KFRI Research Report No. 464
(Final Report of Research Project no. KFRI 554/08)

NATURAL ENEMIES OF THE WEEDS *IMPATIENS GLANDULIFERA* AND *HEDYCHIUM* SPP. NATIVE TO THE HIMALAYAS

(A KFRI - CABI, Europe- UK collaborative research program)

K.V. Sankaran
K.C. Rajeshkumar
Forest Health Division

Kerala Forest Research Institute
Peechi- 680 653, Thrissur, Kerala
2013

KFRI Research Report No. 464

(Final Report of Research Project no. KFRI 554/08)

NATURAL ENEMIES OF THE WEEDS *IMPATIENS GLANDULIFERA* AND *HEDYCHIUM* SPP. NATIVE TO THE HIMALAYAS

(A KFRI - CABI, Europe- UK collaborative research program)

K.V. Sankaran
K.C. Rajeshkumar

in collaboration with

R. Tanner
R. Shaw
D. Djeddour
CABI Europe - UK

and

Y.P. Singh
Forest Research Institute, Dehra Dun

Kerala Forest Research Institute
Peechi- 680 653, Thrissur, Kerala
2013

Contents

Acknowledgements

We thank Mrs. Usha Ganguli-Lachungpa, Senior Research Officer and other Officers of the Sikkim Forest Department, Dr. A.N. Shukla, Forest Research Institute, Dehra Dun and Dr. T.C. Bhuyan, Rain Forest Research Institute, Jorhat for kind help in carrying out the study. Dr. Sean Murphy and Dr. H. Evans, CABI Europe-UK are thanked for their support and guidance. The Director, Kerala Forest Research Institute is thanked for facilities and permission to carry out this work. Funds for this research were provided by CABI, Europe-UK.

Abstract

The Himalayan balsam (*Impatiens glandulifera*) and the wild ginger species complex (*Hedychium gardenarianum, H, coronarium* and *H. flavescens)* are native to the Himalayas and neighbouring areas. These plants were introduced to several countries around the world for ornamental purposes but escaped cultivation and became aggressive colonizers invading natural forests and other ecosystems. They pose a serious threat to native biodiversity and have serious economical and ecological implications. Mechanical and chemical control methods were proved inadequate to control spread of these invasive species.

Surveys for pests and pathogens associated with the above species in the introduced ranges did not succeed in locating any potential agents for use in classical bio-control. Hence, surveys were conducted in the native ranges of the plants to identify natural enemies with these potentials. The survey in the native ranges of the Himalayan balsam focusing in the Kulu Valley and surrounding areas (foot-hills and mid-Himalayas) showed that the plant shows none of the invasive traits as observed in its introduced range in the UK since the population is kept under check by the natural enemies. The plant is affected by an array of arthropods and pathogens which apparently exert significant pressure on its population.

Of the pathogens and pests located, a couple of stem boring weevils including *Alcidodes fasciatus* and *Metialma* sp. and two pathogens, a *Septoria* species causing serious leaf-spot and a rust fungus viz., *Puccinia* sp. infecting the stem and leaves of the plant exhibited potential as bio-control agents. Further work is mandatory to determine their host specificity and efficacy as bio-control agents.

Literature survey and review of herbarium specimens of *Hedychium* spp. showed that the centre of origin of all the three species is Nepal and the eastern Himalayas – states of Assam, Meghalaya and Sikkim. Surveys in selected localities in these states have revealed the presence of a wide variety of arthropods including leaf rollers, fruit/capsule feeders and stem borers. The bio-control potential of these pests are unclear at present. The rare occurrence of pathogens during this survey does not mean that the wild gingers are free of pathogen pressure. More intensive surveys covering the entire growing cycle of the plants across seasons may reveal the presence of serious pathogens. The other species of *Hedychium* located in the survey included *H. coccineum, H. spicatum, H. stenopatalum, H. flavum, H. greenii?* and *H. thyrsiforme.* The diversity and hybridizing potential of *Hedychium* spp. call for molecular characterization of species to complement morphological determination. Further surveys and checking the host specificity of the pests located in the current survey are warranted for identifying suitable bio-control agents to control the spread of wild gingers in the invaded ranges.

Part 1. Natural enemies of Himalayan balsam (*Impatiens glandulifera*) native to the Himalayas

Introduction

Himalayan balsam (*Impatiens glandulifera* Royle, Balsaminaceae) is a tall, glabrous, annual native to the foot-hills of the Himalayas from north-west Pakistan to northern India, Nepal and Bhutan. The plant is commonly called Indian balsam or Policeman's helmet, the latter name indicates the hat-shaped flower of the plant (Fig. 1). The species name *glandulifera* denotes presence of glands in the plant that produces sticky, sweet-smelling and edible nectar.

Fig. 1. *Impatiens glandulifera* - habit, flowering branch and thickets

Description of the plant: The plant grows 50-250 cm tall; the stem is soft green or red-tinged, 0.5 - 5 cm in diameter, either branched or not. Leaves are opposite, lanceolate to obovate, 25 x 7 cm in size, the upper leaves sometimes in whorls of three, petiolate and sharply serrated at edges. The crushed foliage has a strong musty smell. The inflorescences are racemes with 2-14 flowers. Flowers are strongly zygomorphic, their posterior sepal forming a sac that ends in a straight spur. The flower colour varies from white to pink or purple. The capsule is 3-5 cm long and up to 1.5 cm wide. It contains 4 to 16 seeds that are 4-7 mm long and 2-4 mm wide with a mean weight of 7.32 mg. After flowering between June and October, the plant forms seed pods which explode when disturbed, scattering the seeds up to 7 metres. *Impatiens*, meaning "impatient", refers to this method of dispersal. The green seed pods, seeds, young leaves and shoots are all edible.

Distribution: The Himalayan balsam is a highly invasive plant which has spread rapidly in several countries in Europe, parts of Canada, the United States and New Zealand forming dense stands and suppressing the growth of native species. The plant was first introduced into the UK as an ornamental in 1839 and escaped from there to grow wild. Local spread is mainly through seeds which are transported by water. International spread is through import of the seed/plant for ornamental purposes. Transport of seeds as a contaminant in soil, building material etc. also aids in spread.

Habitat: In the introduced ranges, Himalayan balsam is a weed of riparian systems, forest plantations, forest clearings, railway embankments, wasteland, urban areas, roadside ditches and wet meadows where it forms dense clusters. In the native range, the plant is common in moist, fertile valleys in high altitude areas, where it grows in clusters of 30-60 plants along with the surrounding native vegetation. This is in contrast to the dense monocultures found in the invasive ranges (Invasive Species Compendium, CABI).

Impacts: The plant is known to reduce native species diversity in areas where it forms dense thickets and monocultures. The synchronous germination of the plants along riverbanks and its vigorous growth shade out native species and reduce the available niches for their growth. This will have serious consequences to the invertebrate community depended on the native plants. The aggressive seed dispersal and high nectar production, which attracts pollinators, also help Himalayan balsam to outcompete indigenous species.

Native enemies already recorded: In the UK, only 3 arthropod species are known to feed on Himalayan balsam which include two aphid species, *Aphis fabae* and *Impatientinum balsamines*, and the elephant hawk moth *Deilephila elpenor* (Invasive Species Compendium, CABI).

Control: Mechanical control of the weed is through cutting at the base before flowering and fruiting. Herbicides such as 2, 4-D, triclopyr and glyphosate are effective in controlling Himalayan balsam populations. However, these methods are only useful in the short term since vigorous re-growth can occur. Hence, surveys are being conducted by researchers throughout the native range of the plant to identify natural enemies for biological control.

As a management tool for controlling invasive alien species, biological control has been practiced worldwide for over 100 years with more than 1000 releases using 350 biological control agents in 71 countries. However, although European countries have been the source for over 380 releases of biological control agents, there has never been a release against an invasive alien species in Europe. With trade liberalisation and rapid globalisation, the invasive alien species pose a huge threat to biological diversity throughout the world. Application of chemicals to control these species is becoming more tightly regulated because of the non-target effects. Thus, biological control offers an ecologically safe and economically viable solution against all invasive species.

Objectives of the study :

- Collection and collation of information on the distribution of Himalayan balsam in India,

- Identifying natural enemies of Himalayan balsam in the foot-hills of the Himalayas, its native range, so as to identify their potential as biocontrol agents.

Materials and methods

Surveys

Following Royle's path

John Forbes Royle (1799-1858), the British botanist was the first to locate and describe Himalayan balsam from mid-ranges of Himalayas during his expedition to explore flora of Himalayas in the early 1800's.

The field notes by Royle on the exploration the Himalayan flora, deposited in the Natural History Museum, London, helped the research team to work out a basic plan for the survey. The distribution pattern given in various accounts on the Himalayan flora and visits to Herbariums maintained at Kerala Forest Research Institute, Peechi, ICFRE Dehra Dun, Kerala

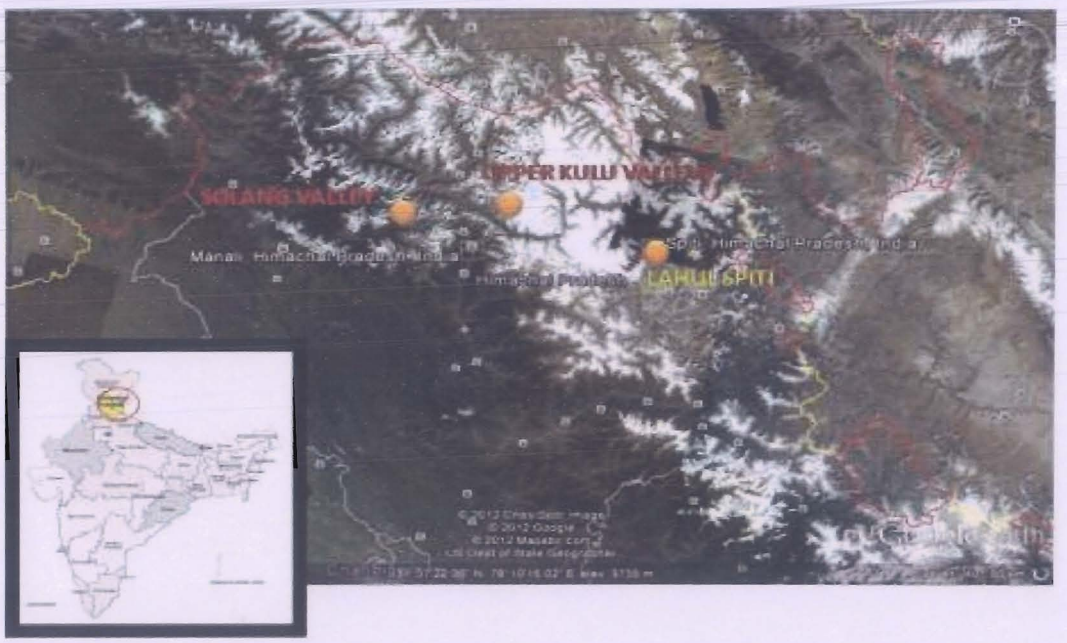


Fig. 2. Areas surveyed for Himalayan balsam in Kullu Valley and neighbouring areas

Agricultural University, Thrissur, Forest Research Institute, Dehra Dun, Botanical Survey of India (BSI) Dehra Dun and BSI, Calcutta provided excellent information on the pattern of distribution of species of the genus *Impatiens* in India. A total of 203 species of Impatiens have been reported from the country and these are mainly distributed in the foot-hills of the Himalayas and the Western Ghats. As discussed above, the Himalayan balsam is native to the foot-hills of Himalayas from north-west Pakistan to northern India, Nepal and Bhutan between 2000 - 3000 m asl. Though the southern Western Ghats are rich in diversity of balsam, the population of *Impatiens glandulifera* is restricted to the Himalayas. Approximately 25% of the native range of the balsam is in Pakistan with the lion's share of the remaining population occurring in India.

In the present study, surveys were conducted from the foot hills to the middle range of Himalayas situated in the states of Himachal Pradesh and Uttara Khand between 2000 and 3, 200 m asl (Fig. 2). In total, 11 major populations of Himalayan balsam were identified during the survey and collections of plant pathogens and arthropods were made at each site surveyed. Estimates were also made on the population size of Himalayan balsam, its structure and the associated vegetation.

In all, four surveys were conducted at different times throughout the growing season of the target plant. These surveys enabled collection of information on different pests and pathogens infesting the plant at different stages of its life cycle. Prior to this study, little information was available on the phenology of *Impatiens glandulifera* in the Himalayas. Our studies showed that the seeds of Himalayan balsam germinate soon after the snow melts at high altitudes. This leads to soaking of the seeds which have been covered by snow during the winter and germination of seeds and rapid growth of the plant occurs soon after (May to June).

Rainfall in the Himalayas is at its peak during July-August (Fig. 3). Travel and surveys were planned in such a way to avoid the unsuitable weather for field surveys. During June- July 2008, when the first survey was conducted, plants had attained considerable size. The last survey conducted in September 2008 showed the end of the growing period of the plants with most of them either already dead or started shedding leaves due to an early fall of snow.

The surveys were focused in and around the Kulu Valley, Himachal Pradesh which included part of the foot-hills of the Himalayas and the mid-Himalayas. Apart from these, two additional surveys were conducted in and around Mussoorie to locate local populations, if any, close to the main scientific base in the Forest Research Institute at Dehra Dun (Fig.4). However, no populations of Himalayan balsam were found in the area. Surveys in the Kulu Valley resulted

in observing Himalayan balsam in its pristine natural habitat i.e., high altitude alpine meadow. The populations were sparse in clusters of 30-60 plants mixed with other vegetation and severely impacted by natural enemy pressure.

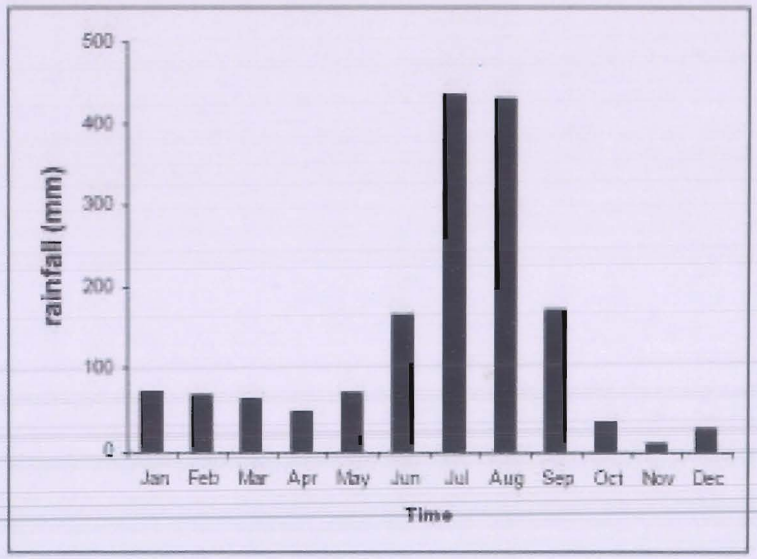


Fig. 3. Average rain fall across months in the Himalayas (2008-09)

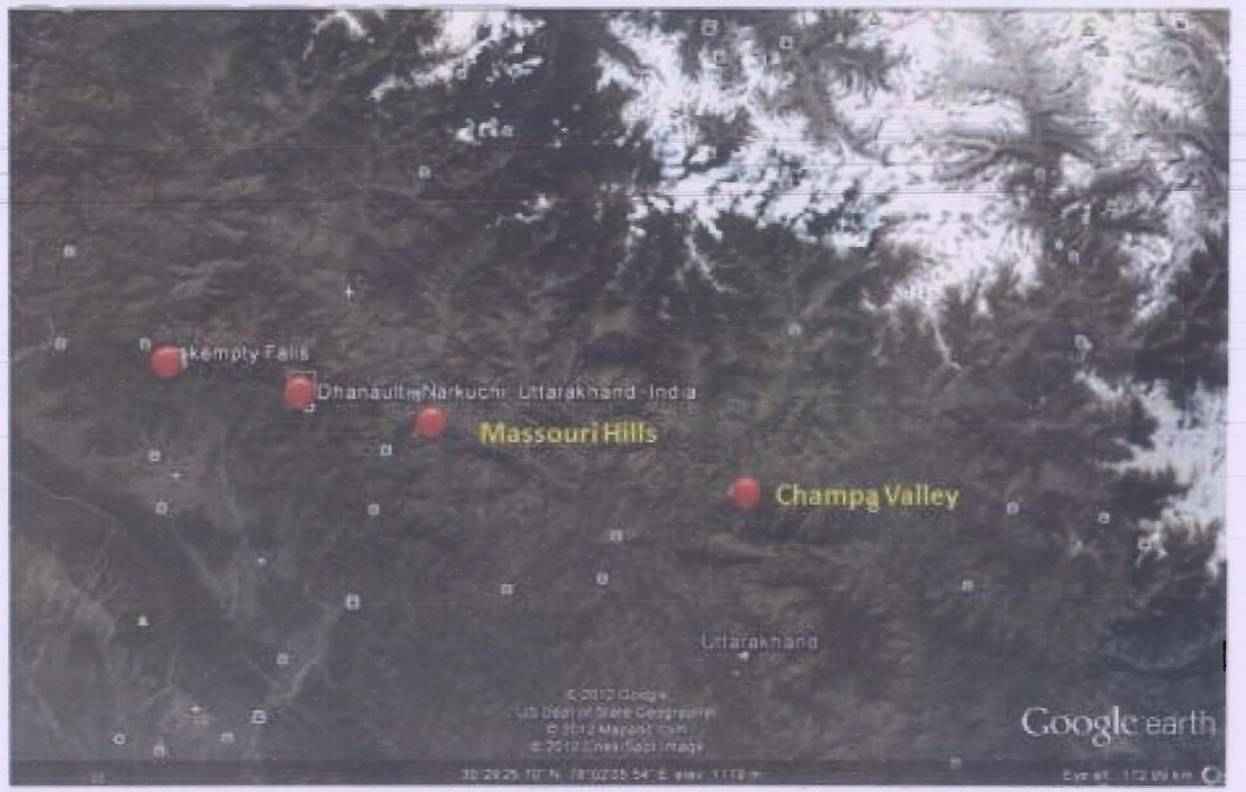


Fig. 4. Areas surveyed in Massouri Hills and adjacent areas

First survey: Lower and middle range Himalayas, Himachal Pradesh (22 June to 10 July 2008)

The survey covered Shimla, Solan, Sangla Valley, Kulu, Manali, Solang Valley, Upper Kulu Valley (Huttu peak and Lower meadows of Brugu lake) and Lahul Spiti. Based on this reconnaissance survey, the Solang Valley (4 sites close to the river or away from it), the Upper Kullu Valley (lower meadows Brugu Lake) and Gulaba which lies on the way to Lahul Spiti-Rothang pass (2800 to 3100 m asl) were selected for detailed studies on the population structure and pests and diseases of Himalayan balsam (Fig. 5).

Second survey: Mussoori hills and Champa valley on the way to Tehri Gadwal in Uttara Khand (26 to 27 July 2008)

Based on the earlier records of Himalayan balsam (BSI and FRI Herbarium, Dehra Dun), a reconnaissance survey was conducted to locate the plant in Mussouri Hills and Champa Valley. The areas visited included Kempty Falls, Bhatta Falls, Bhatta Ghats, Brass Ghats, Dhanaulty Hills, Surkunda Hills and Champa Valley.

Third Survey: Solang river basin, lower meadows of Brugu lake and Gulaba (6 to 13 Sep. 2008)

The areas selected for detailed studies during the first survey were revisited to collect samples of pests and pathogens of Himalayan balsam.

Fig. 5. Infestation by Himalayan balsam in Upper Kullu Valley

Fourth survey: Mussoori Hills, Champa Valley, Tehri Gadwal, Pinswar, Manali- Kulu, Solang River Basin, Brugu Lake lower meadows, Gulaba (20 September to 9 October, 2008)

The first five days of the fourth survey were spent in Mussoori Hills and Tehri Garwal area to locate the Himalayan balsam population. The rest of the time was spent for survey in the Kulu-Manali region and Rothang Pass to identify pests and pathogens of Himalayan balsam.

During each survey, the leaf samples and larvae were collected and stored. The leaf samples were examined for the presence of pathogens and cultured to isolate the pathogen. Attempts were made to rear the larvae using the facility attached to the Forest Research Institute, Dehra Dun. The samples and specimens were referred to experts for authentic identification of insects and fungi.

Results and Discussion

First survey: During the first survey, a major population of Himalayan balsam was located in the Solang Valley in the Beas river basin (about 50 km after Kulu-Manali town towards Lahul Spiti Valley). Four major populations of the plant was located here which included Site 1(before reaching the river), Site 2 (river base), Site 3 (after crossing the river), and Site 4 (hill side after river). Detailed observations were made to locate natural enemies like insect pests and fungal pathogens causing diseases on leaves, stem and roots of balsam.

In the meadows of Upper Kulu Valley which house a diverse population of over 100 plant species, two different populations (Site 1 - tree line, Site 2 - meadows) of Himalayan balsam were found growing luxuriantly amidst pine trees. During the survey it was clear that grazing of Himalayan sheep/goat in these areas has great impact on the balsam population and its distribution. The wool industry is prominent in Kulu-Manali areas and most farmers have sheep in thousands of herds which will graze the meadows floor which affects the late flowering/early fruiting stage of many flowering plants including Himalayan balsam. This eventually restricts the balsam population to spread further in to newer areas. Heavy snow fall during the early winter also has a profound influence on the population of Himalayan balsam in these areas.

Gulaba area is characterized by steep and rocky terrains covered by snow from the top. Himalayan balsam population in this area was mostly found in the steep crevices of the mountains. However, plants were also found growing along roadsides. Balsam plants were found growing quite tall (up to 1.5 m) and healthy in this area apparently due to the high soil fertility. A rust fungus which control the balsam populations by causing severe foliar and stem infections could be collected from the Gulaba area.

Second survey: The survey revealed that *Impatiens glandulifera* is absent in the Mussouri Hills and Champa valley. Instead, *Impatiens sculta, I. bicolour* and *I. scabria* were widely distributed in the area.

Third survey: This survey conducted in the Solang river basin revealed the presence of several arthropod pests and a rust pathogen affecting leaves of balsam. The plants were at the peak of flowering and seed setting stage during the survey. The height of the plants varied from 1-1.2

meters. There were around 40-60 plants in a group. The number of pods in a plant was a good indicator of the health of the plant. Tall and healthy plants in the river basins had more pods and seeds. The stem of the plants growing in the shady terrain of the river basin was fibrous and pinkish red in colour whereas those growing in the flooded areas had a pale green tender stem.

Fig. 6. Surveys in Upper Gulaba, way to Rothang Pass-Lahul Spiti.
Leaves affected by *Uromyces* sp. are also shown

A *Metialma* weevil which feeds on the leaves and tender parts of the balsam plant was collected from shady terrains of the river basin. It posed a big threat to the population. All stages of the life cycle of the weevil were examined at the study site and the pupae were collected for rearing in the laboratory. A couple of other beetles and weevils associated with the balsam plant species were also collected from the study area for further studies and identification. However, no promising plant pathogens were collected from this site.

In the lower meadows of Brugu lake, the balsam plants appeared stunted in growth and the maximum height attained was only 60 cm. Apparently, the lack of shade in the area and the

high temperature prevailed during the season may have affected the luxuriant growth of balsam in this area. Though 95 per cent of the balsam population was damaged by grazing it was possible to collect some arthropod species which feed on balsam. A rust fungus which causes foliar infection was also collected during the survey.

The study site at Gulaba on the way to Rothang Pass and Lahul Spiti area turned out to be the most promising site for plant pathogenic fungi affecting balsam. The entire population of balsam in this area was found affected by the rust fungus *Uromyces* sp. identified earlier at Brugu lake area. An alternate host of the fungus was also identified from this area. Infected materials and alternate host plants were collected for identification and further studies (Fig. 6).

Fourth survey: This survey conducted in the Mussoorie hills and adjacent areas confirmed the presence of species such as *Impatiens bicolour* and *Impatiens scabria*. Natural enemies of these hosts were collected to assess the population of arthropod pests affecting plants of the family Balsaminaceae. *Impatiens glandulifera* was absent in this locality. At other sites, especially at lower meadows of Brugu lake and Gulaba, the climatic was extreme and balsam populations were on the decline due to heavy snow fall. Isolated patches of plants present in the Solang river basin were severely damaged by the *Metialma* weevil. The pupae of the weevil were in the late stage of its life cycle at the time of observation.

Natural enemies

Arthropods

Results of the surveys for arthropod natural enemies are provided below. The information include: the name of the locality from where the arthropod was collected, identification, distribution, host range, potential for bio-control and future research needs.

Fig. 7. 1. *Metialma* sp. (weevil) feeding on leaf of Himalayan balsam, 2. Feeding holes on the stem, 3. Plant fibre cocoon, 4. Exuvia of the weevil *Metialma* sp. feeding on the leaf of balsam.

1. ***Metialma* sp. (weevil)**

Distribution: Solang river basin
Host range: During the survey, the weevil was found feeding on the target plant Himalayan balsam only. Reports indicate that a related species viz., *Metialma balsaminae* from Ceylon lives on 'balsam' and this species (*M. balsaminse* (*sic*)) was reported as occurring regularly at Pusa in late season and was also found at Poona in October 1916 (Bainbridge-Fletcher, 1917). The bored stem swells out into a sort of gall. Pupation takes place in the stem in a special cocoon made of fibre (Fig. 7).
Recommended future work: A culture of this weevil needs to be established. Priority should be to carry out oviposition and development tests on other *Impatiens* species.

2. ***Meristata sp.*** (leaf beetle) (Fig. 8)

Distribution: Collected only from one locality in the Solang river basin.
Feeding habit: The adults are leaf feeders and the larvae are probably surface leaf feeders.
Host range: Unknown.
Recommended future work: Investigate feeding preference if field observations support possible specificity in the presence of other members of the family Balsaminaceae.

3. ***Alcidodes fasciatus*** weevil (Fig. 9)

Distribution: This species occurs in Kashmir and North India (Dehra Dun, Bengal, Sikkim and Assam). During the current survey, the species was located at two sites in the Solang valley.
Feeding habit: At the time of collection, the biology of this weevil was unknown. It was anticipated that the adults were likely to feed on the stems of plants and the larvae were likely to live inside the tissues of the same plants. This has subsequently been confirmed in the laboratory. The adults chew characteristic holes in the stem, often in multiples of three, and eggs are laid in the hollow area from where larvae hatch, feed and develop.
Host range: This weevil has a related species with which it was until recently confused. This species has also been recorded on *Impatiens*.
Recommended future work: Host range studies focusing on oviposition are needed.

4. ***Deilephila rivularis*** (Hawk moth) (Fig. 10)

Distribution: In northern India as far east as Dehra Dun. It tends to occur at an altitude between 2000 – 4000 m. Records on the occurrence of the moth in Sikkim appear incorrect even though

there is a specimen in the National History Museum, London attributed to this locality (Pittaway, 2008). The moth has been recorded in Pakistan also.

Feeding habit: The larvae are voracious leaf feeders.

Host range: Larvae have been recorded from *Arisaema* (Indian turnip) in the family (Araceae) as well as *Impatiens* in India (Bell and Scott, 1937).

Recommended future work: Feeding and development in an Indian *Arisaema* sp. is to be ascertained to confirm the host range of the moth.

Fig. 8. *Meristata sp.*, Fig. 9. *Alcidodes fasciatus* 9a. adult, 9b. larvae and 9c. feeding hole., Fig. 10. *Deilephila rivularis.*, Fig. 11. *Evacanthus repexus.*, Fig. 12. *Languriophasma sp.*, Fig. 13. *Chilocrates sp.*, Fig. 14a. *Altica himensis*-adult and 14b. larva., Fig. 15. *Taeniothrips major.*

5. ***Evacanthus repexus*** (leafhopper) (Fig. 11)

Identification: *Evacanthus repexus* Distant [Hemiptera: Cicadellidae: Evacanthinae).

Distribution: This leaf hopper is widespread in the Oriental region, and specifically in India. In our surveys, *Evacanthus repexus* was recorded from numerous populations of impatiens.

Feeding habit: Xylem feeder

Host range: This species has been recorded from *Chenopodium*. sp. in Pakistan (Baloch and Gaffar, 1984) and collected from maize and Citrus and as such it may not be host-specific.

6. ***Languriophasma*** **sp.** (Lizard beetle) (Fig. 12)

Distribution: Solang river basin.

Feeding habit: Members of the subfamily Languriinae feed within the stems of living plants, but only a few have been recorded as pests. Unidentified larvae were found inside the stems of balsam plants but attempts to rear these were unsuccessful.
Host range: Host specificity is uncertain.
Recommended future work: It needs to be determined whether larval stages previously observed were *Languriophasma*. To confirm this, host range of adults and oviposition are to be ascertained.

7. ***Chilocrates*** sp. (bug) (Fig. 13)

Identification: *Chilocrates sp.* (Hemiptera: Miridae, Mirinae, Mirini).
Distribution: Northern India, Bhutan and Nepal (Yasanuga and Schwartz, 2000).
Feeding habit: Sap sucker
Host range: Unknown
Recommended future work: None at present since the host range is unknown.

8. ***Altica himensis*** (flea beetle) (Fig. 14)

Identification: *Altica himensis* Shukla [Coleoptera: Chrysomelidae]
Distribution: Kuman Hills, Kashmir and in Bhutan. Very common in India
Feeding habit: Both the adult and the larvae chew the leaves and occasionally the stem and flowers of host plants.
Host range: Jyala (2002) reports adults and larvae feeding on *Impatiens, Rumex* and *Oenothera* in the Kumaon Himalayas.
Recommended future work: None unless a population is found showing high specificity to Himalayan balsam in the presence of other *Impatiens* species.

9. ***Taeniothrips major*** (flower thrips) (Fig. 15)

Identification: *Taeniothrips major* Bagnall [Thysanoptera: Thripidae]
Distribution: This species is very common in Pakistan but not abundant in India. There are records of this species from Nepal and Himachal Pradesh. The species was first described in 1916 from 4 females of the thrips on *Rhododendron* flowers in India (11,700ft). The exact location is unclear though it is thought to be in Uttar Pradesh.
Feeding habit: The adults feed on the pollen produced by the flowers and the larvae feed on the leaves.
Host range: Apart from the record on *Rhodendron* and *Impatiens* no other information is available on the host range of this species.
Recommended future work: The host range of the species needs to be evaluated against the important *Impatiens* species to assess the potential of this species as a bio-control agent.

Apart from those described above, several other insect species were also recorded on Himalayan balsam during the survey (Fig. 16). Since the identities of these species their feeding habit and host range are unknown, they are not dealt with in this report. The facilities of the Entomology and Plant Pathology Departments of FRI, Dehra Dun were used for rearing and testing the host specificity of some of the arthropods collected during the survey.

Fig. 16. Miscellaneous arthropods recorded on Himalayan balsam during the survey

Plant pathogens

The most prevalent disease of Himalayan balsam was the *Septoria* leaf spot which inflicted considerable damage to the foliage of almost all populations observed.

1. ***Leaf spot caused by* Septoria sp.**

Identification: A review of fungal databases revealed that three species of *Septoria* have been recorded from *Impatiens* spp. and these can be distinguished on the basis of conidial length. *Septoria noli-tangeris* Thümen was described from *Impatiens noli-tangere* collected from Orenburg (in the Volga district of Russia near the border with Kazakhstan), but its spores are morphologically different to the *Septoria* strains collected on and across the native range of *I. glandulifera*. *S. noli-tangeris* Gerard (a homonym of the first-mentioned species) was reported from *Impatiens* species in north-eastern USA but again, distinct differences in spore morphology suggest this is not the same as the one collected from *I. glandulifera*. A third species, *S. balsaminae* was discovered on cultivated *Impatiens* in northern Italy but a description of the pathogen raises doubts as to whether this is a *Septoria* at all. So, the *Septoria* on Himalayan balsam appears to be a new species (Fig. 17).

Distribution: This conspicuous and damaging leaf spot was observed on populations of *I. glandulifera* in Solang Valley. Almost all populations of Himalayan balsam surveyed had damage indicative of this plant pathogen.

Symptoms: The initial symptoms are small circular leaf spots with white to light tan or grey centres and a purple or brown border or a zone of chlorotic tissue. As the disease progresses, the spots will become larger and may also coalesce. Small, dark brown, pimple-like pycnidia are produced within the leaf spots and are large enough to be seen with the naked eye. Heavily infected leaves turn yellow, dry up, and fall off. Under wet conditions, the pycnidia produce numerous conidia which are exuded under favourable conditions. Spores can then be spread by rain-splash, windblown water or insects. Since free moisture is necessary for the spores to germinate and penetrate through the stomata, long-lasting dew and rainy days (100 percent RH for 48 hr accumulated over several days) favour disease development. Although the fungus is not a soil inhabitant, it is likely that in the field, it will persist from one season to the next on debris of diseased plants incorporated in the soil.

Recommended future work: Host range test needs to be conducted against all *Impatiens* species.

Fig.17a, b.*Septoria* leaf spot., Fig. 18a,b,c. Rust pustules on stem of Himalayan balsam (acedial stage)

2. ***Rust disease caused by Puccinia* spp.** (Fig. 18)

Rust pustules on stem of Himalayan balsam (acedial stage).

Identification: Identification to species level is yet to be done.
Distribution: Evidence of the acedial stage (on stem) and uredinia and telia stages of the rust (on leaves) was observed on balsam population in Kulu valley.
Symptoms: The acedial stage of the rust was observed at the late stage of infection. Observations in the field indicate that the pathogen could perhaps be *Puccinia komavorii* which produces uredinia on the leaves at a later stage as part of its life cycle but further analysis is needed to find out whether there are two distinct rust species affecting *I. glandulifera.*
Recommended future work: Host specificity test against all *Impatiens* species warranted

Conclusions

Surveys revealed that Himalayan balsam in its native range does not exhibit the invasive traits as it does in the UK, due mainly to the pressure exerted by natural enemies. The plants appeared smaller in size in the native range compared to the introduced ranges. Levels of herbivory were higher in the native range. The plant is affected by an array of arthropod species in the Himalayan region. Of these, two stem boring weevils' viz., *Metialma* sp. and *Alcidodes fasciatus* collected during the survey have potential as biocontrol agents. Likewise, plant pathogens such as *Septoria* sp. and *Puccinia* sp. are also potential candidates for biocontrol. However, further research is needed to ascertain the host specificity of these insects and fungi. Research is also mandatory to determine their suitability as bio-control agents. A second phase of the project is thus warranted.

taken to remove all the underground parts. However, this method does not provide long-term control and it has been shown that mechanical control of *H. gardnerianum* could have serious negative impacts on the native biodiversity compared to non-intervention and/or minor disturbance (Lavergne, 2005)

Figs. 1-3. Habit of 1. *Hedychium coronarium*, 2. *H. flavescens*, 3. *H. gardenerianum*

In Hawaii, manual or chemical methods of control can help with outlier populations but most of the areas that have been infested with wild ginger for years are nearly monotypic and are considered lost. It is anticipated that any reduction in ginger cover would result in recruitment of the next generation of invasive weeds. Chemical methods cannot be used in natural forests and water courses since these are environmentally harmful.

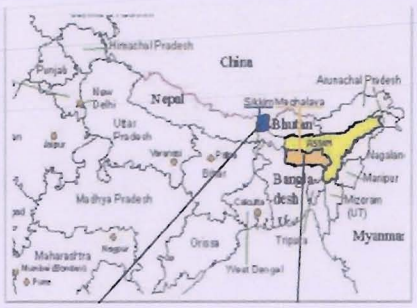
Biological control: No natural enemies with the potential for biocontrol have been detected in Brazil (*H. coronarium*) and New Zealand (*H. flavescens* and *H. gardnerianum*) (Soares and Barretto, 2008; Winks et al., 2008). In Hawaii, use of *Ralstonia solanacearum* , a well known wilt causing bacterium, was considered for the control of *H. gardnerianum* (Anderson and Gardner, 1999). The attempt was successful but not continued since the focus was to use a co-evolved natural enemy from the native range of the weed.

Objective of the study: To survey natural enemies of the three *Hedychium* spp. in their native ranges so as to identify potential biocontrol agents.

Materials and methods

Identifying native region of the species and survey sites

Literature and databases were consulted to identify the origin of the species and to decide on the areas to be surveyed for locating the wild ginger spp. This included the Flora of British India (Hooker, 1894) and the Zingiberaceae of Sikkim (Kumar, 2001). The library/herbaria at Kew and Natural History Museum in London were also consulted to collect details on the origin and distribution of the genus *Hedychium*. Subsequently, details were also collected from the Central National Herbarium of the Botanical Survey of India, Kolkota and consolidated with the information from the Herbarium at the Forest Research, Dehra Dun.



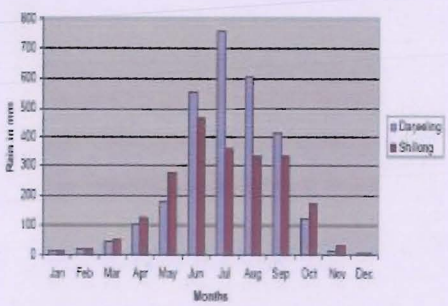


Fig. 4. Areas surveyed for wild ginger spp. in Northern India, Fig. 5. Average rainfall in Darjeeling and Shillong (2008-09)

Information on natural enemies already recorded: Fungal databases (USDA-ARSGrin; CABI Funindex; Bussaban *et al.*, 2002) and other literature were consulted to gather information on natural enemies of the three *Hedychium* spp. in the native range.

Survey: Based on the information collected, it was decided to conduct surveys in selected sites in Meghalaya, Assam West Bengal and Sikkim (Fig. 4). In the wild, most *Hedychium* species start growing to synchronize with the advent of the summer monsoon; the geographic area to be surveyed is characterized by monsoon climate between June and September (Fig. 5). The surveys were carried out during the month of October (the end of the monsoon in the targeted areas) to coincide with the flowering period of the species and the optimum period for infestation by pest and pathogens. Details of the sites surveyed are given in Appendix 1. At each site, observations were made on the vegetation, size of population and level of damage. GPS details were recorded (see Appendix 1 - Sikkim details have been omitted at the request of the Forestry Department) at each site along with any other key features. *Hedychium coronarium* was found at altitudes ranging from 484-1274 m, *H. flavescens* up to 1780 m and *H. gardnerianum* from 1672- 2134 m.

Results and discussion

Identifying native region of the species and survey sites

The literature and the databases on the three *Hedychium* species indicated eastern Himalayas as the centre of origin of these plants (Fig 4, rectangular outline of Himalayan range with area of origin inset). The native range of *H. coronarium* is recorded as north-east India, Nepal, Bhutan and Southwestern China; *H. flavescens* in north-east India and Nepal and *H. gardnerianum* in Nepal, Sikkim and Assam.

Identification of *Hedychium* species in the field was a challenge since the plants were not in flowering stage and were predominantly at the fruiting stage at the time of the survey. Since keys to the genus generally use flower features to distinguish between species, it became necessary to use morphological features of the leaves (e.g. *pubescence*) and/or stems to help identify the species. The local knowledge of the villagers and Staff of the Forest Department also were used to confirm identity of the plants. According to Forestry Staff, in Meghalaya, the flowering period of *H. gardnerianum* was in July-August and in Sikkim, April- June.

A large number of *Hedychium* species and other members of the family Zingiberaceae such as large *Alpinia* species, *Costus* species and ginger (*Zingiber officinale*) and cardamom (*Elettaria cardamomum*) were observed during the survey. This provided an opportunity to observe the host range of natural enemies across the family in the field. All three species of *Hedychium* were recorded from a range of habitats such as roadsides, gardens, under partial shade, forest

canopies and along forest edges. Populations of *H. coronarium* and *H. flavescens* were frequently found in the moist forest margins and swampy grounds. In Sikkim, natural, isolated patches of *H. gardnerianum* were often found growing on steep banks and along waterways.

All *Hedychium* species encountered were found to be affected by pests and pathogens evident by damage to all parts of the plant, including seeds, flower heads, leaves and stems and in a few instances combined attack by insects and pathogens was also observed. Collections of natural enemies and herbarium materials were made and maintained throughout the trip.

The following *Hedychium* spp. were recorded during the survey (Fig. 6)

1) *H. coccineum*, 2) *H. coronarium*, 3) *H. densiflorum*?, 4) *H. flavesecens* , 5) *H. flavum*,
2) 6) *H. gardenerianum*, 7) *H. greenii*?, 8) *H. spicatum*, 9) *H. stenopetalum* and 10) *H.thyrsiforme*

Natural enemies of *Hedychium* spp. already known

Ginger cultivation enthusiasts often state that part of the appeal of growing these plants is that they are relatively pest and disease free (Branney, 2005) and indeed, the only pests reported on ornamental *Hedychiums* are squirrels (feeding on developing shoots) and the occasional cosmetic damage from caterpillars such as the Canna skipper butterfly (*Calpodes ethlius*) and Mushroom rootrot (*Armilariella tabescens*) on older rhizomes.

Literature search showed that of the 9 species of fungi described from *Hedychium* spp., only a few are recorded to be associated with the target wild gingers in their native range. They are: *Mycosphaerella* sp. on *H. gardnerianum* and *Bartalinia robillardoides* (endophyte), *Fusarium oxyspermum, Drechlsera* sp. and an unidentified ascomycete (on stem) on *H. coronarium* from India and *Lecanocybe lateralis* recorded on senescent leaves of *H. flavescens* in Indonesia. *Pseudocercospora costina* and *Pyricularia zingiberis* have also been reported from *Hedychium* sp. in India. Despite their cultural and medicinal value, there seems to be surprisingly little information on the natural enemies of *Hedychium* spp. in the native range.

Hedychium coronarium is known as an alternative host to banana bunchy-top virus (BBTV) in Taiwan (Csurhes and Hannan-Jones, 2008). In Queensland, the BBTV vector banana black aphid

Fig. 6. Habit of 1. *Hedychium coronarium*, 2. *H. coccineum*, 3. *H. spicitum*, 4 & 5 *H. flavascens*/*H. coronarium*, 6 & 7. *H. flavum* (in Meghalaya), 8. *H. coccineum* (in Shillong), 9. *H. flavascens* (in Darjeeling)

Fig. 10. *H. greenii* (in Darjeeling), 11. *H. gardenerianum*, 12. *H. thyrsiforme* (in Sikkim)

Pentalonia nigronervosa is reported from *H. coronarium* (Geering and Thomas 1997). The extent of utilisation of *H. gardnerianum* and *H. flavescens* by *P. nigronervosa* is unknown. The pests recorded on wild ginger in their native range are a pyralid shoot borer (cf. *Conogethes puctiferalis*) and a hesperid leaf roller (cf. *Udaspes folus*). By contrast, in India, fifty eight species of insect pests have been recorded on Cardamom (*Elettaria cardamomum*) and forty six species on ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) which are economically important species of the family Zingiberaceae (Anandaraj and Peter, 1996; Sarma *et al.*, 1992). This shows the high degree of specificity of species found on *Hedychium*.

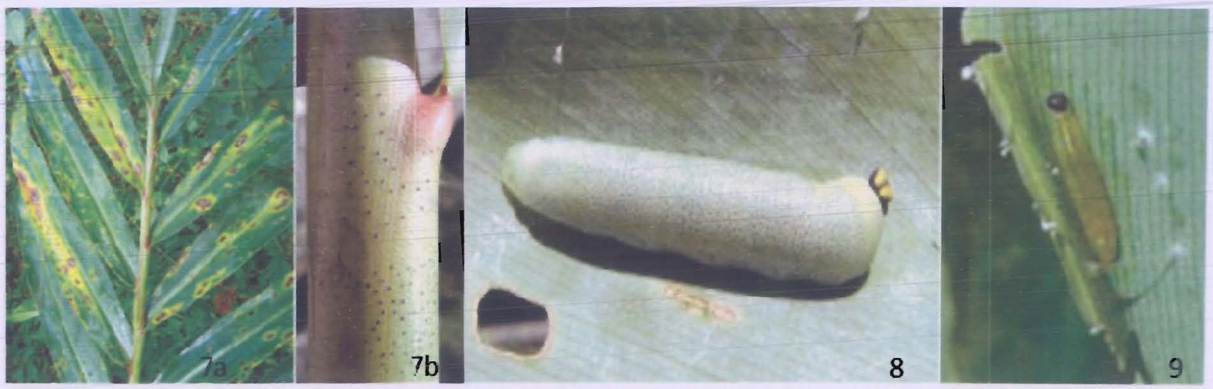


Fig. 7a. Leaf spots on *H. coccineum* and 7b. Fungal fruiting bodies on *H. gardnerianum* caused by an un-identified fungus; Fig. 8. *Notocrypta curvifascia*-larva; Fig. 9. *Udaspes folus*-larva.

Surveys:

Fungi: Compared to insects, fungi were found to be rather under- represented on *Hedychium* spp during this survey. It is presumed that the suite of natural enemies would vary across the growing season of the plants and more pathogens can be located if the survey is made more rigorous by covering different seasons. The results of this study is unlikely to be representative of the true potential of fungal agents which inflict damage on *Hedychium* spp. In contrast to the target *Hedychium* spp., other species of the genus were found to be severely affected by pathogens causing leaf spots and wilts (Fig. 7).

Arthropod natural enemies of **Hedychium** *complex*: In nature there are three types of herbivorous invertebrates and these can be defined by their feeding preference. Polyphagous species show little specificity and will feed on a broad array of plant species. Oligophagous insects will still feed on a variety of plant species but generally these species are within the same plant family. The insect species which biocontrol practitioners are most interested in are the monophagous ones, i.e., those which feed on one or a few very closely related plants.

The literature search has revealed that wild gingers are not affected by any serious pathogens and pests in the introduced ranges and no other native representative of Zingiberaceae occur in these countries. Hence, biocontrol using natural enemies introduced from the native ranges of the *Hedychium* spp. appears to be the best option to control their population in the introduced ranges.

An interesting array of arthropods was collected on various *Hedychium* species during this survey and these are detailed below.

1. **Cf. *Notocrypta curvifascia*** (Felder & Felder) [Lepidoptera: Hesperiidae] (Fig. 8)

Host: *Hedychium gardnerianum*

Identification: Commonly known as the Restricted Demon, this skipper butterfly is relatively large, approx., 4 cm long and with dark brown to black wings and a white eyespot near the trailing end. The insect could be collected in the larval form only.
Distribution: Found in many regions of temperate and tropical East Asia and the Indian subcontinent wherever its preferred larval host plant, *Alpinia specisa,* can be found.
Feeding habit: Larvae feed on the leaves and hide themselves in leaf rolls or tubes.
Host range: The larval host plants include members of the family Zingiberaceae (including *Hedychium* spp.) and Musaceae e.g., *Alpinia* spp., *Cucurma, Costus* spp. *Globba, Musa* and *Zingiber* species.
It was not possible to rear the caterpillar to adult and the insect was collected only on *H. gardnerianum* during the survey.
Biocontrol potential: Low - appears to have a broad host range within the Zingiberaceae and closely related Musaceae but at this stage whether there are more specific races are not known.

2. **Cf. *Udaspes folus* (Cramer)** [Lepidoptera: Hesperiidae] (Fig. 9)

Host: *Hedychium gardnerianum*

Identification: U. folus is a small butterfly known as the Grass Demon, with a wingspan of about 4 to 4.8 cm. It is blackish brown with a large white/yellow spot on the upper side of the hind wing and several smaller white spots on the forewing. The underside of its wings is mostly white with brown edges and spots. Its black and white colouration may have evolved to take advantage of the dappled light in its preferred habitat.
Distribution: Distributed throughout India, mainland China, Hainan, Indonesia, Japan, Java, Laos, Lombok, Langkawi, Malaysia, Nepal to Myanmar, Singapore, Sri Lanka, Sumatra, Thailand and Vietnam The Grass Demon prefers forest edges or clearings where dappled light is present.
Feeding habit: The larva is slug-like, bluish green with black head and feeds by folding the leaves of its host plant.
Host range: The Grass Demon feeds on ginger, turmeric and their relatives such as *Cucurma* spp. and *Hedychium* spp. It is also recorded on grasses. Specific host plants include *Zingiber zerumbet.*
Biocontrol potential: None. Host range broad within Zingiberaceae but may be restricted to specific races.

3. **Cf. *Conogethes punctiferalis*** [Lepidoptera: Pyraliae] (Fig. 10)

Host: *Hedychium gardnerianum* and *Hedychium coronarium*

Fig. 10. 1-3. *C. punctiferalis* on *H. gardnerianum* (1, larva; 2, feeding hole; 3, infestation), 4. Infestation on *H. coronarium*

Identification: Unconfirmed.

This moth is referred to as the cardamom shoot borer in the Himalayas and the yellow peach moth in Australia (which may be a complex of species) and elsewhere.

Distribution: India, Mainland China, Japan, Indonesia, Philippines and Australia.

Feeding habit: In turmeric and cardamom, the young larval stages bore into unopened leaf buds and panicles causing shedding of flowers and drying up of the attacked portions. They also feed on young seeds. The late stages bore into pseudostems and feed on the central core causing terminal leaf to dry up ("dead heart"). Faecal matter of the caterpillar can be seen coming out through the holes and indicates presence of the caterpillars in the pseudostem, inflorescence and pods.

Host range: Recorded from a wide variety of fruit crops, cardamom, ginger, turmeric and *Hedychium* spp. in India.

Biocontrol potential: Low if identification is accurate. An important pest in many crops but whether this tentative identification is valid or whether there are races specific to *Hedychium* are not known.

4. **Unidentified leaf folder (Hesperiidae?)** (Fig. 11)

Host- *Hedychium coronarium*

Fig. 11. 1. Leaf folder on *H. coronarium*, and 2. on *H. coccineum*, 3. Larva of the leaf folder feeding on *H. coronarium*

The larvae are pale green with a brown head capsule and quite distinct from the other leaf folding lepidoptera on *H. gardnerianum*.
Feeding habit: Larvae cut and fold the leaf margin forming a shelter within which it feeds in parallel strips. Rearing was not possible.
Host range: Commonly found on a range of *Hedychium* sp. (e.g., *H. stenopetalum, H. coccineum, H. densiflorum, H. thyrsiforme*).
Biocontrol potential: Unknown. Damaging on the *Hedychium* species which host it but whether it has a broader host range is not known. Further studies and adult rearing needed.

5. **Unidentified stem boring beetle (Coleoptera: Lycidae-like)** (Fig. 12)

Host: H. coronarium or *H. flavescens*. Larvae large, cream, C-shaped, with brown head capsule. Adults are a rich rusty colour, up to 2 adults per stem. Adults are 1.5 cm long x 0.4 cm wide. Antennae is of 11 segments, filiform with raised parallel banding on abdomen.

Feeding habit: The larvae move up the pseudostem feeding actively causing extensive damage before pupating further up the stem.

Host range: Adults only found on *H. coronarium* and perhaps on either *H. coronarium* or *H. flavescens*, identity based on pubescence of leaves.
Biocontrol potential: Unknown. Further studies on identity and specificity are needed. The beetle appears highly damaging and more restricted within *Hedychium* spp.

Fig. 12. Coleopteran borer on *H. coronarium*/ *H. flavescens*
1. Adult on stem, 2. Damage caused by larvae, 3. Adult emergence holes

Miscellaneous damage/insects on *H. coronarium* (Fig. 13) Heavy damage caused by unidentified Lepidopteran, (possibly cf. *Conogethes punctiferalis*) causing premature abortion of flowers. Pupa found at base of flower stalk but could not be successfully reared. Several other insects which cause flower/capsule/stem boring damage has been recorded on *H. gardnerianum* (Figs. 13 & 14). They are not discussed in detailed here for want of information on identity, distribution and host specificity.

Miscellaneous arthropods and damage on *H. gardnerianum*

Fig. 13. 1. Leaf rolling and feeding damage by *Udaspes folus*, 2. Larva of *U. folus*, 3. Coccinellid beetle, 4. Stem borer damage, 5. Leaf folding (*U. folus* ?), 6. Leaf mining damage, 7. True bug nymph (Heteroptera), 8. Leaf hopper, 9. Coleopteran sp.

Other insects and damage on *H. coronarium* (Fig. 14)

Fig.14. 1-4. Flower/capsule/stem boring damage in *H. coronarium*, exit holes on stem

(1), aborted flower (2) and borer damage on flower head (3 and 4) in Sikkim, 5. Leaf tying Lepidoptrera, 6. Web forming Lepidoptreran, 7. Green leaf hopper, 8. Severe feeding damage

Conclusions

Literature and herbaria reviews showed that the Himalayan range in Eastern India notably the states of Meghalaya, Assam, Sikkim and the country of Nepal are the centres of origin of *Hedychium gardnerianum, H. flavescens* and *H. coronarium.*

A ten day survey was carried out in October 2008 in sites located in Meghalaya, Assam West Bengal and Sikkim to locate *Hedychium* populations and to identify natural enemies of the target species. The *Hedychium* species identified during the survey included *H. coccineum, H. coronarium, H. densiflorum*?, *H. flavesecens, H. flavum, H. gardenerianum, H. greenii*?, *H. spicatum, H. stenopetalum* and *H.thyrsiforme. Hedychium gardnerianum, H. flavescens* and *H. coronarium,* the target species, were found growing in equilibrium with native vegetation in moist forest edges or in open woodlands and they did not exhibit any of the invasive traits observed in their introduced range. All the species encountered during the survey were subject to natural enemy pressure.

Despite the limited duration of the survey, a wide variety of arthropods were collected from the target species and other species of *Hedychium.* These included leaf rollers, fruit/capsule feeders and stem borers. A leaf spot caused by an un identified fungus was recorded on *H. coccineum.* The biocontrol potential of these natural enemies is unclear at present as identifications are yet to be confirmed and host specificity is to be ascertained. More surveys are required to cover the suite of natural enemies associated with the target species throughout their growing cycle and across the seasons.

It is recommended that a second phase needs to be implemented for further surveys to collect natural enemies when the plants are in the flowering stage which will help easy identification of the species. The months of June/July (early monsoon) have been identified as the optimum period for the survey. The current survey indicates that an additional survey in early September would be beneficial since this would coincide with the end of the monsoon and the climatic conditions will be suitable for infestation by pests and pathogens.

The huge diversity and hybridising potential of *Hedychium* species highlight the importance of molecular characterisation of species to complement the morphological determination.

References

Anandaraj, M. and Peter, K.V. (1996). Biological control in spices. Indian Institute of Spices Research, Calicut, pp. 1-19.

Anderson, R.C and Gardner, D. E. (1999). An evaluation of the wilt-causing bacterium *Ralstonia solanacearum* as a potential biological control agent for the alien Kahili ginger (*Hedychium gardnerianum*) in Hawaiian Forests. Biological control, 15: 89-96

Branney, T. M. E. (2005). Hardy gingers including *Hedychium*, *Roscoea*, and *Zingiber*. Timber Press, Cambridge, UK, 304p.

Bussaban B., Lumyong P., McKenzie E.H.C., Hyde, K.H. and Lumyong, S. (2002). Index of fungi described from the Zingiberaceae. Mycotaxon, 83: 165-182.

CABI IndexFungorum http://www.indexfungorum.org/Names/NAMES.ASP

CABI: Invasive Species Compendium, *Hedychium flavescens* , *H. coronarium* and *H. gardnerianum*.

Csurhes, S. and Hannan-Jones, M. (2008). Plant pest risk assessment. *H. gardnerianum, H. coronarium* and *H. flavescens*. DPI&F, State of Queensland Report. 18p. Project (2008) http://www.darwinproject.ac.uk/darwinletters/calendar/entry-9296a.html

Geering, A. D.W. and Thomas, J. E. (1997). Search for alternative hosts of banana bunchy top virus in Australia, Australasian Plant Pathology, 26: 250–254.

Hooker J.D. (1894). The Flora of British India. Vol. VI. Orchidae to Cyperaceae. L. Reeve and Co. Ltd., London, UK.

Kumar, S. 2001. Zingiberaceae of Sikkim. Deep Publications, India, 83 p.

Lavergne, C. (2005). Invasion par les plantes exotiques envahissantes dans une île océanique : Impact écologique à la Réunion et valeur patrimoniale des écosystèmes indigènes envahis. Résumé, Programme de Recherche sur les Invasions Biologiques INVABIO, Conservatoire Botanique National de Mascarin et Université de la Réunion, 12 p.

Sarma, Y. R., Devasahayam, S., Anandaraj, M. (1992). Black Pepper and Cardamom: Problems and prospects. In: Proceedings of National seminar on Black Pepper and Cardamom, 17-18 May, 1992, Calicut, Kerala, India.

Soares, D. J. & Barreto, R. W. (2008). Fungal pathogens of the invasive riparian weed *Hedychium coronarium* from Brazil and their potential for biological control. Fungal Diversity, 28: 85-96.

Winks, C., Waipara, N.W., Smith, L.A., Tsai, S., Wilkie , J.P., Peterson, P.G. (2007). Invertebrates and pathogens associated with wild ginger, *Hedychium gardnerianum* and *Hedychium flavescens* (Zingiberaceae), in New Zealand. Landcare Research Contract Report, prepared for the National Biocontrol Collective, 45

Appendix 1
Survey for natural enemies of *Hedychium spp.*
Site details and observations

Date and Ref	Site details	Observations
9.10.08 (9-1)	Guwahati to Shillong Rd Assam Lat. N25°57.679 Long. E091°51.216 Alt. (m). 324	***Hedychium sp./Alpinia*** ?Edge of forest road side-population oflarge, glabrous leaved ginger spp. with prominent midrib vein underside and no colouring of stem. No flower spikes. Evidence of leafminers, shot hole damage, leaf spotting/scorch. Small black scolytid stem boring beetles collected causing necrosis of stem- several adults, eggs and gregarious larvae per stem.
9.10.08 (9-2)	Nongpoh, Guwahati, Shillong Rd Assam Alt. (m). 484	***Hedychium coronarium*** Few plants on the road side (planted) Flowering + seeding. No damage evident
10.10.08 (10-1)	Shillong Peak, Meghalaya Lat. N25°32.859 Long. E91°53.205 Alt. (m). 1874	***Hedychium spicatum*****or *H. densiflorum*?**Steep banked, roadside forest -Large mixed open deciduous. Plants in to broad, veined leaves,sparsely hairy. No flowers but fruits on terminal spike. All plants suffering from severe borer damage,death of whole plants. Evidence of leafspotting, basal rot, tip die back, seedlings damaged. Thrips on seeds, leaf hoppers and large mating weevils found. Leafminer damage common.
10.10.08 (10-2)	30km from Jovai on Shillong to Jowai Rd. Meghalaya Lat. N25°32.694 Long. E092°00.43 Alt. (m). 1452	***Hedychium coccineum?***Open field at edge of pine forest, drier habitat. Flowering ended but long terminal spike with glabrous, thinner and darker green leaves. Harder stem than in 10-1. Stem borer larvae and sap suckers. Leaf necrosis common.
10.10.08 (10-3)	Silchar road, Meghalaya Lat. N25°27.93 Long. E092°16.402 Alt. (m). 1402	***Hedychium coronarium/H. stenopetalum-*** Plants in to white flowers with pale yellow tinge at mouth. Small population growing along roadside in boggy ground on the edge of a conifer forest. Large silky leaves, pubescent. Two flower shapes found a longer spiked one and more stout version. Large boring brown beetle found in stem, adult, larval + pupal stages causing severe damage. Aphids on flowers with many ants tending. Large coalescing lesions on leaf with sclerotia. Leaf larvae common, folding edges of leaf and grazing beneath. Shot hole damage.

11.10.08 (11-1)	Kdoh Kule, Ummulong-Nartiang road, Meghalaya Lat. N25°33.67 Long. E092°11.140 Alt. (m). 1274	*Hedychium coronarium/flavescens?* -Large pubescent leaves (white hairs on underside), 2.5m tall, small stand of 5 individual plants in lantana mix. Compact head, no flowers. Boggy, marshy area at roadside edge of pine forest. Evidence of stem boring, small white larvae moving from tip down. Leaf feeding also evident.
11.10.08 (11-2)	Lumpkah village Further down the same road as in 11-1, Meghalaya Lat. N25°34.112 Long. E092°707 Alt. (m). 1236	**Mixed *Hedychium spp.- H. coccineum* and *H. densiflorum/spicatum?***in large mixed forest (fairly closed canopy) by road edge. Steep sloped. One species with thin dark green glabrous leaves with whitish down on midvein only and other with wider paler green leaves with more pronounced venation. Wider leaved one has leafmines and lep pupating in web formed formed in leaf fold. Thin leaved one has stem borer, mining form tip down and pupating near base, causing yellowing + blackening stems and death of plants. Pupa collected.
11.10.08 (11-3)	1km further down from 11-2, Meghalaya Lat. N25°34.171 Long. E092°147 Alt. (m). 1204	***H. flavescens/coronarium?*** Large plants, 2m tall, large pubescent leaves. Large stand in boggy marsh at edge of forest, cone like compact seed head. Beetles found on leaves and largebrown beetle in stem; lep larvae and green horned insect collected by beating
12.10.08 (12-1)	Umdiengpoh village, Shillong to Cherrapunjee rd, Meghalaya	*Isolated* ***H. gardnerianum*** plants growing out of rock face with forested valley on the other side. Rhizome collected for growing and herbarium material for reference. No flowers. Reddish at petiole base, thick glabrous leaves.
12-2	Cherrapunjee road, Nongbri site Meghalaya Lat. N25°18.123 Long. E092°43.447 Alt. (m). 1528	***Hedychium* spp.** known to have deep yellow flower, coronarium/flavescens like. Leaf not a pubescent and no flower at the time of observation. Compact flower head and sympatric with narrow leaved *Hedychium* (coccineum?). Stem miner present on yellow one.
12-3	Cherrapunjee, Meghalaya Lat. N25°17.008 Long. E092°43.786 Alt. (m). 1389	Many ***Hedychium* spp.** including***H. coccineum, H. densiflorum* types.**Leaf mining in the latter. Dense mixed forest, very steep banked. No flowers.
13.10.08 (13-1)	Shillong, near forest headquarters, Meghalaya Lat. N25°35.390 Long. E091°53.394 Alt. (m). 1437	**Mix of *Hedychium* spp.** in large open canopy woodland with mixed vegetation. Thin leaved ***H. coccineum*** has spotting + leaf folder, cocoon + green plant hopper found. Limacodidae. New weevil found in stem of smooth leaved *Hedychium* with long flower stalk but no fruit. ***H. densiflorum*+ *H. spicatum*** types -large stand, pubescent beneath.

13.10.08 (13-2)	Forest entrance, Quinine village check gate Meghalaya	Very large, smooth leaved, tall ***Alpinia***?spp. found with stem boring scolytid beetle found before, 1 on every 30cm in stem causing yellowing. Translucent coccinellids found. Also ***H. coronarium*** in flower at roadside house, 3 miles from Nongpoh from Quinine.
15.10.08 (15-1)	Darjeeling, Doctor Zakir Hussain street West Bengal	***H. gardnerianum*** -Few plants in a garden, planted. Relatively clean, One large green larva found, feeding kept to rear + webbed pupa. cf *Notocrypta curvifascia*? Plant name "**Bokshi**" **-jakri** flower to worship Durga goddess
15.10.08 (15-2)	Lloyd Botanical Gardens, Darjeeling, West Bengal	Several species of *Hedychium* found growing on site including *H.gardnerianum, H. coccineum*?, *H. greenii* (reddish tinge underside of leaves), *H. aurantiacum, H. flavescens* (flowering). All quite clean. Some growing from tree bark as epiphytes.
17.10.08 (17-1)	Singtham Rd, from Gangtok to Namchi, Sikkim	Cardamom plants. Reddish stem. Insect borer, lep, pathogen damage.
17.10.08 (17-2)	5km up from 17-1. Edge of road. Sikkim	***Hedychium thyrsiforme*** flowering plants on steep road side cliff. Pubescent leaves. Found leaf folder lep. and holes in stem indicate borer activity. Leaf folder collected.
17.10.08 (17-3)	Gangtok to Namchi road. Near Timi point. Sikkim Lat. N27°14.951 Long. E088°26.322 Alt. (m). 909	***H. coronarium***, road side, probably planted. Evidence of borer in stem + frass from hole, dark brown pupa found.
17.10.08 (17-4)	Few km from 17-3, road side, Sikkim	***Hedychium thyrsiforme***-flowering and in isolated patches on edge of road, found gregarious larvae cauing skeletonisation of leaf and red stemmed (coccineum/aurantiacum?) common.
17.10.08 (17-5)	Tendong, Sikkim Lat. N27°13.667 Long. E088°24.650 Alt. (m). 1983	***H. gardnerianum***-large stand, State Biodiversity Park. Planted border of >50 plants. Found, seed feeder which cause severe damage to pods, possibly tiny black beetle causing damage, larvae kept to rear. Thrips, *Altica* sp. leaf roller and miner evidence. Local name = "**Forrah**". Horny black and white heteropteran found.
17.10.08 (17-6)	Puranonamchi village, Sikkim Lat. N27°09.345 Long. E088°20.907 Alt. (m). 1498	***H. flavescens*** found growing in small population, planted and fairly clean. local name "**Kachur**".

18.10.08 (18-1)	Damthang, 2km from Rabangla, Sikkim Lat. N27°16.395 Long. E088°20.992 Alt. (m). 1681	*H. gardnerianum-"Gaousara" in Nepali.* Not flowering but natural population found off road on steep hill to pine forest. Leaffolder lep, leafspot pathogen with fruiting bodies, leafminer on midrib and green lep with black head + yellow spots (cf notocrypta) + 2ndnot so late instar. Bacterial rot? Soft stems at base, easy to pull up. Geometrid looper found on necrotic leaf. Generic name for wild ginger is "Gewpatay" and "Berua" means leafroller (Nepali)
18.10.08 (18-2)	Kewzing village near Rabangla, Sikkim Lat. N27°16.881 Long. E088°19.390 Alt. (m). 1780	*H. flavescens*-planted, 8 or so plants no damage. Collected flower for herbarium. Pubescent leaves, pale yellow flower with golden spot at mouth.
18.10.08 (18-3)	Rabangla village, Sikkim Lat. N27°17.259 Long. E088°17.164 Alt. (m). 735	*H. coronarium*-"Kewari"-Garden planted. Fruit borer causing severe damage and aborted flowers, exploited by millipides. Found 2 beetles (coccinellid leaf feeder black and yellow) and 1 lep larva + green flat plant hopper? Lep borer with frass.
18.10.08 (18-4)	3km from Legship village on way to Geyzing. Sikkim Lat. N27°16.612 Long. E088°16.225 Alt. (m). 810	*H. coronarium*-roadside. Flower thrips, beetle on flowers and larvae mining in the stem (black head capsule + transparent body). Damaged flowers. Huge hairy beetle found oviposit out on leaves. Pupa in stem.
19.10.08 (19-1)	Yuksom to Pelling road, Sikkim Lat. N27°18.215 Long. E088 12.773 Alt. (m). 1672	*H. gardnerianum.* Few isolated plants on cliff edge, large green flat hemipteran?, leaf spotting + fruiting bodies and evidence of stem borers. Coccinellid with 11 yellow spots-leaf feeding. Hard to access plants we were told they are rare and used for fodder.
19.10.08 (19-2)	Just a few 100 meteres from 19-1 Sikkim Lat. N27°18.290 Long. E088 12.504 Alt. (m). 1707	*H. gardnerianum.* Lots of scattered isolated plants amongst natural vegetation, inconspicuous and difficult to reach. Flowering spike + flowers. Forest edge, evidence of stem mining.

Appendix 2

Herbarium and literature records - *Hedychium* spp.

Collected from: Central National Herbarium, Botanical Survey of India, Kolkata, West Bengal

1. *Hedychium flavescens*

Sl. No.	Locality Information	Date of collection	Other information
1.	State: Kerala, Trichur District Parambikulum submergible area	29-Aug-1962	Altitude: 1240m, Accession No: 14362, Remarks: White aromatic flower, Collected by: K. Ramamurthy
2.	State: Tamilnadu (previously Madras state), Nilgiri district, Pakasuramalai	28-Sept-1957	Altitude: 2067m, Remarks: White yellowish flower,slightly scented, Collected by: K. M. Sebastine
3.	State: Tamilnadu, Karianhola	24-July-1960	Attitude: 1300m, Flower white with yellow tinge.
4.	State: Kerala, Trivandrum zoo	04-Dec-1977	An erect herb of 1.5m high, flowers white with pungent smell

2. *Hedychium coronarium*

Sl. No.	Locality Information	Date of collection	Other information
1.	State: Assam (Khasi & Garo Hills)	21.July-1944	Yellow flower, sweet scent
2.	State: Bihar, Chotanagpur		
3.	State: West Bengal, Darjeeling district, Mangpoo		Altitude: 5000ft
4.	State: West Bengal, Midnapore district, Jhargram	26-Nov-1975	Cultivated

5.	State: Tamil Nadu, Godavari district, Nulakamadoi	11-Oct-1929	Altitude: 2000ft
6.	State: Tamil Nadu, Shevaroi Hills	23-Oct-1921	
7.	State: Kerala, Locality: Kurisumala,	30-July-1985	Altitude: 1000m, Herbs up to 1m high, flowers orangish white
8.	State; Andhra Pradesh, Visakapatnam district, Way to Gavvala Guda, Lakshinipuram	22-Oct-1986	Altitude: 650m, Local Name: Bhod Silndhi, Herbupto 1.5m tall, flowers cream coloured to yellow,rare

3. *Hedychium gardenarium:*

Sl. No.	**Locality Information**	**Date of collection**	**Other information**
1.	State: West Bengal, Darjeeling district		
2.	State: Meghalaya, Shillong	06-Sept-1886	6200ft altitude
3.	State: Meghalaya, Khasia hills		
4.	State: Arunachal Pradesh, East Himalaya, Stream between Jabrang and Theyri		Altitude: 1905m, annual herb 2m with perennial stock, Fruit orange yellow, seeds red.
6.	State: Assam, Tashok	14-Oct-1908	Altitude: 3000ft
7.	State: Sikkim, Himalaya		