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Canebrake fauna revisited: additional records of species diversity in a critically endangered ecosystem

Steven G. Platt[1], Thomas R. Rainwater[2]*, Ruth M. Elsey[3], and Christopher G. Brantley[4]

[1]Wildlife Conservation Society, Myanmar Program, Aye Yeik Mon 1st Street, Yadanamon Hosuing Ave., Yangon, Myanmar

[2]U.S. Fish and Wildlife Service, Ecological Services Field Office, 176 Croghan Road, Suite 200, Charleston, South Carolina 29407, USA

[3]Louisiana Department of Wildlife and Fisheries, Rockefeller Wildlife Refuge, 5476 Grand Chenier, Louisiana 70643, USA

[4]United States Army Corps of Engineers
Bonnet Carré Spillway, P.O. Box 216, Norco, Louisiana 70079, USA

ABSTRACT

Monotypic stands of cane (*Arundinaria* Michx.) known as canebrakes were a dominant landscape feature in the southeastern United States at the time of European settlement. Canebrakes disappeared rapidly as a consequence of altered fire regimes, agricultural clearance, and overgrazing by livestock, and are now regarded as critically endangered ecosystems. Canebrake fauna remains incompletely known and recent biodiversity studies of this ecosystem are few. In an earlier paper we used historic and contemporary sources to reconstruct the faunal diversity of canebrakes. However, because information is fragmentary and often found in obscure historical sources, inadvertent omissions were unavoidable in our earlier report. We here revisit this topic, provide additional records of canebrake fauna, and discuss the importance of canebrakes to wildlife. We documented the occurrence of an additional 28 species of vertebrates in canebrake habitats, including one reptile, 20 birds, and seven mammals. Canebrake herpetofauna (amphibians and reptiles) remains poorly documented. Birds use canebrakes as nesting, foraging, and winter roosting habitat, probably consume cane seeds when available, and incorporate cane foliage in nests. Much of what is known about the mammalian fauna of canebrakes is heavily biased towards megafauna, although a small number of studies suggest rodent and insectivore diversity is comparable to other early and mid-successional habitats in the southeast. Canebrakes provide mammals with escape cover, maternal den sites, foraging habitat, and food in the form of foliage and seeds. We reiterate our earlier recommendation for region-wide faunal inventories of existing canebrakes to address deficiencies in our knowledge as highlighted in this paper. Baseline data generated by these studies, combined with information gleaned from the literature, will provide a means to rigorously evaluate future conservation and restoration efforts.

INTRODUCTION

Cane (*Arundinaria* Michx.) is a monopodial bamboo with erect culms bearing evergreen foliage, arising from rhizomes and growing to a height of 10 m (McClure 1973; Platt *et al.* 2006). Cane is the only bamboo native to the United States, occurring throughout the southeastern states (except southern Florida), as far north as southern Illinois, Indiana, Ohio, and Maryland, and westwards into southern Missouri, and eastern Oklahoma and Texas (range map in Farrelly 1984; Platt *et al.* 1997). Mature culms form dense (to 160,314 culms/ha; Marsh 1977), monotypic stands known as canebrakes (occasionally spelled "canebreak" in older accounts; also referred to

*To whom correspondence should be addressed:
Thomas R. Rainwater
U.S. Fish and Wildlife Service, Ecological Services
Field Office, 176 Croghan Road,
Suite 200, Charleston, South Carolina 29407, USA
Telephone: 843-727-4707
E-mail: trrainwater@gmail.com

as cane "thickets", "jungles", or "meadows"; Platt and Brantley 1997; Platt *et al.* 2002). Some historic accounts describe canebrakes as treeless areas, whereas others suggest an open woodland or savanna with cane growing beneath widely scattered trees (Platt and Brantley 1997). Vines were often intertwined among the culms creating a formidable vegetative barrier difficult for humans to penetrate (Platt and Brantley 1997).

Canebrakes were a dominant landscape feature in the southeastern United States at the time of European settlement, and period accounts indicate that hundreds of thousands of hectares were characterized by this ecosystem (Platt and Brantley 1997; Stewart 2007). Cane was an important understory component of various evergreen and deciduous forest types (Platt and Brantley 1997), but the largest canebrakes occurred in river bottoms, generally on the first ridge or natural levee (Delcourt 1976; Hudson 1976). Canebrakes disappeared rapidly before the tide of Euro-American settlement due to a combination of over-grazing by free-ranging livestock, altered fire regimes, and agricultural land-clearing (Marsh 1977; Platt and Brantley 1997; Stewart 2007). Although cane persists as an understory plant throughout most of its historic distribution, large canebrakes are essentially non-existent today (Meanley 1972; Remsen 1986; Pashley and Barrow 1993). Canebrakes are now regarded as critically endangered ecosystems, having been reduced to <2% of their former extent (Noss *et al.* 1995).

Bamboo communities typically support diverse and often specialized assemblages of invertebrates, amphibians, reptiles, birds, and mammals (Platt *et al.* 2001 and references therein). However, the fauna of canebrakes remains incompletely known and recent bio-diversity studies of this ecosystem are few, presumably owing to the paucity of suitable study sites (Brantley and Platt 2001; Platt *et al.* 2001). An improved understanding of the faunal diversity in canebrakes is therefore important for several reasons. First, species inventories of particular habitats are essential data sets for making informed decisions in conservation and resource management (Oliver and Beattie 1993). Second, despite daunting technical challenges, preliminary efforts suggest landscape-scale restoration of canebrakes is ecologically feasible (Brantley and Platt 2001) and considerable interest exists among federal, state, and private land steward-ship agencies in achieving this objective (Zaczek *et al.* 2004; Baldwin *et al.* 2009; Franklin 2009; Zaczek *et al.* 2009). Because the success or failure of restoration efforts is often determined by comparing recent data on species composition with historical data sets (Mazzotti *et al.* 2009; Magurran *et al.* 2010), a thorough understanding of canebrake fauna is necessary before these efforts can be evaluated with scientific rigor. As Aldo Leopold stated, "if we are serious about restoring…ecological integrity, then we must know what the land was like to begin with" (Covington and Moore 1994). Finally, canebrakes were an important resource for Native Americans (Platt *et al.* 2009), and the wildlife found within this ecosystem is of interest to anthropologists, historians, and others attempting to understand indigenous folkways (e.g., Hudson 1976; Etheridge 2003).

In an earlier paper we used a variety of historic and contemporary sources to reconstruct the faunal diversity of canebrakes, and documented the occurrence of 50 species of invertebrates and vertebrates (Platt *et al.* 2001). Because information on canebrake fauna is fragmentary, widely scattered, and often found in obscure historical sources rarely perused by biologists (Platt and Brantley 1997; Platt *et al.* 2001), inadvertent omissions were unavoidable in our earlier report. We here revisit this topic, provide additional records of canebrake fauna that have come to light in the decade since our original paper was published, and discuss the importance of cane and canebrakes to wildlife.

For the purposes of the current paper, we narrowly restrict our definition of "fauna" to vertebrates. Insect diversity in canebrakes is described in greater detail elsewhere (Platt *et al.* 2001; Maupin 2009), and we are unaware of any studies documenting the diversity of other invertebrate groups in canebrake ecosystems. Additionally, although Triplett *et al.* (2006) accorded specific status to three cane taxa [*A. gigantea* (Walt.) Muhl., *A. tecta* (Walt.) Muhl., and *A. appalachiana* Triplett, Weakley and L.G. Clark], we consider cane only at the generic level because in most accounts it is impossible to determine which taxon is being referenced (Platt *et al.* 2009). Scientific names (Table 1) follow Conant and Collins (1991), Sibley (2000), and Kays and Wilson (2009) for reptiles, birds, and mammals, respectively.

TABLE 1. Comprehensive checklist of wildlife associated with canebrakes in the southeastern United States. Asterisk denotes species previously reported by Platt et al. (2001).

Species	Use of cane and canebrake habitat
Reptiles	
American alligator (*Alligator mississippiensis* Daudin, 1802)	Foraging habitat; possibly nested in riverside canebrakes
Cottonmouth (*Agkistrodon piscivorous* Lacépede, 1789)*	Cover and foraging
Copperhead (*Agkistrodon contortrix* Linnaeus, 1766)*	Cover and foraging
Timber rattlesnake (*Crotalus horridus* Linnaeus, 1758)*	Cover and foraging
Pygmy rattlesnake (*Sistrurus miliarius* Linnaeus, 1766)*	Cover and foraging
Birds	
Wild turkey (*Meleagris gallopavo* Linnaeus, 1758)*	Nesting and roosting habitat; consume cane seeds
Northern bobwhite quail (*Colinus virginianus* Linnaeus, 1758)	Foraging, roosting, and escape cover; probably consumed cane seeds when available
Carolina parakeet (*Conuropsis carolinensis* Linnaeus 1758)*	Probably consumed cane seeds when available
Passenger pigeon (*Ectopistes migratorius* Linnaeus, 1766)*	Cane seeds important food; roosting habits favored vegetative expansion of canebrakes by deadening overstory
Wilson's snipe (*Gallinago delicata* Ord, 1825)	Cover for over-wintering birds
American woodcock (*Scolopax minor* Gmelin, 1789)	Foraging habitat and cover for over-wintering birds
Black vulture (*Coragyps atratus* Bechstein, 1793)*	Nesting habitat; communal nesting noted on occasion
American crow (*Corvus branchyrhynchos* Brehm, 1822)	Roosting habitat
Tree swallow (*Tachycineta bicolor* Viellot, 1808)	Roosting habitat for migrating flocks
Carolina wren (*Thryothorus ludovicianus* Latham, 1790)*	Foraging; nesting suspected, but not confirmed
Wood thrush (*Hylocichla mustelina* Gmelin, 1789)	Nesting habitat
Bachman's warbler (*Vermivora bachmanii* Audubon, 1833)*	Nesting and foraging habitat; probably extinct
Swainson's warbler (*Limnothlypis swainsonii* Audubon, 1834)*	Nesting habitat
Yellow-throated warbler (*Setophaga dominica* Linnaeus, 1766)	Foraging habitat; nesting suspected, but not confirmed
Hooded warbler (*Setophaga citrina* Boddaert, 1783)	Preferred nesting habitat in parts of southeastern United States
Kentucky warbler (*Geothiypis formosa* Wilson, 1811)*	Foraging habitat; foliage used in nest construction
Prothonotary warbler (*Protonotaria citrea* Boddaert, 1783)*	Foraging habitat
Orange-crowned warbler (Oreothlypis celata Say, 1823)	Wintering foraging habitat
Worm-eating warbler (*Helmitheros vermivorus* Gmelin, 1789)*	Observed in canebrakes; nesting likely at base of culms
Yellow-rumped warbler (*Setophaga coronata* Linnaeus, 1766)	Winter foraging and roosting habitat
Ovenbird (*Seiurus aurocapillus* Linnaeus, 1766)*	Observed in canebrakes; nesting likely among leaf litter
White-eyed vireo (*Vireo griseus* Boddaert, 1783)*	Nesting habitat; cane foliage used in nest construction
Solitary vireo (*Vireo solitarius* A. Wilson, 1810)	Foraging and nesting habitat

TABLE 1. Comprehensive checklist of wildlife associated with canebrakes in the southeastern United States. Asterisk denotes species previously reported by Platt et al. (2001) *(cont'd).*

Common grackle (*Quiscalus quiscula* Linnaeus, 1758)*	Winter roosting habitat
Rusty blackbird (*Euphagus carolinus* Muller, 1766)	Winter roosting habitat
Red-winged blackbird (*Agelaius phoeniceus* Linnaeus, 1766)	Winter roosting habitat
Brewer's blackbird (*Euphagus cyanocephalus* Wagler, 1829)	Winter roosting habitat
American robin (*Turdus migratorius* Linnaeus, 1766)*	Winter roosting habitat
Bobolink (*Dolichonyx oryzivorus* Linnaeus, 1758)	Winter roosting habitat
Brown thrasher (*Toxostoma rufum* Linnaeus, 1758)	Habitat at northern periphery of winter range
Northern mockingbird (*Mimus polygottos* Linnaeus, 1758)	Nesting habitat
European starling (*Sturnus vulgaris* Linnaeus, 1758)	Winter roosting habitat
Eastern towhee (*Pipilo erythrophthalmus* Linnaeus, 1758)*	Foraging habitat; probably nest in canebrakes
Northern cardinal (*Cardinalis cardinalis* Linnaeus, 1758)*	Nesting habitat
Indigo bunting (*Passerina cyanea* Linnaeus, 1766)	Nesting habitat
Brown-headed cowbird (*Molothrus ater* Boddaert, 1783)	Winter roosting habitat; probably parasitizes other birds nesting in canebrakes

Mammals

Virginia opossum (*Didelphis virginiana* Kerr, 1792)	Foraging habitat
Short-tailed shrew (*Blarina brevicauda* Say, 1823)*	Common in leaf litter of canebrakes
Southeastern shrew (*Sorex longirostris* Bachman, 1837)*	Common in leaf litter of canebrakes
Least shrew (*Cryptotis parva* Say, 1823)*	Common in leaf litter of canebrakes
Mole (Talpidae G. Fischer, 1814)	Abundant in canebrake soils; low bulk density of canebrake soils attributed to mole activity
Bog lemming *(Synaptomys cooperi* Baird, 1857)*	Restricted to early successional mesic habitats in the southeast, including canebrakes
Golden mice (*Ochrotomys nuttalli* Harlan, 1832)*	Common in canebrakes throughout southeast; cane foliage incorporated into arboreal nests often support by cane stems
Rice rats (*Oryzomys palustris* Harlan, 1837)*	Foraging habitat
Harvest mice (*Reithrodontomys fulvescens* J.A. Allen, 1894 and *R. humulis* Audubon and Bachman, 1841)*	Foraging habitat; may consume young cane foliage
Cotton rats (*Sigmodon hispidus* Say and Ord, 1825)*	Trapped in canebrakes; probably consume young cane foliage
Cotton mice (*Peromyscus gosssypinus* Le Conte, 1850)	Abundant in canebrakes
Meadow voles (*Microtus pennsylvanicus* Ord, 1815)*	Trapped in canebrakes; tunnels noted in canebrake soils; probably consume young cane foliage
Eastern woodrat (*Neotoma floridana* Ord, 1818)*	Cane foliage and culm segments used in nest construction
Tree squirrels (*Sciurus carolinensis* Gmelin, 1788 and *S. niger* Linnaeus, 1758)*	Consume cane seeds when available
Beaver (*Castor canadensis* Kuhl, 1820)*	Culms and foliage are important late winter food; tree-felling creates disturbance regime favorable for cane
Swamp rabbit (*Sylvilagus aquaticus* Bachman, 1837)*	Escape cover; browse foliage and young shoots
Eastern cottontail rabbit (*Sylvilagus floridanus* Gray, 1867)	Escape cover; probably browse foliage and young shoots

TABLE 1. Comprehensive checklist of wildlife associated with canebrakes in the southeastern United States. Asterisk denotes species previously reported by Platt et al. (2001) *(cont'd).*

White-tailed deer (*Odocoileus viginianus* Zimmerman, 1780)*	Escape cover for adults; shelter for young fawns; browse cane shoots and new foliage
North American elk (*Cervus elaphus* Erxleben, 1777)*	Escape cover; consumed cane foliage; regionally extinct
American bison (*Bison bison* Linnaeus, 1758)*	Cane foliage provided high-quality browse in southeastern United States; behaviors such as horning and rubbing may have eliminated tree cover, favoring cane; wild populations now regionally extinct
Collared peccary (*Pecari tajacu* Linnaeus, 1758)	Escape cover; only important in limited area of east Texas
Black bear (*Ursus americanus* Pallas, 1780)*	Consumed cane shoots, culms, and foliage; construct dens for over-wintering and reproduction in canebrakes; escape cover
Raccoon (*Procyon lotor* Linnaeus, 1758)	Foraging habitat
Red wolf (*Canis rufus* Audubon and Bachman, 1851)*	Escape cover; canebrakes rich in prey
Bobcat (*Lynx rufus* Schreber, 1777)*	Escape cover; canebrakes rich in preferred prey
Cougar (*Puma concolor* Linnaeus, 1771)*	Escape cover; maternal den sites; canebrakes rich in potential prey
[Ocelot (*Leopardus pardalis* Linnaeus, 1758)]	Escape cover; canebrakes rich in potential prey; provisionally included based on historic account from eastern Texas

SPECIES ACCOUNTS

Our on-going literature review documented the occurrence of an additional 28 species of vertebrates in canebrake habitats, including one reptile, 20 birds, and seven mammals (with one provisional record) (Table 1). Individual records are discussed below.

Reptiles

According to Dowler (1846), American alligators were "frequently to be met" along trails leading through canebrakes. Likewise, early Spanish explorers wrote of encounters with large alligators in canebrakes along the Trinity River in eastern Texas (Foster 1995). Although generally considered aquatic predators, alligators are known to hunt on land, often ambushing prey from dense trailside vegetation (Dinets 2010), and canebrakes are rich in the vertebrate prey (Platt *et al.* 2001; this study) that comprise much of the diet (Wolfe *et al.* 1987; Shoop and Ruckdeschel 1990). Cane rhizomes have been found among the stomach contents of an adult alligator (Ruth Elsey, unpubl. data); whether these were consumed as food or incidental to prey capture remains unclear. Cane rhizomes are rich in starch (Lindahl *et al.* 1949), and although once thought to be obligate carnivores (Neill 1971), subsequent research has demonstrated that crocodilians are capable of digesting carbohydrates, plant-based proteins, and vegetable fats (Staton 1988; Coulson *et al.* 1989). We are unaware of any reports of alligators nesting in canebrakes. However, because natural levees immediately adjacent to creeks and rivers supported extensive stands of cane (Delcourt 1976) and alligators typically position nests among dense vegetation on elevated sites in close proximity to water (McIlhenny 1935; Platt *et al.* 1995), we consider it likely that canebrakes once constituted important nesting habitat for alligators. Moreover, alligators occasionally construct nests of Roseau cane (*Phragmites australis* (Cav.) Trin. ex Steud.) (Joanen 1969), a woody grass structurally similar to *Arundinaria*.

Birds

Among the French-speaking inhabitants of Colonial Louisiana, northern bobwhite quail were known as "calle de cannae" (=cane quail) owing to their association with canebrakes (Brasseaux *et al.* 2004), and Janzen (1976) suggested cane seeds were consumed during mast fruiting events. Although we are unaware of any confirmed reports of quail consuming cane seeds, other seeds similar in size to those of Arundinaria make up a significant portion of the diet (Landers and Johnson 1976) and cane seeds would most likely be eaten if available. Bamboo seeds are rich in carbohydrates and constitute an important food source for gallinaceous birds in Asia during mast fruiting years (Janzen 1976).

Wilson's snipe and American woodcock were said to be abundant in river bottom canebrakes during the winter (Palliser 1853; Thorpe 1854; Flack 1866). According to Flack (1866), woodcock spent the day in canebrakes, venturing out at night to feed in nearby cornfields and pastures. The diverse invertebrate community (particularly annelids) associated with canebrake soils (Griffith *et al.* 2009) likely provided a rich food resource for these birds (Miller and Causey 1985; Blackman *et al.* 2010). Pindar (1925) considered canebrakes important habitat for brown thrashers at the northern periphery of their winter range. Likewise, canebrakes along the Gulf Coast sheltered orange-crowned warblers (Howell 1928) and yellow-rumped warblers (Ferry 1907) during the winter, and insects gleaned from the evergreen cane foliage were an important part of the winter diet. Remnant cane patches continue to be used as wintering habitat by these warblers (Steven Platt, pers. obs.).

A number of species nest in canebrakes, often using cane foliage as a structural component of the nest. Northern mockingbirds (Means and Goertz 1983), northern cardinals (Stockard 1905), and indigo buntings (Stockard 1905) construct nests in canebrakes, and Kopman (1907) noted that where cane is present in bottomland forests, the wood thrush "is most apt to occur as a breeder". White-eyed vireos and Kentucky warblers nest in cane and incorporate cane foliage into the nest (Kopman 1907; Turcotte and Watts 1999). Canebrakes are the preferred nesting habitat of hooded warblers throughout the southeastern United States (Kopman 1907; Howell 1928; Sprunt and Chamberlain 1949; Burleigh 1958; Kilgo *et al.* 1996; Turcotte and Watts 1999). Stockard (1904) described communal nesting by black vultures in a canebrake so dense "it was next to impossible" to find the eggs. Audubon (1839) observed solitary vireos searching for insects on culms and among cane foliage, and found nesting birds in canebrakes. Upon returning to the southeastern United States in early spring, yellow-throated warblers were said to "…throw themselves by the thousands into all the … canebrakes…" where they later nested (Audubon 1839).

Canebrakes are especially important as nocturnal roosting sites for large concentrations of birds wintering along the Gulf and Atlantic coastal plains. American crows, red-winged blackbirds, rusty blackbirds, Brewer's blackbirds, common grackles, American robins, European starlings, bobolinks, and brown-headed cowbirds are all reported to roost in cane (Meanley and Webb 1961; Meanley 1965; Meanley 1971; Davis 1992; Turcotte and Watts 1999; Etheridge 2003). Although wintering flocks will use a variety of vegetation types for roosting, canebrakes are the preferred habitat, with flocks often returning to the same site in successive years (Meanley and Webb 1961; Meanley 1965; Glahn *et al.* 1994). Using data collected from roosts containing >100,000 birds, Glahn *et al.* (1994) concluded the mean density of birds roosting in cane was higher than any other habitat. Meanley (1965) estimated that a single flock roosting in a Louisiana canebrake contained 10 million blackbirds (various species) and one million American robins. A 2.4 ha canebrake was estimated to shelter 10 million roosting birds (ca. 4 million birds/ha), and 4 million birds were found in a 0.6 ha cane patch (6.5 million birds/ha); American robins and blackbirds (primarily red-winged blackbirds) comprised the majority of these flocks (Glahn *et al.* 1994). Large quantities of guano rapidly accumulate in canebrakes hosting large concentrations of wintering birds (Thorpe 1854; Glahn *et al.* 1994).

Seymour (2009) suggested canebrakes along the lower Red and Mississippi rivers

were once critical temporary roosting habitat for tree swallows as migrating flocks passed through en route to wintering grounds in Mexico and Central America. Because this region has largely been converted to agriculture (Stewart 2007), migrating tree swallows now roost in structurally-similar sugarcane (*Saccharum* spp. L.) fields and stands of Roseau cane, although remnant canebrakes continue to be used where available (Seymour 2009).

Mammals

Virginia opossums and raccoons were reportedly common in canebrakes of central Louisiana (Anonymous 1853), and according to Kirkpatrick (1851) great numbers of both succumbed when overtaken by "explosive" canebrake fires that frequently occurred during dry years. Rhoads (1896) found eastern cottontail rabbits common in cane thickets along the Mississippi River in Tennessee. Cottontails undoubtedly used canebrakes as escape cover and probably also consumed cane shoots and foliage, similar to the larger swamp rabbit, which is more often associated with canebrakes and known to feed on cane (Platt *et al.* 2001). While canebrake destruction has resulted in the near extirpation of swamp rabbit populations in parts of their range (Platt *et al.* 2001), cottontails are not dependent on cane and remain common in a variety of early successional habitats throughout the southeast (Webster *et al.* 2003). Cotton mice were sometimes referred to as "cane mice", reflecting their affinity for cane habitats (Rhoads 1896). Griffith *et al.* (2009) found extensive networks of mole tunnels beneath canebrakes, and concluded that moles, as part of a diverse and largely undescribed community of soil fauna, are responsible for the extremely low bulk density (mass of solids per unit of soil volume) of canebrake soils. The frontier naturalist Dr. Gideon Lincecum encountered a herd of collared peccary while hunting in an east Texas canebrake, but was unable to kill any "because the cane was so thick" (Lincecum and Phillips 1994). Similarly, Flack (1866) described hunting collared peccary among dense cane in the same region. Cane occurs only along the eastern-most distributional limit of the collared peccary (Correll and Johnston 1979; Farrelly 1984; Schmidly 2004),

but where the two species were sympatric, canebrakes probably afforded important escape cover and foraging habitat.

In a single paragraph discussing both bobcats and ocelots, Flack (1866) stated that "wildcats" were common in canebrakes of east Texas. Unfortunately the wording of this paragraph leaves considerable doubt as to whether this is a reference to bobcats, ocelots, or perhaps both. Because the association of bobcats with canebrakes is well documented (Young 1958; Platt *et al.* 2001), we consider these felids as the most likely candidate. That said, ocelots once occurred sympatrically with cane in eastern Texas and adjacent areas of Louisiana and Arkansas (Stangl and Young 2011). Furthermore, ocelots are strongly dependent on dense vegetation for "screening cover" (Harveson *et al.* 2004; Horne *et al.* 2009), and as such, canebrakes would seem to be excellent habitat. However, in lieu of a definitive account unequivocally linking ocelots to canebrakes, we included these felids as provisional, albeit likely members of the canebrake fauna (Table 1). Today ocelots in the United States are restricted to dense brush and thorn-scrub in extreme southern Texas (Schmidly 2004).

DISCUSSION

This literature review further reinforces our earlier conclusion (Platt *et al.* 2001) that canebrakes formerly supported a diverse assemblage of vertebrates. To date, we have established the occurrence of 70 species of vertebrates in canebrakes, including five reptiles, 36 birds, and 29 mammals (one provisional). Despite the additional literature records presented herein, we nonetheless regard this list as incomplete and again stress the need for rigorous faunal surveys of canebrake habitats. To our knowledge, with the exception of Maupin (2009), such studies have not been conducted since our original paper was published. This in part seems to reflect a general trend as faunal inventories of the southeastern United States have lagged behind those less diverse northern and western regions (Lydeard and Mayden 1995). Additionally, few large canebrakes are now available for study (Platt and Brantley 1997), and smaller remnant cane patches may harbor

depauperate assemblages owing to species-area relationships (MacArthur and MacArthur 1961; Cooper 2008). Given the dearth of contemporary studies, historic accounts will likely remain the principal source of information on canebrake fauna.

As noted earlier (Platt *et al.* 2001), most literature reports on canebrake fauna concern birds and mammals and little information is available for other taxonomic groups. In particular, canebrake herpetofauna (amphibians and reptiles) is poorly documented; we added but a single species (American alligator) to the list, which previously consisted solely of venomous snakes (Platt *et al.* 2001). We have yet to document the occurrence of any amphibian in canebrake ecosystems, which is surprising given the proximity of many canebrakes to wetlands. Regardless, a number of amphibians and reptiles are likely to be found among the stems and foliage (e.g., treefrogs *Hyla* spp. Laurenti, 1768; green anole *Anolis carolinensis* Voigt, 1832; rough greensnake *Opheodrys aestivus* Linnaeus, 1766), and in the leaf litter below (e.g., toads *Bufo* spp. Laurenti, 1768; Eastern box turtle *Terrapene carolina* Linnaeus, 1758; skinks Eumeces spp. Weigmann, 1834).

We added a significant number of birds to the list of species known to occur in cane-brakes, more than doubling the number of species reported earlier (Platt *et al.* 2001). The tally of canebrake avifauna now consists of 35 native species, including three which are extinct (Bachman's warbler, Carolina parakeet, and passenger pigeon), and a single exotic species (European starling). Canebrakes provide important foraging, nesting, and roosting habitat for resident and migratory birds in the southeast (Meanley 1972; Pashley and Barrow 1993; Platt *et al.* 2001), and cane seeds are consumed by granivorous species during mast fruiting events (Platt *et al.* 2001, 2004). However, owing to the disappearance of large canebrakes, mast fruiting of cane is now considered an "endangered phenomenon" (sensu Brewer and Malcolm 1991), cane seed constitutes a minor food resource for wildlife (Platt *et al.* 2001).

Nineteen species of birds nest or likely nest in canebrakes, a number comparable to other early successional habitats in the southeast, but considerably less than reported for mature forests in the region (Platt *et al.* 2001). Undoubtedly breeding bird surveys of cane habitat will yield additional records. Selection of nest sites within dense vegetation such as cane is thought to inhibit predator efficiency by visually screening the nest and activity of the parents, providing too many potential nest sites for predators to effectively search, and physically impeding predators (Holway 1991; Kilgo *et al.* 1996).

Canebrakes also serve as critical roosting habitat for large flocks of wintering birds (particularly Icterids) along the Gulf Coast and to a lesser extent on the Atlantic seaboard (Meanley and Webb 1961). Although wintering flocks will roost in a variety of mid-successional vegetation types, canebrakes (as well as stands of introduced bamboos) appear to be optimal roosting sites owing to an extremely high basal stem density, availability of horizontal perches, dense evergreen foliage, and vertical height (Meanley 1965; Francis 1976; Glahn *et al.* 1994). The high basal stem density and availability of horizontal perches in a canebrake allows large numbers of individuals to roost within a small area with attendant thermoregulatory benefits accruing to each individual (Francis 1976; Eiserer 1984). The dense evergreen cane foliage insulates the roost slowing the rate of nocturnal temperature decline, intercepts rainfall, and reduces wind velocity within the roost (Francis 1976; Wright *et al.* 1986). Canebrakes also appear resistant to successional change, allowing flocks to return in successive years (Glahn *et al.* 1994). Furthermore, while other vegetation types harboring large roosting flocks usually suffer from over-fertilization and eventual decline due to accumulating bird guano, canebrakes are able to sustain extended periods of bird use (Glahn *et al.* 1994). Indeed, Platt and Brantley (1997) suggested accumulations of bird guano may actually favor canebrake expansion by fertilizing cane and deadening competing woody vegetation. Glahn *et al.* (1994) recommended planting cane or exotic bamboos to shift roosting flocks away from anthropogenic habitats where accumulating dung might pose a risk to human health.

Our current review added few mammals to the list of those already known to occur in canebrake ecosystems (Platt *et al.* 2001). Much

of what is known about the mammalian fauna of canebrakes is based on hunting anecdotes in older accounts and therefore heavily biased towards megafauna (e.g., white-tailed deer, American bison, black bear, and cougar). A limited number of contemporary studies suggest insectivore and rodent diversity in canebrakes is similar to other habitats in the southeast (Platt *et al.* 2001). Conspicuously absent from our data set are any reports of chiropterans, which probably roost among dense canebrake foliage. In contrast to birds, the nature of the association between most mammals and canebrakes is poorly understood; however, cane is known to provide escape cover, maternal den sites, foraging habitat, and food in the form of foliage and seeds for some mammals (Platt *et al.* 2001).

Canebrakes have been impoverished both quantitatively by a decline in areal extent, and qualitatively through degradation in structure, function, and composition (Noss *et al.* 1995; Platt and Brantley 1997; Brantley and Platt 2001). Noss *et al.* (1995) cautioned that degraded ecosystems must not be considered "lost causes", but instead those systems that have suffered the most drastic declines should be accorded the highest priority for conservation and restoration. We therefore reiterate our earlier recommendations (Platt *et al.* 2001) and call for region-wide faunal inventories of existing canebrakes to address deficiencies in our knowledge as highlighted in this paper. Preferably these inventories should focus on the largest canebrakes to avoid problems associated with fragmentation and species-area effects. Baseline data generated by these studies, combined with information gleaned from the literature, will provide a means to rigorously evaluate future conservation and restoration efforts.

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Bergbambos and *Oldeania*, new genera of African bamboos
(Poaceae: Bambusoideae)

Chris M. A. Stapleton

chris@bamboo-identification.co.uk

Two new monotypic genera, *Bergbambos* and *Oldeania* are described for African temperate bamboo species in the tribe *Arundinarieae*, after a comparison of their morphological characteristics with those of similar species from Asia. Morphological differences are supported by their isolated geographical distributions. Molecular evidence does not support the inclusion of these species in related Asian genera, recognising them instead as distinct lineages. New combinations *Bergbambos tessellata* and *Oldeania alpina* are made.

INTRODUCTION

While Asian temperate bamboos have received critical attention over recent decades (Stapleton 1994, Wong 1995, Li et al. 2006), the generic placement of the temperate bamboos of Africa has not been properly addressed. There seem to be only two temperate bamboo species on the African mainland, currently enumerated most frequently as *Thamnocalamus tessellatus* (Nees) Soderstrom & R.P. Ellis and *Yushania alpina* (K. Schum.) W.C. Lin. These species are in tribe *Arundinarieae* Nees ex Asch. & Graebn., a group also known as the northern temperate clade, identified as a strongly supported monophyletic group from the first molecular analyses of bamboos onwards (Watanabe et al. 1994, Zhang 1996).

Tribe *Arundinarieae* contains woody bamboos with semelauctant synflorescences (lacking a capability for indeterminate growth from buds subtended by the basal spikelet bracts), ebracteate or partially bracteate synflorescence paraclades (reduced sheathing subtending inflorescence branches) and 3 stamens in each floret. They constitute ca. 800 of the ca. 1400 woody bamboos, and are found in Asia, Africa, and the USA, having a montane or subtropical to temperate distribution.

Molecular studies reviewed by Bamboo Phylogeny Group (2012) suggest that seme-lauctant inflorescences with 3 stamens and reduced branch sheathing have evolved from tropical bamboos at least twice, once to give the northern temperate clade *Arundinarieae* of Asia and Africa, spreading to N America, and on separate occasions in Central & South America within the *Bambuseae* Kunth ex Dumort., principally to give *Chusqueinae* Bews, with these characters also evolving on a smaller scale within the *Arthrostylidiinae* Bews and *Guaduinae* Soderstr. & R. P. Ellis as well.

Most of the older 3-stamened species were placed at some time in *Arundinaria* Michx., which has 529 combinations, but that genus is now widely recognised as containing only 3 species, all from the Southeast USA (Stapleton *et al.* 2004, Zeng *et al.* 2010, Bamboo Phylogeny Group 2012). Treatments of the other species of tribe *Arundinarieae* vary, according to the breadth of generic concept used, and which characters are given greatest weight. For example, the group of Asian species morphologically closest to *Arundinaria* could be placed (Zhang *et al.* 2012) either in a polyphyletic broad interpretation of *Arundinaria* (e.g. Li *et al.* 2006), in a polyphyletic broad interpretation of *Bashania* Keng f. & T.P. Yi (e.g. Keng & Yi 1996), or in the monophyletic *Sarocalamus* Stapleton (Stapleton *et al.* 2004, Bamboo Phylogeny Group 2012). The morphologically more distinct species are currently placed in other genera, 27 of which were recognised by Bamboo Phylogeny Group (2012), out of a total of 42 genera that have been described within the tribe.

There appears to have been a rapid and relatively recent diversification within bamboos with 3 stamens, including tribe *Arundinarieae* (Stapleton *et al.* 2009, Hodkinson *et al.* 2010, Zhang *et al.* 2011, Kelchner & BPG 2013), especially those found in montane and temperate areas such as the Andes, the Himalayas, and Northeast Asia. There have also been several reports of hybridisation, reviewed by Triplett *et al.* (2010) and Zhang *et al.* (2012). Hybridisation may well have been common in the bamboos, as mechanisms to avoid it have not been documented. Recent rapid diversification and hybridisation, combined with long generation times, appear to have limited the ability of DNA analyses to resolve phylogenetic patterns and define well supported groups for taxonomy, especially at the generic level (Stapleton *et al.* 2009, Hodkinson *et al.* 2010), despite reasonable or sometimes very substantial morphological variation.

In the absence of reliable molecular analyses, for the purpose of descriptive treatments of bamboo species (Li *et al.* 2006, Wong 1995, Dransfield 2000, Widjaja 1997) a more traditional morpho-geographic approach has been maintained in the classification of Asian bamboos. It has only been possible to use molecular data for the elimination of blatantly polyphyletic groups, rather than the determination of monophyletic ones. Attempts to group the genera substantially (e.g. Clayton & Renvoize 1986, Chao & Renvoize 1989) have resulted in polyphyletic and paraphyletic groups, or clades with weak support that are inconsistent in different analyses.

Rapid recent diversification seems to have spawned a host of small groups, often distinguished by relatively minor characters. Combining them together into a few large genera has not been possible without establishing excessively variable genera that are difficult to define and demonstrably polyphyletic. On the other hand recognising only half of the genera described would still lead to a generic concept that is unusually narrow in the grasses. The latter procedure has been followed (Bamboo Phylogeny Group 2012), largely because it has been found unavoidable if a functional binomial classification system is to be maintained. This is necessary in order to allow pragmatic field identification, and subsequently improve sustainable utilisation and conservation of these species, many of which have a limited range of distribution and are threatened by changes in land use and climate. A substantial proportion of the woody bamboos are yet to be described, and the lack of a functional and stable nomen-clatural system for field identification has been a major factor preventing their recognition.

Only two species of temperate bamboo have been described from the African mainland. *Thamnocalamus tessellatus* (Nees) Soderstrom & R.P. Ellis is from mountains in southern Africa, while *Yushania alpina* (K. Schum.) W.C. Lin is from mountains in several countries across tropical Africa. *Y. alpina* was described initially in *Arundinaria*, and *T. tessellatus* was soon transferred into that genus from *Nastus* Juss. They were more recently moved into the morphologically closer Asian genera, *Thamnocalamus* Munro and *Yushania* Keng f., the geographically closest representatives of which are found in the Western Himalayas, Map 1 & Map 2.

Three further, less well known species, *Thamnocalamus ibityensis* (A. Camus) Ohrnb., *Yushania madagascariensis* (A. Camus) Ohrnb. and *Yushania humbertii* (A. Camus) Ohrnb. (including *Yushania ambositrensis* (A. Camus) Ohrnb.) were described from Madagascar. *Thamnocalamus ibityensis* has been considered conspecific with *T. tessellatus* (Chao & Renvoize 1989), but it would appear to have substantially different branch sheathing. The two *Yushania* species would appear to share characteristics with *Y. alpina*, but their culms, branching and culm sheaths are not known. *Y. ambositrensis* resolved in a clade with *Y. alpina* (Triplett 2008), but it is not clear how closely related they really are to *Y. alpina*, or to each other, and which species names should be recognised. Further field work on temperate species of Madagascar is required, as existing collections are incomplete, although any such species may have already become extinct.
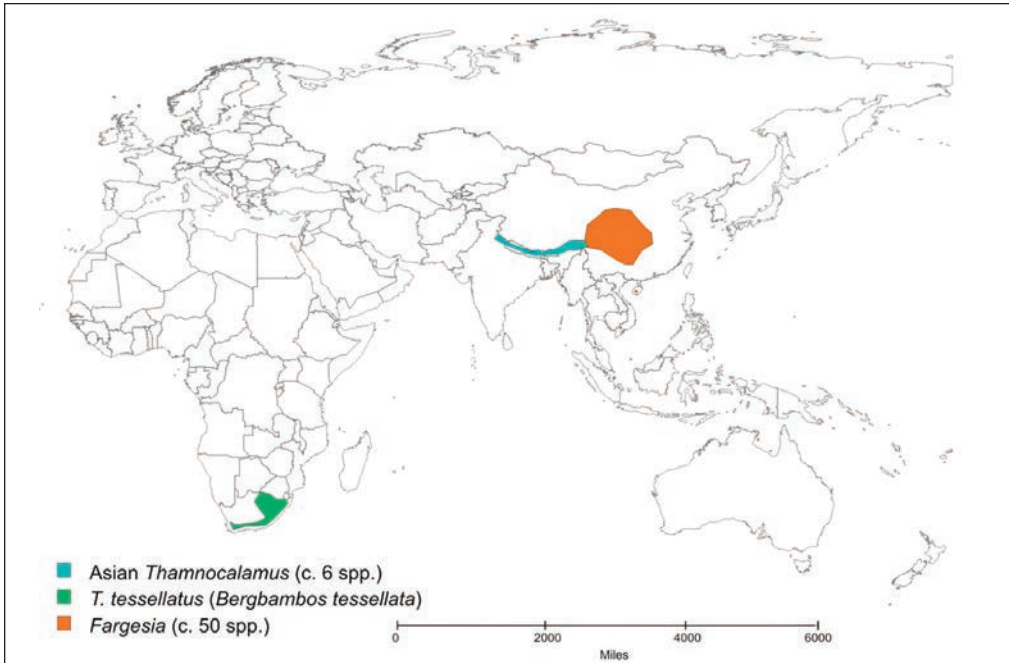
Map 1. Distribution of *Thamnocalamus tessellatus, Thamnocalamus* in Asia, and *Fargesia*.
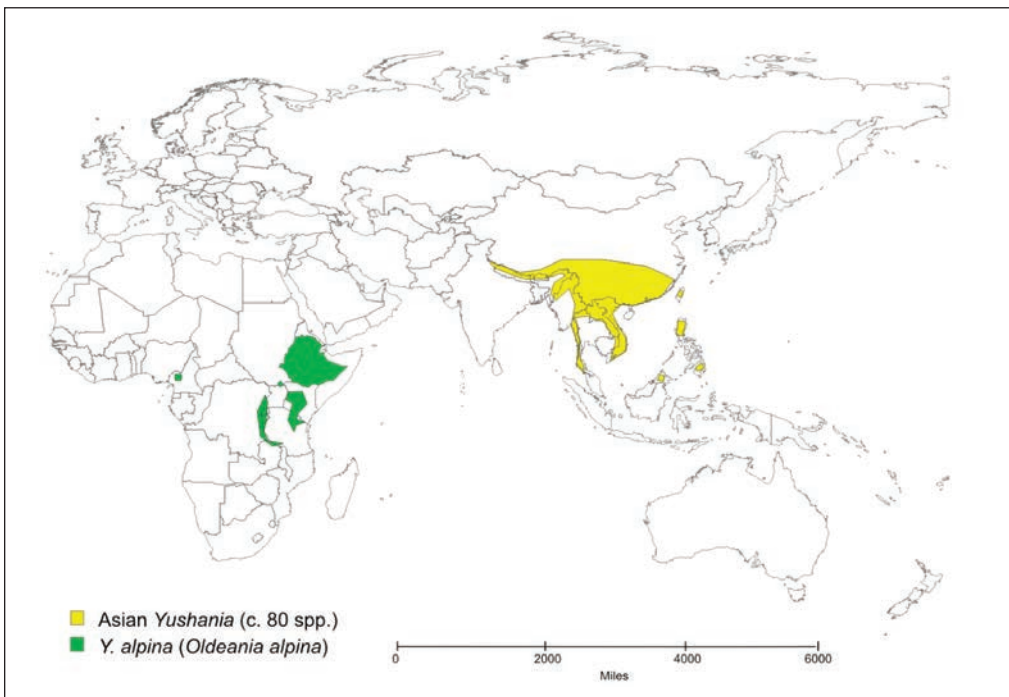
Map 2. Distribution of *Yushania alpina* and Asian *Yushania* species.

COMPARISON OF MORPHOLOGICAL CHARACTERS

Systematics within the grass family has traditionally given greater weight to floral than to vegetative characters. This has often led to polyphyletic genera in the bamboos, the superficiality of their similarities and their separate origins only being revealed by in-depth morphological investigations and/or molecular studies. In order to allow deeper, more objective morphological comparisons and to allow inclusion of consistent and accurate vegetative as well as floral characters in descriptions, the morphology of woody bamboos has been reviewed in depth (Stapleton 1997, available online). Recent bamboo treatments (Judziewicz *et al.* 1999, Li *et al.* 2006, Triplett *et al.* 2006, BPG 2012) have employed these revised concepts and terminologies, and they are followed here.

The characters and character states considered important at the generic level for distinguishing the two African species from similar Asian genera are given in Table 1.

Thamnocalamus tessellatus

Previous generic placements of *Thamnocalamus tessellatus* were based upon an incomplete knowledge of its morphology. *Nastus tessellatus* Nees was described before its flowers were known, and transferred into *Arundinaria* (Munro 1868) simply as it bore "very great resemblance" to that genus. Later discovery of its flowers has shown that it indeed has 3 stamens, rather than the 6 of *Nastus*, but it has pachymorph rhizomes (see Stapleton 1997: Fig.1) rather than the leptomorph rhizomes of *Arundinaria*.

It was transferred into *Thamnocalamus* largely on the basis of leaf anatomical characters by Soderstrom & Ellis (1982), who found that *A. tessellata* shared 10 characters out of 11 with *Thamnocalamus spathiflorus* (Trin) Munro, while it only shared 7 characters with *Fargesia nitida* (Mitford) Keng f. However, *A. tessellata* also shared only 5 characters with *Thamnocalamus aristatus* E.G. Camus, while the possibly conspecific *T. spathiflorus* and *T. aristatus* themselves only shared 6 out of 11 characters. When morphological characters other than those of leaf anatomy, along with

Figure 1. Raceme of *Thamnocalamus tessellatus* (**A**), compared to: **B** *Fargesia nitida*, lateral view with enclosing sheaths; **C** *Fargesia nitida* with enclosing sheaths removed; **D** *Fargesia nitida,* dorsal view, sheaths removed. A from Soderstrom & Ellis (1982), drawn by A. R. Tangerini, © Smithsonian Institution. B, C, D from Stapleton 1061b. Scale bars 2 mm.

Table 1. Principal morphological characters of *Bergbambos*, *Oldeania*, and Asian members of 5 similar genera.

	Bergbambos (*Thamnocalamus tessellatus*)	*Thamnocalamus*	*Fargesia*	*Oldeania* (*Yushania alpina*)	*Yushania*	*Borinda*	*Chimonocalamus*
synflorescence	raceme, not not unilateral	raceme to panicle,	raceme, unilateral unilateral	panicle, not unilateral	panicle, not unilateral	panicle, not unilateral	panicle, not unilateral
paraclades	largely ebracteate	substantially bracteate	variably bracteate	largely ebracteate	largely ebracteate	largely ebracteate	largely ebracteate
pedicel	scabrous	glabrous	glabrous	glabrous	glabrous	glabrous	glabrous
fertile florets	1	2–several	2–several	2–several	2–several	2–several	2–several
glume bud remnants	absent	variable	present	absent	variable	variable	absent
rhizomes	short-necked	short-necked	short-necked	long-necked	long-necked	short-necked	short-necked
clump form	unicaespitose	unicaespitose	unicaespitose	culms solitary	pluricaespitose	unicaespitose	unicaespitose
nodes	without roots	without roots	without roots	with short roots	without roots	without roots	with root thorns
supranodal ridge	obscure	obscure	obscure	well developed	obscure	obscure	well developed
culm internodes	terete	terete	terete	sulcate	terete	terete	terete
branch sheathing	reduced	complete	reduced	reduced	reduced	reduced	complete
branch orientation	erect	erect	erect	spreading	erect to spreading	erect	spreading
mid-culm branches	5–7	3–8	5–7	3–7	5–11	5–7	3
culm sheath blades	erect or reflexed	usually erect	erect or reflexed	usually reflexed	erect or reflexed	erect or reflexed	usually reflexed

more recent molecular results are taken into account, it would appear that the anatomical characters used by Soderstrom and Ellis (1982) are more informative at the level of species or below rather than at generic level.

The synflorescence of *T. tessellatus* has been well illustrated in Hooker's Icones Plantarum (Prain 1913: Tab 2930 http://www.botanicus.org/page/1349516), and by Soderstrom & Ellis (1982). When examined closely, it can be seen that the synflorescence of *T. tessellatus* has similarities to those of both *Thamnocalamus* and *Fargesia* Franchet, see Table 1, as they are compressed, and are associated with several supporting sheaths. However, while *Thamnocalamus* has loose racemose panicles, *T. tessellatus,* like *Fargesia*, consistently bears short racemes. These are structurally very similar to those of *Fargesia*, but differences arise in the arrangement of the florets. In *Fargesia* the racemes are held tightly within imbricating sheaths, which can extend well beyond the spikelets. Development within the sheaths forces them to emerge to one side and appear

unilateral, with the pedicels tightly pressed against the rhachis. Those of *T. tessellatus* are more cylindrical, the spikelets not so constricted by the sheaths, and the pedicels are free to develop in a normal distichous fashion, Figure 1.

In addition, in *T. tessellatus* the pedicels are scabrous, the glumes of each spikelet are basally tight and contain no vestigial bud remnants, and the racemes are usually largely ebracteate. The usually single fertile florets also distinguish *T. tessellatus* from other *Thamnocalamus* and *Fargesia* species, but this character should be treated with caution as it can be a specific as well as a generic character.

Thamnocalamus tessellatus also has vegetative characteristics that distinguish it, notably from Asian members of *Thamnocalamus*, (see Table 1). A close inspection of the branching reveals not the pattern seen in species such as *Thamnocalamus crassinodus* (T.P. Yi) Demoly, but instead the substantial reduction in sheathing seen in *Fargesia, Yushania,* and *Borinda* Stapleton, Figure 2.
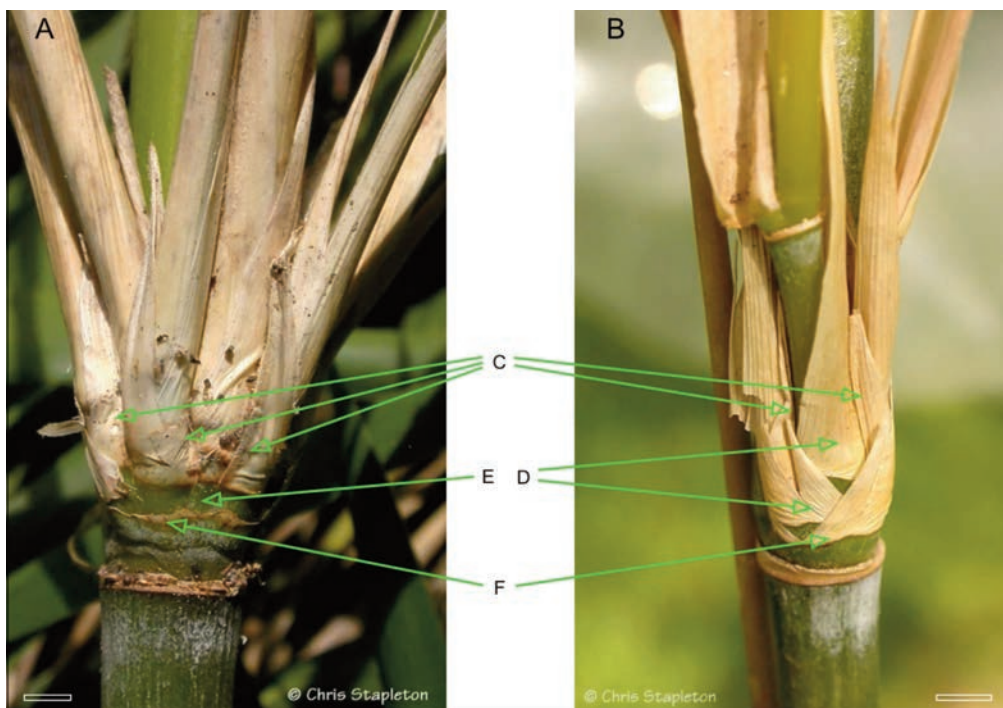

Figure 2. Comparison of branch complement sheathing from mid-culm nodes of *Thamnocalamus tessellatus* **(A)** and *Thamnocalamus crassinodus* **(B)**. **C** Lateral branch prophylls. **D** Sheaths obscuring prophyll bases in *T. crassinodus.* **E** Equivalent sheaths completely absent in *T. tessellatus,* prophylls visible. **F** Branch bud prophyll, removed in A, still present in B. Scale bars 1 cm. From http://www.bamboo-identification.co.uk
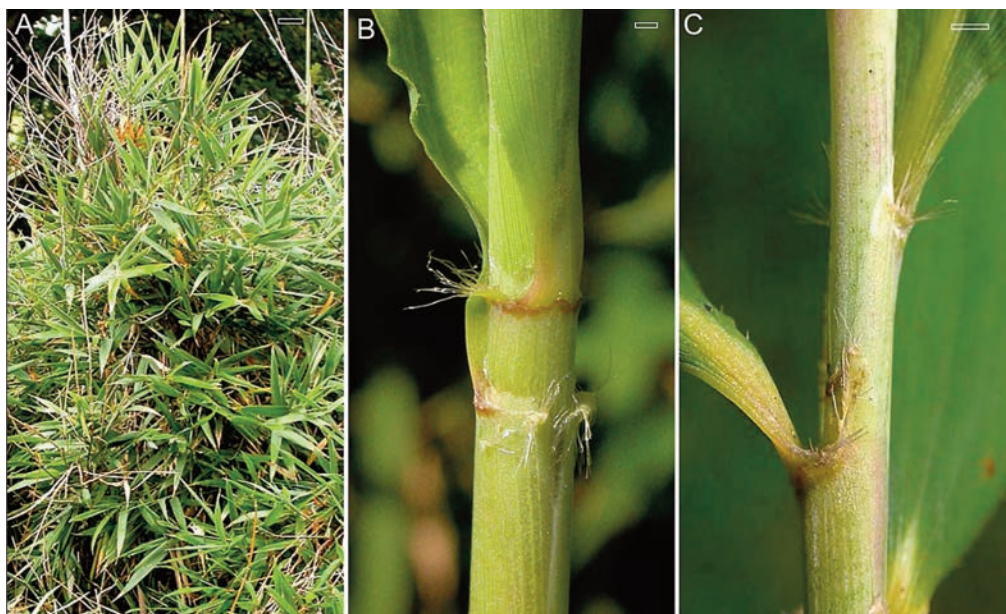
Figure 3. *Thamnocalamus tessellatus.* **A** Random orientation of leaf blades; **B** & **C** Irregular orientation of delicate oral setae. Scale bars A 10 cm, B & C 2 mm. From http://www.bamboo-identification.co.uk/html/tessellatus.html

The branches of *Thamnocalamus tessellatus* are subequal, arranged side by side through strong compression of the basal internodes of the central branch, accompanied by loss of some of the sheaths at the nodes, Fig. 2A, cf *Thamnocalamus crassinodus,* Fig. 2B. This allows lateral branch prophylls to be seen side by side without any intervening sheaths. These patterns were contrasted by Stapleton (1991; 1994: fig. 1; 1997: fig. 2), and also illustrated for *T. tessellatus* by Soderstrom and Ellis (1982: fig.1, fig. 4).

In addition to the synflorescence and branching, *T. tessellatus* also differs in minor details that are harder to quantify, including the more varied orientation of the foliage leaves, and the delicate appearance of its oral setae and their more varied orientation, Figure 3.

Thus in terms of vegetative macro-morphological characteristics important at the generic level, *T. tessellatus* is closer to *Fargesia* than to *Thamnocalamus*, but can be distinguished from both. In general appearance it resembles a coastal species of *Pleioblastus* Nakai from Japan, with rather loose clumps, erect culms with short branches bearing coarse, irregularly arranged foliage with persistent sheaths. This contrasts with the delicate foliage leaves, all oriented towards the light on pendulous branches seen in Himalayan species of *Thamnocalamus* and in *Fargesia*. This is likely to be associated with the more open ecological habitat in which *T. tessellatus* is found, rather than the darker forest understorey habitats of Asian *Thamnocalamus* and *Fargesia* species.

Yushania alpina

The synflorescence of *Y. alpina* is practically indistinguishable from those of several Asian and American bamboos, including species of *Arundinaria*, *Sarocalamus*, and *Yushania* – an open panicle with nearly complete reduction in sheathing at points of branching so that it is essentially ebracteate. However, the sheaths are often reduced to small tough bracts, as well as the more delicate sheath remnants or tufts of hairs seen in similar genera. In addition the lateral spikelets are more often sessile or subsessile, without a long pedicel. However, these characters are relatively minor and quite variable.

Yushania alpina is more distinct vegetatively. Reaching heights of up to 20m in its natural habitat, the tall, very erect culms are potentially much larger than those of any Asian species of *Yushania*, which only reach a maximum height of about 7m. Culm nodes and branching also
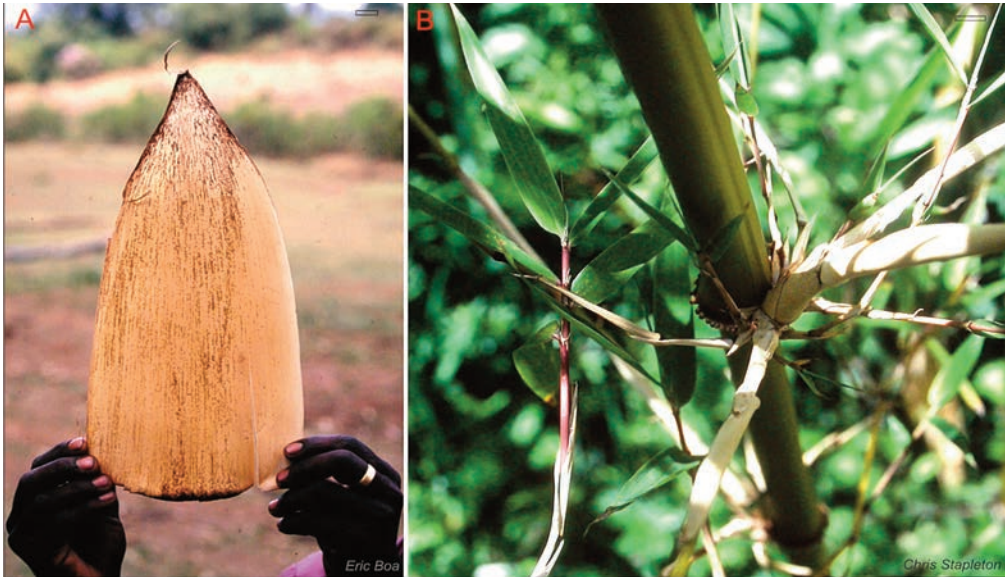
Figure 4. *Yushania alpina.* **A** culm sheath; **B** leaf sheaths, culm node with ring of thorn-like aerial roots and distinct supra-nodal ridge, sulcate internode, and dominant central branch. Scale bars top right, 2 cm.

differ substantially from those of Asian species of *Yushania*, Figure 4.

Branches vary in size more than those of Asian *Yushania* species. The central branch is strongly dominant, and the first two lateral branches are also strong. The orientation of the branches is less erect than those of most species of *Yushania*, becoming nearly horizontal. Above the branches the internode is distinctly sulcate, much more prominently than is seen in Asian *Yushania* species, as a result of the development of strong branches. Moreover there is often a dense ring of short, partially developed aerial roots at nodes in the lower part of the culm, often extending into the mid-culm region as well. This character is only known in species of *Chimonocalamus* Hsueh & T.P. Yi, and the leptomorph-rhizomed *Chimonobambusa* Makino among the Asian temperate bamboos. The roots are not as sharp and thorn-like as those seen in *Chimonocalamus* and *Chimonobambusa*, but they can be very distinct and prominent. Nodes have a distinct infranode between the culm sheath attachment and the supranodal ridge, which is well developed, Figure 5.

In its natural habitat, the open stands have a widely spaced appearance closer to that of a species of *Phyllostachys* Siebold & Zucc., rather than the denser thickets of Asian *Yushania* species, because the rhizomes have consistently long necks, giving solitary culms rather than the denser clusters of pluricaespitose culms seen in Asian species of *Yushania*.

Branch structure and sheathing is difficult to distinguish from that of *Yushania* or *Fargesia*. Although the prophyll is usually 2-keeled, there is replication side by side of lateral branch initials without intervening sheaths. In this way it differs fundamentally from *Chimonocalamus*, which has only 3 branches and full sheathing.

DISCUSSION

The morphological differences between *Thamnocalamus tessellatus, Yushania alpina* and other representatives of these and similar Asian genera suggest that although the two African bamboos share several characters and presumably common ancestors with Asian bamboos, they are not as closely related to their Asian relatives as previously thought.

The morphological distinctions are supported by geographical isolation, (see Maps 1 & 2). Long-distance dispersal of temperate bamboos is highly unlikely because of a lack of any specialized seed dispersal mechanism or dormancy, brief viability of seed, exacting

Figure 5. *Yushania alpina* **A** tall culms arising separately with prominent supra-nodal ridges (arrowed), Rwenzori, Uganda; **B** culm node with ring of thorn-like aerial roots (arrowed), Mt. Kenya. Scale bars A 25 cm, B 5 cm. Photos courtesy of: (A) Peter Gill, (B) Harry Jans, www.jansalpines.com

habitat requirements, and extremely infrequent flowering (Stapleton *et al.* 2004).

Together the morphological distinctions and geographical isolation justify the recognition of two new genera, following the existing relatively narrow generic concepts applied in the northern temperate clade, tribe *Arundinarieae*.

The new genera are keyed out below along with their 6 morphologically closest relatives in the tribe including the two Asian genera with distinct nodal thorns, as well as the North American type genus of the tribe, *Arundinaria*, and its Asian analogue, *Sarocalamus*.

Key 1. *Bergbambos*, *Oldeania* and related genera

1	Rhizome leptomorph **2**
–	Rhizome pachymorph **4**
2	Basal culm nodes with thorns, branches spreading .... ***Chimonobambusa***
–	Basal culm nodes without thorns, branches erect **3**
3	Pedicels glabrous, leaf blades thick, SE USA .... ***Arundinaria***
–	Pedicels not glabrous, leaf blades thin, Himalayas & W China .... ***Sarocalamus***
4	Branches 3, all sheaths developed, basal nodes with thorns .... ***Chimonocalamus***
–	Branches 3-15, sheathing reduced, basal culm nodes with or without thorns **5**
5	Rhizomes long or variable in length, clumps open or spreading **6**
–	Rhizomes consistently short, culms in single clumps **7**
6	Nodes raised, basal culm nodes usually with thorns, Africa .... ***Oldeania***
–	Nodes not raised, basal culm nodes without thorns, Asia .... ***Yushania***
7	Branch sheathing complete .... ***Thamnocalamus***
–	Branch sheathing reduced **8**
8	Synflorescence branching paniculate .... ***Borinda***
–	Synflorescence branching racemose **9**
9	Racemes unilateral, W China .... ***Fargesia***
–	Racemes not unilateral, Africa .... ***Bergbambos***

Sufficient data is now available to test whether this classification would gain support from molecular phylogenetic evidence. These two African species were not clearly resolved with Asian representatives of any genera in any molecular studies. For example, in a comparison of ITS sequences (Guo *et al.* 2002), *Thamnocalamus tessellatus* did not resolve with the type species of *Thamnocalamus, T. spathiflorus*, and its position varied between topologies. In the nuclear ribosomal ITS analysis of Hodkinson *et al.* (2010), *Yushania alpina* did not group with other *Yushania* species or closely with any other taxon. Weak associations between *Yushania alpina* and *Chimonocalamus* species were found by Guo & Li (2004) and Triplett (2008), which is interesting as they share possession of aerial roots developed into thorn-like structures, although they differ in other ways. However, neither *Yushania alpina* nor *Thamnocalamus tessellatus* resolved with putative relatives in these or similar genera of temperate bamboos in the most comprehensive studies undertaken so far, using sequences from 8 regions of cpDNA in 146 species and 26 genera (Zeng *et al.* 2010), and 108 bamboos from 25 genera using plastid DNA and nuclear GBSSI gene sequences (Zhang *et al.* 2012).

The molecular data would suggest that their inclusion in Asian genera would render those genera polyphyletic. Because their monotypic status is considered likely they could not be supported as monophyletic groups themselves in a classification based solely on molecular phylogeny. However, Zeng *et al.* (2010) and Zhang *et al.* (2012) considered them both to represent distinct lineages, and it is not possible to place them in well supported meaningful monophyletic groups except the tribe *Arundinarieae*. Therefore while the molecular data would not allow the diagnosis of monophyletic genera for the African bamboos following a strict Hennigian cladistic analysis, neither their current placement in *Thamnocalamus* and *Yushania*, nor placement in any other existing genus receives any support either. Continuing to include these bamboos in Asian genera causes serious problems when describing or distinguishing between those genera.

Although woody bamboos are considered to have evolved originally in Gondwanaland rather than Eastern Asia (Hodkinson *et al.* 2010), these African representatives are nested within the northern temperate clade, the tribe *Arundinarieae*, with a largely Asian distribution. This is estimated to have diverged from other woody bamboos around 23 mya (Hodkinson *et al.* 2010), 29 mya (Bouchenak-Khelladi *et al.* 2010) or 37.5 mya (Christin *et al.* 2008), but to have radiated only ca. 9 mya (Bouchenak-Khelladi *et al.* 2010) 10 mya (Hodkinson *et al.* 2010), or 19 mya (Christin *et al.* 2008). Peng *et al.* (2013) after sequencing 95% of the *Phyllostachys edulis* genome found evidence of whole genome duplication 7–12 mya, supporting the more recent dates.

Collision of tectonic plates has been suggested as a likely cause of this rapid radiation (Stapleton *et al.* 2009, Hodkinson *et al.* 2010). African and Indian plates met the Eurasian plate around that time, allowing a biotic interchange and subsequent radiation and diversification of Gondwanan elements into a wealth of new habitats. However, the temperate ancestors of these two African bamboo genera seem to have diverged around the same time that temperate bamboos arrived in Eastern Asia. Inclusion of endemic temperate bamboos from S India, Sri Lanka and Madagascar in a molecular phylogeny is required before any conclusions can be drawn as to where bamboos from the northern temperate clade first evolved, but there seems no evidence for an African origin, and it seems more likely that temperate bamboos radiated from India to Asia, Africa, and N America.

NOMENCLATURE

Bergbambos Stapleton

Differing from *Arundinaria* and *Sarocalamus* and similar to *Thamnocalamus* and *Fargesia* in its short-necked pachymorph rather than leptomorph rhizomes, and its compressed synflorescences. Differing from *Borinda* and *Thamnocalamus* in its racemose rather than paniculate synflorescence branching. Differing from *Fargesia* in the distichous rather than unilateral arrangement of spikelets in the racemes, the spikelets usually having only one

fertile floret, and the scabrous pedicels. Differing from *Thamnocalamus* in the branch complement with reduced sheathing, and from *Fargesia* in the more varied orientation of the leaf blades.

Type: *Bergbambos tessellata* (Nees) Stapleton. Basionym: *Nastus tessellatus* Nees, Fl. Afr. Austr. 1: 463. 1841. *Arundinaria tessellata* (Nees) Munro; *Thamnocalamus tessellatus* (Nees) Soderstrom & R.P. Ellis. Type: S Africa, Katberg, 4000–5000ft, J.F. Drège s.n. (lectotype, designated in Soderstrom & Ellis 1982, pg. 54: K!, http://apps.kew.org/herbcat/getImage.do?imageBarcode=K000345516.

Rhizome pachymorph, short-necked, giving dense clumps. Culms to 7 m tall, diam. to 2 cm, nodding to pendulous, terete, smooth, nodes not raised and unarmed. Mid-culm branch complement initially with 5–7 main branches, erect, sheathing reduced. Culm sheaths persistent, tough. Leaf sheaths several to many, persistent, blades thick with random orientation. Synflorescence semelauctant, racemose, branch sheathing occasionally a soft sheath remnant, usually absent. Racemes not unilateral. Spikelets shortly pedicellate with 1(–2) fertile florets, pedicel scabrous. Empty glumes 2, no bud remnants. Lemma and palea similar in length. Stamens 3, filaments free. Stigmas 3. Lodicules 3.

Name *Bergbambos* from the Afrikaans name (Bergbamboes) in South Africa.

This genus would appear to be monotypic, confined to the mountains of South Africa, Lesotho and Swaziland.

Oldeania Stapleton

Differing from *Arundinaria* and *Sarocalamus* and similar to *Yushania* in its long-necked pachymorph rather than leptomorph rhizomes, though similar to all in its open panicles. Differing from *Yushania* in its sulcate culm internodes, fewer, more horizontal branches, culm nodes with well developed supra-nodal ridge and often thorn-like aerial roots. Similar to *Chimonocalamus* in its panicles and thorn-like roots at culm nodes, but differing in its multiple branches with reduced sheathing and sulcate culm internodes.

Type: *Oldeania alpina* (K. Schum.) Stapleton. Basionym *Arundinaria alpina* K. Schum. in Engler, Pflanzenwelt Ost-Afrikas 5: 117. 1895. *Sinarundinaria alpina* (K. Schum.) C.S. Chao & Renvoize; *Yushania alpina* (K. Schum.) W.C. Lin. Type: Kenya, Kikiju, G.A. Fischer 672 (holotype: B n.v., destroyed).

Rhizome pachymorph, long-necked, giving open stands and solitary culms. Culms to 15(–20) m tall, diam. to 6(–10) cm, erect to nodding, terete with shallow sulcus above branches, smooth, nodes with prominent supranodal ridge, in lower to mid culm a nodal ring of dense, short, hard, and thorn-like aerial roots often well developed. Mid-culm branch complement initially with 3–5 main branches, spreading, sheathing reduced. Culm sheaths deciduous, tough. Leaf sheaths several to very many, blades thick. Synflorescence semelauctant, paniculate, branch sheathing reduced to hard bracts, soft sheath remnants or hairs. Spikelets pedicellate with several fertile florets, pedicel scabrous. Empty glumes 2, bud remnants present or absent, fertile glumes 4–8. Lemma and palea similar in length. Stamens 3, filaments free. Stigmas 2. Lodicules 3.

Name *Oldeania* from the Maasai common name (Oldeani) in Tanzania.

Currently only the type species can be reliably placed in the genus, which thus has a distribution across tropical Africa from Cameroon in the west to E Africa, where it occurs from Ethiopia south to Tanzania. There is a possibility that species from Madagascar will be placed in this genus when they are better known, but they may be conspecific or even introduced. It provides important montane wildlife habitats and food, notably for the critically endangered Mountain Gorilla, *Gorilla beringei beringei*.

The holotype, G.A. Fischer 672, was destroyed by fire during the 1939-1945 World War. No trace of the type collection or any duplicate has been found in surviving components of the Berlin collections, nor in other herbaria, including the Hamburg collections taken to Russia and recently repatriated (Poppendieck pers. comm.). The likelihood of substantial infraspecific variation, the possibility of further species, and

the lack of other collections from the type locality together make it inadvisable to select a neotype or epitype until new collections have been made.

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Scientific Investigation of Traditional Water Leaching Method for Bamboo Preservation

Perminderjit kaur[1]*, Vikas Kardam[1], K.K. Pant[2], S. Satya[1], S.N. Naik[1]

[1]Centre for Rural Development and Technology, Indian Institute of Technology, Delhi
[2]Chemical Engineering Department, Indian Institute of Technology, Delhi
Email: perminder.dua@gmail.com

ABSTRACT

In many countries bamboo has played an important role in the livelihood of rural people. Since bamboo species are quite susceptible to insect and fungi attack, traditionally rural people were using simple and cost effective preservation methods. Toxic effects of chromium and arsenic, released from various commercially available preservatives, necessitated the development of environmental friendly treatment techniques for preservation of bamboo species. Indigenous water leaching process is used traditionally to preserve bamboo. This study was conducted to investigate the effectiveness of water leaching method. Physico-chemical characteristics, microstructure properties and decay resistance properties of water leached bamboo specimens were compared with control. The results revealed that the process may make bamboo unattractive to fungi even not being toxic. *D. strictus* bamboo species was chosen for the present study. Decay resistance of water leached samples was found to be better than untreated and comparable to chemically treated bamboo species. Decay resistance analysis of water leached *D. strictus* culms indicates the high fungal resistance of treated samples. Water leaching alone cannot be considered as long term preservation option for outdoor application of bamboo species. However its integration with other technologies can provide viable resistance to bamboo species.

Key words: Bamboo, water leaching, chemical characterisation, traditional preservation

INTRODUCTION

Bamboo is an important natural resource. Due to concerns regarding unplanned rapid deforestation, for meeting the needs of growing construction industry, bamboo has emerged as one of the best alternatives. It is an important construction material which provides homes for a billion of people, not only in rural areas since ancient times. Bamboo with unique characteristics like low weight to height ratio, earthquake resistant properties, high tensile strength and high growth rate has emerged as an excellent substitute of wood in the housing industry, also in the urban housing sector. The potential of utilization of bamboo is very high but it remains largely unrealized in India. The root cause of the problem is the increasing scarcity of the raw material, which is aggravated by the gross loss of raw material under storage and processing. There is no accurate assessment of the demand and supply position of the resources, which results in considerable uncertainties in the industrial and business operations.

Bamboo is a ligno-cellulosic material, which is susceptible to damage by bio-deteriogens like fungi, borer and termites etc. Bamboo culms have minor amount of resins, waxes and tannins and sufficient amount of starch, which makes the culms attractive to bio-deterioration agents. Paper and pulp industry requires healthy bamboo culm i.e. uninfected biomass. Pulp losses affect the efficiency of the process as well as quality of paper produced (Sharma *et al*, 2011). Preservation of bamboo culms is imperative to reduce decay losses as well as for the improvement of safety of structures they are used for. To ensure long service life of the product, a large number of chemical compounds as preservatives have been introduced in the market. The majority of these chemicals pose hazards to human health and environment. Many of them like Copper Chrome Arsenic (CCA) have been banned in

some European countries, The United States and Japan due to chemical toxicity. Problems related to low efficacy, high cost and corrosiveness is associated with many of the commercially available preservatives (Janssen, 2000).

Traditional or non-chemical methods are being widely used by villagers and artisans. Non chemical treatment often referred as traditional bamboo treatment, include lime washing and smoke treatment (Janssen, 2000; Randall, 2000). The data regarding the action and mechanism of these simple traditional bamboo preservation techniques are limited in literature and mostly not known. Proper harvesting time is a crucial parameter for better management of bamboo culms (Nath *et al.,* 2009). The use of mud coating to protect the huts of bamboo is also practiced in many parts of Bangladesh (Uddain 2008). Another most widely adopted practice in traditional treatment includes the soaking of bamboo culm in the running water of river. It is believed that soaking may reduce the water soluble constituents like starch and thus protects the culm from fungi and insect attacks. The present paper attempts scientific investigation of water leaching method of bamboo preservation. In addition to effect on decay resistance, changes in physico-chemical properties, functional groups and microstructure properties of treated and untreated bamboo culms are explored and compared with the control.

MATERIAL AND METHODS

Dendrocalamus strictus is the most commonly used species of bamboo for housing and construction. The bamboo culms were procured from The Energy Research Institute, Gurgaon, Haryana (India) and stored in the micro-model complex at Indian Institute of Technology, Delhi. Chemically treated (Copper Chrome Boron) culms of *D. strictus* were procured from Erosway organization, Nagpur, (India). *Polyporus versicolor* fungi was obtained from Indian Agricultural Research Institute, Delhi.

Bamboo specimens measuring $5 \times 10 \times 100$ mm were cut from the middle section of the culm. All bamboo specimens were conditioned at 20°C and 65% relative humidity for 2 weeks. The specimens were free of knots and visible concentration of resins, and showed no visible evidence of infection by mold, stain, or bamboo-destroying fungi. All specimens were numbered

Fig. 1: Tank for dipping of bamboo samples

and weighed to the nearest 0.001 g. Samples were soaked in a cemented tank (7m x 3m x 0.8m) filled three forth with water (Fig. 1). The heavy weight was kept on bamboo culms to ensure complete soaking.

The tank was covered with polythene sheet for natural protection. Weights were placed on the samples to keep them submerged in water (Fig. 2). The water in the tank was replaced with fresh water every 7 days. Bamboo samples were taken out from the water tank after one month. Untreated specimens were used as control. After the treatment, specimens were reconditioned at 20°C and 65% RH for 2 weeks.

Samples were prepared according to American standards for Testing Materials (ASTM) protocols. Bamboo samples before and after water leaching were ground to fine particle size (40 to 60 meshes) to permit complete reaction of bamboo with reagents used in analysis. The sawdust was air dried for several days to let it attain constant weight prior to physico-chemical analysis. The powdered samples were stored in airtight containers for analysis.

Fig. 2: Weight provided to keep the
bamboo submerged

The chemical analysis was performed according to ASTM standard except for ligno-cellulose and starch content of bamboo. Each test was conducted using three replicates. Moisture content, water soluble, ash content, ethanol-toulene solubility, 1% alkali solubility and lignin were calculated using standard protocols of ASTM D 4442-92, 1110-84, 1102-84, 1107-96, 1109-84, 1106-96 respectively. Ligno-cellulose content was measured using method of elimination. The starch content has been investigated using the protocol recommended by Humphrey and Kelly (1961).

Attenuated Total Reflectance Fourier Transform Infrared Spectrometry (ATR-FTIR) of bamboo samples before and after water leaching was performed using a Perkin Elmer Spectrum One spectrometer. All spectra were recorded in the range of 650 to 4000 cm^{-1} with average of 16 scans per sample.

The microscopic structure of control and leached samples was investigated. Dried bamboo blocks were cut horizontally with a razor blade to expose the radial face and then coated with gold (Au) in a Polaron sputter-coater for approximately 65 to 70 Angström thick. The specimens were examined using ZEISS EVO Series Scanning Electron Microscope EVO 50. It uses a focused electron beam which scans the surface of the sample to produce high quality images of the surface topography. A strong beam of electrons called primary electron beam is produced by thermionic emission using either Tungsten or Lanthanum Hexaboride (LaB$_6$) filament.

Polyporus versicolor, the white rot fungi, was selected to test the durability of bamboo. The fungus was cultivated in Petri dishes on a Potato Dextrose Agar (PDA) medium until the nutrient was completely covered by mycelium. To prepare the cultured bottles, sand was washed with water until the wash was clear. The sand weighed 175 g/100 ml, a pH of 5.98 and 25% water-holding capacity. Glass jars (300 ml capacity) were filled with 100 ml sand.

The surface of the sand was then covered with a filter paper to serve as fungal feeder strip. The cultured bottles were sterilized, inoculated and incubated. The steam-sterilized samples of bamboo were transferred into culture sterilized bottles of fungus. Additionally untreated samples were also used in the process to determine the efficacy of treatment. After 12

weeks of fungal attack at 30°C and 70% relative humidity the specimens were collected. The adhering mycelium was scraped off and the specimens were oven dried, weighted till constant weight. Analysis to test the fungal resistance of the treated blocks was done as per ASTM D1413. Six matched replicates were taken from each treatment and for each fungus. Untreated blocks were taken as controls. Blocks were kept for conditioning in incubators at 70% relative humidity and 300°C to attain constant weight. On completion of a period of 12 weeks, test blocks were withdrawn from the cultured bottles. These blocks were cleaned carefully by brushing off the fungal mats. The samples were dried in warm air and conditioned to obtain constant weight. Percentage of weight loss was calculated for each block after fungal exposure.

RESULTS AND DISCUSSION

The moisture content of water treated bamboo samples was found to be high as compared to untreated due to long duration in contact with water.

In general bamboos possess a very high moisture content which is influenced by age, season of felling and species. Among these the season has a greater influence than any other cause. Moisture is at its lowest in the dry season and reaches a maximum during the rainy season. Bamboo contains large amounts of starch (about 2-6%) which makes bamboo highly susceptible to attack by staining fungi and powder-post beetles. Water treatment was found to be very effective with respect to starch leaching out from the bamboo culms.

Low starch in water leached bamboo indicates high decay resistance against pests (Table 1). The presence of high quantities of starch in untreated bamboo makes it more attractive to organisms, especially stain fungi and borer beetles. Cold water extractives in the bamboo include tannins, gums, sugars, colouring matter whereas hot water solubility include all this in addition to starch. Low water solubility in water leached bamboo protects the bamboo against attack by pests and insect as these substances acts like a food to them.

Hot alkali solution extracts the low-molecular weight carbohydrates consisting mainly of hemicelluloses and degraded cellulose in bamboo. The alkali solubility could indicate

Table 1: Chemical properties of *D. strictus*, bamboo species (The values in parenthesis represent standard deviation)

Property	Untreated	Chemical treated	Water treated
Moisture	6.2(0.4)	10.5(0.7)	11.4(0.5)
Ash	2.6(0.02)	3.8(0.1)	1.6(0.01)
Cold water solubility	6.2(0.5)	7.9(0.3)	2.4(0.3)
Hot water solubility	8.3(0.2)	9.3(0.2)	4.7(0.3)
Ethanol toluene solubility	4.9 (0.1)	2.9(0.1)	1.6(0.02)
1% Alkali solubility	30(1.4)	26(0.5)	24(0.7)
Starch	2.5(0.4)	2.4(0.6)	1.2(0.07)
Lignin	24(0.4)	25.9(0.2)	26(0.1)
Ligno-cellulose	53.0	56.0	62.3

the degree of degradation by a fungus or by heat, light, oxidation, etc. As the bamboo decays or degrades, the percentage of alkali soluble material increases. The solubility in 1% NaOH is very high for Indian bamboo i.e., 17-23%, 39.5% for *Bambusa blumeana* (Fengel and Shao 2008). Lowest alkali solubility of water-leached sample showed highest decay resistance while highest solubility of untreated bamboo specimens exhibited its lowest decay resistance. Lignin composed of three lignin units, p-hydroxyphenyl, guaiacyl, and syringyl in varying ratios. As a major component of the cell wall of tracheids, vessels, and fibres, lignin contributes to the compression strength of woody stems and to the waterproofing of conductive elements within the xylem. The high lignin concentration in the cell wall is beneficial for the fibreboard industries but disadvantageous in pulp and paper industry (Li, 2004). Water leached and chemically treated bamboo samples have a higher amount of lignin and ligno-cellulosic content as compared with untreated indicating a better structural rigidity and strength property. The results showed the efficacy of bamboo water treatment in terms of low starch, low water solubility, low alkali solubility but high lignin and lignocellulosic content in water leached bamboo if we compared these with untreated bamboo specimens.

Detailed SEM observations suggest that water leaching of bamboo specimens has removed the starch from cells of bamboo species. It is observed that untreated bamboo cells are filled, while in water leached samples, cells are empty (Fig 3). The removal of starch and other solubles in SEM photographs in is accordance with the results obtained by physico-chemical analysis.

The spectra of control and water leached bamboo samples were recorded as shown in Fig. 4. The most representative bands can be
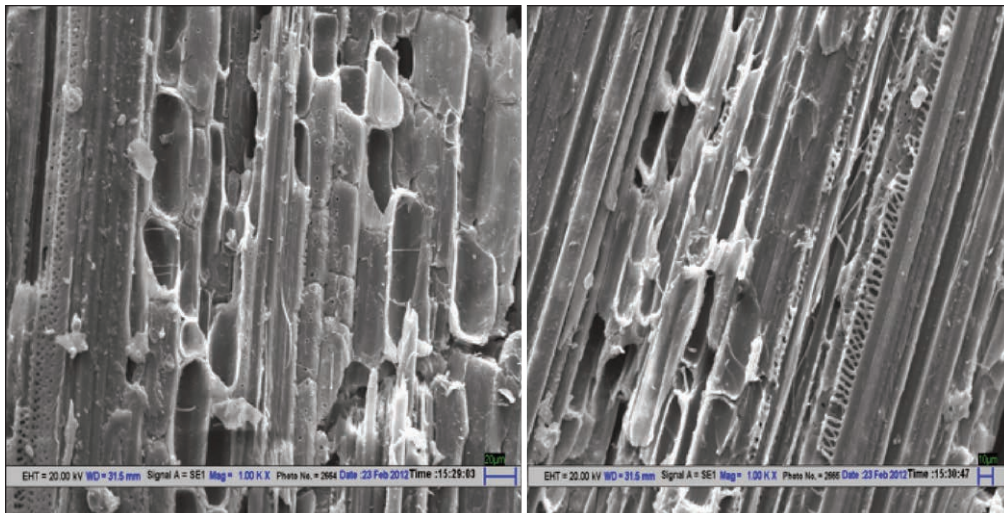

Fig. 3: SEM investigation of untreated (left) and water leached bamboo specimen (right)
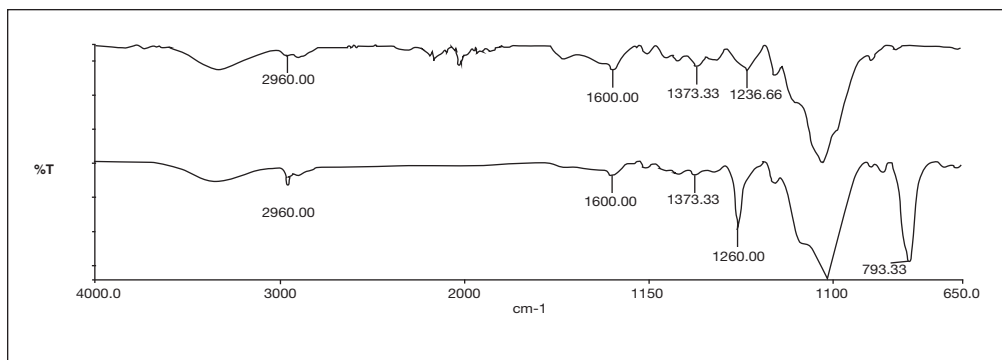
Fig. 4: Comparison of water leached samples (below) with untreated samples (above)

summarised as follows: the spectrum of bamboo shows the basic structure different from wood samples. Strong broad OH stretching (3300-4000 cm⁻¹) as observed in wood is not visible in *D. strictus* bamboo samples. C-H stretching in methyl and methylene groups (2800-3000 cm⁻¹) of wood is detected in bamboo. Absorptions centred at 1510 and 1600 cm⁻¹ (aromatic skeletal vibrations) are caused by lignin (Pandey and Pitman, 2003). Comparing the two spectra's, it is revealed that the leached samples have shown broader peaks, which is in accordance with qualitative assessment of lignin reported earlier. Broader strong peaks of 1000 cm⁻¹ are caused by O-H groups. This is because of absorption of moisture by water leached samples. Surprisingly, an additional sharp peak at 799 cm⁻¹ was observed for leached bamboo samples. This could be because of formation of C-H aromatic ring or presence of nitrogen compounds. The enhanced decay resistance of leached samples may be due to formation of this new group.

The decay resistance analysis of water leached samples has shown a marked improvement in weight loss of fungal exposure. Decay resistance of water treated bamboo sample was done twice. i.e during April and November months. Thus mean weight loss of water leached and chemically treated samples, was observed to be 9.6 (0.38) and 7.3 (0.44) respectively. The control showed severe degradation with weight loss of 55.6 (0.41). The fungal decay resistance of water-leached samples was found to be very high as compared to untreated samples and quite comparable to commercial chemically treated samples.

CONCLUSION

The preservation of bamboo by water leaching is an age old practice. The results from our study show its effectiveness to provide durability to bamboo under storage conditions. The physico-chemical analysis and SEM investigation shows the leaching of starch and water soluble components after dipping of bamboo species in water. The results are very encouraging. Interestingly, FTIR analysis indicates the presence of nitrogen compounds that might have helped to improve the decay resistance. Decay tests also confirmed the efficacy of water treatment method as only 9.6% decay occurred compared to 55.6% in control specimens. The decay resistance efficiency is almost comparable to chemically treated culms. It is hoped that this preliminary investigation on traditional bamboo treatment methods would open new avenues for eco-friendly, cost effective methods based on traditional knowledge of tribal community. Further research on the strength of bamboo after treatment in outdoor application is warranted.

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Adaptive Strategies of Reed Bamboos, *Ochlandra* spp., to the Western Ghat Habitats of India

B. Gopakumar[1, 2]*& Bhavna Motwani[1]

[1]CHM College 421003, University of Mumbai, Maharashtra, India
[2]Jawaharlal Nehru Tropical Botanic Garden and Research Institute 695562, Kerala, India

ABSTRACT

The endemic bamboos *Ochlandra travancorica* and *O. wightii* have developed many adaptive strategies, which help their successful co-existence with the wet terrains of Western Ghats, India. Data were collected from populations in the state of Kerala. Pachymorph rhizome with fibrous root system, monocarpy, gregarious growth, flowering and fruiting, production of baccate caryopses, adaptability to riparian life, hydrochory, fruiting in response to humid weather, absence of fruit dormancy and mycorrhizal association are understood to be successful strategies of reed bamboos. These reed bamboos were found ideal in protecting soils from sliding and eroding.

INTRODUCTION

The shrubby, thickly clumped, thin walled and large leaved members of the genus *Ochlandra* Thwaites are the major reed bamboos of India. They inhabit the wet hill slopes and river banks of Western Ghats. They are the much sought raw-material for traditional cottage industries and modern paper industries. In the State of Kerala itself these reed bamboos account for the livelihood of about 100,000 workers belonging to the socially and economically backward sections of the society (Seethalakshmi, 1978). Availability of reeds in the state is much less than the annual requirement of 314,000 tonnes (Surendranath, 2004). Of the 11 membered genus, 10 species including the *Ochlandra travancorica* (Bedd.) Benth. Ex Gamble and *Ochlandra wightii* (Munro) C.E.C. Fisch. are endemic to the Western Ghats of India.

They are monocarpic bamboos with intermast periods above 30 years (Bourdillon, 1899). They reproduce mainly through seeds produced at the end of a long vegetative growth phase. Even though many edaphic and biotic factors restrain their regeneration (Gopakumar and Motwani, 2013), they prove successful in recruiting offsprings. This is the result of curious growth and reproductive strategies, which we try to unveil here.

*Corresponding Author.

Details of Corresponding Author:
email: gopugokulamtbg@gmail.com

METHODOLOGY

Constant monitoring of the vegetative and flowering populations of *Ochlandra travancorica* and *O. wightii* in the Western Ghat hill ranges of Kerala, India from 2006 to 2013 is the source of data. This included flowering events of *O. travancorica* at Palode (N 08˚43'160", E 077˚01'538") and Kottoor [N 08˚35'159", E 077˚09'715") (35km apart) and *O. wightii* at Nanniyode (N 08˚41'573", E 077˚01'246") and Rose Mala [N 08˚56'570", E 077˚10'552") (70km apart). Light incidence over study plants was measured using Lutron LX 102 Light Meter. Pictures were taken with a Canon EOS 1000D camera. The fruit moisture and soil moisture was determined on weight basis. Clump details of plants at river banks and forest interiors were measured manually. Pollen count was performed following Prieto-Baena *et al.* (2003).

RESULTS AND DISCUSSION

From observations, some major features of these bamboo species were identified as strategies that help them to acclimatize, explore and contribute to the wet valleys of the Western Ghats, India. They are: 1. Pachymorph rhizome and fibrous root systems 2. Arching

culms and canopy with large leaves 3. Monocarpy or Semelparity 4. Gregarious growth, flowering and fruiting 5. Protogyny and mass production of pollen 6. Production of baccate caryopses 7. Absence of seed dormancy 8. Adaptability to riparian habitats 9. Hydrochory 10. Fruiting in response to wet, humid weather and 11. Association with mycorrhizae.

Pachymorph rhizome and fibrous root systems

A well branched subterranean pachymorph or sympodial rhizome system connects the upright separate culms in to a single unit, and gives out numerous fibrous roots. Each rhizome is an underground stem with compact nodes, having a swollen 'rhizome proper', producing roots and new branches, and a narrow connecting 'neck' portion. The rhizome initials start developing in response to pre-monsoon showers in *O. travancorica* and *O. wightii*. They grow and branch dichotomously (at 120° with respect to one another). This is repeated in successive years forming a series of irregular, open, polygons (Figs. 1 & 2), which could hold soil in between tightly from all sides. Clumps in the wild often consist of more than one seedling. In such cases, the rhizome system is multitiered (2-3) and interwoven. These, along with the tuft of fibrous roots keep the soil particles entangled, protecting them from eroding, better than other associated trees. The polygonal rhizome formations (shape known for its stability) and the ramifying root system anchor and stabilize the plant and soil firmly. Fibrous roots stitch the top soil together and keep it porous.

Fig. 1. Base of a dug out clump

Fig. 2. Two tiered rhizome system, overturned view

Further studies are needed to unravel details of growth and development of the subterranean system in *Ochlandra travancorica* and *O. wightii*. The thickened pachymorph rhizomes are advantageous in allowing greater storage potential (Stapleton, 1998), so that the plants can regenerate the plants even after felling. Reed bamboos, *Ochlandra* spp. are excellent soil binders in hilly riparian zones of Kerala (Gopakumar, 2013). Because of the extensive fibrous root system and clasping rhizomes, soil on the banks of water ways are protected from erosion.

Clumps of the species line both banks of rivers near the Ghats, stabilize soil and guard associated plant and animal lives. Sujatha *et al.* (2008) reported the role of reed bamboos in the development and fertility of soils and in its conservation. The authors suggest *O. travancorica* for revegetating lateritic soils as well.

Arching culms and canopy with large leaves

The culms constituting healthy clumps, in open areas, are arched to all sides and form an umbrella-like canopy. This helps bamboo plants to resist uprooting in winds, prevent tree seedling regenerations and assist formation of population climaxes. Culms of *O. travancorica* are rough externally (glaucous) and their apices whip like, which help them to adhere each other and to nearby tree branches. Also the large sizes of their leaves (Koshy *et al.* 2010) help to tap more light energy and survive damage from herbivory.

Monocarpy (Semelparity)

Monocarpy is the peculiar self-destructive reproductive outburst characteristic of certain plants, whereby the parents fruit and die at the end of long years of vegetative growth. Most bamboos, including the *O. travancorica* and *O. wightii* are monocarpic or semelparous in nature. Since reed bamboos are thin walled and reluctant to proliferate vegetatively, seeds form the suited means of propagation (Gopakumar, 2004). Bourdillon (1899) reported the intermast period of *O. travancorica* as 30-35 years and Iyppu (1964) as 20-25 years. This monocarpic nature help in recruiting new generation seedlings amidst extreme seed and seedling predation. Monocarpy reduces existence of predators to minimal number during every second reproductive instance. Also the associated parent death creates canopy openings, which assure receipt of sunlight to seedlings and thus their establishment (Fig. 3). Populations with high adult mortality often prefer semelparity to iteroparity (Young, 2010). Bamboos are such plants, which lose culms (individual stems of a bamboo clump) every year during their perennial growth period, 9 to 37 percent in thin walled bamboos (Banik, 1983), and this may be one of the reasons for their semelparity.

In bamboos the phenomenon of synchronous semelparity is attributed to predator satiation, which is also agreed upon by Young (2010). As in the case of crop plants, also in bamboos semelparity results in far higher seed production. Gadgil and Prasad (1984) suggested exponential plant growth, increased seed production and resultant parent death as reasons for evolution of a monocarpic life cycle in most bamboos.

Monocarpy also helps in opening up canopy, which renders seedlings ambient sunlight and thus assured establishment. The monocarpic nature of the *Ochlandra* members has been confirmed by Koshy & Mathew (2009), by ruling out the annual flowering nature of *O. scriptoria*.

Gregarious growth, flowering and fruiting

The reed bamboos usually grow, flower and fruit gregariously. Such gregarious growth enables *Ochlandra* plants to thrive despite extensive elephant browsing and human felling practices. The study species *Ochlandra travancorica* and *O. wightii* are gregarious and usually synchronous in growth and reproduction. Gregarious flowering allows profuse out crossing, thus genetic transfer leading to production of vigorous offsprings, which can compete among individuals of the same community and other plant communities. Gregarious flowering and thus fruiting (Fig. 4) is understood to be specially evolved to escape excessive seed and seedling predation through satiation. In addition, the gregariously semelparous nature of these species helps to establish more or less same aged offspring population, ensuring reproductive synchrony. It is observed that most seedlings of the species emerging under closed tree canopies could not survive because of insufficient light. Even with the inevitable parent death associated with monocarpy, absence of gregarious nature drastically reduces seedling survival. Even when the seeds and seedlings produced were subjected to high predation (Gopakumar and Motwani, 2013), the high number of produced seeds could result in successful recruitments.

Fig. 3. Clump died after fruiting

Fig. 4. Fruiting culms

The gregarious nature, combined with larger leaves of *Ochlandra* plants help them to withstand extensive elephant browsing and human felling practices (Koshy *et al.* 2010). Also this nature help to resist regeneration of trees and in tapping more light energy so as to develop in to climax formations. The gregariously synchronous flowering of bamboos allows cross-breeding, especially in the genus *Ochlandra*, characterized by bunches of stamens and pollen, suited for insect assisted anemophily. The cross-bread offsprings can contribute to the health of upcoming new population. This is advocated by Janzen (1976), where he finds reason for the gregarious nature of bamboo plant in effecting successful genetic exchanges through out-crossing. He added that clumps of bamboos that are spatially far from their cohort may suffer reduced pollination even if they flower in synchrony. Increased pollination efficiency and satiation of seed predators are described as the principal causes for mast seeding in perennial plants (Kelly, 1994).

The *Ochlandra* spp. inhabit constant environmental regimes such as those dense stands lining water courses. According to Gadgil and Prasad (1984), in *Bambusa bambos*, which occupies similar habitats synchronous flowering is advantageous in swamping predators. The riparian habitats are comparatively open or only with loose overhead tree canopies, thus suited for seedling regeneration. Iyppu (1964) also agreed upon the poor seedling regeneration under closed canopy.

Protogyny and mass production of pollen

The florets of *Ochlandra* spp. are tubular and protogynous (Fig. 5). In *O. travancorica* the female to male interval is found to be 2 to 5 days and in *O. wightii* 2 to 4 days. Stigma is 5-7 lobbed, wet and receptive during humid morning hours. The prolonged protogyny prevents selfing and allows only cross pollination. This cross pollination may be geitonogamous or allogamous. Cross fertilization improves genetic traits, thus offspring-vigour and therefore is advantageous.

This out-crossing amongst the *Ochlandra* plants is facilitated by the production of masses of pollen from each floret containing 50 to 70

Fig. 5. Floret in female stage

stamens, which on dehiscence (in the morning hours) release clouds of non-sticky anemophilous pollen (Fig. 6). The pollen grains get widely dispersed even by gentle breezes. Visits of pollenivorous bees facilitated the process. The pollen showed 80-100% initial viability and 59% viability at one hour after release. It was estimated that a single anther of both species contains an average of 4,000 pollen. The average number of anthers per flower is 60, against only one ovule. Therefore, the pollen-ovule ratio is 240,000:1.

The dichogamous and protogynous nature of *Ochlandra travancorica* flowers has been reported by Venkatesh (1984). He described the prolonged protogyny of the species as a 'seductive tactic' to invite alien pollen. Even though he reported the absence of female stage exposure in certain spikelets, its importance as a strategy in averting seed set during unfavorable times is a novelty of the present observation.

Up to a maximum of 120 stamens (pollen ovule ratio can be 480,000:1) and six types of pollenivorous visitors were reported in *O. travancorica* (Koshy *et al.* 2001). They belong

Fig. 6. Floret in male stage

to genera *Apis, Halictus, Trigona* and *Braunsapis*. Higher pollen production attracts them, which leads to more effective dispersal. The recent discovery of UV induced blue flourescence from the pollen grains of bamboos, especially *O. travancorica*, describes how insects get easily attracted towards them (Baby *et al.* 2013). Seed set is also facilitated by longer duration of pollen viability, 1 hour, in *O. travancorica*, which is higher than the existing report of 30 minutes (Beena & Seethalakshmi, 2011).

Production of baccate caryopses

A comparative account of the fleshy fruited *O. wightii* and dry fruited *Schizostachyum beddomei*, two semi-evergreen endemic Western Ghat (from Rose Mala) bamboos was done. Fruits of *O. wightii* (Fig. 7) are 4-8cm long, 1.5-3cm broad and weigh 3-13gms. Fruits of *S. beddomei* are only 0.5-1cm long, 0.1-0.2cm broad weighing only 0.2-0.3 gms. Fruits of both were shed to the bottom on ripening. They germinate and transform to seedlings on next few showers. Seedlings of both differ greatly. *S. beddomei* seedlings were only 1/10th that of *O. wightii* with much smaller leaves. The *O. wightii* seedlings can tap more available light energy and successfully establish (10%) in shaded forest floor, whereas the success is much less in *S. beddomei* (2%), causing decline in its population.

According to Harigopal and Mohanram (1987) production of baccate caryopses in fleshy fruited bamboo genera, including *Ochlandra* are advantageous, in having thick pericarp, a large scutellum and reduced endosperm. These 'bacciform caryopses' are considered a specialization for peculiar ecological conditions (Rudall and Dransfield, 1988). Observations showed that in *O. wightii* and *O. travancorica* fruiting intensified in response to pre-monsoon showers. At Palode, the *O. travancorica* fruited area, rain fall was 3,064mm and soil moisture 19-32% during 2010.

The production of larger fruits was described to be an adaptation for seedling survivorship at low light intensities (Foster, 1986). Foster added that the larger sized seeds in sub-canopy habitats provide energy for construction of large amounts of photosynthetic tissue or provide energy for growth in higher light intensity strata or provide nutrients for replacement of lost or damaged seedling tissues. The moisture availability also can cause upper limits on seed size. In addition to bulk production, the baccate nature of caryopses also help to satiate predators.

Absence of seed dormancy

The fruits of *O. travancorica* and *O. wightii* show no dormancy and germinate within a week of fall or rarely before (viviparous) during rainy season (Fig. 8). Rudall and Dransfield (1989) are of the opinion that the rapid germination (lack of dormancy) is advantageous in that the seedlings can have an edge on its competitors in the rain forest. The seedlings can readily take advantage of periods of high light intensity which follows. Both these observations are true with *Ochlandra* spp. in the Western Ghat habitats, where a seedling can come up only after competing with its kin and other seedlings; and that here they are best making use of the ambient high sunlight resulting from parent death.

Fig. 7. A mature fruit

Fig. 8. A viviparous fruit

Absence of seed dormancy helps the *Ochlandra* plants to best make use of their moist tropical surroundings. The fruits, formed in response to first few summer showers, mature by 30 days (April-May), fall and germinate soon in the continuing rains of South West Monsoon (June-July). This is in testimony of their recalcitrant nature as well. It is opined by Bellairs *et al.* (2008) suggest that absence of seed dormancy is a factor that may contribute to the general restriction of bamboos to regions with higher rain fall. He adds that seed dormancy may be disadvantageous for gregariously semelparous plants because it disrupts the high levels of reproductive synchrony needed for success.

Adaptability to riparian habitats

The *Ochlandra*, reed-bamboo, plants and the riparian habitats containing them are found to be mutually beneficial. The banks of hilly water-ways provide plenty diffuse sunlight and moist fertile soil, which results in healthy reed bamboo growth. In return the river bank soils are protected from eroding and sliding. A comparison between clumps in riparian and forest interior habitats clearly indicates the suitability of the former (Table 1).

Hydrochory

During reproductive phase, fruits borne on culms arching over streams/ rivers (Fig. 9) are subjected to desiccation under high ambient sunlight, so that they could float in river waters on fall (Fig. 10), enabling hydrochory, *ie.* seed dispersal through water currents. Only those fruits which receive sufficient high irradiation, due to their exposed position, could lower their

Fig. 9. Fruiting culms arched over river

moisture content below 40% (*ie.* 10-15% reduction) and could float. But fruits positioned under shade were unable to desiccate properly and failed to float. In addition, fallen fruits washed and deposited down along with litter, by flood waters, were found germinated.

Fruits fallen from clumps occupying hill slopes also were carried down by water currents created by heavy rains, common in those regions. For this fruits need not float, but the presence of 5 attached glumes is beneficial. Glumes also help fallen fruits in moisture retention and germination. Thus in *Ochlandra*

Fig. 10. Fruit carried down by river water

Table 1. Comparison of clumps.

Parameters / clump	Clumps under thick tree canopy		Clumps in partially open river banks	
	O. travancorica	*O. wightii*	*O. travancorica*	*O. wightii*
No. of culms	15-50	10-40	50-350	50-150
Height (m)	6-7	5-6	8-9	5-6
Basal Circumference (m)	2-6	1.5-5	8-12	4-10
Canopy circumference (m)	10-15	8-15	15-25	15-20
Light over canopy (μmol m^{-2}s^{-1}) [10.00am]	59.2-98.05	50.88-88.8	829.41-1054.5	253.45-791.8
Soil moisture (%)	19-21	28.1-29.2	27-28.5	29.7-31.6

spp. limited hydrochory is prevalent, supported by their riparian habitats. Water disbursement of reed bamboo fruits is a novel observation.

Fruiting in response to wet, humid weather

Many bamboos fruit once only in life time at the end of long years of vegetative growth period, determined genetically and environmentally (Janzen 1976). In the case of reed-bamboos, when the time is ripe, flowering is found triggered by summer (*ie.*, drought season). But summer is noticed by absence of seed set (negligible in number if developing under deep shade) caused due to the absence of proper stigma exposure and thus fertilization. But the situation changes all of a sudden with the onset of rains (summer rains), when florets differentiate at a greater pace, expose their stigma properly, leading to successful fertilization and fruit set. Intermittent clear sun and showers increases humidity to 80 to 95% during morning hours. At an average of 30 days time fruits ripe and start falling, resulting a masting (peak fruiting). Annual rainfall in Kerala part of the Western Ghats is above 3000mm; extending most part of the year (April to November, 8 months) which ensures high humidity, suited for reed bamboos.

Association with mycorrhizae

Roots of *O. travancorica* were associated with 5 to 8 arbuscular mycorhizal fungal species in the soils of Western Ghats (Rajeshkumar *et al*. 2013). The mycorhizal fungi facilitates nutrient intake and growth in plants. Terminal feeder roots and rhizosphere soil samples (pH 3.9–5.6.) of *Ochlandra travancorica* collected during 2011 from different localities in Kerala State revealed the presence of nine AM fungal taxa, namely, *Claroideoglomus etunicatum, Glomus aggregatum, G. boreale, G. macrocarpum, G. multicaule, G. tortuosum, Sclerocystis clavispora, S. rubiformis* and *S. taiwanensis.* Root colonization was 42–72 % and extensive hyphal and vesicular stages were observed. The extra-radical hyphae were hyaline and dichotomously branched on root epidermis. The hyphal coils were observed in cortex cells as well. Similar positive results were obtained in *O. wightii* as well.

CONCLUSION

The "elephant grasses", *Ochlandra travancorica* and *O. wightii* have developed a number of adaptive strategies, which contribute to their healthy co-existence with the endemic habitats of Western Ghats, India. These reed bamboos keep soils wet and porous and protect them from sliding and eroding. Hence *Ochlandra* spp. are priority plants to be conserved and used in river bank protection programmes. Water current as the chief seed dispersal agent, polygonal rhizome formations, absence of proper stigma exposure at summer to avert seeding, etc are novel perceptions about these bamboos.

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Flowering occurrences of *Bambusa cacharensis* in Barak Valley, Assam, India since its type collection: a note

Moonmee Devi and Debjyoti Bhattacharyya*

Plant Taxonomy and Biosystematics Laboratory,
Department of Life Science & Bioinformatics,
Assam University, Silchar 788 011, Assam, India

ABSTRACT

Sporadic flowering in *Bambusa cacharensis* R. B. Majumdar was noticed during last three years in Barak Valley region of Assam, India. At least about sixty clumps were found in flowering state from the region without any seed setting. In this present paper, data on the flowering of this species are provided since its type collection. Frequent flowerings during last three years and subsequent death of the species or weakness of clumps enhanced its vulnerability rate in their natural habitats. As the species is distributed in a small geographical region, germplasm erosion of the species may occur due to its large-scale, frequent flowering. Hence, vegetative propagation methods are encouraged to safeguard this species from extermination.

INTRODUCTION

The Barak Valley region of Assam, India comprises three districts viz. Cachar, Karimganj and Hailakandi. Out of this, district Cachar is the type locality of *Bambusa cacharensis* R. B. Majumdar. Field surveys conducted in the region during January 2010 to April 2013 revealed that more than sixty clumps of *B. cacharensis* were in flowering state without any seed setting. The flowering of the species was sporadic in nature where blooms occurred either in isolated clumps or in parts of one clump. More flowering occurrences of this bamboo are expected in near future from the region.

Bambusa cacharensis [Vernacular name: *Betua* (Bengali)] is one of the important and dominant bamboos in Barak Valley where maximum home gardens are occupied by this species (Fig. 1A). The species is also distributed in Brahmaputra Valley of Assam (Majumder 1983; Shukla 1996; Barooah and Borthakur 2003), Meghalaya (Kharlyngdoh and Barik 2008), Manipur (Naithani *et al.* 2010) & Tripura (Anonymous 2013) of India and in Bangladesh (Alam and Hassan 1994).

Bambusa cacharensis R. B. Majumdar in Bull. Bot. Surv. India 25: 237. 1983; D. N. Tewari, A Monograph on Bamboo: 36. 1992; U. Shukla, The Grasses of North-Eastern India: 181. 1996; K. K. Seethal. & M.S.M. Kumar, Bamboos of India: a compendium: 49. 1998; Barooah & Borthakur, Diversity and Distribution of Bamboos in Assam: 54. 2003.

The species was described by R. B. Majumdar from a collection made by him from Lockhipur area of Cachar district of Assam. The species is a tall, straight and scarcely branched, loosely tufted bamboo. Leaves linear-lanceolate, 11-18 x 1.3-2 cm, attenuate at base, acute-acuminate at apex, scabrous on ventral surface with main vein prominent at

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*Corresponding Author.

Details of first author:
e-mail: moonmee25devi@gmail.com
Phone: +919854212277 (Cell.)

Details of Corresponding Author:
Dr. Debjyoti Bhattacharyya
Assistant Professor
Room No. – 215; 1st Floor
Department of Life Science & Bioinformatics
Assam University
Silchar 788 011, Assam, India
Phone: +91-3842-270823 (O); +919401437473 (Cell.)
E-mail: debjyoti_bsi@yahoo.co.in

Fig. 1. *Bambusa cacharensis* R. B. Majumdar. A. Species in the home garden. B. Culm with culm sheaths.
C. Culm sheath: close up. D. Full blooming culm. E. Died culm after full bloom. F. Partially blooming culm.
G. Spikelets before opening. H. Spikelets after opening showing drooping versatile anthers. I. Strong, healthy
culm in vegetative stage. J. Culm arising from weakened clump after blooming. K. Felling of the species by
the local villagers after flowering.

least up to middle portion; secondary veins 4-5 pairs on either side; intermediate veins 9-10; leaf sheath striate, glabrous, entire at margin; auricle small with long bristles; ligule c. 0.5 mm long, entire. Culm sheath deciduous, sheath proper variable in size, 12-17 cm long, 26-32 cm broad at base, gradually attenuate upwards, 13-20 cm broad at apex, ciliate at one side at margin, glabrous at other side, densely hairy abaxially; hairs deep brown, sharp, appressed, spicular. Imperfect blade 4-12 cm long, 13-20 cm broad at base, triangular, acuminate at apex, ciliate at margin, densely hairy abaxially; hairs orange-yellow, sharp. Auricles wavy, c. 2 cm long, 4-7 cm broad at base, erect, hairy at outer surface, ciliate with thick, rigid, stiff hairs at margin; ligule c. 3 mm broad, entire. Inflorescence branched panicles with cluster of spikelets. Spikelets many flowered, glossy green, 3.5-4 cm long with terminal immature floret. Lower glume c. 6 x c. 3 mm; upper glume ovate-lanceolate, 7-9 x 3.5-4 mm, entire, glabrous, mucronate, 14-20 nerved; lemma lanceolate to oblong, c. 13 x 6 mm, mucronate, 16-18 nerved, glabrous; palea 2-keeled, c. 12 x c. 4 mm, ciliate at keels at upper half portion, glabrous on both surfaces, smooth at margins; rachilla c. 4 mm long, pubescent, ciliate at apex; lodicules 3, oblong-obovate, 5-8 x 1-2 mm, fimbriate at apex, hyaline; stamens 6; anthers 4-5 x c. 1 mm, basifixed; ovary oblong-ovate, 2-5 x c. 1 mm, pubescent at upper half portion; style short, pubescent; stigmas 3, 3-5 mm long, plumose.

Due to its scarce branching pattern, straight and loosely tufted culms (Figs. 1B, 1C), the species is used in the construction of house and roofing, thatching, wall partitioning, scaffolding, basket making, etc. Leaves are used as fodder for cattle and goat. The edible young shoots are an important component of the traditional delicious dishes of several tribal communities inhabiting in the area. Mature culms of this bamboo species are especially used for long term preservation of dry processed fish (Singha *et al.* 2003).

OBSERVATIONS

We collected flowering twigs as well as vegetative parts of *B. cacharensis* from thirteen different clumps from Cachar district and one from Karimganj district. Table 1 shows the flowering occurrences of this species in Barak Valley since its first collection and description.

It was found that in all the clumps, two to three culms were in full bloom from their nodes. Most of the culms flowered from their branchlets. In full bloomed culms, all the nodes from base to apex were with flowering spikes without any leaves (Fig. 1D). After attaining maturity, some culms became yellow and ultimately died (Fig. 1E). In others, flowers remained only at few nodes or at branches/branchlets (Fig. 1F). These flowering clumps instead of dying became weakened, less vigorous and smaller than its normal size and height.

No seed setting of one third of the pollen grains resulted after successful flowering of the species. The failure of the seed set may be due to close overlapping of lemma and palea encircling pistil, sterility of 1/3rd pollen grains and dry nature of stigma (Singha *et al.* 2003); it may also be due to presence of comparatively long filaments and drooping nature of anthers (Figs. 1G, 1H) which retard effective pollination.

It is not always true that the bamboo dies after flowering; if the original clump is well established and vigorous, it overcomes the possibility of death after blooming (Lawson 1968) but becomes considerably weakened (McClure 1966). The phenomenon of either death or weakness of clumps subsequently after blooming was also noticed in *B. cacharensis* during last three years of field surveys. In vegetative stage, the culm circumference measured about 23-26 cm whereas the same in weakened culms (which arise after flowering) seldom exceeds 12 cm (Figs. 1I, 1J).

CONCLUSION

Due to large-scale frequent flowering, although of sporadic type, there may be occurrence of weak clumps and even death of this species in a particular geographical region. If the culms become weak, it will not be of any use for mankind which may create an economic disparity to the local poor people. Moreover, felling of bamboos by the local villagers after flowering (Fig. 1K) is a common practice due to enhanced activities of the rodents and superstitious belief on evil's power.

Owing to its smaller geographical distribution, germplasm erosion of this species may occur from the region due to its frequent flowering. Lack of seed setting is another probable cause

Table 1: Flowering occurrences of *Bambusa cacharensis* in Barak Valley, Assam. The voucher specimens collected by the present authors during present investigation are housed in the Herbarium of Assam University, Silchar, India.

District	Locality	Year of flowering	Voucher Specimens/ References
Cachar	Lockhipur, Mar Bastee; Lockhipur Steamer Ghat	Aug.-Sept., 1978	*Majumder* 74265 A (Holotype, CAL!)
	Exact locality not mentioned	1993-1995	Singha *et al.* 2003
	Dargakona; near Assam/ University Campus	Aug., 2010	*M. Devi & D. Bhattacharyya 10603*
	Meherpur	May, 2011	*M. Devi 10690, 10691, 10692*
	Amraghat, on way to Bhuban hills	Feb., 2012	*M. Devi 10800*
	Salganga; towards foothill of Barail Range	Apr., 2012	*M. Devi 10889*
	Dargakona	Apr., 2012	*M. Devi 10910, 10911, 10912, 10913, 10914, 10915*
	Chandighat, on way to Madhura Koari	Apr., 2013	*D. Bhattacharyya & Party 11061*
Karimganj	Patharkandi, Madhuban	Oct., 2011	*M. Devi 10765*

of population deterioration which may lead the species to the threatened category. So, germplasm conservation of this species becomes inevitable not only for strengthening the economy but also for conservation of genetic backup of this bamboo. Vegetative propagation methods are encouraged to safeguard the species from being exterminated in future. *In vitro* culture technique can also be practiced for better sustenance of this species in its type locality.

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