Wild Ginger (*Hedychium* spp.) :

Prospects for Biological Control

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DATE: June 1996

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1. Summary

1.1 Project and Client

Wild ginger (*Hedychium* spp.) is regarded by DoC and several regional councils as a serious weed in New Zealand and a major threat to native forests. Conventional control methods are proving both expensive and ineffective. This report was funded by FRST through non-specific output funding. It outlines the status of wild ginger in New Zealand, investigates the feasibility of biological control, and outlines the steps and funding that would be necessary to initiate a biological control programme.

1.2 Objectives

- Outline the development of wild ginger as a problem weed in New Zealand and the limitations of existing methods of control.
- Review information on invertebrates and pathogens associated with wild and cultivated ginger worldwide that have potential as biological control agents.
- Outline steps and funding necessary to initiate a biological control programme.

1.3 Sources of Information

Information for this report was obtained from computer (CAB abstracts and Biosis) and library searches for information on wild ginger and other members of the family Zingiberaceae, and from contacting researchers in relevant fields internationally.

1.4 Main Findings

- Two species of wild ginger occur in New Zealand, *H. gardnerianum* and *H. flavescens*.
- Wild ginger is a garden escapee with the capacity to invade some native forests.
- Wild ginger is distributed widely within the North Island and found in isolated patches in the South Island predominantly near built up areas. Its distribution has increased markedly since the 1970s and is likely to increase further.
- Chemical and mechanical control is labour intensive, expensive, time-consuming, and often ineffective. These factors combine to make eradication unlikely.
- No endemic members of the family Zingiberaceae occur in New Zealand. The cultivated spices in this family are of greatest importance internationally but their cultivation (with the possible exception of myoga ginger) is not commercially viable in New Zealand at present.
- A relatively small number of records were found for invertebrates and pathogens associated with wild ginger compared to cultivated species. The low number probably reflects a lack of research on this genus.
- None of the documented invertebrates are candidates for introduction due to their wide host range or mode of feeding.
- Several potentially host specific fungi have been documented from species of wild ginger.
- Rot-causing fungi have been recorded from ginger rhizomes in New Zealand.
- Relatively specific strains of the wilt causing bacterium *Pseudomonas solanacearum* have been isolated from wild and cultivated ginger in Hawaii and are currently under investigation for control of selected wild ginger species in Hawaii.

- A wide range of pests and diseases of cultivated ginger are documented, reflecting its economic importance. Some of these pests and diseases also attack wild ginger. Some of the pathogens may have potential for use against wild ginger but low temperatures are likely to limit their effectiveness in New Zealand.

1.5 Conclusions

- Biological control of wild ginger is needed because of its continuing spread and the difficulty of controlling it with chemical and mechanical techniques.
- Several pathogens have potential as biological control agents of wild ginger. Further research is required to determine their specificity and assess the damage they are likely to cause to wild ginger in New Zealand.
- A large undocumented invertebrate and pathogen fauna associated with wild ginger is likely to exist within its native range and components of this fauna may have potential as control agents.
- To initiate a biological control programme for wild ginger would require a minimum of $60,000 for the first year. After this period the identity of potential control agents would have been determined enabling a more specific programme to be developed.

1.6 Recommendations

- A biological control programme for wild ginger is feasible and should be initiated as soon as funding is available. Steps in the first year should involve:
  * Contracting researchers of IIBC to conduct a collection trip to India for invertebrates and pathogens associated with wild ginger (approx. $28,300).
  * Monitoring progress with the use of *P. solanacearum* for control of wild ginger in Hawaii.
  * Surveying New Zealand populations of wild ginger for pathogens and invertebrates ($29,000).
- After the first year a joint review of the results of these initial steps should be conducted with researchers and funding organisations to redefine the future directions of the biological control programme. Likely next steps will involve:
  * Determining specificity and damage of potential agents identified from the collection trip to India.
  * Determining pathogenicity of fungi and bacteria isolated from wild ginger in New Zealand.

2. Introduction

Wild ginger (*Hedychium* spp.) is regarded as a serious weed in New Zealand and a major threat to native forests (Craw 1990; Vervoort 1991). Conventional control methods are proving both expensive and ineffective at reducing this threat. This makes wild ginger a potential candidate for biological control. Biological control is a long-term and often expensive approach initially. However, long-term economic benefits can outweigh costs (e.g., Greer & Sheppard 1990) and in many situations it is the only option for sustained population suppression. This report reviews the status of wild ginger in New Zealand, investigates the feasibility of biological control, and outlines the steps that would be necessary to initiate a programme.

3. Objectives

- Outline the development of wild ginger as a problem weed in New Zealand and the limitations of existing methods of control.
- Review information on invertebrates and pathogens associated with wild and cultivated ginger worldwide that have potential as biological control agents.
- Outline steps and funding necessary to initiate a biological control programme.

4. Sources of Information

Information for this report was obtained from computer (CAB abstracts and Biosis) and library searches for information on wild ginger and other members of the family Zingiberaceae, and from contacting researchers in relevant fields internationally (particularly India).

5. Main Findings

5.1 Distribution and status of wild ginger in New Zealand

Hedychium is primarily a Himalayan genus (Appendix 10.1: Naik & Panigrahi, 1961) with several species also occurring in Malaysia and Indonesia (Smith, 1987). Wild ginger was introduced into New Zealand by English colonists about 130 years ago (Byrne, 1992). Two species are established in the wild, *H. gardnerianum* and *H. flavescens*. Of the two species, *H. gardnerianum* has the widest distribution and is of primary concern. It occurs mainly in the North Island, with some coastal patches centred around human settlements in the South Island and has spread widely in both islands since the early 1970s (Fig.1). The wide geographical distribution and increase in range since the early 1970s suggests that wild ginger has the potential to considerably increase its distribution within New Zealand (Fig.1).

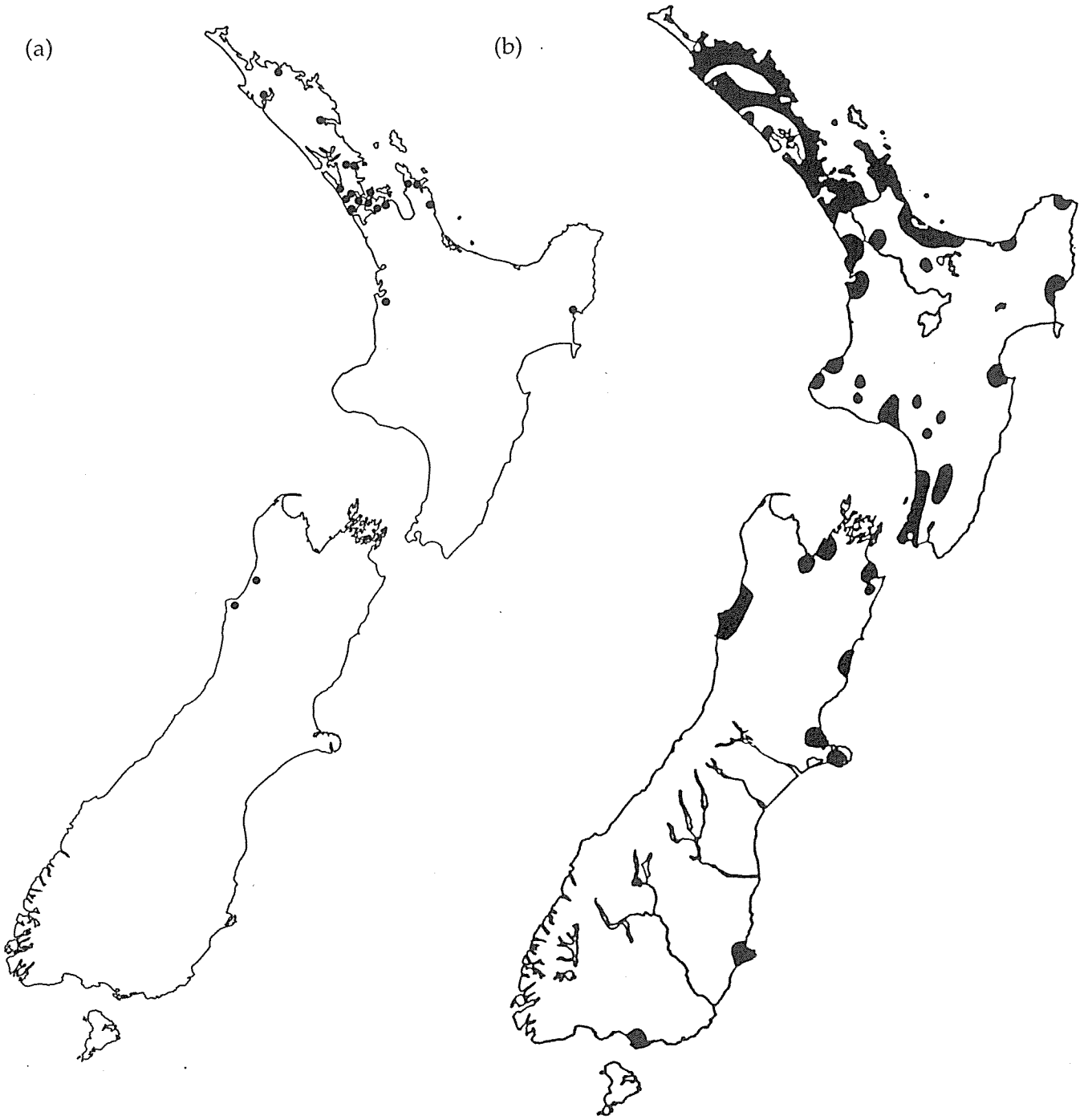

Fig. 1 Distribution of *Hedychium gardnerianum* in New Zealand in a) the early 1970s (Orchard 1973) and b) the mid 1990s (Prepared by Auckland Regional Council).

H. gardnerianum was growing around Auckland in the 1930s and it is possible that *H. flavescens* established earlier (Esler, 1986). Wild ginger was not regularly on sale to the public at plant nurseries until the mid-1950s (Orchard, 1973), but it soon became a popular ornamental plant (Byrne, 1992). The two species later fell into disfavour due to their prolific growth, and gardeners often cleared them out and dumped them in unoccupied spaces. Disposal of wild ginger refuse and/or seed transportation (of *H. gardnerianum* only as *H. flavescens* does not produce viable seed) has allowed wild ginger to establish in waste areas, roadsides, and forest margins (Byrne, 1992).

Wild ginger initially grows on bush margins and slowly creeps back into the surrounding bush areas, unlike in its endemic range where it is never found as a component of forest understorey (Naik & Panigrahi, 1961). Seedling and juvenile plants are often found in areas of disturbed bush, but there is an increasing amount of wild ginger in the Waitakere ranges growing under established bush canopy (L. Vervoort, pers. comm.). Both *H. flavescens* and *H. gardnerianum* are shade tolerant, but *H. gardnerianum* does not appear to flower as prolifically in shaded areas compared to bush margins (L. Vervoort, pers. comm.).

The competitive ability of wild ginger has enabled it to become established in native forests (Byrne, 1992). The spread of ginger along the forest floor hinders the regeneration of forest patches by suppressing seeding development (Byrne, 1992) and large stands also compete with native plants for water, nutrients, and space on the forest floor (L. Vervoort, pers. comm.). Wild ginger has the capacity to persist at sites for long periods of time forming a physical barrier to other species. It displays effective recovery after removal of top growth, rapid maturation and reproduction by vegetative means, and bird-assisted seed dispersal (of *H. gardnerianum*). *H. gardnerianum* produces over 900 seeds per head (Sparrow, 1995).

In their recently completed Pest Management Strategies, Environment Waikato, and Northland and Auckland Regional Councils listed wild ginger as a major weed, while Environment Bay of Plenty, Marlborough, Taranaki, and Hawke's Bay Regional Councils were concerned about its spread into their region. In addition the West Coast Regional Council listed wild ginger as a major weed problem in their Regional Policy Statement. Williams and Timmins (1990) listed wild ginger as a problem weed in scrub-forest margins and scrublands of the DOC estate in northern New Zealand.

5.2 Current control options

Control of wild ginger is hampered by three factors: the wide distribution, the large size of infestations in many regions, and the nature of the weed itself. Cultural methods of removal are tedious, time-consuming, and difficult. Grubbing is not always effective because of the size of the plant and its large, deep-rooting rhizomes which regrow from fragments. All of the plant has to be removed and discarded (preferably incinerated) otherwise regrowth can occur. Removal of rhizomes from steep slopes can promote soil erosion.

Chemical control can be ineffective, with repeated applications often necessary to control clumps (Byrne, 1992). Trials of five herbicides in the Auckland region demonstrated that Escort (metsulfuron-methyl) was the only one to kill wild ginger. Effects of application were often not visible for 3 months but total plant death was achieved within 12 months. The recommended use rate of Escort for wild ginger is 25 g/100 litres when applied with a hand

gun and 50 g/100 litres when applied with a knapsack with application from spring to late autumn (DuPont, 1990). Escort must be applied to the whole plant or to rhizomes and cut shoots once foliage has been removed. The use of Escort to control ginger is not advisable along waterways and drainage courses. Replanting of natives is recommended after 3 months of treatment for large clumps to prevent reinvasion by wild ginger or other weeds. When present in native bush, hand spraying is required to avoid killing non-target plants, and this is time-consuming and expensive over large areas. In addition full public participation in control is essential for management of the weed to succeed (Vervoort, 1989). If not, properties neighbouring sprayed areas will provide seed sources for reinvasion and newly established seedlings will not be detected early and destroyed.

There is increasing concern among residents of treated areas and environmental groups as to the environmental and human health effects of the use of Escort. These concerns include the soil leaching capacity, ground water contamination potential, and possible effects on native plant communities and soil micro-organisms (Byrne, 1992).

Environment Waikato is attempting to eradicate wild ginger from its region. However, eradication on a national scale is probably not feasible using the currently available techniques and resources. A self-sustaining suppression of the weed is needed to integrate with existing control methods.

5.3 Relatives of wild ginger in New Zealand

Some of the genera of the family Zingiberaceae are listed in Appendix 10.2. The genera *Alpinia, Cautlega, Costus, Globba, Hedychium, Nicolaia* (Torch gingers) and *Roscoea* contain species grown and/or sold as ornamentals in New Zealand. Shell ginger, *Alpinia zerumbet* (tribe Hedychieae, family Zingiberaceae), is common in and north of Auckland (W. Sykes, pers. comm.) and red ginger (*Alpinia purpurata*) and white ginger (*H. coronarium*) are also present in gardens in Auckland (L. Vervoort, pers. comm.).

A plantation of myoga ginger (*Zingiber mioga*) is being established in Warkworth. It is a native of Japan and the flower buds are considered a culinary delicacy there.

The most widely grown members of the Family worldwide are the cultivated spices, ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), and cardamom (*Elettaria cardamomum*). Cultivation of these species of tropical Asian origin, is unlikely outdoors in New Zealand and cultivation in glasshouses is not economically viable at present.

5.4 Comparison of wild ginger and *Z. officinale*

Z. officinale belongs to a different tribe within the Zingiberaceae family from the two *Hedychium* species. *Hedychium* species are morphologically quite different from those in the genus *Zingiber*. *H. flavescens* and *H. gardnerianum* have larger leaves and flowers and are taller plants than *Z. officinale*. Both genera have the characteristic 'ginger fragrance' as do other members of the family.

A major point favouring finding a suitable biological control agent to control wild ginger is that members of the Zingiberaceae family are absent from the native New Zealand flora, and

none are of major economic importance in New Zealand. However, the damage any potential agent may cause to myoga ginger, now being cultivated in New Zealand, would have to be determined prior to any introduction.

5.5 Insects associated with *Hedychium* spp. and *Z. officinale*

As wild ginger is not of major economic significance internationally, information on insects that feed on plants of the *Hedychium* genus is scarce (Appendix 10.3). *Hedychium* species have been introduced and achieved weed status in Hawaii (Wagner *et al.*, 1990), the Azores Islands (eastern Atlantic Ocean) (Roper 1960), La Reunion Island (MacDonald *et al.*, 1991) and Puerto Rico (Holm *et al.*, 1979), but no insects have been reported attacking wild ginger from these countries.

A much greater number of insect species have been recorded from *Z. officinale* (Appendix 10.4), as insects that feed on economically important plants receive greater scrutiny. Many of the insects cause sufficient damage to the crop to warrant control (e.g., Jacob, 1980; Koya *et al.* 1988). Two of these insects, the shoot borer *Conogethes puctiferalis* and the leaf roller *Udaspes folus* have also been recorded on *Hedychium* sp. in India (S. Davasahayam, pers. comm.). None of the major pest species of *Z. officinale* have potential as biological control agents in New Zealand because of their wide host range.

5.6 Pathogens associated with members of the Zingiberaceae family

Several pathogens have been isolated from members of the *Hedychium* genus and *Z. officinale* (Appendix 10.5). Some of the fungi found on *Hedychium* (*Phosmopsiodes natalinae, Microthyriella azorica, Verticillium chlamydosporium*) may be highly host specific as they are not recorded from other hosts. However, little is known of their biology and pathogenicity other than the symptoms on the host plant from which they were collected. In addition to these possibly host-specific fungi, distinct strains of the bacterium *Pseudomonas solanacearum* have been isolated from *Z. officinale* in Hawaii, and are reported to have limited host ranges (Quinon & Aragaki, 1964; Aragaki & Quinon, 1965). Strains of this bacterium are currently being used by researchers in Hawaii to attempt to control *H. gardnerianum*. Initial tests at 27-35°C resulted in wilting and breakdown of rhizome tissue of *H. gardnerianum* plants within 45 days of inoculation (L. Morin, pers. comm.). It is not known if the bacteria work at the lower temperatures encountered in New Zealand.

A number of pathogens cause significant damage to *Z. officinale* crops and research is ongoing to develop control strategies for these (e.g., Dake *et al.* 1988; Das *et al.* 1990; Koya, 1990). These pathogens may also have potential to damage wild ginger but many may not grow at the lower temperatures prevalent in New Zealand.

In New Zealand, a number of fungi have been isolated from a diseased *H. gardnerianum* rhizome (P. Johnson, pers. comm.). The pathogenicity of these fungi to wild ginger has not been demonstrated.

5.8 Possibilities for biological control

Survey of invertebrate and pathogen fauna of wild ginger in New Zealand

A survey of the fauna of wild ginger in New Zealand should be conducted early in a biological control programme. This would determine whether any minor damage is already being done to plants established in New Zealand and would aid later selection of biological control agents to complement any measure of population control already being exerted. An initial survey could be completed within 12 months and cost about $29,000. The cost of determining the pathogenicity of collected material would depend on the number and types of pathogens isolated. If a pathogen suitable as a mycoherbicide is isolated in New Zealand this would save considerably on the costs associated with safety testing and preparing an Importation Impact Assessment required for release of an exotic mycoherbicide into New Zealand.

New mycoherbicides

Field trials of the bacterium *Pseudomonas solanacearum* as a mycoherbicide are currently being conducted in Hawaii to determine whether wild ginger can be infected in the cooler mountain regions where its abundance is greatest. Temperatures in this region more closely resemble New Zealand conditions than coastal Hawaii where temperatures favour *Pseudomonas* infections. Wild ginger and *Z. officinale* are both grown in Hawaii and *H. coronarium* flowers are considered important culturally, so host specificity is more of a constraint in Hawaii than in New Zealand. It is highly probable that if suitable isolates are found in Hawaii they could be used in New Zealand.

New biological control agents

A number of the pathogens on wild ginger and close relatives discussed above (5.6) have potential as biological control agents. The fungi that have been documented solely from members of the genus *Hedychium* could be collected to determine pathogenicity and specificity. Several of those documented were in the Azores. However, *Hedychium* is not endemic to the Azores and the fungi may also not be endemic. A separate collecting trip to the Azores is not suggested at this stage as these fungi may be collected with other potential biological control agents during a collection trip to India.

It is likely that more species of both pathogens and invertebrates are associated with wild ginger than have been reported. The starting point for finding a specific biological control agent is to conduct a field survey of the *Hedychium* genus within its endemic range, starting in Assam, India. To cover both invertebrates and pathogens in such a survey a minimum of two people (a plant pathologist and an entomologist) would be required. Staff of the International Institute of Biological Control (IIBC) in England have experience in working in the Indian-Himalayan region and a survey would cost an estimated $28300 (£11850). After the initial collection further work in England would be required to identify and determine the potential of any collected species (a minimum of $100,000 per year in year 2 and 3).

A collaborative project to determine whether pests and diseases of *Z. officinale* have potential as control agents could be initiated if no suitable control agents are identified from a survey of *Hedychium* in India. Researchers at the National Research Centre for spices, in the Kerala Region of India have provided much of the resent literature on pests and diseases of *Z. officinale* and their control (e.g., Dake *et al.*, 1988; Koya, 1990; Ravindran *et al.* 1994).

Invertebrate pests associated with *Z. officinale* have a wide host range, but a number of pathogens appear to be more host-specific. However, in many cases the low temperatures in New Zealand compared to India would limit the effectiveness of pathogens so this option should only be pursued if pathogens likely to have lower temperature requirements or specific insects with potential as control agents are not located.

Once suitable agents are selected for introduction into quarantine a rearing colony needs to be established and host specificity tests conducted. Based on experience from previous biological control projects, this is likely to take an estimated 3 years after agent selection and cost about $200,000 annually to get to the stage of releasing a selection of suitable agents. The exact details of these steps in the development of a control programme would depend on which of the above options were pursued and the results that were obtained.

6. Conclusions

- Biological control of wild ginger is needed because of its continuing spread and the difficulty of controlling it with chemical and mechanical techniques.
- Several pathogens have potential as biological control agents of wild ginger (strains of the bacterium *P. solanacearum*, and several fungi recorded only from wild ginger). Further research is required to determine their specificity and assess the damage they are likely to cause to wild ginger in New Zealand.
- A large undocumented invertebrate and pathogen fauna associated with wild ginger is likely to exist within its native range and components of this fauna may have potential as control agents.
- Steps to initiate a biological control programme would involve:
  * Assessing the potential of Hawaiian isolates of the bacterium *P. solanacearum* from wild ginger and *Z. officinale* for use under New Zealand conditions.
  * Surveying *Hedychium* species in India and collecting potential pathogen and invertebrate control agents.
  * Determining invertebrates and plant pathogens associated with wild ginger in New Zealand to aid decision making regarding types of agents to consider for introduction.
  * Assessing the potential of pathogens found on wild ginger in New Zealand as mycoherbicides.
- To initiate a biological control programme for wild ginger would require a minimum of $60,000 for the first year. After this period the identity of potential control agents would have been determined enabling a specific programe of introductions to be developed.

7. Recommendations

- A biological control programme for wild ginger is feasible and should be initiated as soon as funding is available. Steps in the first year should involve:
  * Contracting IIBC to conduct a collection trip to India for invertebrates and pathogens associated with wild ginger (approx. $28,300).
  * Monitoring progress with the use of *P. solanacearum* for control of wild ginger in Hawaii.
  * Surveying New Zealand populations of wild ginger for pathogens and invertebrates ($29,000);
- After the first year a joint review of the results of these initial steps should be conducted with researchers and funding organisations to redefine the future directions of the biological control programme. Likely next steps will involve:
  * Determining specificity and damage of potential agents identified from the collection trip to India.
  * Determining pathogenicity of fungi isolated from wild ginger in New Zealand.

8. Acknowledgements

Our thanks to Lance Vervoort (Auckland Regional Council) and overseas researchers for responding to our requests for information. Funding for the preparation of this report was provided by the Foundation for Research Science and Technology. Louise Morin provided constructive comments and obtained information on research in Hawaii, and Megan Ogle-Mannering provided editorial comments.

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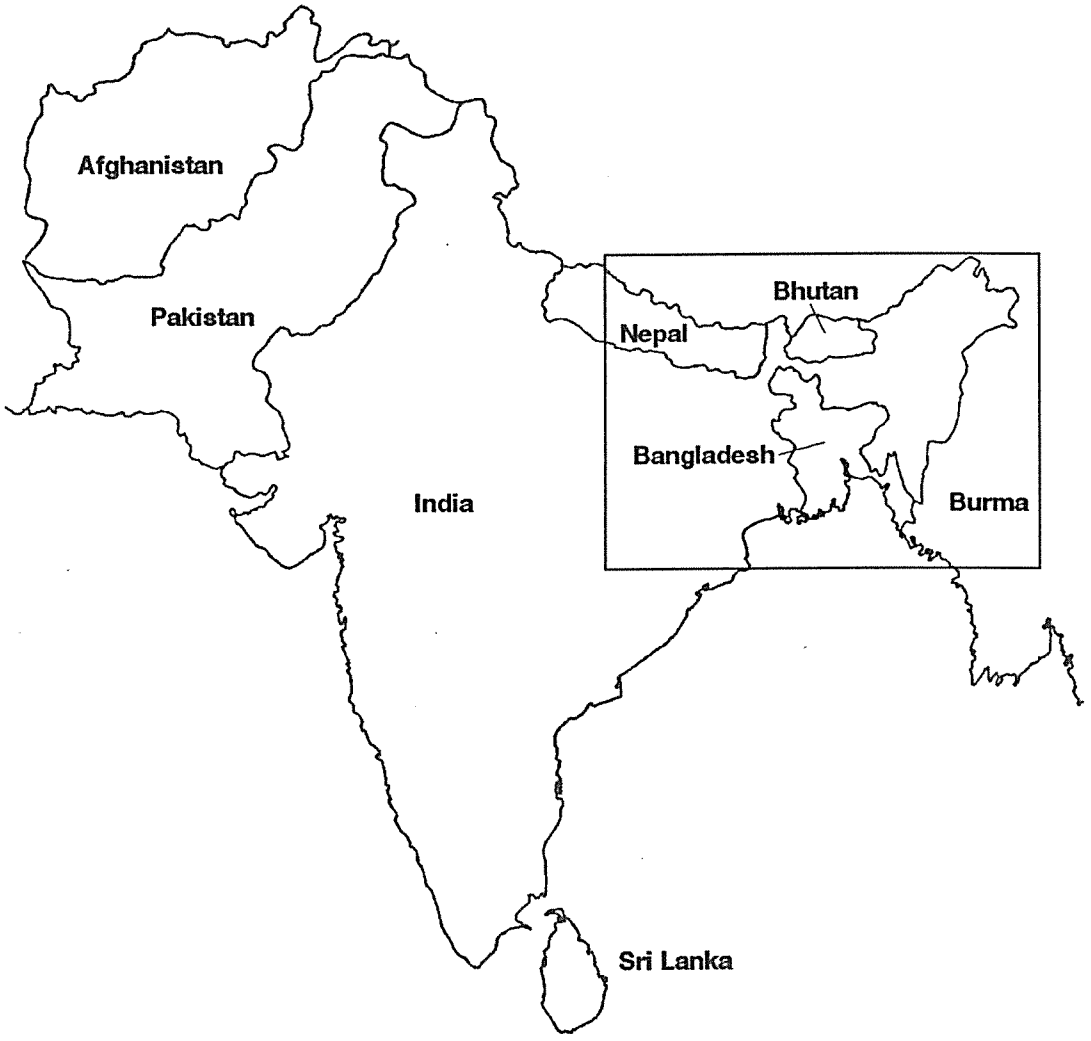
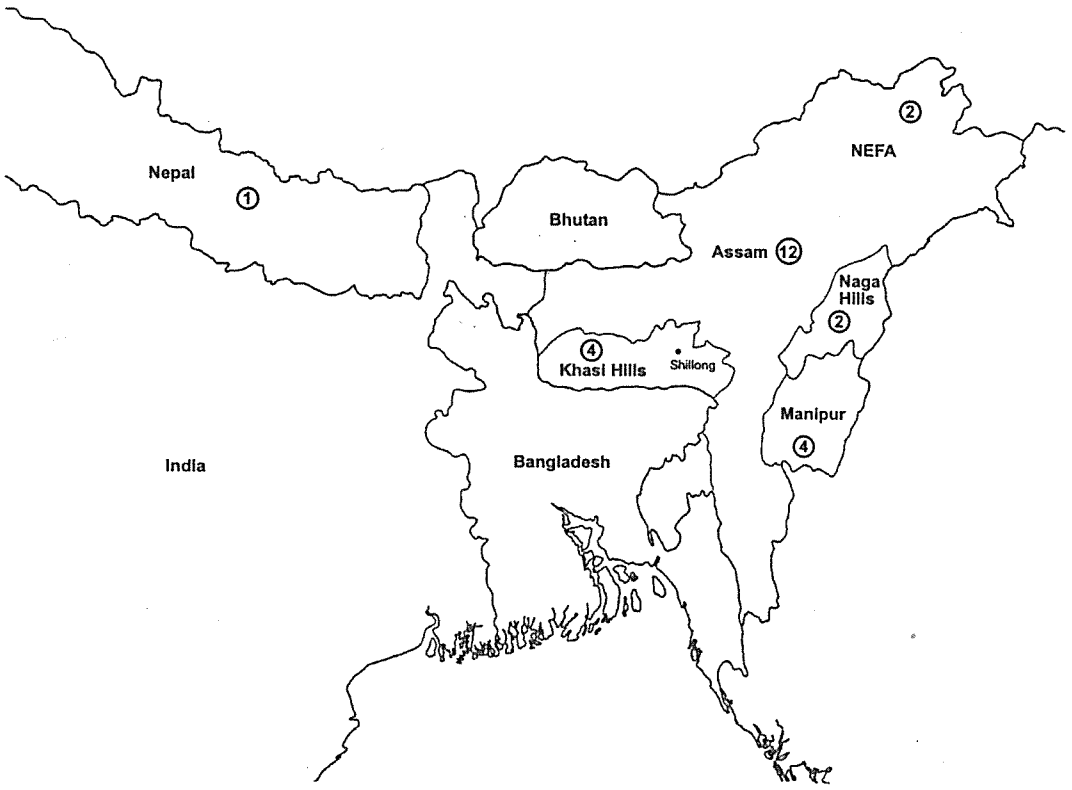
10. Appendices

10.1 Concentration of genera of *Hedychium* in the India/Himalayan region

Map 1: Indian locality map. The boxed area is shown in more detail in map 2.



Map 2: Distribution of *Hedychium* species. Circled numbers represent the number of species in a given region



10.2 Families related to Zingiberaceae and Genera related to *Hedychium*

Order	Family
Zingiberales	Zingiberaceae

Genera (about 45 in total)

Achasma	*Haplochorema*
Aframomum	*Hedychium*
Alpinia	*Hemiorchis*
Amomum	*Hitchenia*
Boesenbergia	*Hornstedtia*
Brachychilum	*Kaempferia*
Burbidgea	*Mantisia*
Camptandra	*Monocostus*
Caulokaempferia	*Nicolaia*
Cautlega	*Parakaempferia*
Costus	*Plagiostachys*
Curcuma	*Pleuranthodium*
Curcumorpha	*Rhynchanthus*
Elettaria	*Roscoea*
Elettariopsis	*Scaphochlamys*
Etlingera	*Siliquamomum*
Gastrochilus S	*Tahlianthus*
Geanthus	*Tapeinochilos*
Geostachys	*Zingiber*
Globba	

Related Families

Strelitziaceae
Musaceae
Lowiaceae
Heliconiaceae
Costaceae
Cannaceae
Marantacea

10.3 Insects recorded on wild ginger (*Hedychium* spp.)

Order	Family	Genus	Species	Host	Host range	Location	Source	NB
Coleoptera	Curculionidae	*Elytroteinus*	*substruncatus* Frm.	*H. coronarium*	polyphagous	Hawaii	Miller 1923	Fijian ginger weevil. Root feeder. Feeds on lemons in New Zealand.
Hemiptera	Aphididae	*Pentalonia*	*nigronervosa Coq.*	*H. coronarium*	polyphagous	Phillipines, Australia, Hawaii	Lomerio & Calilung 1993, Hansen et al. 1991	Banana aphid
	Miridae	*Halticus*	*tibialis*	*H.* spp.	?	China	Zhang pers. comm.	
	Psueudococcidae	*Nipaecoccus*	*nipae*	*H. coronarium*	polyphagous	Hawaii	Hansen et al. 1991	Coconut mealy bugs. On bracts
		Planococus	*citri*	*H. coronarium*	polyphagous	Hawaii	Hansen et al. 1991	Citrus mealy bugs. On bracts
		Pseudococcus	*affinis*	*H. coronarium*	polyphagous	Hawaii	Hansen et al. 1991	Obscure mealy bug. On bracts
		Pseudococcus	*longispinas*	*H. coronarium*	polyphagous	Hawaii	Hanson et al. 1991	Longtailed mealy bug. On bracts
Lepidoptera	Hesperiidae	*Udaspes*	*folus*	*H.* sp.	polyphagous		Jacob 1980	
Orthoptera	Acrididae	*Chorthippus*	*chapini*	*H.* sp.	?	China	Zhang pers. comm.	
	Tridactylidae	*Tridactylis*	*japonicus*	*H.* sp.	?	China	Zhang pers. comm.	
Thysanoptera	Thripidae	*Sciothrips*	*cardomomi*	*H. coronarium*	polyphagous	Hawaii	Hansen et al. 1991	On bracts

Order	Family	Genus	Species	Host Range	Location	Source	NB
	Pentatomidae	*Udonga*	*mantana*			Prakasan *et al.* 1992	Stink bug – various hosts
	Pseudococcidae	*Psedococcus*	*citri*		Philippines	Ehrhorn 1923	
		Psedococcus	spp.		Philippines	Ehrhorn & Whitney 1926	On roots
	Tingidae	*Stephanitis*	*typica* Distant			Jacob 1980	Lace wing bug, minor pest
Hymenoptera	Formicidae	*Dorylus*	*orientalis* Westw.		Ceylon	Hutson 1937	Found on rhizome – reported as pest
		Pheidole	*javana*		China	Ehrhorn 1924	Found on green ginger from China
Thysanoptera	Phlaeothripidae	Haplothrips	kurdjumovi			Jacob 1980	
	Thripidae	*Thrips*	*tabaci* Lindeman			Miyazaki & Kido 1988	
		Panchaetothrips	*indica*			Jacob 1980	

10.5 Pathogens associated with wild *Hedychium* and cultivated ginger (*Zingiber officinale*)

Kingdom	Genus	Species	Host	Host specificity	Location	Source	NB
Bacterium	*Erwinia*	*carotavora* subsp. *carotovora*	*Z. officinale*			Bradbery 1986	
	Pseudomonas	*solanacearum*	*Z. officinale, H. coronarium*	Specific isolates		Aragaki & Quinon 1965	Causes bacterial wilt. A major constraint on production of many crops.
Fungi	*Antennularia*	sp.	*H. gardnerianum*		India	IIBC	Extensive, scooty mould like growth covering leaf surface
	Cercospora	*hedychii*	*H. coronarium, H. coccineum*		Burma, Hong kong, Indonesia	IIBC	
	Cladosporium	*tenuissimum*	*Z. officinale*		India	Dohroo et al. 1992	New host record
	Fusarium	*sp.*	*Z. officinale*		India	Koya 1988	
	Fusarium	*oxysporum*	*Z. officinale*		India	Dake & Edison 1989	"Yellows"
	Fusarium	*solani*	*Z. officinale*		India	Dake & Edison 1989	
	Gliocladium	*roseum*	*Z. officinale*		India	Dohroo et al. 1992	New host record
	Gliomastix	*luzulae*	*H. gardnerinum*		Azores	IIBC	
	Graphium	*album*	*Z. officinale*		India	Dohroo et al. 1992	New host record
	Microthyriella	*azorica*	*H. gardnerinum*		Azores	IIBC	Type specimen
	Memnoniella	*subsimplex*	*H. gardnerianum*		New Zealand	IIBC	
	Mucor	racemosaus	*Z. officinale*		India	Dohroo et al. 1992	New host record
	Mycorrhizas		*Z. officinale*			Statz & Sakai 1984, Tamin 1984	From 6 Genera of ginger
	Mycosphaerella	sp.	*H. gardnerinum, H. coronarium*		India, Venezuela	?	Extensive leaf necrosis, spreading lesions
	Patinellaria	*hedychii*	*H. acuminatum*		India	IIBC	Type specimen
	Phomopsiodes	*natalinae*	*H. gardnerianum*		Azores	IIBC	Type specimen
	Phyllostica	*zingiberi*	*Z. officinale*			Ravindron et al. 1994	Leaf spot disease
	Puccinia	*roscoeae*	*H. spicatum*		India	IIBC	Wide host range

Kingdom	Genus	Species	Host	Host specificity	Location	Source	NB
	Pythium	*aphanidermatum*	*Z. officinale*		India	Koya 1988	Rhizome rot of ginger and other crops
	Pythium	*gracile*	*Z. officinale*			Butler 1918	Soft rot
	Pythium	*myriotylum*	*Z. officinale*		India	Dake & Edison 1989	Rhizome rot
	Stachybotrys	*sansevieriae*	*Z. officinale*		India	Dohroo et al. 1992	New host record
	Taphrina	*maculans*	*Z. officinale*			Brooks 1953	Causing yellowish spotting of turmeric and ginger
	Thanaitephorus	*cucumeris*	*Z. officinale*		India	Dohroo et al. 1992	New host record
	Typhula	*thindii*	*H. acuminatum*		India	IIBC	Type specimen
	Verticillium	*chlamydosporium*	*Z. officinale*		India	Dohroo et al. 1992	New host record
Nematoda	*Meloidogyne*	sp	*H.* sp.			Goodey 1956	On *Hedychium*
	Meloidogyne	*incognita*	*Z. officinale*		India	Sukumaran & Sundararaju 1986	Innoculation of ginger seedlings
	Rotylenchulus	*reniformic*	*Z. officinale*			Goodey 1956	