Cogongrass (*Imperata cylindrica)* : Biology, Distribution and Impacts in the Southeastern U.S.

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Biology

Cogongrass is a warm-season perennial grass species found throughout the tropical and subtropical regions of the world (Holm et al., 1977). It produces extensive rhizomes which allow it to spread and dominate a wide range of disturbed sites (Holm et al., 1977; Brook, 1989). In addition to rhizome production, cogongrass invades and persists through: 1) adaptation to poor soils and drought, 2) prolific wind disseminated seed, and 3) the ability to withstand and thrive in a fire-based ecosystem (Hubbard et al., 1944; Holm et al., 1977; Brook, 1989; Dozier et al., 1998).

Cogongrass leaves grow directly from creeping underground rhizomes, giving the plant a stem-less appearance (Holm et al., 1977; Bryson and Carter, 1993). The leaves possess smooth or sometimes hairy sheaths, with a membranous ligule. The leaves are slender, flat and possess serrated margins and an off-center prominent white mid-rib (Hall, 1978; Holm et al., 1977; Terry et al., 1997). The serrated margins of the leaves accumulate silicates, which deter grazing (Dozier et al., 1998). The leaves can reach 4 to 5 feet in height under conditions of good moisture and fertility (Holm et al., 1977).

Cogongrass rhizomes can comprise over 60% of the total plant biomass and this low shoot to root/rhizome ratio contributes to its rapid regrowth after burning or cutting (Sajise, 1976). Cogongrass rhizomes are white and tough with shortened internodes. Rhizomes are covered with brownish colored cataphylls (scale leaves), which form a protective sheath around the rhizome (Ayeni, 1985; English, 1998). The formation of rhizomes occurs within 3 to 6 weeks of initial growth, depending on whether the plant is regenerating from a seed or rhizome fragment. Soerjani (1970) estimated cogongrass rhizome production and calculated that over 2 million shoots could be present per acre. More recent research by Terry et al. (1997) suggests fresh weights of rhizomes as high as 40 tons per hectare; this providing a tremendous amount of biomass for regeneration after foliar loss.

Gaffney (1996) observed apical dominance in cogongrass rhizomes, where the shoot tip will sprout, but other shoots along the rhizome remain unsprouted because the shoot tips produce hormones (auxins) that keep the subtending shoots from sprouting. English (1998) induced axillary buds along cogongrass rhizomes with exogenous applications of synthetic auxins, further supporting the role of auxin-regulated apical dominance.

Cogongrass is also a prolific seed producer, with over 3000 seeds per plant. Cogongrass produces a shortly-branched, compacted and dense seedhead. The seedhead is cylindrical and spike-like averaging 10 to 20 cm long, with fluffy, white plumes. Flowering time is highly variable depending on region and environment. In the U.S., flowering generally occurs in the late winter/early spring (Shilling et al., 1997; Willard, 1988); but disturbances such as burning, mowing, grazing, frost or the addition of nitrogen can also stimulate flowering (Holm et al., 1977; Soerjani, 1970; Sajise, 1972). The plumed seeds can travel long distances but generally movement is 15 m (Holm et al., 1977) although McDonald et al. (1996) reported greater movement from larger clumps of aggregate seed. No dormancy mechanisms have been observed in cogongrass seed, and research has shown a rapid decline in seed viability over time, with a complete loss of viability after one year.

The spread of cogongrass through seeds has been debated by several researchers in the southeastern U.S. Viable seed has been reported in Alabama, Mississippi and parts of Florida; although Willard et al. in 1990 reported the primary spread in Florida was from rhizome pieces, either through contaminated fill dirt used in construction or intentional plantings for forage. Previous research has shown that cogongrass is not self-compatible and must out-cross to produce viable seed. Therefore, populations originating from rhizomes spread clonally until they grow within close proximity to genetically different populations. This lack of seed viability within populations has occurred in the regions along the Gulf Coast, but not as frequently in peninsular Florida. Burnell et al. (2003) showed that cogongrass first-year seed germination from populations in southern Mississippi, U.S. was over 95%.

Seedlings tend to emerge in groups and seeds require light for germination. Burnell et al. (2004) found germination in seed collected from Mississippi populations occurred from 11 to 43 C with an optimum temperature of 30 C. Dozier et al. (1998) indicated that seedling establishment is favored in areas of limited competition, such as disturbed sites, and further suggested that cogongrass seedlings would be unlikely to establish in areas with >75% sod cover. However, additional research has shown that cogongrass seed is able to invade and grow in established native plant communities but that tillage and burning does favor cogongrass establishment. Therefore, activities such as natural disasters (e.g., hurricanes) and human disturbance (e.g., logging, road construction) will favor cogongrass spread and establishment from seeds.

Cogongrass is differentiated from the other species of *Imperata* by the presence of two flower anthers, while other species, including Brazilian satintail (*Imperata brasiliensis*), have just one anther (Gabel, 1982; Hitchcock, 1951). However, Hall (1978) did not differentiate between *I. cylindrica* and *I. brasiliensis*, reporting single populations with both one and two anthers. The variability observed and presence of differing anther number within a single population suggests potential hybridization between the species (Hall 1998). Molecular characterization has been performed, but on a limited scale. Therefore, no clear genetic classification for cogongrass distribution throughout the southern U.S. can be made.

Another important genetic aspect is the sale of cogongrass var. Rubra, or var. koenigii. This variant is widely promoted as an ornamental grass under the names Rubra, Red Baron and Japanese Blood Grass. These varieties have been reported as non-aggressive, but research by Greenlee (1992) and Bryson (personal communication) suggest that under certain environmental conditions these plants revert to the green, invasive form. The greatest concern, however, is the potential for hybridization between ornamental ecotypes and weedy biotypes found in the southern U.S. The ornamental varieties have been shown to survive as far north as Ann Arbor, Michigan and this could dramatically extend the host range of this invasive species. Studies by Gabel (1982) and observations by Hall (1998) which suggest a high degree of variability and potential hybridization within the species further elevate the importance of this issue.

Distribution, Habitats and Impact

Cogongrass is found throughout the world, thriving in areas of natural and particularly human disturbance, and is reported established on over 500 million hectares world-wide (Holm et al., 1977;

Dozier et al., 1998). Cogongrass is found along the Mediterranean Sea in Europe and northern Africa to the Middle East. It is present in Iran and Afghanistan and throughout India. There are *Imperata* grasslands in northern India that stretch into Nepal. Cogongrass is most wide spread in Asia where over 70 million acres are reported as infested (Garrity et al., 1997). It occurs throughout Southeast Asia, Indonesia and the Pacific Islands and estimates of infestation in Indonesia range from 8.5 million hectares (Garrity et al., 1995) to over 64 million hectares (Suryanta and McIntosh, 1980). These areas possess large, solid stands, often called mega-grasslands, Imperata savannas or sheet Imperata. Many of these areas are reported to be greater than 22,000 continuous acres. Areas like this also occur in Africa, where cogongrass is prevalent in the West African countries, and in the eastern countries of Egypt, Sudan, Ethiopia (Holm et al., 1977). Cogongrass is also found in western South America while the closely related Brazilian satintail (*Imperata brasiliensis* Trin.) is found in central South America. Brazilian satintail is also found throughout the Caribbean and south Florida and is often confused with cogongrass.

Cogongrass was inadvertently introduced in the U.S. (Mobile, Alabama) in 1912 as a packing material in Satsuma oranges from Japan (Tabor, 1949; 1952; Dickens, 1974). Cogongrass from the Philippines was purposefully introduced to Mississippi as for forage in 1921, with subsequent forage trials carried out in Florida, Alabama and Texas, although the Texas planting died out in the first year (Hubbard et al., 1944; Dickens and Moore, 1974). Cattlemen in Florida interested in cogongrass as a forage acquired the grass in 1939 and by 1949 over 1000 acres had been established in central and northwest Florida (Tabor, 1952; Hall, 1983; Coile and Shilling, 1993). Trials concluded that cogongrass was not an acceptable forage due to poor nitrogen content, poor digestibility and accumulation of silica in the mature leaf tissue.

Cogongrass tolerates a wide range of soil conditions, but appears to grow best in soils with acidic pH, low fertility and low organic matter. Habitats infested with cogongrass are quite diverse, ranging from the course sands of shorelines, the fine sands or sandy loam soils of swamps and river margins, to the >80% clay soils of reclaimed phosphate settling ponds. Saxena and Ramakrishnan (1983) report cogongrass to be extremely efficient in nutrient uptake. Brook (1989) also report associations with mycorrhiza, which may help explain its competitiveness on unfertile soils. Brewer and Cralle (2003) also suggested that cogongrass is a better competitor for phosphorus than native pine-savanna species in the southern U.S., citing that legume species are frequently displaced through this competitive mechanism.

Cogongrass is a C^4 grass species (Paul and Elmore, 1984), and while it is best adapted to full sun, cogongrass can also thrive under moderate shade (Hubbard et al., 1944). Studies by Gaffney (1996) and Ramsey et al. (2003) showed that cogongrass has a light compensation point of 32 to 35 $mol \cdot m^{-2} \cdot s^{-1}$ (approximately 2% full sunlight) indicating the ability to survive as an understory species. This would explain its ability to both rapidly invade deforested areas and persist in plantation crops.

Cogongrass habitats in the southern U.S. are often fire-based ecosystems where excess leaf biomass provides fuel for fires. In its native range cogongrass is a pyrogenic species, relying on fire for survivability and spread (Holm et al., 1977). Cogongrass fires are very intense and hot, with little above ground vegetation able to survive, limiting natural secondary succession (Eussen and Wirjahardja, 1973; Seavoy, 1975; Eussen, 1980; Lippencott 2000). Fires from cogongrass are typically 15 to 20% hotter and more intense than natural fires in pine-based ecosystems in the Southern U.S.

Another mechanism by which cogongrass maintains dominance is through allelopathy. Cogongrass has been reported to suppress the growth of crops and studies have demonstrated the potential allelopathy of cogongrass (Eussen, 1979; Casini et al., 1998; Koger and Bryson, 2003). Interference can also be in the form of physical injury; the hard, sharp points of cogongrass rhizomes penetrate the roots, bulbs and tubers of other plants, leading to infection (Boonitee and Ritdhit, 1984; Eussen and Soerjani, 1975; Terry et al., 1997).

Cogongrass invades and persists in moist tropical areas and is considered a primary weedy species in tea (*Camillia sinesis* L.), rubber (*Hevea spp*.), pineapple (*Ananas comosus* Merr.), coconut (*Cocos nucifera* L.), oil palm (*Elaeis spp*.) and other perennial plantation crops in Asia. In Africa it causes the greatest damage in agronomic production (Ivens, 1980) and is considered to be the most serious agricultural weed in Benin, Nigeria and southern Guinea, infesting over 20 crop species (Chikoye et al., 2000). Early reports by the International Institute of Tropical Agriculture (1977) showed 54% of the total crop production budget was cogongrass weeding. Chickoye et al. (2000) stated farm size in west Africa was limited by the labor intensiveness of cogongrass and Terry et al. (1997) reports that vast areas of arable land in west Africa has been abandoned due to the lack of effective cogongrass control. Cogongrass is occasionally used as a forage crop in underdeveloped countries, but can only be grazed when the plants are very young. Intensive management is needed to maintain the foliage in the juvenile vegetative stage. Cogongrass has also been shown to harbor locusts, and there is evidence that swards of this grass are a major breeding ground for these pests (Brook, 1989).

In the U.S., cogongrass poses the most serious threat to native ecosystems. There are over 1,000,000 acres with some level of infestation in Florida alone. Several thousand acres are also infested in the states of Alabama and Mississippi (Bryson and Carter, 1993; Matlack, 2002). This species can also be found as far west as Louisiana and as far north as the coastal regions of Virginia. Cogongrass generally invades areas after a disturbance, such as natural fire or flood or mining/land reclamation, forest operations, highway construction and maintenance.

Once established, cogongrass out-competes native vegetation, forming large solid stands with extremely low species diversity and richness. Lippencott (2000) found that cogongrass altered normal fire cycles of sandhill communities, a natural ecosystem of the southeastern U.S. The fires within swards of cogongrass had higher maximum temperatures at greater heights and increased fire mortality of long-leaf pine, normally a fire tolerant species. The author further hypothesized that the changes in fire behavior due to cogongrass invasion could shift sandhill ecosystems from a species-diverse pine savanna to a cogongrass grassland. Cogongrass is also becoming a major constraint in the forestry industry, invading and persisting in newly established pine plantations (Jose et al., 2002; Miller, 2000). In addition, cogongrass poses a major fire hazard along state highways and federal interstate highways due to excessive smoke and thus limited visibility. It also may promote wildfires in residential communities, especially those near wooded areas.

Biocontrol

Literature records suggest a considerable number of potential natural enemies of cogongrass, including over 80 pathogens, 90 insects, and several nematodes and mites associated with cogongrass world-wide (Van Loan et al., 2002). Several researchers have studied the gall midge (*Orsioliella javanica* Kieffer), which is reportedly specific to cogongrass (Soerjani, 1970; Mangoendiharjo, 1980; 1986). This insect destroys shoot meristems, but only after the foliage is cut and the rhizome system debilitated. This requirement, along with natural enemies of the midge, significantly reduces the potential of this control option. Recent research by Yandoc et al. (1999) has shown cogongrass in the U.S. is susceptible to infection with two fungal pathogens, *Bipolaris sacchari* (E. Butler) Shoem. and *Drechslera gigantea* (Heald & F.A. Wolf). Subsequent studies utilizing these pathogens as bioherbicides report good foliage control, but limited activity on rhizomes (MacDonald et al., 2001; Yandoc, 2001). Although several organisms have been found and tested, several researchers state that there is little hope of finding a successful biological control for cogongrass (Ivens, 1980; Brook, 1989). They claim the distribution of this species is so world-wide that the chances of finding a novel biological control agent in an area where cogongrass does not exist are slight.

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