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Preliminary exploration for natural enemies of
***Rubus ellipticus* in China**

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Abstract

The Yellow Himalayan Raspberry, *Rubus ellipticus*, is an invasive plant in Hawaii. As chemical, physical and manual controls are expensive and difficult to implement against this plant, biological control is being considered. The collaboration between China and the U.S. for finding potential biological control agents in the native range of *R. ellipticus* was recently reinitiated in 2006. Here, we report 60 arthropod species in 30 families that were directly collected on *Rubus ellipticus* in field surveys in 2006-2008. We also provide a review of the potential agents, including 49 species of arthropods in 16 families and 65 species of fungi in 3 phyla and 19 families, from literature or online data. Among these species, the warty beetles *Chlamisus setosus* (Bowditch) and *Chlamisus* spp., the flea beetles *Chaetoenema*, an unidentified stem borer, the leaf-rolling moth *Epinotia* spp. and an unidentified sawfly were the most promising potential agents. Preliminary lab tests indicated that the warty beetles *Chlamisus* spp., the flea beetles *Chaetoenema*, may have narrow host range. We recommend further screening of these organisms to investigate their impacts on the target plant, host specificity, and the risk of undesired effects in Hawaiian ecosystems.

Introduction

Rubus ellipticus, yellow Himalayan raspberry, is a serious invasive plant in Hawaii, posing a great threat to local ecosystems. It was listed as one of the 100 World's worst invasive alien species by IUCN. Mechanical and herbicidal control has been performed on a limited scale, but large scale eradication is not feasible, because of the extensiveness and rugged terrain of the infested area. The plant is native to the Himalayan region in Asia, including China, Bhutan, India, Laos, Myanmar, Nepal, Pakistan, Philippines, Sikkim, Sri Lanka, Thailand and Vietnam.

Rubus is one of the largest genera in Rosaceae, consisting about 700 species worldwide. According to Gu et al (1996), 201 species grow in China. They are distributed in 27 Provinces, but around 70% of these species occur in southwestern China. *Rubus ellipticus* is distributed in Guangxi, Guizhou, Sichuan, Tibet, and Yunnan. It is a small deciduous shrubby plant about 1-2 m in height. The plant is perennial, reproducing by both vegetative means and seeds. It blooms from March to April and fruits from April through May. The plant grows along hillsides, roadsides or thickets in valleys, sparse forest, and broad-leaf forest at altitudes of 300-2000 m. Twigs and leaves are used medicinally, and fruits are eaten.

Previous biological control efforts by Dr. Don Gardner (USGS PIERC, Honolulu) focused on pathogens for *R. ellipticus*, but he retired and no promising pathogenic agent was screened. Dr. Gardner suggested that continued efforts should be put on insects associated with the plant in its native areas.

With funding from the state of Hawaii and USDA Forest Service, efforts for survey of and study on natural enemies were conducted in China in since spring 2006. Specifically, the objectives of this project are to: (1) identify prospective biocontrol agents and source areas from Chinese literature, (2) to locate source populations of *Rubus ellipticus* and associated arthropods in southwestern China; (3) evaluate life histories and biocontrol potential of 1-2 selected insect species; and (4) identify collaborators and plan in-depth studies at field sites in China.



Figure 1. Distribution of *Rubus ellipticus* in China (in grey)

Potential biocontrol agents and source areas identified from Chinese literature and field surveys

We conducted a thorough literature search for information on *Rubus ellipticus* and its associated natural enemies in China. We collected information from international databases, such as BIOSIS, CAB, and major Chinese databases (in Chinese), and Chinese books on forest and agricultural fauna, as well as internet information. A total of 49 arthropod species in 16 families have been recorded in literature as associated with *Rubus* in its Asian range (Table 1).

Table 1. Literature review: species of phytophagous insects on the genus *Rubus* in East Asia

Order : Family	Species	Feeds on	Location ^a	Host Range	References
Coleoptera					
Buprestidae	<i>Coraebus quadriundulatus</i> Motschulsky	Leaves	YN, SC (China); Japan	M	(Lei and Zhou 1998)
Chrysomelidae	<i>Aphthona howenchuni</i> (Chen)	Leaves	China	O	(Yu et al. 1996)
	<i>Batophila impressa</i> Wang	Leaves	China	O	(Yu et al. 1996)
	<i>Chaetocnema simplicifrons</i> (Baly)	Leaves	China	O	(Yu et al. 1996)
	<i>Phaedon fulvescens</i> Weise	Leaves	China; Vietnam	O	(Yu et al. 1996)
	<i>Enaptorrhinus convexiusculus</i> Heller	Leaves	HeN, YN, ShX (China)	P	(Zhao and Chen 1980)
Curculionidae	<i>Enaptorrhinus convexiusculus</i> Heller	Leaves	HeN, YN, ShX (China)	P	(Zhao and Chen 1980)
	<i>Basilepta leechi</i> (Jacoby)	Leaves	JS, ZJ, HB, JX, FJ, GD, GX, SC, GZ, YN (China); Vietnam	P	(Tan et al. 1980)
	<i>Basilepta ruficollis</i> (Jacoby)	Leaves	ZJ, HB, FJ, GX, SC, GZ, YN (China)	P	(Tan et al. 1980)
	<i>Chlamisus indicus</i> Jacoby	Leaves	GX, SC, YN (China); India	O	(Tan et al. 1980)
Eumolpidae	<i>Chlamisus latiusculus</i> Chūjō	Leaves	FJ, TW, HaiN, GX (China)	M	(Tan et al. 1980)
				(<i>R. amphidasys</i>)	

Order : Family	Species	Feeds on	Location ^a	Host Range	References
	<i>Chlamisus ruficeps</i> (Chen)	Leaves	FJ, GX (China)	P	(Tan et al. 1980)
	<i>Chlamisus semirufus</i> (Chen)	Leaves	JX, FJ, GD, GX (China); Vietnam	P	(Tan et al. 1980)
	<i>Chlamisus setosus</i> (Bowditch)	Leaves	YN(China)	M (<i>R. ellipticus</i>)	(Tan et al. 1980)
Hispidae	<i>Alledoya vespertina</i> (Boheman)	Leaves	HB, BJ, TW (China); Korea; Japan	P	(HIRANO 1998; Lei and Zhou 1998)
Hemiptera					
Coreidae	<i>Derepteryx fuliginosa</i> (Uhler)	Leaves, stems	JL (China),	P	(Zhang 1985)
	<i>Derepteryx lunata</i> (Distant)	Leaves, stems	HB, ZJ, GS, TW (China)	P	(Zhang 1985)
Pentatomidae	<i>Amyntor obscurus</i> (Dallas)	Leaves	China	P	(Zhang 1985)
Homoptera					
Aphididae	<i>Amphorophora rubi</i> (Kaltenbach, 1843)	Unknown	Turkey; UK; Finland; Belgium, US; Canada	M (<i>R. caesius</i>)	(Aslan and Uygun 2005; Database 2007)
	<i>Aphis ruborum</i> (Borner, 1932)	Leaves, flowers, shoots	Turkey; Europe	O (<i>R. caesius</i> , <i>R. fruticosus</i>)	(Aslan and Uygun 2005)
	<i>Acyrtosiphon rubiformosanum</i> (Takahashi)	Leaves	China	P	(Zhang and Zhong 1983)
Lepidoptera					
Geometridae	<i>Dysstroma cinereata</i> (Moore)	Leaves	HN, JX, TW, SC, YN (China); Japan; Korea; India; Burma; Sikkim; Bhutan EU; Urals; Caucasus; Transcaucasia;	M	(Xue and Zhu 1999)
	<i>Dysstroma citrata</i> (L.)	Leaves	N.Kazakhstan; Mongolia; South Siberia; Amur; Sakhalin; Kurils; China; Korea; Japan; Canada; North US	P	(Xue and Zhu 1999)
	<i>Mesoleuca albicillata</i> (L.)	Leaves	North China; Korea; Austria; Czech Republic; Denmark; Finland; France; Germany; Ireland; Italy; Japan; Latvia; Luxembourg; Moldova; Norway; Romania; Sweden; United Kingdom	P	(Sun et al. 1998; Xi et al. 2002; Xue and Zhu 1999)
	<i>Photoscotia miniosata</i> (Walker)	Leaves	HeN, GS, HN, TW, SC, GZ, YN, TB (China); India; Sikkim; Pakistan; Philippines	M (<i>R. ellipticus</i>)	(Xue and Zhu 1999)
	<i>Plagodis dolabraria</i> (L.)	Leaves	GS, SC, HB, HN ZJ, JS (China); Austria; Czech Republic; Denmark; Finland; France; Germany; Ireland ; Italy; Japan; Latvia; Luxembourg; Norway; Portugal ; Romania; Slovenia; South Korea; Sweden; United Kingdom	O	(Sun et al. 1998)
Hesperiidae	<i>Abraximorpha davidii</i> (Mabille)	Leaves	ShX, HeN, HB, HN, JX, ZJ, SC, GD, HaiN, YN, TW (China); Burma; Vietnam; Indonesia	M	(Zhou 1994)
Lycaenidae	<i>Sinthusia chandrana</i> (Moore)	Leaves	JX, ZJ, TW (China); Sikkim; Burma; Thailand; Vietnam; Singapore; Indonesia	M	(Zhou 1994)
Noctuidae	<i>Acronicta rumicis</i> (L.)	Leaves	SC, HB, GZ, XJ (China); Korea; Japan; Turkey; Russia; Syria; Europe	P	(Chen 1983; Wu et al. 1999; Zhu and Chen 1962)
	<i>Anaplectoides prasina</i> (Denis & Schiffermüller)	Leaves	HLJ, NM, XJ, HeN (China); Japan; Europe	P	(Chen 1983; Wu et al. 1999)
	<i>Anomis mesogona</i> (Walker)	Leaves, fruits	HeB, HLJ, HB, ZJ, (China); India; Malaysia; Japan; Korea	O	(Chen 1983; Zhu and Chen 1962)
	<i>Grammodes geometrica</i> (Fabricius)	Leaves, fruits	ZJ, TW, GD, SC, HB (China); Thailand; India; Burma; Singapore; Sri Lanka; Europe; Africa; Australia	P	(Chen 1985; Zhu and Chen 1962)
	<i>Grammodes stolidia</i> (Fabricius)	Leaves	YN (China); India; Burma; Iran; South Europe; Africa - Oriental Region; Australia.	P	(Zhu and Chen 1962)
	<i>Sypnoides picta</i> Butler	Leaves	HLJ, LN, ZJ, HN, YN (China); North Korea; Japan	p	(Chen 1983; Zhu et al. 1964)
Nymphalidae	<i>Argynnis paphia</i> (L.)	Leaves	China; Japan; Korea; Europe; Africa	P	(Zhou 1994)
	<i>Brenthis daphne</i> (Denis & Schiffermüller)	Leaves	China; Japan; Korea; Turkey; Greece; South Europe	P	(Zhou 1994)
	<i>Brenthis ino</i> (Rottemburg)	Leaves	HLJ; XJ; ZJ (China); Korea; Japan; Russian; Turkey; Spanish; Kazakhstan	P	(Zhou 1994)
Saturniidae	<i>Loepa damaritis</i> Jordan	Unknown	China	P	(Zhu and Wang 1996)
Tortricidae	<i>Adoxophyes orana</i> Fischer von Röslerstamm	Buds, leaves	East China; Europe; India; Japan	P	(Liu and Bai 1977)
	<i>Ancylys comptana</i> (Frölich)	Buds, leaves	Northeast China; Europe; Minor Asia; North America	p	(Liu and Bai 1977; Liu et al. 1983)
	<i>Archips xylosteana</i> (L.)	Buds, flowers, fruit	East and north China; Europe; Siberia; Korea; Japan	P	(Liu and Bai 1977)
	<i>Epiblema tetragonana</i> (Stephens)	Leaves	Northeast China; Europe	P	(Liu and Bai 1977; Liu et al. 1983)
	<i>Epinotia ustulana</i> Hübner	Leaves, buds	Northeast China; Europe	O	(Liu and Bai 1977; Liu et al. 1983)

Order : Family	Species	Feeds on	Location ^a	Host Range	References
	<i>Orthotaenia undulana</i> (Denis & Schiffermüller)	Leaves	Northeast China; Europe; Minor Asia	P	(Liu and Bai 1977; Liu et al. 1983)
	<i>Pandemis corylana</i> (Fabricius)	Buds	Northeast and Central China; Europe; Siberia; Japan	P	(Liu and Bai 1977)
	<i>syndemis musculana</i> (Hübner)	Leaves	Northeast China; Europe; Siberia; North America; Japan	P	(Liu and Bai 1977)
	<i>Capua favillaceana</i> (Hübner)	Leaves	Northeast China; Europe; Minor Asia	P	(Liu and Bai 1977)
	<i>Argyroploce lacunana</i> (Denis & Schiffermüller)	Leaves	Northeast China; Europe; Siberia; Minor Asia	P	(Liu and Bai 1977)
	<i>Ancylis unculana</i> Haworth	Leaves	Northeast China; Europe; Minor Asia; Korea	P	(Liu et al. 1983)
Notodontidae	<i>Stauropus basalis</i> Moore	Leaves	HLJ, HeB, ZJ, SD, JS, JX, TW, HB, YN, SC, SH (China); Korea; Vietnam; Russia; Japan	P	(Cai 1979)

^a Abbreviated names of Chinese Provinces, autonomous regions and municipalities: AH, Anhui; BJ, Beijing; FJ, Fujian; GD, Guangdong; GS, Gansu; GX, Guangxi; GZ, Guizhou; HaiN, Hainan; HeB, Hebei; HB, Hubei; HeN, Henan; HLJ, Heilongjiang; HN, Hunan; JL, Jilin; JS, Jiangsu; JX, Jiangxi; LN, Liaoning; NM, Inner Mongolia; SC, Sichuan, SD, Shandong; SH, Shanghai; ShaX, Shaanxi; ShX, Shanxi; TB, Tibet; TW, Taiwan; XJ, Xinjiang; YN, Yunnan; ZJ, Zhejiang.

^b P=polyphagous species known to feed on *Rubus* and other families; O=oligophagous species occurring mainly on *Rubus*; M=monophagous on one *Rubus* species.

We also conducted extensive field surveys for potential biological control agents in Guangxi, Guizhou, Sichuan and Yunnan Provinces. We have developed collaboration with Professor Yang Chunhua, an ecologist at Sichuan Agricultural University. Professor Yang and her team member conducted frequent visits (at intervals of 2-4 weeks) to field sites in Sichuan. A total of 60 species in 30 families were directly collected on *Rubus ellipticus* (Table 2).



Fig. 1 Jianqing Ding in a field trip to Sichuan Province



Fig. 2 Jialiang Zhang worked with students

Table 2. Phytophagous insects collected on *Rubus ellipticus* in China during 2006-2007

Order/Family	Species	Frequency	Stages found ^a	Plant part	Host Range ^b	Economic Pest	
Coleoptera							
Buprestidae	Unidentified (5 morphotypes)	common	A	Leaves	U		
Melolonthidae	<i>Serica orientalis</i> Motschulsky	rare	A	Leaves	P		
Rutelidae	<i>Anomala cypriogastra</i> Ohaus	occasional	A	Leaves, flowers, buds	P	*	
	<i>Anomala aulax</i> wiede	rare	A	Leaves	P		
	<i>Anomala rirens</i> Linnaeus	occasional	A	Leaves, flowers buds	P		
	<i>Popillia quadrigutata</i> Fabricius	rare	A	Leaves	P	*	
Cetoniidae	<i>Dicranocephalus wallichi bowringi</i> Passos	rare	A	Leaves	P	*	
	<i>Oxycetonia bealiae</i> (Gory et Passoe)	rare	A	Leaves	P	*	
Lagriidae	<i>Cerogria chinensis</i> Fairmire	common	A	Leaves	U		
	<i>Cerogria anisocena</i> (Wied.)	occasional	A	Leaves	U		
Cassidinae	<i>Taiawania (s.str)guadriramosa</i> (Gressitt)	rare	A	Leaves	U		
Hispiinae	<i>Dactylispa</i> sp.	occasional	A	Leaves	U		
Cerambyciidae	<i>Linda (Linda)atricornis</i> Pis♀	occasional	A	Leaves, stems (borer as larva)	P	*	
Curculionidae	<i>Sympiezomias menlongensis</i> Chao	rare	A	Leaves	U		
	<i>Apoderus minimus</i> Roelofs	rare	A	Leaves	U		
	<i>Apoderus nigroapicatus</i> Jekel	occasional	A	Leaves	P		
	<i>Drepanoderes leucofasciatus</i> Voss	rare	A	Leaves	P		
	<i>Henicolabus hypomelas</i> Faust	rare	A	Leaves	U		
	<i>Involvulus</i> sp.	occasional	A	Buds	O		
	<i>Lixus mandaranus fukienensis</i> Voss	rare	A	Leaves	O		
	<i>Macrocorynus</i> sp.	rare	A	Leaves	U		
	<i>Phymatopoderus latipennis</i> Jekel	rare	A	Leaves	P		
	<i>Phytoscaphus dentirostris</i> Voss	rare	A	Leaves, stems	P		
	<i>Ptochus</i> sp.	occasional	A	Leaves	U		
	Alticinae	<i>Chaetoenema kingpinesis</i> Chen	occasional	A	Leaves	O	
		<i>Chaetoenema</i> sp.	occasional	A	Leaves	U	
		<i>Nisotra gemella</i> (Erichson)	rare	A	Leaves	U	
<i>Hemipyxis tonkinensis</i> (Chen)		rare	A	Leaves	P		
Eumolpinae	<i>Basilepta leechi</i> (Jacoby)	occasional	A	Leaves	P		
	<i>Basilepta</i> sp.	rare	A	Leaves	U		
	<i>Cleoporus varriabilis</i> (Baly)	occasional	A	Leaves	P		
Galerucinae	<i>Oides tarsatus</i> (Baly)	rare	A	Leaves	P		
	<i>Paleosepharia liquidambara</i> Gressitt et Kimoto	rare	A	Leaves	P		
	<i>Exosoma flavoventris</i> (Motschulsk)	rare	A	Leaves	U		
	<i>Paridea sinensis</i> Laboissiere	rare	A	Leaves	P		
	<i>Morphosphaera viridipennis</i> Laboissiere	rare	A	Leaves	U		
	<i>Stenoluperus parvus</i> Gressitt et Kimoto	rare	A	Leaves	U		
	<i>Linaeidea placida</i> (Chen)	rare	A	Leaves	U		

Order/Family	Species	Frequency	Stages found ^a	Plant part	Host Range ^b	Economic Pest
Chlamisinae	<i>Chlamisus</i> sp.(2 morphotypes)	occasional	A, L, P	Leaves	O/M	
Cryptocephalinae	<i>Cryptocephalus</i> sp.	rare	A	Leaves	U	
Homoptera						
Cicadidae	<i>Platypleura kaempferi</i> (Fabricius)	rare	A	Leaves, roots, stems	P	
Ledridae	Unidentified	rare	A	Leaves, Stems	U	
Aphrophoridae	<i>Clovia quadrangularis</i> Metcalf & Horton	rare	A	Leaves, Stems	U	
Membracidae	<i>Tricentrus aleuritis</i> Chou,	occasional	A, N	Leaves, Stems	O	
Cicadellidae	<i>Bothrogonia (O.) acuminata</i> yang & Li	common	A	Leaves, Stems	P	*
	Unidentified	rare	A	Leaves, Stems	U	
Cercopidae	<i>Paphnutius ruficeps</i> (Melichar)	occasional	A	Leaves, Stems	U	
	<i>Cosmoscarta exultans</i> (Walker)	rare	A	Leaves, stems	U	
	<i>Paphnutius semirufus</i> (Haupt)	rare	A	Leaves, stems	U	
Lepidoptera						
Acraeidae	<i>Acraea issoria</i> (Hübner)	rare	A	Leaves	O	*
Thyatiridae	<i>Gaurena delattini</i> Werny	common	A, L	Leaves	U	
Noctuidae	<i>Anomis mesogona</i> (Walker)	common	A, L, P	Leaves	P	*
Lymantriidae	<i>Euproctis flava</i> (Bremer)	rare	A, L	Leaves	P	*
Lycaenidae	<i>Sinthusa chandrana grotei</i> (Moowe)	rare	A, L, P	Leaves	O	
Choreutidae	<i>Choreufis</i> sp.	rare	A, L, P	Leaves	U	
Tortricoidae	<i>Epinotia</i> sp.	occasional	A, L, P	Leaves, buds	U	
Pyralidae	Unidentified	rare	L	stems	U	
Hymenoptera						
Argidae	Unidentified	common	A, L, P	Leaves, buds	U	
Orthoptera						
Catantopidae	<i>Xenocatantops brachycerus</i> (Will.)	common	A, N	Leaves	P	*
Tettigoniidae	<i>Tegra novaehollandiae viridiotata</i> (Stal)	common	A, N	Leaves	P	*

^a L, larva; P, pupa; A, adult; N, nymph.

^b P, polyphagous species from other families; O, oligophagous species occurring mainly on Polygonaceae; M, monophagous on *Rubus ellipticus*, U, unknown.

Important insects

Chlamisus setosus (Bowditch) and *Chlamisus* sp. (Coleoptera: Chlamisinae)

The warty leafbeetle, *Chlamisus setosus* (Bowditch) (Fig. 3), was recorded on *R. ellipticus* var. *obcordatus* in Yunnan Province and some species from this genus *Chlamisus* were also recorded as monophagous or oligophagous (Reu Jr. and Del-Claro 2005; Tan et al. 1980). In our survey, larvae and adults of *Chlamisus* sp. were found on the *R. ellipticus* var. *obcordatus* from Kunming, Dali, and Simao, Baoshan city in Yunnan province. However, from our preliminary host range test in Wuhan Botanical Garden, it could be oligophagous by feeding on some plants in *Rubus* other than its original host (unpublished data). It has the whole life cycle on *R. ellipticus* var. *obcordatus*, with one generation per year. We found it mates and lays eggs in field during summer and hibernate during winter in our lab, but no emergence in Wuhan Botanical Garden. It makes small feeding holes on the back of leaves. Although the damage by this leafbeetle on *R. ellipticus* var.

obcordatus is not serious, its feeding scars could be helpful for some fungal infection. This beetle could be considered as a biological control agents for further study.



Fig. 3 *Chlamisus* larva



Fig. 4 *Chaetoenema* adult

Flea beetles (Coleoptera: Alticinae)

Two species in genus *Chaetoenema* (Coleoptera: Alticinae) (Fig. 4) were collected in the same site, Qinghai Lake in Tengchong county, where 5-6 species in Rosaceae naturally distributed. These 2 flea beetles have very similar size and color, and collected on *R. ellipticus* and another *Rubus* sp. (close to *Rubus alceifolius*). We could not distinguish them in field at first, so we collected them together, and then conducted preliminary host range test in laboratory. The feeding holes on *R. ellipticus* observed in lab were more intensive than on the *Rubus* sp. in our study site and laboratory test got the host range result as oligophagous. But more study should be taken to know whether they have respective or common host range.

Weevils (Coleoptera: Curculionidae)

Weevils have been considered as potential successful biological control agents of many weeds for many years for their narrow host range. In our study, four species in Family Curculionidae were considered to be potential candidates. They are: *Involvulus* sp., *Ptochus* sp., *Sympiezomias menlongensis* Chao and *Apoderus minimus* Roelofs. *Involvelus* sp. is shiny bronzed colorful, feeding on the buds of *R.ellipticus*. We also collected it on *Rubus niveus* Thunb. The weevil inserts its mouthpart to the base of buds, and then the buds wither. It can be found in wide range but mostly in hills near Yunnan Agricultural University. *Ptochus* sp. and *Sympiezomias menlongensis* Chao are grey. They were very common in several sites, but it just has limited number in each site. *Apoderus minimus* Roelofs, a dark orange leaf-rolling weevil, was collected in a wide range in Yunnan province. It makes small holes in raspberry leaves. Further testing is needed to determine the host range of these potential candidates.

Epinotia sp. (Lepidoptera: Tortricoidae)

The larvae of the leaf-rolling moth, *Epinotia* sp. (Lepidoptera: Tortricoidae) (Fig. 5-6), were collected in several sites from Yunnan province and reared to adults in laboratory in Wuhan Botanical Garden (WBG). The rolling impacts of the larvae on the leaves were very heavy in many exploring sites, where they can be found in nearly all the top of the raspberry twigs, these actions of the larvae can limit the growth of branches. After being reared in our laboratory, some

larvae emerged to adults while some are parasitized by unidentified hymenopterans during larval and pupa stage. No moth mating and oviposition was found in laboratory. Other species in genus *Epinotia* were recorded as forest or agriculture pests in some literatures and some are report as monophagous or oligophagous (Liu and Bai 1977; Muenster-Swendsen 1991; Su et al. 2003). More field exploration and laboratory tests are needed to determine if the leaf-rolling moth could be a biological control candidate.



Fig. 5 *Epinotia* Larvae



Fig. 6 A *Epinotia* larva in buds

Stem borer (Lepidoptera: Pyralidae)

Larvae of unidentified stem borer (Fig. 7-8) were found in both Sichuan and Yunnan Provinces. The larvae were white with light brown head. The damage of the borer was heavy. Fresh or brown waste of larvae stuffed the hole of the stem. We collected some stems with borer, but failed to rear adults in the laboratory. Larvae in Pyralidae have been noted as good candidates for weed biocontrol (Goolsby et al. 2003), thus this insect may warrant further study.



Fig. 7 A stem borer



Fig. 8 Feeding damage in stem

Sawfly (Hymenoptera: Argidae)

Larvae of the sawfly (Fig. 9) were found to feed on *R. ellipticus* in both Sichuan and Yunnan province. They were reared to pupae and adults in WBG. Pupae were covered in brown cocoons. Adults are shiny metallic black/blue. Most of the species recorded in this family may have narrow host range (Badenes-Perez and Johnson 2007; Bruzzese 1982; Goulet 2007; Sahragard and Heydari 2001), so further study on identification and host range should be conducted.

Metallic wood-boring beetles (Coleoptera: Buprestidae)

A large number of beetles with 5 morphotypes were collected in the Yunnan and Sichuan province. They fed on the leaves, and their impacts are significant in some sites (Fig. 10). Some beetles in this family may have narrow host range and have been considered as biological control agents (Bruzese 1980; Kaya and Kovanc 2004 ; Lei and Zhou 1998). More study on identification and host range of these beetles should be considered.



Fig. 9 Sawfly



Fig. 10 Buprestid adult in stem

Important fungal pathogen

Sixty five fungal species in 19 families of 3 phylum are associated with *Rubus*, (Table 3), some of them may be potential candidates for biological control *Rubus ellipticus* in Hawaii. There are 32 species from Ascomycota, 32 from Basidiomycota and 1 from Oomycota. Among those fungus, 19 species were directly reported from *R. ellipticus*. All fungi data of in this paper are from published literature or online database.

Table 3. Literature review: species of pathogenic microorganisms on the genus *Rubus* in East Asia

Phylum/ Family	Species	Damage	Distribution ^a	HostRange ^b	References
Ascomycota					
Amphisphaeriaceae	<i>Coryneopsis rubi</i> (Westend.) Grove	Twigs, branches, leaves, Shoots.	Europe; North America (USA); Asia (China, India); Africa (Ethiopia, South Africa); Australia; New Zealand	O	(Bai 2003; Cybernome 2007)
Clavicipitaceae	<i>Aschersonia tamurai</i> Henn.	Leaves	GX(China);Japan; Burma	P	(Cybernome 2007; Dai 1979; Index 2007)
Cercoseptoria	<i>Cercoseptoria heteromalla</i> (Syd.) Kamal & Narayan	Uncertain	India	U	(Bioscience 2007; Cybernome 2007)
Dothideaceae	<i>Septoria darrowii</i> Zeller	Leaves	TW (China)	O <i>(R. triathus R. hispidus)</i>	(Dai 1979; Index 2007)
Elsinoaceae	<i>Elsinoë veneta</i> (Burkh.) Jenkins	Twigs, leaves	JL (China); Greece; Chile; the United States; the British Isles; Ireland; Australia	O	(Bioscience 2007; Cybernome 2007; Dai 1979)

Phylum/ Family	Species	Damage	Distribution ^a	HostRange ^b	References
Hyaloscyphaceae	<i>Polydesmia fructicola</i> Korf	Stems	Jamaica; Spain	P (<i>R. ellipticus</i>)	(Cybernome 2007; Farr et al. 2007; Zhuang 1987)
Hypocreaceae	<i>Verticillium albo-atrum</i> Reinke & Berthold	Roots, stems, twigs, leaves, buds	China; Ukraine; Uzbekistan; Armenia; Russia; Canada; Cuba; Turkmenistan; Venezuela; Brazil; Japan; Chile; Georgia; France; Puerto Rico; Australia; the United Kingdom; Spain; Argentina; the former USSR	P	(Cybernome 2007; Dai 1979; Index 2007)
Hyaloscyphaceae	<i>Calycellina tetraspora</i> K.S. Thind & M.P. Sharma	Stems	India	M (<i>R. ellipticus</i>)	(Lowen and Dumont 1984; Thind and Sharma 1980)
Leotiaceae	<i>Strossmayeria basitricha</i> (Sacc.) Dennis	Stems	British Isles; Jamaica; Slovakia	P(<i>R. ellipticus</i>)	(Cybernome 2007; Zhuang 1987)
	<i>Strossmayeria jamaicensis</i> (Seaver) Iturr. & Korf	Stems, culms	Jamaica	P(<i>R. ellipticus</i>)	(Iturriaga and Korf 1990)
	<i>Unguiculariopsis ravenelii</i> (Berk. & M.A. Curtis) W.Y. Zhuang & Korf apud W.-y. Zhuang	Stems, twigs	Jamaica, Venezuela	P (<i>R. ellipticus</i>)	(Zhuang 1987)
	<i>Velutarina rufo-olivacea</i> (Alb. & Schwein.) Korf	Stems, twigs, branches	Argentina; British Isles; Jamaica; United Kingdom; Ukraine; USA	P (<i>R. ellipticus</i>)	(Cybernome 2007) (Zhuang 1987)
Meliolaceae	<i>Appendiculella calostroma</i> (Desm.) Höhn.	Leaves and Stems	China; Uganda; South Africa; India; Ecuador; Colombia; Costa Rica; Sao Tome and Principe Democratic Republic; Venezuela; Brazil; Japan; Chile; Puerto Rico; Australia; Guadeloupe; the United States; the United Kingdom; the Philippines; Vietnam; Ireland.	P (<i>R. ellipticus</i>)	(Cybernome 2007; Dai 1979; Hu 1996)
	<i>Meliola rubi</i> F. Stevens & Roldan ex Hansf.	Leaves	Philippine	M (<i>R. moluccanus</i>)	(Cybernome 2007)
	<i>Meliola rubiella</i> Hansf.	Leaves	Philippine; India	O (<i>R. ellipticus</i> , <i>R. moluccanus</i>)	(Cybernome 2007; Farr et al. 2007; Patil et al. 2004)
	<i>Meliola formosensis</i> W. Yamam.	Leaves	TW(China)	O	(Cybernome 2007; Dai 1979; Hu 1999)
Mycosphaerellaceae	<i>Cercospora rubicola</i> Thüm.	Leaves	YN, GX (China); Georgia	O (<i>R. cochinchinensis</i> <i>R. caucasigenus</i>)	(Liu and Guo 1998)

Phylum/ Family	Species	Damage	Distribution ^a	HostRange ^b	References
	<i>Mycosphaerella confusa</i> F.A. Wolf	Leaves	HB, SC, GZ, (China); Russia; India; Latvia; Chile; Georgia; Puerto Rico; United Kingdom	P (<i>R. ellipticus</i>)	(Index 2007; Liu and Guo 1998)
	<i>Mycosphaerella fragariae</i> (Tul.) Lindau	Leaves, stems, fruit stalks, berry caps	JS, JL, FJ, LN, HLJ, SD, ZJ, XJ, HeN, GD, SC (China); Ukraine; Cuba; Turkmenistan; the Dominican Republic; Venezuela; Chile; Georgia; Puerto Rico; Jamaica; the British Isles; Ireland; Japan	P	(Cybernome 2007; Dai 1979)
	<i>Mycosphaerella rubi</i> Roark	Leaves, shoots	China; Ukraine; Venezuela; Georgia; Puerto Rico; Azerbaijan.	O	(Cybernome 2007; Dai 1979)
	<i>Pseudocercospora arcuata</i> S.K. Singh, P.N. Singh & Bhalla	Leaves	Nepal	M (<i>R. ellipticus</i>)	(Index 2007; Singh et al. 1997)
	<i>Pseudocercospora heteromalla</i> (Syd.) Deighton	Leaves	China; Zaïre; Sudan; India; Ethiopia; Uttar Pradesh; Bhutan; Uttaranchal; New Zealand; United Kingdom; Australia	O (<i>R. ellipticus</i> , <i>R. idaeus</i> .)	(Cybernome 2007; Index 2007; Liu and Guo 1998)
Patellariaceae	<i>Rhytidhysteron rufulum</i> (Spreng.)	Stems, shoots	China; India; Cuba; Colombia; the Dominican Republic; Venezuela; Brazil; Chile; Haiti; Jamaica; Trinidad; Tobago; Virgin Islands (United States)	P	(Cybernome 2007; Dai 1979)
Phaeosphaeriaceae	<i>Stagonospora brevispora</i> (Ellis & J.J. Davis) Castellani & E.G. Germano	Leaves	JL (China)	O (<i>R. idaeus</i> , <i>R. occidentalis</i>)	(Dai 1979; Index 2007)
	<i>Hendersonia vulgaris</i> Desm.	Twigs	HB(China); Ukraine	P	(Cybernome 2007; Dai 1979)
Sclerotiniaceae	<i>Botryotinia fuckeliana</i> (de Bary) Whetzel	Stems, fruits, flowers, twigs, shoots, leaves	China; Ukraine; Uzbekistan; Israel; Iran; Russia; Congo; South Africa; India; Cuba; Kazakhstan; Colombia; Tanzania; Ethiopia; Cyprus; Dominican Republic; Venezuela; Brazil; Italy; Moldova; New Zealand; Japan; Chile; Georgia; Poland; Zimbabwe; Australia; Estonia; USA; Kenya; United Kingdom; Netherlands; Portugal; Azerbaijan; Argentina	P	(Cybernome 2007; Dai 1979)
	<i>Lambertella aurantiaca</i> V.P. Tewari & D.C. Pant	Stems, petiole	Jamaica; India	P (<i>R. ellipticus</i>)	(Cybernome 2007; Index 2007; Zhuang 1987)
	<i>Lambertella corni-maris</i> Höhn.	Uncertain	Jamaica;	P (<i>R. ellipticus</i>)	(Cybernome 2007; Index 2007; Zhuang 1987)
Incertae sedis	<i>Acrothecium rubi</i> Sawada	Leaves	TW (China)	O (<i>R. conduplicatus</i> , <i>R. trianthus</i>)	(Dai 1979; Index 2007)

Phylum/ Family	Species	Damage	Distribution ^a	HostRange ^b	References
	<i>Chalara verruculosa</i> B. Sutton	Stems	Malawi	M (<i>R. ellipticus</i>)	(Bioscience 2007; Index 2007; Sutton 1993)
	<i>Sporendocladia kionochaetoides</i> B. Sutton	Stems	Malawi	M (<i>R. ellipticus</i>)	(Bioscience 2007; Cybernome 2007)
Venturiaceae	<i>Coleroa chaetomium</i> (Kunze) Rabenh	Leaves	Ukraine; Germany; the Czech Republic; Georgia; United Kingdom; India	O (<i>R. ellipticus</i> , <i>R. caesius</i> , <i>R. idaeus</i>)	(Bioscience 2007; Cybernome 2007)
Basidiomycota					
Incertae sedis	<i>Caecoma cheoanum</i> Cummins	Leaves	GX, GZ (China)	M (<i>Rubus</i> sp.)	(Dai 1979; Index 2007)
	<i>Phragmotelium barnardii</i> (Plowr. & G. Winter) Syd.	Leaves	Japan; Australia	M (<i>R. parvifolius</i>)	(Berlese et al. 1888; Cybernome 2007; Sydow 1897)
	<i>Phragmotelium formosanum</i> (Hirats.) Thirum.	Leaves	TW (China)	O	(Cybernome 2007; Dai 1979)
	<i>Phragmotelium okianum</i> (Hara) Thirum.	Leaves	HLJ (China)	O	(Cybernome 2007; Dai 1979)
	<i>Phragmotelium rubi-fraxinifolii</i> (Syd. & P. Syd.) Thirum	Leaves	TW (China); India	O	(Dai 1979; Index 2007)
	<i>Uredo spinulosa</i> Y. Ono	Leaves	TW (China); India	P (<i>R. ellipticus</i>)	(Farr et al. 2007; Ono 1982; Patil et al. 2004)
Phragmidiaceae	<i>Arthuriomyces peckianus</i> (Howe) Cummins & Y. Hirats.	Leaves	HLJ (China), Russia, United states, North America	O	(Dai 1979; Index 2007)
	<i>Arthuriomyces rubicola</i> J.Y. Zhuang	Leaves	SC (China)	P (<i>R. pileatus</i>)	(Index 2007)
	<i>Gerwasia rubi</i> Racib.	Leaves	SC, GX, GZ, GD, TW, FJ, HN (China)	O	(Cybernome 2007; Dai 1979)
	<i>Hamaspora acutissima</i> P. Syd. & Syd	Leaves	TW, GZ, ShX, JX, GD, GX, HN(China); Papua New Guinea; Philippines; Indonesia; Australia; Papua New Guinea; Japan; New Guinea; South Africa	O	(Dai 1979; Farr et al. 2007)
	<i>Hamaspora benguetensis</i> Syd.	Leaves	YN, TW, GZ (China), Philippine	O (<i>R. ellipticus</i> , <i>R. lambertianus</i> , <i>R. taiwamianus</i>)	(Cybernome 2007; Dai 1979)
	<i>Hamaspora hashiokai</i> Hirats. f.	Leaves	TW, ZJ, GX, SC (China)	O	(Dai 1979)
	<i>Hamaspora rubi-sieboldii</i>	Leaves	New Guinea	O	(Cybernome 2007; Dai 1979; Farr et al. 2007)

Phylum/ Family	Species	Damage	Distribution ^a	HostRange ^b	References
	(Kawagoe) Dietel				
	<i>Hamaspota sinica</i>	Leaves	GZ, HN, SC, GX (China)	O	(Cybernome 2007; Dai F.L. Tai & C.C. Cheo
	<i>Hamaspota tairai</i>	Leaves	HB(China)	M (<i>Rubus</i> sp.)	(Dai 1979)
	<i>Hamaspota taiwaniana</i>	Leaves	TW (China)	M (<i>R kawakamii</i>)	(Cybernome 2007; Dai Hirats. f.
	<i>Phragmidium arisanense</i>	Leaves	ShaX, TW, (China)	O	(Cybernome 2007; Dai & Hashioka
	<i>Phragmidium griseum</i>	Leaves	TW, HeB, LN, JL, AH (China)	O	(Cybernome 2007; Dai Dietel
	<i>Phragmidium occidentale</i>	Leaves	North America	O	(Cybernome 2007; Index
	<i>Phragmidium orientale</i>	Leaves	China, India	M (<i>R. ellipticus</i>)	(Cybernome 2007; Index Syd
	<i>Phragmidium rubi-thunbergii</i>	Leaves	ZJ, AH, GZ (China); Japan	O	(Dai 1979; Index 2007)
	<i>Phragmidium rubi-eucalypti</i>	Leaves	SC (China)	M (<i>R. eucalyptus</i>)	(Index 2007; Wei 1988)
	<i>Phragmidium rubi-idaei</i>	Leaves	ShaX (China); Ukraine; Russia; the Czech Republic; Georgia; Switzerland; United States; United Kingdom	O	(Cybernome 2007; Index Karst.
	<i>Phragmidium rubi-saxatilis</i>	Leaves	Georgia	M (<i>R. saxatilis</i>)	(Cybernome 2007; Index Liro
	<i>Phragmidium rubi-parvifolii</i>	Leaves	China	M (<i>R. parvifolius</i>)	(Cybernome 2007; Index Liou
	<i>Phragmidium rubi-oldhami</i>	Leaves	Japan	M (<i>R. oldhami</i>)	(Cybernome 2007; Index & Wang
	<i>Phragmidium rubi</i>	Leaves	Ukraine, Russia, Georgia	P	(Cybernome 2007; Index Togashi & Y. Maki
	<i>Phragmidium shensianum</i>	Leaves	ShaX (China)	O	(Cybernome 2007; Dai (Pers.) G. Winter
	<i>Phragmidium sikangense</i>	Leaves	ShaX, SC (China);	O	(Cybernome 2007; Dai Petr.

Phylum/ Family	Species	Damage	Distribution ^a	HostRange ^b	References
	<i>Phragmidium sinicum</i> F.L. Tai & C.C. Cheo	Leaves	HeB (China)	M (<i>R. crataegifolius</i>)	(Cybernome 2007; Dai 1979)
	<i>Phragmidium violaceum</i> (Schultz) G. Winter	Leaves	YN (China); Ukraine; France; Greece; Chile; Georgia; the United Kingdom; Azerbaijan	O	(Cybernome 2007; Dai 1979)
	<i>Phragmidium yamadanum</i> Hirats.	Leaves	ShaX, SC (China); Japan	O	(Dai 1979)
Oomycota					
Pythiaceae	<i>Phytophthora citricola</i> Sawada	Leaves, stems, twigs	China; Sweden; British Columbia; Italy; Zimbabwe; Switzerland; Portugal; Northern America; Yugoslavia; India; South Africa; New Zealand; Sicilia; New South Wales; Ireland; United Kingdom; France; Great Britain; Southern South America; South Australia Western Australia; United States	P	(Index 2007; Yun 1998)

^a Chinese Provinces abbreviated as in Table 1.

^b P, polyphagous species from other families and *R. ellipticus* listed in parentheses for the known ones; O, oligophagous species occurring mainly on *Rubus* and plant names listed in parentheses for the known ones; monophagous on one weed and plant name listed in parentheses for the known one, U, unknown. All information based on literature records and online database.

Potential candidates in phylum Ascomycota

Six species in Ascomycota were listed in this literature. Two species are leaves spot *Pseudocercospora arcuata* S. K. Singh, P. N. Singh & Bhalla and *Pseudocercospora heteromalla* (Syd.) Deighton (Ascomycota: Mycosphaerellaceae), which were reported as monophagous and oligophagous respectively, *P. heteromalla* also reported on *Rubus idaeus* (Cybernome 2007; Index 2007; Singh et al. 1997). *Chalara verruculosa* B. Sutton and *Sporendocladia kionochoetoides* B. Sutton (Ascomycota: Incertae sedis) were found on *R. ellipticus* from Malawi in 1993 (Bioscience 2007; Index 2007; Sutton 1993). *Calycellina tetraspora* K.S. Thind & M.P. Sharma (Ascomycota: Hyaloscyphaceae) was found on stems of our target weed in India (Lowen and Dumont 1984; Thind and Sharma 1980). *Coleroa chaetomium* (Kunze) Rabenh could be oligophagous on *R. ellipticus*, *R. caesius*; *R. idaeus*, which epiphyllous, superficial, solitary or clustered pseudothecium parasitizes on live leaves (Ellis and J.P. 1997).

Potential candidates in phylum Basidiomycota

Two rust species, *Phragmidium orientale* Syd. & P. Syd and *Hamasporea benguetensis* Syd. (Basidiomycota: Phragmidiaceae) were recorded as monophagous and oligophagous respectively on *R. ellipticus*, the later also was found on *R. lambertianus*, *R. taiwanianus* and some *Rubus* sp.

Preliminary host range test of the warty leaf beetle and flea beetle

The warty leaf beetle (*Chlamisus* spp.) was recorded as monophagous in some literature. We tested

its host specificity in no-choice test in lab, using about 20 plant species, of which, 13 species are in the genus of *Rubus*. Our tests indicated both the warty leaf beetle and flea beetle may be oligophagous (Table 4).

Table 4. Preliminary host range tests of *Chlamisus* spp. and *Chaetocnema* spp.

Plant species	<i>Chlamisus</i>	<i>Chlamisus</i>	<i>Chlamisus</i>	<i>Chaetocnema</i>	<i>Chaetocnema</i>	<i>Chaetocnema</i>
	Pop. 1	Pop. 2	Pop. 3	Pop. 1	Pop. 2	Pop. 3
<i>Rubus ellipticus</i> Smith	√	√	√	√	√	√
<i>Rubus niveus</i> Thunb.	√	√	light feeding	light feeding	light feeding	×
<i>Rubus pinfaensis</i> Lévl.et Vant.	√	Light feeding	√	√	√	Light feeding
<i>Rubus irenaeus</i> Focke	Light feeding	√	Light feeding	×	Light feeding	×
<i>Rubus sumatranus</i> Miq.	×		√	×	×	×
<i>Rubus tephrodes</i> Hance	√	√	Light feeding	×	×	×
<i>Rubus amabilis</i> Focke	×	×	×	×	×	×
<i>Rubus reflexus</i> Ker	×	×	×	×	×	×
<i>Rubus lambertianus</i> Ser.	√	×	Light feeding	×	×	×
<i>Rubus</i> sp.	√	Light feeding	Light feeding	×	×	
<i>Rubus coreanus</i> Miq.var.tomentosus Card.	Light feeding	×	Light feeding	√	Light feeding	Die out
<i>Rubus trianthus</i> Focke	×	×	Light feeding	×	×	
<i>Rubus</i> sp.	×	×	×	×	×	
<i>Vaccinium virgatum</i> Ait.	×	×	×	×	×	×
<i>Potentilla fulgens</i> Wall	×	×	×	×	×	×
<i>Sanguisorba officinalis</i> L.	×	×	×	×	×	×
<i>Diospyros kaki</i> Thunb.	×	×	×	×	×	×
<i>Cerasus cerassoides</i>	×	×	×	×	×	×
<i>Eupatorium adenophorum</i>	×	×	×	×	×	×
<i>Rosa chinensis</i> Jacq.	×	×	×	×	×	×
<i>Rosa omeiensis</i> Rolfe	×	×	×	×	×	×

Discussion and future directions

This literature and field survey has revealed numerous herbivorous arthropods and pathogenic microorganisms associated with *Rubus ellipticus* in its native range. Some of them appear specialized and have been reported or observed to have an impact of the target species.

The most promising insect candidates, in our study, for control of the invasive *R. ellipticus* appear to be the warty beetles, the flea beetles, the stem borer, the leaf-rolling moth, and the sawfly. However, more controlled screening of their host specificity is a necessary next step. Considering the fragile of ecology in Hawaii, all candidate species should be subjected to further risk assessment. More importantly, investigations of the impact of these insect species upon *R. ellipticus*, and of their host specificity, are needed in order to evaluate their potential as bio-control agents.

Literature review (Tables 1 and 3) provides more clues to screen potential natural enemies. If

herbivores have a wider distribution than the range of the target plant, it may suggest the candidates as not host-specific. Comparing Table 1 with Table 2, few common herbivores could be found in both tables, which indicates the herbivory diversity on *Rubus* taxa in the original region and the current limited knowledge of the herbivory on *Rubus ellipticus*. Buprestidae has 5 unidentified morphotype in our survey but only one species was recorded in literature (Lei and Zhou 1998), the distribution of the species matched that of *Rubus ellipticus* well in China, but it was recorded in Japan. Thus, further study is needed to show if they are the same species. The distribution of warty leafbeetles, *Chlamisus setosus* (Bowditch) (Coleoptera: Chlamisinae) found in Yunnan province matches well with the literature record (Tan et al. 1980). The leaf-rolling moth, *Epinotia* sp. (Lepidoptera: Tortricoidae) could be found from a large range in Yunnan Province, which does not match to the distribution of the moth *Epinotia ustulana* Hübner, which is a pest on fruit trees (Liu and Bai 1977; Muenster-Swendsen 1991; Su et al. 2003).

Historically, fungi have been used as biological controls for *Rubus* and some of them have been effective (Gardner and Davis 1982; Goeden et al. 1974). However, out of 7 insects and 3 fungi rust species imported to New Zealand in 1920s none showed significant impact on wild blackberry, and only one rust, *Phragmidium violaceum*, with narrow host range was considered for further study (Pennycook 1997). Rusts in genus *Phragmidium* are also potential choice in control of *R. ellipticus*, 12 species list in this paper are from China, one report from *R. ellipticus*, the other fungi species listed also could be considered.

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