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Status and Geographical Distribution of Indigenous and Quarantine Fruit Fly Species (Diptera: Tephritidae) in Sarawak

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ABSTRACT

The provision of reliable pest records, one of which is fruit fly record, is one of the vital components under the International Plant Protection Convention. A fifteen-month survey to detect fruit flies using male pheromone lure trapping method was carried out from April 2010 to July 2011. The standard Steiner traps and three types of lures (ME-lure, CUE-lure and Trimed-lure) were used. The traps were placed at every five kilometre interval along the east-west trunk road of Sarawak. The geographical distribution of the fruit fly species was established through Global Positioning System mapping. Twenty species of Dacinae fruit flies which includes nine unknown *Bactrocera* species were detected along the east-west trunk road of Sarawak. The main species of fruit fly caught in the ME-lure trap were *Bactrocera papayae*, *B. carambolae* and *B. umbrosa*, whereas *B. cucurbitae*, *B. papayae*, *B. caudata*, *B. tau*, *B. apicalis*, *B. nigrotibialis* and *B. albistrigata* were caught in the CUE-lure trap. The quarantine species, which is species of potential economically importance in Sarawak, *B. correcta*, *B. dorsalis*, *B. occipitalis* and *B. zonata* were absent in both ME-lure and CUE-lure traps. The Mediterranean fruit fly (*Ceratitis capitata*) was not detected in the Trimed-lure trap. Out of the twelve identified species, eleven of them were detected along the main road of Sarawak. *Bactrocera papayae* and *B. caudata* were abundant, whereas the other species were more prevalent at some locations.

Keywords**:** survey, fruit fly, species, traps, lure, detection

INTRODUCTION

Fruit flies, belonging to the family Tephritidae, are economically important as they cause significant damage to fruits and vegetables, resulting in significant losses and high control costs (White & Elson-Harris 1992). The family Tephritidae is further divided into subfamily Dacinae, Ceratitidinae, Trypetinae, Tephritinae and Schistopterinae (Hardy 1997). Under this classification, the Dacinae fruit flies are considered major pests of agriculture (Waterhouse 1997). The climatic condition in Malaysia enables the whole year round cultivation of the fruit fly host plants and therefore encourages the fruit fly to multiply in a rapid manner since the food source is always available. Thus, they can cause serious threat to the Malaysian fruit industry (Vijaysegaran & Shamsudin 1991).

The importance of fruit flies in Malaysia has been highlighted since the establishment of National Agricultural Policy in 1984 (Tan 2004). Their occurrence has considerable quarantine implications and poses serious problems in the export of fruit and vegetables commodities, particularly to countries where certain fruit fly species are absent (McMaugh 2005).

The provision of reliable pest records is one of the vital components under the International Plant Protection Convention. Pest record, which indicates the presence or absence of a specific pest, is essential for the importing and exporting countries to establish, maintain or verify their pest free area and produce their pest risk analysis. Therefore, a fruit fly surveillance report, reporting the status of fruit fly species, is vital for pest free assurance or low pest prevalence to the importing and exporting countries based on their quarantine regulations and requirements.

This is the first survey of Dacinae fruit fly in Sarawak. This paper reports on the types and numbers of species caught in different types of lures and their geographical distribution.

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MATERIALS & METHODS

The surveillance procedures, following the International Standards for Phytosanitary Measure No. 6 (International Plant Protection Convention 1997) are adopted in this project. The survey was carried out in seven phases, from April 2010 to July 2011.

Trap and Lure Selection

The standard Steiner trap, which is a horizontal and clear cylinder with an opening at both ends (John 2008), was used. Three types of lures were used. They were Methyl-Eugenol lure (ME), CUE lure and Trimed lure. Each lure was targeting at certain fruit fly species. The use of Trimed-lure was meant to attract the Mediterranean fruit flies (*Ceratitis capitata*). Eighty four percent Malathion was mixed with the lure at a ratio of 1: 3, to avoid the fruit flies from escaping and predation of the trapped flies. The lure was impregnated into a cotton wick hung in the center of the trap.

Trapping Procedure

The survey team comprised three persons. Each personnel handled each type of lure because it is essential that the lures did not become cross contaminated with each other and attracts the wrong targeted species of fruit fly. Suitable and proper sites at every 5 kilometre interval along the main road were selected. The traps were placed at, at least 5 metres from the east-west trunk road of Sarawak. The trapping height was about one and a half metres and distance of each trap at each site was one metre apart. The trap entrance was also cleared from twigs and leaves to allow proper air flow and easy access of the fruit fly. Global Positioning System (GPS) was used for the trap mapping. The samples at each site were collected at weekly interval while the lures were refilled fortnightly. The trappings were conducted at seven phases (Table 1) along the east west trunk road of Sarawak, from Kuching Division to Lawas Division. Each phase consists of several areas. The trappings were done one or two phases at a time. The traps were relocated every three months.

A total of 678 traps were placed at 226 locations along the east-west trunk road of Sarawak (Table 1). The traps were also fixed along the access road to Biawak, Serikin, Tebedu and Lubok Antu, which are near to the Indonesian border. These could be the points of entry of the quarantine species.

Identification

Every single sample was identified morphologically in the laboratory. The wings of fruit fly bear significant taxonomic characteristic and were extensively used for identification. Other important characters occur on the thorax, abdomen, head and legs. The main references used for the specimen identification were Handbook of identification of fruit flies in the tropics (UPM Serdang) (Rohani & Abdul Ghani 1990) and Fruit fly of economic significance: their identification and bionomics (ACIAR and CABI) (Ian & Elson-Harris 1992). The identified and unidentified samples were also cross checked with Department of Agriculture Semenanjung Malaysia in Kuala Lumpur.

Mapping

The GPS data was converted to Borneo Rectified Skew Orthomorphic (BRSO) data using State Geomatic Data Clearinghouse 2.0 online toolbox. The BSRO data was then sent to Soil Management Branch for mapping. The geographical distribution of the traps through GPS mapping is shown in Figure 1.

Table 1. Number of traps and area of survey.

Phase	Area	No. of location	No. of trap
1	Bau – Lundu (including Biawak and Serikin)	28	84
2	Siburan – Lachau (including Tebedu)	30	90
3	Lachau – Saratok (including Lubok Antu)	42	126
4	Saratok – Selangau	35	105
5	Selangau – Bintulu	40	120
6	Bintulu – Miri	28	84
7	Miri – Lawas	23	69
	Total	**226**	**678**

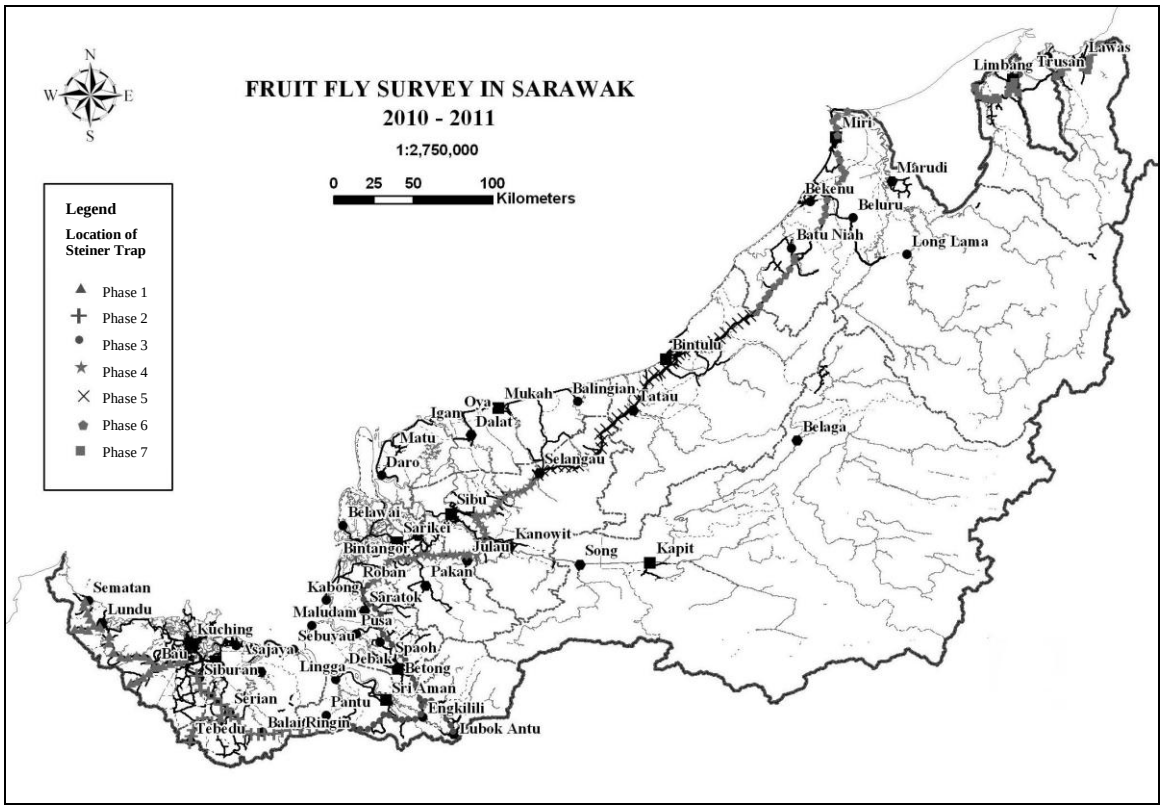

Figure 1. Location of the Steiner traps along the east-west trunk road of Sarawak.

RESULTS & DISCUSSION

A total of 177, 505 Dacinae fruit fly samples were collected and identified (Table 2). 664 fruit flies from the other Tephritidae subfamily were also trapped but are not discussed in this paper.

Twenty species of Dacinae fruit flies which includes eight unknown *Bactrocera* species were detected along the east-west trunk road of Sarawak. The identified species are *B. papayae*, *B. caudata*, *B. carambolae*, *B. cucurbitae*, *B. tau*, *B. albistragata*, *B. nigrotibialis*, *B. umbrosa*, *B. apicalis*, *B. ubiquitus*, *D. longicornis* and *D. hochii*. The *Bactocera* species which had not been clearly identified are currently categorized under *Bactrocera* complex species and further identification is needed.

The highest number of fruit fly caught occurred in Phase 1 (Bau to Lundu area), followed by Phase 7 (Miri to Lawas area) and Phase 2 (Siburan to Lachau area) (Table 2). These stretches of road are along the cultivated areas with various types of fruit trees such as *Psidium* sp., *Syzygium samarangense*, *Artocarpus heterophyllus*, *samarangense*, *Artocarpus heterophyllus*, *Artocarpus integer* and *Mangiferae* sp., and fruit vegetables such as *Cucumis sativa*, *Momordica charantia*, *Luffa* sp. and *Capsicum* sp. (S1). As trapping moved along the highway from Phase 3 to Phase 5 (Lachau to Bintulu area), where secondary jungle and oil palm plantations were found, the number of fruit fly caught dropped dramatically (Table 2).

The main species of fruit fly caught in ME-lure trap were *B. papayae* (97.94%), *B. umbrosa* (1.50%) and *B. carambolae* (0.49%) (Table 3). CUE-lure trap has attracted *B. papaya*e (46.00%), *B. caudata* (28.72%), *B. cucurbitae* (12.70%), *B. albistrigata* (4.62%), *B. nigrotibialis* (1.99%), *B. carambolae* (1.69%), *B. tau* (1.42%) and others (2.86%). The quarantine species, *B. correcta*, *B. dorsalis*, *B. occipitalis* and *B. zonata* were absent in both ME-lure and CUE-lure traps. Trimed-lure trap did not detect any Mediteranean fruit fly but had attracted some other species. They were *B. papayae* (41.03%), *B. caudata* (19.87%), *B. cucurbitae* (16.67%), *B. albistrigata* (5.13%) and other species (17.31%).

The geographical distribution patterns of the indigenous fruit fly along the main road of Sarawak are shown in Table 2. All the fruit fly species showed some fluctuations in population as trapping process moved along the main road of Sarawak. *Bactrocera papayae* and *B. caudata* were found abundant throughout the trapping locations and *B. papayae* is the predominant species from Phase 1 to Phase 7 (Table 2). This suggests that either *B. papayae* has a wide host range or that its host plant is widely spread throughout Sarawak. The other species were more prevalent at some locations. The population fluctuation patterns were almost similar except for *B. apicalis*. Generally, the number of fruit fly species trapped declined at secondary jungle areas whereas the number of *B. apicalis* increased in secondary jungle areas. This is because forest fruits served as the host plant for this species (Rohani Ibrahim, Faculty of Agriculture, Universiti Putra Malaysia, personal communications). Out of the eleven identified species, ten of them were detected in all the trapping phases. *Dacus hochii* was detected in Phase 1, trap no.1 in Bau (S1). Other species which were trapped in low numbers i.e. less than 100 per phase were *B. apicalis* and *D. longicornis*.

Bactrocera apicalis, *D. longicornis* and *D. hochii* are not of economic importance. *Bactrocera apicalis*, formerly known as *B. modica* (Allwood *et al*. 1999) is distributed in China (Yunnan, Hainan), Thailand, Vietnam, Phillipines (Mindanao), Malaysia, Brunei and Indonesia. According to Allwood *et al*. (1999), the flower *Trichosanthes wawraei* belonging to the Family Cucurbitaceae is the host plant for *B. apicalis*.

Table 2. Number of fruit fly species caught for 3 types of lures in each phase.

Species/Phase	1	2	3	4	5	6	7	Total
B. papayae	44213	21016	11252	16373	6933	21020	30408	151215
B. caudata	1726	4574	1898	738	1548	1178	854	12516
B. cucurbitae	3024	1062	476	207	245	95	437	5546
B. albistrigata	495	272	14	4	342	472	442	2041
B. umbrosa	416	382	226	150	367	134	328	2003
B. carambolae	253	35	94	230	80	237	468	1397
B. nigrotibialis	240	202	65	42	17	18	282	866
B. tau	99	147	53	42	51	81	151	624
B. apicalis	2	1	27	114	3	11	24	191
D. longicornis	13	8	12	5	2	14	2	56
D. hochii	1	-	-	-	-	-	-	1
Bactrocera complex species	156	148	257	233	47	63	145	1049
Total	50638	27847	14374	18138	9635	23323	33541	177505
Percentage (%)	29	16	8	10	5	13	19	100

Table 3. Number of fruit fly species caught for 3 types of lures.

Species/Lure	ME	Incidence (%)	CUE	Incidence (%)	Trimed	Incidence (%)
B. papayae	131187	97.94	19964	46.00	64	41.03
B. caudata	20	0.02	12465	28.72	31	19.87
B. cucurbitae	7	0.005	5513	12.70	26	16.67
B. albistrigata	27	0.02	2006	4.62	8	5.13
B. umbrosa	2002	1.50	-	-	1	0.64
B. carambolae	662	0.49	734	1.69	1	0.64
B. nigrotibialis	1	0.001	864	1.99	1	0.64
B. tau	1	0.001	614	1.42	9	5.77
B. apicalis	-	-	191	0.44	-	-
D. longicornis	-	-	56	0.13	-	-
D. hochii	-	-	1	0.002	-	-
Bactrocera complex species	40	0.03	994	2.29	15	9.62

Key: "-" indicates no data.

Another minor pest, *D. longicornis*, has been regularly misidentified with numerous synonyms including *D. semieroides*, *D. destillatoria*, *D. eumenoides* and *D. variegate* (Drew *et al*. 2007). This species attacks plants belonging to the Family Cucurbitaceae such as *Luffa acutangula*, *Luffa aegyptiacca*, *Melothria wallichii* and *Trichosanthes cucumerina* (Allwood *et al*. 1999). It is widely spread across the region from Southern Asia to Southeast Asia (Drew *et al*. 2007).

The GPS data and mapping are important as they provide valuable information such as the exact location where the fruit fly species trapped and the geographical distribution patterns of the fruit fly along the east-west trunk road of Sarawak (S1). This is particularly important when the quarantine species are detected.

The availability of cultivated crops could be considered as the most important environmental factor affecting the population fluctuations. Climatic factors such as rainfall and relative humidity may also influence the population pattern. The unknown species were categorized under *Bactrocera* complex species due to the difficulty to distinguish them morphologically. Thus, it is suggested that the molecular genetics technique should be adopted for precise identification.

In this survey, the common Solanaceae fruit fly species, *B. latifrons* was not detected. This species is not attracted to ME or CUE male lures (McQuate 2008). Therefore, a host fruit sampling is needed to confirm the presence or absence of fruit fly species particularly those not attracted to male lures.

CONCLUSION

There is an abundance of fruit flies along the east-west trunk road of Sarawak. Twenty Dacinae fruit fly species have been trapped and eleven of them were identified as *B. papayae*, *B. caudata*, *B. carambolae*, *B. cucurbitae*, *B. tau*, *B. albistrigata*, *B. nigrotibialis*, *B. umbrosa*, *B. apicalis*, *D. longicornis* and *D. hochii*. *Bactrocera papayae*, which either has a wide host range or that its host plant is widely spread throughout Sarawak, is the predominant species. The population fluctuations are affected by the types of vegetation. The survey did not detect any foreign quarantine species. This fruit fly surveillance report, reporting the status of fruit fly species in Sarawak, therefore serves as a pest free assurance to the importing and exporting countries based on their quarantine regulations and requirements.

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Supplementary Materials

S1. Fruit fly species trapped and vegetation types at each location.

Phase	Trap No.	GPS data	Vegetation Types	*B. albistrigata*	*B. apicalis*	*B. carambolae*	*B. caudata*	*B. cucurbitae*	*B. nigrotibialis*	*B. papayae*	*B. tau*	*B. umbrosa*	*D. longicornis*	*D. hochii*
1	1	N01°25'34.1" E110°08'39.6"	*Artocarpus integer*, *Mangiferae* sp., *Psidium* sp., *Archidendron pauciflorum*	√		√	√	√	√	√	√	√	√	√
	2	N01°27'48.0" E110°07'03.1"	*Musa* sp., *Durio* sp., *Mangiferae* sp., *Citrus maxima*, *Nephelium lappaceum*, *Syzygium samarangense*			√	√			√	√	√		
	3	N01°29'08.3" E110°05'08.0"	*Musa* sp., *Artocarpus integer*, *Citrus maxima*, *Nephelium lappaceum*			√	√	√	√	√	√	√	√	
	4	N01°29'23.8" E110°02'31.6"	*Durio* sp., *Lansium domesticum*, *Mangiferae* sp., *Artocarpus heterophyllus*, *Citrus maxima*	√		√	√	√	√	√	√	√		
	5	N01°28'41.4" E109°59'45.2"	*Psidium* sp., *Lansium domesticum*, Litsea garciae, mata kucing, *Mangiferae* sp., *Artocarpus heterophyllus*, *Averrhoa carambola*, *Nephelium lappaceum*			√	√	√	√	√		√		
	6	N01°28'58.5" E109°57'18.9"	*Artocarpus integer*, *Citrus* sp., *Psidium* sp., *Syzygium samarangense*, *Nephelium lappaceum*, *Piper nigrum*, *Capsicum* sp.			√	√	√	√	√	√	√		
	7	N01°30'31.0" E109°54'40.4"	Secondary jungle, *Acacia*			√	√	√	√	√				
	8	N01°33'35.4" E109°53'17.0"	*Musa* sp., *Mangiferae* sp., *Pangium edule*	√		√	√	√	√	√	√	√		
	9	N01°36'01.7" E109°53'21.8"	*Syzygium samarangense*, *Lansium domesticum*, *Capsicum* sp.						√	√		√		
	10	N01°38'35.0" E109°52'25.9"	*Artocarpus integer*, *Cocos nucifera*, *Mangiferae* sp.	√		√	√	√	√	√		√	√	
	11	N01°28'06.3" E110°19'00.2"	Secondary jungle			√	√			√	√			
	12	N01°27'16.1" E110°16'51.0"	*Mangiferae* sp.	√		√	√	√	√	√	√	√		
	13	N01°26'42.4" E110°14'05.4"	*Nephelium lappaceum*		√	√	√	√	√	√	√	√	√	
	14	N01°25'49.5" E110°11'39.0"	*Manilkara zapota*, *Durio* sp. belanda			√	√		√	√		√	√	
	15	N01°25'15.6" E110°09'59.6"	*Nephelium lappaceum*	√		√	√	√	√	√	√			

Phase	Trap No.	GPS data	Vegetation Types	*B. albistrigata*	*B. apicalis*	*B. carambolae*	*B. caudata*	*B. cucurbitae*	*B. nigrotibialis*	*B. papayae*	*B. tau*	*B. umbrosa*	*D. longicornis*	*D. hochii*
	16	N01°39'13.5" E109°50'07.6"	Secondary jungle	√			√		√	√			√	
	17	N01°39'43.9" E109°48'10.3"	*Dimocarpus longan*	√		√	√	√	√	√		√		
	18	N01°41'47.5" E109°46'53.3"	*Musa* sp., *Citrus sp.* sp., *Lansium domesticum*, *Mangiferae* sp., *Mangiferae* sp.steen, *Carica Carica papaya*, *Nephelium lappaceum*, *Syzygium samarangense*											
	19	N01°43'56.4" E109°46'03.6"	*Musa* sp., *Psidium* sp., *Syzygium samarangense*, *Momordica charantia*, *Capsicum* sp., *Vigna unguiculata sesquipedalis*, *Cucumis sativa*	√			√	√	√	√	√	√		
	20	N01°46'05.2" E109°44'48.1"	*Nephelium lappaceum*	√		√	√	√		√				
	21	N01°47'56.9" E109°45'11.3"	*Mangiferae* sp.	√		√	√	√	√	√	√	√	√	
	22	N01°38'02.5" E109°46'17.6"	Asam, *Artocarpus integer*, *Annona muricata*, *Mangiferae* sp., *Artocarpus heterophyllus*, *Nephelium lappaceum*, *Capsicum* sp.			√	√	√	√	√	√	√		
	23	N01°38'21.1" E109°43'57.2"	*Artocarpus integer*, *Dimocarpus longan*, *Artocarpus heterophyllus*, *Carica papaya*, *Averrhoa carambola*	√		√	√	√	√	√	√	√		
	24	N01°38'26.9" E109°41'43.3"	*Musa* sp., *Mangiferae* sp., *Nephelium lappaceum*			√	√	√	√	√	√	√		
	25	N01°23'30.6" E110°06'48.7"	*Citrus* sp., *Artocarpus integer*, *Dimocarpus longan*, *Mangiferae* sp., *Nephelium lappaceum*, *Syzygium samarangense*			√	√		√	√	√			
	26	N01°21'57.3" E110°04'55.5"	*Theobroma cocoa*, *Citrus* sp., *Capsicum* sp.			√	√	√	√	√	√		√	
	27	N01°20'40.3" E110°02'51.3"	*Musa* sp., *Artocarpus integer*				√		√	√		√		
	28	N01°20'02.2" E110°00'42.5"	*Citrus* sp.				√	√	√	√		√	√	
2	1	N01°08'46.6" E110°31'49.5"	*Nephelium lappaceum*				√	√	√	√				
	2	N01°06'49.2" E110°30'51.7"	Secondary jungle	√		√	√	√	√	√	√	√		
	3	N01°06'28.8" E110°28'21.5"	Secondary jungle				√	√	√	√				
	4	N01°07'44.5" E110°25'24.2"	Secondary jungle				√		√	√	√	√		
	5	N01°06'25.1" E110°23'27.0"	Secondary jungle						√	√				
	6	N01°03'47.4" E110°22'10.8"	Secondary jungle	√	√		√		√	√	√	√		
	7	N01°01'36.8" E110°21'26.1"	Secondary jungle	√			√	√		√	√	√		
	8	N00°59'30.7" E110°20'55.1"	Secondary jungle	√		√	√		√	√	√			
	9	N01°10'53.3" E110°33'37.5"	*Musa* sp., *Nephelium lappaceum*, *Saurapus androgynous*, *Capsicum* sp., Luffa sp., *Cucumis sativa*	√		√	√	√	√	√	√	√		
	10	N01°12'25.1" E110°31'33.9"	*Artocarpus heterophyllus*, nangcem, *Carica papaya*, *Averrhoa carambola*, *Vigna unguiculata sesquipedalis*, *Cucumis sativa*, Momordica charantia,	√		√	√	√	√	√	√	√		
	11	N01°14'37.5" E110°29'22.3"	*Musa* sp., *Artocarpus integer*, *Syzygium samarangense*				√	√	√	√	√	√		
	12	N01°16'22.7" E110°27'12.2"	*Musa* sp., *Citrus* sp., *Manilkara zapota*, *Solanum melongena*, *Artocarpus integer*, *Syzygium samarangense*, *Momordica charantia*, *Capsicum* sp., *Cucumis sativa*	√			√	√	√	√	√	√		

Phase	Trap No.	GPS data	Vegetation Types	*B. albistrigata*	*B. apicalis*	*B. carambolae*	*B. caudata*	*B. cucurbitae*	*B. nigrotibialis*	*B. papayae*	*B. tau*	*B. umbrosa*	*D. longicornis*	*D. hochii*
	13	N01°17'19.3" E110°24'54.0"	*Musa* sp., *Citrus* sp., *Citrus maxima*, *Carica papaya*, leafy vegetables				√	√	√	√	√	√		
	14	N01°19'36.4" E110°24'11.3"	Secondary jungle				√	√	√	√	√	√		
	15	N01°22'18.7" E110°23'14.2"	*Musa* sp., *Citrus* sp., *Capsicum* sp.	√			√	√	√	√	√	√		
	16	N01°08'56.4" E110°34'43.6"	*Citrus* sp.	√			√	√	√	√	√	√	√	
	17	N01°07'32.3" E110°37'09.1"	*Citrus* sp.	√		√	√	√		√		√		
	18	N01°05'17.2" E110°37'46.7"	Secondary jungle				√	√	√	√	√	√	√	
	19	N01°03'17.4" E110°39'14.9"	*Citrus sp.* sp.				√	√		√		√		
	20	N01°02'23.1" E110°41'47.4"	Secondary jungle			√	√	√	√	√		√		
	21	N01°02'24.8" E110°44'12.0"	*Syzygium samarangense*			√	√	√		√	√			
	22	N01°02'29.7" E110°46'22.1"	Secondary jungle			√	√	√	√	√				
	23	N01°02'31.2" E110°49'29.1"	*Citrus* sp.				√			√				
	24	N01°03'28.9" E110°52'21.1"	Secondary jungle				√	√	√	√	√	√	√	
	25	N01°04'21.9" E110°54'54.2"	Secondary jungle				√		√	√				
	26	N01°04'33.7" E110°58'18.0"	*Nephelium lappaceum*						√	√		√		
	27	N01°04'39.8" E110°01'30.8"	Secondary jungle				√			√				
	28	N01°04'50.7" E110°04'01.1"	Secondary jungle			√	√	√	√	√				
	29	N01°04'44.7" E110°07'24.8"	Secondary jungle				√	√	√	√				
	30	N01°04'30.9" E110°09'18.1"	Secondary jungle				√		√	√				
3	1	N01°05'30.4" E111°11'52.5"	Secondary jungle		√	√	√		√	√	√			
	2	N01°05'54.4" E111°13'36.6"	Secondary jungle					√	√	√				
	3	N01°05'03.9" E111°16'02.2"	Secondary jungle			√	√			√				
	4	N01°04'03.2" E111°18'30.1"	Secondary jungle			√	√		√	√				
	5	N01°04'10.6" E111°21'02.9"	Secondary jungle				√			√		√		
	6	N01°05'38.7" E111°23'01.2"	Secondary jungle				√	√	√	√	√	√		
	7	N01°06'59.8" E111°24'59.3"	Secondary jungle	√	√	√	√	√	√	√	√	√		
	8	N01°09'01.1" E111°26'25.2"	*Musa* sp., *Mangiferae* sp., *Artocarpus heterophyllus*, *Averrhoa carambola*	√		√	√	√		√	√	√		
	9	N01°08'54.6" E111°28'20.5"	*Nephelium lappaceum*, *Capsicum* sp.	√			√	√	√	√		√		
	10	N01°07'33.7" E111°30'30.1"	*Psidium* sp.			√	√	√	√	√	√	√		
	11	N01°07'17.8" E111°32'30.7"	Secondary jungle				√	√	√	√		√		
	12	N01°07'30.8" E111°34'37.1"	Secondary jungle				√	√		√	√	√		
	13	N01°07'32.4" E111°37'04.8"	Secondary jungle		√	√	√	√	√	√				
	14	N01°09'11.4" E111°38'58.7"	Secondary jungle		√		√	√		√		√		

Phase	Trap No.	GPS data	Vegetation Types	*B. albistrigata*	*B. apicalis*	*B. carambolae*	*B. caudata*	*B. cucurbitae*	*B. nigrotibialis*	*B. papayae*	*B. tau*	*B. umbrosa*	*D. longicornis*	*D. hochii*
	15	N01°12'01.4" E111°39'11.8"	Secondary jungle			√	√	√	√	√		√		
	16	N01°14'31.9" E111°38'33.4"	Secondary jungle							√		√		
	17	N01°16'39.2" E110°37'29.3"	Secondary jungle		√		√	√	√	√		√		
	18	N01°19'02.4" E111°37'06.0"	Secondary jungle, *Musa* sp.			√	√	√	√	√				
	19	N01°21'10.1" E111°36'20.0"	Secondary jungle, *Musa* sp., bamboo, *Mangiferae* sp.		√		√	√		√		√		
	20	N01°23'22.5" E111°35'52.4"	Secondary jungle			√	√	√	√	√				
	21	N01°25'42.3" E111°34'59.8"	Secondary jungle			√	√			√				
	22	N01°27'42.1" E111°33'47.0"	Secondary jungle		√		√		√	√				
	23	N01°29'34.1" E111°32'21.7"	Secondary jungle, *Acacia* sp.				√		√	√				
	24	N01°31'40.4" E111°31'14.2"	Secondary jungle			√	√		√	√				
	25	N01°32'52.5" E111°29'13.5"	Secondary jungle			√				√				
	26	N01°35'01.2" E111°27'43.8"	Secondary jungle			√	√			√				
	27	N01°36'28.1" E111°26'10.1"	Secondary jungle				√	√	√	√			√	
	28	N01°38'43.2" E111°25'23.7"	Secondary jungle						√	√				
	29	N01°41'08.5" E111°25'51.9"	Secondary jungle		√	√	√		√	√		√		
	30	N01°43'24.0" E111°25'22.4"	Secondary jungle		√		√			√				
	31	N01°13'40.4" E111°40'30.0"	*Mangiferae* sp.					√		√				
	32	N01°13'43.7" E111°42'33.9"	Secondary jungle		√	√	√	√	√	√				
	33	N01°12'05.6" E111°44'14.9"	Secondary jungle			√	√		√	√				
	34	N01°09'53.8" E111°45'58.7"	*Mangiferae* sp.			√	√	√		√				
	35	N01°07'43.2" E111°47'34.5"	Secondary jungle		√	√	√	√	√	√			√	
	36	N01°05'27.5" E111°49'06.7"	Secondary jungle		√	√	√	√	√	√				
	37	N01°03'17.9" E111°49'53.8"	*Musa* sp., Citrus sp.			√	√	√	√	√		√	√	
	38	N01°45'16.0" E111°23'36.6"	Secondary jungle				√			√				
	39	N01°46'55.6" E111°21'38.1"	Secondary jungle	√		√	√	√	√	√	√		√	
	40	N01°48'31.2" E111°19'39.8"	Secondary jungle		√	√	√			√		√	√	
	41	N01°51'06.7" E111°19'20.8"	Secondary jungle		√		√			√		√		
	42	N01°53'14.3" E111°21'03.2"	Secondary jungle		√	√	√		√	√				
4	1	N01°54'46.2" E111°22'55.9"	Secondary jungle			√			√	√				
	2	N01°55'38.9" E111°24'45.1"	Secondary jungle			√	√	√	√	√				
	3	N01°57'39.7" E111°25'41.5"	Secondary jungle			√			√	√		√		
	4	N01°59'17.9" E111°26'34.2"	Secondary jungle	√	√			√		√	√	√		

Phase	Trap No.	GPS data	Vegetation Types	*B. albistrigata*	*B. apicalis*	*B. carambolae*	*B. caudata*	*B. cucurbitae*	*B. nigrotibialis*	*B. papayae*	*B. tau*	*B. umbrosa*	*D. longicornis*	*D. hochii*
	5	N02°01'36.0" E111°28'06.8"	Secondary jungle			√	√	√		√		√		
	6	N02°03'12.2" E111°30'11.6"	Secondary jungle		√	√	√	√	√	√			√	
	7	N02°03'05.6" E111°31'59.3"	Secondary jungle			√	√	√	√	√	√			
	8	N02°02'19.6" E111°34'27.0"	Secondary jungle, *Musa* sp.	√		√	√	√	√	√			√	
	9	N02°02'25.5" E111°36'43.1"	Secondary jungle, *Musa* sp., *Nephelium lappaceum*				√	√		√	√	√		
	10	N02°03'58.1" E111°38'57.8"	Secondary jungle, *Musa* sp., *Citrus* sp., *Mangiferae* sp.			√	√		√	√		√	√	
	11	N02°03'38.5" E111°41'17.3"	Secondary jungle, *Musa* sp., bamboo		√	√	√	√		√	√	√	√	
	12	N02°03'17.5" E111°43'26.8"	*Nephelium lappaceum*, *Musa* sp.		√		√	√		√		√	√	
	13	N02°03'43.8" E111°46'21.0"	Secondary jungle		√	√	√	√	√	√	√	√		
	14	N02°03'58.3" E111°48'59.1"	Secondary jungle, *Musa* sp.		√	√	√	√		√				
	15	N02°03'31.6" E111°50'57.0"	Secondary jungle				√			√				
	16	N02°03'47.2" E111°53'44.5"	Secondary jungle, *Musa* sp.		√	√	√	√	√	√		√		
	17	N02°03'51.4" E111°55'37.9"	Secondary jungle		√					√				
	18	N02°03'44.9" E111°58'02.6"	Secondary jungle, *Musa* sp.			√	√			√		√	√	
	19	N02°06'13.5" E111°58'38.7"	Secondary jungle, *Musa* sp., *Mangiferae* sp., bamboo			√	√	√	√	√		√		
	20	N02°08'03.2" E111°59'54.2"	Secondary jungle		√	√				√				
	21	N02°10'41.8" E112°00'52.8"	Secondary jungle			√				√				
	22	N02°12'54.0" E112°00'13.1"	Secondary jungle				√		√	√				
	23	N02°14'18.1" E111°58'42.0"	Secondary jungle	√			√	√		√		√		
	24	N02°16'11.1" E111°57'36.2"	Secondary jungle				√			√				
	25	N02°17'16.1" E111°58'06.9"	Secondary jungle			√	√	√		√		√		
	26	N02°17'22.3" E111°00'17.3"	Secondary jungle			√	√	√		√		√		
	27	N02°17'41.6" E111°03'03.3"	Secondary jungle			√	√		√	√	√			
	28	N02°19'46.9" E112°03'51.0"	Secondary jungle			√	√	√		√		√		
	29	N02°21'43.7" E112°05'30.2"	Secondary jungle				√			√		√		
	30	N02°23'12.4" E112°07'28.8"	Secondary jungle			√		√		√		√		
	31	N02°24'51.0" E112°09'17.0"	Secondary jungle			√	√	√	√	√		√		
	32	N02°24'46.9" E112°11'47.2"	Secondary jungle			√	√	√	√	√		√		
	33	N02°25'48.8" E112°14'00.6"	Secondary jungle			√	√	√		√				
	34	N02°27'15.1" E112°16'09.3"	Secondary jungle			√	√	√		√	√	√		
	35	N02°29'12.2" E112°17'15.5"	Secondary jungle			√	√	√	√	√				
5	1	N03°25'05.3" E113°31'01.7"	*Musa* sp., *Nephelium lappaceum*				√			√	√	√		

Phase	Trap No.	GPS data	Vegetation Types	*B. albistrigata*	*B. apicalis*	*B. carambolae*	*B. caudata*	*B. cucurbitae*	*B. nigrotibialis*	*B. papayae*	*B. tau*	*B. umbrosa*	*D. longicornis*	*D. hochii*
	2	N03°24'03.5" E113°28'35.4"	Secondary jungle				√			√		√		
	3	N03°22'34.0" E113°26'36.6"	Secondary jungle, *Musa* sp., *Citrus* sp., *Mangiferae* sp.				√	√		√		√		
	4	N03°21'06.1" E113°24'19.8"	*Musa* sp., *Cocos nucifera, Lansium domesticum, Syzygium samarangense, Elaies guineensis*				√	√		√		√		
	5	N03°19'17.9" E113°22'29.5"	*Canarium odontophyllum*, terap, *Nephelium lappaceum, Syzygium samarangense*				√	√	√	√		√		
	6	N03°17'19.1" E113°20'39.9"	Secondary jungle, *Elaies guineensis*		√		√	√		√				
	7	N03°16'11.4" E113°18'22.2"	Secondary jungle, *Mangiferae* sp., *Nephelium lappaceum*, terap				√	√		√	√	√		
	8	N03°14'48.2" E113°16'03.8"	Secondary jungle, *Musa* sp., *Artocarpus integer*				√	√		√		√		
	9	N03°14'27.6" E113°13'44.7"	Secondary jungle			√	√	√		√		√		
	10	N03°13'57.7" E113°11'06.0"	Secondary jungle, *Canarium odontophyllum, Cocos nucifera*				√	√		√	√	√		
	11	N03°13'03.7" E113°08'48.1"	*Mangiferae* sp., *Artocarpus integer*, terap	√			√	√		√		√		
	12	N03°11'51.1" E113°06'36.2"	Secondary jungle	√			√	√		√		√		
	13	N03°10'31.5" E113°05'39.8"	Secondary jungle				√			√		√		
	14	N03°08'49.3" E113°04'15.4"	Secondary jungle	√			√			√		√		
	15	N03°07'26.3" E113°02'01.6"	Secondary jungle				√	√		√		√		
	16	N03°05'38.5" E113°00'18.8"	Secondary jungle			√	√	√	√	√				
	17	N03°04'40.7" E112°58'12.5"	Secondary jungle				√	√		√		√		
	18	N03°03'o3.3" E112°56'16.4"	Secondary jungle			√	√			√		√		
	19	N03°00'55.8" E112°55'12.1"	Secondary jungle				√	√		√		√		
	20	N02°58'33.1" E112°53'57.3"	Secondary jungle, *Zea mays*			√	√	√	√	√		√		
	21	N02°56'16.5" E112°53'10.6"	Secondary jungle			√	√	√		√		√		
	22	N02°54'26.4" E112°51'25.0"	Secondary jungle				√	√		√		√		
	23	N02°52'31.8" E112°49'59.2"	Secondary jungle							√		√		
	24	N02°51'27.8" E112°47'48.8"	Secondary jungle, *Elaies guineensis*				√	√		√	√			
	25	N02°50'03.8" E112°45'44.1"	Secondary jungle			√	√	√		√		√		
	26	N02°48'02.3" E112°44'19.1"	Secondary jungle, *Musa* sp., *Saurapus androgynous*			√	√	√	√	√		√		
	27	N02°46'17.3" E112°41'59.7"	Secondary jungle	√		√	√	√	√	√		√		
	28	N02°44'53.9" E112°39'52.3"	Secondary jungle			√	√	√	√	√		√	√	
	29	N02°42'35.2" E112°40'32.8"	Secondary jungle, *Musa* sp., *Elaies guineensis, Capsicum* sp.			√	√	√	√	√		√		
	30	N02°39'53.9" E112°40'17.4"	Secondary jungle, *Musa* sp., *Mangiferae* sp.			√	√			√				
	31	N02°37'37.8" E112°38'49.5"	*Elaies guineensis*				√			√				
	32	N02°36'28.3" E112°36'41.8"	*Acacia* sp., *Musa* sp., *Mangiferae* sp., *Carica papaya*							√		√		
	33	N02°36'05.6" E112°34'07.5"	Secondary jungle, *Musa* sp.			√			√	√		√		

Phase	Trap No.	GPS data	Vegetation Types	*B. albistrigata*	*B. apicalis*	*B. carambolae*	*B. caudata*	*B. cucurbitae*	*B. nigrotibialis*	*B. papayae*	*B. tau*	*B. umbrosa*	*D. longicornis*	*D. hochii*
	34	N02°34'01.7" E112°32'33.0"	Secondary jungle			√	√		√	√				
	35	N02°33'23.9" E112°30'31.4"	Secondary jungle			√	√	√	√	√		√		
	36	N02°33'37.5" E112°27'59.6"	Secondary jungle			√				√	√			
	37	N02°33'52.7" E112°25'22.4"	Secondary jungle			√	√	√		√				
	38	N02°33'07.2" E112°23'00.1"	Secondary jungle, *Mangiferae* sp., *Nephelium lappaceum*, *Syzygium samarangense*			√	√			√				
	39	N02°32'26.6" E112°20'29.1"	Secondary jungle				√			√				
	40	N02°30'51.1" E112°18'50.0"	Secondary jungle, *Artocarpus integer*			√	√	√		√				
6	1	N04°34'55.5" E114°04'12.5"	Secondary jungle	√			√			√				
	2	N04°32'52.2" E114°03'28.9"	Secondary jungle		√		√	√		√				
	3	N04°33'08.2" E114°00'42.7"	*Musa* sp., *Cocos nucifera*, *Artocarpus heterophyllus*, *Mangiferae* sp., *Saurapus androgynous*	√	√		√	√		√		√		
	4	N04°31'27.8" E113°59'15.3"	Secondary jungle	√			√	√		√				
	5	N04°29'13.3" E114°00'15.6"	*Musa* sp., *Artocarpus heterophyllus*	√			√			√		√		
	6	N04°26'33.9" E114°00'37.5"	*Musa* sp., *Mangiferae* sp.	√			√	√		√		√		
	7	N04°20'17.5" E114°00'37.5"	*Citrus* sp., *Citrus maxima*, *Syzygium samarangense*, leafy vegetable	√	√		√	√		√		√		
	8	N04°18'09.5" E114°01'31.8"	Secondary jungle	√			√	√		√		√		
	9	N04°15'29.1" E114°02'02.6"	Secondary jungle, *Musa* sp.	√		√				√		√		
	10	N04°13'47.2" E114°03'12.8"	Secondary jungle							√		√		
	11	N04°11'49.4" E114°02'20.9"	Secondary jungle				√			√		√		
	12	N04°09'49.7" E114°00'46.4"	Secondary jungle	√				√		√				
	13	N04°04'34.3" E113°57'08.2"	Secondary jungle, *Averrhoa carambola*	√	√	√	√		√	√		√	√	
	14	N04°02'03.0" E113°56'24.8"	*Citrus* sp., terap	√	√	√	√	√		√		√		
	15	N03°59'32.0" E113°56'27.9"	*Cocos nucifera*, *Artocarpus heterophyllus*, *Nephelium lappaceum*			√	√	√		√	√	√	√	
	16	N03°57'31.9" E113°55'19.4"	*Durio* sp., *Artocarpus heterophyllus*, terap			√	√		√	√				
	17	N03°54'13.8" E113°54'04.9"	Secondary jungle	√		√	√			√			√	
	18	N03°46'59.3" E113°49'49.4"	*Musa* sp., *Psidium* sp., *Nephelium lappaceum*, *Mangiferae pajang*			√	√	√	√	√	√	√		
	19	N03°44'55.0" E113°45'54.8"	*Durio* sp., *Nephelium lappaceum*, terap				√	√		√	√	√		
	20	N03°43'38.6" E113°45'54.8"	*Musa* sp., *Artocarpus integer*			√	√			√		√	√	
	21	N03°41'02.9" E113°44'26.0"	Secondary jungle			√	√	√		√	√			
	22	N03°38'48.9" E113°42'58.5"	*Cocos nucifera*, *Musa* sp., *Mangiferae* sp., *Psidium* sp.			√	√			√		√		
	23	N03°36'52.7" E113°40'59.9"	Secondary jungle, *Musa* sp.			√	√			√				
	24	N03°35'05.7" E113°39'02.4"	*Musa* sp., *Psidium* sp., *Nephelium lappaceum*, *Mangiferae* pajang			√	√		√	√				

Phase	Trap No.	GPS data	Vegetation Types	*B. albistrigata*	*B. apicalis*	*B. carambolae*	*B. caudata*	*B. cucurbitae*	*B. nigrotibialis*	*B. papayae*	*B. tau*	*B. umbrosa*	*D. longicornis*	*D. hochii*
	25	N03°32'53.8" E113°37'23.4"	*Durio* sp., *Nephelium lappaceum*			√	√		√	√				
	26	N03°30'59.7" E113°36'00.7"	*Durio* sp., mempalam			√				√		√		
	27	N03°28'33.3" E113°34'10.7"	Secondary jungle			√	√			√				
	28	N03°26'15.2" E113°33'07.6"	*Musa* sp.			√	√	√	√	√				
7	1	N04°57'28.1" E115°30'21.1"	*Psidium* sp., *Nephelium lappaceum*	√		√	√	√	√	√	√			
	2	N04°55'56.3" E115°29'47.4"	Secondary jungle	√		√	√		√	√				
	3	N04°54'46.8" E115°27'44.4"	Secondary jungle	√		√			√	√				
	4	N04°52'19.0" E115°26'29.7"	Secondary jungle	√		√	√		√	√	√			
	5	N04°50'24.7" E115°26'11.4"	Secondary jungle			√	√	√	√	√		√		
	6	N04°48'36.6" E115°25'44.7"	*Musa* sp., *Hylocereus* sp., mata kucing	√		√	√	√	√	√	√			
	7	N04°49'25.7" E115°24'00.9"	*Theobroma cocoa*, *Dimocarpus longan*, australian laichi, *Nephelium lappaceum*, lombok	√		√	√	√	√	√	√			
	8	N04°51'22.3" E115°23'27.6"	*Vitex pinnata*	√		√	√	√	√	√	√			
	9	N04°50'52.9" E115°21'10.7"	*Musa* sp., *Cocos nucifera*, *Mangiferae* sp., *Nephelium lappaceum*	√		√	√	√	√	√	√	√		
	10	N04°49'38.4" E115°18'53.5"	*Musa* sp., *Artocarpus heterophyllus*, *Durio* sp. belanda, *Citrus maxima*			√	√		√	√	√	√		
	11	N04°47'48.1" E115°16'50.9"	*Musa* sp., *Citrus* sp., *Psidium* sp., *Mangiferae* sp.			√	√	√	√	√	√	√		
	12	N04°46'31.8" E115°15'03.8"	*Musa* sp., *Artocarpus heterophyllus*, *Psidium* sp., *Artocarpus heterophyllus*			√	√	√		√				
	13	N04°41'07.1" E115°02'00.7"	*Musa* sp., *Cocos nucifera*, *Psidium* sp., *Citrus* sp. maxima, *Nephelium lappaceum*			√	√	√	√	√	√	√		
	14	N04°42'05.9" E115°00'20.0"	*Musa* sp., *Psidium* sp., *Artocarpus heterophyllus*, *Capsicum* sp., *Luffa* sp., leafy vegetables	√		√	√	√		√	√	√		
	15	N04°44'36.8" E115°00'51.2"	*Musa* sp., *Artocarpus heterophyllus*, *Syzygium samarangense*, leafy vegetables, *Luffa* sp., *Capsicum* sp.	√			√	√	√	√		√		
	16	N04°43'20.3" E114°59'17.8"	*Mangiferae* sp., *Averrhoa carambola*	√			√	√	√	√	√	√		
	17	N04°40'41.0" E114°58'43.4"	*Musa* sp., *Citrus* sp., *Hylocereus* sp., *Psidium* sp., *Mangiferae* sp., *Carica papaya*	√			√	√	√	√				
	18	N04°39'25.9" E114°54'15.1"	*Musa* sp., *Manilkara zapota*, *Psidium* sp.	√		√	√	√	√	√		√		
	19	N04°38'53.0" E114°55'20.6"	*Cocos nucifera*, *Psidium* sp.				√		√	√	√	√		
	20	N04°38'39.4" E114°53'22.7"	*Musa* sp., *Mangiferae* sp.	√	√	√	√	√	√	√	√	√		
	21	N04°38'55.8" E114°50'58.6"	*Musa* sp., *Citrus* sp., *Nephelium lappaceum*	√	√		√		√	√	√	√		
	22	N04°40'06.1" E114°48'40.1"	*Citrus* sp., *Cocos nucifera*, *Dimocarpus longan*, *Nephelium lappaceum*				√	√	√	√		√		
	23	N04°42'48.2" E114°47'36.0"	Secondary jungle	√	√	√	√	√	√	√		√		

Reference of common names for the scientific names

Acacia sp.	Acacia
Annona muricata	Soursop
Archidendron pauciflorum	Jering
Artocarpus heterophyllus	Jackfruit
Artocarpus integer	Cempedak
Averrhoa carambola	Star fruit
Canarium odontophyllum	Dabai
Capsicum sp.	Chilli
Carica papaya	Papaya
Citrus maxima	Pamelo
Citrus sp.	Citrus
Cocos nucifera	Coconut
Cucmis sativa	Cucumber
Dimocarpus longan	Longan
Durio sp.	Durian
Elaies guineensis	Oil palm
Hylocereus sp.	Dragon fruit
Lansium domesticum	Langsat
Litsea garciae	Engkalak
Luffa sp.	Luffa
Mangifera sp.	Mango
Mangiferae pajang	Membangan
Manilkara zapota	Chiku
Momordica charantia	Bittergourd
Musa sp.	Banana
Nephelium lappaceum	Rambutan
Pangium edule	Kepayang
Piper nigrum	Pepper
Psidium sp.	Guava
Solanum melongena	Brinjal
Syzygium samarangense	Wax apple
Theobroma cocoa	Cocoa
Vigna unguiculata sesquipedalis	Long bean
Vitex pinnata	Kulimpapa
Zea mays	Maize