Weed Risk Assessment for *Chrysopogon aciculatus* (Retz.) Trin. (Poaceae) – Golden false beardgrass

United States Department of Agriculture

Animal and Plant Health Inspection Service

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Version 1

Left: *Chrysopogon aciculatus*, its growth habit (source: BWS, 2004); center: *C. aciculatus*. A. habit, B. triad of spikelets (source: Skerman and Riveros, 1990); right: inflorescence [source: Chris Gardiner, James Cook University (U.S. Forest Service, 2012)].

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Introduction Plant Protection and Quarantine (PPQ) regulates noxious weeds under the authority of the Plant Protection Act (7 U.S.C. § 7701-7786, 2000) and the Federal Seed Act (7 U.S.C. § 1581-1610, 1939). A noxious weed is defined as "any plant or plant product that can directly or indirectly injure or cause damage to crops (including nursery stock or plant products), livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment" (7 U.S.C. § 7701-7786, 2000). We use weed risk assessment (WRA)—specifically, the PPQ WRA model (Koop et al., 2012)—to evaluate the risk potential of plants, including those newly detected in the United States, those proposed for import, and those emerging as weeds elsewhere in the world.

Because the PPQ WRA model is geographically and climatically neutral, it can be used to evaluate the baseline invasive/weed potential of any plant species for the entire United States or for any area within it. As part of this analysis, we use a stochastic simulation to evaluate how much the uncertainty associated with the analysis affects the model outcomes. We also use GIS overlays to evaluate those areas of the United States that may be suitable for the establishment of the plant. For more information on the PPQ WRA process, please refer to the document, *Background information on the PPQ Weed Risk Assessment*, which is available upon request.

Chrysopogon aciculatus **(Retz.) Trin. – Golden false beardgrass**

Species Information

Family: Poaceae

Initiation: Keith Bradley and Sarah Martin (Institute for Regional Conservation) detected a population of *Chrysopogon aciculatus* in a grassy area next to the runway at the Homestead Air Reserve Base in Miami-Dade County, Florida on October 2, 2012 (Bradley, 2012). This is the first known report of this weed in the continental United States (Floyd, 2012). Subsequently, the PPQ New Pest Advisory Group (NPAG) prepared a report on this weed (PERAL, 2013). We evaluated this species with the PPQ WRA to support NPAG's decision making process.

Foreign distribution: The native range of *C. aciculatus* includes tropical areas of Asia, Australia, and the Pacific (U.S. Forest Service, 2012). It has spread to numerous countries in sub-Saharan Africa, Panama in Central America, and new regions of the Pacific (CABI, 2012; eFloras, 2012; GBIF, 2012; NGRP, 2012; Porteres, 1950; Space et al., 2003; Tropicos.org, 2012; U.S. Forest Service, 2012).

U.S. distribution and status: *Chrysopogon aciculatus* is listed as a Federal Noxious Weed for the United States (PPQ, 2010). This designation was recommended by PPQ in 1981 (Ritchie, 1981), before the current WRA model was available.

Chrysopogon aciculatus is either native or a very early introduction to Hawaii (NGRP, 2012; NRCS, 2012; Wagner et al., 1990). It is not established in any other area of the United States (Kartesz, 2011; NRCS, 2012). Prior to the recent detection in Florida, it had been known only from controlled plantings in Gainesville, Florida (Flora of North America Editorial Committee, 2003). The Florida population is currently under survey and eradication (CERIS, 2012; Derksen, 2012; Marzolf, 2012).

WRA area[1]: Entire United States, including territories.

1. *Chrysopogon aciculatus* analysis

Establishment/Spread Potential

Chrysopogon aciculatus is a widely distributed tropical/subtropical grass (ABRS, 2012). Beyond its native range, it has naturalized in other regions of the Pacific, parts of Africa, and Panama in Central America. It is known to propagate and spread rapidly (Porteres, 1950; Webster, no date), form dense mats (Galinato et al., 1999; Whistler, 1995; Whitney et al., 1939), have prolific seed production (Jha and Jha, 2006), be self-compatible (Subba Reddi et al., 2010), and tolerate or benefit from grazing pressure, trampling, and burning (Agrawal, 1990; Galinato et al., 1999; Partridge, 1986; PROSEA Foundation, 2012; Space et al., 2003). It can be dispersed by people, birds, and other animals, as its spiked seeds stick to fur, feathers, clothing, or other fibrous material (Galinato et al., 1999; Porteres, 1950; Powell, 1968; Space et al., 2003; U.S. Forest Service, 2012); its seed may also be spread as a contaminant of seed lots (Baki et al., 2000; NGRP, 2012) and propagative plant material (CABI, 2012; PestID, 2012). We had low uncertainty with this element.

Risk score = 19 Uncertainty index = 0.10

Impact Potential

Chrysopogon aciculatus is a weed of tea (Barthakur et al., 2005), rubber plantations, tobacco (CABI, 2012), upland rice (Galinato et al., 1999), palm oil plantations (Sarada et al., 2002), grazing systems (McClelland, 1915; Veldkamp, 1999), and turf (Kamal-Uddin et al., 2009; Veldkamp, 1999). Some reports exist of it being a threat to natural systems (Space and Flynn, 2000, 2002; Space et al., 2003), but we found no specific evidence of impacts or control measures in those environments. It impacts grazing systems by crowding out and replacing plants with forage value (McClelland, 1915). Some evidence indicates *C. aciculatus* affects community composition, but only under heavy grazing (CABI, 2012; Kessler, 2011; Skerman and Riveros, 1990). Control measures have been used in grazing systems (McClelland, 1915), turfgrass (Zulkaliph et al., 2011), and rice production (Galinato et al., 1999). The sharp seeds can injure humans and dogs in particular (Skerman and Riveros, 1990; Veldkamp, 1999), and animal mouths and skin in general (PROSEA Foundation, 2012; Veldkamp, 1999). Sores in farm animals can lead to increased veterinary expenses (Anderson, 2012) but it is not clear by how much this happens. We had high uncertainty with this element.

Risk score = 3 Uncertainty index = 0.32

Geographic Potential

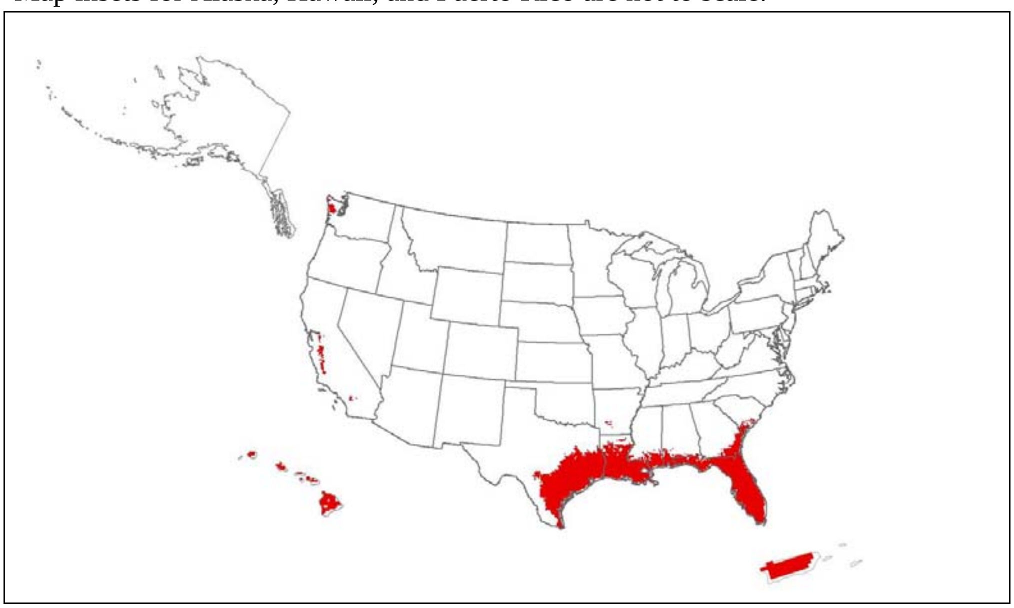
Based on three climatic variables, we estimate that about 5 percent of the United States is suitable for the establishment of *C. aciculatus* (Fig. 1). This predicted distribution is based on the species' known distribution elsewhere in the world and includes point-referenced localities and areas of occurrence (GBIF, 2012). The map for *C. aciculatus* represents the joint distribution of Plant Hardiness Zones 9-13, areas with 20-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical rainforest, tropical savanna, steppe, humid subtropical, and marine west coast.

[1] "WRA area" is the area in relation to which the weed risk assessment is conducted [definition modified from that for "PRA area" (IPPC, 2012).

The area estimated likely represents a conservative estimate as we based this on only three climatic variables. Other environmental variables, such as soil and habitat type, may further limit the areas in which this species is likely to establish. *Chrysopogon aciculatus* is adapted to growing in moderately dry to humid environments with sandy loamy soils of pH 5-6 (PROSEA Foundation, 2012). Its habitats include dry exposed areas, slopes and ridges, seashores, riversides, disturbed areas, grazing systems, turf, rail/roadsides, waste places, grasslands, orchards, cultivated areas, and urban/peri-urban areas (CABI, 2012; eFloras, 2012; Galinato et al., 1999; Skerman and Riveros, 1990; U.S. Forest Service, 2012; Veldkamp, 1999; Whitney et al., 1939; Zhang and Hirota, 2000; Zheng et al., 2005; Zhirong, 1990).

Entry Potential We did not assess *C. aciculatus*' entry potential because this species is already present in the United States (Bradley, 2012; Flora of North America Editorial Committee, 2003; NGRP, 2012; NRCS, 2012; Wagner et al., 1990).

Figure 1. Predicted distribution of *Chrysopogon aciculatus* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.



2. Results and Conclusion

Model Probabilities: P(Major Invader) = 89.5%
P(Minor Invader) = 10.1%
P(Non-Invader) = 0.4%

Risk Result = High Risk

Secondary Screening = Not Applicable

Figure 2. *Chrysopogon aciculatus* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

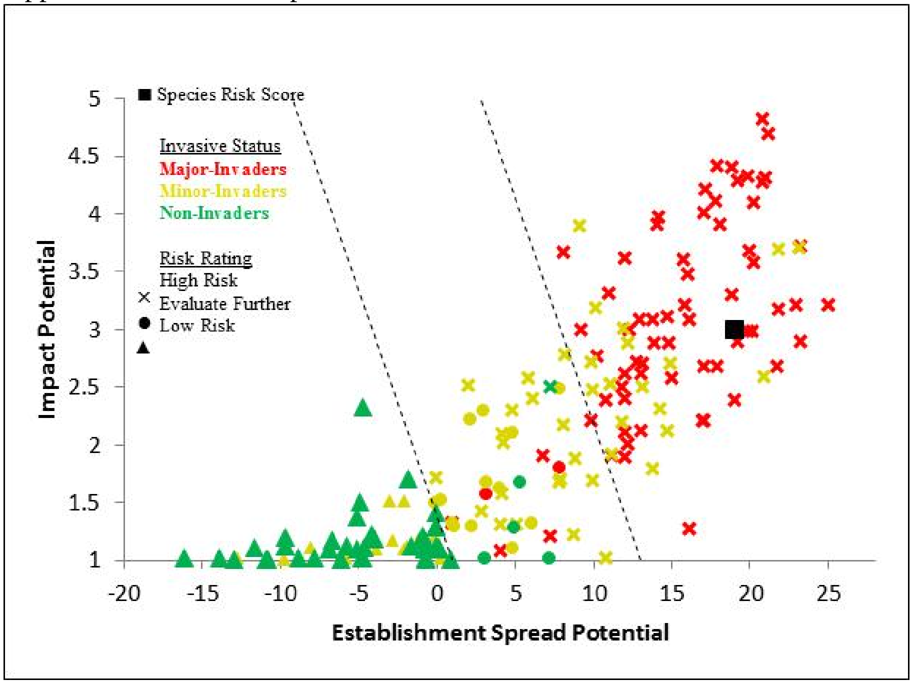
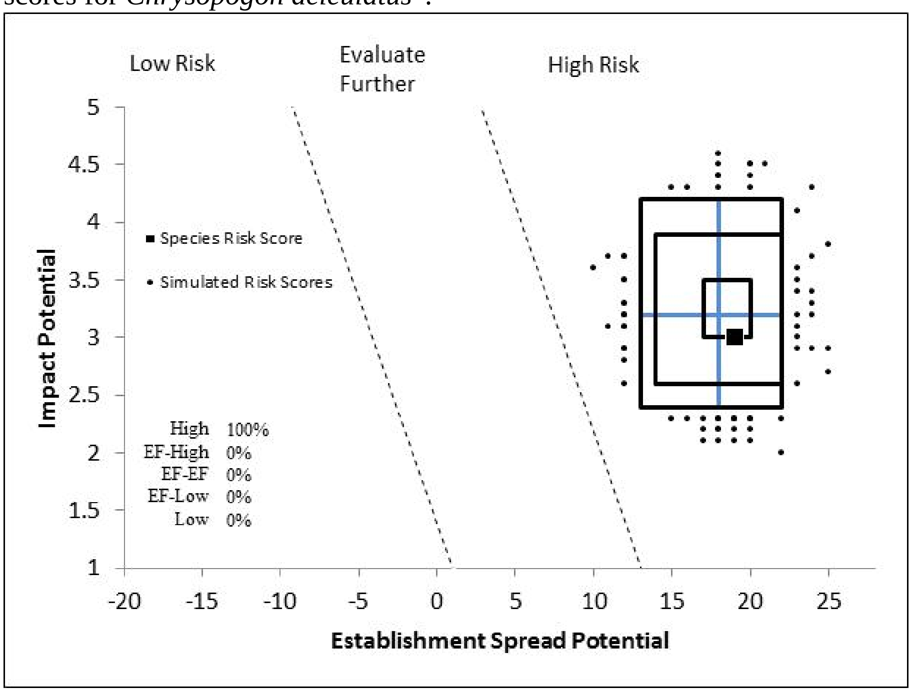


Figure 3. Monte Carlo simulation results (N=5,000) for uncertainty around the risk scores for *Chrysopogon aciculatus* [a].



[a] The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *C. aciculatus* is High Risk. *Chrysopogon aciculatus* is a tropical/subtropical grass species that is a weed of turfgrass and certain production systems (e.g., grazing systems). Comparison of *C. aciculatus* to the 204 species used in the validation of the WRA model indicates that it shares many of the same traits and impacts as other major-invaders and high-scoring minor-invaders (Fig. 2). Our level of uncertainty was low for the establishment/spread risk element, but high for the impact potential element. Despite the high uncertainty for impact potential, all the simulated risk scores resulted in a conclusion of High Risk (Fig. 3), so the overall model conclusion of High Risk seems statistically robust.

Of the systems in which *C. aciculatus* is reported to be a weed, rice, tobacco, turf, and grazing lands are economically important in the continental United States where *C. aciculatus* could establish (Charleston Tea Plantation, 2012; Haydu et al., 2006; NASS, 2012a, 2012b; Nickerson et al., 2011; Snyder and Slaton, 2001). In regard to rice, *C. aciculatus* has only been reported as a weed of upland, or rainfed, rice (Galinato et al., 1999; Moody, 1989), so it probably is not a risk to U.S. (flooded) rice producers (CIPM, 2013; Gupta and Toole, 1986; USA Rice Federation, 2013). Although *C. aciculatus* has been reported in Hawaii as a weed of grazing systems (McClelland, 1915), we found no recent evidence of problems due to *C. aciculatus* (Reimer, 2012). The noxious weed specialist for the Hawaii Department of Agriculture (Reimer, 2012) thinks *C. aciculatus* may have been displaced by kikuyu grass (*Pennisetum clandestinum*), also a Federal Noxious Weed, that was introduced there for pasture use in 1925. Therefore, the situation in Hawaii may not reflect how the weed could behave in other parts of the United States.

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Appendix A. Weed risk assessment for *Chrysopogon aciculatus* (Retz.) Trin. (Poaceae). The following information is from the species' risk assessment, which was conducted using Microsoft Excel. The information shown in this appendix was modified to fit on the page. The original Excel file, the full questions, and the guidance to answer the questions are available upon request.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Establishment/Spread Potential			
ES-1 (Status/invasiveness outside its native range)	f - low	5	*Chrysopogon aciculatus* is a "garden escape," has naturalized in new geographic areas, and is described as "invasive" (i.e., "species may have escaped from gardens, cultivation or both") (Randall, 2012). Its native range includes tropical parts of Asia, Australia, and parts of the Pacific (U.S. Forest Service, 2012). It has spread to new parts of the Pacific (CABI, 2012; GBIF, 2012; NGRP, 2012; U.S. Forest Service, 2012), multiple countries in Africa (CABI, 2012; GBIF, 2012; Tropicos.org, 2012), as well as Panama in Central America (GBIF, 2012; Tropicos.org, 2012). It is "a widely distributed tropical and subtropical grass" (ABRS, 2012) and a "widespread weed in many Pacific islands" (Fosberg and Evans, 1969). In Cote D'Ivoire, where it has naturalized, "it propagates itself readily and spreads rapidly" (Porteres, 1950). It was probably introduced to Christmas Island as a lawn grass, and is now common in cleared areas and around habitation and the golf course (ABRS, 2012). It is "an aggressive, noxious weed" (Space et al., 2003) that "quickly spreads" from seeds and vegetative offshoots (Webster, no date) and is difficult to eradicate (Flora of North America Editorial Committee, 2003; Webster, no date). It has been recorded as a Category 5 weed, i.e., "as an invasive species"; "this is the most serious criterion that can be applied to a plant and is generally used for serious high impact environmental and/or agricultural weeds that spread rapidly and often create monocultures" (Randall, 2007). In contrast, CABI (2012) states that "*C. aciculatus* is a widespread grass with nuisance value but limited capacity for widespread invasion." It is reported as "invasive" in multiple islands in the Pacific (U.S. Forest Service, 2012); however this source does not give a definition for "invasive." Because the majority of the evidence suggests it does meet the criteria of invasiveness as described in the PPQ WRA model (e.g., "widely distributed" and "spreads rapidly"), answering "f." The alternate answers for the Monte Carlo simulation are both "e."
ES-2 (Is the species highly domesticated)	n - low	0	*Chrysopogon aciculatus* is "cultivated" in China (NGRP, 2012) and is listed as "cultivated" by Randall (2012). It is currently or has been used for erosion control, lawns/turf, forage, and as a medicinal herb (CABI, 2012; Lai et al., 2012; NGRP, 2012; PROSEA Foundation, 2012; Randall, 2012; Tangjang et al., 2011; Veldkamp, 1999). In parts of Africa and Asia, "it is commonly grown as a lawn-grass" (Crane, 2012). In Cote d'Ivoire, it is useful as a lawn grass (Porteres, 1950), and it is used as turfgrass in Ghana (Asiedu et al., 2012). In China, it is used as a grass sod in vegetating air fields, horse racing fields, embankments, and highways (Bai, 1994). "It used to be used as a cover for coconut plantations in the Philippines" (FAO, 2012). Despite this widespread use, we found no evidence that it has been bred to reduce its likelihood of becoming a weed.
ES-3 (Weedy congeners)	n - low	0	We found no evidence that other species of *Chrysopogon* are

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
			considered to be significant weeds or invasive plants.
ES-4 (Shade tolerant at some stage of its life cycle)	n - low	0	It "is often abundant in open areas" (Galinato et al., 1999). The habitats of this species under natural conditions include "sunlit hills" (Zheng et al., 2005). In a study comparing the plant compositions of sunny and shady meadows, *Andropogon aciculatus* (synonym of *C. aciculatus*) was one of two dominant species in the sunny meadow (Rahman et al., 1983). Occurs in "sunny localities" (Veldkamp, 1999). It naturalizes especially in sunny areas (Porteres, 1950). Planting conditions include "partial to full sun" (BWS, 2004).
ES-5 (Climbing or smothering growth form)	n - negl	0	It is a grass with culms ascending to 45 cm (Skerman and Riveros, 1990) and forming dense mats (see ES-6). It is not a vine and does not form rosettes.
ES-6 (Forms dense thickets)	y - negl	2	It forms "dense green mats...It spreads and forms a firm mat over the ground" (Galinato et al., 1999). "An extensively creeping perennial with many rather brittle, leafy stolons rooting at the joints and forming a close, thick mat" (Whitney et al., 1939). "Creeping perennial grass forming mats by means of leafy stolons...leaves [of culms] mostly crowded near the base" [see image in the WRA spreadsheet] (Whistler, 1995). "This mat-forming grass" has "stolons covered by old leaf sheaths" (Whistler, 1995). It is "mat-forming" (ABRS, 2012).
ES-7 (Aquatic)	n - negl	0	It is a terrestrial plant (NGRP, 2012). It is often found on dry soil (Whistler, 1995). It "is very resistant to...drought due to its vigorous, deep root system" (Win and Jung, 2012). "It is fairly drought tolerant," but "it prefers moist soils" (Skerman and Riveros, 1990).
ES-8 (Grass)	y - negl	1	Plant is a grass in the family Poaceae (NGRP, 2012).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	This plant is not a woody plant and is not in a family (NGRP, 2012) known to fix nitrogen (Martin and Dowd, 1990).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	*Chrysopogon aciculatus* is propagated by seed (CABI, 2012; Zhang and Hirota, 2000). "*C. aciculatus* is propagated by seed or rooting tillers" (Galinato et al., 1999). "Reproduction by seeds and vegetatively" (OSWALD, 2012). It propagates vegetatively as well as through sexual reproduction (Jha and Jha, 2006).
ES-11 (Self-compatible or apomictic)	y - low	1	*Chrysopogon aciculatus* is andromonoecious (having hermaphrodite and male flowers on the same plant); it has a "high level of compatibility to xenopollen" and is "treated as predominantly outcrossing", but geitonogamy (the transfer of pollen to a stigma of a different flower on the same plant) and autogamy (self-fertilization) can occur (Subba Reddi et al., 2010). Using low instead of negligible uncertainty because answer is based on only one reference.
ES-12 (Requires special pollinators)	n - negl	0	It is wind pollinated (anemophily) (Abe, 2006).
ES-13 (Minimum generation time)	b - high	1	We found two references stating it is an annual (Mall and Singh, 2011; OSWALD, 2012); all other references state it is a perennial (e.g., Clayton et al., 2006 onwards; eFloras, 2012; Galinato et al., 1999; Whitney et al., 1939). It starts to flower within 6-8 weeks after it has formed a firm mat over the ground, and "it flowers throughout the year" (Galinato et al., 1999). We found no specific generative time data on the taxon. The alternate answers for the Monte Carlo simulation are both "c."

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-14 (Prolific reproduction)	y - high	1	In one study, the seed production per meter square of *C. aciculatus* was 17,340 ± 42.0, but the viability of freshly harvested seeds was only 37 percent (Jha and Jha, 2006), which translates to approximately 6,400 viable seeds per meter square. *C. aciculatus* can produce 308 seeds per plant (Galinato et al., 1999). As a weed in turf grass situations, it can have a mean density of 9.79 plants per meter square (Kamal-Uddin et al., 2009). In a grassland setting, it produced between 234.9 and 1,388.5 tillers/m2 depending on the season ["Each annual erect shoot was considered to be a plant tiller...In case of sod-forming grasses, any portion of the plant possessing an independent shoot and root that could be separated from others is regarded as one tiller...In this context, the term 'plant' was synonymous with…a tiller in grasses."] (Agrawal, 1990). In one study, the germination percentage of *C. aciculatus* seed in field soils was determined to be between 68.0 and 99.7 (Datta and Sinha-Roy, 1975). In another study, its seed had 93 to 95 percent germination (Subba Reddi et al., 2010). Using this data to extrapolate, we estimate that the number of seeds per meter square is somewhere between 1,116 (= 9.79 x 308 x 0.37) and 426,375 (= 1,388.5 x 308 x 0.997). Because the high end of the range is well above 5,000, answering yes. However, because of the wide range, in particular the range in viability/germination data, we use high uncertainty.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	"Its spiked seeds are carried from place to place in...clothing" (Space et al., 2003). "[T]he sharp barbed points of the spikelets stick to clothing and...provide an effective method of seed dispersal" (Galinato et al., 1999). "The sharp barbed points of the spikelets are very penetrating and stick readily to clothing" (Whitney et al., 1939). The seeds of *C. aciculatus* have been intercepted "adhering to footwear" and "adhering to fibrous material (particularly clothing)" during port-of-entry inspections in New Zealand (Powell, 1968).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - low	2	*Chrysopogon aciculatus* seeds are a weed contaminant of rice seed in southern Vietnam (Baki et al., 2000). It is recorded as a "potential seed contaminant" (NGRP, 2012) and a "species that ha[s] been documented as a contaminant" (Randall, 2012). The seeds of *C. aciculatus* are considered liable to be carried in the trade/transport of flowers, growing medium accompanying plants, and seeds/grain; "highly likely to be transported internationally accidentally" (CABI, 2012). We found one interception of *C. aciculatus* (plant stage not indicated) in permit cargo (commercial plant products) at U.S. ports-of-entry, which was with leaves of *Eria javanica* (an orchid) for propagation from the Philippines (PestID, 2012; queried October 30, 2012).
ES-17 (Number of natural dispersal vectors)	2	0	Information relevant for ES-17a through ES-17e: "Seed a caryopsis, linear, 1.5-3 mm long, with 2 fine sharp bristles." (Galinato et al., 1999). "Caryopses of *C. aciculatus* are rough to touch, loosely enclosed by glumes, and bear an awned (average length 5mm) lemma" (Jha and Jha, 2006). The caryopsis denotes the seed and fruit, "as pericarp and seed coat layer are contiguous in caryopsis and therefore inseparable from the standpoint of seed handling" (Jha and Jha, 2006).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-17a (Wind dispersal)	n - low		We found no evidence that wind contributes significantly to the dispersal of the seed. The structure of the seed does not suggest specific adaptations for wind dispersal.
ES-17b (Water dispersal)	n - mod		There are no obvious fruit/seed adaptations for water dispersal, and we found no evidence that the propagules are water dispersed. Its habitats include dry exposed areas, open hillsides, seashores, and disturbed areas (e.g., grazing systems, roadsides, waste places, cultivated areas (CABI, 2012; eFloras, 2012; Galinato et al., 1999; U.S. Forest Service, 2012; Whitney et al., 1939; Zhang and Hirota, 2000; Zhirong, 1990; Skerman and Riveros, 1990; Veldkamp, 1999). We did find one report that its habitats include riversides (Zheng et al., 2005); therefore, using moderate uncertainty.
ES-17c (Bird dispersal)	y - low		"Its spiked seeds are carried from place to place in...feathers..." (Space et al., 2003). "Sharp spiked seeds carried in ...feathers" (U.S. Forest Service, 2012).
ES-17d (Animal external dispersal)	y - negl		"Its spiked seeds are carried from place to place in fur..." (Space et al., 2003). "[T]he sharp barbed points of the spikelets stick to...the hair of animals and provide an effective method of seed dispersal" (Galinato et al., 1999). "The sharp barbed points of the spikelets are very penetrating and stick readily to...hair of animals" (Whitney et al., 1939). It "spreads rapidly through attachment of the spikelets to animals" (Porteres, 1950).
ES-17e (Animal internal dispersal)	n - low		No evidence. "Eaten by horses and cattle when not in fruit" (Veldkamp, 1999). "Animals eat it but avoid the fruiting spikes...eaten by cattle before flowering, but not palatable later" (Delfeld and Delfeld, 2007). "Cattle browse it...but is normally avoided if in flower...needle-like awns cause injury to the mouth of cattle" (Crane, 2012). In one study, *C. aciculatus* was found in 39 percent of rumen samples from rusa deer (*Cervus timorensis russa*) in New Caledonia (de Garine-Wichatitsky et al., 2005); however, this study did not state what plant parts of *C. aciculatus* were found.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	? - max	0	Unknown. We found no concrete evidence that this species' seeds can persist for extended periods in a soil seed bank. The freshly collected seeds of *C. aciculatus* "exhibited dormancy as they failed to germinate even after acid scarification and incubation under various light qualities, and temperature regime which permitted germination in older seeds," while seven to nine month old seeds exhibited 4 percent germination without acid scarification or nutrient treatment (Jha and Jha, 2006). Although this suggests *C. aciculatus* may have a persistent seed bank, answering unknown without more conclusive information.
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - negl	1	It is often found in overgrazed areas, resisting trampling, and "tends to dominate with regular burning" (Galinato et al., 1999; PROSEA Foundation, 2012). In one study, *C. aciculatus* was one of two dominant plant species under high goat grazing pressure (Mueller-Dombois, 1981). In another study, it dominated the site with "grazing prohibited but open for annual selective fire and scraping" as well as the site that was "heavily grazed...open to cattle"; *C. aciculatus* "increased in number after burning" (Agrawal, 1990). "One of the few grasses which can stand heavy grazing in India" (Skerman and Riveros, 1990). In

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Fiji, in pastures grazed continuously for eight years, *C. aciculatus* "increased under heavier grazing" (Partridge, 1986). "Proliferates under heavy grazing regimes" (CABI, 2012). "Common pioneer species on volcanic ash and cinders" (Fosberg et al., 1975). "Resistant to trampling and fire" (Veldkamp, 1999). It withstands trampling and mowing (Space et al., 2003).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low	0	No evidence. Heap et al. (2012) do not list any species in the genus *Chrysopogon* as having herbicide resistance.
ES-21 (Number of cold hardiness zones suitable for its survival)	5	0	
ES-22 (Number of climate types suitable for its survival)	5	2	
ES-23 (Number of precipitation bands suitable for its survival)	9	1	
Impact Potential			
General Impacts			
Imp-G1 (Allelopathic)	? - max		Unknown. We found no evidence of allelopathy involving the use of non-concentrated natural plant parts or products, but we did find some evidence of allelopathy using concentrated extracts. In a study on the allelopathic influences of weeds on two crop plants, the "inflorescence extracts of *Chrysopogon aciculatus* slightly inhibited the vegetative phase of mustard and moderately inhibited both the vegetative and reproductive phases of wheat" (Datta and Bandyopadhyay, 1981). In a laboratory germination tests on possible allelopathic effects of pasture plant extracts on *Pinus kesiya*, "radicle elongation was significantly inhibited by *C. aciculatus*" (Peñafiel, 1986).
Imp-G2 (Parasitic)	n - negl	0	*Chrysopogon aciculatus* does not belong to a family known to contain parasitic plants (Heide-Jorgensen, 2008; NGRP, 2012; Nickrent, 2009; Walker, 2010).
Impacts to Natural Systems			
Imp-N1 (Change ecosystem processes and parameters that affect other species)	n - mod	0	No evidence.
Imp-N2 (Change community structure)	n - mod	0	No evidence.
Imp-N3 (Change community composition)	n - high	0	There is some evidence of it affecting community composition, but only in disturbed systems. See Imp-P1 for evidence of systems disturbed by agricultural production. On Sarigan Island, part of the Northern Mariana Islands, over 100 years of grazing by feral ungulates (goats and pigs that were introduced to the island by people) have resulted in grasslands, of which *C. aciculatus* dominates, replacing dry remnant native forest (Veitch et al., 2011). "Probably represents the final stage of deterioration of the *Phragmites/Saccharum/Imperata* swamp grasslands in India" (Skerman and Riveros, 1990); it is not clear from this reference, however, if *C. aciculatus* is directly affecting

Question ID	Answer - Uncertainty	Score	Notes (and references)
			community composition. CABI (2012) states that it has a "negative impact" on the environment (generally) and native fauna and flora; however specifics on how it has a negative impact are not provided.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species)	n - high	0	This species is generally found in systems heavily disturbed by people (e.g., pastures, roadsides, waste places, cultivated areas) (Anderson, 2012; Galinato et al., 1999; Porteres, 1950; PROSEA Foundation, 2012; Skerman and Riveros, 1990). It can also be found in natural areas, such as rocky slopes (Whitney et al., 1939), hillsides, seashores (U.S. Forest Service, 2012 CABI, 2012), grasslands (eFloras, 2012; Zhang and Hirota, 2000; Zhirong, 1990), and riverside (Zheng et al., 2005). Also, it is reported as part of pioneer or early successional plant communities (Bunvong, 1984; Palaniappan, 1974). However, because we did not find evidence of impacts to natural systems, it seems unlikely to affect T&E species.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions)	n - high	0	The predicted distribution in the United States of *C. aciculatus* includes globally outstanding ecoregions, as defined by Ricketts et al. (1999) (e.g., Hawaii, Florida, and other small parts of the southeast). However, as we found no evidence of it affecting community composition in undisturbed areas, answering no.
Imp-N6 (Weed status in natural systems)	b - high	0.2	It is an "invasive species of environmental concern" in Palau, Niue, and Cook Islands in the Pacific (Space and Flynn, 2000, 2002; Space et al., 2003). It is also listed as a weed in natural environments by Randall (2007; 2012). We found no specifics on how it is a weed in natural environments and no evidence that it is being controlled in natural systems. In a report on invasive plant species of environmental concern in the Republic of Palau, it is recommended that *C. aciculatus* be eradicated whenever detected on new islands (Space et al., 2003); however, we found no evidence that such eradication efforts have occurred. The alternate answers for the Monte Carlo simulation are both "c."
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Impacts human property, processes, civilization, or safety)	n - low	0	No evidence.
Imp-A2 (Changes or limits recreational use of an area)	? - max		In a survey in Malaysia of 50 different types turfgrass fields such as football field, rugby field, hockey field, lawn area, landscape area, recreational park area, green golf and fairway golf, *C. aciculatus* was the most common and frequent grass, occurring in 56 percent of the turf fields surveyed (Kamal-Uddin et al., 2009). It "can annoy humans…due to its prickly spikelets that stick to and penetrate clothing or skin" (PROSEA Foundation, 2012). "Its sharp seeds can penetrate flesh and work their way in, causing festering sores" (Space et al., 2003). It "may become a noxious weed because the diaspores adhere to clothing...and may penetrate the skin in man...causing itches and sores" (Veldkamp, 1999). In Asia, "dogs frequently develop abscesses between the toes from [the ripe fruits becoming attached to their hair by the sharp basal callus], and germinating seeds of this grass can sometimes be pressed out of large bags of pus in the dog's flesh" (Skerman and Riveros, 1990). It is a "serious pest" in north Queensland; "the seeds work through

Question ID	Answer - Uncertainty	Score	Notes (and references)
			clothing and cause irritating sores" (Skerman and Riveros, 1990). The fact that this plant occurs in recreational areas and affects human and dog health suggests it could change or limit the recreational use of an area; however, we did not find direct evidence for this type of impact, therefore answering unknown.
Imp-A3 (Outcompetes, replaces, or otherwise affects desirable plants and vegetation)	? - max		We did not find direct evidence that it displaces desirable plants and vegetation. However, it is a weed of turfgrass (e.g., ABRS, 2012; Kamal-Uddin et al., 2009; Veldkamp, 1999); as turfgrass is usually planted to form a dense monotypic mat, any presence of *C. aciculatus* in such a setting would probably be deemed unacceptable. Because of the lack of direct evidence, answering unknown.
Imp-A4 (Weed status in anthropogenic systems)	c - mod	0.4	In Malaysia, it is reported as a weed of turfgrass (Kamal-Uddin et al., 2009). It is a "common weed of lawns" (Veldkamp, 1999) and is a "common garden weed" in the Darwin to Katherine area in Australia (Miller and Walduck, 2011). "Useful for rough lawns, forming dense, hard-wearing turf, but a troublesome weed when uncontrolled because of the sharp-pointed seeds" (Skerman and Riveros, 1990). In the humid tropics, it is "usually considered a weed in lawns" (ABRS, 2012). The use of saline water has been studied for the control of *C. aciculatus* in turfgrass (Zulkaliph et al., 2011). Because we found limited evidence of control in anthropogenic areas, using moderate uncertainty. The alternate answers for the Monte Carlo simulation are both "b."
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	y - high	0.4	There is evidence that *C. aciculatus* can replace other plant species in grazing systems. On Hawaiian ranches, it crowds out and replaces the plants that have forage value (McClelland, 1915). In Kalimantan, Indonesia, cattle grazing on grasslands resulted in the replacement of *Imperata cylindrica* by *Axonopus compressus* and *C. aciculatus* (CABI, 2012), and in Khon Kaen, Thailand, *C. aciculatus* replaced *Arundinaria ciliata* under heavy grazing (Skerman and Riveros, 1990); however, these references do not indicate if these change were of negative consequence for cattle grazing. Because we found only one old reference (i.e., McClelland, 1915) that clearly indicates a reduction in pasture productivity, we use high uncertainty. In other agricultural systems, the evidence is even less clear as to whether it can affect yield. "It competes with crops" (Galinato et al., 1999). It "damages rice and dry-land crops" (Zhirong, 1990). In Cote d'Ivoire, it has been considered to only present a danger in overexploited pastures; it does not cause problems in cultivated fields (Porteres, 1950).
Imp-P2 (Lowers commodity value)	y - high	0.2	"[I]t can annoy...livestock due to its prickly spikelets that stick to and penetrate...skin" (PROSEA Foundation, 2012). "Its sharp seeds can penetrate flesh and work their way in, causing festering sores" (Space et al., 2003). "Spikelets readily attach themselves to fur and can cause sores on animals" (Whistler, 1995). "May become a noxious weed because the diaspores adhere to ...fur and may penetrate the skin in...cattle causing...sores" (Veldkamp, 1999). "Grazing animals suffer severely from the ripe fruits becoming attached to their hair by the sharp basal callus...[b]y

Question ID	Answer - Uncertainty	Score	Notes (and references)
			this means the fruit works its way into the flesh and causes extensive ulceration" (Skerman and Riveros, 1990). "The needle-sharp callus on the diaspore can injure cattle and other animals, catching in fur and then penetrating the skin" (eFloras, 2012). "May cause bad sores on the heads & feet of animals" (Delfeld and Delfeld, 2007). Festering sores in cattle and other farm animals can lead to veterinary expenses (Barkworth et al., 2007, as cited by Anderson, 2012), which could increase livestock production costs. As livestock skin injured by sharp awns of plants can cause holes in the grain of leather (Anonymous, 2011), *C. aciculatus* might also cause a decrease in the commodity value of leather. Additionally, *C. aciculatus* can be a seed contaminant of rice seed (see ES-16). We found some limited evidence of control measures for this weed in grazing systems (McClelland, 1915) and rice production (Galinato et al., 1999), which we assume can increase the cost of production and therefore lower commodity value. Because we found limited evidence for control measures in production systems, and we found no specific information on lowering commodity value, we use high uncertainty.
Imp-P3 (Is it likely to impact trade)	y - low	0.2	This species has "been recorded as a noxious (declared) weed. This is a legal category and may take the form of a prohibition on entry, sale and movement to requirements to eradicate or control" (i.e., Category 4 weed) (Randall, 2007). Recorded as a "quarantine weed" (which is a "species prohibited entry under a countries quarantine laws, either because it's not present or present and under a management program") (Randall, 2012). It is reported as a regulated weed (i.e., "Harmful organism") by Israel, Mexico, and New Zealand (APHIS, 2012). It is reported as a contaminant of plant products in trade (see ES-16).
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - mod	0	No evidence. It is often found on dry soil (Whistler, 1995). It "is very resistant to...drought due to its vigorous, deep root system" (Win and Jung, 2012). "It is fairly drought tolerant," but "it prefers moist soils" (Skerman and Riveros, 1990). Because at least one reference states it prefers moist soils, using moderate uncertainty.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - negl	0	Used as forage for animals (NGRP, 2012). It is a pasture plant ("plants specifically grown for grazing or fodder production for stock or native species that are utilized for the grazing of stock") (Randall, 2012). "*Chrysopogon aciculatus* is used for grazing" (PROSEA Foundation, 2012). "The leaves are highly palatable...[it] is a naturally occurring grass for livestock" (PROSEA Foundation, 2012). It is commonly fed to livestock in Punjab State in India (Bakshi et al., 2005). Some references refer to it as inferior or "practically worthless" fodder (Galinato et al., 1999; Webster, no date; Whitney et al., 1939), but this is apparently because of its low nutritional value, the fact that animals avoid it when at the fruiting stage as it can cause injury to the animals' mouths, and the fact that the spikelets can cause injury to other parts of the animals' skin (Delfeld and Delfeld, 2007; PROSEA Foundation, 2012; Veldkamp, 1999; Webster, no date), not because of any toxicity.
Imp-P6 (Weed status in production systems)	c - negl	0.6	It is recorded as a weed of agriculture (Randall, 2007; Randall, 2012) and as a "serious," "principal," or "common" agricultural

Question ID	Answer - Uncertainty	Score	Notes (and references)
			weed in multiple countries where it occurs (Holm et al., 1979). It has a "negative impact" in livestock production and crop production (CABI, 2012). It is reported as a weed of crops such as tea in India (Barthakur et al., 1989; Barthakur et al., 2005; CABI, 2012), rubber plantations in Malaysia, tobacco in the Philippines (CABI, 2012), rice (in Bangladesh, India, Malaysia, Philippines, Thailand, Vietnam) (Galinato et al., 1999; Moody, 1989), and oil palm plantations in India (Sarada et al., 2002). It is "harmful (pest or invasive)" in managed forests, plantations, and orchards (CABI, 2012), and is a "weed of cultivated sites" (OSWALD, 2012). In rice production, cultural and chemical controls are recommended: "cultivation of infested fields before seeds mature can help to control the plant" and "*C. aciculatus* can be controlled by early postemergence (1-3 leaves) application of fenoxaprop-P-ethyl (34 g ha")...Beyond the 3-leaf stage, higher rates are recommended" (Galinato et al., 1999). On Hawaiian ranches, "it is easily eradicated by plowing, and where it is possible to do this better grasses may be substituted for it" (McClelland, 1915). We found no evidence of control measures in other production systems. The alternate answers for the Monte Carlo simulation are both "b."
Geographic Potential			All geographic information used below was obtained from GBIF (2012) and is based on point-source (PS) data (geo-referenced data points) and areas of occurrence (Occ).
Plant cold hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	No evidence.
Geo-Z2 (Zone 2)	n - negl	N/A	No evidence.
Geo-Z3 (Zone 3)	n - negl	N/A	No evidence.
Geo-Z4 (Zone 4)	n - negl	N/A	No evidence.
Geo-Z5 (Zone 5)	n - negl	N/A	No evidence.
Geo-Z6 (Zone 6)	n - negl	N/A	No evidence.
Geo-Z7 (Zone 7)	n - mod	N/A	No evidence.
Geo-Z8 (Zone 8)	n - high	N/A	In one place in China (PS data), it occurred just on the edge of this zone.
Geo-Z9 (Zone 9)	y - low	N/A	PS: China, Taiwan, Hawaii
Geo-Z10 (Zone 10)	y - negl	N/A	PS: Bhutan, China, Taiwan
Geo-Z11 (Zone 11)	y - negl	N/A	PS: Cameroon, Bhutan, Vietnam, Taiwan, Australia
Geo-Z12 (Zone 12)	y - negl	N/A	PS: Burkina Faso, Cote d'Ivoire, Togo, Papua New Guinea, Australia, Fiji, New Caledonia, Vanuatu
Geo-Z13 (Zone 13)	y - negl	N/A	PS: Benin, Cameroon, Cote d'Ivoire, Equatorial Guinea, Gabon, Ghana, Togo, Indonesia, Papua New Guinea, Panama, Fiji, Hawaii
Köppen-Geiger climate classes			
Geo-C1 (Tropical rainforest)	y - negl	N/A	PS: Cameroon, Cote d'Ivoire, Equatorial Guinea, Gabon, Indonesia, Papua New Guinea, Australia, Hawaii, Fiji, New Caledonia
Geo-C2 (Tropical savanna)	y - negl	N/A	PS: Benin, Cameroon, Cote d'Ivoire, Gabon, Ghana, Togo, Indonesia, Vietnam, Papua New Guinea, Taiwan, Australia, Panama, New Caledonia, Hawaii
Geo-C3 (Steppe)	y - low	N/A	PS: Burkina Faso, Australia, Hawaii
Geo-C4 (Desert)	n - negl	N/A	No evidence.

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Geo-C5 (Mediterranean)	n - negl	N/A	No evidence.
Geo-C6 (Humid subtropical)	y - negl	N/A	PS: Bhutan, China, Taiwan; Occ: Hong Kong
Geo-C7 (Marine west coast)	y - high	N/A	PS: China (only one point)
Geo-C8 (Humid cont. warm sum.)	n - negl	N/A	No evidence.
Geo-C9 (Humid cont. cool sum.)	n - negl	N/A	No evidence.
Geo-C10 (Subarctic)	n - negl	N/A	No evidence.
Geo-C11 (Tundra)	n - negl	N/A	No evidence.
Geo-C12 (Icecap)	n - negl	N/A	No evidence.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	n - negl	N/A	No evidence
Geo-R2 (10-20 inches; 25-51 cm)	n - high	N/A	There is one point in Australia in this band; however, because this point occurred on the edge of the 20-30 inches band, we are answering no with high uncertainty.
Geo-R3 (20-30 inches; 51-76 cm)	y - high	N/A	In two places in Australia (PS data), it occurred on the edge of this band. Because of these two points, including one in the 10-20 band, answering yes with high uncertainty.
Geo-R4 (30-40 inches; 76-102 cm)	y - low	N/A	PS: Burkina Faso, Australia
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	PS: Benin, Ghana, Togo, China, Australia
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	PS: Cote d'Ivoire, Togo, Bhutan, China, Australia
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	PS: Cameroon, Cote d'Ivoire, Gabon, China, Australia, New Caledonia, Hawaii
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	PS: Gabon, Bhutan, Indonesia, Taiwan, Australia
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	PS: Cote d'Ivoire, Gabon, Indonesia, Vietnam, Papua New Guinea, Taiwan, Vanuatu
Geo-R10 (90-100 inches; 229-254 cm)	y - negl	N/A	PS: Cameroon, Gabon, Papua New Guinea
Geo-R11 (100+ inches; 254+ cm))	y - negl	N/A	PS: Cameroon, Equatorial Guinea, Indonesia, Papua New Guinea, Fiji
Entry Potential			
Ent-1 (Plant already here)	y - negl	1	This plant is considered either naturalized (NRCS, 2012) or native (NGRP, 2012) to Hawaii. It is either native or a very early introduction to Hawaii (Wagner et al., 1990). It is not considered established in any other area of the United States (Kartesz, 2011; NRCS, 2012). However, a population of “large colonies” was recently (10/2/12) detected at the Homestead Air Reserve Base in Miami-Dade County, Florida (Bradley, 2012). Prior to this report, it had been known "only from controlled plantings at the experiment station in Gainesville, Florida" (Flora of North America Editorial Committee, 2003). A search of the University of Florida Herbarium Collections Catalog shows reports of this plant in plots at the University of Florida Herbarium Agricultural Experiment Station and in a "grass garden" in Gainesville, Florida, all from the 1920s (UF, 2012).

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	All propagules of *C. aciculatus* are prohibited entry from all countries unless accompanied by a valid “Permit to Move Live Plant Pests or Noxious Weeds” (PPQ, 2012).
Ent-3 (Human value & cultivation/trade status)	-	N/A	In its native/established range, C. aciculatus is currently or has been used for erosion control, lawns/turf, forage, and as a medicinal herb (Bai, 1994; CABI, 2012; Crane, 2012; Lai et al., 2012; NGRP, 2012; Porteres, 1950; PROSEA Foundation, 2012; Randall, 2012; Tangjang et al., 2011; Veldkamp, 1999).
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	-	N/A	It occurs in Panama in Central America (GBIF, 2012; Tropicos.org, 2012) and China (GBIF, 2012).
Ent-4b (Contaminant of plant propagative material (except seeds))	-	N/A	The seeds of *C. aciculatus* are considered liable to be carried in the trade/transport of growing medium accompanying plants (CABI, 2012). We found one interception of *C. aciculatus* (plant stage not indicated) in permit cargo (commercial plant products) at U.S. ports-of-entry, which was with leaves of *Eria javanica* (an orchid plant) for propagation from the Philippines (PestID, 2012; queried November 13, 2012).
Ent-4c (Contaminant of seeds for planting)	-	N/A	The seeds are a weed contaminant of rice seed in southern Vietnam (Baki et al., 2000). It is recorded as a "potential seed contaminant" (NGRP, 2012). The seeds are considered liable to be carried in the trade/transport of seeds (CABI, 2012).
Ent-4d (Contaminant of ballast water)	-	N/A	No evidence.
Ent-4e (Contaminant of aquarium plants or other aquarium products)	-	N/A	No evidence.
Ent-4f (Contaminant of landscape products)	-	N/A	No evidence.
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	-	N/A	The plant species has been intercepted at a U.S. port-of-entry one time as florets with “equipment” in general cargo (PestID, 2012; queried November 13, 2012); however, the type of equipment was not indicated. Its spiked seeds can be carried from place to place in fibrous material, footwear, or baggage (Galinato et al., 1999; PestID, 2012; Powell, 1968; Space et al., 2003). The seeds have been intercepted "adhering to footwear" and "adhering to fibrous material" during port-of-entry inspections in New Zealand (Powell, 1968). It has been intercepted at U.S. ports-of-entry five times with baggage (PestID, 2012; queried November 13, 2012). In one of the baggage interceptions, it was detected as hitchhiker seed on the undercarriage of luggage.
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	-	N/A	In rice production it can be a seed contaminant (Baki et al., 2000), and the seeds are considered liable to be carried in the trade/transport of grain (CABI, 2012).
Ent-4i (Contaminant of some other pathway)	-	N/A	Its spiked seeds stick to fur, feathers, and clothing (Galinato et al., 1999; Porteres, 1950; Space et al., 2003; U.S. Forest Service, 2012), which suggests it could be a hitchhiker on passengers, pets, and farm animals coming into the country. The seeds of *C.*

Question ID	Answer - Uncertainty	Score	Notes (and references)
			aciculatus have been intercepted adhering to clothing during port-of-entry inspections in New Zealand (Powell, 1968).
Ent-5 (Likely to enter through natural dispersal)	-	N/A	This plant does not occur in countries bordering the continental United States nor in the Caribbean; therefore, it seems unlikely for it to enter the continental United States through natural dispersal.