Project title:	Outdoor salads: Literature review of the effects of mechanical, ultrasonic and sonic shock on insects as potential approaches to insect control
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Project leader:	Professor Mark Tatchell
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GROWER SUMMARY

Headline

A desk study has identified a limited number of potential approaches to the physical removal of insects from plants that are worthy of further study. The primary opportunity is to develop and refine pneumatic methods through a detailed study of fluid mechanics combined with an understanding of how vibration and insect anaesthesia may dislodge insects from plants. There are no financial benefits to be gained by growers from this desk study.

Background and expected deliverables

Growers of outdoor salad crops are continually seeking new approaches to control and remove insects from crops. This is because:

- Reviews of approved insecticides are resulting in fewer chemicals being available for use.
- The desire by retailers and consumers for less pesticide use on food crops, particularly those eaten fresh and without processing
- The high quality expectations of retailers and consumers that demand produce free from pests and 'casual intruders'.

An earlier desk study done by Professor Chris Pearson (FV 253) explored potential engineering solutions for crop protection in outdoor salad crops. Subsequent workshops identified the potential for mechanical and electromagnetic approaches to the removal of insects from growing crops. However, before any experimental or practical work can be done, the available knowledge must be reviewed.

This project will deliver:

- A review of the available knowledge of mechanical means of removing insects from plants
- Priorities for the further development of mechanical methods to remove insects from plants.

Summary of the project and the main conclusions

The scientific literature was accessed via the "Web of Knowledge" and reviewed. Additionally, the World Wide Web was searched for electromagnetic and mechanical approaches to the removal of insects from plants that might be available commercially. A workshop with the HDC and engineers reviewed the engineering practicality of emerging findings and identified a small number of options for more detailed review. The following priorities, which may be suitable for further research leading to a mechanical approach to insect control in salads, were identified:

1. *Pneumatic devices have potential for removing insects from plants, but careful design is required to maximize efficiency in salad crops. The topics worthy of further study are:*
    - *the application of fluid dynamics to the airflow around plants to maximize the removal of insects*
    - *the study of vibration to remove insects from plants.*
2. *There may be opportunities to combine insect anaesthesia with pneumatic approaches to the removal of insects.*

Further development work will be required to develop and test systems that are usable in salad crops.

Financial benefits

There are no financial benefits to be gained by growers from this desk study.

Action points for growers

There are no recommended changes to current growing practice for the removal of pests and casual intruders from salad crops.

SCIENCE SECTION

Background

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2. The desire by retailers and consumers for less pesticide use on food crops, particularly those eaten fresh and without processing
3. The high quality expectations of retailers and consumers that demand produce free from pests and 'casual intruders'.

An earlier desk study done by Professor Chris Pearson (FV 253) explored potential engineering solutions for crop protection in outdoor salad crops. Subsequent workshops identified the potential for mechanical and electromagnetic approaches to the removal of insects from growing crops. However, before any experimental or practical work can be done, the available knowledge must be reviewed. This project reviews the available knowledge.

Project objectives

The overall aim of the project is to review the available knowledge on the interaction between insect pests and "casual intruders" to mechanical shocks, including electromagnetic or acoustic, as a basis for dislodging insects from plants, and to prioritise opportunities worthy of further investigation.

The specific objectives to achieve this are:

1. Review current knowledge on the response of insect and vertebrate pests and casual intruders to "mechanical" stimuli.
2. Present findings to a combined group of growers and engineers.
3. Define and prioritise opportunities for further levy-funded research.

Approach

The available scientific literature has been searched primarily through the Web of Knowledge. The World Wide Web has also been searched for other information and knowledge, but in this case the information was included only if at least some of the claims made could be validated. Searches were not confined to the pests of salad crops but looked at arthropods more widely. A number of review articles from the Annual Review of Entomology were also used as a way into the relevant literature (Foster & Harris, 1997; Spangler, 1988; Alexander, 1967; Vincent *et al.,* 2003; Claridge, 1985; Čokl & Virant-Doberlet 2003).

Two general approaches have been adopted:

1. Identify and investigate potential physical approaches to insect control without regard to insect biology
2. Take knowledge of insect biology as a starting point and determine whether this can be modified by physical methods

These approaches identified a considerable literature, though much of it is repetitive of methodologies and findings, while being applied to different commodities or insects. The information from this literature is summarises below.

Review of Literature

Physical Approaches to Insect Control

Vincent *et al.* (2001, 2003) provide useful reviews of the available approaches. Physical approaches can be divided into active and passive methods as follows:

Active:

- Thermal shock (heat or cold)
- Electromagnetic radiation (microwave, infrared, radio frequencies)
- Mechanical shock

- Pneumatic control (blowing, vacuuming)

Passive:

- Barriers
- Covers

This review will focus on active methods, the passive methods being outside the scope of the study.

Thermal Shock

The basic premise is that the commodity treated is less sensitive to sudden changes in temperature than the target insect. It is not considered practical to instigate sudden temperature changes in the field. The approach is not discussed further here.

Electromagnetic radiation

The focus of this study is on non-ionising radiation (radio frequencies, microwave infrared) as approaches using ionising radiation are considered unsafe for field use. When approached from an engineering perspective there are limited wavelengths available for use in the USA. These are 13.56, 27.12 and 40.68 MHz for radio frequencies and 915 and 2450 MHz for microwaves. The position in the UK is unclear. Useful reviews of the technologies, with particular reference to the quarantine control of insects in nuts (Wang & Tang, 2001) and in stored grain (Nelson, 1996), are available.

A search of the web has identified numerous companies that sell electromagnetic and ultrasonic devices that are claimed to deter a huge range of vertebrate and invertebrate pests simultaneously, including mice, cockroaches, mosquitoes etc in the home and garden. The basis of these claims is very unclear. There are a number of reports from the extension services of US universities that state that none of these devices work and should be treated with great caution (e.g. Sauls, 1996; Ghidiu, 2003; www.ipmofalaska.com/files/electronicpestcontrol.html). I have also contacted Dr Moray Anderson of the KillGerm Group, and previously of the University of

Birmingham, who delivers pest control solutions in the public health sector, and he confirms the ineffectiveness of these products.

Microwaves and radio frequency energy have the benefit that energy is transferred directly to the target without using a transfer medium. Microwaves have found a use in insect control where the material to be treated can be readily handled and is dry. For example in stored grain:

- Wheat infested with the maize weevil (*Sitophilus zeamais*) and flour infested with the red flour beetle (*Tribolium castaneum*) were treated with microwaves at 10.6 GHz at 9-20 kW, which achieved over 90% control in bulk samples (Halverson *et al.,* 1996).

Microwave and radio frequency treatments are also used for quarantine treatments of a range of fruit and nuts. Some of these commodities have a high water content and therefore warm up during microwave treatment. Care is required to retain product quality. Successful use has been achieved in the following examples:

- Microwaves at 915 MHz achieved some control of codling moth (*Cydia pomonella*) in cherries (Ikediala *et al*., 1999).
- Treatments of radio frequency energy in a 27 MHz pilot system killed third and fourth instar codling moth larvae in walnuts (Wang *et al.,* 2001) but was less successful at killing fifth instar larvae in apples (Hansen *et al*., 2004).

<u>Mechanical and acoustic shock</u>

The beating tray has been an established method used by entomologists for sampling and collecting insects for many decades. A white sheet is placed under a plant to collect those insects which are dislodged when the plant is tapped sharply with a stick. There are also anecdotal suggestions that low frequency pulses of sound, such as that produced by the engine of a tractor, can similarly dislodge insects from plants. An extensive review of literature did not provide any information on mechanisms, or examples where the approaches had been explored in detail.

Pneumatic Control

A number of machines have been developed that blow and/or suck insects from plants. Such devices are most likely to be effective against insects that are readily dislodged from plants. Some of the commercial machines available are summarised by Khelifi *et al.* (2001). In addition, modelling studies have explored the airflow and design of equipment (Khelifi *et al.,* 1996 a, b) and these studies could be the starting point for an application relevant to salad crops.

Machines have been developed most effectively for the control of tarnished plant bug (*Lygus lineolaris* and *L. hesperus*) in strawberry (Vincent & Boiteau, 2001). Such machines clearly benefit from optimisation in the laboratory to maximise the efficacy of insect collection (Vincent & Chagnon, 2000).

Pneumatic devices have been developed in both North America (Lacasse *et al.,* 2001) and Israel (Weintraub *et al.,* 1996) for the control of Colorado potato beetle (*Leptinotarsa decemlineata*). The equipment in Israel combined both blowing to remove insects from the plant and a vacuum to collect them. Interestingly, a large number of other species of insects were recorded amongst the insects removed from potatoes including the potato aphid (*Macrosiphum euphorbiae*) and the peach-potato aphid (*Myzus persicae*), both of which are found on salad crops (Lacasse *et al.,* 2001).

In no instances were insect numbers reduced as much as by using insecticides alone. However, the practitioners considered the pneumatic removal of insects to be an effective component of an integrated pest management strategy.

Care needs to be taken to ensure that the pneumatic treatments do not damage plants. To date machines have been used on crops that are processed prior to consumption and aesthetic appearance is of minor importance (Khelifi *et al*., 1995a). Leafy salads may be more sensitive to mechanical damage, but this requires testing.

Biology-Based Approaches to the Physical Control of Insects

Insects sense and respond to their environment in diverse ways. Knowledge of interactions that depend on the detection of sound, electromagnetic energy or vibration might enable insect behaviour to be disrupted physically. The key behaviours of insects that may have the potential for disruption and are relevant to salad crops are:

- Mate finding
- Predator avoidance
- Remaining on host plant

The disadvantage of this approach is that a certain behaviour is usually specific to individual species or groups of species and is not readily transferable between groups. However, some of the literature highlighted below is relevant to insects found in salad crops.

Each of the three topics was explored and the relevant literature is summarised below.

Mate finding

Some insect species use acoustic signals to communicate between males and females. Grasshoppers, cicadas, crickets and leafhoppers are the best examples, where complex species-specific calls have evolved (e.g. Alexander, 1967; Claridge, 1985; Spangler, 1988). The species specificity of this communication and the fact that none of these groups occur regularly on leafy salad crops means that little of this information is relevant here. However, in some insect groups, part of the signal may also be used to communicate between species. For example male and female lacewings (*Chrysoperla carnea*) respond to calls from another lacewing species (*C. downesi*) (and vice versa) when the low frequency components are transmitted through a suitable substrate (Henry, 1980). As with the grasshoppers, this communication is only between closely-related species and there is no obvious way that the knowledge could be applied to other species.

Many insects use pheromones to find their mate. These are volatile chemicals, usually released by the female to attract a mate. Pheromones would normally be outside the scope of this review, but one paper (Skals *et al.,* 2003) may have some relevance. In this research, a specialist device was developed for the precision release of odour stimuli during olfactory research. The device generated high-frequency sound that could be heard by moths. In flight tunnel experiments, the behaviour of the silver Y moth (*Autographa gamma*) was affected when the device was driven at 120 kHz, resulting in only 5% of moths reaching the lures compared to 65% of controls. Hearing sensitivity was highest at 15 kHz where the threshold was 35 dB SPL, and the threshold increased to 94 dB at 160 kHz (Skals *et al.,* 2003). The silver Y moth is a pest of salad crops. However, as many moths mate soon after emergence rather than when they find their host plant, it is not clear how this information could be used to prevent crop infestations.

Predator avoidance

Bats are predators of flying insects. Some insects are able to hear the sound of echo locating bats and take avoiding action. This has been recorded particularly in night-flying moths (e.g. Roeder, 1967, Yager & Spangler, 1997), but also in a scarab beetle (Forrest *et al.,* 1995). This suggests that ultrasound of the appropriate frequency may deter insects. Experiments, where ultrasound frequencies similar to those emitted by flying bats were transmitted, have explored the impact on the colonisation of crops by moths that are able to hear bats, and the approach might be applied to salad crops. Examples include:

- An airborne ultrasound broadcast at a frequency of 50Kc/s more than halved the infestation of maize by the European corn borer (*Ostrinia nubilalis*) (Belton & Kempster, 1962)
- Experiments determined the effect of a pulsed ultrasonic sound broadcast over lettuce and broccoli on oviposition by the cabbage looper (*Trichoplusia ni*). The most effective frequency, selected to simulate echo-locating bats, was at 20kHz, pulsed at 1 sec every 5 secs, or for 25 ms every 50 ms. Oviposition was reduced by up to 40% (Payne & Shorey, 1968).

In some instances, bats are able to detect insects on plants, from where they are gleaned. Some insects, particularly some moths, can use their hearing to detect mates and also predatory bats. They modify their behaviour by becoming silent and motionless in the presence of bats (Greenfield & Baker, 2003). Gleaning bats are more abundant in the tropics, so the translation of this knowledge to temperate salad crops seems unlikely.

Predators and parasites rely on an array of chemical and physical stimuli to locate their hosts. The ability of spiders to detect vibrations, both within the leaf substrate and their webs is a prime example. Other predatory and parasitic insects can detect the vibration of leaves caused by their prey, while some prey are able to detect their attacker and take avoiding action by moving. The prey may not always be able to distinguish fully between the vibration of leaves caused by the parasite and those caused by rain and wind (e.g. Casas *et al.,* 1998, Devetek, 1998).

Remaining on host plant

There are many reports that heavy rain reduces the numbers of insects on plants, though few, if any, studies have identified exactly how insects are lost from plants. Insects could be dislodged through direct impact from a rain drop, or by the impact of rain or wind on the substrate. Examples of such studies include:

- A seven-fold reduction in oviposition by the diamondback moth (*Plutella xylostella*) on watercress in a glasshouse was recorded during overnight overhead irrigation (Tabashnik & Mau, 1986)
- Simulated heavy rain and wind reduced the numbers of aphids on cereals (Mann *et al.,* 1995) and reductions in the numbers of wingless aphids on cereals have been associated with strong winds and wind gusts (Cannon, 1986)

Insect physiology

The literature review indicated that insects, in particular *Drosophila melanogaster* larvae, have been used to explore the potential damage that diagnostic ultrasound might cause to human tissue (Child *et al*., 1981, Child & Carstensen, 1982). Ultrasound can produce profound biological effects through its action on microscopic gas bodies in tissues. Such gas bodies are found in the trachea, the respiratory system of insects, particularly in small insects. The gas bodies in the trachea are constrained from expanding by the physical structure of these organs. Ultrasound, applied in very short pulses and at low temporal average intensity, may cause the gas bodies to collapse violently, producing mechanical shock and chemical products from extremely high temperatures in the compression phase of the transient cavity. The resultant biological effect may be different to that predicted by classical cavitation theory (Carstensen *et al.,* 1990, 2000; Child *et al.,* 1992).

Presentation of findings to HDC and engineers at a workshop

A workshop was organised by the HDC on 20 April 2005 and the findings of the knowledge review were presented and discussed (See Annex 1 for workshop report).

This review to this point had identified a small number of opportunities for the physical removal or control of insects on salad crops if engineering solutions were cost effective. The following opportunities and questions were discussed at the workshop:

1. Radio frequency energy and ultrasound are being developed for the control of both storage and quarantine insects. Examples of controlling codling moth in apples, a substrate with high water content, must give some hope that the technology could be applied to insects on salads. Questions to be answered are:
    - Are insects and salad leaves sufficiently different that the insects will absorb sufficient energy to kill them without harming salad quality?
    - Can microwave/RF equipment be packaged to move around a field to deliver a lethal dose to insects safely?

2. Ultrasound used under specific conditions kills *Drosophila* through a process akin to cavitation rather than heating. Questions to be answered are:
    - Does this phenomenon apply to insect species more generally?
    - Can the equipment be deployed in the field safely and effectively?

3. Pneumatic devices have been demonstrated to remove a number of insects successfully, including aphids. Questions to be answered are:
   - Are any of the pneumatic machines likely to be suitable for use on lettuce and how could they be adapted to be sufficiently effective?
   - Can the observed physical dislodgement of insects by rain and wind be incorporated within a pneumatic device?

Following discussion the workshop participants identified four topics for more detailed investigation as follows:

1. The use of microwaves and radio frequencies to control codling moth in apples and cherries. This was of interest due to the similar water contents of the fruit and lettuce. If codling moth larvae could be controlled without damaging the fruit, there may be scope to control insects on lettuce. The coupling needed between the microwave source and the insects was also an issue.

2. The observation that a phenomenon induced by ultrasound and akin to "cavitation" had killed *Drosophila* larvae was of interest. A key paper was forwarded to Duncan Billson in Engineering at the University of Warwick for his comments. Based on his views, a deeper review of the subject will be done.

3. Pneumatic methods for blowing and/or sucking insects from plants may be the most practical way forward. A more detailed synthesis of the available knowledge will be completed.

4. It was considered that insect anesthesia, possibly combined with pneumatics warranted further investigation. A few key entomologists will be approached to determine times and concentrations of CO_2 or nitrogen used in insect research.

Further investigations following workshop

1. <u>The use of microwaves and radio frequencies to control codling moth in apples and cherries.</u>

When material containing water molecules is subjected to an electromagnetic field that rapidly changes direction, the water molecules rotate into alignment with the direction of the electrical field. The water molecule friction produces internal heat in the material. A frequency in the range 12 MHz - 2450 MHz is usually used in food engineering. Dielectric materials, such as most agricultural products, can store electrical energy and convert electrical energy into heat. An increase in temperature depends on the power, frequency, heating time and the material's dielectric loss factor. The dielectric loss factor between the insect and the commodity is key to control. Higher temperatures can be achieved by a longer heating duration and a higher power input (Wang & Tang 2001).

Research by a group of collaborating laboratories in North America has focused on the control of insects in fruit (particularly apples, cherries, oranges) and nuts (particularly walnuts (Wang & Tang, 2001)). This is for quarantine purposes to ensure that pest species are not exported to other countries. The work builds on earlier research that focused on the control of insects in stored grain (Nelson, 1973; 1996). The information that follows will focus on the fresh fruit that have a high water content similar to that of salad crops, as the nuts and stored grain have a significantly lower water content.

There are a number of threads to the research programme, which have explored different components of an approach to killing insects, particularly the codling moth (*Cydia pomonella*) in fruit. These include:

- The temperatures required to kill fifth instar codling moth larvae were related to the duration of exposure. All larvae were killed by exposure to 46ºC for 50 min or 52ºC for 2 min (Wang *et al*., 2002)
- A theoretical framework was used to develop models that will predict insect mortality and commodity quality based on cumulative thermal input. However, this needs to be parameterized by measurement of the dielectric properties for each insect and commodity (Tang *et al*., 2000). These properties have been

measured for six commodities (fruit and nuts) and four of their associated insects (Wang *et al*., 2003).

- Immersion of fruit in a saline bath improves the uniformity of heating and kill of codling moth larvae (Ikediala *et al*., 2002). The uniformity of heating of fruit, and hence the potential for insect kill, was further improved by the development of techniques that rotated and moved fruit while it was subjected to radio frequency heating (Birla *et al*., 2004).
- Examination of temperatures, codling moth mortality and measures of the quality of cherries treated with 915 MHz microwaves suggested little effect on quality, though these measures may not be transferable to lettuce. It should be noted that stem greenness was reduced after microwave treatment (Ikediala *et al*., 1999) and this may equate to discolouration of salads.

All this research was brought together in a study that attempted to achieve the quarantine control of codling moth in fresh apples (Hansen *et al.,* 2004). Apples infested with fifth instar codling moth larvae were exposed to a radio frequency at 27.12 MHz. However, it was difficult to produce a predictable and uniform energy field, even though this was improved by moving fruit in water. The consequence was that temperatures both within and between fruit varied considerably (40-68ºC) and quarantine control could not be achieved, even if the fruit were held at a high temperature for 20 minutes.

Conclusion: *The use of radio frequency or microwaves to control insects or remove them from salad plants in the field seems to have very limited potential at present because of the lack of uniformity when heating plants in air, and the duration of heating and relatively high temperatures required to achieve insect death. The dielectric properties of salad plants or the relevant insects are unknown.*

2. The observation that a phenomenon induced by ultrasound and akin to "cavitation" killed *Drosophila* larvae.

The key paper by Carstensen *et al.* (1990) was forwarded to Dr Duncan Billson at the Department of Engineering, University of Warwick. Dr Billson is a specialist in ultrasound. A subsequent meeting with Dr Billson identified that the ultrasound used in the study to kill *Drosophila* larvae was of very high power and the target had to be immersed in water. The approach therefore could not be used for control of insects in the field, but it could perhaps be used to kill insects while salads were being washed in processing plants.

A wider discussion with Dr Billson indicated that he and his colleagues had worked briefly with entomologists from Scotland who had an interest in controlling biting midges. They had explored the effect of airborne ultrasound on the insects and observed no deleterious effects on the insects.

Conclusion: *The use of ultrasound to produce a phenomenon akin to cavitation does not have scope for removing insects from plants in the field due to the high energy requirement and the need for coupling between the energy source and the target with water.*

3. Pneumatic methods for blowing and/or sucking insects from plants

There are a number of tractor-mounted vacuum and blowing devices reported in the entomological literature for the removal and control of pest insects from plants. An early machine (Insectovac) was a sampling device for counting insects for research purposes and had a free air delivery of 1,132,800 cm^3 sec^{-1} and an airspeed at the inlet of 17,645 cm sec^{-1} (Ellington *et al*., 1984). A later device (Biovac) with three inlets was used to control tarnished plant bug (*Lygus lineolaris*) on strawberry. This machine had a vacuum of 79.2 m^3 min^{-1} at each inlet at an air speed of *c.* 53 km h^{-1} and achieved significant reductions in the numbers of pests (Vincent and Lachance (1993). Another study, also in strawberry to control *Lygus hesperus,* compared vacuum machines that covered one, two or three beds of strawberries (Pickel *et al*., 1994). These had airflows of 17.0 km h^{-1}, 29.6 km^{-1} and 55.6 km h^{-1} respectively. Unsurprisingly machines with higher airflow were generally more efficient at controlling insects.

Machinery has become more sophisticated since then, combining both a blowing action at an angle to the plant to dislodge insects from plants and a secondary sucking action to remove insects. The first such machine, developed in Canada (Boiteau *et* *al*., 1992), was used primarily to control Colorado beetle on potato and was most effective (40-48% removal) against adults and small larvae, while large larvae were more difficult to remove (27%). Unfortunately no data on airflows etc. are provided for this equipment. This machine also reduced significantly the numbers of wingless aphids on potato plants. A similar device developed independently in Israel achieved 50-75% control of insects on celery and potato (Weintraub *et al*., 1996). This machine blew air onto plants from the side and vacuumed upwards at an air speed of 40 m sec^{-1}. Experiments to test the efficacy of airstreams orientated in different directions for the optimum removal of Colorado beetle found that those blowing horizontally across the plant at a mean velocity of 27.5 m sec^{-1} effected 100% removal (Khelifi *et al*., 1995b).

Up to this point, little engineering expertise seems to have been applied to maximize the efficiency of these machines. More recently, researchers have used laboratory experimentation to understand individual components of the system better. Much of this research has been done on Colorado beetle on potato. Misener and Boiteau (1993a) found that the force required to remove adults from plants was 40 mN, and this value decreased to 30 mN for fourth instar larvae and 10 mN for second and third instar larvae. There was some variation in the forces required, depending on the position of the insect on the plant, and whether larvae were holding on to the plant with their mandibles as well as their tarsi. In a second study, Misener and Boiteau (1993b) found that the suspension velocity of adult beetles was 9.4 m sec^{-1} while that of second instar larvae was only 5.9 m sec^{-1} indicating, unsurprisingly, that once dislodged from plants, the smaller larvae would be more readily removed from the crop than adults which may just fall to the ground. In a related laboratory study, potato leaves were vibrated mechanically. Adults and larvae of the Colorado beetle fell from the leaves within 2 sec when vibrations generated by a system akin to a loud speaker were at frequencies greater than 20 Hz, with an amplitude above 0.6 mm. This rapid response probably occurred before insects were able to hold on to plants more tightly with their tarsal claws, or mandibles in the case of larvae (Boiteau and Misener 1996).

Modeling studies have to date focused on simulating the airflow inside and around the hoods of existing pneumatic devices under different conditions (Khelifi *et al*., 1996b).

When tested, the simulations gave good predictions of how airspeeds varied with different configurations of fan (Khelifi *et al*., 1996a). These modeling studies can only be considered as a starting point for further theoretical investigations to improve the design and efficiency of insect removal.

A practical consideration, not discussed in any of the literature, is the efficiency of pneumatic methods when plants are wet. It is possible that such methods may either blow insects and other debris into the heart of the plant, or onto water droplets, where it will become lodged and therefore not remove them from the plant as planned.

Conclusion: *Pneumatic devices have potential for removing insects from plants, but careful design is required to maximize efficiency in salad crops. The topics worthy of further study are:*

- *the application of fluid dynamics to the airflow around plants to maximize the removal of insects*
- *the study of vibration to remove insects from plants.*

Insect anaesthesia

Carbon dioxide (CO_2) from cylinders is used in laboratory studies to immobilise insects to enable experimental manipulation. The details of treatments are rarely written in papers. A number of entomologists in the UK were telephoned to determine their familiarity with the technique. A number had used the method and indicated that it took from 3 to 15 sec to render an insect (aphids and bees) immobile. No one had used elevated levels of nitrogen for the same purpose.

Conclusion: *There may be opportunities to combine insect anaesthesia with pneumatic approaches to the removal of insects.*

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Annex 1

Report of Workshop 20 April 2005

Held at Warwick HRI

In attendance:
Emma Garrod, HDC
Mark Tatchell, Independent consultant
Chris Pearson, Independent consultant
Ken Young, Warwick Manufacturing Group, University of Warwick
Jim Rawley, Warwick Manufacturing Group, University of Warwick

The HDC circulated the interim project report to attendees prior to the workshop. Mark Tatchell summarised the findings from the desk study to date. A constructive round-table discussion identified four topics which may provide opportunities for insect control and on which the final part of the desk study should focus. They were as follows:

1. The use of microwaves and radio frequencies to control codling moth in apples and cherries. This was of interest due to the similar water contents of the fruit and lettuce. If codling moth larvae could be controlled without damaging the fruit, there may be scope to control insects on lettuce. The coupling needed between the microwave source and the insects was also an issue.

2. The observation that a phenomenon induced by ultrasound and akin to "cavitation" had killed *Drosophila* larvae was of interest. A key paper will be forwarded to Duncan Billson in Engineering at the University of Warwick for his comments. Based on his views, a deeper review of the subject will be done.

3. Pneumatic methods for blowing and/or sucking insects from plants may be the most practical way forward. A more detailed synthesis of the available knowledge will be completed.

4. It was considered that insect anesthesia, possibly combined with pneumatics warranted further investigation. A few key entomologists will be approached to determine times and concentrations of CO_2 or nitrogen used in insect research.

Each of these four areas will be followed up in more detail and a report forwarded to Emma Garrod for circulation to workshop participants and David Barney by 12 May 2005.