0.0002
fall Rx fire	19.70 abc	0.0067	27.60 ab	0.007
fertilizer + fall sulfosulfuron	21.80 abc	0.0119	17.20 ab	0.0016
fall sulfosulfuron	23.00 abc	0.0161	19.10 ab	0.0021
sickle mow & remove vegetation + fall sulfosulfuron	23.80 abc	0.02	5.70 a	0.0003
rotary mow + fall sulfosulfuron	28.00 bc	0.0554	11.20 ab	0.0006
spring Rx fire	35.30 cd	0.2556	40.10 b	0.0342
fertilizer	42.70 d	0.7585	100.40 c	0.4541
control	45.30 d	----	83.90 c	----
sickle mow & remove vegetation	45.80 d	0.954	117.00 c	0.1514
rotary mow	50.30 d	0.5654	106.80 c	0.3073

[a]Treatments with different letters differ significantly from each other ($P = 0.05$).

In plots with low ventenata cover, 5 treatments—including fall or spring prescribed fire followed by fall application of herbicide—had significantly less ventenata cover compared to the control. Without herbicide, spring and fall prescribed fire did not have significantly less ventenata cover compared to the control (table 5) [73].

Table 5—Foliar cover and biomass of ventenata 2 years after treatments in a Palouse prairie with low ventenata cover (<25%). *P*-values are a pairwise comparison of each treatment to the control [73].

Treatment	Foliar cover (%, SE 6.1)		Biomass (kg/ha, SE 5)	
	Mean[a]	*P*-value	Mean	*P*-value
spring fertilizer + fall sulfosulfuron	1.30 a	0.0019	8.20 ab	0.2117
fall Rx fire + fall sulfosulfuron	1.70 a	0.0021	1.80 a	0.102
spring Rx fire + fall sulfosulfuron	2.20 ab	0.0024	14.20 ab	0.3773
fall sulfosulfuron	2.50 ab	0.0027	3.00 a	0.1186
sickle mow & remove vegetation + fall sulfosulfuron	9.20 ab	0.0161	4.40 a	0.1393
spring Rx fire	17.30 abc	0.1124	32.80 abc	0.8288
fall Rx fire	17.80 abc	0.1249	32.30 cde	0.3347
rotary mow + fall sulfosulfuron	19.30 bcd	0.1696	15.10 ab	0.4059
control	31.50 ce	----	29.10 abc	----
fertilizer	32.30 cde	0.9234	70.40 d	0.0358
sickle mow & remove vegetation	35.80 de	0.618	50.70 cd	0.2352
rotary mow	38.30 e	0.4336	40.00 bcd	0.5375

[a]Treatments with different letters differ significantly from each other (*P* = 0.05).

This study suggests that as part of an integrated control program, prescribed fire can help control ventenata in the Inland Northwest. Where cover of ventenata was <25%, litter removal also helped control ventenata, probably by reducing fall germination. The researcher speculated that prescribed burning prior to herbicide application might have increased herbicide contact with ventenata by burning off litter. However, he cautioned that consideration of other nonnative species present is warranted before prescribed fire is planned as part of integrated treatments to control ventenata. For example, cheatgrass cover may increase after prescribed fire on sites where it was present beforehand [73].

MANAGEMENT CONSIDERATIONS

FEDERAL LEGAL STATUS

Ventenata is not federally classified as noxious weed [111].

OTHER STATUS

As of 2016, ventenata was not classified as a noxious weed or weed seed in any U.S. state or Canadian province [97]. See the Invaders and Plants databases for more information.

IMPORTANCE TO WILDLIFE AND LIVESTOCK

Ventenata has limited use as ungulate forage but otherwise has no or little value for wildlife. Degradation and loss of wildlife habitat occurs on sites with severe ventenata infestations [14, 57].

Palatability and Nutritional Value

High silica content of stems and leaves renders ventenata unpalatable for most of the growing season. Ungulates may graze it in early spring, before panicles emerge [38, 80, 102, 120] and silica content of stems is low [91]. Even then, ungulates may not select it if other herbaceous forage is available. Its comparatively slow growth rate and short stature in early spring probably reduce grazing pressure on ventenata compared to associated grass species [94]. Ventenata's silica content increases throughout the growing season. It is highest (~2.7%), and palatability lowest, when seeds mature [91].

Cover Value

Ventenata provides cover for small mammals and birds until it dries. It provides poor cover after that [73].

OTHER USES

Besides limited value as spring forage, there are no known uses of ventenata [102] in North America. It does not provide good erosion protection; its shallow roots do not hold soil as well as the roots of native perennial grasses [9].

IMPACTS, PREVENTION, AND CONTROL

Impacts

Native Plant Communities: Ventenata's range expanded rapidly in the Northwest during the early 21st century. It is particularly invasive in Palouse prairies, sagebrush steppes, and hayfields of eastern Washington and northern Idaho [120]. Low-elevation ponderosa pine woodlands of the Blue Mountains are also vulnerable to ventenata establishment and spread [3].

Palouse prairie is a critically endangered ecosystem [81, 86, 101]. Along with agricultural development, nonnative annual grass invasion is a primary cause of Palouse prairie loss and a fundamental cause of its degradation [34, 71]. From 1% to 6% of historical Palouse prairie remains, mostly on the edges of streams and croplands; on steep slopes and ridges [10, 34]; and other untillable lands [39]. Ventenata is considered one of the primary weeds constraining restoration of remnant Palouse prairies in the Inland Northwest [119]. Ridgetops with shallow soil are especially vulnerable to ventenata establishment and spread (Site Characteristics).

Among nonnative annual grasses, ventenata is considered a particularly serious threat to Palouse prairie and sagebrush steppe communities [53]. Ventenata infestations reduce native perennial grass and forb diversity [14, 87, 102] and alter community structure and ecosystem function [14, 87]. Its thick litter can prevent or inhibit establishment of native perennial grasses [57, 82]. Because ventenata has shallower roots than perennial grasses, invaded sites are prone to more erosion than uninvaded sites [14, 73, 102, 120]. Biological soil crusts may reduce ventenata establishment [25]. On the Turnbill National Wildlife Refuge in eastern Washington, presence of soil crusts was negatively associated with ventenata [25].

In Idaho, ventenata is encroaching upon the habitats of several federally listed rare plants: Idaho pepperweed, Palouse goldenweed, and Spalding's catchfly ([50], review by [82]). Ventenata is considered one of the most invasive herbs in Spalding's catchfly Palouse prairie habitats of the Inland Northwest [50].

Ventenata infestations can result in habitat and forage loss for wildlife [14, 119] and livestock. Ventenata is highly invasive in rangelands, pastures, and hayfields [114], especially on sites with exposed soil, such as overgrazed sites. In antelope bitterbrush/Idaho fescue-bluebunch wheatgrass associations of the Ochoco Mountains, ventenata established in stands with >30% bare ground and <25% cover of Idaho fescue and bluebunch wheatgrass. In the central and southern Blue and Ochoco mountains, ventenata dominated low sagebrush-Idaho fescue-bluebunch wheatgrass plots that had been severely grazed. On these plots, bluebunch wheatgrass cover was <5% and Idaho fescue was absent or present only as relict individuals. Researchers concluded that on such sites, restoration of native bunchgrasses was not possible "without intervention by managers" [57].

As a nonnative, invasive annual grass that is adapted to low- and midelevation, disturbed sites, ventenata is functionally similar to cheatgrass [100]. There is growing anecdotal evidence that like cheatgrass, ventenata increases fuel continuity, fire spread, and fire frequency in Palouse prairie, sagebrush steppe, and low-elevation ponderosa pine communities. If sagebrush communities invaded by ventenata burn multiple times within a few decades, they are susceptible to the same type conversion that has occurred when sagebrush communities invaded by cheatgrass have burned multiple times within a few decades [100, 115]. See Fuels and Fire Management Considerations for detailed discussions of those topics.

Agriculture and agriculture-wildland mosaics: Ventenata infestations have caused economic losses in the Northwest. Ventenata contamination lowers the value of hay [119]. Timothy, Kentucky bluegrass, alfalfa, and winter wheat fields are especially prone to ventenata invasion [87, 93, 120], reducing yields by as much as 50% [120] to 75% within a few years. On Conservation Reserve Program lands, high ventenata cover has made compliance of maintenance requirements, such as developing wildlife habitat, difficult to meet [119].

Ventenata can harbor diseases that lower vigor and fecundity of crops and native bunchgrasses. It is a host of the barley cereal yellow dwarf virus (BCYDV), which is vectored by aphids. The virus infects common barley and common wheat in croplands and can potentially infect native bunchgrasses. In the laboratory, ventenata transmitted BCYDV to common barley via aphid vectors [53]. In a California valley grassland, BCYDV infection rate of native blue wildrye more than doubled when BCYDV-infected wild oat was present. Aphids preferred feeding on annual grasses, and their fecundity rates were higher when feeding on annual grasses than on perennial grasses [75]. This suggests that ventenata and other nonnative annual grasses may attract BCYDV vectors and amplify BCYDV infection rates of perennial grasses [53, 75] in Palouse prairies [53] and other communities in the Pacific Northwest.

Ventenata is apparently more competitive than associated annual grasses on some sites. It has replaced cheatgrass in bluebunch wheatgrass communities in the Blue Mountains [57], and it has replaced medusahead on some sites in eastern Washington and northern Idaho [85].

Competitiveness: Mechanisms of ventenata competition were not well studied as of 2016. As a winter annual, ventenata utilizes shallow soil water in early spring. It may outcompete other annual herbs, such as pinkfairies, when water is limited early in the growing season [2]. It is apparently adapted to shallow, dry soils and does not invest energy in growing an extensive root system, even when soil water is plentiful. A growth chamber experiment found that among ventenata, cheatgrass, and medusahead, ventenata gained the least root biomass with pulses of watering designed to simulate pulses of precipitation, while medusahead gained the most root biomass. Shoot biomass gain was similar among the 3 grasses, and did not differ with increasing clay content of soil ($P < 0.001$ for all variables) [6].

Ventenata is apparently a poor competitor for available soil nitrogen. In a common garden study in Burns, Oregon, ventenata was least efficient among 5 other associated grass species (bluebunch wheatgrass, bottlebrush squirreltail, cheatgrass, crested wheatgrass, and medusahead) in leaf biomass production in nitrogen-limited soils. Ventenata tiller production, root length, and total plant biomass were also least among the 5 other grass species. Unlike the more competitive grasses, ventenata took up soil nitrogen at a steady rate regardless of the amount of nitrogen applied to the soil ($P < 0.05$ for all variables) [56]. The author stated that factors other than nitrogen competition, such as a short generation time, likely contribute to ventenata's competitive success [55, 56].

Different effects of soil fungi infections on ventenata compared to other nonnative annual grasses and native bunchgrasses may partially explain ventenata's competitiveness in Palouse prairies. While collecting ventenata and cheatgrass from a Palouse prairie on Paradise Ridge, northern Idaho, Griffith [44] observed that ventenata plants infected with *Fusarium* spp. fungi were taller than uninfected plants, while cheatgrass plants infected with *Fusarium* spp. were shorter than uninfected plants (P = 0.05). As a follow-up experiment, *Fusarium* spp. were isolated from infected ventenata and cheatgrass and cultured in the laboratory. In the greenhouse, ventenata, cheatgrass, and bluebunch wheatgrass seeds were planted in either soil inoculated with the fungi or in uninoculated soil. *Fusarium* inoculation increased seedling emergence and aboveground biomass of ventenata seedlings compared to uninoculated seedlings but reduced seedling emergence and aboveground biomass of cheatgrass and bluebunch wheatgrass seedlings compared to uninfected seedlings ($P \leq 0.05$ for all variables). Griffith [44] suggested that *Fusarium* has a symbiotic relationship with ventenata but is pathogenic to cheatgrass and bluebunch wheatgrass, and that these relationships may contribute to ventenata's ability to establish and spread in cheatgrass monocultures and remnant Palouse prairies.

NatureServe [82] ranks ventenata as having low to medium impact in dry parts of eastern Washington, Oregon, and Idaho. In light of the above problems, this assessment underestimates ventenata's impact on Palouse prairie and sagebrush steppe communities of the Inland Northwest.

Other regions of the United States may be vulnerable to ventenata invasion and spread. A study comparing areas of the Pacific Northwest that currently have ventenata infestations to uninfested areas in other regions projected that disturbed, low- and midelevation grasslands and forests of the Sierra Nevada and the Northern and Central Rocky Mountains are susceptible to ventenata invasion. Invasibility of the Cascade Range was not rated due to insufficient information. Analyses were based on similarity of elevation, proximity to water, and plant community type of invaded and uninvaded areas [90].

Climate change: Rates of establishment and spread of nonnative annual grasses in Palouse prairies and savannas will likely increase with a warmer climate and disturbances associated with a warmer climate, including fire and insect and disease outbreaks [65, 67]. As of 2016, there were no studies or models of how climate change may specifically impact ventenata populations.

Prevention

It is commonly argued that the most cost-efficient and effective method of managing invasive species is to prevent their establishment and spread by maintaining "healthy" natural communities [72, 104] (e.g., avoid road building in wildlands [110]) and by monitoring several times each year [59]. Managing to maintain the integrity of the native plant community and mitigate the factors enhancing ecosystem invasibility is likely to be more effective than managing solely to control the invader [52]. Weed prevention and control can be incorporated into many types of management plans, including those for fire management; logging and site preparation; grazing allotments; recreation management; road building and maintenance; and research projects [113]. See the Guide to noxious weed prevention practices [113] for specific guidelines in preventing the spread of weed seeds and propagules under different management conditions. The Center for Invasive Plant Management provides an online guide to noxious weed prevention practices.

Local experts concur that most effective means to prevent ventenata establishment and spread is to maintain healthy grasslands and use integrated control treatments including suitable grazing, forage management, and spot spraying when necessary [80, 102, 120]. Cleaning equipment before leaving ventenata-invaded areas [18, 102, 120], seeding bare areas with weed-free seed [18, 102, 121], protecting biological soil crusts [25], and careful rotation of livestock [18, 121] can help prevent ventenata establishment and spread and promote healthy native grasslands.

Control

In all cases where invasive species are targeted for control, the potential for other invasive species to fill their void must be considered no matter what method is employed [15]. Control of biotic invasions is most effective when it employs a long-term, ecosystem-wide strategy rather than a tactical approach focused on battling individual invaders [72].

Rapid detection and eradication of new infestations best controls or contains spread of ventenata and other invasive nonnative plants. Control programs are necessary when ventenata populations are well established [84]. Because ventenata is an annual with a short-term seed bank, control programs focused on preventing infestations and stopping or reducing seed production can be most successful [9, 77]. Ventenata seeds are thought to persist in the soil for <4 years, so 3 or 4 years of aggressive control, followed by monitoring and follow-up control, may eliminate or greatly reduce new infestations [94, [121].

Fire: For information on the use of prescribed fire to control this species, see Fire Management Considerations.

Cultural Control: Planting competitive herbs after other control treatments, such as prescribed fire followed with herbicide, may reduce ventenata cover. Native herbs that have been planted for ventenata control include grassy tarweed, pinkfairies, bluebunch wheatgrass, Idaho fescue, and Sandberg bluegrass. Nonnative herbs planted for ventenata control include intermediate wheatgrass and smooth brome [24, 88, 120].

Physical or Mechanical Control: Hand-pulling may control new, small ventenata infestations. Because ventenata has shallow roots, it pulls easily when soil is moist [38, 102, 120].

Where feasible, mowing may provide ventenata control. However, effectiveness of mowing on wildlands is not well known. A study on Conservation Reserve Program (figure 10 and text above) land near Troy, Idaho, found that mowing increased ventenata cover compared to controls [73]. If mowing is desired, experts recommend mowing ventenata early, before soils dry [18]. To prevent or reduce seed production, Washington State University Extension [121] recommends keeping ventenata height to <2 inches (5 cm) until soil dries and growth stops. Ventenata usually sprouts when cut before flowering, so several mowings may be needed. Plants kept short until soils dry may not produce seed [101]. Ventenata is not easy to cut. The stems are tough and require sharp equipment and slow mow speeds [120]. Mowing when seeds are heading is difficult because the culms often bend over or get tangled in blades [102].

Biological Control: Biological control methods had not been considered or tested on ventenata as of 2016 [102, 120]. Because ventenata is in the same taxonomic tribe as oats (Aveaneae) [18], such biocontrols would likely have adverse impact on oat crops and therefore be unfeasible.

Given ventenata's unpalatability, grazing is not likely to control it [120]. Grazing to maintain perennial bunchgrasses can indirectly provide some ventenata control [38]. Deferring grazing until late summer or fall, after perennial grasses shatter their seeds, promotes bunchgrass health and recovery from grazing [8, 16, 116].

Chemical Control: Herbicides are effective in gaining initial control of a new invasion or a severe infestation, but they are rarely a complete or long-term solution to weed management [23]. For large infestations, herbicides are most effective when incorporated into long-term management plans that include replacement of weeds with desirable species, careful land use management, and prevention of new infestations. See the Weed control methods handbook [109] for considerations on the use of herbicides in wildlands and detailed information on specific chemicals.

Herbicides (sulfosulfuron, imazapic, aminopyralid) have helped reduce ventenata cover in the short term [98, 119]. However, herbicides are most effective against ventenata when used in combination with other treatments such as prescribed fire and follow-up planting of competitive herbaceous species [120] or fertilizing to promote perennial bunchgrasses [80, 118]. Generally, late fall application of herbicide, just after ventenata seedlings emerge, is most effective because it depletes ventenata's soil seed bank [120]. See these publications for timing, application rates, and other details of herbicide use to control ventenata: [18, 38, 102, 114, 118, 122]. Wallace and Prather [119] discuss the effects of various herbicides on desirable grasses that grew with ventenata on test plots in southeastern Washington and central Idaho.

Fall application of herbicide followed by spring application of fertilizer may increase ventenata control over herbicide use alone. Because fertilizing helps perennial bunchgrasses recover from herbicides, it may indirectly reduce ventenata numbers by increasing growth rates of associated bunchgrasses [80, 118].

Integrated Management: Best control of ventenata is accomplished with a combination of control methods. For example, prescribed burning or mowing followed by herbicide may help control ventenata, especially when followed by seeding of native bunchgrasses. Two years after fall herbicide and seeding of perennial bunchgrasses in Oregon, there was an approximate 60% to 95% reduction in density of a new ventenata infestation (based on visual estimates) compared to control plots, which had approximately 90% to 100% density of ventenata. Herbicide use alone resulted in an approximate 68% to 80% reduction in ventenata density compared to control plots. Bunchgrasses seeded in included native bluebunch wheatgrass, bottlebrush squirreltail, and Sandberg bluegrass; and nonnative intermediate wheatgrass and smooth brome [17, 18]. On the Warm Springs Reservation in Washington, herbicide spraying immediately followed by grass seedings resulted in 100% control of ventenata in cattle-grazed rangelands 2 years after treatments. Establishment of Sandberg's bluegrass was "strong" in posttreatment year 1, while that of intermediate wheatgrass and smooth brome was “moderate". In posttreatment year 2, control of ventenata ranged from 60% to 81%, depending on the herbicide applied [24].

Fire Management Considerations discusses a study that used prescribed fire in combination with herbicide, fertilizer, and other treatments to control ventenata [73].

Management practices that include soil disturbance may increase ventenata abundance. In Palouse prairie near Ritzville, Washington, ventenata density increased after seedbed preparation treatments were followed by seeding of bluebunch wheatgrass and desert wheatgrass by mechanical drilling, mechanical soil imprinting, or broadcasting. Seedbed preparation treatments included summer or fall prescribed fire; and summer prescribed fire followed by herbicide applied in fall; herbicide applied in spring; and spring or fall disking. One year after treatments, ventenata density was significantly greater on most treatment plots compared to untreated control plots. The exception was summer prescribed fire followed by fall herbicide application, where ventenata density did not increase compared to untreated control plots [45].

A Joint Fire Science Project to study impacts of ventenata invasion in eastern Oregon and northern Idaho is underway. Objectives include examining how site characteristics affect rate of spread, how management actions affect ventenata populations, response of ventenata after prescribed and wildfires, impacts of ventenata invasion on fuel structure and fire behavior, and possible effects of climate change on ventenata rates of invasion. Publication of study results is targeted for 2019 [67].

These local extension services provide information on ventenata control:

- Washington State University Extension
- Oregon State University Extension Service
- University of Idaho Extension
- Montana State University Extension

APPENDIX

Table A: Common and scientific names of plant species. Follow the links to FEIS Species Reviews.	
Common name	Scientific name
Trees	
Douglas-fir	*Pseudotsuga menziesii* var. *glauca*
Engelmann spruce	*Picea engelmannii*
Oregon white oak	*Quercus garryana*
ponderosa pine	*Pinus ponderosa* var. *ponderosa*
subalpine fir	*Abies lasiocarpa*
western juniper	*Juniperus occidentalis*
Shrubs	
antelope bitterbrush	*Purshia tridentata*
common snowberry	*Symphoricarpos albus*
low sagebrush	*Artemisia arbuscula*
Pacific poison-oak	*Toxicodendron diversilobum*
mountain big sagebrush	*Artemisia tridentata* subsp. *vaseyana*
red-osier dogwood	*Cornus sericea*
sagebrush	*Artemisia* spp.
Wyoming big sagebrush	*Artemisia tridentata* subsp. *wyomingensis*
Forbs	
alfalfa	*Medicago sativa*
arrowleaf balsamroot	*Balsamorhiza sagittata*
grassy tarweed	*Madia gracilis*
Idaho pepperweed	*Lepidium papilliferum*
largehead clover	*Trifolium macrocephalum*
Palouse goldenweed	*Pyrrocoma scaberula*
pinkfaries	*Clarkia pulchella*
Spalding's catchfly	*Silene spaldingii*
tall autumn willowherb	*Epilobium brachycarpum*

Wasatch desertparsley	*Lomatium bicolor* var. *leptocarpum*
Graminoids	
bluebunch wheatgrass	*Pseudoroegneria spicata*
blue wildrye	*Elymus glaucus*
bottlebrush squirreltail	*Elymus elymoides*
bulbous bluegrass	*Poa bulbosa*
California oatgrass	*Danthonia californica*
cheatgrass	*Bromus tectorum*
common barley	*Hordeum vulgare*
common wheat	*Triticum aestivum*
crested wheatgrass	*Agropyron cristatum*
desert wheatgrass	*Agropyron desertorum*
elk sedge	*Carex geyeri*
Idaho fescue	*Festuca idahoensis*
intermediate wheatgrass	*Thinopyrum intermedium*
Japanese brome	*Bromus japonicus*
Kentucky bluegrass	*Poa pratensis*
oat	*Avena* spp.
onespike oatgrass	*Danthonia unispicata*
orchardgrass	*Dactylis glomerata*
medusahead	*Taeniatherum caput-medusae*
Pennsylvania sedge	*Carex pensylvanica*
prairie Junegrass	*Koeleria macrantha*
Sandberg bluegrass	*Poa secunda*
smooth brome	*Bromus inermis*
timothy	*Phleum pratense*
ventenata	*Ventenata dubia*
wild oat	*Avena fatua*
Mosses	
hoary fringe-moss	*Racomitrium ericoides*

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