ELEMENT STEWARDSHIP ABSTRACT

for

Cenchrus ciliaris L.

African foxtail, buffelgrass, anjangrass

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SCIENTIFIC NAME

Cenchrus ciliaris L.

The genus name "*Cenchrus*" is derived from the Greek *kegchros*, meaning millet. The species epithet "*ciliaris*" in Latin means ciliate or fringed, most likely referring to the bristly fruits of this species.

SYNONYMS

Pennisetum ciliare (L.) Link is the most commonly used synonym for *Cenchrus ciliaris*. Other lesser-known synonyms include: *Cenchrus aequiglumis* Chiov., *C. anjana* Ham. ex Wallich, *C. bulbosus* Fresen., *C. digynus* Ehrenb. ex Boiss., *C. echinoids* Wight ex Steud., *C. glaucus* Mudaliar & Sundaraj, *C. lappaceus* Tausch, *C. longifolius* Hochst. ex Steud., *C. mutabilis* Wight ex Hook. f., *C. pennisetiformis* Hochst. & Steud., *C. pubescens* L. ex B.D. Jacks., *C. rigidifolius* Fig. & De Not., *C. rufescens* Desf., *Pennisetum cenchroides* Rich. ex Pers., *P. distylum* Guss., *P. incomptum* Nees ex Steud., *P. longifolium* Fenzl ex Steud., *P. petraeum* Steud., *P. polycladum* Chiov., *P. prieurii* A. Chev., *P. rangei* Mez, *P. rufescens* (Desf.) Spreng., *P. rufescens* Hochst. ex Steud., *P. teneriffae* Steud., *Panicum vulpinum* Willd., and *Setaria vulpine* (Willd.) P. Beauv. (TROPICOS 2002).

COMMON NAMES

African foxtail grass, buffelgrass, anjangrass

DESCRIPTION AND DIAGNOSTIC CHARACTERISTICS

Cenchrus ciliaris is a perennial bunchgrass in the grass family (Poaceae). At maturity, it ranges in height from 10 to 150 cm (averaging 70 cm) tall. Stems of *C. ciliaris* can be either erect or decumbent, often forming mats or tussocks. The leaf blades are bluish-green, 5 to 30 cm long and 2.5 to 11.0 mm wide, with the upper surface soft-hairy. The leaf sheaths of *C. ciliaris* are glabrous to sparingly pilose, 2 to 7 cm in length, and the ciliate ligule is 0.5 to 1.5 mm.

C. ciliaris can reproduce either vegetatively through rhizome or stolon production, or sexually by seed. Flowering inflorescences of *C. ciliaris* are dense, cylindric, 2 to 13 cm long by 1.0 to 2.6 cm wide; each inflorescence has 30 to 50 involucre bracts, and is colored purple, gray, or yellowish. Spikelets are either solitary or clustered, and are surrounded by numerous conspicuous bristles. The spikelets are clustered into burs (2 to 4 per bur), 2.5 to 4.5 mm long by 1.0 to 1.5 mm wide, lanceolate to ovate in shape, and gray to green. The lower glume is 1.0 to 2.5 mm long, the upper glume 1.5 to 3.5 mm long, and the lower floret is either staminate or sterile. The fruit is an ovoid caryopsis, 1.4 to 1.9 mm long by 1.0 mm broad (Hickman 1993; Duke 1983).

STEWARDSHIP SUMMARY

C. ciliaris is a hardy, drought-resistant, non-native grass that is widely planted as a pasture grass throughout Texas and northern Mexico. In central Sonora, more than a million hectares of native desert scrub and thorn scrub have been converted to *C. ciliaris* pasture since the 1940s (Van Devender et al. 1997). It has become well-established in disturbed as well as in intact desert scrub communities in many parts of the southwestern U.S., Hawaii, and Australia.

C. ciliaris is a problematic invasive species not only because it can outcompete and displace native species, but also because it strongly modifies the communities it invades. In the arid southwest, *C. ciliaris* changes plant communities by encouraging and carrying wildfires through communities that are not adapted to fire. It burns readily (even when green) and recovers quickly after fire. Recurrent fires maintain *C. ciliaris* populations, and the ecological result is a conversion of native desert scrub communities to an African-type savannah with reduced native biological diversity.

There is no single control method for the successful management of *C. ciliaris* in large-areas. For large infestations, an integrated management approach has the highest probability of being successful. This includes removing or reducing much of the *C. ciliaris* standing biomass (either manual removal, burning, or mowing), spraying herbicide (glyphosate or hexazinone) to control new seedlings or resprouts, followed by active restoration to create dense native vegetation. For smaller areas, carefully pulling or digging out entire plants, followed in the second and later years by the pulling of new seedlings, has been successful in disturbed, low-nutrient areas. There are no known biological controls for *C. ciliaris.*

CULTIVARS

C. ciliaris cultivars have been developed with increasing growth rates and increased ranges of tolerance to different environmental conditions, and for disease resistance. The most widespread cultivar in the U.S. is known as the "common" cultivar, strain T-4464. This strain is genetically uniform because it reproduces by apomixis. 'Higgins' is another common variety, but this strain reproduces sexually without apomixis.

Cultivars have been developed that are resistant to buffelgrass blight, a disease caused by the fungus *Pyricularia grisea* (syn. *Magnaporte grisea*). Cultivars 'Laredo' and 'Pecos' are both reported to be blight resistant.

Cultivars of *C. ciliaris* have also been produced with increased cold-tolerance. The cultivars 'Blue', 'Nueces', and 'Llano' are cold tolerant, but they have decreased seed set rates, and have not been commercially successful. A new cultivar, 'Frio', was recently developed by USDA-ARS and also has depressed seed production. How these new cultivars may affect the current range of *C. ciliaris* is unknown. The invasive tendencies of these cultivars are also unknown.

HABITAT & RANGE

C. ciliaris is widely distributed and is resilient to a number of harsh environmental conditions. It can withstand strong winds, low annual rainfall, acute erosion, and a nutrient-depleted soil profile (Ziegler et al. 2000).

C. ciliaris is native to Africa, Arabia, the Canary Islands, Madagascar, Indonesia, northern India and Pakistan. In its native range, *C. ciliaris* is common in dry, sandy areas. It can also occur in warm, temperate thornscrub habitats, tropical deserts, and in moist forests (Duke 1983).

C. ciliaris has been introduced into many tropical and subtropical areas of the world for grazing purposes. It is in or near these pasture areas, where *C. ciliaris* often becomes invasive and problematic. For instance, *C. ciliaris* was introduced into western Australia in 1870-1880 with Afghan camels and their packsaddles and Afghani handlers (Winkworth 2000). It is now common in Australia, ranging from the western sea coast eastward toward the arid inland as far as the Murchison and Ord Rivers, throughout central Australia from the Flinders Range north to the Barkly Tableland, and occurs diffusely in western parts of Queensland and New South Wales (Winkworth 2000).

In North America, *C. ciliaris* is now documented from Arizona, California, Florida, Hawaii, Louisiana, Missouri, New Mexico, New York and Texas, and in Sonora, Mexico (USDA,NRCS 1999). In the Sonoran Desert region, *C. ciliaris* is common along the Rio Cuchujaqui in southern Sonora, Mexico, in Organ Pipe Cactus National Monument and the Tucson area in Arizona, and is also present in south Texas in the Rio Grande Valley (Williams 2001; Rutman 1998; Van Devender et al. 1997; Tucson Weekly 1996). The range of *C. ciliaris* appears to be expanding northward in North America. It was first reported in California in 1993 (Hickman 1993).

C. ciliaris is also documented from Puerto Rico, the Virgin Islands, in South America and in the West Indies (Duke 1983).

IMPACTS AND THREATS POSED BY *CENCHRUS CILIARIS*

C. ciliaris can invade and dominate a variety of vegetation types. In natural areas, it tends to form dense swards that exclude native vegetation, decreasing biodiversity and altering successional processes (Daehler & Carino 1998). In upland arid regions, *C. ciliaris* can transform native desert shrub and thornscrub into grasslands. For instance, in Arizona's Organ Pipe Cactus National Monument, *C. ciliaris* excludes native shrubs such as creosote (*Larrea tridentata*), saltbush (*Atriplex* spp.), and bursage (*Ambrosia* spp.) and their associated native grasses and forbs in saguaro (*Carnegiea gigantea*) cactus desert communities. In Hawaii, *C. ciliaris* displaces native pili grass (*Heteropogon contortus*) communities and discourages the succession of native woody species (Daehler & Carino 1998).

In lowland riparian areas, *C. ciliaris* can replace native riparian vegetation along riverbanks. In the arid inland of central Queensland, Australia, *C. ciliaris* outcompetes and displaces native grasses and riparian vegetation such as brigalow (*Acacia harpophylla*), gidgee (*A. cambagei*) and eucalypts (*Eucalyptus populnea* & *E. melanophloia*) along riverbanks (Fairfax & Fensham 2000). By dominating these riparian areas and their moist refuges within arid regions, *C. ciliaris* threatens keystone habitats that are vital to the survival of many plant and animal species (McCormick et al. 1999).

C. ciliaris can also significantly alter environmental conditions. When *C. ciliaris* invades new habitats, there is often a loss of soil fertility, an increase in soil erosion that increases surface water runoff, and creates unstable watersheds with degraded water quality (Fabel 2000). In subtropical regions with high rainfall, areas that have been converted to *C. ciliaris* grasslands have soils that are depleted in total organic carbon and nitrogen (Ibarra-Flores et al. 1995, 1999). Additionally, in areas with high nutrient levels (places with increased nitrogen and phosphorous, such as in rodent middens or sites of past fires), *C. ciliaris* can easily outcompete and kill the native vegetation (Rutman 1998, 2001).

C. ciliaris is fire-adapted, and has the capability to drastically change plant community composition in communities that are not fire-adapted. For instance, following the invasion of *C. ciliaris* in Arizona, *C. ciliaris* first increases the available fuel source for wildfire. Following fire, it is then able to rapidly resprout. In contrast, the native long-lived plant species (*Carnegiea gigantea*, *Fouquieria splendens*, *Opuntia* spp.) are not adapted to these frequent fire cycles (Rutman 1998; Esque & Schwalbe 2000; Fabel 2000; Tix 2000).

C. ciliaris may also produce phytotoxic chemicals that inhibit the germination and growth of both native and planted legumes, which are often used in native restoration efforts (Fulbright & Fulbright 1990). On some soil types, *C. ciliaris* is able to accumulate levels of selenium that are dangerously high for livestock.

Lastly, lush *C. ciliaris* plants may cause oxalate poisoning if heavily grazed by sheep. This does not appear to be a problem for cattle and sheep in well-managed pastures. Horses can also be affected by *C. ciliaris*, since they are susceptible to a condition known as "bighead", or hyperparathyroidism, caused by an induced calcium deficiency that can occur when grazing upon thick swards of *C. ciliaris* (Tropical Savannas CRC; McCormick et al. 1999).

BIOLOGY AND ECOLOGY

Light, temperature and moisture

C. ciliaris can survive in a range of harsh environmental conditions, but has the highest yields in arid areas with relatively high rainfall during the growing season (180 to 250 mm) and in soils with high levels of nitrogen (Rao et al. 1996). It tolerates a variety of moisture regimes, from dry sandy areas to tropical forests. It can grow in shallow or heavy clay soils of low fertility, and may occur at elevations ranging from sea level to 2000 meters.

C. ciliaris can tolerate annual precipitation levels of 1.8 to 26.7 dm, annual temperatures of 12.5 to 35 degrees Celsius, soil pH levels of 5.5 to 8.2 (Rao et al. 1996; Duke 1983), and can withstand flooding of up to 20 days (Anderson 1970, *in* Duke 1983). It responds to high rainfall by developing brighter color and increased growth rate, giving highest yields when rain is plentiful. It is however, frost-sensitive and fares poorly on heavy clay or soils deficient in calcium (McCormick et al. 1999).

Reproduction
Plants of *C. ciliaris* are bisexual (having both male and female flowers), with bisexual spikelets and hermaphrodite florets. *C. ciliaris* can produce seed either sexually or by apomixis (asexual reproduction without fertilization or meiosis) (Van Devender et al. 1997). It can also reproduce vegetatively, via rhizome or stolon sprouts.

Seed Dispersal, dormancy and seedling establishment
Seeds of *C. ciliaris* can be spread widely by wind since they are light and surrounded by stiff, fluffy bristles (Duke 1983). The seeds are also dispersed by the barbed bristles on its seed coat (burs) that stick to animal fur and to human clothing (Tix 2000). Seed dormancy is increased if water stress occurs during the time of seed maturation. Alternately, seed dormancy decreases if temperature and soil fertility is increased (Sharif-Zadeh & Murdoch 2000). Seedlings may become established throughout the year, but seedling establishment is greatest at the onset of the wet season.

ECONOMIC USES
C. ciliaris is an important pasture grass in Texas and many parts of the tropics, mainly because of its low cost of establishment, high yields and high level of nutrients, tolerance to drought conditions and crop pests, and its ability to withstand heavy grazing and trampling by livestock (Duke 1983). Some strains are also good for forage during the wet season in the tropics. It is often touted for its ability to increase the flow of milk in cattle and give a sleek and glossy appearance to their coats (Duke 1983).

C. ciliaris has also been used as folk remedies for kidney pain, tumors, sores and wounds. It can be used as an anodyne (pain reliever), lactogogue (increase milk flow), diuretic, and as an emollient (Duke & Wain 1981, *in* Duke 1983).

MANAGEMENT
Potential for Restoration of Invaded Sites
As with all prolific invaders, the key to the successful control of *C. ciliaris* is to prevent new infestations or to begin control efforts while the infestation is still small and manageable. *C. ciliaris* has a high degree of reproductive vigor, a wide range of adaptability, and few pests and predators. It can reproduce both vegetatively and/or sexually, and is difficult to manage once firmly established. If controlled during the early stages of invasion, the potential for successful management is high. The potential for large-scale restoration of wildlands where *C. ciliaris* has become established is probably medium.

The best control of *C. ciliaris* will likely occur with the use of an integrated management approach. The use of manual and mechanical methods, followed by another control treatment (such as a herbicide spray to control for new seedlings) for several years, must be followed by active restoration efforts to obtain desired results.

Manual and Mechanical Control
Manual and/or mechanical methods can successfully control *C. ciliaris* in small, isolated patches. These methods, however, are very time and labor-intensive, as the long, dense

root mass makes manual removal difficult and all pieces of the root must carefully be removed or resprouting may occur (Rutman 2001.).

Repeated cultivation (tilling) can also eventually eliminate a *C. ciliaris* infestation, but the applicability of such measures is limited in natural areas.

Infrequent cutting or mowing of *C. ciliaris* is not effective since even low-mowed grasses can produce seed. Mowing may even increase rates of growth. Butt et al. (1992) found repeated cutting to a 10 cm stubble height suppressed plant growth, but seedlings must be removed and monitored for several years for control to be successful (Rutman 1998). Prior to herbicide applications, cutting or mowing can be used to decrease standing biomass. In this way, less herbicide can be used and the herbicide may be more effective.

Grazing

Grazing alone, similar to cutting or mowing, does not control *C. ciliaris*. However, continual heavy grazing led to more than 65% of the roots being found in the upper 15 cm of soil (Chaieb et al. 1996)--this might lead to more effective herbicide treatment(s) following grazing. Additionally, if continually grazed, *C. ciliaris* may become more susceptible to drought damage.

Flooding

Flooding to control *C. ciliaris* is unlikely to be effective. In Australia, five days of continuous flooding resulted in no loss of *C. ciliaris*, while twenty days of flooding resulted in a loss of 20-85% (Morisawa 2000). The plants must be completely submerged for flooding to be effective, and taller varieties appear to be more flood-tolerant. Cutting or grazing prior to flooding may increase control.

Prescribed Burning

Burning is not an effective control method for this species. *C. ciliaris* populations are essentially unharmed by burning, and may respond with an increase in cover and improved herbage production. Burning is particularly ineffective when soil water availability is high, as is often the case during winter burns (Mayeux & Hamilton 1983).

Martin-Rivera et al. (1999), however, found that when burned at the peak of live biomass production, *C. ciliaris* production was reduced by almost 50%, even 4 years post-treatment.

Herbicides

Herbicides can control *C. ciliaris*, particularly when combined with a manual or mechanical method to first reduce the standing biomass. Tix (2000) reports that the most effective chemical control is to use a combination of glyphosate and ammonium sulfate. This application may need to be repeated several times to kill all the underground stems of *C. ciliaris*, and all applications should be completed before restoration plantings occur. Following restoration plantings, additional grass-specific herbicides (such as fluazifop-p-butyl) may be required to control *C. ciliaris* seedlings.

Bovey et al. (1984) and Rasmussen et al. (1985) both report that tebuthiuron and hexazinone were effective at significantly reducing growth of *C. ciliaris* in older individuals (older than 45 days), and that seedlings could be controlled by dicamba, 2,4-D, 3,6-dichloropicolinic acid, triclopyr, tebuthiuron, or hexazinone. Picloram was not effective at killing *C. ciliaris* seedlings. See the "Examples of Management Programs" section below for more details on herbicide use against *C. ciliaris*.

Restoration
C. ciliaris competes poorly with dense vegetation, and rarely becomes well-established in well-managed pastures or in areas with high shade (low-light levels) (Williams, pers. comm.). Disturbances that bury burs and remove existing vegetation can stimulate *C. ciliaris* seed germination and enhance seedling establishment, so soil disturbance should be minimized in restoration work.

Lisa Williams (TNC-Texas) has experience planting native trees and shrubs such as mesquite (*Prosopis* spp.) and *Acacia* spp. in restoration plantings. She recommends that *C. ciliaris* be removed (to lower the potential fire hazard and reduce competition) before native shrubs are planted.

Biological Control
There are currently no available biocontrol agents for *C. ciliaris*. Leaf blight (also called rice blast or buffelgrass blight) caused by the fungus *Pyricularia grisea*, causes lesions in leaves and can damage plants up to 90% (Perrott & Chakraborty 1999). Some buffelgrass cultivars are resistant to this fungus (Tix 2000). Since there is concern that this fungus may affect agricultural crops and because *C. ciliaris* is considered a valuable pasture grass in Texas, the fungus is not being developed as a potential biocontrol agent.

Spittlebugs (*Aeneolamia albofasciata* Lall.) have also been reported by Martin-Rivera et al. (1999) to kill more than 50% of some *C. ciliaris* populations in Mexico. The goal of this study was to determine the effects of fire on spittlebugs and to protect *C. ciliaris* for pasture. No further work has been published regarding other potential biocontrol agents for *C. ciliaris*.

EXAMPLES OF MANAGEMENT PROGRAMS FOR *CENCHRUS CILIARIS*
At the Chihuahua Woods and Mesquite Brushland Preserves in south Texas, *C. ciliaris* unnaturally increases the fuel load for fires, and excludes the establishment of native shrubs. TNC's Lisa Williams has been treating *C. ciliaris* with herbicides, followed by an active restoration program. She found that *C. ciliaris* competes poorly with the native shrubs once the shrubs are well-established and have formed a closed canopy. Therefore, when she works in large *C. ciliaris*-infested areas, she first prepares the area by disking/plowing then irrigating the area to stimulate *C. ciliaris* growth. She then sprays glyphosate (tradename RoundUp Ultra) 2 to 4 weeks after irrigation at a rate of 1 qt/acre mixed with 8 to 10 gallons of water/acre (2 to 3% solution) sprayed by a boom. Native shrub seedlings are planted during the fall-winter season and irrigated if necessary. Post-planting, she continues to irrigate if necessary, and monitors the *C. ciliaris* population. If *C. ciliaris* growth is observed, a follow-up spray of fluazifop-p-butyl (tradename

Fusilade), a grass-specific herbicide, is used at 24 oz/acre, mixed with a non-ionic surfactant at 8 to 10 gallons per acre (2 to 3% solution).

In Arizona's Organ Pipe Cactus National Monument, plant ecologist Sue Rutman developed an invasive plant removal program involving the manual removal of *C. ciliaris*. She found that pulling and digging (with a shovel or trowel, or using a cultivator/tiller) are effective in controlling *C. ciliaris*, although labor-intensive. She used help from seasonal employees, volunteers, and college students to remove *C. ciliaris* from over 25 mi^2 (64.7 km^2), with over 150 tons of material removed since 1994! Rutman found that a second-year follow-up is necessary to pull-out new seedlings. After this work, in most places *C. ciliaris* has not returned. She recommends that when pulling and digging, it is important to carefully remove the entire plant, as root and stem fragments left behind can resprout.

In her first year of *C. ciliaris* removal, 15-20 volunteers were able to remove approximately half a ton of *C. ciliaris* from around the Visitor's Center by digging and pulling. The pulled material was bagged and moved off-site. The following year, the only follow-up required took one volunteer one single day to remove the seedlings. In 1995-1996, 16 college students removed *C. ciliaris* from a 1 mi^2 (2.6 km^2) area in 3 days. Rutman has now expanded her *C. ciliaris* removal efforts to include the highway edge and other disturbed areas.

Sue Rutman adds that pulling is not effective in places with recurrent fires. She also found that along the southern border of the monument, *C. ciliaris* continues to reinvade from Mexico, where it is often planted and used as a pasture grass. Sue has an ongoing monitoring program with 17 plots on various soil-types and densities of *C. ciliaris*, in order to quantify the impacts of her removal efforts.

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MONITORING

To determine the effectiveness of the control treatments, monitoring should occur both before and after control efforts. Monitoring should be continued for several years following the treatments to determine whether the impacts are lasting. Data should be collected to assess changes in abundance (percent cover or density) of *C. ciliaris* and of desirable native species over time. Changes in community attributes may also be important to monitor.

Following initial control treatments, further control efforts and monitoring must be performed at least once-a-year for a minimum of 3 to 5 years, due to the ability of many invasive species to resprout, the viability of seeds in the seedbank, or the likelihood of re-invasion from nearby sources of propagules.

Monitoring the status of other conservation targets, such as the growth and survival of restoration plantings, the regeneration of native plant species, invertebrates, and mammals, may be important indicators of ecosystem health. In general, the objectives of monitoring should track those of management.

While usually considered a research technique, measuring change in both "control" (unmanaged) as well as in the treated areas can be an effective way of assuring that any changes detected in treated areas are actually the result of management actions and not due to other factors. In communities that are in early successional stages or which have been recently disturbed, declines in abundance of invasive species may occur over time without management.

Research Needs

Although much is known regarding *C. ciliaris* biology and growth, little is known regarding how to control it. The following research topics need attention:
1) What are the mechanisms of *C. ciliaris* invasion and spread in different community types?
2) How does competition and shading affect the growth, survival, and reproduction of *C. ciliaris*?
3) Which, if any, insects or pathogens control *C. ciliaris* abundance in its native range?
4) Can prescribed burning be used to control *C. ciliaris* and encourage regeneration of native species community types that are fire-adapted?

REFERENCES

Bovey, R.W., Hein, H., Jr. and R.E. Meyer. 1984. Effect of herbicides on the production of common buffelgrass (*Cenchrus ciliaris*). Weed Science 32: 8-12.

Butt, N.M., Donart, G.B., Southward, M.G., Pieper, R.D. and N. Mohammad. 1992. Effects of defoliation on plant-growth of buffel grass. Annals of Arid Zone 31: 19-24.

Chaieb, M., Henchi, B. and M. Boukhris. 1996. Impact of clipping on root systems of 3 grasses species in Tunisia. Journal of Range Management 49: 336-339.

Daehler, C.C. and D.A. Carino. 1998. Recent replacement of native pili grass (*Heteropogon contortus*) by invasive African grasses in the Hawaiian Islands. Pacific Science 53: 220-227.

Duke, J.A. 1983. *Cenchrus ciliaris* L. Handbook of Energy Crops, unpublished. (http://www.hort/purdue.edu/newcrop/duke_energy/Cenchrus_ciliaris.html).

Esque, T. and C. Schwalbe. 2000. Non-native grasses & fires create double jeopardy. People, Land & Water, July/August. Department of the Interior. (http://www.usgs.gov/invasive_species/plw/grassfire.html).

Fabel, S. 2000. Assessing the impacts and control of invasive species in grasslands. Restoration and Reclamation Review – student online journal Vol. 6.1. (http://www.hort.agri.umn.edu/h5015/00papers/overfabel.htm).

Fairfax, R.J. and R.J. Fensham. 2000. The effect of exotic pasture development on floristic diversity in central Queensland, Australia. Biological Conservation 94: 11-21.

Fulbright, N. and T.E. Fulbright. 1990. Germination of 2 legumes in leachate from introduced grasses. Journal of Range Management 43: 466-467.

Hickman, J.C. (ed.) 1993. The Jepson Manual: Plants of California. University of California Press, Berkeley.

Ibarra-Flores, F., Cox, J.R., Martin-Rivera, M., Crowl, T.A., Norton, B.E., Banner, R.E. and R.W. Miller. 1999. Soil physicochemical changes following buffelgrass establishment in Mexico. Arid Soil Research and Rehabilitation 13: 39-52.

Ibarra-Flores, F.A., Cox, J.R., Martin-Rivera, M.H., Crowl, T.A. and C.A. Call. 1995. Predicting buffelgrass survival across a geographical and environmental gradient. Journal of Range Management 48: 53-59.

Martin-Rivera, M., Cox, J.R., Ibarra-Flores, F., Alston, D.G., Banner, R.E. and J.C. Malecheck. 1999. Spittlebug and buffelgrass responses to summer fires in Mexico. Journal of Range Management 52: 621-625.

Mayeux, H.S., Jr. and W.T. Hamilton. 1983. Response of common goldenweed (*Isocoma coronopifolia*) and buffelgrass (*Cenchrus ciliaris*) to fire and soil – applied herbicides. Weed Science 31: 355-360.

McCormick, L., Bourke, C. and B. McGufficke. 1999. Buffel grass. NSW Agriculture, Agnote DPI/289, November. (http://www.agric.nsw.gov.au/reader/1541).

Morisawa, T.M. 2000. Weed Alert: *Cenchrus ciliaris* L. The Nature Conservancy's Wildland Invasive Species Program. (http://tncweeds.ucdavis.edu/alert/alrtcenc.html).

Perrott, R.F. and S. Chakraborty. 1999. *Pyricularia grisea* causes blight of buffel grass (*Cenchrus ciliaris*) in Queensland, Australia. Tropical Grasslands 33: 201-206.

Rao, A.S., Singh, K.C. and J.R. Wight. 1996. Productivity of *Cenchrus ciliaris* in relation to rainfall and fertilization. Journal of Range Management 49: 143-146.

Rasmussen, G.A., Smith, R.P. and C.J. Scifres. 1985. Seedling growth responses of buffelgrass (*Pennisetum ciliare*) to tebuthiuron and honey mesquite (*Prosopis glandulosa*). Weed Science 34: 88-93.

Rutman, S. 1998. At what cost? Deciding whether to control exotic plants. Natural Resource Year in Review-1998, National Park Service, US Dept. of the Interior, Publ. D-1346. (http://www.aqd.nps.gov/pubs/yir/yir98/chapter04/chapter04pg4.html).

Rutman, Sue. 2001, August 22. Personal communication.

Sharif-Zadeh, F. and A.J. Murdoch. 2000. The effects of different maturation conditions on seed dormancy and germination of *Cenchrus ciliaris*. Seed Science Research 10: 447-457.

Tix, D. 2000. *Cenchrus ciliaris* invasion and control in southwestern U.S. grasslands and shrublands. Restoration and Reclamation Review – student online journal Vol. 6.1. (http://www.hort.agri.umn.edu/h5015/00papers/tix.htm).

Tropical Savannas CRC. No date. Buffel grass (Cenchrus ciliaris). Tropical Savannas Cooperative Research Centre for Tropical Savannas Management (http://savanna.ntu.edu.au/information/r0/t2/r0_t2_4.html). Accessed February 2001.

TROPICOS. 2002. Missouri Botanical Garden's VAST (VAScular Tropicos) nomenclatural database. (http://mobot.mobot.org/W3T/Search/vast.html). Accessed February 2001.

Tucson Weekly. 1996. The grass that ate Sonora. Tucson Weekly Paper (http://www.tucsonweekly.com/tw/04-18-96/cover.htm). Accessed July 24, 2000.

USDA, NRCS 1999. The PLANTS database (http://plants.usda.gov/plants). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Van Devender, T.R., Felger, R.S. and A.M. Burquez. 1997. Exotic Plants in the Sonoran Desert Region, Arizona and Sonora. California Exotic Pest Plant Council 1997 Symposium Proceedings.

Williams, Lisa. 2001, August 21. Personal communication.

Winkworth, R. 2000. Buffel grass: the camel legacy to the rangelands. Threatened Species Network (http://www.nccnsw.org.au/member/tsn/projects/NT/buffel.html).

Ziegler, A.D., Warren, S.D., Perry, J.L. and T.W. Giambelluca. 2000. Reassessment of revegetation strategies for Kaho'olawe Island, Hawai'i. Journal of Range Management 53: 106-113.

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