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### Bamboo witches' broom disease in the Philippines, its spread and what we need to do

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#### Abstract

Bamboo witches' broom disease (BWBD) was first recorded in the Philippines from Laguna Province in 1995. The symptoms include infected branches showing excessive clustering of smaller branches and leaves. Affected culms also break when they give way to the weight of heavy witches' brooms hanging. It was popularly assumed then as caused by mycoplasma like organism (MLO). Recent molecular characterization, however, identified the pathogen as a phytoplasma. Past surveys showed that BWBD affected only two bamboo genera, *Gigantochloa* and *Dendrocalamus*. Usually, the incidence is high where the species are abundantly growing. For example, *G. levis* is abundant in Quezon and *D. asper* in Davao, South Cotabato and Bukidnon. After 20 years, a few cases with similar appearance were observed in *Dendrocalamus merrillianus* (= *Bambusa merrilliana*) and *Bambusa spinosa*. However, the spread among *Bambusa* spp. is minimal unlike in *G. atter* and *G. levis*. The declining natural stands of *G. levis* in Quezon province may have been caused by BWBD. However, the spread is alarming in *Dendrocalamus asper* as observed by the increasing number of clumps infected by BWBD especially in the Davao area going to Bukidnon. Clumps in Lake Sebu, South Cotabato are also vanishing, and they were first observed to be heavily infected in 1999. Lately, planting propagules of *D. asper* are being transported around the country. This poses a great danger of spreading BWBD. Precautionary measures must be in place as phytoplasma is systemic in nature and can be transmitted using infected bamboo propagules. Potential vectors among locally occurring insects and other arthropods should be surveyed, along with transmission studies. With these developments and with the current increasing interest in bamboo, there is a need to continue this research on BWBD and its insect vectors. The supply of quality bamboo may be affected in the future if BWBD is left unchecked.

**Keywords:** Bamboo; Phytoplasma; Vectors; Broom Disease; Philippines

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## 1. Introduction

Bamboo witches' broom disease (BWBD) is increasingly becoming a threat to bamboo production in the Philippines ever since it was first recorded from Laguna Province in 1995 (Sinohin 1995). The symptoms include infected branches showing excessive clustering of smaller branches and leaves. They give way to the increasing weight of heavy witches' brooms hanging/dangling and this even causes breakage of the culms. BWBD is popularly assumed then as caused by mycoplasma like organism, MLO (Mohanani, 1994; Caasi-Lit et al. 1999). Recent molecular characterization, however, identified the pathogen as *Candidatus Phytoplasma luffae* - related strain 16SrVIII (Dolores et al. 2023). The samples were collected from an endemic bamboo species, *Dendrocalamus merrillianus* (local name: Bayog) in 2019. This is the first report on this species of bamboo in the Philippines. The recent molecular identification of the causal organism as phytoplasma (formerly broadly grouped as mycoplasma-like organisms or MLO) changed perspectives in the concept of the disease. One step that needs to be done is the identification of vectors. This will help understand the spread and manage the disease and its pathogen. Vectors are expected to be arthropods that can transmit the pathogen from one bamboo plant or culm to another. To contribute to this effort, we reviewed our previous work and collections and conducted additional fieldwork involving further observations, gathering of samples, and laboratory examination and identification of specimens. Arthropods associated with BWBD-infected bamboo belong to various orders, most notably hemipterans and some mites. This paper documents the historical background and consolidates geographical information of the bamboo witches' broom disease from 1995 up to the present. This includes observations on its current local distribution and sightings of symptomatic bamboo samples that are not included in our latest paper (Dolores et al. 2023). The survey of arthropods collected from infected branches is reviewed from previous work and additional fieldwork conducted, involving further observations, gathering of samples, and laboratory examination and identification of specimens. The additional information will be valuable in studying the extent of infection or spread in the different bamboo species and in locations where they are collected. This is also useful in formulating pest management options for the control of bamboo witches' broom disease in the Philippines. We are hopeful that the government will be able to prioritize research funds for this important disease of bamboo and its vector before any epidemic will arise.

## 2. Continuing survey of bamboo witches' broom disease among Philippines bamboo species

How this study came about from the very beginning is a result of accumulated data from official trips conducted from externally funded projects and personal trips. This is also an exercise of collective and participatory science called citizen science. Other researchers, relative and friends are cooperative to share their time and effort to observe and send pictures. However, its limitation lies on the collection of specimens for molecular studies and vector identification. The GPS is very important to track the exact location of the specimen and future observations will have this as a must. Already recognizing the importance of BWBD in almost two decades, research funds are difficult to come by. Nonetheless, the collective effort of the Cassava Research Team of the Institute of Plant Breeding with DABAR funding paved the way to identify the causal organism of the bamboo witches broom disease (Dolores et al. 2023).

The following observations are still helpful to track the presence of BWBD around the country. Questions are relevant to pursue the basic and applied aspects of this important disease of bamboo in the Philippines.

1. Tracing the putative origin(s) of the bamboo witches broom in the Philippines
2. Around 1999, there were only two genera that have been recorded as affected by the disease. The genus *Bambusa* was not observed to be affected then (1990s).
3. As the local effects of the changing climate became more pronounced in the 2000s, a few more sightings began to emerge for some species of *Bambusa* and other genera. Factors affecting possible vectors as well as the possible relative differences in the resistance or susceptibility of the host bamboo species to both the potential vectors and the pathogen might have played roles in these observations.
4. The infection happened to coincide with the spread of cassava witches broom disease, and surprisingly the identification of the pathogen for both the cassava and the various bamboo species turned out to be the same.
5. There is an urgent need to collect and identify the witches broom disease of Philippine bamboo.

We continue the observations around the country, though limited, it will still provide an avenue for collaboration, generate research funding and a better understanding of the ecology of this threat to bamboo production toward pertinent policy formulation. We start with a detailed description of the development of signs and symptoms and then proceed to the discussion of the survey results with

the bamboo species that had been continuously infected, showing symptoms of the disease, and those that will appear successively on Table 1.

**Table 1. Field observations of bamboo species showing symptoms of the bamboo witches' broom disease in several provinces in the Philippines from 1995-2023.**

Plant Species Common/Local Names	Year Observed	Disease Presence	Location -Locality	Reference
<i>Dendrocalamus asper</i> (Schult. & Schult. f) Backer  Giant (English) Patong (Cebuano) Botong (Bikol) Butong (Bisaya) Bukawe (Tagalog)	1999	+	Agusan del Sur	Lit et al. 1999
	1999	+	Cuenca, Batangas	Caasi-Lit et al. 1999
	1999	++	Malaybalay, Bukidnon	Caasi-Lit et al. 1999
	1999	++	Lake Sebu, South Cotabato	Lit et al. 1999
	1999	++	T-Boli, South Cotabato	Caasi-Lit et al. 1999
	2000	++	Kennon Road, Baguio City	MCLit unpublished
	2009	++	Lake Sebu, South Cotabato	MCLit unpublished
	2009-2019	++	General Santos City to Tupi along the Pan-Phil Highway	MCLit unpublished
	2017	++	Loakan, Baguio, Benguet	MCLit unpublished
	2017	+++	Datu Salumay, Marilog, Davao del Sur	MCLit unpublished
	2017	+++	Buda, Marilog, Davao Sur	MCLit unpublished
	2019	+++	Marilog, Davao del Sur	Dolores et al 2023
	2022	+	Saranggani	MCLit unpublished
	2022	+++	Kitaotao, Bukidnon	MCLit/MIPCaasi unpublished
	2023	+++	Kalasungay, Dalwangan Malaybalay City, Bukidnon	MCLit/EVElladora unpublished
	2023	+++	Lake Sebu, South Cotabato	MCLit/PCMorito unpublished
	2023	+++	Jagupit, Santiago and Poblacion Santiago, Agusan del Norte	MCLit/JMTCaasi unpublished
2023	++	CENRO, Baguio, Benguet	MCLit/MOdney unpublished	
<i>Gigantochloa levis</i> (Blanco) Merrill	1995	+++	Cavinti, Laguna	Sinohin 1995
	1999	++	Jamboree, UPLB, Laguna	Caasi-Lit et al. 1999

Bolo				
Bongsina	1995	++	Luisiana, Laguna	Sinohin 1995
Buhong-china	1999	++	Luisiana, Laguna	Caasi-Lit et al. 1999
Bulung-china				
Kauayang-china	1999	++	Lucban, Quezon	Caasi-Lit et al. 1999
Kauayan-sina				
Kawayang tsina (Tagalog-Quezon)	1999	++	Pagbilao, Quezon	Sinohin 1995
Boko	1999	+	Laguna	Caasi-Lit et al. 1999
Bolo				
Botong	1999	++	Tayabas, Quezon	Caasi-Lit et al. 1999
(Panay Bisaya)				
Buton (Cebuano)	2015	++	Majayjay, Laguna	MCLit unpublished
Kabolian (Bikol)				
Patong (Bikol, Bisaya, Sulu)	2015	+	Jamboree Road, Mt.Makiling, Los Baños Laguna	MCLit unpublished
Botong (Bisaya)				
	2018	++	Kidapawan,Makilala North Cotabato	MCLit/JMTCaasi unpublished
	2018	++	Loboc, Bohol	Dolores et al. 2023
	2022	++	Mabini, Monkayo, New Bataan, Pantukan, Davao de Oro	MCLit/JMTCaasi unpublished
	2022	+	Mainit, Nabunturan Davao de Oro	MCLit/MIPCaasi unpublished
	2023	+	Cabadbaran, Agusan Norte	MCLit unpublished
	2023	+	Lawaguin, Nagcarlan, Laguna	MCLit/ RAPLaude unpublished
	2023	+	Balayong, Nagcarlan, Laguna	MCLit/RAPLaude unpublished
	2023	+	Cavinti, Laguna	MCLit/JESmabe unpublished
	2023	+	Majayjay, Laguna	MCLit unpublished
<i>Gigantochloa atter</i> (Hassk.) Kurz	1999	+	Lucban, Quezon	Caasi-Lit et al. 1999
Kayali (Tagalog)	1999	+	Tayabas, Quezon	Caasi-Lit et al. 1999
Kajali (Surigaonon)				
Lasak (Lake Sebu – B’laan)	1999	+	Lake Sebu, South Cotabato	Caasi-Lit et al. 1999
	1999	+	T’Boli, South Cotabato	Caasi-Lit et al. 1999
	2018	+	Sikatuna, Bohol	Dolores et al. 2023
	2019- 2022	+	Sampaloc Demo Area, IPB UPLB College Laguna	MCLit/RAPLaude unpublished
	2023	+	Cabadbaran, Agusan Norte	MCLit unpublished
	2023	+	Mainit, Davao de Oro	MCLit/JMTCaasi

					unpublished
	2023	+	Pungtod, Alegria, Surigao del Norte	MCLit/JMTCaasi Unpublished	
	2023	+	San Isidro, San Francisco, Agusan del Sur	MCLit/JMTCaasi Unpublished	
	2023	+	Victory, Tubay, Agusan del Norte	MCLit/JMTCaasi Unpublished	
	2023	+	Lake Sebu, South Cotabato	MCLit/PCMorito unpublished	
<i>Bambusa spinosa</i> Roxb.	2019	*	Roxas, Isabela	Dolores et al. 1999	
Kawayang tinik (Tagalog)	2019	*	Bagabag, Nueva Viscaya	Dolores et al. 2023	
Batakan, Tunukon (Bisaya)	2019	*	Iguig, Cagayan	MCLit unpublished	
Siitan (Ilocano)	2019	*	Nueva Viscaya	MCLit unpublished	
	2019	*	Pintor, Gamu, Isabela	MCLit/RAPLaude unpublished	
<i>Dendrocalamus merrillianus</i> (Elmer) Elmer	2018	*	Gamu, Isabela	MCLit/RAPLaude unpublished	
Bayog	2019	#	Gamu, Isabela	Dolores et al. 2023	
	2020	*	Tarlac	MCLit/EGDLeus unpublished	
<i>Schizostachyum lumampao</i> (Blanco) Merrill Buho	2019	*	Ilocos Norte	Caasi-Lit et al. 1999	
<i>Thyrsostachys siamensis</i>	2019	*	Mainit, Bay, Laguna	MCLit/(RAPLaude unpublished)	
Pole bamboo Pole vault bamboo Monastery bamboo Undetermined Species 1	2023		Purok 1, Mainit, Bay, Laguna	MCLit/JDPaderon unpublished	
Undetermined Species 2	2019	*	Opposite Sampaloc Area, Along railroad, Mainit, Bay, Laguna	MCLit/RAPLaude unpublished	
Undetermined Species 2	2023	*	Brooks Point, Palawan	Dolores et al 2023 LMDolores unpublished	
Undetermined Ornamental Bamboo	2022	*	Maahas, Los Baños, Laguna	MCLit unpublished	

Disease presence: + Sporadic; ++ Occasional; +++ Almost always present/abundant.

\* Only observed once or twice; # reported already in Dolores et al. 2023.

Unpublished- Observations that were not included in Dolores et al. 2023.

### 3. Witches' broom disease development of signs and symptoms

The signs and symptoms of bamboo witches broom disease is described on *G. levis* in Figure 1.

Early sign is usually observed on the developing branch with the distinct light yellow green leaves (Figure 1A). When compared to the green normal leaves, the sight of these deformed branches and

leaves while they are still young is already pronounced (Figure 1B). These light green little leaves are quite noticeable and can easily be detected from a distance with the naked eye. Depending on which branch the causal organism will thrive, the affected branch starts to produce thin branchlets and leaflets and develops into abnormal clusters primarily emanating from the node (Figure 1C-D). It continues to form into clusters of smaller leaves and branchlets and this looks like a “bouquet” or “mistletoe” (Figure 1B-D). Excessive branching/leafing which forms the “bouquets” usually concentrates in the center originating either at the terminal branch or the secondary/tertiary branches (D). It is observed that there is no specific site where these clusters will develop, and examination of affected culms confirms this observation as shown in Figure 1E with clusters occurring in two branchlets. In this sample, the whole branch is still intact and only a few normal leaves are formed. Most of the clusters or “bouquets” observed in the field are single as shown on several bamboo species from the different locations visited (Figure 2). Branches that are mostly affected are from the upper portion of the culms. These excessive outgrowths from the nodes affect the culms which tend to lean and give way to the weight of hanging “witches’ brooms”. The clusters or witches’ brooms are in different shapes and sizes. Examples of which are shown in *G. levis* in Luisiana, Laguna (Figure 2A) and Cabadbaran City, Agusan del Norte (Figure 2B); About to drye “bouquet” of giant bamboo in Impalutao, Impasug-ong, Bukidnon (Figure 2C). The largest “bouquet” or witches broom so far is on *G. levis* documented in Loboc, Bohol which is almost three meters (Figure 2D). There are two clusters/”bouquets” in one branch in Majayjay Laguna as shown in Figure 2E. The ones observed on *D. asper* in Jagupit, Santiago, Agusan del Norte vary in size and some of the “bouquets” are already touching the ground (Figure 2F). BWBD is also observed emanating from the base of the culm as seen in giant bamboo in Jagupit, Santiago Agusan and Baguio City (Figure 2G-H).

There is also a misconception in some areas that the “bouquet” of small leaves hanging from BWB affected bamboo clumps are “bamboo flowers” or “epiphytes” (in Tagalog, “*dapò*” - similar to orchids or other epiphytic plants). These misconceptions may have prevented some local folks from cutting bamboo clumps with “flowers” or others may have seen the bouquet of leaves as ornamental.

### ***Dendrocalamus asper***

There is no record of infection on giant bamboo, *Dendrocalamus asper* (Local name: ‘Patong’) when Sinohin (1995) conducted the first survey of BWBD. This is interesting as ERDB then had stations

in different parts of the country. This poses the question where did this disease originate? The disease is first reported on giant bamboo only in 1999 in four provinces (Agusan del Sur, Batangas, Bukidnon and South Cotabato and in Baguio, Benguet the following year. It is possible that giant bamboo had already been infected even before 1999 in Bukidnon, South Cotabato and Baguio as the level of infection is already prevalent. The presence of BWBD is already quite severe especially along the roads going to Lake Sebu, South Cotabato during our visit but no specimens were collected. The observed lines of infected giant bamboo are still present in 2009. Several trips from General Santos City to Tupi along the Pan-Philippine Highway between 2009 onwards up to the present also reveal the presence of infected culms in natural stands of giant bamboo beside the road. In retrospect, because of this situation, we are encouraged to gather observations of its presence around the country. More clumps of this species are infected as observed in the succeeding trips in 2017 along Loakan Road and in the CENRO Baguio area. Interestingly, important observations that are not recorded are the sightings, also in 2017, along the road going to Bukidnon from Davao City. Severe infection of giant bamboo is observed in Buda and Datu Salumay both in Marilog district, Davao del Sur and more clumps are observed two years after (Dolores et al. 2023).

Survey this year revealed the extent of infection in several places in Bukidnon such as in Kitaotao, Poblacion Impasugong and Kalasungay/Dalwangan, Malaybalay City. BWBD on giant bamboo inside the Hotspring Resort in Kitaotao is quite plentiful as shown in Figure 3A. Giant bamboo growing along the national highways in Kalasungay/Dalwangan, Malaybalay City going to Poblacion Impasug-ong are full of infected “bouquets” (Figure 3B-C) It is interesting to survey the presence of BWBD in the province as this is the best habitat for giant bamboo. Another place where BWBD was found in 1999 is in Lake Sebu, South Cotabato (Figure 3D-E). There are still clumps that show symptoms of BWBD and they are heavily infected. Going to Caraga region along the highway, BWBD symptoms are observed in Jagupit, Santiago, Agusan del Norte, Poblacion 2, Santiago, Agusan del Norte and Tabon-Tabon, Sibagat Agusan del Sur (Figure 3F-H). Several clumps in Jagupit, Santiago in Agusan del Norte are already producing these “bouquets” and many are already dried. In the Cordillera region, there are also sporadic sightings of clumps with BWBD especially when plying by Kennon Road with all the giant bamboo clumps beside the national highway. This is possible as this region is also suitable for growing giant bamboo. For this year in the Cordillera region, infected clumps are observed at CENRO, Barangay Manuel Roxas, Baguio City (Figure 3I).



### ***Gigantochloa levis***

BWBD is first collected on *Gigantochloa levis* (Local name: ‘Bolo’) by Sinohin (1995) in Cavinti and Luisiana located in the southern part of Laguna. Early sightings in Quezon province is in Pagbilao, only 45 and 75 km away from Cavinti and Luisiana, respectively. In between 1999 and 2023, there are sightings, but they are not recorded (Table 1). For example, there are already BWBD in the different municipalities of Laguna and Quezon but only sporadic in Majayjay, Laguna in 2015. There are also infected clumps growing on the right side of the Jamboree Road facing the Boys Scout hand statue in Mt Makiling, Los Baños Laguna. Continued observations showed infected *G. levis* in Kidapawan and Makilala in North Cotabato and Loboc, Bohol. Recent sightings of infected *G. levis* are found in Davao de Oro particularly in Mainit, Nabunturan along the national highway (Figure 4A) and in other municipalities in Mabini, Monkayo, Nabunturan, New Bataan, Pantukan) and in Davao del Sur (Sta. Cruz). A clump of *G. levis* is heavily infected with BWBD in the main highway in Cabadbaran City, Agusan del Norte (Figure 4B). This is so far the most numerous “bouquets” per culm observed during the survey. The culm holds combined fresh and dry “bouquets” as shown in Figure 4C and there are no more culms that do not have the infection. Around Laguna, clusters of brachlets with little leaflets in the infected culms are found beside the winding road to Luisiana (Figure 4D). The long infected “bouquet” is not very visible because is already covered with viny weeds. Along the road going to Balayong, Nagcarlan before turning left to Bunga Falls, there were big clumps of *G. levis* with BWBD. One of the clumps had a lot of “bouquets” hanging beside the coconut tree (Figure 4E). The largest clump had a very thick “bouquet” almost touching the coconut trunk as the culm is already leaning (Figure 4F). This area in Balayong going to Luisiana had a lot of healthy *G. levis*. In Cavinti, only one clump has symptoms of BWBD which is not the case in 1999, which had a number of infected culms along the way to Cavinti from Luisiana (Figure 4G). Almost all the clumps growing beside the Atilo Bridge in Majayjay Laguna are infected with BWBD (Figure 4H).

There are still a lot of natural stands of *G. levis* in Laguna especially in Luisiana, Laguna. It is possible that the declining natural stands of *G. levis* in Laguna and Quezon provinces may have been caused by BWBD aside from the fact that bamboo planting is not yet encouraged in 1999. In addition, urbanization also contributes to the decline in this bamboo species in the area. Previous knowledge in the past revealed that *G. levis* is predominantly growing in Southern Tagalog region

especially in Quezon province (Caasi-Lit et al. 2010). This is shown by the abundance of bamboo shoots which is cooked in popular dish sauteed in sardines by the local residents.

### ***Gigantochloa atter***

*G. atter* is not listed in Santos' (1986) Guide to Philippine Flora and Fauna. However, it is in the list of Dransfield and Widjaja (1995) but the Philippines is not included. Therefore, this species is first recorded and listed in Caasi-Lit et al. 1999 and in the book "Philippine erect bamboo, a field identification guide" by Rojo et al (2000). *Gigantochloa atter* is already known to occur in the Philippines particularly in Davao Province as a source of propping material for banana plantations as early as 1985 (Rikkens 1994). Prior to its use as a propping material, this bamboo species is discovered to be most abundant in Surigao and Agusan provinces. Planting propagules are collected in Surigao (the existing provenance in Davao and later introduced in Laguna in 1996) and grown in bamboo nurseries in many locations in Davao del Norte. Later, several bamboo plantations of *G. atter* are established and became the source of banana proppings in Mindanao. According to the latest survey of Pelser et al (2023), *G. atter* is found in Davao Province and Polilio, Quezon. Infected *G. atter* is found along the national highway going to Bilawa Mainit Hot Waterfall Mainit, Maco, Davao de Oro (Figure 5A). A clump of *G. atter* with infected "bouquet" is observed along the highway in Cabadbaran City, Agusan del Norte (Figure 5B). An unusually smaller "bouquets" are found in a thick clump in Pungtod, Alegria, Surigao del Norte (Figure 5C). This is the first observation to have come across these "bouquets" which are relatively plenty but with tiny leaflets. This needs to be collected and identified. Huge clumps beside the road going to San Isidro, San Francisco, Agusan del Sur are observed with BWBD (Figure 5D). "Lasak" is another local name for "Kayali" among the B'Laan in Lake Sebu, South Cotabato. In this area, some of the clumps are infected with BWBD (Figure 5E). There are also clumps with BWBD in Victory, Tubay, Agusan del Norte. It is observed that *G. atter* is not heavily infected with the BWBD. The infected "bouquets" are usually hidden in the canopy and they do not develop as big as those in the other species.

### ***Dendrocalamus merrillianus***

It is interesting to note that after more than 20 years, a few cases with similar appearance of damage symptoms are observed in *Dendrocalamus merrillianus* (Local name: 'Bayog') (Dolores et al.

2023). However, the prevalence of the disease is only minimal unlike those in *G. levis* and *D. asper*. The presence of symptomatic “bouquets” on *Dendrocalamus merrilianus* (“Bayog”) is first sighted along the road going to Gamu, Isabela in 2018 (Figure 6A). In 2019, a clump of “Bayog” with BWBD is seen on the roadside before the welcome arc of Barangay Pintor, Gamu, Isabela (Figure 6B). This is the sample specimen collected for PCR analysis that turned out positive for the BWBD (Figure 6C). Interestingly, there are no symptoms of the disease during our visit last year. The same symptomatic clusters are seen along the highway of Tarlac beside a ricefield (Figure 6D-E).

### ***Bambusa spinosa***

Symptoms of BWBD are also observed on *Bambusa spinosa* (Local name: ‘Kawayang tinik’). BWBD symptoms are first sighted in Roxas, Isabela in 2019. This is followed in 2020 with sighting in Barangay, Baretbet, Bagabag Nueva Viscaya as shown in Figure 7A and in another location in Nueva Viscaya (Figure 7B). Surprisingly, symptoms are also observed in one of the clumps along the highway going to Iguig, Cagayan (Figure 7C). The clump is huge but it is already deteriorating. Traces of infected clusters are observed at the base of the clumps (Figure 7D).

### ***Thyrsostachys siamensis***

Recent significant findings reveal the presence of witches’ broom disease on *Thyrsostachys siamensis* (Local name: Pole bamboo), in the residential areas in Purok 1, Barangay Paciano Rizal (Mainit), Bay Laguna where this bamboo species is growing as ornamental plant. This is first observed in 2019 (Figure 8A-B). The signs and symptoms showed excessive clustering of branches and leaves (Figure 8C). Clustering is sometimes observed at the growing tip leaving no growth on the lower nodes of the culm (Figure 8D). When dried, infected culms are brush-like in appearance (Figure 8 E-F). Molecular detection of this infected bamboo species needs to be conducted to confirm the identity of the phytoplasma. Is this another kind of witches’ broom disease in bamboo?

### ***Unidentified ornamental bamboo***

Symptoms of BWBD is observed on unidentified ornamental bamboo in Maahas, Los Baños, Laguna (Figure 9A-B). This is the first sighting of an ornamental bamboo species with exceptionally all the nodes are with the distinct “bouquets” (Figure 9C). With bamboo species of this kind, the developing “witch broom” is usually smaller and shorter (Figure 89D).

#### 4. Spread of the bamboo witches broom disease

Based on the signs and symptoms, only two bamboo genera, *Gigantochloa* and *Dendrocalamus* are affected by BWBD in 11 provinces as observed in 1999. The trend during the past and the recent surveys indicate that the incidence of the disease is high where the species are abundantly growing. This means that the disease is prevalent in *G. levis* because Laguna and Quezon have abundant natural stands of *G. levis*. The same is true for *D. asper* where this bamboo species is also abundantly growing in cooler habitat and in higher elevation like South Cotabato and Bukidnon. This is supported and confirmed by the results conducted for the two projects on the survey of arthropods and on bamboo shoot resources in 29 provinces around the country (Lit and Caasi-Lit 2004; Lit and Caasi-Lit 2009; Caasi-Lit et al. 2010). However, the spread is alarming on *Dendrocalamus asper* as observed by the increasing number of clumps infected by BWBD especially in this area in Davao City going to Bukidnon. Clumps of giant bamboo in Lake Sebu, South Cotabato are also heavily affected even today. This is the place where BWBD is first observed in 1999 abundant with “bouquets” hanging on many culms. The growing interests on bamboo in the last decade is historical. This significantly highlighted the importance of bamboo and its many uses especially in these critical times of climate change. These are exemplified by several programs of the government. One program is the Expanded National Greening Program requires the use of bamboo to help rehabilitate denuded and degraded forestlands and unproductive areas. Another one is the Senate Bill No. 2172 known as the Philippine Bamboo Industry Development Act which will promote the development of the bamboo industry. Private companies and individuals are also partners in promoting bamboo as an important renewable community resource. This will pave the way to massive production and utilization with these recent developments.

From our study, the spread of BWBD since 1995 is already evident after several years of observations and sightings on the different bamboo species around the country. The spread of BWBD is by collecting propagules or seeds from infected clumps. In the last decade, planting propagules of *D. asper* are being transported around the country. This is made possible especially during the pandemic when couriers are easily accessible not only to food and things but also to plants with the “plantitos and plantitas”. Planting materials with BWBD that are transported in other places need to be regulated and under quarantine as they may become potential source of inoculum and it paves the way to an unwanted spread of the disease. Also, the spread, not only of infected bamboo

planting materials but also of potential vectors, need to be managed properly. There is no quarantine or regulatory measures involve in the transport of the planting materials. Hence, this poses a great danger of spreading BWBD. Recent surveys also include other species of bamboo like *Thyrsostachys siamensis* and new records in places of sighting. These are added to the list and the number of provinces increased to 20 (Table 1). Like in India, Ravi et al (2022) reported a wide genetic diversity of phytoplasma in bamboo species and these are first records in the world. This is supported by Mondal et al. in 2019 and Sundaraj et al (2022) where a few of bamboo species in India are affected by phytoplasma diseases. Based on the symptoms of the bamboo witches broom disease collected in different provinces, it is possible that there is also a wide genetic diversity of phytoplasma among Philippine Bamboo. This needs to be further studied especially the molecular identification. When a species of plant or animal is introduced, either intentionally or accidentally, into a place where it is non-native, it escapes from its natural enemies (herbivores and predators) in its native habitat. Hence, assuming all conditions like availability of sunlight, adequate rainfall, etc. are available, which are generally the case for most tropical countries, their growth, development, and reproduction will go on unhampered. There are many consequences but the most widely known are within the aspects of competition with native species. The other consequence, however, relates to the possibility of the introduced planting materials or propagules harboring or containing pestiferous insects or other arthropods and/or pathogens. This is the reason why ideally strict quarantine or biosecurity measures should be followed and observed before introducing and releasing organisms intended for introduction. Unfortunately, introductions of many planting materials of bamboo in the past might not have undergone proper plant quarantine procedures.

##### **5. Potential vectors and other associated arthropods on witches' broom-infected**

Survey and identification of possible vectors of BWBD is an important requirement in the management of phytoplasma disease. This is even difficult because of the work devoted to this specialized field of study. This part will help understand the spread and manage the disease and its pathogen. Vectors are expected to be arthropods that can transmit the pathogen from one bamboo plant or culm to another. Arthropods associated with BWBD-infected bamboo belong to various orders, most notably hemipterans and some mites. They include leafhoppers (Cicadellidae) and planthoppers (Fulgoridae and Delphacidae), groups previously reported to transmit MLOs as reported then by Harris & Maramorosch (1982). Phytoplasma (Weintraub and Beanland 2006).

**Table 2. Insects collected from affected parts of the witches' broom diseased bamboo in the Philippines (updated from Lit and Caasi-Lit 1999).**

ORDER FAMILY	COMMON NAME	SCIENTIFIC NAME	SURVEY	
			1999	2023
<b>HEMIPTERA</b>				
<b>Suborder</b>				
<b>Sternorrhyncha</b>				
Pseudococcidae	Bamboo node mealybug	<i>Antonina thaiensis</i> Takahashi	√	√
	Bamboo culm mealybug	<i>Chaetococcus bambusae</i> (Mask.)	√	√
	Bamboo leaf mealybug	<i>Paracoccus interceptus</i> Lit	√	√
	Bamboo leaf mealybug	<i>Trionymus</i> sp.		√
	Bamboo leaf mealybug	<i>Exilipedronia</i> (?) sp.		√
Asterolecaniidae	Common bamboo pit scale	<i>Bambusaspis bambusae</i> (Boisd.)	√	√
	Bamboo pit scales			
	Black bamboo pit scale	<i>Bambusaspis</i> spp. <i>Bambusaspis</i> sp. (black)	√	√ √
Diaspididae	Armored scales			
		<i>Odonaspis</i> spp.	√	√
Aphididae	Bamboo leaf aphids ('T-shirt')	<i>Astegopteryx insularis</i> (v.d.Goot)	√	√
	Bamboo leaf aphids			
	Bamboo leaf aphids	<i>Astegopteryx</i> spp	√	√
	Bamboo shoot aphids	<i>Cerataphis</i> sp. <i>Pseudoregma</i> spp.	√	√ √
<b>Suborder</b>				
<b>Auchenorrhyncha</b>				
Cicadellidae	Bamboo leafhopper	<i>Cofana</i> sp.	√	√
	Typhlocybinae leafhopper	Typhlocybinae (undetermined)	√	√
Fulgoridae	Bamboo planthopper	<i>Purohita cervina</i> Distant	√	√
<b>HYMENOPTERA</b>				
Formicidae	Crazy ant	<i>Anoplolepis gracilipes</i> (Jerdon)	√	√
	Common black ant	<i>Dolichoderus thoracicus</i> Mayr	√	√
	Green tree ant	<i>Oecophylla smaragdina</i> (Fabr.)	√	√
	Red fire ant	<i>Solenopsis geminata</i> (Fabricius)	√	√
<b>COLEOPTERA</b>				
Coccinellidae	Small black lady beetle	<i>Scymnus</i> sp.		√
Chrysomelidae	Hispine beetle	<i>Callispa</i> sp.		√
<b>THYSANOPTERA</b>				
Thripidae	green/black thrips	Undetermined species	√	

In our previous study, some arthropods associated with BWBD include leafhoppers (Cicadellidae) and planthoppers (Fulgoridae and Delphacidae), groups previously reported to transmit phytoplasmas (Table 2, Lit et al. 1999). There were also aphids (Aphididae), mealybugs (Pseudococcidae) and other scale insects (Cocomorpha: Coccoidea). Acarine species include some spider mites (Tetranychidae) and false spider mites (Tenuipalpidae). Potential vectors that may be evaluated in transmission as well as molecular detection studies include *Purohita cervina* Distant

(Delphacidae) and *Pseudoregma* spp. (Aphididae). A taxonomic survey and biological observations of insects associated with bamboo shoots was reported by Lit and Caasi-Lit (2004). Interestingly, the closeness of the phytoplasma that causes BWBD with that identified for cassava witches' broom, being vectored by mealybugs (Lit et al. 2023), makes it also imperative to include and examine Pseudococcidae like *Palmicultor* sp., *Antonina* spp. and *Chaetococcus bambusae* (Maskell) (Lit et al. 2023, in press). From the recent survey, a few insects were collected from the infected "bouquets" and they are included in the list in Table 2. Planthoppers (A) and ants (B) are some insects collected from fresh witches' broom diseased "bouquets" on *G. levis* in Nagcarlan, Laguna (Figure 9A-B). There are also ants attending to these large black scale insects in Majayjay, Laguna (Figure 9 C-D). Bug, grasshopper, scale insect and brown planthoppers are collected from fresh witches' broom diseased "bouquets" on *Thyrsostachys siamensis* in Barangay Paciano Rizal (Mainit), Bay Laguna (A-D). For the unidentified ornamental bamboo observed in Barangay Maahas, Los Baños, Laguna, another scale insect attended by ants are observed and also aphids on the normal leaves. (Figure 10E-F).

There is a lack of work on insect vectors of BWBD. This shows that there should be a strong collaboration among the different disciplines, including epidemiologists to have a clearer understanding of the ecology of this disease and how to manage its occurrence and prevent further spread.

## 6. Regulatory measures and recommendations

The most ideal control management measures for bamboo witches broom disease is to create a National Program composed of the different agencies of the government like DENR, DA, LGU, DepEd and this effort will be led by the Department of Environment and Natural Resources. Government funding for BWBD research, development, extension and public service is very critical and necessary. The following are some of the recommendations:

1. National Program on quarantine measures to mitigate the spread of BWBD.

Precautionary measures must be in place as phytoplasma is systemic in nature and can be transmitted using infected bamboo propagules.

- 2 Search for healthy clumps of *D. asper* and *G. levis* as sources of healthy planting materials/propagules
- 3 Survey and collection (with proper permits) of BWBD disease on Philippine bamboo around the country

- 4 Basic studies on potential vectors among locally occurring insects and other arthropods should be surveyed, along with transmission studies.
- 5 BWBD Awareness through IEC materials, lectures and exhibits.
  6. Rapid detection kit should be developed which is very useful in the field.
  7. Molecular analysis through PCR or LAMP of the collected infected specimens

With these developments and with the current increasing interest in bamboo, there is a need to continue this survey and R&D on BWBD and its insect vectors. The supply of quality bamboo may be affected in the future if BWBD is left unchecked especially for *Dendrocalamus asper* and *Gigantochloa levis*.

### **Conflict of interest**

The authors declare there is no conflict of interest

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