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Department of Horticultural Science
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Cenchrus ciliaris Invasion and Control in Southwestern U.S. Grasslands and Shrublands

Dan Tix

C. ciliaris, buffelgrass, is an aggressive perennial grass invading arid tropical habitats around the globe. Otherwise highly diverse communities, grasslands and shrublands, have been overtaken by a monoculture of this fire tolerant plant. The biology of this grass ideally suits it for dry communities and colonization of other disturbed sites, especially following fires. Humans have spread *C. ciliaris* for livestock forage in pastures, but its biological characteristics contribute to copious natural dispersal. Now natural land managers are trying to find ways to remove it from degraded natural areas in order to protect native species and unique communities. Control of *C. ciliaris* is costly but must be weighed against the loss of unique ecosystems. Furthermore, *C. ciliaris* continues to be planted and selected genetically by humans. This dichotomy in land management needs to be addressed before *C. ciliaris* will be constrained permanently.

Ecology

The life history traits of *C. ciliaris* suit this grass for the arid tropics. *C. ciliaris* is a warm-season, perennial grass, about 70 cm tall, that may be found in bunches but more often has creeping rhizomes. This grass grows in areas with average annual rainfall as low as 250 mm and as high as 2670 mm. The optimum temperature for photosynthesis is 35° Celsius and the average annual temperature ranges from 12.5° to 27.8°. Therefore, *C. ciliaris* prefers very warm climates and is restricted to these tropical environments (Duke, 1983).

Since *C. ciliaris* is productive in arid climates, it is a favorite of ranchers and farmers. *C. ciliaris* is preferred because it is highly nutritional forage for livestock and recovers well from grazing (Morisawa, 2000). In order to improve productivity and vigor in extreme conditions of drought, disease, frequent fire and other factors, numerous cultivars have been created (Duke, 1983). Therefore, artificial selection makes *C. ciliaris* suitable for a wide array of specific habitats around the world. For example, in Australia, *C. ciliaris* lives in moist riverine habitats (D Antonio and Vitousek, 1992) and has survived two weeks under water (Anderson, 1970).

Besides human seed transfer, seeds disperse profusely by clinging to animal fur, similar to other *Cenchrus* species, i.e. *C. longispinus*, sand bur, which have spiny seeds. *C. ciliaris* seed is lighter than the sand burs, has barbed bristles and may disperse in the wind as well (Morisawa, 2000). Seed formation is apomictic, asexual; so vast quantities of *C. ciliaris* seeds generate naturally, without pollen transfer. Moreover, the aggressive expansion of *C. ciliaris* rhizomes rapidly forms dense monocultures of newly colonized sites. This, however, means that *C. ciliaris* tends to have limited genetic exchange while cultivars tend to have limited genetic variability in the first place (Perrott and Chakraborty, 1999). Therefore, it has been speculated that *C. ciliaris* may be susceptible to local epidemics due to this lack of genetic diversity (Morisawa, 2000). The ability of the grass to generate and spread seed that colonizes new sites has compensated for this vulnerability so far.

Following *C. ciliaris* invasion, wildfires spread easily in the grass and further benefit this fire-adapted species. The leaves are narrow, less than 8.5 mm wide at the base, and dry out promptly after the rainy season (Duke, 1983). This provides high surface area on which a fire can catch. The dense growth of the rhizomatous grass then carries the fire rapidly across broad areas. *C. ciliaris* like most grasses, perennates in the soil, therefore fire has minimal negative effects on it. After a fire, fire-tolerant perrenial grasses benefit from the increase in solar penetration to the ground surface. The light provides energy for photosynthesis in emerging leaves and this environment increases the plant s nitrogen use efficiency (Ojima, *et al*, 1994), so most grasses that are adapted to fire actually benefit from it. This is especially true for *C. ciliaris*, which is native to frequently burned grasslands.

In addition, *C. ciliaris*, like many grasses, is particularly efficient at using water. Overall, rhizomatous grasses draw down soil moisture rapidly and outcompete other species in the subsoil. Likewise, because of the dense growth of such grasses, the light levels at the soil surface are very low (D Antonio and Vitousek, 1992). To make matters worse, *C. ciliaris* exudes phytotoxic chemicals that inhibit germination and growth of some other plants (Nurdin and Fulbright, 1990). Consequently, re-colonization by extirpated native plants is very difficult once *C. ciliaris* has established.

Around the World

C. ciliaris is native to southern Africa, parts of the Middle East and India. In the last century people have planted the grass across Africa, India, South America, Oceania, Puerto Rico, and elsewhere (Morisawa, 2000). Following each of these introductions, seed has disperse uncontrollably. Below are some examples of the negative effects *C. ciliaris* invasions have on natural communities. This paper focuses on Australian and Hawaiian introductions to demonstrate the types of problems typical of this grass. The shrublands of the American Southwest are used in this paper to demonstrate control strategies.

Hawaii

The Hawaiian native bunch grass *Heteropogon contortus*, pili grass, dominated grasslands in the lower altitude leeward parts of the islands. This community suffers from invasions of *C. ciliaris* and other African grasses. Sites dominated by *C. ciliaris* harbor a much lower diversity than those without it (Daehler and Carino, 1998). Furthermore, Morisawa (2000) states that *Ambrosia cheiranthifolia* and *Lesquerella thamnophila,* on the federal list of endangered species, are threatened by *C. ciliaris* invasions. In these communities, naturally adapted to fire, the problem is primarily due to the aggressive growth habit of *C. ciliaris*. Daehler (1998) argues, however, that fires in dense *C. ciliaris* spread faster and farther than in typical pili grasslands which may alter the disturbance in the pili grasslands.

The negative effect *C. ciliaris* has on Hawaiian ecosystems is exacerbated by continued encouragement of the foreign grass. Seed continues to be imported to Hawaii without regulation according to Becky Azama, Noxious Weed Specialist for the Hawaii Department of Agriculture (HDOA). Shipments are used in roadside vegetation projects (personal communication) and on military reclamation sites (Warren and Aschmann, 1993). *C. ciliaris* will continue to be problematic in the pili grasslands unless these introductions are prohibited.

Australia

C. ciliaris is considered one of the most destructive exotics in Australia because it flourishes in moist, high fertility areas where biodiversity is concentrated (Low, 1997). Before *C. ciliaris* invasions, the rich lowlands were barriers to fire. Now, the fuel matrix of the exotic provides two to three times the flammable material as the native grasses in the watercourses, increasing fire frequency throughout the landscape (D Antonio and Vitousek, 1992). Furthermore, in one region, the Aborigines regard *C. ciliaris* as a major threat to their food plants. Finches and parrots also seem to be declining because they do not eat *C. ciliaris* seed. In Epping National Park, the coverage of *C. ciliaris* exploded from 13% to 54% in only seven years. The exotic now composes nearly 50% of the diet of the endangered northern hairy-nosed wombats, *Lasiorhinus kreffti*, in this park (Low, 1997).

South Texan and Mexican Brushlands

Domestic cattle have grazed land in South Texas since the 1700 s. *C. ciliaris* was introduced for grazing forage in the 1940 s and, by 1976, occupied 90% of the seeded rangeland south of San Antonio (Mayeaux and Hamilton, 1983). This remains a favorite grass in the ranching industry, public and private. The United States Department of Agriculture has a website that links browsers to five retailers that sell cultivars (Alderson, 2000). The Mexican government promotes the use of *C. ciliaris* (Morisawa, 2000), and it presently covers over one million hectares in the state of Sonora alone (Van Devender, *et al.*, 1997). Cattle ranching drives so much of the economy in this region that regulation of *C. ciliaris* is not likely to be widely accepted by the public.

Lisa Williams, South Texas Land Steward for The Nature Conservancy, and Chris Best, Plant Ecologist in the Lower Rio Grande Valley National Wildlife Refuge, believe the difficulty in *C. ciliaris* removal to be the perpetual seed rain from surrounding pastures and roadsides. Best has noticed that any soil disturbance, even from grazing animals, is invaded by *C. ciliaris*. It does especially well on large disturbances such as roadsides, where fires commonly begin, and old fields (personal

communication).
Many native communities in the southwestern US are not tolerant to the frequent fires associated with arid grasslands and pastures. Chihuahuan thorn forests, tamaulipan thornscrub and saquaro cacti forests are fire intolerant communities that have been invaded by *C. ciliaris* and other exotic grasses. Dense patches of *C. ciliaris* convey fire near these unique habitats and often burn the shrubs, trees and cacti. Usually *C. ciliaris* does not grow immediately within the brush because it is intolerant of the shading of the canopy. Instead, another African grass, *Panicum maximum*, which grows under dense shade, carries the fire into the brush, completely altering the brushland ecosystem (L. Williams, personal communication).

If a fire does occur in shrublands, then restoration is extremely difficult. The increased light penetration to the ground layer allows *C. ciliaris* to colonize (L. Williams, personal communication). The ability of *C. ciliaris* to exclude other woody and non-woody species, allows it to form dense monocultures. Dense stands of *C. ciliaris* are severely flammable. These compounded impacts provide larger areas that support frequent fires, further eliminating re-colonizing woody plants, ultimately promoting the spread of *C. ciliaris*.

Control Techniques in North American Shrublands

Control of *C. ciliaris* is especially difficult since it promotes a disturbance regime that benefits itself. Restoration techniques for *C. ciliaris* invaded ecosystems cannot be generalized because of the diversity of habitats the grass invades. The above examples show a collection of effects *C. ciliaris* has on unique communities. The North American Southwest will be the focus of the control techniques with some strategies taken from other communities. All of the strategies may be useful, to some extent, in other ecosystems throughout the range of *C. ciliaris*.

There are three general approaches to the control of *C. ciliaris*: First, leave it alone and encourage the natural community to competitively exclude it. Second, provide a natural check on *C. ciliaris*, such as a biological control, that minimizes its affect. Third, actively remove it chemically or physically and then re-establish the desired community. Choosing one of the three methods will depend on the ecosystem to restore, the land manager s ability to control fire, and surrounding seed sources.

Competitive exclusion

In South Texas, *Isocoma coronopifolia* (goldenweed), *Prosopis spp.*(mesquite), and *Acacia spp.* (huisache) are native shrubs that commonly invade *C. ciliaris* rangeland (Mayeaux and Hamilton, 1983). Best and Williams plant these shrubs, and about 70 other woody species, in their restorations (personal communication). *C. ciliaris* is intolerant of shade so thorough canopy closure is usually sufficient to diminish it (L. Williams, personal communication). However, planting shrubs into a pasture with *C. ciliaris* is risky. A grass fire before canopy development will likely kill the plantings (Mayeaux and Hamilton, 1983). Such a setback would be very costly. Therefore, re-establishing a shrub community without eliminating *C. ciliaris* is not suggested. Both Williams and Best agree that *C. ciliaris* removal is the first step to a successful restoration (personal communication).
In Hawaii, Curt Daehler is experimenting with the restoration of pili grassland communities. Preliminary findings lead him to a similar conclusion as in South Texas; *C. ciliaris* must be removed before a restoration will succeed. However, in one area he has found that *C. ciliaris* is unable to recruit because it is too dry, whereas the native pili, *Heteropogon contortus*, is much more successful (personal communication). Consequently, *C. ciliaris* in these areas may be outcompeted if the sites are seeded with native species. With this exception, restoration on *C. ciliaris* dominated sites cannot rely on competitive exclusion as a dependable technique.

Biological control

Biological control is a method of human induced naturalization of exotic species in order to limit the species affects. Since *C. ciliaris* will never be eliminated from many habitats (D Antonio and Vitousek, 1992), introducing a natural biological control is a logical response. There are numerous fungal pathogens known to live on *C. ciliaris* around the world (Morisawa, 2000).

The most notable is *Pyricularia grisea*, rice blast, which has recently caused epidemics in pastures of Texas and Australia (Rodriquez, *et al.*, 1999; Perrott and Chakraborty, 1999). *P. grisea* (formerly *Magnaporthe grisea*) produces leaf lesions causing *C. ciliaris* to wilt, especially when exposed to heat and water stress (Rodriquez, *et al*, 1999). This fungus is causing great concern among landowners who have planted *C. ciliaris* in their pastures, however, from an ecological perspective it may be very fortunate.

People who are committed to controlling *C. ciliaris* and wish to rely on *P. grisea* may want to encourage the spread of the fungus. However, according to John Reilly, director of Kika de la Garza Plant Materials Center (U.S. Department of Agriculture Natural Resources Conservation Service), a seed company already claims to have a blight resistant strain of *C. ciliaris* (personal communication). In Australia, one cultivar is less affected by *P. grisea* than the more common strains from North America (Perrott and Chakraborty, 1999). Thus, the appropriate control method may not be in the field, but to stop cultivar development and seeding legislatively by placing *C. ciliaris* on noxious weed lists. Furthermore, introductions of *P. grisea* should be cautious because rice blast may also affect agricultural rice crops (Hawksworth et al., 1995) as well as unknown native plant species.

P. grisea has not been used by ecological managers as a biological control. The potential effectiveness, therefore, must be inferred from the pathogen s virulence in pastures where it already exists. Perrott and Chakraborty (1999) refer to the blights of South Texas and Mexico as epidemics. Rodriguez et al. (1999) express concern for *C. ciliaris* in this region because genetically identical plants cover millions of acres. However, neither paper quantifies the extent of the blight. J. Reilly does not describe the infestation as an epidemic and states that impacts of droughts confound the recent reduction of forage yields (personal communication). Therefore, the effectiveness of *P. grisea* as a biological control agent may be only minimally effective.

Chemical control

Chemical control certainly is the most effective technique for control of *C. ciliaris*. C. Best uses a combination glyphosate, broad-spectrum herbicide, and ammonium sulfate (fertilizer) to treat an area of *C. ciliaris* after a rainfall, if possible. The application may need to be repeated three or more times to thoroughly kill *C. ciliaris* before shrub seedling plantings to be effective. After adding the woody plants it may be necessary to apply Fusillade DX, a grass-only herbicide, to prevent grass regrowth. The most important aspect of the *C. ciliaris* removal is to create a healthy, intact community with a complete canopy before a fire occurs (personal communication).

Other techniques that may kill or discourage *C. ciliaris* can be taken from studies to improve management of *C. ciliaris* for forage. Numerous reports have tested herbicides on *C. ciliaris*. Bovey, *et al.* (1984) found hexazinone to inhibit regrowth following clipping; it was lethal at 1.1 kg/ha. In addition, tebuthiuron eliminated regrowth at rates over 0.6 kg/ha. Sardar (1993) found *C. ciliaris* to be sensitive to repeated clippings, this information is difficult to use for large areas, especially once woody vegetation is established. However, mowing repeatedly next to intact brushland communities would provide a firebreak and possibly allow some native re-colonization, if the operators avoid shrub seedlings.

Although chemical removal of *C. ciliaris* is the most effective technique, there are certainly negative aspects to these harsh treatments. Applying a broad-spectrum herbicide to an area with existing native plants, especially rare plants, is unacceptable. Grass-only herbicides are sometimes effective to control *C. ciliaris* although these tend to be slower to breakdown than herbicides such as glyphosate. In a grassland ecosystem however, this is still problematic. C. Best is presently undertaking the challenge to restore native grasslands infested with *C. ciliaris* (personal communication). He will need to remove all *C. ciliaris* before seeding with the natives. This process exposes the site to other invasions, erosion, and eliminates most, if not all, animal life on the site. If *C. ciliaris* returns once the natives are present, it is nearly impossible to remove *C. ciliaris* without harming desirable plants.

Conclusion

C. ciliaris has spread all over the tropics via human agriculture and by its own ability to procreate. Following each introduction, the grass changes the ecology and disturbance regime of the natural systems in which it grows. In order to restore these ecosystems land managers are trying to cope with the grasses prolific growth and ability to carry fire in otherwise fire-intolerant lands. So far, the only reliable method to control the invader is the application of potentially harmful herbicides. Since *C. ciliaris* continues to be transferred around the world, it is important that federal and international governments decide if economic gains are more important than natural systems.

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