



Original Article

Survey of flood-tolerant bamboos in 2011 flooding in Thailand

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ABSTRACT

This survey work was undertaken in 2013 but has never been published. Several places that suffered from the 2011 Thailand floods were surveyed during December 2012 to March 2013 to identify potential bamboo species that could tolerate flooding stress. In total, 23 survey points were investigated, mainly in those places where flooding persisted for relatively long periods. These also included another flood-prone area in the riparian forests along the Mun River, northeastern Thailand. Ten bamboo species were found in the study areas. Some bamboo species in the genus *Bambusa* were more flood-tolerant than those from other genera. The relatively well-known multi-purpose bamboo species, *B. beecheyana*, was the most flood-tolerant and it appeared that it could withstand being flooded for at least 5 mth.

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Introduction

Now, there is no doubt that climate change is human caused and that a severe result of climate change is flooding, which causes the death of both agricultural crops and forest plants and consequently can lead to food and wood shortages (The Intergovernmental Panel on Climate Change, IPCC, <http://www.ipcc.ch/>; Wheeler and von Braun, 2013). Even though terrestrial plants have aquatic origins, only about 1–2% of the extant angiosperms are aquatic (Cook, 1999; Colmer and Voesenek, 2009; Jackson et al., 2009; The Plant List, 2010). However, some land plants can tolerate flooding too and bamboos are among them (Franklin et al., 2010).

Due to their high species diversity, wide distribution and availability, rapid growth and easy handling, bamboo is centrally involved in human daily life, especially in Asia, America, and Africa, where they grow naturally, so that consequently, bamboo is recognized as one of the best multi-purpose plant species in the world (Kurz, 1876; Dransfield and Widjaja, 1995; Rashford, 1995; Wong, 1995; Sungkaew et al., 2011). Bamboo is also regarded as a potential crop for flood-prone areas and as a suitable material for flood countermeasures. However, to date, there are few studies on

this specific topic available (Franklin and Hogarth, 2008; Franklin et al., 2010; Banik, 2015). In Thailand, bamboo has been involved in the everyday life of Thai people from ancient time to the present (Sungkaew et al., 2011) and has been used in many applications including as food and construction material and in musical instruments, furniture and handicrafts (Wong, 1995; Sungkaew et al., 2011).

Following the widespread flooding in Thailand in 2011, bamboo was acknowledged as one of the most useful plants that both people and animals can use during such hard times; however, at that time, such knowledge was relatively vague (Forestry Research and Development Bureau, 2009; Sungkaew et al., 2011; Deechaoen, 2014). Despite the lack of data, this study focused on the flood-tolerant bamboo species which can survive in flood-prone areas and specifically their period of submergence and the depth of flooding.

Material and methods

Field surveys on potential bamboo species that can tolerate flooding were made during December 2012 to March 2013 in flood-prone areas, particularly in Phitsanulok, Chainat and Phra Nakhon Si Ayutthaya provinces. Bamboo species in riparian forests along the Mun River of northeastern Thailand were also investigated.

Primary data of flood-tolerant bamboo species were directly observed and documented in the study areas. Plant specimens were

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collected for identification using classical herbarium techniques. At each survey point, information was collected about the utilization of each bamboo species, vernacular names and parts used by the indigenous people together with some secondary data from relevant publications.

Results and discussion

In total, 23 survey points, in four regions of Thailand, were observed (6 in the north, 5 in the northeast and 12 in central and eastern Thailand) as shown in Fig. 1. All the bamboo species found in this study were of mature size (Ohrnberger, 1999; Sungkaew et al., 2011).

Central region

In Ang Thong province one survey point was chosen in Ratchasathit municipality, Chai Yo district (47P: 654501.09 m E/1623078.57 m N). The flood levels were around 1–2 m high in 2011. This area was affected by flooding for 4 mth. *Bambusa beecheyana* Munro and *B. blumeana* Schult. f. were identified as flood-tolerant species.

In Phra Nakhon Si Ayutthaya (Ayutthaya) province, three survey points were selected in Kob Chao municipality, Bang Ban district (47P: 658883.87 m E/1587383.05 m N), Singhanat municipality, Lad Bua Luang district (47P: 651524.57 m E/1564930.17 m N) and Phai

Phra municipality, Bang Sai district (47P: 655221.68 m E/1572134.66 m N). The flood levels were around 1–2 m high during the 2011 Thailand floods. These areas were submerged for 2–4 mth. Two bamboo species (*B. beecheyana* and *B. blumeana*) were identified as flood-tolerant.

In Chainat province, three survey points were selected in Wung Man municipality, Wat Sing district (47P: 599745.84 m E/1679284.47 m N), Makham Tao municipality, Wat Sing district (47P: 612526.46 m E/1685947.49 m N) and Khao Kaew municipality, Sapphaya district (47P: 639194.05 m E/1674702.18 m N). The flood levels were around 0.5–2 m high. These areas were submerged for 1 wk to 4 mth. Three flood-tolerant bamboo species were identified: *B. beecheyana*, *B. blumeana* and a tentative hybrid species *Dendrocalamus membranaceus* × *Thyrsostachys siamensis* (Dr. Somran Suddee, pers. comm.), known in Thai as ‘pai liang’.

In Nakhon Pathom province, two survey points were selected in Salaya municipality, Buddha Monthon district (47P: 642779.17 m E/1523362.88 m N) and Bang Phasi municipality, Bang Len district (47P: 633809.15 m E/1548028.85 m N). The flood levels were around 1–2 m high. These areas were affected by flooding for 1–2 mth. Six bamboo species were found alive in the areas surveyed: *B. bambos* (L.) Voss, *B. beecheyana*, *B. blumeana*, *B. vulgaris* Schrad., *B. longispiculata* Gamble and *Thyrsostachys siamensis* Gamble.

In Prachin Buri province, two survey points were selected in two villages (Wung Hang and Nong Ean) in Na Kham municipality,

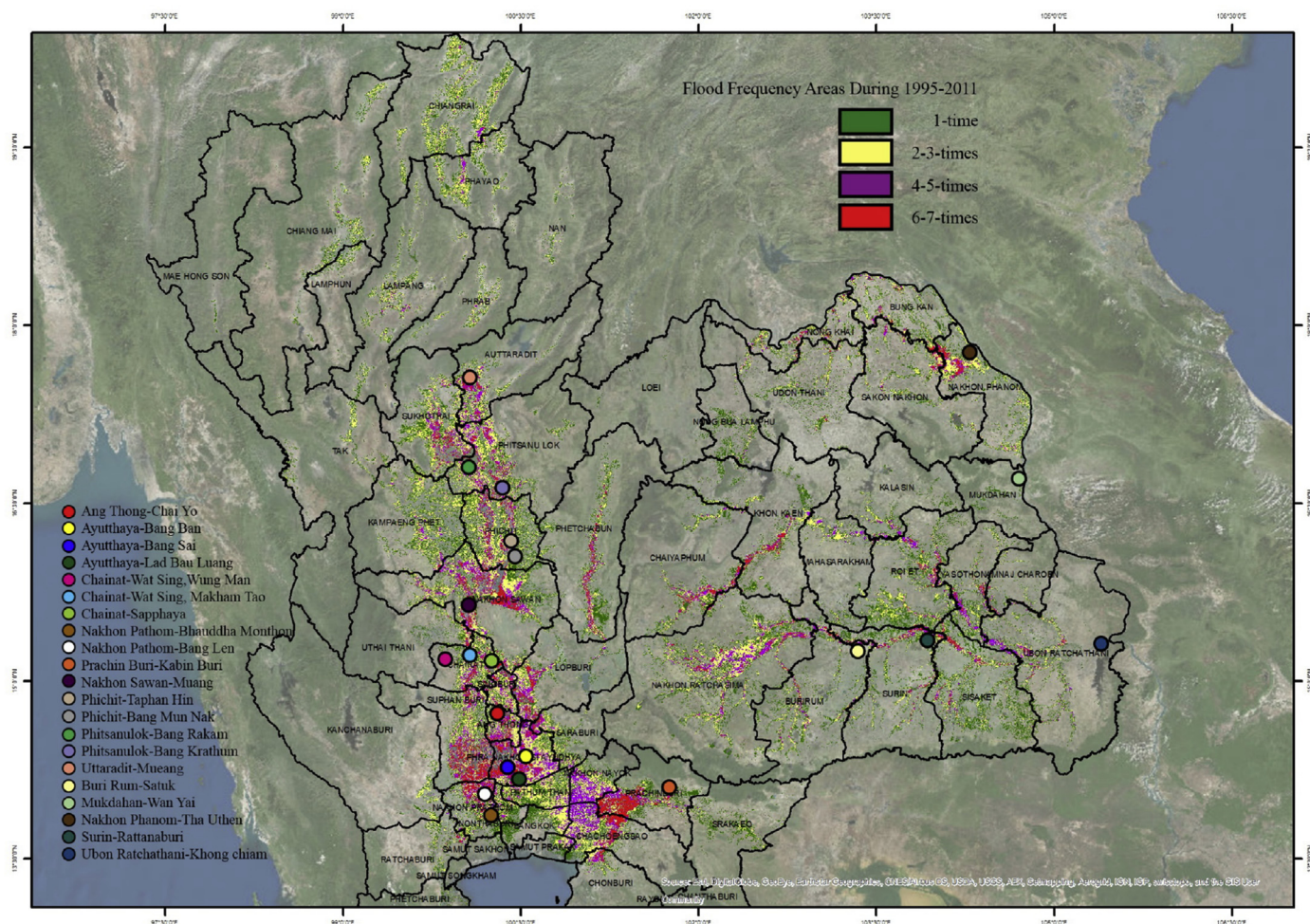


Fig. 1. Map of areas of repeated flooding in Thailand during 1995–2011 showing survey points (eastern region is omitted, adapted from <http://flood.gistda.or.th>).

Table 1

Species, local names, habitats, local uses and flooding condition of bamboos identified at the survey points.

Species	Local name	Habitat	Local uses	Province	Clump height (m)	Culm diameter (cm)	Flooding depth (m)	Flooding period
<i>Bambusa bambos</i> (L.) Voss	Pai pa, Pai nham	Cultivated, usually found close to the river	Construction, handicrafts, fencing	Nakhon Pathom, Phitsanulok, Buri Rum, Mukdahan, Nakhon Phanom, Surin and Ubon Ratchathani	10.0–25.0	5.0–15.0	1.0–5.0	1.0–5.0 mth
<i>B. beeheyana</i> Munro	Pai kim sung, Tong luem laeng	Cultivated	Food, charcoal, chopsticks, BBQ skewers, incense sticks	Ang Thong, Ayutthaya, Chainat, Nakhon Pathom, Phitsanulok and Trat	7.0–15.0	7.0–12.0	0.5–2.0	1.0–5.0 mth
<i>B. blumeana</i> Schult.f.	Pai si-suk	Cultivated, usually found close to the river	Food, construction, handicrafts, fencing	Ang Thong, Ayutthaya, Nakhon Pathom, Prachin Buri, Chainat, Nakhon Sawan, Phichit, Phitsanulok, Uttaradit and Trat	15.0–25.0	5.0–15.0	0.1–2.0	1.0–5.0 mth
<i>B. cf. flexuosa</i> Munro	Pai kasa	Riverbanks and riparian forests	Food, prevent riverbank erosion	Buri Rum, Mukdahan, Nakhon Phanom, Surin and Ubon Ratchathani	5.0–10.0	3.5–7.5	1.0–5.0	1.0–2.5 mth
<i>B. longispiculata</i> Gamble	Pai lam malok	Cultivated	Plant support, mussel farming, blocking waves, furniture	Nakhon Pathom and Trat	10.0–12.0	4.0–7.0	0.5–2.0	1.0–2.0 mth
<i>B. vulgaris</i> Schrad.	Pai kam yan	Cultivated	Construction, fencing	Nakhon Pathom and Phitsanulok	10.0–20.0	5.0–10.0	1.0–2.0	1.0–5.0 mth
<i>Dendrocalamus</i> sp.	Pai sang-mon	Cultivated	Furniture	Uttaradit	10.0–20.0	5.0–10.0	0.1–0.2	1.0 wk
<i>Schizostachyum brachycladum</i> (Kurz) Kurz	Pai thong	Cultivated	Ornamental plant	Prachin Buri	5.0–15.0	4.0–6.5	1.0	2.0–3.0 wk
<i>Thyrsostachys siamensis</i> Gamble	Pai ruak	Cultivated	Food, construction, handicrafts, fencing, furniture	Nakhon Pathom and Prachin Buri	3.5–7.0	2.0–3.5	1.0–2.0	1.0 mth
<i>D. membranaceus</i> × <i>T. siamensis</i> (tentative hybrid)	Pai liang	Cultivated	Food, construction, handicrafts, fencing	Prachin Buri, Chainat and Phitsanulok	5.0–10.0	2.0–4.0	0.5–2.0	2.0 wk

Table 2
Bamboo categories, classified by their tolerance to flooding duration^a.

Species	Local Name	Bamboo categories
<i>Bambusa bambos</i> (L.) Voss	Pai pa, Pai nham	2
<i>B. beecheyana</i> Munro	Pai kim sung, Tong luem laeng	2
<i>B. blumeana</i> Schult.f.	Pai si-suk	2
<i>B. cf. flexuosa</i> Munro	Pai kasa	2
<i>B. longispiculata</i> Gamble	Pai lam malok	2
<i>B. vulgaris</i> Schrad.	Pai kam yan	2
<i>Dendrocalamus</i> sp.	Pai sang-mon	1
<i>Schizostachyum brachycladum</i> (Kurz) Kurz	Pai thong	1
<i>Thyrsostachys siamensis</i> Gamble	Pai ruak	2
<i>D. membranaceus</i> × <i>T. siamensis</i>	Pai liang	1

^a Bamboo categories, classified by the flooding period the bamboos can tolerate (flood level at 0.3–1.5 m high), where 1 = intolerant (<1 mth) and 2 = tolerant (>1 mth).

Kabin Buri district (47P: 794126.92 m E/1548523.03 m N). The flood levels were around 1 m high. The areas had been submerged for 2 wk to 1 mth. Four flood-tolerant bamboo species were found: *B. blumeana*, *T. siamensis*, *Schizostachyum brachycladum* (Kurz) Kurz and *D. membranaceus* × *T. siamensis*.

Northern region

In Nakhon Sawan province, one survey point was selected in Takhiean-luean municipality, Muang district (47P: 614024.89 m E/1727581.05 m N). The flood level was around 1 m high in 2011. This area was affected by flooding for 3 mth. The only flood-tolerant bamboo species identified was *B. blumeana*.

In Phichit province, two survey points were identified in Pai Luang municipality, Taphan Hin district (47Q: 650180.91 m E/1790767.75 m N) and Phum municipality, Bang Mun Nak district (47Q: 653273.55 m E/1773018.00 m N). The flood levels were around 0.3–1.5 m high during 2011. These areas were submerged for 1–3 mth. Only *B. blumeana* survived.

In Phitsanulok province, two survey points were investigated in Chum Saeng Songkhram municipality, Bang Rakam district (48Q: 612459.62 m E/1860691.47 m N) and Nakhon Pamak Bang municipality, Bang Krathum district (47Q: 644289.46 m E/1833721.01 m N). The flood levels were around 1.5–2 m high. These two places were submerged for 2–5 mth. Four bamboo species survived during the extended flooding: *B. bambos*, *B. beecheyana*, *B. blumeana* and *B. vulgaris*. Another species, *D. membranaceus* × *T. siamensis*, survived only for 2 wk.

In Uttaradit province, one survey point was selected in Wang Kaphi municipality, Muang district (47Q: 616908.74 m E/1938779.80 m N). The flood levels here were around 10–20 cm high during the flooding. Some of these areas were submerged for 0.5–1 mth. Only *B. blumeana* survived after 1 mth flooding, while *Dendrocalamus* sp. withstood flooding for 2 wk.

Northeastern region

Five survey points were inspected in: Sa-kae municipality, Satuk district, Buri Rum province (48P: 324569.97 m E/1696315.50 m N), Chanod municipality, Wan Yai district, Mukdahan province (48Q: 471156.12 m E/1849491.92 m N), Chaiyaburi municipality, Tha Uthen district, Nakhon Phanom province (48Q: 442789.11 m E/1950697.37 m N), Yang Sawang municipality, Rattanaaburi district, Surin province (48P: 392379.51 m E/1689123.21 m N) and Khong Chiam municipality, Khong Chiam district, Ubon Ratchathani province (48P: 550639.80 m E/1689572.01 m N). The flood levels were around 1–5 m high during the flooding. These areas were submerged for 1–2.5 mth. Two bamboo species were found alive: *B. bambos* and *B. cf. flexuosa* (or 'pai kasa').

Eastern region

Thep Nimit municipality, Khao Saming district, Trat province (48P: 221822.99 m E/1377114.40 m N) was selected as the survey point. The flood level was around 50 cm high during 2011. The area had been submerged for 1 mth. Three bamboo species were found alive: *B. blumeana*, *B. beecheyana* and *B. longispiculata* Gamble.

In total, 10 different bamboo species were found alive after the 2011 Thailand floods. Their local names, botanical names, origins, habitats and utilization are listed in Table 1. These species were also placed into three categories according to their ability to resist flood damage (Table 2). The species belonging to the genus *Bambusa* seemed to be more flood-tolerant than those of the other genera. A bamboo endemic to Australia from this genus, *B. arnhemica*, also grows on flood-prone river banks (Franklin and Hogarth, 2008). However, information about the flooding duration bamboo can withstand is relatively scarce (Franklin et al., 2010; Ohrnberger, 1999).

Plants have several means to cope with flooding stresses (Jackson et al., 2009; Colmer and Voesenek, 2009). In the case of domesticated rice (*Oryza sativa* L.), in the same family (Poaceae or the so-called Gramineae) as bamboo, there is a *Sub1* locus on chromosome 9 which helps coding for ethylene-response factors that influence the vigor of the elongation response to submergence by various organs of the shoot (Fukao et al., 2009; Jackson et al., 2009). This helps that rice species to survival extended flooding periods. In the case of bamboo, however, study on how they can deal with flooding stress still needs further investigation.

Of the 10 bamboo species found to have survived in the flood-prone areas, some species of the genus *Bambusa*, especially *B. bambos*, *B. blumeana* and *B. beecheyana*, were more flood-tolerant than the others, as these three species bamboos could withstand flooding for at least 5 mth at a flood level of 1 m high. *Schizostachyum brachycladum* and *T. siamensis* should be regarded as flood-intolerant species based on the current study as they could withstand flooding for less 1 mth. The genus *Dendrocalamus*, represented by *Dendrocalamus* sp. or 'pai sang-mon' seemed to be the weakest bamboo species at surviving flooding found in this study as it was able to withstand flooding for only around 2 wk and died soon after that.

The bamboo species identified were used mainly for construction and food. Local people also used bamboo to produce tools, furniture, handicrafts (such as baskets and hats), fencing, plant support and fishing poles. The most popular species for its shoots and culms was *B. beecheyana*, where the culms were used for charcoal production and producing toothpicks, disposable chopsticks, bamboo skewers and incense sticks among other implements. *Thyrsostachys siamensis* and the tentative hybrid species *D. membranaceus* × *T. siamensis* were usually used for food and construction. *Schizostachyum brachycladum* was only used as an ornamental plant.

Some species such as *B. bambos* and *B. blumeana* were very useful both for young shoot consumption and the culm was used for

handicrafts and construction. However, most of the bamboo clumps were neglected because they had spines and were relatively difficult to manage. Proper methods for culm and clump management (for example thinning) should be applied and the bamboo clumps would then provide a higher yield to the people. Moreover, in order to avoid the issue of gregarious flowering, the quality of seedlings or planting materials should be taken into consideration (Janzen, 1976; Dransfield and Widjaja, 1995; Wong, 1995; Sungkaew et al., 2011).

Knowing which bamboo species are potentially flood tolerant could help in deciding which species to choose and where to grow them in order to deal with or avoid flooding. Furthermore, the results of this study can be used as a reference to investigate which bamboo species that may be suitable for dry areas. Rubaiyath Bin Rahman and Zhang (2016) recently mentioned that the two apparent opposite stresses (flooding and drought) in plants may be regulated by the same signaling pathways. This could be important in terms of food, wood and also energy security.

Conflict of interest

The authors declare that there are no conflicts of interest.

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