Pest and disease analysis in hazelnuts

Lester Snare
NSW Department of Primary Industries

Project Number: NT05002

NT05002

This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the nuts industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of Hazelnut Growers Australia Limited.

ISBN 0 7341 1390 0

Published and distributed by:

Horticultural Australia Ltd

Level 1
50 Carrington Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399

E-Mail: horticulture@horticulture.com.au

HAL

Know-how for Horticulture™

Horticulture Australia Ltd

Project No: **NTO5OO2 (July 2006)**

Pest and Disease Analysis in Hazelnuts

Lester Snare
N.S.W. Department of Primary Industries

Project No: NTO5002

Project Title: Pest and Disease Analysis in Hazelnuts

Chief Investigator: Mr Lester Snare

Address: N.S.W. Department of Primary Industries
Orange Agricultural Institute
Forest Rd, Orange, N.S.W. 2800
Phone: 02 63913800 Fax 02 63913899
Email: lester.snare@dpi.nsw.gov.au

The purpose of this project, is to compile and document a list of current and potential pests and diseases, which could impact on hazelnut production in Australia.

Funding Sources: Horticulture Australia Ltd, Hazelnut Growers of Australia Ltd, N.S.W. Department of Primary Industries.

Date of Report: July 2006

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Know-how for Horticulture™

Contents

Media Summary

Hazelnuts are an emerging crop in Australia, and as commercial plantings come on line it will be important for growers to have an understanding of threats to production. Current Australian production is small and is estimated at less than 50 tonnes. Major manufacturers import kernel from Turkey, Italy, Spain and the U.S.A. Estimated import tonnage into Australia is about 2000 tonne and current tree numbers are estimated at between 34,000 and 50,000.

Early attempts at hazelnut production were based upon seedling types with seed most likely introduced into Australia. Over the last 30-40, years controlled introductions from the key hazelnut producing areas in Europe and the U.S.A. have formed the basis of the developing industry.

There is a distinct lack of information relating to aspects of cultural production in Australia, with much of the current research aimed at yield assessment and varietal performance. The aim of this project is to compile and document a list of current and potential pests and diseases which could impact on hazelnut production in Australia. As the industry is small, so is the knowledge that surrounds the biology and ecology of the plant pest relationship in Australian hazelnut groves.

Insect pests, diseases, exotic and domestic animal damage can be major constraints to production. In some parts of the world losses due to insect and mite pests has been estimated as high as 20%. In Australia it is difficult to estimate what losses occur due to pest and disease problems but it has been widely accepted that we do not have many of the key pests that affect overseas production. This may be due to geographical isolation, vigilant quarantine restrictions or other cultural and environmental influences.

The project aims to document pests that are currently an issue, and to identify pests and diseases that are likely to cause problems in the future. Samples submitted by growers and processors have created new pest records for hazelnuts in Australia. A better understanding of which pest or beneficial is present in the orchard, will provide greater opportunity for an integrated pest and disease program to succeed. This minimises pesticide resistance, decreases ecological disturbance and promotes hazelnuts as a clean healthy product.

The project combines current knowledge on pests and diseases, highlights exotic threats that could potentially impact on the Australian industry, and offers potential strategies for management.

Technical Summary

Australian hazelnut production is minor, compared with other nut crops produced in Australia. Production is less than 50 tonnes, and a recent industry census indicated approx 110 members in the industry association, Hazelnut Growers of Australia Ltd (HGA). The number of producers is somewhat higher than this, as not all growers are members of the industry association. Like-wise not all members of the industry association are producers.

There is a high degree of interest by current growers to expand their plantings into larger viable enterprises. Other horticultural producers may wish to diversify into newer crops, and hazelnut production may have advantages over other fruit and nut enterprises. As plantings expand into larger monocultures, it is likely that pest population pressures will increase.

There has been no investigation into pest and disease issues affecting hazelnut, *Corylus avellana*, in Australia, so the compilation of current endemic pests, identification of new pests and an awareness of exotic pest threats will become essential. Biological control and the presence of natural organisms that attack pests has also been considered. Hazelnut growers can manipulate grove practices and a range of beneficial organisms, to increase effectiveness of biological control. In some developing horticultural crops, biological control can alleviate the need to spray.

Depending upon region, management strategies and environmental conditions hazelnuts may not be affected by a great range of pests. The majority of groves in Australia are unsprayed and this is probably due to isolation, lack of use of insecticides in the past, and a natural ecological balance. The status of balance is desirable and the Australian industry is well situated to maintain this position. Reduced levels of pesticides provide a more stable environment and reduces fluctuations within pest populations. Whilst this situation is ideal, it is unknown whether this can be maintained in the future.

Industry survey results indicate that approximately a third of growers apply control measures of some type. Chemicals offer short term control, but insecticide resistance, ecological disturbance and marketing restrictions make long term dependence on chemicals undesirable.

As the industry develops, potential major pests maybe targeted with pesticides. These pesticides not only affect the target but also have an effect on beneficial organisms. Bird damage featured in many growers' discussions, and an update on bird and vertebrate pest control strategies is included.

The research was supported by the Hazelnut Growers of Australia Ltd, and this network was used to create awareness of the project. The investigator attended major events in the industry calendar and presented project objectives. Growers and processors were asked to submit samples for identification during the growing season. In some cases samples may not have been associated with a problem, but all submissions assist in gaining a better understanding of the diversity in a hazelnut grove. Previous records of pests recorded on hazelnut in Australia are also included. Sample collection at grower's properties and hazelnut variety trial sites, increased

opportunities for data capture. A review of the literature relating to hazelnut pest and diseases was undertaken, to compile a list of endemic and exotic threats to hazelnut production in Australia.

The project has provided background data, to base control measures on, but more importantly develop an understanding of the biology and ecology of pests in Australian hazelnut groves. Sixty five records of pests in Australia are presented and a wide range of beneficials and pests from Europe and America are documented.

In Europe some 200 species of insects and mite, associated with hazelnuts, have been identified. Less than 30% are considered harmful. The majority can be viewed as being incidental or beneficial insects (AliNiazee, 1998). Sampling in Australia follows European and American trends, and indicates a great diversity of fauna. Turkey, which is a major exporter of kernels to Australia, shows great diversity. Tuncer and Ecevit (1997) indicate over 100 species were found feeding on hazelnuts in the Black Sea region. Serious damage is caused by approximately ten key pests. A similar situation exists in the U.S.A. where approximately 8 pests are regarded as important. Creating awareness within the Australian industry, can only assist with maintaining our relatively pest free status. Growers can use the information and images associated with this project, to refer to, as problems arise.

At the time of printing, the compiled information has been requested by Plant Health Australia, to assist in developing and prioritising a list of exotic and endemic pest and disease threats, which could affect the development of the hazelnut industry. Recommendations from the project can be summarised into three areas. Firstly, contingency plans can be further developed for the management of the major exotic pests and diseases identified. Secondly, post entry quarantine and diagnostic protocols should be reviewed in light of the expanded lists of pests compiled. Movement of planting material between states should be assessed with the presence of Big bud mite in Tasmania. This pest has not been formerly identified on the mainland. The third recommendation is to continue updating fact sheets, and work with the industry, to expand on newly identified pest and disease issues.

Introduction

Hazelnuts are a developing crop in Australia, and early development work has evolved around variety evaluation and the assessment of suitable regions for production (Baldwin, Snare, Gilchrist 1999). With the identification of suitable varieties and regions for production, greater available quantities of true to type planting material, and ongoing importation of improved varieties by nursery organisations, it is projected that plantings will expand. Although many growers have not been subjected to major pest and diseases, it cannot be guaranteed that this situation will remain in the future.

The aim of the project is to compile and document a list of current and potential pests that may impact on hazelnut production in Australia. Knowledge of the major exotic pest and disease threats is the first step to reducing their potential of becoming established. The other key aim is to provide producers with information on the biology, damage, and management of current pest problems. The industry generally consists of producers who have not developed from a traditional orchard background,

and are looking for applied information. It is anticipated that identification, and a greater awareness of problems, will lead to increased tree health, and greater productivity.

The project addresses priority nine in Annex C "Research Projects", in the Hazelnut Growers of Australia Ltd Business Plan, 2001-2011. This calls for the investigation and documentation of pest and diseases currently affecting hazelnut production in N.S.W, Victoria and Tasmania. Following commencement of the project, Plant Health Australia, The Australian Nut Industry Council, Horticulture Australia Ltd. and a range of Australian State Government/Territory Agriculture Departments initiated a plan to develop a priority pest list for each commodity nut group in Australia. Although this report highlights lists of local and exotic pests and diseases, it does not represent an official import risk analysis.

Insect and mite pests cause serious damage to the hazelnut crop worldwide with estimations varying from 20-50%. AliNiaze (1996) points out that most growers in other parts of the world depend on application of broad- spectrum insecticides to control problematic pests. The effect of this is disruption of natural enemies, and development of resistance in the target and secondary pests. This approach causes environmental contamination and undesirable crop residues.

Due to the lack of a heavy chemical regime in Australian groves, there is a great opportunity for fauna interaction. This interaction produces stability, and reduces the frequency, and quantity of pest invasions. There maybe cultural and environmental reasons for this current stability. The limited number of registered pesticides available for use on hazelnuts in Australia, the lack of a concentrated growing region, physical distance between key growing areas and the use of integrated pest management programs are possible reasons.

In the U.S.A, the key pest is the filbert worm, *Cydia latiferreana* a lepidopteran that causes between 20 and 30% damage if not controlled. Like-wise, in Europe, the hazelnut weevil, *Curculio nucum,* can cause major damage if left untreated. These pests have not been recorded in Australia. The Big bud mite *Phytoptus avellanae* is an important pest in Europe and a pest problem on some varieties in the U.S.A. This mite has been identified in Australia, presently in Tasmania. It is desirable that the mite not be introduced to the mainland states. A mite sometimes associated with P. *avellanae* and yet to be identified in Australia is *Cecidophyopsis veriformi.* Harmful and beneficial mite species are included in Appendix 4.

Eastern filbert blight, *Ansiogramma anomala* is the most destructive disease of the European Hazelnut and occurs only in North America. The disease became commercially important in 1970, and is a major threat to the industry in Oregon. Expanding cankers result in canopy die back, and death in mature trees. This disease would have a major impact on the Australian industry, requiring expensive chemical control. Cultivars range in their susceptibility to Eastern filbert blight, with Daviana and Ennis being highly susceptible. Barcelona, Willamette and Lewis are moderately tolerant, while the new release Santiam, is resistant.

The key disease in Australia is Bacterial blight *Xanthomonas arboricola* which causes dieback of young twigs and branches.

Crop damage caused by pest birds, is a significant problem for many hazelnut producers in Australia, and growers seek advice on how to address the problem. Growing practices are changing, values for nut products are increasing, and the geographical range of production is expanding. These changes often result in expanding range and impact of pest birds.

Many growers confirm bird damage as a key constraint to production in certain areas. Unquantified plantings of hazelnuts have suffered considerable damage in producing areas. Bird damage at hazelnut variety trial sites on the east coast has been a common problem. Birds, particularly Sulphur-crested cockatoos (*Cacatua galerita*), are regularly observed chewing and removing buds and mature nuts. Birds harvest immature nuts from the trees as well as damaging mature nuts on the ground. Information on bird management and other vertebrate pests affecting hazelnut growers has been included.

Materials and Methods

Four components contributed to the gathering of pest and disease information for this project.

Information has been collated from data bases, and samples submitted by growers and the investigator. Vertebrate pest information has been provided by the Vertebrate Pest Research Unit and Agricultural Protection Officer, N.S.W. Dept. of Primary Industries (D.P.I), Orange Agricultural Institute.

The pests and diseases of hazelnuts, that are known to be present in Australia, have been collated. These records have been assessed by taxonomic specialists, and compiled from a number of databases in Australia. Many of the samples have been collected by the investigator, and NSW D.P.I. extension officers, over a period of 20 years. The majority of samples related to hazelnut have been identified by staff of the Agricultural Scientific Collections Unit, N.S.W. D.P.I.

Exotic pest threats from around the world have been compiled and compared with those in Australia. These can be rated as key or secondary pests. Key pests cause greater significant economic damage, generally on an annual basis. Secondary pests are more sporadic and usually feed on foliage and not the nuts. In some cases the pest maybe noted as a pest overseas, but although present in Australia, not recorded on hazelnut. In some cases pest and disease records maybe incomplete or not well validated. Records are further complicated with name changes of species over time.

Literature sources examined included:

- CAB abstracts
- Proceedings from the past three International Symposium/Congress on Hazelnut (encompassing a period of 12 years)
- Australian Plant Pest Database (links together 17 pest collections to provide information on recorded pests of Australia's economically important crops)
- C.S.I.R.O Australian Insect Common Names Database
- Australian Biological Resources Study (ABRS Fauna online)
- Pacific Northwest Fungi Database – Washington State University

Records of pests from overseas have been cross referenced with those noted on Australian databases.

Over the 12 month period of the project producers have been encouraged, via the Australian Nutgrower journal, to submit samples of fauna, including beneficial insects from their hazelnut groves. The investigator has collected samples from the key hazelnut producing areas in N.S.W and Victoria. This included blocks associated with the hazelnut variety evaluation program in the central west of N.S.W and N.E. Victoria, where planting material was derived from a wide range of regions (figure 1).

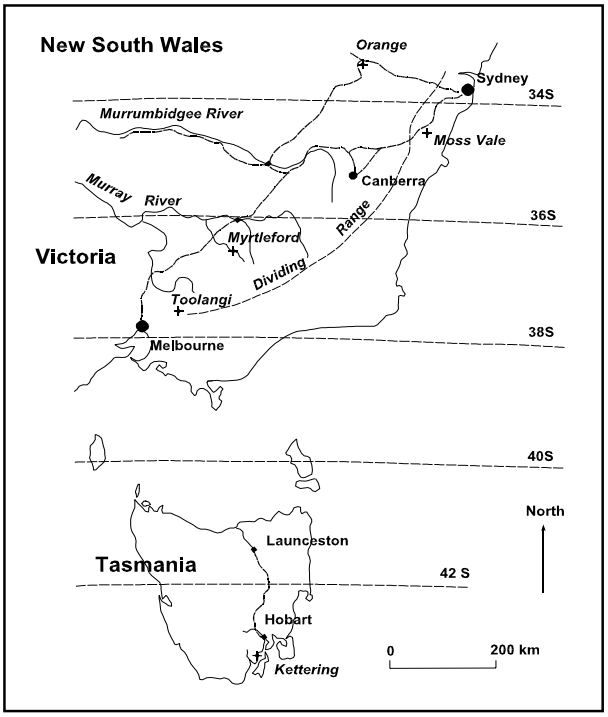


Figure 1. Samples were submitted from major producing areas in Australia
Source: RIRDC. No. 99/6

Net sweeps were included in the central west of N.S.W. and are presented in Table 6.

Problems of kernel decay and post harvest issues have not been emphasised by growers or processors, and Teviotdale (2002), points out that on average, losses in hazelnut are less than 1%, but can reach as high as 10% in the U.S.A. Interest in kernel decays in Australia should increase, as issues of contamination by aflatoxins and mycotoxins, and other food safety aspects of production, become more important. A small number of kernels collected from hazelnut variety trials in Australia, were examined visually, for the presence of mould and decay. Quality issues were largely associated with shrivelled kernels. An *Aspergillus* sp. (fungi) was isolated from samples submitted. and this fungi is described in the fact sheets in Appendix 5. No major spoilage was noted.

Results

The scientific literature contains a wide range of hazelnut pest and diseases that impact on production. Many of the records lack detailed information. Generally, it is recognised from the literature, that the organism most frequently recorded, is likely to have the greatest significance. In terms of exotic pests, these represent the greatest potential threat. It is acknowledged that environmental differences, and other factors, could have an impact on establishment and epidemiology, should these exotic pests and diseases enter Australia. It is also acknowledged, that minor pests and diseases overseas, may have a greater impact than anticipated if introduced into Australia.

Some 30 records were compiled from the Australian plant pest database. Many of these have been described to species level. In some cases the project time frame did not allow for the full completion of life cycle for collected samples. This allowed for identification to family level only. Table 1 indicates organisms that were compiled from the Australian Plant Pest Database data base and found in association with hazelnut. Of most significance are the hazelnut aphid, Big bud mite, and bacterial diseases.

Table 1. Organisms recorded in Australia on hazelnuts as compiled from the Australian Pest and Disease Database (APPD).

Scientific Name	**Common Name**
Anoplognathus concolor	Scarab beetle
Coccidae	Soft scale insects
Coptophylla lamimani (unpublished data)	Filbert leaf mite
Edusella sp.	
Ephestia cautella	Almond moth
Isoptera	Termites
Lecanium sp	Scale insect
Myzocallis coryli	Hazel aphid
Phytoseius fotheringhamiae	Predatory mite
Phytoseius sp.	Predatory mite
Plodia interpunctella	Moth
Pyralidae	Moths
Repsimus manicatus	Beetle
Scarabaeidae	Scarab beetles
Thrips australis	Eucalyptus thrips
Ahasverus adven	Foreign grain beetle
Cylindrocarpon sp.	Fungi
Diphucephala smaragdula	Beetle
Gliocladium roseum	Fungi
Gloeosporium perexiguum	Fungi
Halothrips victoriensis	Thrips
Leptosphaeria vagabunda	Fungi
Pesotum sp.	Fungi
Phytoptus avellanae	Filbert big bud mite
Pythium sp.	Fungi
Tuber maculatum	Fungi
Wettsteinina coryli	Fungi
Xanthomonas arboricola	Bacteria
Xanthomonas campestris	Bacteria
Xanthomonas corylina	Bacteria

Table 2 represents samples submitted by growers and nurseries generally, over the 12 month period of the project, and also includes samples collected by the author, over a longer period of time. Samples submitted by growers totalled 17. These included organisms that were giving direct damage, with high populations, and others that were causing minor damage, or considered to have a predatory role.

Table 2. Samples submitted by hazelnut growers and nurseries in Australia.

Scientific Name	**Common Name**
Teia anartoides	Painted Apple Moth
Neumichtis saliaris	Green cutworm
Myzocallis coryli	Hazel Aphid
Merophyas divulsana	Lucerne Leaf roller
Ectropis sp.	Loopers
Parthenolecanium sp.	Plum scale
Naupactus leucoloma	White fringed weevil
Physarum cinereum	Slime mould
Poecilometis strigatus	Pentamonidae
Caedicia simplex	Inland katydid
Clania ignobilis	Faggot case moth
Neoaratus sp.	Robber flies (predator)
Phytoseius fotheringhamiae	Predatory mite
Typhlodromus sp.	Predatory mite
Typhlodromus pyri	Predatory on two spotted mite
Tetranychus urticae	Two spotted mite
Corticaria sp.	Minute mould
Pachydissus sp.	Cerambycid borer
Myzus persicae	Green peach aphid
Aades cultratus	Weevil
Aphodius tasmaniae	Black headed cockchafer

From this table the Hazelnut aphid, Green peach aphid, White fringed weevil, *Pachydissus* sp. and Plum scale are considered key pests at this point in time. The weevil *Aades cultratus* caused significant damage to mature plantings in Victoria.

Table 3 indicates key European and secondary pests. Other less significant pests in Europe are included in Appendix one.

Table 3: Key and secondary pests in Europe

Key Pests Scientific Name	**Common Name**	**Recorded from Australia**
Curculio nucum	Nut weevil	No
Palomena prasina	Green shield bug	No
Xyleborus dispar	European shot hole borer, Ambrosia beetle, Small fruit tree borer	Yes
Obera linearis	Hazel longhorned beetle, Twig borer	No
Gypsonoma dealbana	Tortrix moth, Shoot/twig borer	No
Parthenolecanium sp.	European fruit scale, Brown scale, Peach scale	Yes

Secondary Pests Scientific Name	Common Name	Recorded from Australia
Hyphantria cunea	Fall webworm, American white moth	No
Myzocallis coryli	Fibert or Hazel aphid	Yes
Lepidosaphes ulmi	Oytstershell scale	Yes
Lymantria dispar	Gypsy moth	No
Archips rosanus	Filbert leafroller	No
Melolantha melolantha	Common cockchafer	Red and black headed cockchafer
Polyphylla fullo	Pine chafer	No
Choristaneura rosaceana	Oblique banded leaf roller	No

Insect and mite pests present in the U.S.A. are presented in Table 4. Many of the pests in the U.S.A are not recorded or known to be in Australia. Filbert aphid and *Phytoptus avellanae*, Big bud mite are present in Australia.

Table 4: Insect and mite pests of hazelnut in the USA

Scientific Name	Common Name
Insects	
Cydia latiferreana	Filbert worm
Myzocallis coryli	Filbert aphid
Archips rosanus	Filbert leafroller
Choristoneure rosaceana	Obliquebanded leafroller
Syneta albida	Syneta beetle
Lecanium corni	Lecanium scale
Cnephasia longana	Omnivorous leaf tier
Operophtera brumata	European winter moth
Anarsia spp.	Twig and tree borers
Spilonota ocellana	Eye spotted bud moth
Xyleborus dispar	Ambrosia beetle
Curculio uniformis	Filbert nut weevil
Phenococcus aceris	Apple mealybug

Mites	
Phytoptus avellanae	Filbert bud mite
Cecidophyopsis vermiformis	Filbert bud mite
Aculus comatus	Filbert rust mite

Table 5 lists diseases that have been recorded in association with hazelnuts. In Australia Bacterial blight is the most significant disease, with Eastern filbert blight the most important in the USA.

Table 5: Fungal, bacterial, and viral diseases associated with hazelnut, from a range of producing areas around the world.

FUNGAL DISEASES	
Anthracnose	*Piggotia coryli*
	Monostichella coryli
	Gloeosporium coryli
	Labrella coryli
Armillaria root disease	*Armillaria spp.*
Borro sec	*Cryptosporiopsis tarraconensis*
Cytospora canker	*Cytospora spp.*
Eastern filbert blight	*Anisogramma anomala*
Kernel molds	*Mycosphaerella punctiformis*
	Ramularia sp.
	Phomopsis spp.
	Septoria ostryae
Kernel spot	*Nematospora coryli*
Leaf blister	*Taphrina coryli*
Leaf spots	*Anguillosporella vermiformis*
	Asteroma coryli
	Cercospora corylina
	C. coryli
	Mamianiella coryli
	Monochaetia coryli
	Mycosphaerella punctiformis
	Ramularia sp.
	Phyllosticta coryli
	Ramularia coryli
	Septoria ostryae
	Sphaceloma coryli
Nectria canker	*Nectria ditissima*
Texas root rot	*Phymatotrichopsis omnivora*
Powdery mildew	*Microsphaera coryli*
	M. ellisii
	M. hommae
	M. verruculosa
	Phyllactinia guttata
	P. suffulta
Rust	*Pucciniastrum coryli*
BACTERIAL DISEASES	
Bacterial blight	*Xanthomonas arboricola pv. corylina*
Bacterial canker	*Pseudomonas syringae pv avellanae*
Crown gall	*Agrobacterium tumefaciens*
VIRAL DISEASES	
Hazelnut mosaic	Apple mosaic virus
	Prunus necrotic ringspot virus
	Tulare apple mosaic virus
PHYTOPLASMAL AND SPIROPLASMAL DISEASES	
Filbert Stunt	unknown, suspect a phytoplasma
Hazelnut Yellows	phytoplasma(s)

Table 6: Net sweep results from the central west of N.S.W, conducted March/April 2006

ORDER	FAMILY	COMMON NAME
Lepidoptera	*Lycaenidae*	Butterflies
	Nymphalidae	
	Pyralidae	Moths
	Pieridae	Pieris rapae rapae(Linnaeus) Brassicae pests
Hymenoptera	*Braconidae*	Larval Parasites
	Colletidae	Native Bees
	Cynipoidae	Gall forming Wasps
	Chalcidoidea	Parasitic or plant feeding (3 Families)
	Formicidae	Predatory Ants
	Platygasteridae	Parasites
Coleoptera	*Staphylinidae*	Rove Beetles, mainly predatory
	Cucujoidae	(Undetermined family)
Orthoptera	*Tettigonidae*	Katydids
Hemiptera	*Cicadellidae*	Leaf Hoppers
	Margarodidae	Ground Pearls
	Pseudococcidae	Mealybugs
Thysanoptera	*Thripidae*	Thrips
Collembola		Springtails
Diptera	*Sciaridae*	Fungus gnats
	Chironomidae	Midges
	Asilidae	Robber flies, predatory
	Lonchopteridae	larvae feeding in deaying vegetation
	Muscidae	

Appendix 5 provides photographs and information fact sheets on many of the pests and diseases, including exotic threats, which have been noted in this study.

Discussion

The tables indicate a great diversity of insect and mite records. The Australian tables also reflect the diversity that is present in other parts of the world. In Europe, almost two hundred species of insects and mites have been associated with hazelnuts. In the USA, about 150 species have been recorded in association with hazelnut. Not all are regarded as pests. In the USA approximately 7 insect /mite pests are important.

This project has commenced the cataloguing of pests in Australia. Tables 1 and 2 document pests and beneficials recorded in Australia, that are, associated with hazelnuts. Apart from a few lepidopteran and coleopteran pests, it would appear that most pests in groves are kept under control by natural enemies and predators. This has allowed the crop to be less intensively sprayed, providing a stable plant system, however larger developing plantations, may not enjoy a similar balance.

The lepidopteran insects cause leaf feeding or leaf mining type damage. Some can become shoot and twig borers as in the case of Fruit tree moth borer, *Maroga melansotigma.* The coleopteran weevil *Aades cultratus*, caused significant damage to trees in Victoria, as has the White fringed weevil *Naupactus leucoloma*, in the Braidwood region of N.S.W. These are new records for damage to hazelnut in Australia.

Big bud mite, *Phytoptus avellanae* is a key overseas pest that is present in Australia. At this point in time, it is known to be present only in Tasmania, and care should be taken when exporting host planting material to the mainland states.

The hazel aphid *Myzocallis coryli,* is a common pest in most hazelnut producing areas in Australia, and occurs with fluctuating populations. Damage is caused to the underside of young expanding leaves in spring- early summer and a final generation appears in autumn. Populations decrease with higher temperatures in mid summer. The long term effect of high aphid population has not been quantified, but reduction of nut size and fill has been reported (Painter and Jones 1960). In other parts of the world, it has become less important as a pest, and in the USA the hazelnut aphid parasitoid, *Trioxys pallidus* is used effectively for control. Olsen (2002) reports that this parasitoid introduced from Europe, is well adapted to orchards in Oregon, where growers rarely spray for control.

Excessive use of nitrogen fertiliser should be avoided, as succulent young growth can encourage higher aphid populations. Water shoots should also be pruned out where possible.

The most common parasitoids of aphids belong to the *Aphidius* genus. Natural enemies of aphids in Australia include ladybird beetles, Hover flies (*Syrphidae*) and Lace wings. Lace wing larvae can consume up to 60 aphids per hour (Hetherington 2005). Parasitoids of hazelnut pests are included in Appendix 2. A member of the ladybird group *Hippodamia variegata*, is a recently discovered predator of aphids, and is available commercially for release in Australia, but its integration into the hazelnut orchard is yet to be fully tested. A list of predators for aphids is included in Appendix 3.

Australia appears to be free from the key pests and diseases affecting production in other parts of the world. Producers report little damage to the hazelnut in regard to nut boring damage or damage to developing kernels.

In the U.S.A the filbert worm, *Cydia latiferreana* is the key pest. This larvae moves between the husk and the nut, proceeds to penetrate the hylum and feed on the kernel. Of significance to Australian growers, is that this pest is a close relative of the Codling moth, *Cydia pomonella*, which is a pest in many orchard areas. Host plants to the filbert worm in the U.S.A include the oak, walnut and pomegranate.

In Europe the nut weevil *Curculio nucum*, is the most destructive pest and thin shelled varieties appear to be more susceptible. This pest feeds on vegetative parts of the hazelnut, and then feeds on small developing nuts. Damage can cause a browning in kernel colour and premature nut drop. This weevil is not known in Australia.

The Green shield bug *Palomena prasina*, is a member of the pentatomidae family and is an important pest in Europe, but not known in Australia. *Poecilometis strigatus*, identified in Australia in this study, is in the same family and is a sap feeding insect associated with hazelnut plantings. There is limited information available on the host range.

As the industry develops, growers will have the opportunity to establish and maintain the nut grove, to minimise pest and disease damage. Healthier trees have less pest and disease problems. Hetherington (2005), points out that topography, soil types and associated vegetation can contribute to a healthier orchard. The choice of resistant varieties to pest and diseases, management of the orchard floor, alternate host removal and cultural practices of training, pruning and fertilising, can influence pest and disease pressures.

Diseases

Table 5 presents fungal and bacterial disease associated with hazelnut culture. As with many of the key insect and mite pests, Australia is free from some of the more devastating diseases. Eastern Filbert blight *Anisogramma anomala*, is a major, well documented fungal disease in the USA, and has a lethal effect on *Corylus avellana*. The fungus moves into shoots and branches, and can be identified by oval shaped raised pustules above the bark surface. Tree productivity declines slowly, and trees will die, if no action is taken. The disease has a 15 month latent period, where no symptoms are visible. It is reported not to spread through the nuts.

Varieties such as Daviana and Ennis are highly susceptible. Barcelona, Butler, Halls Giant and Willamette have intermediate susceptibility. Lewis has better tolerance than Willamette. The pollinators, Gamma, Delta, Epsilon, and Zeta, are all resistant to Eastern filbert blight (Azarenko et al. 2003).

Armillaria is a soil inhabiting fungus that can cause root rots. Symptoms include poor shoot growth, defoliation, branch die back, stunted leaves and premature yellowing. It is a disease associated with orchards that are planted in recently cleared hardwood land. Although a relatively common disease on many horticultural crops, records in Australia related to hazelnut are limited. Destruction of infected trees and roots by burning and good sanitation will assist in controlling the spread.

Hazelnut blight *Xanthomonas arboricola* pv. *corylina* is the most debilitating and underestimated disease affecting production in Australia. The effects are most injurious to trees four years and younger. In older trees yields may be reduced through the loss of nut bearing branches. The first infection on the current seasons stems consist of dark green water soaked areas on the bark, turning to a reddish brown (Snare and Baldwin 1997). Spread to new groves is caused by the planting of infected nursery stock. Early spring blight strikes can be the most damaging to new growth, and varieties that leaf out early can be the most affected (pers.obs). Early leaf out in Australia is typically late August, and includes varieties such as Tonda di Giffoni, Tonda di Romana and Tonda Gentile delle Langhe.

Phytophthora is an important disease of deciduous fruit trees, and is anecdotally reported to cause tree death in Australian groves. Teviotdale *et al.* (2002) report that no *Phytophthora sp.* has been recorded in association with hazelnut. Records were not found for hazelnut in Australia.

Of major significance in 2006, is that the importation of plants and plant parts (other than tissue cultures) of the Corylus genus/species into Australia, will be prohibited from New Zealand, U.S.A., France, Italy and Spain (AQIS 2006). This genus/species is a host of *Phytophthora ramorum* (Sudden Oak Death) and/or other Phytophthora complex species. Other countries in Europe are also included on the prohibited import list. A new pathogen, *Phytophthora kernoviae*, a very similar organism to *Phytophthora ramorum*, has recently been detected in New Zealand.

Post harvest

Limited investigation has been undertaken in regards to kernel contamination and breakdown in Australia. Decay problems are most commonly related to insufficient drying, or not collecting nuts from the ground quickly enough in damp harvest conditions. Some Australian processors report mouldy nuts. *Aspergillus* sp. was recorded on samples submitted from N.S.W. and is discussed in Appendix 5.

Fungi are associated with symptoms of kernel decay in hazelnut kernels in other parts of the world, but pathogenicity has not been proved (Teviotdale 2002). Kernel tips can be blackened or shrivelled, and kernel quality is reduced. *Mycosphaerella punctiformis* has been isolated from kernels in Oregon. *Phomopsis* sp. and *Septoria ostryae* are associated with internal discolouration of kernels from a white to a yellow colour.

Most problems related to storage are related to the development of off flavours under high humidity, and this is due to the break down of sucrose to glucose. Oezdemir and Devers (1999), report that levels of glucose greater that 0.1g/100g in mature kernels can indicate poor storage conditions or that kernels have been stored over a long period of time.

Managing bird damage to hazelnuts

Bird damage to hazelnut orchards includes pruning of foliage and buds, ringbarking of trees, and cracking and eating of hazelnuts. Sulphur-crested cockatoos, galahs, little corellas and long-billed corellas are the main bird pests to the nut industry. Other species cause damage to growing tips, buds, and mature fruit.These include crows and ravens, and a variety of rosellas and parrots.

In a recent national survey by NSW Department of Primary Industries bird damage was found to be higher in nuts than any other horticulture industry, with average reported bird damage found to be 22.5% (S.E =3.2, n=100) overall. There are also further costs associated with management, and opportunity costs, where growers are reluctant to grow nuts because of bird damage. In a parliamentary inquiry into cockatoo damage in Victoria in 1995, 42% damage was reported to walnuts by the Australian Nut Industry Council and nut growers. Hazelnuts (10%), chestnuts (5%) and pistachios (5%) were also reported to suffer high levels of damage, costing between $6500 and $204 000 in lost production in Victoria (Environment and Natural Resources Committee 1995). In the case of hazelnuts, nuts are removed from the trees before the kernels are mature. With crops that are harvested from the ground the removal of nut before it becomes harvestable is of major concern.

There are a diverse range of management options for pest birds with variable effectiveness, and no single solution applicable to all situations. Greatest crop damage is usually caused late in the harvest season, which coincides with the busiest time for growers, although hazelnuts can be selectively attacked as they mature. As a result, bird management is often not initiated until after considerable damage has already occurred. Integrated pest management is a concept well understood for insect and disease problems however birds have not often been managed in the same strategic way.

Rather than focussing on killing as many pests as possible, it is now realised that, similar to most other aspects of agriculture, bird management needs to be carefully planned and coordinated. Bird control is just one aspect of an integrated approach to the management of production. Many birds are highly mobile and can readily replace those that are killed in control programs. Unless actions are well planned and coordinated they are unlikely to have a lasting effect. When planning bird management, there are some important steps that should be considered.

What is the problem?

In the past the pest was usually seen as the only problem. Hence the solution was to kill as many birds as possible. We now know that the situation is more complex. First, determine what the problem is. It may be reduced crop yields, secondary losses causing downgrading of nuts, complaints from neighbours or emotional stress from worrying about the next attack. Several factors impact on each of these problems and control of birds is often only part of the solution. The following questions will help define the problem:

- Where is the problem?
- How severe is the problem?
- Will the problem change with time?

Remains of cracked hazelnut shells damaged by birds.

Identify the birds involved

Implementing an effective bird control program requires a basic understanding of the ecology and biology of the targeted pest species and, in some cases, those species affected directly (non-targets) or indirectly (prey species) by a control program. It is also essential to understand the impact created by the pest, for example, what is the problem? Control strategies can be targeted for particular birds. For example, some species, such as little corellas can be nomadic, suddenly arriving in nut orchards at a certain time. Therefore, out of season control may be inappropriate for these species. Most native birds are beneficial or desirable and it is important that management does not affect these species.

Estimate the damage caused to production

Estimating the amount of damage and calculating the cost will provide a basis for deciding how you can best reduce pest bird impact and how much you can afford to invest in any control effort. The percentage of crop damaged by birds in a hazelnut orchard can be estimated by randomly or systematically sampling rows and trees. Bird damage to individual nut or clusters can be estimated by counting, weighing or by using a visual estimate. Often sampling and calculating damage for the edges of a crop separately will increase the efficiency.

Identify any key constraints

Consider legal, social and environmental issues. For example, will scare devices be acceptable to the local community; are the techniques legally and/or environmentally responsible and acceptable?

Decide when the most cost-effective time is to implement the plan
Even when good information is available it is often not practical to be immediately responsive to short term fluctuations in bird numbers or the damage they cause. When damage becomes significant it is usually too late to implement control. For example, effective use of scaring often requires a 'start early' approach to prevent birds establishing a feeding pattern. Likewise investment in netting cannot be simply withdrawn for those seasons in which damage is below the cost-benefit threshold. Instead growers need to look at costs and benefits over a longer time frame and make decisions accordingly. Where damage in your area is likely to be high or you have a history of high damage you should be more inclined to invest in continuing management action. Measuring damage this year will assist in selecting the optimal management option next year and beyond.

Develop the most appropriate bird management plan
The management plan must have details of what will be done, who will do it, when it will be done and how much it will cost. Options can include individual techniques or combinations, and different levels of application. The plan must have long-term, year to year strategies to prevent damage and short-term reactive strategies to cope with sudden increases in damage. For example, in the long-term, managers may use netting on a small part of their crop every year. In the short-term, when damage is higher, they may also implement a scaring program.

Monitor and evaluate
Has your management been successful? Estimating damage is the most direct way you can measure the effectiveness of your management program. All costs and labour of implementing control should also be considered. For example, nets may have significantly reduced bird damage, but if they were repeatedly removed for maintenance or spraying there are additional costs to consider. Evaluating management will enable improved decision making for future strategies and allows you to modify your actions to maximise any economic return.

There is no one simple solution for managing birds effectively. However, the following information may assist in deciding the most appropriate action for your situation.

Management options

Scaring
Many visual and sound devices have been used by managers in an attempt to scare birds. Some of these include: acetylene and LPG gas guns, electronic devices, radio, flashing or rotating lights, scarecrows, reflective mirrors or tape, helium or air-filled balloons and predator models or kites. Habituation is the main drawback of all types of scaring. Birds quickly become accustomed to noise or visual cues.

Best results for scaring are achieved when:

- combinations of techniques are used
- scaring commences before birds establish a feeding pattern
- the sound is reinforced by shooting or a threat
- the timing and placement of devices is changed frequently, but not at regular intervals.

The following suggestions may improve or prolong the effectiveness of scaring:

- loud sounds are more aversive than quiet sounds
- sounds with a wide frequency range are more aversive than pure tones
- loud sounds produced by simple cheap methods are likely to be just as effective as sounds produced by expensive electronic devices
- devices are more effective when used for the shortest time necessary for a response
- adult birds are more easily scared than juveniles
- all species habituate to nearly all sounds tested so the effect of most sound generating devices is short-term
- ultrasonic devices are ineffective as most birds cannot hear ultrasound (≥20 kHz)
- broadcast alarm and distress calls can be effective but are subject to similar habituation to other sounds, are species-specific and may cause a 'mobbing' rather than an escape response
- birds of prey rarely call when hunting hence pre-recorded raptor calls are likely to represent something novel to birds rather than create an avoidance response from a predator

Birds of Prey

Attracting birds of prey or use of falconry is often perceived to be of value in scaring birds or reducing pest numbers. However, while falconry has been used previously in airports to reduce bird strikes, it is impractical in most situations. Falconry is strictly regulated in Australia, requires skilled handlers and considerable training, and is labour intensive.

Encouraging raptors to specific areas is difficult as different species occupy a different ecological niche. For example, sparrowhawks, and goshawks prefer hunting amongst trees and tall shrubs to surprise prey; most falcons prefer open country; and Australian hobbies prefer lightly timbered country along watercourses. The most effective predators of adult birds are unlikely to be attracted by carrion or other food sources. Species that may be attracted (e.g. wedge tailed eagles, little eagles and whistling kites do not normally hunt birds in flight). Some studies have shown that providing perches increases the numbers of birds of prey. However, this has not yet been demonstrated to reduce the number of pest birds or the damage they cause. More investigation is required.

Lethal control

Many attempts to kill birds, despite alleviating frustration, often do not reduce damage. The techniques used are usually labour intensive and may have legal, welfare and social concerns. Permits from national parks and wildlife agencies are required for most native species.

The use of traps requires considerable labour and is therefore often cost prohibitive. However, trapping may be of benefit in situations where a single resident species is involved and a large proportion of the population can be trapped. A multitude of different trap designs are available including: remotely operated nets, cage and roost traps, funnel entrance traps, modified Australian crow traps, and nest box traps. The success of trapping varies according to the skill of the operator and the time of year.

Shooting is most beneficial when employed as a part of a scaring program. If regarded as a training tool rather than a method of population control, it can educate birds to associate noise with a real threat. To reduce habituation, shooting should occur at the same time scaring devices are used. This establishes a connection between the scarer and danger.

Although some lethal poisons are registered for use in some states (contact the agriculture department in your state or see http://www.apvma.gov.au/pubcris/subpage_pubcris.shtml), their use is strictly regulated. For example, many products can only be applied for introduced species, in or around buildings, by licensed pest control operators, and require site permits from national parks and wildlife agencies.

Orchard management and habitat considerations

A range of landscape and habitat factors influence the number of pest birds and the damage they cause. These factors can be considered when attempting to minimise losses. The varieties grown and timing of maturity can be important. For example, growing varieties that mature simultaneously can help alleviate the damage to individual growers. Depending on the birds involved, sites with adjacent roosting habitat or powerlines can have higher losses. The numbers of pest birds and the levels of damage will vary according to the preferred habitat of different species. These factors can be considered before planting new crops.

Providing alternative food sources by decoy or sacrificial planting may be effective for some situations. This relies on knowledge of the feeding habits of the main pest birds involved. A decoy planting ideally will produce food of equivalent or enhanced nutritional requirements and attractiveness for birds; and is available just before, and at the same time that your crop is susceptible to damage. However, supplying alternative foods may also attract more pest birds to the area. Additionally, a scaring program is likely to be more effective if alternative food sources are available.

Netting

Exclusion netting using throw-over or permanent nets has high up-front costs but may be appropriate where high value crops are grown and levels of damage are high. A variety of netting options are available. Machines can be used to install and remove drape-over nets of varying width (for example, 1, 2 or 4 rows). ‘Lock-out’ netting provides a continuous cover of netting by joining draped nets without the need for poles and cables. Nets can also be used on infrastructure to prevent birds roosting or nesting. If maintained, netting with ultra-violet stabilisers can provide between five and ten years of protection.

Throw-over netting is more easily damaged than permanent netting and often does not provide as much protection. Permanent netting is easier to maintain and allows easier spraying of trees.

Throw-over netting can be difficult to manage.

Netting overcomes many of the legal, environmental, social and animal welfare concerns of other techniques. The decision to net is mainly an economic one. Will the increase in returns from excluding birds be beneficial over the life of the netting? As an example, cost-benefit analysis on netting in Orange NSW suggests drape-over nets are cost-effective when damage is consistently greater than 10% and permanent nets are cost-effective where damage is over 25%. The value of the crop and the practicalities of netting must be considered.

Roosting deterrents

There are a variety of spikes, coils, and wire products that are available to exclude birds from perching on buildings and infrastructure. Electrified wires, which can be attached to the top of roosting areas, are also available. These wires give birds a small electric shock but do not harm them. Monofilament lines have been successful for deterring larger birds from fish farms but are found to be ineffective for deterring species from nut crops.

Chemical deterrents

There are several chemical deterrent products commercially available in Australia. However the majority of these may be ineffective for reducing damage to nuts. Check with the Australian Pesticides and Veterinary Medicines Authority for up-to-date registration information (http://www.apvma.gov.au/pubcris/subpage_pubcris.shtml), and appropriate applications. Some deterrents are based on Polybutene, which is a tactile roosting repellent; Aluminium Ammonium Sulphate, which acts on a sense of smell and taste; or Methiocarb, which is an insecticide that causes conditioned aversion.

Polybutene is a sticky substance that irritates the bird's feet and can prevent birds from roosting on infrastructure hence is applicable for buildings and urban areas. Aluminium Ammonium Sulphate may be applied to vegetables, nuts, fruit, orchard trees and vines, provided the guidelines on the permit are adhered to (e.g. thorough

washing before consumption). Garlic and chilli sprays have been used to deter birds from feeding, but these are unlikely to be effective.

Summary of the main points to consider:

- Identify bird species
  - ⇒ Consider behaviour, movements and legalities
- Measure damage
  - ⇒ How much are birds actually costing you?
- Integrated control
  - ⇒ Multiple techniques
  - ⇒ For scaring; start early, persistence, variation and reinforcement
- Review your bird management strategy
  - ⇒ Do the benefits outweigh the costs?

Vertebrate Pest Control in Hazelnuts

Hares, rabbits, kangaroos, wallabies, mice and foxes have been identified as having an impact on hazelnut production. In order to control these vertebrate pests it is important to gain a basic understanding of their biology and population dynamics. This understanding allows producers to develop effective control programs that target different species at critical times. In order to achieve maximum results individual control programs should be linked to a combined neighbour or district species program.

Field Mice

The house mouse, *Mus domesticus* has quickly established itself in a wide range of urban and rural habitats. Mice are largely a problem in processing and storage sheds where in shell and processed kernel is stored. Processing equipment and conveyers can be contaminated causing loss of product.

Mice are known to continually use their fast growing incisor for gnawing. The gnawing controls the length of their teeth and will be applied to all types of material not all of which will be tasted or ingested.
The teeth shape and size is one of the distinguishing features between the native mouse and the house mouse.

Mice eat a wide variety of foods eating 3-5 g daily. Rolled oats, peanut butter, vegetable oil, pumpkin seeds and molasses are rated high on their menu. Exposed hazelnut kernels are also highly attractive. Mice can survive and breed if their feed source has at least 15% moisture content. Where the moisture content is below 15% they will require 1-2g of water daily to survive. Hazelnuts, when stored are typically dried to 5% moisture.

Breeding
In Australia, mice living under field conditions have a seasonal pattern of breeding. This generally begins in early spring and continues until cold or wet conditions develop in late autumn. Mice living in unfavourable seasonal conditions may have a shorter breeding period, while those with nests in the warmth of buildings or haystacks are likely to have an extended breeding period.

Mice are most active at night. Their home range is limited to an area of about 5m2 in closed buildings; but in crop situations, with available food and water, the home range may be even less. Young mice are forced to seek new areas during periods of high breeding and this is one of the factors associated with the development of a plague. When mice move, they tend to follow the same path from refuge to feeding area. Paths are often confined to walls, pipes or natural barriers, so the tell tale smear marks can be an indication of mouse activity. In the field, distinct tracks through the vegetation become obvious.

Mice can squeeze through openings as small as 8 mm in width. In addition they can climb almost any rough surface, climb upside down and run down ropes and electric wires.

Size of the problem
One effective way to gauge the extent of the problem is to soak small 10cm x 10cm paper cards (Figure 1) in vegetable oil and peg the cards in the ground 10 metres apart in 100 metre transects. Place them overnight, and check and record the chewing damage the next morning.

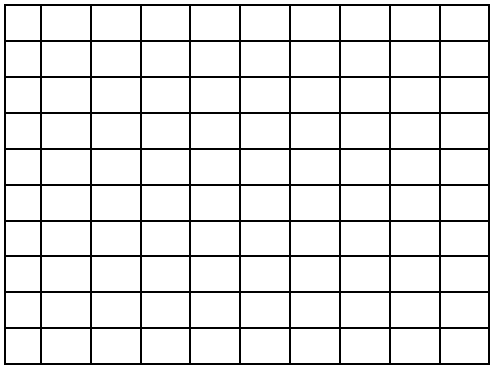


Figure 2. Example of the paper pad that indicates mice numbers in a field environment.

One chewed square = 1%. If 5 squares or 5 % of the pad is eaten then this figure may indicate depending on seasonal conditions that you may have an emerging mice population.

Control options
Mouse control options can be physical, ultrasonic or chemical.

Physical control includes mouse proofing facilities, grazing or mowing between rows and surrounds, keeping rubbish around farm buildings to a minimum, trapping, and the use of deterrents.

Snap back traps and water filled drums using leather or felt soaked in vegetable or linseed oil, bacon rind, or pumpkin seed as baits are effective on small scale control programs. Trapping will have little impact on large plagues and are labour intensive.

There have been a number of ultrasonic devices promoted to either repel or reduce the number of mice in buildings. These devices have no scientific validity and are not recommended.

Most chemical control uses two types of anticoagulants, indandiones and hydroxycoumarins. These poisons are safer for use around humans and domestic animals, except pigs. Anticoagulants are marketed as grains, pellets, powder or liquid and include the following;

- Bromadiolone traded as Bromakil.
- Brodifacoum traded as Talon.
- Coumatetraly traded as Racumin.
- Flocoumafen traded as Storm.
- Warfarin traded as Ratsak.

It should be noted that bromadiolone liquid, traded as Bromakil is permitted in NSW for preparation of a crop perimeter bait. Zinc phosphide is a registered rodenticide traded as Mouseoff for in crop baiting. In general zinc phosphide is applied as one kilogram of wheat bait per hectare or about three grains of wheat per square metre. This application rate should potentially kill 10,000 mice per hectare. Caution should be taken if vacuum harvest equipment is used to collect nuts from the orchard floor.

Strict safety procedures have been developed to avoid any hazards during the handling of bait. The use of poisons that have not been registered for mice control should not be used as they are ineffective and have the potential to cause major ecological disasters.

Foxes

The European red fox *Vulpes vulpes*, was introduced into Australia by early settlers as early as 1850. Within 20 years they had attained pest status, and today, they maintain that status in most states. Foxes cause minor crop loss to hazelnuts by cracking and eating fallen nuts that are awaiting collection. The red fox is now found throughout many parts of Australia, including urban areas. They have one litter in spring, giving birth on average in early September. Litter sizes range from 2-5 and cubs become independent of the den at the age of 10-12 weeks.

Foxes have a high metabolic turn over and require 300-500 grams of food per day. They are opportunistic scavengers and their diets and proportions vary depending on locations across Australia. The following breakdown is an estimate of the average food source.

Sheep - carrion or lamb	20%
Insects - invertebrates	10%
Berries/nuts	5-10%
Rabbits and house mice	30-40%

The optimal months for baiting are March/April just prior to mating and September/October before giving birth. November can be successful when the average breeding family appetite is at its most voracious.

Control

Exclusion fencing – This can take the form of either electric or conventional fencing or a combination of both. Fox proof conventional fencing is expensive and is not cost effective. Traditional stand alone electric fencing will also be labour intensive and less effective than a combination of both electric and conventional fencing. Foxes are very intolerant of electric shocks and quickly learn to avoid electrified fencing. When used in combination with conventional fencing it is important to place two offset live wires 200mm from the ground and 200 to 250 mm out from the conventional fence. The top live wire should be placed near the top of the conventional fence again about 200 -250 mm out. It is important to exclude any option for foxes to crawl underneath conventional fences or have clear unobstructed access over fences via strainer posts and gates.

Shooting – Shooting should be seen as a follow up exercise and is labour intensive and opportunistic. Success is less likely to be sustained in the long term.

Trapping- Trapping is not recommend as it is time consuming and requires the placement of large number of traps, approximately 150 per fox. Some foxes can escape with severe injuries from the new soft jaw traps attracting animal welfare concerns.

Fumigation/destruction of dens - This is an effective method and target specific. The disadvantages are being able to find the dens and female foxes. The females have been known to re-use fumigated dens.

Baiting: The use of 1080 sodium monofluoroacetate baits is the most effective way to control foxes. Monofluroaceate occurs naturally in some 40 plant species in Australia and will breakdown in soil and water. The Rural Lands Protection Boards in NSW and similar organisations in other states are responsible for the sale and explanation of where and how to use these baits in accordance with specific legislation. i.e. baits have to be buried at 10cms and can not be laid within certain distances of residential property.

Kangaroos and Wallabies

Kangaroos and Wallabies belong to the family Macropodidae. Included in this family are about 52 recognised species of kangaroos, wallabies, wallaroos, hare wallabies, nail tail wallabies, rock wallabies, pademelons, quokka, tree kangaroos and swamp wallaby.

Most macropodids are nocturnal, although some of the larger species are more active in the early morning and late afternoon during hot conditions. All are herbivores that have adapted to a variety of habitats. Damage to young hazelnut plantings can be severe if animal densities are high and there is a shortage of fresh green growth. Tops of small trees can be removed creating undesirable tree forms.

Usually adults of all species are basically sedentary. They will have varying home ranges from a few hectares in the case of the smallest forest dwelling species to a few square kilometres for an Eastern Grey to over 300 kilometres for the arid based Red Kangaroo *Macropus rufus*. The larger species that live in semi open habitats with access to a common food sources are generally gregarious and well organised as a group.

Control

In NSW kangaroos and wallabies are protected under the National Parks and Wildlife Act 1974 (NPW). This Act gives an authorised officer the power to issue licences to mitigate against damage (s120) or to harm, dispose of, or sell fauna in a commercial or non commercial capacity (ss121). The NSW Director-General of the Department of Environment and Conservation (DEC) has developed, from time to time, management programs to guide the exercise of those powers.

DEC has also developed a management program for a number of species, including Red Kangaroo *Macropus rufus,* the Western Grey Kangaroo *Macropus fuliginosus*, the Euro *Macropus robustus erubescens*, the Eastern Grey Kangaroo *Macropus giganteu* and the Wallaroo *Macropus robustus*.

Additional information on gaining a licence for such control outside NSW should be sought from your appropriate state authority.

Fencing

There have been a number of fence designs that have been developed to control or exclude kangaroo and wallaby movement. Larger species of kangaroos such as the Eastern Grey *Macropus giganteus*, and some wallabies, have the ability to jump traditional sized fencing. However, in an unprovoked situation both wallabies and kangaroos will try to get through the fence by crawling through or under the wire, particularly where there is a depression of 60 mm or better in the ground or gaps between the ringlock and top wire.

Generally, these species will have a tendency to travel along a fence in search of depressions or gaps between the bottom wire and the ground or general gaps in the construction material of the fence. Once these gaps are found they will try and force their way through by placing their head through the hole, placing paws on the wire below, and then use their powerful hind legs to push through the fence.

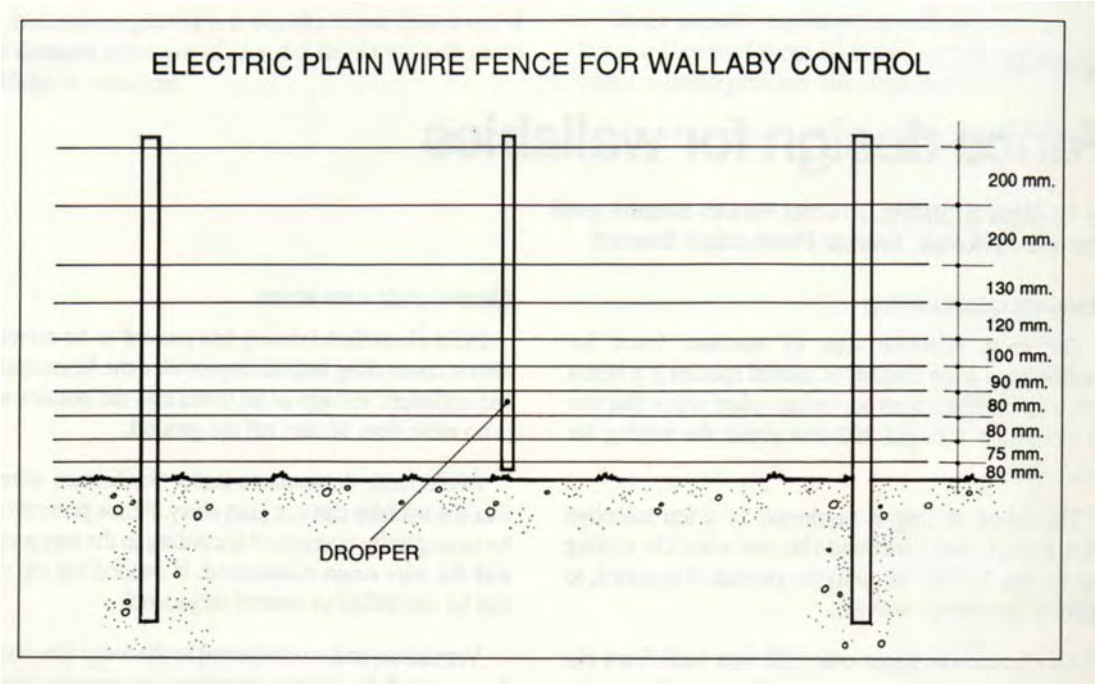
The amount and configuration of the fence will depend on the species to be excluded with the exclusion of smaller species requiring more wires. Some farmers in NSW have suggested that a 3 wire cattle fence can control the larger species. Suggested fencing in western NSW for larger species includes an electrified 7 line plain wire fence, with if necessary, an additional wire to be added at the top by alternating the length of the droppers, or adding leaning electrified offsets close to the ground. Posts should be at a maximum of 20m spacings with droppers at 10m spacings.

Trip wires should be set at 200 mm above the ground and 150mm out from the fence to deter the animal crawling underneath. The trip wire can be mounted on the offsets or attached to insulating wooden posts set in the ground. The fence wires need to be tensioned in an effort to slow down the movement of the animal in order for it to

receive a shock from energisers omitting 60-70 pulses per minute. Research in Tasmania has shown that Wallabies will test out electrified fences and if the fence is switched off for 4-5 days they will re-establish a route through the fence. Electronic fencing should be checked for faults, or, have a device attached to the fence that signals any faults.

In some areas of NSW ringlock or hinge joint has been used with and without electrified offsets and with varying results.

Total wildlife exclusion fencing designs that use a combination of offset wires, galvanised standard rabbit netting, and up to 7 plus hotwires are available, but can be 10 times the costs of normal rural fencing to install.



Wire arrangement for wallaby control.

Hares

Hares are *Lagomorph*s, the same as rabbits, but as *Lepus* species have distinct features that set them apart. The hare has a bigger body and the length of their long black tipped ears is noticeably longer than the rabbits. They are an herbaceous nocturnal feeder preferring tender long grass shoots and more woody plants, but, have the capacity to survive longer than rabbits on lower protein levels and higher roughage levels.

They occupy very exposed habitats and can be seen individually or in small loose groups when feeding. They do not burrow, but live above ground making small depressions in the ground called “forms”. They stay close to these during the day but will travel further during the night. Several forms can be created during the breeding season. As a rule, hares have a life span of 3-4 years.

Hares do not get myxomatosis or rabbit haemorrhagic disease (RHD) which is also known as rabbit calicivirus disease (RCD) but they do get Brown Hare Syndrome which is similar to RCD but is exotic to Australia. They are known to carry internal parasites and fleas similar to rabbits.

Hares will gnaw as well as chew with the gnawing action designed to keep their growing teeth at a functional level. Like mice they do not always eat the material they have just gnawed and will cause economic and aesthetic damage to crops, orchards, gardens, nurseries and shelter belts. They are well known for pruning plants that will result in undesirable growth patterns, nipping new buds and bark off small trees and bushes that in severe cases cause ringbarking and possible death of the plant. Damage is greatest in late winter until spring when weather conditions limit food supply and where overgrazing or drought conditions force hares to attack trees as an alternative food source. Research has shown that that the damage is less in areas that have livestock and where crops have moved to oilseeds (*brassicacea)* species.

Control strategies

Mesh fencing should be at least one metre high and buried 10 cm into the ground. Hare can climb up mesh fencing so that an electrified wire placed 10-15 cm above the ground and 50 to 100 mm off the fence will increase efficiency. An additional two appropriately tensioned wires on the top of the fence is also recommended.

Shooting is a time consuming option that is opportunistic, and results will vary according to the skill of the operator. When disturbed, hares can move at high speeds, making shooting, an inefficient option.

There is currently no poisoning registered for controlling hares. It has been difficult to develop a poison for hares due to their browsing feeding action which does not guarantee the uptake of any bait at the required quantity to be effective.

Deterrents are probably the most widely used option other then exclusion fencing. Aluminium ammonium sulphate, marketed as "D-TER" can be placed around the boundary of the area to be protected.

On young hazelnut stock, tree guards such as aluminium foil or thick plastic placed around the trunk of the plant has been successful in preventing damage. This also assists with sunburn protection to the stem.

Inter- row ground cover and around fence lines should be kept mown. The more the hare feels exposed the less likely it will remain for long periods. If possible, try and include perches that will allow large raptors to roost at the site as this will increase your chances to naturally discourage their presence. This can also assist with bird control.

Trapping is an option but it is also time consuming and not always successful. Soft jaw traps are available that will catch the hare by the foot and hold it firmly until released by the trapper. Cage traps are noticeably different and will entice the hare inside the cage leaving it restricted to the small area inside. Both styles of traps place the onus on the trapper to regularly check the traps to avoid a prolonged inhumane death.

Rabbits

The European rabbit *Oryctolagus cuniculus,* is found throughout most of NSW with the general exception of the black soil areas. Although there is no accurate figure on the present distribution, past surveys indicate that at least three quarters of NSW has some degree of rabbit infestation. Rabbits are most active from late afternoon until early morning, but they can be active at any time if they are undisturbed or if their numbers are high. Activity appears to decrease at night if there are high winds or rain, which limits their ability to detect predators.

Daily movements are generally within 150 to 200 m of the warren but this distance can increase during droughts or decrease during the breeding season. Rabbits usually do not travel vast distances, but movements in excess of 20 km have been recorded.

Rabbits are herbivorous and eat a wide variety of plants including crops, roots, pastures, young trees and vines. Their preference is for short succulent, high protein green grasses. Damage to newly planted hazelnut groves consists of stem damage to young trees and exposure of roots to sunlight and air. In nursery stool beds rabbits can disturb root development of hazelnut suckers. Grazing generally continues throughout the night, varying from 2.5 to 6 hours. Where the warren complex supports a large population of rabbits, feeding grounds or rabbit lawns develop a short distance from the warren with a central dung heap.

The main breeding season is determined primarily by rainfall and the early growth of high protein plants. It usually starts after the autumn break and finishes in late spring but rabbits can breed at any time provided there is short green feed supplying sufficient protein. Under favourable conditions an adult female can produce seven or eight litters in a year.

Control

Control options depend on the level of infestation. Monitoring the numbers is critically linked to control options. There are many types of monitoring. The easiest is visual observation such as sightings and scratchings during the day, or population counts by spotlight at night. Bait stations and the amount of bait consumed during free feeding are more reliable techniques. Transect counts of active warrens i.e. the number of warrens in a straight line, or the proportion of active entrances in warrens, can also be used as a guide to rabbit populations.

Control programs have to be regular and systematic to remain economical and avoid reinfestation. It is strongly advised to link your control program with adjoining land managers to minimise economic and environmental damage. This approach can reduce the population to a level where it does no harm and cannot quickly build up.
Initial control is usually accomplished by a poisoning program, but only during the non-breeding season. If control must be carried out during the breeding season, use ripping or fumigating instead of poisoning.

If a myxomatosis or RHD outbreak is present during the inspection, it might be better to delay control to see if the disease will achieve this initial reduction but extensive control consists of harbour destruction, usually by ripping warrens, using explosives, pressure fumigating, burning fallen logs and eliminating blackberries.

In cold wet climates, apart from drowning in flooded burrows, coccidiosis a disease caused by an internal parasite *Eimeria stiedai,* is more likely to be fatal than myxomatosis.

Poison
The time to poison rabbits is when they are not breeding.

Sodium fluoroacetate more commonly known as 1080 is an effective poison. This substance must be used in accordance with specific conditions stated in the Pesticide Control Order for its use. The conditions will be explained with the purchase of the substance from an authorised control officer. In NSW, this is usually your local Rural Lands Protection Board Ranger.

Carrots are effective rabbit bait, being used extensively throughout more than two thirds of NSW and combining high acceptability with reasonable economy.

Carrot baits are cut in a carrot cutter before the poisoning operation. This cutter should have a swift, clean action that avoids cutting too many small chaffy pieces or large chunks. Baits should be roughly 2 cm on a side and about 5 g in weight.

While carrots are generally recommended, oat grain has certain advantages in dry seasons because it is readily available, suitable for storage, and easier to handle as it does not deteriorate or require processing. Pellets, when available, have similar advantages to oat grain.

It is a requirement of the 1080 Pesticide Control Order for rabbit baits that there is a minimum of three free feeds. Free feeding has two main advantages. Firstly, it provides a guide to the rabbit population and secondly, it allows for a more accurate determination of the amount of poisoned bait required to give maximum knock down yet leave minimum bait for non target species. Rabbits do not feed on the warren, so make sure that trails can circle the warren but maintain a 3–5 metre distance.

Pindone is an alternative bait for rabbits and has a specific control order that must be adhered to.

Chopped carrots are again the preferred bait although manufactured pellets or oats can be used. After mixing, the bait must be bagged, but when using plastic bags, take care to avoid excess bait sweating which can wash the poison off the bait. It is preferable to use bait as soon as it is prepared and keep it cool.

At least two, but preferably three free feeds are suggested at two-day intervals to get an idea of rabbit numbers and to get the maximum effect from the poisoning program.

Warren destruction by ripping
Ripping of warrens is the major type of harbour destruction that can be very useful as a control method. Ripping techniques depend heavily on local conditions such as soil type and position of the warren as well as the equipment available to carry out the work. Only the basics of warren ripping are mentioned here. The land manager will have to rely on local experience to determine what the most suitable techniques for the area are.

It is wise to have barking dogs run over the area to force surface rabbits into warrens before the start of ripping. Backyard dogs are ideal for this task. It is essential to drive over the area thoroughly; otherwise, rabbits forced out of the warrens through social interaction will be missed.

Use tines at least 900 mm long. Start ripping at least 3 m beyond the outermost burrow opening of the warren. This allows the ripper to get to a maximum depth before the warren is reached and increases the chance of ripping tunnels outside the visible warren diameter.

If parts of a warren cannot be ripped because of obstructions such as trees or fences, be sure to fumigate these burrows a few hours before ripping. If ripping near trees or stumps, back up to them and rip away from the trees so that the tines travel along roots and not across them. An alternative ripping technique which can also be used in more hilly terrain is to begin ripping from one of the long sides of the warren, each time reversing over the last rip.

Blasting is a follow-up technique sometimes used to destroy warrens that cannot be ripped. Explosives can only be used by authorised persons.

Fumigation

Fumigation can be very effective for controlling rabbits as a follow-up technique to ripping or blasting. It can also be used for treating small, isolated infestations discovered when doing other work or in places where ripping is undesirable because of the risk of erosion.

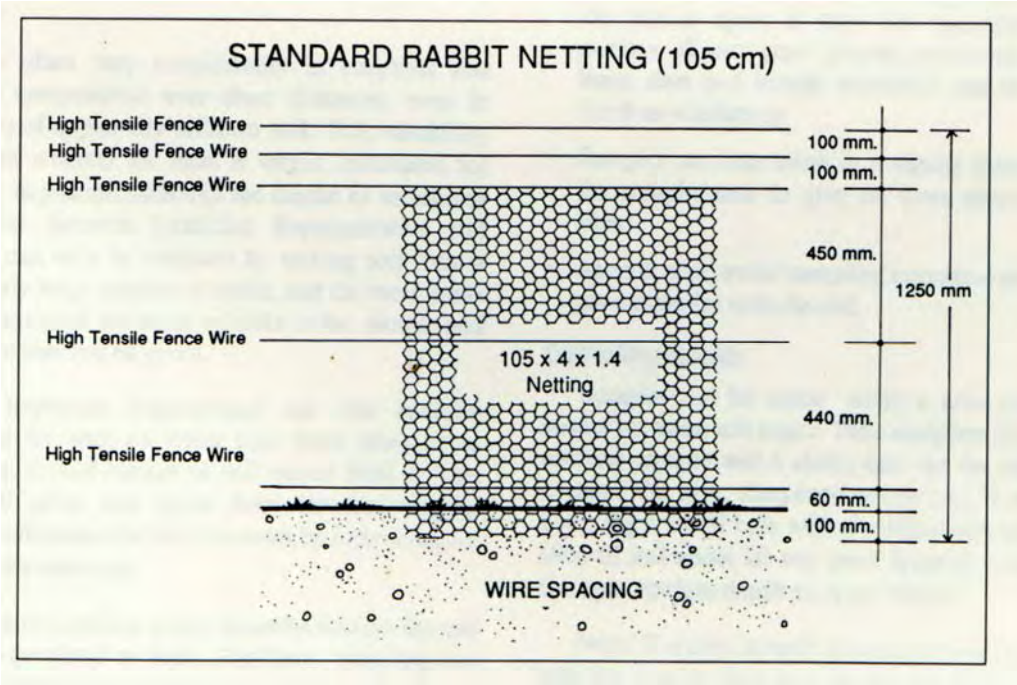
Fumigation is a possible alternative to 1080 poisoning on properties where 1080 cannot be used. Reasons for this can be: the property may be too close to town, the occupier may not allow 1080 (or any other poison) to be used, the removal of stock may not be possible, or the use of poisoning is not advisable because the rabbits are breeding. These are important but rarely considered reasons for using fumigation.

There are a number of types of fumigants. For fumigation to be effective, run dogs over the area to chase rabbits underground. All openings of a warren must be found and sealed remembering that fumigants are also lethal to humans. Labels must be read and safety recommendations followed.

Trapping and shooting are other options. Support and assistance in the co-ordination of the tasks involved can be obtained from your local Rural Lands Protection Boards in the first instance.

Fencing

Rabbit-proof netting fences are very expensive to construct and are generally not used by many landholders. In 2006, the average construction cost for a rabbit-netting fence was approximately $12,000 per kilometre with labour representing approximately 50% of the cost. This cost does not include the extra cost and time involved in rabbit proofing stays and gateways (sections of the fence which are unfortunately often overlooked). In comparison, ringlock/hinge joint fence can be up to 25% cheaper.



A standard rabbit wire netting fence will control a range of animal species

The size of all control programs should be directly linked to the damage caused and not the numbers of species sighted. The most effective control programs usually involve a combined approach by all immediate land managers that is strategically linked to a clear understanding of the species breeding cycle, behavioural and dispersal activities.

Co-ordinated groups of land managers have a greater degree of success when they combine their individual efforts.

Information on vertebrate pest control has been collated from N.S.W Agriculture Vertebrate pest control manual. (see further reading list)

Technology Transfer

Through the life of the project the investigator has liased closely with representatives of the Hazelnut Growers of Australia Ltd R&D committee.

The investigator presented a progress report to the Hazelnut Growers of Australia Ltd, Annual Conference in Canberra in October 2005.

A field walk was provided to interested growers at the recent Hazelnut Growers of Australia Ltd field day held in Orange on the 21st January 2006. This covered pest and disease issues related to hazelnut production, and included discussions on specific bird pests.

Three meetings with representatives from the industry funding body, (Hazelnut Growers of Australia Ltd R&D group) have been held at Orange since June 2005. These discussions have provided progress reports and industry feedback.

The investigator is assisting the Hazelnut Growers of Australia Ltd research and development team, with their efforts to be represented in the National Biosecurity Plan for the nut industry in Australia.

Representatives from major hazelnut processors in Europe, who are interested in growing in Australia, visited Orange in November 2005, and were briefed on the progress of this project.

Calls for sample submissions through the life of the project, were communicated through the "Australian Nutgrower" and the hazelnut growers association news.

An update article was submitted to the "Australian Nutgrower" for the March issue 2006. This article also encouraged growers to submit samples for identification.

Future technology transfer is expected, with components of this report being available on the N.S.W. DPI website and linked to the Hazelnut Growers of Australia Ltd website.

Recommendations

1. Industry support since the projects conception, has been invaluable. The information collated on Australian pests, represents an initial commitment by industry, to better understand the diversity in Australian hazelnut orchards. Growers and nursery operators should continue passive surveillance, and increase knowledge on new pest and disease issues. Once assessed by taxonomists, these can be documented and incorporated onto D.P.I and H.G.A. websites.
2. The movement of host planting material for Big bud mite from Tasmania, to the mainland states, requires a formalised commitment from exporters, and state governments, to reduce the chance of spread of this pest.
3. New AQIS rulings, prohibiting the import of *Corylus* species nursery material (excluding tissue cultures) from some counties, due to the threat of the Sudden Oak Death pathogen, will slow down traditional import pathways for Australian nursery operators. AQIS rulings should be consulted regularly for updates. In light of this, consideration should be given by industry to maintain an Australian repository of 'true to type' material.
4. Consideration should be given, to investigate the hazelnut aphid parasitoid, *Trioxys pallidus*, and its potential use in controlling aphids in Australian hazelnut groves.
5. Most hazelnuts are dried sufficiently, which limits post harvest microbial problems. A better understanding of microbial issues, may provide large processors with confidence to purchase kernels from Australian growers.
6. Limited chemicals are registered for use on hazelnuts in Australia. Options for registration need to be investigated, in particular those related to an insecticide option and the use of sulphur products.
7. Investigations are needed to explain why growers do not implement bird control early enough, and then often implement ineffective controls. The use of less expensive measures, such as decoy food (either from revegetation programs, specially cultivated crops, pasture management or alternative foods such as grain),

and other habitat manipulation approaches to bird damage, may offer effective alternatives to conventional control.

8. Virus indexing of true to type planting material at repository and nursery level would give growers access to virus free material, and associated yield benefits.

Acknowledgements

I wish to acknowledge the financial support provided by Horticulture Australia Ltd, and the Hazelnut Growers of Australia Ltd.

Thanks are extended to staff of the Agricultural Scientific Collections Unit - N.S.W. Department of Primary Industries (DPI) who have enthusiastically supported this project. In particular, Peter Gillespie, Merydyn Davison, Danuta Knihinicki and Dr Michael Priest, for identification of pest and disease samples. Stephen Gottschall assisted with database searches.

I also wish to thank John Tracey, Vertebrate Pest Research Unit, N.S.W. DPI, for bird control strategies. Rob Williamson and David Croft, Agricultural Protection Officers, N.S.W. DPI, contributed information on vertebrate pests and their control. Jennifer Tarleton assisted with layout.

Thanks also to members of the Hazelnut Growers of Australia Ltd (HGA), and other producers and processors, who contributed samples.

Support from the board of the HGA is acknowledged, and in particular, past president, Mr P. Wheelwright, for assistance during the projects initial development. Members of the HGA research and development committee, Lyn McRae, Vanessa Cox, Nicole Schmid and Bruce Thompson also provided support.

Finally I would like to thank Basil Baldwin (University of Sydney - Orange) for access to hazelnut variety evaluation trial plots, and provision of several interstate samples for identification.

Bibliography

AliNiaze, M.T. (1996) Integrated pest management of hazelnuts: A world wide perspective, in Proceedings 4th International Symposium on Hazelnut, Acta Horticulturae No.445, 469-473.

AliNiaze, M.T. (1998) Ecology and management of hazelnut pests. Annual Review of Entomology 43:395-419.

AQIS (2006) Import case details- *Corylus sp.* http://www.aqis.gov.au

Azarenko, A.N., Mehelenbacher, S.A., Smith, D.C., McCluskey, R.L. (2003) Hazelnut Pollinizer Cultivars http://www.extension.oregonstate.edu (Accessed 21/6/06)

Baldwin, B., Snare, L., Gilchrist, K. (1999) A field evaluation of the productivity of hazelnuts. No. 99/6 Rural Industries Research and Development Corp. Canberra.

Braysher, M. and Saunders, G. (2002). Best practice pest animal management. AgNote DAI 279. NSW Department of Primary Industries, Orange NSW.

Duke J.A. (1989) Handbook of Nuts. CRC Press, Florida.

Environment and Natural Resources Committee (1995) Problems in Victoria caused by Long- Billed Corellas, Sulphur-Crested Cockatoos and Galahs, No. 67 session. Victorian Government Printer.

Hetherington, S. (2005) Integrated pest and disease management for Australian Summerfruit. N.S.W. Dept. Primary Industries.

Kay, B.J., Twigg, L. E., Nicol, H. I., and Korn, T.J. (1994). The use of artificial perches to increase predation on house mice (Mus domesticus) by raptors. Wildlife Research 21: 95-106.

Oezdemir, M.and Devers, O. (1999) Turkish hazelnuts: Properties and effect of microbiological and chemical changes on quality. Food Rev. Int. 15 (3) 309-333.

Olsen, J.L. (2002) Oregon State University's integrated pest management program for the Oregon hazelnut industry. Hort. Technology,12 (4)

Painter, J.H., Jones, S.C. (1960) Effect of aphid control on quality and yield of filberts. Proceedings.Or. Wash.,B.C. Nut Grower Soc. 46:23-24.

Pscheidt, J.W., Stone, J. (2001) Diseases of European Hazelnut, online http://www.apsnet.org (Accessed 23 May 2006)

Pscheidt, J.W. (2003) Hazelnut eastern filbert blight plant disease control
http://www.plant-disease.ippc.orst.edu
(Accessed 21/08/03)

Sinclair, R. (2000). Guidelines to best practice bird control to minimise losses in vineyards. Australian Viticulture Mar/Apr: 60-85.

Snare,L., Baldwin, B. (1997) Hazelnut blight: An overview. Australian Nutgrower 2(3)

Teviotdale, B.L., Michailides, T.J., Pscheidt, J.W. (2002) Compendium of nut crop diseases in temperate zones. APS Press.

Tracey, J. and Saunders, G. (2003). Bird damage to the wine grape industry. Report to the Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry. NSW Agriculture, Orange NSW.

Tracey, J. (2004). Managing bird pests in orchards. in Orchard Plant Protection Guide for deciduous fruits in NSW 2004/05 (S. D. Hetherington, J.D. Bright, and W.G. Thwaite, (eds). NSW Department of Primary Industries, Orange NSW: pp 2-5.

Tuncer, C., Ecevit, O. (1997) Current status of hazelnut pests in Turkey. Acta Horticulturae. No. 445:545-552.

Tuncer, C., Saruhan, I., Akca,I. (2005) The insect pest problem affecting hazelnut kernel quality in Turkey. Acta Horticulturae No. 686 367- 369

Tuncer, C. 2006 Hazelnut pests homepage, online
http//www.findikci.net/
(Accessed 23 May 2006)

Further reading related to vertebrate pest control

Bomford, M. and O'Brien P. (1990). Sonic deterrents in bird damage control: a review of device tests and effectiveness. Wildlife Society Bulletin 18: 411-422.

Bomford, M. and Sinclair, R. (2002). Australian research on bird pests: impact, management and future directions. Emu 102: 29-45.

Braysher, M. (1993). Managing Vertebrate Pests: Principles and Strategies. Australian Government Publishing Service, Canberra.

N.S.W. Agriculture (1996) Vertebrate Pest Control Manual 4th edition
N.S.W. Agriculture.

Appendix One

Other pests of hazelnut in Europe

Order	Family	Species
Coleoptera	*Buprestidae*	*Agrilus viridis, Anthaxia smaragdifrons, Agrilus hastilifer Trachys minutus*
	Curculionidae	*Coelides ruber, Anoplus setulosus, A. roboris, A. plantaris Myollocerus spp., Bangasterus orienatlis, Myllocerus spp., Apion dichroum, A. nigritarse, A. semivittatum, Otiorrrhynchus bractialis, Polydrosus alaiensis, P. corrusus, P. micans, P. sparsus P. pterygomalis, , P. urali, P. rufulus Phyllobius schneideri*
	Elateridae	*Quassimus elongatus, Agriotes spp., Synaptus filiformis, Ampedus elongatus, Adrastus limbatus, A. turcicus*
	Tenebrionidae	*Cylindrotus spp., Athous spp.*
	Scarabaeidae	*Hoplia pellinosa, Anomola sp. Melolantha albida, M.pectoralis*
	Scolytidae	*Dryocoetes coryli, Xyleborus xylographus,*
	Chrysomelidae	*Galerucella lineola, Haltica bicarinata, H. nemorum, Chrysolina chalcites, Labidostomis propinqua, Agelastica halensis, A. alni, Psylloides spp., Cassida spp., Cryptocephalus sp., Chrysolina polita*
	Rutelidae	*Phyllopertha lineolata, Anomola osmanlis*
	Clytridae	*Gynandrophtalma xanthapes, Clytra nigrocincta*
	Aphodiidae	*Aphodius fimetarius*
	Oedemeriidae	*Oedemera lurida*
	Mordellidae	*Mordellistana pumila, Mordella aculeata*
Hemiptera	*Pentatomidae*	*Rhaphigaster nebulosa, Eusarcoris inconspicuus, Holcostethus vernalis, Eurydema oleraceum, Piezedorus lituratus, Carpocoris purpureipennis, Dolycoris baccarum, Nezara viridula, Pentatoma rufipes*
	Aconthosometidae	*Coreas marginales*
	Miridae	*Pantilius tunicatus, Pylus coryli*
	Coreidae	*Gonocerus acuteangulatus*
Homoptera	*Aphididae*	*Corylobium avellanae,*
	Coccidae	*Puvinaria sp., Aspidiotus ostreaformis,*
	Diaspididae	*Quadraspidiotus ostreaeformis*
	Cicadellidae	*Typlocyba spp., Eupteryx sp., Edwardsiana spinigera, E. collina, Ledra sp., Cicadella viridis, Zyginia sp., Frutioidia bisignata*
	Issidae	*Issus coleoptratus*
Lepidoptera	*Tortricidae*	*Spilonata ocellana, Caccocia rubeana,*
	Gracillaridae	*Phyllanorycter sp., Lithocolletis corylifoliella, L. scitella Parornix davoniella*
	Lyonetiidae	*Leucoptera scitella*
	Lasiocampidae	*Malacosoma neustria*
	Coleophoridae	*Coleophora badipenella*
	Cossidae	*Zeuzera pyrina*
	Nepticulidae	*Nepticula floslactella, N. malella*
	Noctuidae	*Pyrrhia umbra, Heliothis armigera, Orthosia incerta*
	Geometridae	*Operophtera brumata*
Diptera	*Cecidomyiidae*	*Contarinia coryli, C. corylina*
Orthoptera	*Tettigoniidae*	*Isophia tenuicerca, Poecilimon sp. Phaneroptera nana nana*
	Gryllidae	*Oecanthus pellucens*
Acarina	*Tetranychoidea*	*Tetranycopsis horridus, Tetranychus sp., Panonychus ulmi, Eotetranychus carpini*
	Eriophyidae	*Aculus comatus, Tegonotus depressus*

Appendix Two

Parasitoids of hazelnut pests

Order	Family	Species	Host
Diptera	*Tachinidae*	*Compsilura Cincinnati*	*H. cunea*
		Exorista larvarum	*H. cunea*
		Gymnosoma rotundatum	*Palomena prasina, Piezodorus spp., H. cunea*
		Nemoraea pellucida	*H. cunea*
		Pales pavida	*H. cunea*
		Sylindromyia bicolor	*Raphigaster nebulosa*
Hymenoptera	*Aphelinidae*	*Aphytis mytilaspidis*	*L. ulmi*
	Braconidae	*Agathis rufipes*	*G. dealbana, Spillonata ocellana*
		Apanteles pallipes	*G. dealbana, Aphid*
		Apanteles spp.	*G. dealbana, H. cunea, S. ocellana*
		Aridelus sp.	*P. prasina*
		Bracon sp.	*G. dealbana, Lepidoptera, Aphid*
		Chrobus sp.	*?*
		Eubadizon pallipes	*G. dealbana*
		Macrocentrus grandii, M. thoracicus	*G. dealbana*
		Meteorus fragitis	*G. dealbana*
	Encyrtidae	*Anabrolepis zetterstedtii*	*L. ulmi*
		Apterencrytus microphagus	*L. ulmi*
	Euloohidae	*Tetrastichus sp.*	*Mikomyia coryli, P. avellanae, C. vermiformis, Mite*
	Ichneumonidae	*Apechitis compunctor*	

Appendix 3

Predators of hazelnut pests

Order	Family	Species	Host
Acarina	*Phytoseidae*	*Ambrlydromella rhenana*	*Mite*
		Amblyseius aberrans	*Phytoptus avellanae, Cecidophyopsis vermiformis, Mite*
		A. masseei	*Mite*
		A. potentillae	*Mite*
		Phytoseiulus macropilis	*Phytoptus avellanae, Cecidophyopsis vermiformis, Mite*
		Phytoseius finitimus, P. echinus	*Mite*
		Typhlodromus sp.	*Mite*
	Tarsonemidae	*Polyphagotarsonemus sp.*	*Mite*
		Tarsonemus sp.	*Mite*
	Trombiidae	*Allotrombium sp.*	*Lepidosaphes ulmi, Mite*
	Tydeidae	*Tydeus sp.*	*Mite*
	Coccinellidae	*Adalia bipunctata, A. decempunctata,*	*Aphid*
		A. fasciatopunctata	*Aphid*
			Aphid
		Chilocorus bipusttulatus	*Aphid, L. ulmi*
		Coccinella septempunctata	*Aphid, Mite, Coccidae*
		Exochomus quadripustulatus	*Aphid*
		Harmonia quattuordecimpunctata	*Aphid, Mite, Coccidae*
		Hyperaspis campestris	*Aphid*
		Propylae quattuordecimpunctata	*Aphid, Mite, Coccidae*
		Psyllobora vigintiduopunctata	*Aphid*
		Scymnus apetzi	*Aphid*
		Subcoccinella vigintiquatuorpunctata	*Aphid*
		Synharmonia conglobata	*Aphid*
		Vibidia duodecimguttata	*Aphid*
Dermaptera	*Forficulidae*	*Forficula auricularia*	*Aphid*
Diptera	*Cecidomyiidae*	*Arthrocnodax coryligallarum*	*P. avellanae, C. vermiformis*
	Syrphidae	*Episyphus balteatus*	*Aphid*
Hemiptera	*Anthocoridae*	*Cardiastethus nazarenus*	*?*
		Orius minitus	*P. avellanae, C. vermiformis, Aphid, Mite*
		Orius sp.	*Aphid, Mite*
	Miridae	*Cyphodema instabilis*	*?*
		Deraeocoris lutescena,	*Aphid, Mite*
		D. ruber	*Aphid*
		Malacocoris chlorizans	*Mite*
		Phylus coryli, P. melanocephalus	*Aphid*
		Pilophorus pusillus	*Aphid, Mite*
		Plagiognatus bipunctatus	*Aphid*
		Psallus salicellus	*Aphid, Mite*
	Nabidae	*Himacerus apterus*	*Aphid*
		Nabis rugosus	*Aphid*
	Reduviidae	*Nagusta goedeli*	*Aphid*
		Rhinocoris iracundus	*Carpocoris pudicus, Gonocerus acuteangulatus, Hyphantria cunea*
Neuroptera	*Chrysopidae*	*Chrysoperla carnea*	*H. cunea, Mite, Diaspididae, Aphid*

Appendix 4

Harmful and beneficial mite species

Harmful mite species

Order	Suborder	Family	Species
Acariformes	*Prostigmata*	*Eriophyidae*	*Phytoptus avellanae*
			Cecidophyopsis vermiformis
			Aculus comatus
			Tegenotus depressus
			Anthocoptes loricatus
			Phyllocoptes lamimani
			Phyllocoptes coryli
		Tetranychidae	*Tetranycopsis horridus*
			Eotetranychus coryli
			Tetranychus sp.
		Tarsonemidae	*Tarsonemus karli*
			Tarsonemus lobosus
			Stenotarsonemus sp.
			Brevipalpus obovoides
			Tenuipalpidae

Beneficial mite species

Order	Suborder	Family	Species
Parasitiformes	*Mesostigmata*	*Phytoseiidae*	*Kampimodromus aberrans Oudemans*
			Phytoseius echinus
			Phytoseius finitimus
			Typhloctonus tiliarum
			Paraseiulus soleiger
			Euseius finlandicus
			Amblyseius andersoni
			Amblyseius potentillae
			Amblyseius cucumeris
			Amblyseius sp.
Acariformes	*Prostigmata*	*Ascidae*	*Blattisocius tarsalis*
		Tydeidae	*Tydeus californicus*
			Tydeus caudatus
			Pronematus elongatus
		Stigmaiedae	*Zetzellia mali*
			Mediolata sp
		Anystidae	*Anystis sp.*
		Bdellidae	*Bdella sp.*
		Cunaxidae	*Cunaxa sp.*
		Trombidiidae	*Trombidium sp.*

APPENDIX 5

Hazelnut Pest and Disease Fact Sheets

Powdery Mildew

Photo: J. Pscheidt

Powdery mildew is a minor disease in Australian hazelnut plantings, and in most cases, the disease is not severe enough to warrant control. Colonies appear mid to late season, when the weather is hot and humid. They appear as a dusty white covering, and eventually cover the surface of infected leaves. The fungi is readily disseminated by wind. Some growers have observed that infected hazelnut leaves occur near pome and vineyard plantings. Identification of the fungus causing powdery mildew in Australia has been difficult, due to the small number of samples submitted for analysis. In other parts of the world, hazelnut is the type host of *Phyllactinia guttata*, which has been reported on other nut crops.

Preventative control includes pruning to an open canopy which maximises air movement and reduces humidity. No chemicals are specifically registered for use on hazelnut in Australia.

Armillaria root disease

Gumming associated with Armillaria.
Photo: F Baker, Utah State University

Armillaria is a soil inhabiting fungus which causes root rots. Species of *Armillaria* are native to forests worldwide, and most infections arise because orchard blocks are planted on recently cleared land which contains infected native trees; especially wattles.

Foliar symptoms include poor shoot growth, defoliation, branch dieback, premature yellowing and stunted leaves.
The presence of white, fan-shaped mycelium (fungal strands) between the bark and the wood, indicate infection. In severe cases the wood on the tree can be stringy, and light golden coloured mushrooms can grow around infected trees in autumn.

Spread, is via roots of the hazelnut coming into contact with other infected roots. Where possible previously infected root material should be removed from the orchard and burnt. Infection is common in light sandy soils, and the history of new blocks should be considered, before they are planted.

Eastern Filbert Blight

Ansiogramma anomala

Photo J. Stone, Orgeon State University

Eastern filbert blight is a destructive disease of European hazelnut and is known to occur only in North America. The disease was initially noted in Washington State, and then spread to the Willamette valley in Oregon. The fungus has a life cycle of two years and a 15-month latent period when no symptoms are visible. Spread is by wind driven rain, and splashing droplets onto shoots. Trees become susceptible during leaf out and during initial shoot elongation. The disease is often not identified for some years, following an initial infection.

Although not present in Australia, growers should be aware of symptoms and observe their orchards in spring. The pathogen typically develops under the bark of diseased branches, causing raised bumps down the parrel line of the branch. Wilting and dead leaves attached to a branch in summer can also be symptomatic. Cultivars differ in their susceptibility and growers may wish to consider this when establishing new plantings. Varieties such as Daviana and Ennis are highly susceptible. Barcelona, Butler, Halls Giant and Willamette have intermediate susceptibility. Lewis has better tolerance than Willamette.

Control strategies include application of fungicides in spring, pruning of infected branches and use of resistant varieties.

Bacterial Blight

Xanthomonas arboricola pv.corylina

Early stage of bacterial spotting.
Photo: BC Ministry of Agriculture, Food & Fisheries

Hazelnut Blight.
Photo: L. Snare

Hazelnut blight is one of the most debilitating diseases effecting hazelnut production in Australia. The first record of occurrence of bacterial blight on hazelnut in Australia occurred in Victoria in 1980.

The disease is caused by *Xanthomonas corylina*, a bacterium that affects the buds, leaves, branches and trunk. Occasionally it attacks the nuts and spotting is observed on the husks. Varieties to leaf out early, which can be associated with early spring rains, are often affected by early blight strikes.

Hazelnut blight is most injurious to trees up to four years old. Trees more than four years old rarely die following infection, but nut yields maybe reduced through the loss of nut bearing branches. Poor environmental conditions, such as sunscald, poor soil drainage, moisture stress, cold injury, mechanical equipment damage, pruning cuts and general cultural neglect, can contribute to making trees susceptible to blight.

The first infection on current season stems, consist of dark green water soaked areas on the bark, turning to reddish brown. One and two year old twigs are attacked and

killed. Infection occurs through wounds, blighted buds and shoots of the current seasons growth. Dead leaves often cling to diseased stems for longer periods when compared against normal leaf fall.

Heavy dew, hail, and exposure to high winds causing mechanical rubbing to leaves, also favour the development of hazelnut blight. Observations of heavily protected sites from wind, have shown a tendency for a decrease in blight symptoms.

Protective copper based sprays in the late summer; autumn (three quarter leaf fall), winter, and early spring, are the current means of control. Copper applications create a protective coating, where spores are destroyed as they contact the treated surface. A number of copper products are registered for hazelnuts.

In seasons of heavy winter rainfall, two to three applications may be required. A suitable spreader – sticker, will make these treatments last longer.
Effective containment of this disease evolves around; securing disease free planting material, using appropriate copper based sprays; and maintaining good sanitation in the orchard. Removal and destruction of infected plant material, including dead trees, will decrease the chances of inoculum spreading.

Hazelnut Mosaic

(Various pathogens)

Apple mosaic virus symptom.
Photo: J.D. Postman. USDA

Hazelnut mosaic, is a widespread disease in Europe, and was first recorded in 1957. In Australia, it is not widespread, but symptoms indicative of virus patterns have been observed in hazelnut variety trials. Leaf symptoms include general yellowing, yellow rings and lines. Infected trees may also be symptomless. Apple mosaic virus, (ApMV) is commonly associated with mosaic symptoms, and can cause reduction in yield. In young trees a small reduction in vegetative growth can occur. Trials in Spain indicate no reduction in nut size or quality.

ApMV occurs world wide in apple and birch trees, and is spread largely by vegetative propagation. Chemical control is totally ineffective against viruses. Avoid planting and propagating with virus infected material or if possible, avoid any material, which has not been virus-tested. ApMV is best detected by ELISA testing.

Aspergillus Species

Aspergillus on the surface of stored hazelnuts.
Photo: L. Snare

Aspergillus is a genus of around 200 fungi (moulds) found worldwide. The aflatoxin-producing *Aspergillus* species, is a saprophytic fungi, commonly found in areas of the world with hot humid climates. The moulds, *Aspergillus flavus* and *Aspergillus parasiticus*, can produce the toxin aflatoxin. If batches of hazelnuts intended as a human foodstuff are affected by this toxin, the product can no longer be used for human consumption. Hazelnut samples from the central tablelands of N.S.W. have been identified with this fungus.

Post harvest handling has a major influence on hazelnut mycoflora, and nuts with fungi are usually colonized by several fungi, rather than by a single species. Usually, hot humid conditions lead to mould growth on the nuts and to high levels of aflatoxin. Improper storage conditions can lead to aflatoxin contamination after crops have been harvested. If a long delay is anticipated, nuts should be stored under controlled conditions to prevent aflatoxin production, and to keep them dry, and protected from insects and rodents.

Harvesting of nuts should begin as soon as practicable after maturation, to minimize diseases caused by fungal attack and insect infestation.
Containers, equipment and machinery that have been used for harvesting operations should be cleaned and stored to reduce contamination with fungi, chemicals, fertilizers or toxic substances.

Processors need to establish good quality control, traceability/product tracing and safety procedures at every step in the processing sequence, to avoid cross contamination of aflatoxins between various lots of nuts during processing.
If contamination is suspected, the orchard floor should be cleared of litter and debris to reduce the colonization of *Aspergillus* fungi in the orchard

Nuts should be dried as soon as possible. The drying rate and heat intensity should be determined by the intended end use of the final nut product.

Nuts should not be used for processing, unless they are free from obvious faecal contamination, infestations, decomposition and other defects. Precautions need to be taken to reject insect-damaged or split nuts because they can be associated with a risk of aflatoxin contamination. Finished processed products, raw kernels or in shell nuts, should be of the appropriate moisture, and packaged so as to maintain their quality under normal transportation and storage conditions.

Painted apple moth

Teia anartoides

Painted apple moth larvae.
Photo © NSW Department of Primary Industries

Adult male painted apple moth.
Photo © NSW Department of Primary Industries

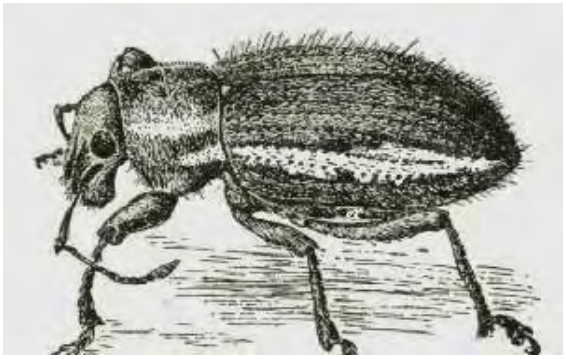
The Painted apple moth is an Australian native insect, and has been recorded on hazelnuts in N.S.W. in low populations. Its host range includes apple, stone fruit, pine, acacia and various ornamentals. Damage occurs in spring, summer and autumn.

Caterpillars make small, window pane like injuries, on the leaf surface and later skeletonize the leaf. There are normally several generations each year, and in most orchards it is usual for only a few trees to be infested. Damage has not been observed on developing nuts or husks.

Painted apple moth is not established in Western Australia, where a surveillance program is maintained for this species.

White fringed weevil

Naupactus leucoloma



The White fringed weevil is able to feed on a wide range of plant species, which includes grape, peach and willow. Significant damage to hazelnut in Australia has occurred in the Braidwood region of N.S.W., and the pest is widespread in Victoria and Western Australia.

Adults feed on the leaves, and low population densities can cause significant damage. It is the damage caused by larval feeding that causes most concern. Larva pupate in the soil in early summer, and adults emerge later in summer. Larvae feeding on roots are noticed when plants show stress, become yellow and are stunted. With newly planted nursery whips fibrous roots are attacked, and the main root can be severed to a depth of 12cm. Ants and wireworms feed on this pest in the field whilst birds feed on adult beetles. Poultry can be used to reduce weevil numbers and around 50 birds per hectare will appreciably reduce weevil numbers.

Chemicals, if necessary should be confined to butt sprays and to the soil immediately around the trunk. Pesticide registration for use on hazelnut plantings is limited and chemicals should be used as a last option.

Plum Scale

Parthenolecanium corni

Over wintering scales.
Photo : L. Snare

Plum scale, *P. corni* is present in Victoria, Tasmania and has also been recorded in hazelnut orchards in the Central West of N.S.W. Scales are closely related to aphids, mealy bugs, and whiteflies which have piercing- sucking mouthparts. Large infestations can kill twigs, retard growth, and produce quantities of honeydew. Over wintering, occurs as an immature scale, or a fertilized female on twigs and branches. They resume feeding in the spring, and eggs are laid underneath the scales. These eggs hatch in early summer, and crawlers migrate to the underside of leaves and begin to feed.

Sooty mould development on the honeydew can give the tree a blackened, sticky appearance. Nuts and husks can be occasionally stained, and although the mould is not feeding on the plant, it can restrict the light reaching the leaves.
Wind is the main source of dispersal but scale is also spread on propagating material.

Chemical control is timed to target the over-wintering scales, using oil sprays while trees are dormant. Ornamental trees and neglected fruit trees can be alternate hosts, and infested trees should be treated. Infested branches should be removed and burnt before crawlers emerge.

Lacewings are aggressive predators of scale and can assist with biological control.

Fruit tree borer

Maroga melanostigma

Borer larvae tunnelling.
Photo L. Snare

Damage to hazelnut stems.
Photo L. Snare

The fruit tree borer, *Maroga melanostigma* can cause severe damage to hazelnuts by ringbarking the tree, weakening laterals, and boring tunnels into the wood. Infestation is usually in the fork of the tree, and is evidenced by a fine sawdust-like frass on the surface. Control measures are limited to scraping away the sawdust-like material, and flooding the entrance holes with a registered insecticide, or infiltrating the borer hole with a thin piece of wire and piercing the larva.

Chemical control to prevent egg laying and damage from the new generation of insects may be an option. Effective control is difficult, because the borer is exposed to the insecticide only during the period when it hatches from the egg, and before it bores into the tree. External trees in a block tend to be affected first, and where infestation is high, entry points have been observed where larger pruning cuts have been made.

The use of a small parasitoid wasp, *Trichogramma*, as a biological control agent is currently under investigation in Australia.

Loopers

Family: *Geometridae*

Adult moth.

Lepidopteran eggs on hazelnut leaves.

This geometrid was reported from the Mudgee district of N.S.W. with caterpillars feeding on developing catkins. The caterpillars are either green or brown in colour, and are normally hairless with a slender body. Caterpillars are well camouflaged, as are the adult moths, which press against the plant surface with outspread wings for concealment.

Caterpillars feed on a wide host range which includes walnut, gum and acacia.

At this point in time, damage from the Geometridae in Australia, is of little economic importance.

Hazel aphid

Myzocallis coryli

Aphids on underside of the leaf.

Adult lady beetles.

Hazel aphid is a common pest in Australian hazelnut plantings, and the biology is well documented. Aphids feed on the leaves in spring and early summer, causing the leaves to become yellow and drop. In heavy infestations, honeydew is produced which aids the development of sooty mould in the tree. Nuts can be stained with residue and nut size and fill ratios are also reported to be affected. In mid summer, aphid numbers decline due to high temperatures. In the autumn aphids produce eggs, which are deposited in cracks and around bud scales.

Preventative strategies, which encourage biological control, are preferred. Ladybird beetles are an active and voracious predator of many aphids. Oil sprays at bud swell are used in other crops to control aphids and can be used successfully to smother eggs. At this point in time no aphicides are registered for use in Australia on hazelnuts.

Over use of nitrogen can encourage excessive young growth, which is attractive to aphids. Water shoots should be pruned out, and weed hosts controlled, to avoid build up of high aphid populations.

Big bud mite

Phytoptus avellanae

Expanding enlarged buds.

Close up of enlarged popcorn like buds.
Photo: L.Snare

The big bud mite (also known as filbert bud mite and hazelnut gall mite), *Phytoptus avellanae*, is known to be a problem in most of the major hazelnut production areas around the world. This mite has long been associated with the formation of excessive large buds in hazelnuts and causes economic losses.

Specific plant damage is indicated by enlarged buds whereby infested terminal buds become swollen and deformed. Bud deformation also occurs in which the development of leaves, blossoms and fruits are affected.

Big bud mite infestation first becomes obvious during late summer and early autumn. Affected buds become spherical and swell to several times their normal size, reaching about 10 mm in diameter. These buds are prone to desiccation and fall from the tree prematurely). The big bud mite can affect both the vegetative and flower buds of hazelnut trees.

Big bud mites living within buds are protected from adverse conditions during the cold months of winter. However, they are subject to desiccation by warm, dry air when they start to migrate to new leaf buds during spring.

Loose bud cultivars including Royal and Daviana are more sensitive to Big bud infestation. Varieties such as Butler, Daviana, Ennis, Negret and Tonda Gentile delle Langhe are reported to be highly susceptible. Barcelona, Tonda Romana, Riccia di Talanico and Halls Giant are reported as resistant.
Lewis has a moderate level of resistance. Willamette and Casina have an intermediate level of tolerance.

In Australia, there are no registered chemicals for the treatment of Big bud mite. Studies in Europe indicate that a single application of Sulphur 80% WP (400 g/100 L) before the peak period of mite migration from old big buds to new buds has proven to be effective in keeping mite numbers low. Monitoring should determine the timing of

application and leaf out dates can act as a guide. Early varieties such as Tonda di Giffoni can commence late August and Halls Giant late September.

An alternative to chemical sprays is that swollen buds can be picked off and burnt during autumn and winter before mites emerge in spring.
Naturally occurring predators, such as phytoseiid mites, may also help to keep mites in check. In Australia, the pest is only known in Tasmania.

Weevil

Aades cultratus

Larvae of Ades cultratus.
Photo: L. Snare

This weevil is a member of the *Curculionidae* family and was recorded on hazelnut in Victoria in 2005. Damage resulted in the death of older hazelnut trees over two years. The larvae are about 6mm long, fat and white with a brown head. Damage is caused by a boring action into the cambium and then ringbarking of the tree. Adults are characterized by an elongated head and mouth, which they use to chew holes in plants for food and to make egg chambers.

Almost all weevils are associated with woody plants and feed upon: wood, cambium, roots, leaves, seeds, fruits, flowers and terminal shoots. Wood boring weevils are common, can cause significant damage, and usually take advantage of decreased plant resistance.

Mealybug

Mealybug on emerging hazelnut suckers.
Photo: L. Snare

Corylus species are susceptible to mealybugs which belong to the same group of insects as scales. They can be an occasional problem. Damage is most likely to be significant in the nursery-stool bed environment and where apple blocks are planted close by. The photos show mealybug attacking the roots just below the level of the soil, especially where the root and the stem meet.

These insects are small (< 6mm in length) and are covered in a woolly substance. The bodies are oval shaped and can be white to an off pink in colour. Their body fluid is usually pinkish in colour when squashed. They have waxy filaments around the body.

Mealybugs excrete honeydew as a waste product following feeding and this is a medium for the growth of sooty mould fungi. Trees infected with mealy bug tend to develop a coating of black, soot like fungus, on the surfaces of branches and leaves. This blemish results in a reduction in quality and reduces the light available for photosynthesis. Mealybug has not been a problem in above ground parts of the tree.

Ants are also commonly associated with mealybugs. Mealybugs are preyed upon by many natural enemies including predatory ladybirds (*Cryptolaemus montrouzieri*) and Lacewings.

Noctuid Moths

Family*: Noctuidae*

Noctuidae larvae which has emerged from the nut.
Photo: L. Snare

This family is the largest in moths, with some 25,000 known species in the world.

The moths have scales covering their wings and can usually be distinguished from butterflies by their antennae, which are typically threadlike or feathery. The caterpillars eat voraciously, are distinctive, smooth, and have very few hairs.

The family includes pests of crop plants and includes cutworms and armyworms. Some are called semi- loopers due to the movement of the caterpillar. They live near the soil surface and can chew off young plants above ground level. Others climb the trees and feed on leaves and other parts. The above sample was collected in the Mudgee district of N.S.W. and found to be eating the nut. This sample could be identified to family level only, but is of interest due to the damage caused to the nut.

Heliothis sp. are also associated with this family and have been noted feeding on hazelnut, and a range of deciduous fruit trees in central N.S.W. Clovers, medics and a wide range of weeds, are hosts for larvae.

Wingless grasshopper

Phaulacridium vittatum

Wingless grasshopper feeding on hazelnut leaves.
Photo: D. Campbell

The wingless grasshopper is a native insect that feeds on a great variety of plant material. They are widely distributed in pastures in eastern and southern Australia, and appear in orchards from December to February. Their distribution is related to rainfall. In dry summers, these pests move into orchards only when other sources of herbage and broad- leafed plants become limited. In hazelnut orchards damage usually occurs in the lower branches. In severe infestations, trees can be defoliated, with young trees the most likely to be affected. No damage has been noted to nut husks and developing nuts. Wingless grasshoppers lay eggs in open, dry, bare patches of soil. Egg beds can be destroyed if located early in the season, which will assist in controlling emerging grasshoppers in September and November.

Baiting, spot spraying and strip spraying around the perimeter of orchards can be effective in protecting orchard blocks. Effectiveness is increased if grasshoppers have not yet entered the block. Where pesticides are not used, poultry in the block maybe a control option.

European earwig

Forficula auricularia

Earwigs concealed in the hazelnut husk.
Photo: L. Snare *© NSW Department of Primary Industries*

The European earwig, *Forficula auricularia*, is an occasional inhabitant of hazelnut orchards and can be found at the join between the nut and the husk. Earwigs are brown elongate insects with distinctive pincers at the ends of their abdomens.

Earwigs can be associated with nuts that are discoloured and damp around the basal scar. They are nocturnal and nest during the day in cool shady places. The chewing mouth parts maybe a problem in nursery stool beds where growth is young and succulent. Adults can migrate onto young suckers in spring and feed on foliage. Generally they are considered to be of a nuisance value only. Over-wintering occurs at ground level in underground nesting chambers. Tree guards can also become a nesting site for earwigs, and if they are not necessary, should be removed.
Earwigs show a preference for live prey, particularly aphids, and are reported to feed on European red mite and some scale species.

Faggot case moth

Clania ignobilis

Stick like cases conceal the caterpillar.
Photo: L. Snare

Case moth is a common name given to caterpillars which make coverings of silk and woody debris as protection. Different case moths attack different plants but between them they can feed on a wide range of plants and can cause damage to leaves. The faggot case moth is in the *Psychidae* family and known to feed on gum trees.

This species makes cases about 40mm length, some with one or two of their sticks being much longer than the other.

The caterpillars are very mobile and can move readily between trees. Each species make cases in different shapes. The case has two openings, one at the top and other at the bottom. The caterpillar comes out from the top to feed and ejects the waste from the bottom end. The bottom opening, which is smaller than the top, is also the exit hatch for the emerging adult.

Control is usually unnecessary, however, hazelnuts in the Canberra region have suffered from heavy infestations in the past.

Nut Weevil

Curculio nucum

Adult weevil

This weevil is one the most destructive pests in Europe and Asia, but is not present in Australia. Adult weevils feed on flowers, buds and young foliage. Major damage is due to feeding on developing nuts that drop prematurely. Females make small holes on the nut surface and deposit eggs. Upon hatching, the larvae puncture the developing nut and chew on the kernel. Fully grown larvae drop to the ground and overwinter under infested trees. Larvae can hibernate for 2-3 years in the top 15cm of soil. Thin shelled varieties are reported to be at greater risk of damage than thick shelled varieties.

Other host plants include pear, peach, plum, apple and cherry.
Weevil infestation is a problem occurring frequently in hazelnut kernels. It generally originates in the producing country and makes the produce inedible and worthless. Imports from Turkey to other European countries, exhibit an elevated susceptibility to damage in the early summer. This is normally associated with products from previous harvests.

The quarantine regulations of the country of destination must be complied with. A phytosanitary certificate, and fumigation certificate, may have to be enclosed with the shipping documents.

Fungicides registered for use on hazelnuts

Fungicide	Nufarm copper oxychloride fungicide/bactericide	Copper present as copper oxychloride
Fungicide	Lancop 500 WP fungicide	Copper present as copper oxychloride
Fungicide	Runge agrichems copper oxychloride-WP agricultural fungicide / bactericide	Copper present as copper oxychloride
Fungicide	Oxydul DF fungicide	Copper present as copper oxychloride
Fungicide	Country copper oxychloride 500 WP fungicide	Copper present as copper oxychloride
Fungicide	Agcl-parkens copper oxychloride WP fungicide	Copper present as copper oxychloride
Fungicide	Tradewyns copper oxychloride fungicide	Copper present as copper oxychloride
Fungicide	Ospray copper oxychloride-WP agricultural fungicide/bactericide	Copper present as copper oxychloride

Insecticides registered for some nut crops other than hazelnuts

Insecticide	Natrasoap insecticidal soap spray	Potassium salts of fatty acids
Insecticide	Naturalure fruit fly bait concentrate	Spinosad
Insecticide	Multicrop bugguard insecticide concentrate	Glycerol 99.5% / potassium hydroxide - flake / potassium salts of fatty acids / water
Insecticide	Natrasoap ready to use insecticidal soap spray	Potassium salts of fatty acids
Insecticide	Multicrop bugguard insect spray	Potassium salts of fatty acids

Source: Australian Pesticides and Veterinary Medicines Authority