COMMERCIAL - IN CONFIDENCE

ADAS*

Report to: Dr E Moorhouse
Horticultural Development Council
18 Lavant Street
Petersfield
Hants GU32 3EW
Tel: 01730 263736

ADAS Contract Manager: J A Bennison
ADAS Cambridge
Brooklands Avenue
Cambridge
CB2 2BL
Tel: 01223 455752

CONTRACT REPORT
No HNS 59
A Review of leatherjackets on nursery stock: Biology and control

Period of investigation: September 1994 to March 1995

Date of issue of report: 16 May 1995

No of pages in report: 59

No of copies of report: 15

* ADAS is an Executive Agency of the Ministry of Agriculture, Fisheries and Food and the Welsh Office

ADAS

mw/jbhn559.doc/dnr

PRINCIPAL AUTHOR

J A Bennison, BSc Entomologist

AUTHENTICATION

I declare that this work was done under my supervision according to the procedures described herein and that this report represents a true and accurate record of the results obtained.

Signature ......J A Bennison...........

J A Bennison BSc
Author of Report
ADAS Cambridge
Brooklands Avenue
Cambridge
CB2 2BL
Tel: 01223 455752

Date: 16 May 1995

Report authorised by ......C S Speller......
(Signature)

C S Speller BSc (Agric), Hons. CBiol., MIBiol.
ADAS Horticulture Centre Manager
ADAS Huntingdon

CONTENTS

INTRODUCTION

Leatherjackets are a sporadic problem on containerised nursery stock, occurring regularly on some nurseries and occasionally on others. When occurring, damage can be severe unless detected quickly and timely control measures applied. Symptoms include girdling of stem bases eg of heathers, conifers and shrubs, leading to poor growth, and grazing-off of the foliage of low-growing plants eg Saxifrage. Damage seems to be worse in some years than others, with most incidences occurring on sandbeds or in polythene tunnels. The incidence and severity of damage is probably due to several factors including weather conditions, soil or compost moisture, attack by natural enemies and choice and timing of pesticides.

The species most commonly attacking nursery stock is though to be *Tipula oleracea*, although *Tipula paludosa*, the species more common on grasses and arable crops, has also been recorded. However, identification of the larvae is difficult as the two species may be indistinguishable visually, and it is only recently that an accurate laboratory technique has been developed for reliable confirmation of each species of larva. Species identification is relevant to control, as *T. paludosa* has only one generation per year whereas *T. oleracea* has two.

There are no pesticides currently approved for the control of leatherjackets on ornamentals, either outdoors or under protection. Under the long-term off-label pesticide arrangements, growers of ornamentals can use at their own risk, pesticides approved for leatherjacket control on other crops. Most growers use drenches of chlorpyrifos, although this may only be used outdoors and can be phytotoxic. Other pesticides used are gamma-HCH drenches or methiocarb slug pellets. All these pesticides rely on contacting or being eaten by leatherjackets, so are only effective if larvae are grazing close to the surface of the compost at the time of application.

Pesticides drenches used against leatherjackets are not compatible with biological agents; they are not only harmful but persistent for many weeks. There is currently no compatible method for controlling leatherjackets within IPM. There is some anecdotal evidence that the controlled release granular formulation of chlorpyrifos, 'SuSCon Green', could give incidental control of leatherjackets, when used for vine weevil control on nursery stock. However, this has not been substantiated by trials data, and the product has only been on the market for the past two seasons.

Owing to environmental pressures to reduce pesticide usage, an increasing number of nursery stock growers are using IPM under protection and is interested in extending the use of IPM outdoors. MAFF has recently commissioned ADAS to develop biological control of HONS outdoors, in order to improve the competitiveness of UK HONS growers in the market place. Initial work will investigate naturally occurring biological control agents of vine weevil and foliar pests. Collaborative work with Rothamsted will investigate the use of semiochemicals to enhance biological control. Leatherjackets are not included in this project, but there are a number of natural enemies of the pest worth conserving on nurseries, or biological control agents with the potential for commercial use, on HONS both outdoors and under protection.

OBJECTIVES

(a) To review the species and life cycles of leatherjacket species attacking nursery stock.

(b) To review chemical, cultural and biological methods of control on nursery stock, including any relevant information on other crops.

(c) To include six "case studies" of nurseries experiencing leatherjacket problems, to examine the characteristics of infestations, extent of damage and methods of control.

(d) To assess the significance of leatherjackets as a pest of nursery stock in the UK and identify the most effective control measures currently used.

(e) To make recommendations for future research on the biology and control of leatherjackets on nursery stock.

BIOLOGY OF LEATHERJACKET SPECIES ATTACKING NURSERY STOCK

Leatherjackets are the larvae of crane flies, which belong to the insect family *Tipulidae*, within the order *Diptera* (flies). Leatherjackets are important soil pests of grassland. Other arable and horticultural crops planted in land following infested grass can also be seriously damaged eg cereals, sugar beet, soft fruit, vegetable and ornamental crops. Leatherjackets are also common pests of containerised nursery stock and herbaceous plants.

Species associated with nursery stock

The two main species of crane fly occurring in Northern Europe are *Tipula paludosa* and *Tipula oleracea*. The species most commonly attacking nursery stock is thought to be *T. oleracea*, although *T. paludosa*, the species more common on grasses and cereals, has also been recorded. Other species which can attack ornamentals are *T. lateralis* and *Nephrotoma appendiculata* (Alford, 1991).

This review will deal with the two most common species, *T. oleracea* and *T. paludosa*. Morphologically, the two species are very similar and are difficult to tell apart. However, there is an important difference in the life cycles; *T. paludosa* has only one generation per year, whereas *T. oleracea* has two.

Adults - description

Crane flies (commonly known as daddy longlegs) are large flies with long, slim bodies, long ungainly legs and narrow wings. There are slight differences between *T. paludosa* and *T. oleracea* (Alford, 1984).

	T. paludosa	*T. oleracea*
Body length	17-25 mm	15-23 mm
Wing length	13-23 mm	18-28 mm (noticeably longer than body)
Legs	Long, brown	As for *T. paludosa* but distinctly thinner.
Antennae	14 - segmented	13 - segmented

Adults - activity

Tipula paludosa

T. paludosa is a univoltine species ie it has one generation per year. The emergence period tends to be well synchronised, with peak adult activity occurring from mid-August to mid-September (Blackshaw, 1994; den Hollander, 1975b). However, some adults can emerge as early as July and others as late as October, with emergence being later in the South of England than the North. Adults usually emerge between dusk and midnight, often on still, warm evenings after rain.

T. paludosa females are gravid (ie they bear mature eggs) on emergence (Laughlin, 1967). Binns (1976) describes the brief courtship of the species. Mass emergence by both sexes ensures that the females are mated soon after emergence. A sex pheromone has been detected, but it is only active over a distance of one centimetre. Males are reputed to sit waiting beside female pupae and assist the females to emerge. Laughlin (1967) also observed at least one male hovering around each emerging female. Mating is initiated by the male grabbing the female as soon as she leaves the pupal case. Due to their full egg burden, *T. paludosa* females in particular are weak fliers and eggs tend to be laid at the emergence site, often by the morning after emergence and mating. Up to 300 eggs are laid by each female (Alford, 1984).

Tipula oleracea

T. oleracea is a bivoltine species ie it usually has two generations per year. The emergence period tends to be less synchronised than *T. paludosa*. The first adults of the Spring Generation begin to emerge between late April and mid-May in most years, although this is variable, probably depending on weather conditions (den Hollander, 1975b). Peak emergence of the Spring Generation occurs in late May/early June, with a few adults still emerging in late June/early July.

The Autumn Generation begins to emerge in early August with peak emergence occurring in late August/early September, but continuing until mid-October. Thus, the flight period of each generation lasts for approximately two months, with the Autumn Generation overlapping with that of *T. paludosa*. However, more *T. oleracea* adults usually emerge in the spring than in the autumn; in the Netherlands during 1973 and 1974, 80% of the total adults monitored per year occurred in the spring (den Hollander, 1975b). However, these generation differences are again variable in different localities and different years.

Unlike *T. paludosa*, *T. oleracea* are non-gravid ie (do not bear mature eggs) at emergence and this, together with their longer wing: body length, means they are stronger fliers. Adults disperse before mating and oviposition, therefore this species is more adapted to finding and living in temporary habitats eg. containerised ornamentals (Blackshaw *et al.*, 1993).

T. oleracea females are reputed to be attracted to the males by pheromones (Binns, 1976) but the chances of mating are not as high as for *T. paludosa*. To increase the likelihood of a fertile male mating with an unfertilised female, *T. oleracea* display a more complex courtship pattern than *T. paludosa*, involving a series of stimulus-response reactions (Stich, 1963). This also tends to prevent the mating between different species, although interbreeding between *T. paludosa* and *T. oleracea* has been observed in the laboratory (den Hollander, 1975b).

Adult males live for approximately seven days and females for eight. They do not feed during their lifespan, needing only water. Provided that fertilisation occurs during the first four days after emergence, each female lays an average of 600 eggs, in two or three batches. If not mated during the first four days of her life, the female lays no or very few eggs before she dies. Even in laboratory cultures, it has been observed that 20% of adult *T. oleracea* die before reproducing (den Hollander, 1975b). Eggs are laid just below ground level in the soil or other substrate; the female inserts her ovipositor by a rotary or stabbing movement, whilst using her legs like a tripod to support her body vertically (Brindle, 1960).

Eggs

The eggs are approximately 1.0 x 0.4 mm and are oval, black and shiny (Alford, 1991). In the natural habitat, eggs take approximately two weeks to hatch, the incubation period depending mainly upon temperature. In North-East England, the mean temperature at 2-3 cm depth in August and September is usually around 15°C and *T. paludosa* eggs incubated in the laboratory at this temperature take 15 days to develop (Laughlin, 1967). Other workers have observed egg hatch after seven days at 20°C (Carter, 1975a; Wiegers *et al.*, 1992). Dry conditions can retard hatching date (Laughlin, 1967).

Larvae - description

Leatherjackets have four larval instars or stages. When fully grown the fourth instar is 34-44 mm long, brownish-grey with a dull, dusty and wrinkled appearance (Alford, 1984). Brindle (1960) gives average body lengths of 34 mm for *T. oleracea* and 44 mm for *T. paludosa*, but length is variable and cannot be used to distinguish species. The body is fat and composed of three thoracic and eight abdominal segments, each of which bears a row of short, inconspicuous hairs or setae.

The body is slightly tapered towards the head end and the head is retractile. The posterior end is flat and bears the main diagnostic features to distinguish species; the spiracular and anal lobes (see Fig. 1, Appendix I). Surrounding the two circular spiracles are one pair each of dorsal, lateral and ventral spiracular lobes. Surrounding the anus are one pair each of lateral and ventral anal lobes or papillae.

As the larvae of *T. paludosa* and *T. oleracea* are so similar, the shape of the anal papillae has been used for many years to distinguish between the species. In *T. paludosa*, the lateral papillae are reputed to be elongate and the ventral ones rounded, whereas in *T. oleracea*, both lateral and ventral papillae are said to be elongate (Brindle, 1960; Alford, 1984,) (see Fig. 1, Appendix I). However, other workers consider that the larval stages of the two species are visually inseparable (Humphreys *et al.*, 1993).

Owing to the current lack of confidence in the reliability of anal papillae as key characters, an isoelectric focusing (IEF) technique has been developed for identification of the two species. This technique uses extracts of any stage in the life cycle of the insects, to display a series of stained protein bands on a gel. The number and position of the bands is used to separate *T. paludosa* from *T. oleracea* (Humphreys *et al.*, 1993b) (see Fig. 2, Appendix II).

Larvae - development and activity

Tipula paludosa

Laughlin (1967) made a detailed study of the development of *T. paludosa* in N England between 1954 and 1963. The following account is a summary of his findings. Leatherjackets of this species are active from early September until June/July. The larvae feed at or just beneath the soil surface, the main periods of feeding and growth being the autumn and spring periods.

The majority of first instar larvae hatch from eggs in the second week of September and moult to second instars in late September. The second moult into third instars usually occurs in late November, but can occur any time between October and February. The third moult into fourth instars usually occurs in early April, on average two to three weeks after the soil temperature reaches 5°C. This final fourth larval stage feeds voraciously for a few weeks to reach full size, then waits in underground burrows for six to eight weeks before pupating in late July. This 'diapause' or waiting period is typical of *T. paludosa* and the reason for it is unknown.

The development of each stage is variable. In a 'normal' year, fourth instars are not present until the spring, but in an 'early' year they can appear from November onwards. In a 'late' year, second instars can persist until March. Growth is slow but does not stop completely over the winter period, with activity being accelerated when soil temperatures are above 5°C (see Fig. 3, Appendix III).

Tipula oleracea

The larval activity period of the Autumn Generation is similar to that of *T. paludosa* until April, ie first and second instars feed in the autumn, winter is spent as third instars and the moult to fourth instar occurs in April (den Hollander, 1975a). However, the time spent as the fourth instar is shorter than for *T. paludosa*, with pupation occurring in May rather than July.

This faster development time for *T. oleracea* has been confirmed in laboratory studies which have shown that at 20 or 21°C, the average larval development period is 50-60 days (Laughlin, 1960; den Hollander, 1975a; Carter, 1975a; Wiegers *et al.*, 1992). There is little in the literature regarding the larval activity period of the Spring Generation. However, adults emerging in late May/early June produce the Autumn Generation adults by August/September, so the Spring Generation larvae must be active during June, July and August.

As has been discussed earlier, the adult emergence period for *T. oleracea* is less synchronised than for *T. paludosa*. This is due to the variation in the length of time spent as the fourth larval instar (den Hollander, 1975a). The first three instars of *T. oleracea* feed at or just below the soil surface. Just before moulting into the fourth instar, the larvae burrow deeper into the substrate and remain there motionless, for between 10 and 35 days (den Hollander, 1975a).

Pupae

Just before pupation, the fourth instar larvae shrink in length and become yellow in colour (den Hollander, 1975a). The pupae are approximately 20-30 mm long, brown and parallel-sided, with paired respiratory 'horns' on the head. Female pupae are larger than males, and are pointed at the posterior end rather than flattened as in the males.

The time spent as a pupa is on average seven days in culture at 20°C (Carter, 1975a; den Hollander 1975b) and 7-14 days in nature, depending on climatic conditions (Brindle, 1960). Thus, *T. paludosa* usually pupates in late July and *T. oleracea* during May and again in August.

When ready to emerge, the pupa wriggles up through the soil or substrate and remains with its anterior end protruding out of the ground. A longitudinal split in the pupal case allows the adult to emerge. In culture, only 53% of fourth instar larvae may complete pupation and 78% pupae emerge as adults (den Hollander, 1975b).

Summary of life cycles of *T. paludosa* and *T. oleracea*

Generation	*T. paludosa*	*T. oleracea*
Autumn Generation		
Adult emergence (peak)	Mid-August to mid-September	Late August to early September
Larval activity	September to June/July	September to April
Pupation	Late July	May
Spring Generation		
Adult emergence (peak)	-	Late May/early June
Larval activity	-	June to August
Pupation	-	August

FACTORS AFFECTING ABUNDANCE OF LEATHERJACKETS ON NURSERY STOCK

Apart from the use of pesticides (see 'Chemical Control' and 'Case Studies' Sections), several other factors are likely to affect leatherjacket abundance on nursery stock.

1. Availability of host plants in the vicinity

As has already been described, grassland is the major habitat, particularly for *T. paludosa* (Blackshaw *et al.*, 1993b; den Hollander, 1975b). However, a wide range of arable and horticultural crops are also attacked. Often, attacks occur following grass, as eggs have already been laid in the soil and young larvae transfer from the ploughed up grass to the next crop. The presence of grass weeds on HONS nurseries may also attract egg-laying females, possibly from grass or other host crops nearby.

However, as has already been discussed, *T. paludosa* adults tend to mate and lay eggs in the immediate vicinity of the emergence site, (usually grassland), due to the poor flying ability of egg-bearing females. Thus, this species is unlikely to migrate into HONS nurseries from surrounding crops. In contrast, *T. oleracea* is a stronger flier and mating and dispersal occurs before the eggs are laid. This enables it to exploit a wider range of habitats eg containerised ornamentals (Blackshaw *et al.*, 1993). The full details of habitat selection by adult *T. oleracea* is not known, but they have been shown to prefer high vegetation, composed of various plant species, whereas *T. paludosa* prefer low vegetation, mainly composed of grasses (den Hollander, 1975b). Thus, *T. oleracea* could potentially fly in from surrounding vegetation, but are more likely to be "resident" on some HONS nurseries. They are unlikely to originate from surrounding grass; although they are listed as a natural inhabitant of pasture, surveys carried out showed that only one of 75 fields in N. Ireland and one of 32 in N.E. Scotland contained *T. oleracea*, whereas the majority contained *T. paludosa* (Humphreys *et al.*, 1993a).

2. Whether plants are grown under protection or sheltered by wind-breaks

An increasing number of containerised nursery stock plants spend at least some time under protection and wind-breaks are also commonly employed. Many occurrences of leatherjacket attack occur on plants under tunnels or protected by wind-breaks (see Case Studies). Leatherjackets are widely known to feed more actively in mild periods and any protection or shelter will favour activity.

Apart from this, it is possible that once "resident" on the nursery, populations of crane flies and leatherjackets are maintained due to tunnels or wind-breaks restricting dispersal. Certainly, any *T. paludosa* adults are likely to remain on site, due to their restricted flight. Possibly they are maintained on any grass weeds, or even mosses, which have been shown to be an alternative habitat (Brindle, 1960; Morris, 1986). It has been suggested that *T. oleracea* is more likely to occur where dispersal is limited (Humphreys *et al.*, 1993a). Severe attacks by *T. oleracea* larvae to winter cereals following oilseed rape have been observed in N. Britain and this has been attributed to the rape canopy preventing second generation adults dispersing.

3. Irrigation

The climatic factors affecting the yearly and regional population variations in leatherjackets have been widely studied, in order to try to explain and predict relative abundance and crop damage. Mathematical models have been devised, taking into account various environmental factors to predict population trends (Meats, 1974; Blackshaw and Perry, 1994). The major climatic influence affecting population numbers seems to be rainfall, and thus soil moisture.

The critical times for soil moisture to affect survival are:-

(a) September and October, when high rainfall/soil moisture ensures survival of the young larvae (Blackshaw, 1983). For example, the abnormal September droughts of 1955 and 1959 were thought to cause heavy mortality of young leatherjackets (Milne *et al.*, 1965).

(b) November, when very high soil moisture can lead to drowning of the larvae.

(c) July and August, when excess water on the soil could inhibit emergence of adults from the pupae.

It has been estimated that when August/September rainfall is 50% lower than normal, sharp decreases in populations of *T. paludosa* will occur, whereas when rainfall is 100% or more than average, increases will occur (Milne *et al.*, 1965).

However, if soil moisture is not limiting in August and September, egg and larval survival is not affected, eg in N Ireland where rainfall is adequate throughout the year (Blackshaw and Perry, 1994). Similarly, on HONS nurseries, rainfall is unlikely to have a significant effect as plants are regularly watered. However, the high incidence of severe leatherjacket damage occurring on containerised HONS stood on sandbeds (see Case Studies), indicates that when composts are kept continuously and consistently moist, this favours leatherjacket survival. This was confirmed by work on irrigated and unirrigated grasses, when there was a high percentage survival of *T. paludosa* eggs and young larvae on irrigated plants and minimal survival and damage on those unirrigated in August and September (Pesho *et al.*, 1981). *T. oleracea* in particular is thought to prefer moist soil; in nature, marshy soil has been recorded as a favourite habitat (Brindle, 1960) and its occurrence in grassland could be due to wetter conditions prevailing (Humphreys *et al.*, 1993b).

4. Other climatic factors

Various other climatic factors can affect leatherjacket numbers eg temperature, sunshine, wind etc (Blackshaw and Perry, 1994). It is worth noting that most of the work on crane fly/leatherjacket population dynamics has been carried out on *T. paludosa*. Factors affecting the abundance of *T. oleracea* have not been fully established. Now that the larvae of *T. oleracea* can be reliably identified, the role of this species in crop damage can be investigated and further work on its population dynamics undertaken (Humphreys *et al.*, 1993a).

5. Other biological factors

Various other biological factors will affect abundance eg frequency of mating, fertility, fecundity (how many eggs are laid), percentage of larvae pupating and emerging, attack by natural enemies etc. Many workers have commented on these natural mortalities (see Biology and Biological Control Sections). Another interesting phenomenon is the cannibalistic tendency of leatherjackets, particularly when in high densities (Carter, 1975a; Barbash, 1990).

It is worth noting that in order to maintain population stability, only one male and one female from each egg batch needs to survive and reproduce. With the hundreds of eggs laid by crane flies, 99% mortality can therefore be tolerated (Carter, 1976).

ANNUAL SURVEYS OF LEATHERJACKET POPULATIONS

Marked fluctuations of leatherjacket numbers in grassland occur from year to year. Often a year of high incidence will be followed by a sharp decline in numbers, after which numbers increase over the next few years, to reach another peak. Peaks in numbers of *T. paludosa* have often occurred every five or six years (Mayor and Davies, 1976; French, 1969).

Due to this variation in populations, ADAS Entomologists have sampled permanent grass fields every autumn and, in years where populations are large, again in the spring. This has enabled advice to be given concerning the risk of damage to grassland and also spring-sown arable crops after grass. Thresholds have been devised based on numbers of leatherjackets per m². Pesticide treatment of the grass crop or the following arable crop is advised if these thresholds are exceeded, eg:-

For established, intensively managed lowland grass - 130/m².
For less intensively managed lowland grass - 300/m².
For pre-sowing of spring cereals or grass reseeds - 50/m².
For post-emergence of spring cereals - 30/m².

Similar surveys of leatherjacket populations are also carried out in N. Ireland (Blackshaw, 1983; Blackshaw, 1990;, Blackshaw and Perry, 1994) and in Scotland (Humphreys *et al.*, 1993a).

Since 1990, the ADAS leatherjacket surveys (on 35-40 grassland sites throughout the country) have been carried out on behalf of Dow Elanco (suppliers of Dursban 4). A summary of the results from 1990/91 to 1994/95 is shown in Fig. 4, Appendix V. Numbers were higher in all regions in 1990/91, particularly in the west of the country. Numbers in 1994/95 were higher in all regions than the previous three years.

Although, for reasons discussed, leatherjacket populations in nursery stock may not necessarily follow the same pattern as those on grassland or arable crops and obviously thresholds are not applicable, it is interesting to note that 1990 was also the year several growers remembered severe damage occurring to nursery stock (see Case Studies).

CHEMICAL CONTROL OF LEATHERJACKETS ON NURSERY STOCK

There are no pesticides currently approved for the control of leatherjackets on ornamentals, either outdoors or under protection. Up to the withdrawal of aldrin in May 1989, many growers using aldrin for vine weevil control in container-grown ornamentals would have benefited from incidental control of leatherjackets. Since 1 January 1990, many pesticide products have been allowed to be used for additional "minor uses". These long term off-label arrangements for extensions of use were revised in December 1994. The revised arrangements are valid until 31 December 1999.

Revised long term arrangements for extension of use on non edible crops and plants

Subject to specific restrictions and **at growers' own risk**, pesticides provisionally or fully approved for use on any growing crop may be used on commercial agricultural and horticultural holdings and in forest nurseries on the following crops and plants:-

(i) Hardy ornamental nursery stock, ornamental plants, ornamental bulbs and flowers and ornamental crops grown for seed where neither the seed nor any part of the plant is to be consumed by humans or animals.

(ii) Forest nursery crops prior to final planting out.

Revised long term arrangements for extension of use on leaf herbs and edible flowers

Subject to specific restrictions, pesticides provisionally or fully approved for use on lettuce, spinach, parsley, sage, mint or tarragon may be used on commercial agricultural or horticultural holdings on the following leaf herbs or edible flowers:-

Angelica, balm, basil, bay, borage, salad burnet, caraway, chamomile, chervil, chives, clary, coriander, dill, fennel, fenugreek, feverfew, hyssop, land cress, lovage, marjoram, marigold, mint, nasturtium, nettle, oregano, rocket, rosemary, rue, sage, savory, sorrel, tarragon, thyme, lemon verbena, woodruff.

Restrictions for extension of use

A full list of restrictions is given in Appendix IV. Particular attention is drawn to condition 5 which states:-

"Pesticides must only be used in the same situation as that on the product label ie outdoor or protected. Pesticides must not be used on protected crops, ie crops grown in glasshouses, poly tunnels, cloches or polythene covers or in any other building, unless the product label specifically allows use on that crop under protection. (NB unless specifically restricted to outdoor crops only, pesticides approved for use on tomatoes, cucumbers, lettuce, chrysanthemum and mushrooms include use under protection). Products approved for use only under protection must not be used outdoors."

Under these long term arrangements, the following pesticides may be used on nursery stock for leatherjacket control (see Table 1 for summary).

1. **Chlorpyrifos**

Chlorpyrifos is a contact and ingested organophosphorus insecticide, available as both emulsifiable concentrate and granular formulations.

(a) Emulsifiable concentrates - Various products (see Table 1) are approved for use as sprays against leatherjackets on a range of outdoor crops eg cereals, grassland, brassicas, sugar beet and peas. Thus, these products may be used on non-edible nursery stock **outdoors**. In addition, Dursban 4 and Lorsban T are approved for use against vine weevil in conifers, and together with Spannit, against black pine beetle, pine weevil and vine weevil in forestry transplant liners.

Dursban 4 is the most commonly used product used against leatherjackets in nursery stock. It should be applied as a high volume drench, in mild (above 5°C), moist conditions when leatherjackets will be active on or near the surface of the compost.

Dursban 4 is also approved for use on outdoor lettuce, for cutworm control. Theoretically, it can thus be used at growers' own risk, on **outdoor** herbs and edible flowers. However, the label warns against using the product on young lettuce or sugar beet plants, as damage can occur. Thus it should be used with caution on herbs. Indeed, all chlorpyrifos drenches carry the risk of phytotoxicity on ornamentals, and the labels warn against using on any other than some species of conifers. Many growers using chlorpyrifos on nursery stock wash the product off the foliage with plain water after application, to reduce the risk of damage.

(b) Granular formulations - SuSCon Green is a slow release granule approved for use against vine weevil larvae in HONS. It is mixed into the compost before potting and gives control for two years after potting. Although no efficacy data is available against leatherjackets, it is possible than when used against vine weevil, incidental control of leatherjackets may be given. Evidence is so far anecdotal, with some growers believing the product has contributed to leatherjacket control and others not. Until efficacy data is available, the product should not be used for leatherjacket control alone.

2. **Gamma - HCH**

Gamma-HCH is a contacted, ingested and fumigant organochlorine insecticide. Formulations suitable for leatherjacket control include suspension concentrates and granular baits.

(a) Suspension concentrates - Various products (see Table 1) are approved for use as drenches against leatherjackets on a range of outdoor crops eg cereals, grassland, maize, sugar beet, brassicas and strawberries. In addition, Atlas

Steward and Gamma-col are approved on protected ornamentals and salad crops, not for leatherjackets but for other pests. Thus, there are gamma-HCH formulations available for use against leatherjackets on both outdoor and protected ornamental nursery stock.

One product, Atlas Steward, is approved for use on outdoor spinach and protected celery; not for leatherjackets but for other pests. Therefore, it may be used on both outdoor and protected herbs and edible flowers. However, gamma-HCH can damage young lettuce seedlings, therefore it is advisable to avoid spraying herbs until at least the 2-true leaf stage.

No Gamma-HCH drench should be made when the roots are dry.

(b) Granular baits - One product, Unicrop Leatherjacket Pellets, is available in a ready made pelleted bran bait. The product is approved for the control of leatherjackets in arable crops and can thus be used on **outdoor** ornamental nursery stock. Atlas Steward may be mixed with moistened bran for application as a bait; see product label for details.

3. **Triazophos**

Triazophos is a contact and stomach acting organophosphorus insecticide. There is only one approved product (Hostathion) which has approval for leatherjacket control on cereals and grassland. Although the product has specific off-label approval for protected ornamentals for the control of American Serpentine leaf miner, there are no label recommendations for outdoor or protected ornamentals. The product is not recommended on crops suffering from stress. Use on outdoor ornamentals would be at growers' own risk. Use on protected ornamentals for leatherjacket control is not permitted, as extrapolations for extensions of use must not be made from specific off-label approvals.

4. **Methiocarb**

Methiocarb is a stomach acting carbamate molluscicide and insecticide. There are two products available; Decoy and Draza. Both are recommended primarily for control of slugs and snails, but the label also states some reduction of leatherjackets will be given. Both products can be used on arable and outdoor horticultural crops, so may be used on both outdoor nursery stock and herbs. Decoy contains 2% methiocarb rather than 4% as in Draza, so is useful where more pellets per m^2 are required. Draza also has specific off-label approval for use on all protected edible and non-edible crops (0186/92), so may be used on protected nursery stock and herbs.

Timing/efficacy of pesticides against leatherjackets

Chemical control of leatherjackets by drenching or using baits relies on the pest being active on or near the surface of the soil or compost. Therefore, the following factors must be considered before applying a pesticide:

1. Weather conditions - The minimum environmental conditions for leatherjacket activity on the surface have yet to be defined (Blackshaw *et al.*, 1994). However, it is well known from work on leatherjackets on arable crops, that surface activity is encouraged by mild weather, when the surface is moist. In nursery stock, if irrigation techniques ensure the soil or compost surface is kept moist, then temperature could be a limiting factor. Leatherjacket activity is greater above 5°C (Laughlin, 1967). Surface activity will increase the chances of control by contact pesticide drenches and also the chances of encounter with bait formulations.

   In addition to affecting leatherjacket activity, weather conditions also affect pesticide efficacy eg chlorpyrifos activity may be reduced below 5°C or on organic soils.

2. Time of year - In addition to weather conditions, time of year is relevant regarding the growth stage of the larvae. Pesticides applied to grassland have given greater responses when applied in September to January, than when applied between March and April (Stewart and Kozicki, 1987; Blackshaw, 1984; Newbold, 1981). During the autumn, larvae of both *T. paludosa* and the autumn generation of *T. oleracea* will be in their early stages and it is known that immature larvae are more susceptible to pesticide toxicity (Newbold, 1981). In April, both species will usually be in their fourth instar, when the larvae are deeper in the compost and inactive (see Biology section). Therefore at this time of year, the larvae will not be exposed or susceptible to pesticide treatment.

   For valuable nursery stock subjects, low numbers of larvae can do considerable damage, therefore growers apply a pesticide at the first signs of feeding damage; there is no "threshold" for treatment as for arable crops. This is usually during September or October, but can also be in the spring or summer periods, depending on the season and the species present (see Case Studies and Biology Sections).

3. Relative efficacy of pesticides

   Most of the work carried out on efficacy of pesticides against leatherjackets has been done on grassland. Much data has been published on yield responses to treatment, but information on relative efficacy against the pest is scarce (Blackshaw, 1985).

   (a) Chlorpyrifos - No efficacy data is available for leatherjacket control on nursery stock, but growers interviewed estimated that up to 90% control is given, provided it is timed accurately and applied as a high volume drench. In grassland, at least 80% mortality is usually given by chlorpyrifos, although field trials have shown reduction varying from 53-100% (Blackshaw and Newbold, 1987). Subsequent work on grassland has shown mortality rates from 92-96% with chlorpyrifos sprays (Blackshaw, 1984).

   (b) Gamma - HCH - No efficacy data is available for leatherjacket control on nursery stock. It is likely that control will be poorer than on arable crops, as label recommendations for field crops state that control is better when harrowing is carried out after application. Most growers interviewed considered chlorpyrifos to be more effective on nursery stock, but gamma-HCH was used occasionally eg on plants susceptible to chlorpyrifos damage or on protected plants where chlorpyrifos may not be used.

Efficacy of pelleted baits will depend upon leatherjacket activity, as already discussed. Most growers interviewed considered that pellets contributed to control but that pesticide drenches were needed for severe attacks.

(c) Triazophos - No efficacy data is available for leatherjacket control on nursery stock and no growers interviewed had used it for control.

(d) Methiocarb - Leatherjackets feeding on methiocarb pellets rapidly become immobilised (Blackshaw, 1994). There is no data available for efficacy compared with other pesticides, but some growers using methiocarb considered the pellets to be contributing to control of leatherjackets (see Case Studies).

Table 1 Summary of pesticides which may be used for leatherjacket control on hardy nursery stock.

Pesticide	Trade name	Formulation	Ornamentals		Herbs		Harvest Interval
			Outdoor	Protected	Outdoor	Protected	(Herbs)
chlorpyrifos	Barclay Clinch	EC	✓	X	X	X	N/A
	Dursban 4	EC	✓	X	✓	X	21 days
	Lorsban T	EC	✓	X	X	X	N/A
	Spannit	EC	✓	X	X	X	N/A
	Talon	EC	✓	X	X	X	N/A
	SuSCon Green	GR	✓	✓	X	X	N/A
gamma-HCH	Atlas Steward	SC	✓	✓	✓	✓	14 days
	Gamma-Col	SC	✓	✓	X	X	N/A
	Lindane Flowable	SC	✓	X	X	X	N/A
	Unicrop Leather-jacket Pellets	GB	✓	X	X	X	N/A
triazophos	Hostathion	EC	✓	X	X	X	N/A
methiocarb	Decoy	RB	✓	X	✓	X	7 days
	Draza	PT	✓	✓*	✓	✓*	7 days

* Specific off-label approval sheet 0186/92 required before use.

<u>Abbreviations</u>
EC Emulsifiable concentrate
GR Granules
SC Suspensions concentrate (= flowable)
GB Granular bait
RB Ready-to-use bait

ADAS

CULTURAL CONTROL OF LEATHERJACKETS

The majority of cultural control methods available for arable crops are not applicable to nursery stock:-

1. Cultivation

In arable crops, the main method of cultural control for leatherjackets is by cultivation. If possible, early ploughing up of the previous grass crop in July or August, reduces egg-laying. Mortality of leatherjackets during seed-bed preparation can be as high as 70% (Blackshaw, 1988). Deaths are caused by the cultivation itself, subsequent desiccation due to exposure and by predation by birds, which are efficient predators of leatherjackets. Cultivation is obviously not an option available to growers of containerised ornamentals, although it can be used on open-field grown trees and shrubs.

2. Use of fertiliser

In grassland, extra applications of nitrogen can compensate for leatherjacket attack and give yield responses equivalent to those from the use of chlorpyrifos (Blackshaw and Newbold, 1987). Again, under most circumstances, this is not a practical option for nursery stock, where plant quality is more important than yield. Extra feed could boost the growth of flagging plants, but if left unchecked, leatherjackets could continue to cause severe damage. In addition, use of extra nitrogen is not a particularly environmentally sound option.

3. Irrigation

Containerised nursery stock is rarely over-watered and plants are not allowed to dry out. Therefore there are no opportunities to take advantage of dry periods during crane fly egg laying times, to reduce survival of eggs and young larvae.

4. Weed control

This is the main cultural control method available for nursery stock.

Weed control should reduce egg-laying sites, although it is still to be confirmed whether crane flies on HONS nurseries are attracted to weeds or the plants themselves for egg-laying. Use of Mypex can help and there is also good potential for the various pot covers which are now gaining commercial interest as alternatives to chemical weed control in container nursery stock (Hewson, personal communication). These covers or mulches, in addition to controlling weeds, could also act as a physical barrier against egg-laying by crane flies and vine weevils and may also deter other pests such as slugs and snails.

BIOLOGICAL CONTROL OF LEATHERJACKETS

Owing to environmental pressures to reduce pesticide usage, there is increasing interest in developing IPM on outdoor crops, either by conserving and enhancing naturally occurring biological control agents, or by introducing those commercially available. In order to increase the competitiveness of UK nursery stock growers in the marketplace, MAFF has recently commissioned ADAS to carry out a 3-year research project to develop biological control of pests of outdoor hardy nursery stock. This collaborative project with the Institute of Arable Crops Research, Rothamsted, will investigate the naturally occurring biological control agents of vine weevil and foliar pests and evaluate the potential of semiochemicals to increase foraging behaviour and enhance control.

There is considerable interest in developing biological control of leatherjackets in grassland in Northern Europe and Canada. Field and laboratory studies have been carried out on naturally occurring predators, parasites and pathogens and also those with commercial potential:-

1. Parasitic nematodes

Three species of parasitic nematodes are already commercially available and widely used in the UK on both protected and outdoor ornamentals, for the control of vine weevil and, on protected ornamentals only, sciarid fly control. These species are:-

Steinernema feltiae (for vine weevil and sciarids), *Steinernema carpocapsae* (for vine weevil) and *Heterorhabditis* sp. (for vine weevil and sciarids). Work has been carried out using all three nematode species against leatherjackets and results indicate that *Steinernema* species show most commercial potential:-

(a) *Steinernema feltiae*

Ehlers and Gerwien (1990; 1993) demonstrated that *S. feltiae* was more effective against *T. paludosa* larvae than *Heterorhabditis* sp. In the laboratory, a mean larval mortality of 50% was given, ranging from 13 to 90%. Some of this variation was due to the fourth larval instar being less susceptible to nematodes than the younger instars. *S. feltiae* tended to remain in the upper soil layer after application. Therefore, although attracted to leatherjackets, the nematodes may not reach the fourth instars which tend to burrow lower into the soil. Another cause of variation in control was the ability of some larvae to survive nematode invasion by encapsulating the nematodes in the haemocoel (the insect's equivalent to the vertebrate's blood system). This would prevent release of the lethal bacteria, *Xenorhabdus* sp., which cause death of the host by septicaemia.

Peters and Ehlers (1994) compared the susceptibility of *T. paludosa* and *T. oleracea* to *S. feltiae* and found *T. oleracea* to be more susceptible. Highest mortality was in the first instar larvae approaching the first moult. Nematode penetration was found to be mainly directly through the leatherjacket skin, so this would be easier at moulting. Host penetration through the skin has been recorded in *Heterorhabditis* spp., but never before for *Steinernema* spp. In leatherjackets, the morphology of the spiracles would make nematode access impossible, whereas the cuticle (skin) is thin. It is possible that nematodes also secrete enzymes to digest the cuticle to facilitate access. Penetration through the mouth or anus was found to be of minor importance in leatherjackets.

Leatherjacket mortality was shown to be correlated with the number of invading nematodes. The second to fourth instars decreased in susceptibility with age, particularly in *T. paludosa*. All instars except the first were able to encapsulate nematodes in the haemocoel, but sometimes the bacteria were released before encapsulation.

(b) *Steinernema carpocapsae*

Lam and Webster (1972) showed that *S. carpocapsae* can penetrate and reproduce in leatherjackets, causing 30-100% mortality, depending on dose rate. Their work was carried out on third and fourth instar larvae, so it is possible that control may have been better with younger larvae. Encapsulation of nematodes was not observed in *T. paludosa*, but Peters and Ehlers (1994) have since observed this defence reaction occurring in *T. oleracea*. Death of *T. paludosa* occurred between 3 and 26 days after infection.

(c) *Heterorhabditis* sp.

Ehlers and Gerwien (1993) showed that *Heterorhabditis* sp. have little potential for the control of leatherjackets. Mortality never exceeded 20% and nematodes released near leatherjackets made no attempt to penetrate them.

Of the nematode species above, UK nursery stock growers currently use both *Heterorhabditis* sp (eg Nemasys H, Fightagrub) and *Steinernema carpocapsae* (eg Exhibit C) for control of vine weevil larvae. From the work described, *S. carpocapsae* could also give control of leatherjackets, although the timing of application for vine weevil control may not coincide with the best timing for leatherjacket control. For vine weevil, *S. carpocapsae* is used in April/May and again in August/early September, to target the larvae before pupation, but whilst soil temperatures are above 13-14°C. In April/May, *T. paludosa* larvae are likely to be in their fourth instar and *T. oleracea* in the fourth instar or pupal stage. In August/early September, most *T. paludosa* larvae are likely to be in their fourth instar and *T. oleracea* in the fourth instar or pupal stage. In August/early September, most *T. paludosa* will be in the adult stage, and *T. oleracea* in the pupal/adult stage.

The most effective timing of nematode application for leatherjacket control is likely to be when the majority of first instar larvae are moulting to second instars ie late September for both *T. paludosa* and *T. oleracea* and late June for the Spring Generation of *T. oleracea*. However, if nematodes were applied one or two months earlier for vine weevil control, they may survive in the compost due to reproduction in vine weevil larvae and subsequent release from the cadavers. Otherwise, a separate application may be necessary for each pest if both pests require control on the nursery, in which case *S. feltiae* is likely to give better control of leatherjackets than *S. carpocapsae*. *S. feltiae* (eg Nemasys, Exhibit F) also has the advantage that it is tolerant of lower temperatures than *S. carpocapsae*. It is effective down to 10°C, thus an application in late September may still give control.

Work on the timing, rate of application and species of nematode for leatherjacket control is justified on nursery stock.

2. *Bacillus thuringiensis*

Bacillus thuringiensis (B.t.) is a bacterium which produces a protein crystal which, when ingested by insect larvae, is dissolved in the gut, causing death of the host. There are various strains of B.t.; one strain kills caterpillars, another kills beetle larvae and another, *B.t. var. israelensis*, kills fly larvae (Waalwijk *et al.*, 1992).

B.t. var. israelensis (Bti) has been developed as a biological control agent against insects carrying disease eg. mosquitos and blackflies. In the UK, three products are currently approved for professional use for blackfly control; Bactimos, Skeetal and Teknar. Various Bti products have been evaluated against leatherjackets, as an alternative to chemical control.

Laboratory studies have shown that a liquid formulation of Bti sprayed onto cabbage or lettuce leaves, subsequently fed on by leatherjacket larvae can kill 100% fourth instar larvae within seven days at 20°C (Waalwijk *et al.*, 1992). Bti was shown to be toxic to both *T. paludosa* and *T. oleracea* in the laboratory.

Laboratory studies using Bti mixed with wheat bran, subsequently fed on by leatherjackets, led to 71% mortality of late instar larvae (Chard *et al.*, 1990). Only 8% mortality was given by *B.t. subsp. kurstaki* (Dipel); the strain used commercially in the UK for caterpillar control. This demonstrated the specificity of Bti to Dipteran (fly) larvae.

Evans (1993) showed that three novel formulations of Bti were effective against *T. paludosa* larvae in the laboratory. Liquid concentrate sprayed onto barley or oilseed rape leaves subsequently fed on by leatherjackets was effective at various dose rates. However, at the lower doses, mortality did not occur for 22 days, as the larvae had to consume enough Bti-sprayed leaf material for a toxic effect. However, the Bti also appeared to have a feeding deterrent effect, which led to reduced plant damage before mortality occurred. The pelleted and granular formulations were also effective in killing and reducing feeding by leatherjackets, but the rate of kill was variable and slower than the sprayed treatment.

The laboratory work described above has been followed up with field trials on grassland to evaluate the commercial potential of Bti applied as sprays, granules or pelleted baits (Evans, pers. communication). As with pesticide treatments, timing of Bti is important as control relies on leatherjackets feeding on the surface in order to ingest the product. Autumn sprays of Bti either as a flowable concentrate or a wettable powder gave up to 70% reduction in leatherjackets. Control was as good, or sometimes better than chlorpyrifos (Dursban). In the field situation, the granules and pellets broke down quickly and thus were effective as baits for only a short period.

ADAS Redesdale has also carried out field trials using Bti for leatherjacket control on organic grassland (Keatinge, personal communication). Granular formulations have been used in the spring as baits for leatherjackets. Some control has been demonstrated, but leatherjacket pressure was variable and results so far inconclusive. Results to date indicate that Bti has commercial potential against leatherjackets on nursery stock, particularly if applied as a spray. The bacterium has no lower temperature limit but, as with pesticides, would have to be timed carefully to coincide with leatherjackets feeding near the surface.

3. Viruses

Leatherjackets can be naturally infected with two viruses:-

(a) Tipula iridescent virus (TIV)

TIV is a lethal virus, spread within leatherjacket populations by cannibalism ie when healthy larvae feed on infected ones (Carter, 1975b). All stages in the life cycle can be infected, but early larval instars are the most susceptible (Carter, 1978). Infected pupae are malformed and often fail to emerge as adults. The adults apparently do not play a significant role in virus transmission (Kelly and Blackshaw, 1987).

TIV can be detected in the laboratory by observing the development of a brilliant blue iridescence in the insect's tissues (Carter, 1975b; Carter *et al.*, 1983). Laboratory studies indicated that TIV was active between 3 and 27°C, with optimal activity varying between the different stages of the insect. This would be an adaptation to infecting the host in the field; the temperature range of *T. oleracea* is also 3-27°C (Carter, 1975b). The optimal temperature for TIV infection of fourth instar larvae and pupae is 20°C. Field studies showed that TIV incubation periods and leatherjacket survival times were longer in the winter than in the spring.

Carter (1978) evaluated the potential of TIV as a biological control agent against leatherjackets in grassland. The virus was used as a spray, bran bait or introduced in infected larvae. Only 1-17% of the leatherjacket population became infected with TIV despite the high concentration of infective material introduced to the field. It was concluded that all methods of introduction could introduce TIV but with low efficiency.

(b) Nuclear polyhedrosis virus (NPV)

NPV is a baculovirus of *T. paludosa*, which infects the haemocytes (cells in the haemocoel). Infected larvae appear pallid due to infected haemolymph becoming milky white. NPV infection appears to inhibit moulting and prevent pupation (Carter and Green, 1988). Infection seems to develop slowly, with symptoms not developing for several months. Carter (1976) found levels of natural infection between 1 and 27% in *T. paludosa* in grassland in Northumberland, with greater infection occurring between April and June.

Work to date indicates that neither TIV nor NPV currently have commercial potential as biological control agents against leatherjackets.

4. Ground beetles

Ground beetles (carabids) are polyphagous predators ie they feed on a range of invertebrates. Much work has been published on ground beetles as natural enemies of aphids in cereal crops, but their diet also includes springtails, midges, other fly larvae, mites, beetle larvae and earthworms (Burn, 1992). There is now interest in their role as predators of horticultural pests eg vine weevil larvae. The HDC is already funding a PhD project at HRI East Malling, to investigate the potential of a range of predators, including ground beetles, against vine weevil on soft fruit. ADAS has just commenced MAFF-funded work on natural enemies of pests of HONS, including predatory beetles against vine weevils. Some of the predators studied in both HRI and ADAS work may also have the potential to contribute to control of leatherjackets.

Many predatory ground beetles have been observed feeding on leatherjackets (Wilkinson, 1984). One species of ground beetle, *Pterostichus melanarius*, has already been shown to detect and kill leatherjackets in the laboratory, whether near the soil surface or burrowed underground (Chapman, 1994). This work was carried out in Aberdeen, and in North East Scotland where *P. melanarius* is the most abundant large ground beetle in agricultural land. Here, adult beetles are present between May and September, with a peak in August but still abundant in September and May. In England, adult *P. melanarius* are also common in arable land and breed mainly in the late summer or autumn, over-wintering as larvae in the soil (Burn, 1992). Thus, adults of this ground beetle species should be active at the same time as young leatherjackets in September, and fourth instar larvae in the late spring. The habit of fourth instar leatherjackets burrowing deeper in the soil should not deter *P. melanarius*, which seemed able to hunt leatherjackets underground in May, possibly following chemical stimuli (Chapman, 1994).

<u>Side effects of pesticides on ground beetles</u>

Ground beetles are not available as commercial biological control agents but could be well worth conserving as natural predators on HONS nurseries. Chlorpyrifos and gamma-HCH, the pesticides most commonly used against leatherjackets, are both active against Coleoptera (beetles) and are persistent for many weeks. Their long-term side effects on biological control agents are well-known (various publications by the IOBC; International Organisation for Biological Control) and these two pesticides are generally avoided in IPM strategies.

The effects of chlorpyrifos against non-target/beneficial organisms in grassland have been widely studied (Rushton *et al.*, 1989; Luff *et al.*, 1990). Luff *et al.*, (1990) reported that when chlorpyrifos was used against leatherjackets in grassland, there was a marked effect against common ground beetles. Different beetle species varied in their response to chlorpyrifos; those with longer life cycles and in the adult phase at the time of spraying would be more affected, for up to 18 months after spraying. *P. melanarius* adults are present in the early autumn, when chlorpyrifos is often applied against leatherjackets. Experiments by Luff *et al.*, (1990) with chlorpyrifos resulted in 100% mortality of *P. melanarius*.

Active fliers eg. *Trechus quadristriatus*, another common ground beetle, are less affected by pesticides, as they can recolonise habitats after treatment.

Results of Luff *et al.*, (1990) have been confirmed by intensive studies on the environmental side effects of pesticides, within the "Boxworth Project". This long-term MAFF-funded project began in 1981 and compared the effects of various pesticide regimes on non-target organisms. The "full insurance regime" included chlorpyrifos, methiocarb, triazophos and pyrethroids in the autumn/winter period. This regime led to a 53% reduction in numbers of predatory insects and spiders (Cilgi *et al.*, 1993). Those species which walk rather than fly were most affected, including many predatory beetles.

A new long term project called SCARAB (Seeking Confirmation about Results at Boxworth) is already giving similar results. Following a chlorpyrifos spray in a "Current Farm Practice Regime", many non-target species, including ground beetles, took at least six months to recover populations in the field (Cilgi and Frampton, 1994); see Fig. 5, Appendix VI.

Thus, it is clear that should ground beetles prove to be significant predators of leatherjackets (and vine weevil larvae), use of certain pesticides on HONS nurseries will be preventing populations becoming established. Current ADAS work on monitoring vine weevil predators on HONS nurseries should indicate which species are present, and their potential as natural enemies of various nursery stock pests.

5. **Parasites**

(a) *Siphona geniculata*

This Tachinid parasitic fly was first described by Rennie and Sutherland (1920), who found it naturally infesting leatherjackets; mainly *T. paludosa*, but also *T. oleracea*. This fly is reported to be widely distributed throughout Great Britain and has also been found parasitising caterpillars of the cabbage moth, *Mamestra brassicae*. The fly has two generations. First generation flies lay their eggs in young leatherjackets in the autumn and spend the winter as larvae inside the host before emerging to pupate in the soil in April/May. Second generation flies lay their eggs in leatherjackets in June, develop inside the host during June and leave to pupate in the soil in July.

In 1920, surveys showed that an average of 21% leatherjackets were infested with first generation *S. geniculata* in February/March, and 40% infested with second generation parasites in June/July. More recent surveys for natural enemies of leatherjackets have detected up to 73% parasitism by *S. geniculata* in June (Carter *et al.*, 1981).

Thus, it seems that in some years, this parasite is common in leatherjackets. However, as it does not kill the host until the fully developed larva emerges to pupate (Carter, 1976), its lethal effect is likely to be too slow for use as a commercial biological control agent. However, it may contribute to natural regulation of leatherjacket numbers in some years.

(b) *Phaonia signata*

This muscid fly was found parasitising *T. paludosa* larvae in May and June, with up to 22% parasitism recorded in 1981 (Griffiths *et al.*, 1984). This was the first record of this species attacking leatherjackets, but none were detected in surveys the following year. As with *S. geniculata*, this parasite may contribute to natural regulation of leatherjacket numbers in some years.

(c) *Protozoa*

Gregarine and coccidian parasites are commonly found in leatherjackets, in both the gut and the haemocoel. Up to 100% of the population can be infested, but there is no evidence to suggest that they affect the well-being of their hosts (Carter, 1976).

6. Fungal pathogens

Two species of *Entomophthora*, *E. gigantea* and *E. caroliniana* have been found infecting *T. paludosa* adults, causing up to 80% mortality of adult populations in Switzerland (Keller, 1979). It is possible that this fungus has the potential for use as a biological control agent. *Entomophthora* spp. occur naturally in the UK on various insects eg aphids and have been studied as potential biological control agents, but none are yet available commercially.

7. Other potential biological control agents

Although not recorded in the literature as a predator of leatherjackets, the predatory mite *Hypoaspis miles* may have potential. *H. miles* naturally occurs in the soil, where it is a predator of various small organisms. It is now commercially available for use on ornamentals and mushrooms for the control of the larvae of sciarid and phorid flies. It is being used increasingly on containerised HONS under protection, for control of sciarid and shore fly larvae. Adult flies of these species can build up to large numbers in conditions of high humidity eg propagation tunnels and in houses where puddles of water collect, attracting moss and algae which attract the flies.

Hypoaspis is approximately only 1mm long and can only feed on small larvae. In addition to sciarid and phorid larvae, it has been found feeding on other fly larvae, mites and may also even feed on small vine weevil larvae (Natural Pest Control, personal communication). When *T. oleracea* first instar larvae hatch, they measure approximately 1mm, growing to approximately 5mm before moulting to second instars (den Hollander, 1975a). It is likely that *Hypoaspis* could feed on newly hatched leatherjacket larvae. *Hypoaspis* is an active searcher and rapidly establishes in potted ornamentals. As it can survive for up to six weeks in moist compost without food, it can be introduced preventively, so that established populations are present when the target pest species hatch. *H. miles* are active down to 10°C and thus could be used both under protection and outdoors at certain times of the year. First instar *T. paludosa* and *T. oleracea* are present in September, when soil temperatures are 10°C or above (see Fig 3, Appendix III) (Laughlin, 1967). First instar second generation *T. oleracea* are present in June, when temperatures should not be limiting for *Hypoaspis*.

It is recommended that *H. miles* is investigated as a potential biological control agent of leatherjackets on nursery stock.

CASE STUDIES

Six leading growers with a history of leatherjacket damage were contacted:-

Site 1 - Alpines

(a) Plant species attacked and damage in recent years

This nursery has a history of severe damage, particularly in polythene tunnels. Damage has regularly been recorded since 1987 on various containerised alpines eg Arabis, Aubretia, Saxifrage, Sempervirum and also on herbs eg Hyssop. Leatherjackets have been found in the compost, feeding on the roots and leading to poor growth and die back. Severe grazing of stem bases at the surface of the compost has also been recorded. Damage in 1990 was considered more severe than in subsequent years, but the pest has caused notable damage in most years. This year, severe damage occurred in early May on Saxifrage outdoors and both Dianthus and Gentians under polythene.

(b) Time of year of attack

Leatherjacket activity has usually occurred in the winter or spring (November to May) but larvae have also been found in August, indicating that both *Tipula oleracea* and *T. paludosa* could have been present. In addition, adult crane flies have been noted in both spring and summer, sometimes in "plague" proportions.

(c) Surrounding crops

Grassland/cereals.

(d) Control measures used

Since the withdrawal of aldrin, various control measures have been used eg mini-leatherjacket pellets (containing gamma-HCH) or methiocarb pellets broadcast over the surface of the pots, or drenches of gamma-HCH, fonofos or chlorpyrifos. Treatments have been applied during the adult activity period, or at the first signs of larvae or damage.

Efficacy has been variable, with drenches considered more effective than pellets against severe attacks. However, drenching adequately is a difficult and time-consuming operation, and for safety reasons unpopular with nursery staff who frequently handle the pots. Phytotoxicity has also been recorded, eg with chlorpyrifos on Arabis and Aubretia. Although vine weevil occurs on the nursery, "SuSCon Green" is not used routinely due to high cost and potential phytotoxicity on a wide range of unusual and valuable species.

(e) Interest in IPM

This nursery uses IPM on all plants under glass and also in some polythene tunnels. There is a strong commitment to IPM and preference for biological methods of control, by both management and nursery staff. Choice of pesticide is limited, not only by persistent side effects on biological control agents, but also by the limited range of pesticides approved for use on herbs.

The nursery would be keen to help develop and use a control measure for leatherjackets which would be compatible with IPM.

Site 2 - Nursery Stock

(a) Plant species attacked and damage in recent years

This nursery has a history of damage on many species, particularly on sandbeds eg on Lavender, Potentilla and Syringia. Damage was particularly severe in 1989 and 1990, when heavy root grazing occurred, leading to backward and stunted growth and plant losses. Up to 50% root loss was recorded on Syringia. Since then, routine pesticide treatments have been applied against leatherjackets.

(b) Time of year of attack

Most leatherjacket activity has been in the autumn to spring period, but larvae have also been found in the summer. Adult activity has been seen as early as March during warm weather. It is likely that both *Tipula* species have been present.

(c) Surrounding crops

Grassland/cereals.

(d) Control measures used

Carbaryl drenches were used in 1989 and 1990, thereafter chlorpyrifos drenches have been used. High volume drenches are applied in the autumn (early September to late October) as a matter of routine. All stock is treated except Hydrangeas, on which phytotoxicity has been recorded. Treatment is only made in the spring if necessary. Since routine treatments have been made in the autumn, incidence of leatherjacket damage and adult activity has been significantly reduced. It is estimated that chlorpyrifos drenches give approximately 90% control, as long as applications are timed carefully and high volume drenches used.

(e) This nursery uses IPM, both under protection and outdoors and the manager has been keen to help develop and adopt new biological control agents. Use of chlorpyrifos in the autumn does not currently interfere too much with IPM, as applications are usually made when temperatures are becoming too cool for biological control agents. If chlorpyrifos drenches are necessary in the spring, they are timed if possible just before sale, but if needed earlier, use of IPM is not possible due to persistent side effects on biological control agents. The nursery would be keen to use a control measure for leatherjackets which would be compatible with IPM.

Site 3 - Nursery Stock

(a) Plant species attacked and damage in recent years

The last major leatherjacket problem at this nursery was in October 1990, when 20% of Weigelas, Vibernums and deciduous Azaleas on sandbeds in polythene tunnels were infested. The larvae had caused large "tunnels" in the compost and were feeding on the fibrous roots, contributing to poor growth. Since 1990, outbreaks have been sporadic and minor.

(b) Time of year of attack

Attacks have occurred in the autumn. In October 1990, the larvae were well developed, indicating they may have been *Tipula oleracea*.

(c) Surrounding crops

Grassland.

(d) Control measures used

In the major attack of 1990, control was achieved by heavy use of HCH leatherjacket pellets and also a thorough drench with chlorpyrifos. A dilutor was used to apply a very high volume drench and plain water was used afterwards to wash the insecticide off the foliage to avoid phytoxicity. High larval mortality was observed approximately two weeks after drenching.

The nursery manager attributes the reduced leatherjacket damage since 1990 to various factors:-

(i) All the stock is now grown in trays placed on Mipex, rather than directly onto sandbeds.

(ii) Methiocarb pellets are used as a routine, both on and under plant trays, which may be giving some incidental control of leatherjackets.

(iii) All liners are now treated with "SuSCon Green" for vine weevil control, which may be giving some incidental control of leatherjackets

(e) Interest in IPM

The nursery would be interested in adopting a control measure for leatherjackets which would be compatible with IPM.

11. PAYMENT

On each quarter day the Council will pay to the Contractor in accordance with the following schedule:

Quarter/Year	1994	1995
1	-	990
2	-	-
3	990	-
4	2970	-

Contract No: HNS59
Date: 12.10.94

TERMS AND CONDITIONS

The Council's standard terms and conditions of contract shall apply.

Signed for the Contractor(s)

Signature.......M. C. Heath..........

Position....ADAS ACCOUNT MANAGER

Date.......31.10.94..........

Signed for the Contractor(s)

Signature..

Position..

Date..

Signed for the Council

Signature.......[signature]..........

Position.......CHIEF EXECUTIVE

Date.......12.10.94..........

ADAS

Site 4 - Heathers

(a) Plant species attacked and damage in recent years

Leatherjackets are seen regularly on this heather nursery, although damage is not usually severe as control measures are applied at the first sign of the pest. This year, damage was significant in February in pot-grown heathers grown outdoors on capillary sandbeds. Slight damage had also been seen in plants grown in polythene tunnels over the winter. On average over the years, approximately 0.5% plants are damaged by leatherjackets, which graze on the roots and necks of the plants. The grower considers leatherjackets would be a more major pest if timely control measures were not applied.

(b) Time of year of attack

In most years, attacks are detected in the autumn or winter, but in some years, damage has also been noted in the spring and summer periods. The grower considers that the extent of damage seems to be linked with the amount of exposed compost in the pots during periods of adult crane fly activity.

(c) Surrounding crops

Arable/grass.

(d) Control measures used

Diazinon drenches used to be applied, but since its withdrawal, chlorpyrifos has been used. Routine pesticides are not used on the nursery. Chlorpyrifos drenches are applied at the first sign of the pest. Increased bird activity can often indicate the presence of leatherjackets and regular plant inspections are made during risk periods. Damaged plants found this February had not been treated last autumn.

SuScon Green had been used for vine weevil control on stock plants two years ago, but leatherjackets were still detected. The grower considers this pesticide too expensive for routine use.

(e) Interest in IPM

Pesticides are only used if necessary on the nursery. IPM is not currently used, but the grower would be interested in adopting IPM if proved to be effective and economic outdoors, particularly in view of the potential future restrictions in pesticide usage due to environmental pressures.

Site 5 - Nursery Stock

(a) Plant species attacked and damage in recent years

Leatherjackets were a major problem on this nursery until a few years ago; even more severe than vine weevils which are now the major pest on the nursery. Damage occurred to various nursery stock species eg ground cover roses. Since then, only minor damage has been detected.

(b) Time of year of attack

Mainly in the autumn period, but also in the spring/summer.

(c) Surrounding crops

Grass.

(d) Control measures used

No control measures are currently used specifically against leatherjackets on this nursery. SuSCon Green is used on stock plants for vine weevil control and it is possible that incidental control of leatherjackets is being given. In addition, regular treatments are made in the late spring and early autumn period against adult vine weevils eg methiocarb (Draza) pellets and sprays of bifenthrin (Talstar). These treatments are thought to be contributing to control of leatherjackets and adult crane flies respectively.

(e) Interest in IPM

The nursery uses IPM on nursery stock under glass and is extending this into polythene tunnels. Currently, vine weevil is such a big problem outdoors that pesticides are the preferred method for control. Should vine weevil be reduced so that integrated control be feasible, the manager would be interested in extending some use of IPM outdoors.

Site 6 - Nursery Stock (a range of sites)

(a) Plant species attached and damage in recent years

Severe damage was recalled on heathers and confers in the late 1970's and early 1980's, but no serious or widespread damage has been seen in the past five years.

(b) Time of year of attack

In 1994, damage to Lewisia and Weigelia occurred in the late summer/early autumn, indicating the species could have been *T. oleracea*.

(c) Surrounding crops

Most, but not all of the sites were surrounded by grass.

(d) Control measures used

Where leatherjacket damage occurred in the past, gamma-HCH drenches were made to sandbeds. Most of the sites now use SuSCon Green for vine weevil control, but the growers did not consider this to be the reason for the reduced leatherjacket damage in recent years, as the product has only been on the market for the past two seasons.

(e) IPM is used in propagation areas under protection on several of the nurseries. These growers are pro-IPM and would be interested in extending its use outdoors if applicable.

Discussions with other growers/ADAS Consultants

Various ADAS Horticultural Consultants and other growers around the country were contacted to discuss incidence and control of leatherjackets on nursery stock. A summary of these discussions is given below:-

(a) Plant species attacked and damage in recent years

The most susceptible plants were considered to be heathers, alpines, conifers and various shrubs, particularly those stood outside on sandbeds, protected by polythene tunnels or windbreaks, or planted into open ground after broken-up grass. Damage regularly occurs on some nurseries and sporadically on others. Damage can be severe in some years, with 1990 being recalled as particularly bad. Some nurseries who used to experience serious damage have seen only slight damage in recent years. This was sometimes attributed to the regular use of pesticides against vine weevil and sometimes unaccounted for and was thought to be due to the natural fluctuations of the pest. Most growers and consultants felt that when occurring, leatherjackets would be a more major pest if not detected quickly and timely control measures applied.

(b) Time of year of attack

Most leatherjacket activity is seen in the autumn to spring period, but attacks also occur regularly during the summer, indicating that *T. oleracea* could be the major species attacking nursery stock, but *T. paludosa* may also be present in the autumn to spring period. Adult crane flies are commonly seen in the spring, summer and autumn periods.

(c) Surrounding crops

Most nurseries are surrounded by at least strips of grass, or grassland/cereals/arable rotations. This has not yet been confirmed as being relevant to leatherjacket incidence, and some nurseries may have their own "resident" populations.

(d) Control measures used

Chlorpyrifos (usually Dursban) is the most commonly used pesticide, applied as a drench at the first sign of attack. Some growers wash off the foliage with water after application, to avoid phytotoxicity. Gamma-HCH is used as an alternative on plants known to be susceptible to chlorpyrifos, or on protected plants, as Dursban may only be used outdoors. Gamma-HCH or methiocarb pellets are used on some nurseries, but it is generally considered that drenches are required for control of severe attacks. SuSCon Green and other pesticides used against vine weevil, are thought to be contributing to leatherjacket control on some nurseries.

(e) Interest in IPM

All growers were unanimous in the wish to avoid unnecessary pesticide use. Growers are well aware of environmental pressures and the possible future restrictions on use of pesticides. Pesticides are only used when necessary and as containerised plants are handled frequently, staff on many nurseries preferred pesticides to be kept to a minimum. Many HONS nurseries are already using IPM to some extent on protected areas, and would be keen to use any non-chemical methods of pest control outdoors, should they prove to be both effective and economic.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

Further work is justified on the biology of leatherjackets attacking nursery stock and on methods of control compatible with IPM. The pesticides currently used for control are not compatible with IPM and the most commonly used one, Dursban, is not permitted on protected crops. There are increasing pressures to reduce pesticide usage, and rapidly increasing interest within the HONS sector to extend the use of IPM on plants both under protection and outdoors. Work on non-chemical methods of control would complement MAFF-funded work recently started by ADAS, investigating the use of biological control on outdoor nursery stock.

Recommendations for further work

1. The species of leatherjackets attacking nursery stock should be confirmed by monitoring and identifying adult crane flies on a range of nurseries, in both August/September and May/June. Larvae subsequently damaging plants should be identified to species by the IEF (isoelectric focusing) technique.

2. Egg-laying sites should be investigated on HONS nurseries to clarify whether eggs are laid directly into the compost in containerised plants or whether surrounding weeds attract oviposition.

3. The HDC has recently commissioned ADAS to investigate the use of various 'pot toppers' or mulches, as methods for non-chemical weed control in container grown nursery stock. Their role in incidental prevention of egg laying by crane flies should also be investigated.

4. SuSCon Green should be evaluated against leatherjackets, as there is anecdotal evidence that some incidental control is given when used for vine weevil.

5. The most promising commercially available biological control agents with potential for leatherjacket control should be evaluated:-

   (a) *Bacillus thuringiensis*, var. *israelensis* (Bti), applied as a spray.

   (b) Parasitic nematodes; both *Steinernema feltiae* and *S. carpocapsae*.

   (c) *Hypoaspis miles*. Laboratory studies should initially be undertaken to confirm their potential against young leatherjackets.

   All the above treatments should be evaluated on a commercial nursery, using plants artificially infested with eggs or first instar larvae, to ensure even distribution of the pest. If possible, the trial should be carried out on one of the sites used as part of the MAFF-funded ADAS work on evaluation of biological control agents on nursery stock. Information on species and numbers or predatory beetles will then be available, in order to assess their potential as natural enemies of leatherjackets.

ACKNOWLEDGEMENTS

Thanks are due to the following:-

The Horticultural Development Council for funding the review.

All the growers interviewed for the "case studies".

ADAS Consultants

John Buxton and Roger Umpelby at ADAS Worcester for help with the "case studies".

David Green at ADAS Wolverhampton for information on leatherjackets in grass and cereals, and data from the ADAS/Dow Elanco leatherjacket surveys.

Bill Parker at ADAS Wolverhampton and Ray Keatinge at ADAS Redesdale for information on biological control of leatherjackets in organic grassland.

David Rowell, David Hutchinson, Chris Stevens and other ADAS Nursery Stock Consultants for information on leatherjacket incidence in HONS.

Andrew Hewson of ADAS Lincoln for information on non-chemical weed control in container grown nursery stock.

Other ADAS Staff

Staff at the ADAS Library at Wolverhampton for carrying out the literature searches and retrieving numerous publications.

Marion Wilkinson at ADAS Huntingdon for typing the report.

Other sources of information

Dr Andy Evans at the Scottish Agricultural College, Edinburgh, for recent information on biological control of leatherjackets.

Dow Elanco Limited (suppliers of Dursban 4) for agreeing to data being used from the ADAS leatherjacket surveys undertaken on their behalf.

REFERENCES

ALFORD, D.V. (1984). *A colour atlas of fruit pests: their recognition, biology and control*, 101-103. Wolfe Publishing Ltd; London.

ALFORD, D.V. (1991). *A colour atlas of pests of ornamental trees, shrubs and flowers*, 151-153. Wolfe Publishing Ltd; London.

ASTERAKI, E.J., HANKS, C.B. and CLEMENTS, R.O. (1992). The impact of two insecticides on predatory ground beetles (Carabidae) in newly-sown grass. *Annals of Applied Biology* **120**, 25-39.

BARBASH, N.M. (1990). Improving techniques of rearing *Tipula paludosa* in the laboratory. *Entomologists Monthly Magazine* **126**, 1512-1515.

BINNS, E.S. (1976). Post emergence aggregation and mating in *Tipula paludosa*. *Entomologists Monthly Magazine* **111**, 93-96.

BLACKSHAW, R.P. (1983). The annual leatherjacket survey in Northern Ireland, 1965-82, and some factors affecting populations. *Plant Pathology* **32**, 345-349.

BLACKSHAW, R.P. (1984). The impact of low numbers of leatherjackets on grass yield. *Grass and Forage Science* **39**, 339-343.

BLACKSHAW, R.P. (1985). A preliminary comparison of some management options for reducing grass losses caused by leatherjackets in Northern Ireland. *Annals of Applied Biology* **107**, 279-285.

BLACKSHAW, R.P. (1988). Effects of cultivations and previous cropping on leatherjacket populations in spring barley. *Research and Development in Agriculture* **5**, 35-37.

BLACKSHAW, R.P. (1990). Observations on the distribution of leatherjackets in Northern Ireland. *Annals of Applied Biology* **166**, 21-26.

BLACKSHAW, R.P. (1994). Sampling for leatherjackets in grassland. *Aspects of Applied Biology* **37**, *Sampling to Make Decisions*, 95-102.

BLACKSHAW, R.P. and NEWBOLD, J.W. (1987). Interactions between fertiliser use and leatherjacket control in grassland. *Grass and Forage Science* **42**, 343-346.

BLACKSHAW, R.P., HUMPHREYS, I.C. and COLL, C. (1993). A new leatherjacket pest configuration in Northern Britain. *Proceedings Crop Protection in Northern Britain 1993*, 365.

BLACKSHAW, R.P. and PERRY, J.N. (1994). Predicting leatherjacket population frequencies in Northern Ireland. *Annals of Applied Biology* **124**, 213-219.

BLACKSHAW, R.P., STEWART, R.M., HUMPHREYS, I.C. and COLL, C. (1994). Preventing leatherjacket damage to cereals. *Aspects of Applied Biology* **37**, *Sampling to Make Decisions*, 189-196.

BRINDLE, A. (1960). The larvae and pupae of the British Tipulinae. *Transactions of the Society for British Entomology* **14**, part III, 63-114.

BURN, A.J. (1992). Interactions between cereal pests and their predators and parasites. *Pesticides, Cereal Farming and the Environment; The Boxworth Project*. Eds Greig-Smith, Frampton and Hardy, 110-131. HMSO; London.

CARTER, J.B. (1975a). Rearing *Tipula oleracea* in laboratory cultures. *Plant Pathology* **24**, 101-104.

CARTER, J.B. (1975b). The effect of temperature upon *Tipula* iridescent virus infection in *Tipula oleracea*. *Journal of Invertebrate Pathology* **25**, 115-124.

CARTER, J.B. (1976). A survey of microbial, insect and nematode parasites of Tipulidae larvae in North East England. *Journal of Applied Ecology* **13**, 103-122.

CARTER, J.B. (1978). Field trials with *Tipula* iridescent virus against *Tipula* spp. larvae in grassland. *Entomophaga* **23**, 169-174.

CARTER, J.B. GRIFFITHS, C. and SMITH, A.D. (1981). A high level of parasitism by *Siphona geniculata* in a population of *Tipula paludosa*. *Entomologist's Gazette* **32**, 257-258.

CARTER, J.B., GREEN, E.I. and KIRKHAM, A.J. (1983). A *Tipula paludosa* population with a high incidence of two pathogens. *Journal of Invertebrate Pathology* **42**, 312-318.

CARTER, J.B. and GREEN, E.I. (1988). Haemocytes of Baculovirus-infected *Tipula paludosa* larvae. *Journal of Invertebrate Pathology* **52**, 393-400.

CHAPMAN, P.A. (1994). Control of leatherjackets by natural enemies: the potential role of the ground beetle *Pterostichus melanarius*. *Brighton Crop Protection Conference - Pests and Diseases*, **2**, 933-934.

CHARD, J.M., McKINLAY, R.G. and BATY, J. (1990). Observations on the effects of *Bacillus thuringiensis* subsp. *israelensis* on crane fly larvae. *Aspects of Applied Biology* **24**, *The exploitation of micro-organisms in applied biology* 277-278.

CILGI, T., WRATTEN, S.D., FRAMPTON, G.K. and HOLLAND, J.M. (1993). The long-term effects of pesticides on beneficial invertebrates - lessons from the Boxworth Project. *Pesticide Outlook* **4**, 30-35.

CILGI, T. and FRAMPTON, G.K. (1994). Arthropod populations under current and reduced-input pesticide regimes: Results from the first four treatment years of the MAFF 'SCARAB' project. *Brighton Crop Protection Conference - Pests and Disease.* **2**, 653-660.

DEN HOLLANDER, J. (1975a). The growth of larvae of *Tipula oleracea. Tijdschrift voor Entomologie, Deel* **118**, 67-82.

DEN HOLLANDER, J. (1975b). The phenology and habitat of the species of the subgenus *Tipula* in the Netherlands. *Tijdschrift voor Entomologie* **118**, 83-97.

EHLERS, R.U. and GERWIEN, A. (1990). Evaluation of *Steinernema* spp. for the biological control of crane fly larvae *Tipula paludosa. Nematologica* **36**, 347.

EHLERS, R.U. and GERWIEN, A. (1993). Selection of entomopathogenic nematodes (Steinernematidae and Heterorhabditidae) for the biological control of crane fly larvae *Tipula paludosa. Journal of Plant Diseases and Protection* **100**, 343-353.

EVANS, K.A. (1993). The control of leatherjackets using novel formulations of *Bacillus thuringiensis* var. *israeliensis. Proceedings Crop Protection in Northern Britain 1993*, 366.

FRENCH, N. (1969). Assessment of leatherjacket damage to grassland and economic aspects of control. *Proceedings 5th British Insecticide and Fungicide Conference*, 511-521.

GRIFFITHS, C., CARTER, J.B. and OVEREND, J. (1984). *Phaonia signata* (Diptera; Muscidae) larvae predatory upon leatherjackets, *Tipula paludosa* larvae. *Entomologist's Gazette* **35**, 53-55.

HUMPHREYS, I.C., BLACKSHAW, R.P. and STEWART, R.M. (1993a). Distribution of *Tipula oleracea* and *Tipula paludosa* in Northern Britain. *Proceedings Crop Protection in Northern Britain 1993*, 85-90.

HUMPHREYS, I.C., BLACKSHAW, R.P., STEWART, R.M. and COLL, C. (1993b). Differentiation between larvae of *Tipula paludosa* and *Tipula oleracea* using isoelectric focusing, and their occurrence in grassland in Northern Britain. *Annals of Applied Biology* **122**, 1-8.

KELLER, S. (1979). *Entomophthora gigantea* sp. nov. and *E. caroliniana* comb. nov., two pathogens of *Tipula paludosa. Sydowia-Annales Mycologici* **31**, 87-93.

KELLY, M.S. and BLACKSHAW, R.P. (1987). Studies on natural enemies of leatherjacket populations in Northern Ireland. *Proceedings Crop Protection in Northern Britain 1987*, 422.

LAM, A.B.Q. and WEBSTER, J.M. (1972). Effect of the DD-136 Nematode and of a β-Exotoxin preparation of *Bacillus thuringiensis* var. *thuringiensis* on leatherjackets, *Tipula paludosa* larvae. *Journal of Invertebrate Pathology* **20**, 141-149.

LAUGHLIN, R. (1960). Biology of *Tipula oleracea*, growth of the larva. *Entomological experimentation and applications* **3**, 185-197.

LAUGHLIN, R. (1967). Biology of *Tipula paludosa*, growth of the larva in the field. *Entomological experimentation and applications* **10**, 52-68.

LUFF, M.L., CLEMENTS, R.O. and BALE, J.S. (1990). An integrated approach to assessing effects of some pesticides in grassland. *Brighton Crop Protection Conference - Pests and Disease* **1**, 143-152.

MAYOR, J.G. and DAVIES, M.H. (1976). A survey of leatherjacket populations in South-West England, 1963-74. *Plant Pathology* **25**, 121-128.

MEATS, A (1970). Susceptibility of the leatherjackets *Tipula oleracea* and *T. paludosa* to soil flooding. *Annals of Applied Biology* **65**, 25-30.

MEATS, A (1974). Simulation of population trends of *Tipula paludosa* using a model fed with climatological data. *Oecologia* **16**, 139-147.

MILNE, A., LAUGHLIN, R. and COGGINS, R.E. (1965). Population crashes in the leatherjacket *Tipula paludosa* in Northumberland. *Journal of Animal Ecology* **34**, 529-544.

MORRIS, R.F. (1986). Notes on an unusual habitat for overwintering European crane fly larvae in Newfoundland. *Canadian Entomologist* **118**, 1205-1206.

MOWAT, D.J. and JESS, S. (1986). The control of leatherjackets *Tipula paludosa* in grasslands by early application of insecticide. *Grass and Forage Science* **41**, 27-30.

NEWBOLD, J.W. (1981). The control of leatherjackets in grassland by winter pesticide applications. *Proceedings Crop Protection in Northern Britain 1981*, 207-211.

PESHO, G.R., BRAUEN, S.E. and GOSS, R.L. (1981). European crane fly: larval infestations in grass cultivars. Journal of Economic Entomology **74**, 230-233.

PETERS, A. and EHLERS, R.U. (1994). Susceptibility of leatherjackets (*Tipula paludosa* and *Tipula oleracea*) to the entomopathogenic nematode *Steinernema feltiae*. *Journal of Invertebrate Pathology* **63**, 163-171.

RENNIE, J. and SUTHERLAND, C.H. (1920). On the life history of *Bucentes (Siphona) geniculata* (Diptera: Tachinidae), parasite of *Tipula paludosa* and other species. *Parasitology* **12**, 199-211.

RUSHTON, S.P., LUFF, M.L. and EYRE, M.D. (1989). Effects of pasture improvement and management of the ground beetle and spider communities of upland grasslands. *Journal of Applied Ecology* **26**, 489-503.

STICH, H.F., (1963). An experimental analysis of the courtship pattern of *Tipula oleracea*. *Canadian Journal of Zoology* **41**, 99-109.

STEWART, R.M. and KOZICKI, K.K. (1987). DIY Assessment of leatherjacket numbers in grassland. *Proceedings Crop Protection in Northern Britain 1987*, 349-354.

RENNIE, J. and SUTHERLAND, C.H. (1920). On the life history of *Bucentes (Siphona) geniculata* (Diptera: Tachinidae), parasite of *Tipula paludosa* and other species. *Parasitology* **12**, 199-211.

WAALWIJK, C., DULLEMANS, A., WIEGERS, G. and SMITS, P. (1992). Toxicity of *Bacillus thuringiensis* var *israelensis* against tipulid larvae. *Journal of Applied Entomology* **114**, 415-420.

WHITE, J.H. and FRENCH, N. (1968). Leatherjacket damage to grassland. *Journal of the British Grassland Society* **23**, 326-329.

WIEGERS, G.L., DULLEMANS, A.M., and WIJBENGA, J. (1992). The rearing of *Tipula oleracea*. *Journal of Applied Entomology* **114**, 410-414.

WILKINSON, A.T.S. (1984). *Tipula paludosa*, European cranefly. In *Biological Control Programmes against Insects and Weeds in Canada 1969-1980*, Eds. Kelleher, J.S. and Hulme, M.A., 85-88. Commonwealth Agricultural Bureaux, Slough.

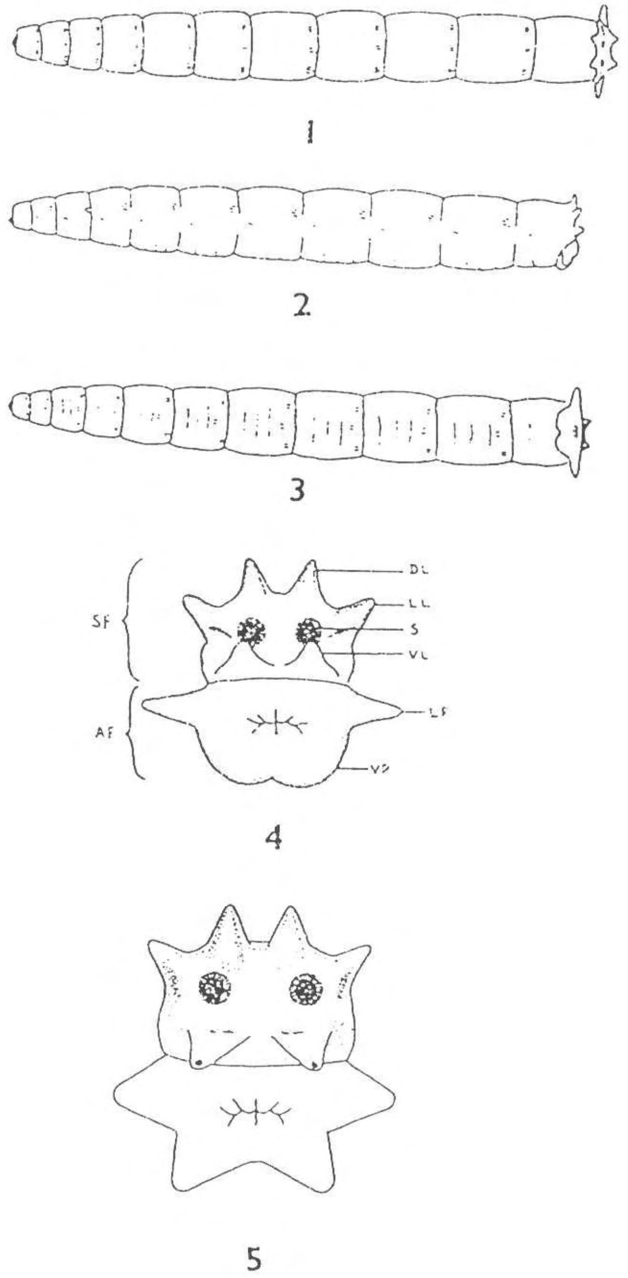

Fig. 1. *Tipula paludosa* 1, larva, dorsal view; 2, larva, lateral view; 3, larva ventral view; 4, anal segment of larva, posterior view. DL - dorsal lobe, LL - lateral lobe, VL - ventral lobe, S - spiracle, LP - lateral anal papilla, VP - ventral anal papilla, SF - spiracular field, AF - anal field. 5, *Tipula oleracea*, anal segment of larva, posterior view.

After Brindle, 1960.

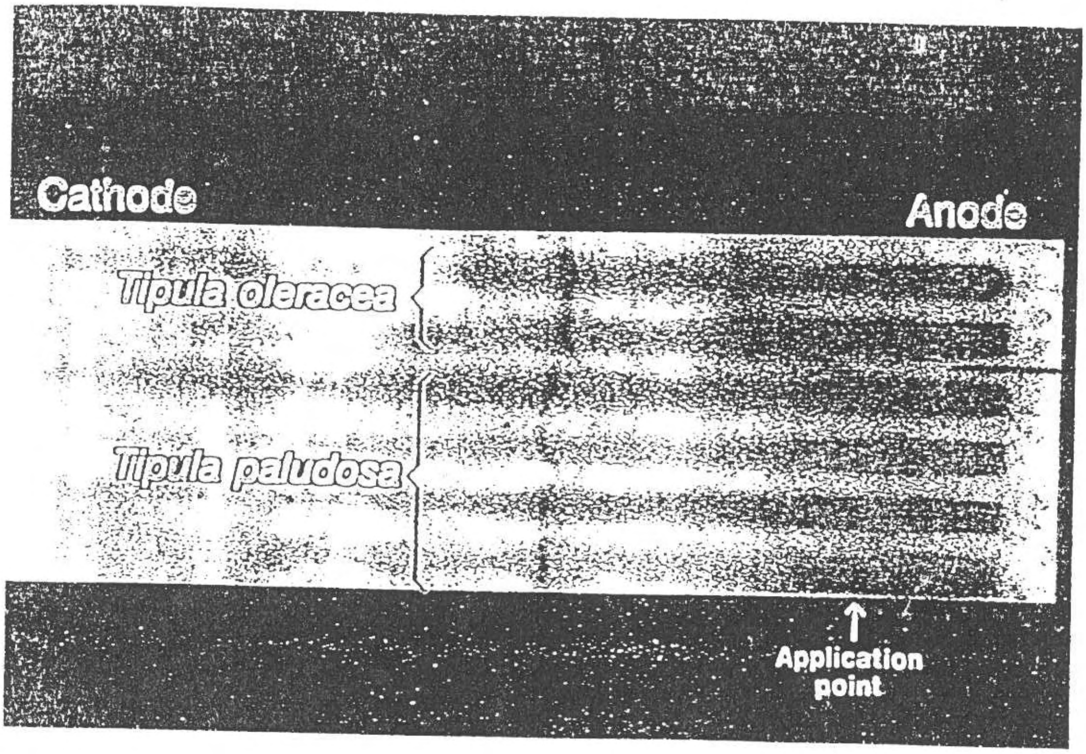

Fig 2 Thin layer agarose isoelectric focusing (pH 5-6) and silver staining of leatherjacket proteins showing characteristic banding patterns of *T. paludosa* (single band nearest cathode, approximate p I 5.4) and *T. oleracea* (two bands nearest anode, approximate p I 5.4 and 5.3)

From Humphreys, Blackshaw, Stewart and Coll (19[illegible])

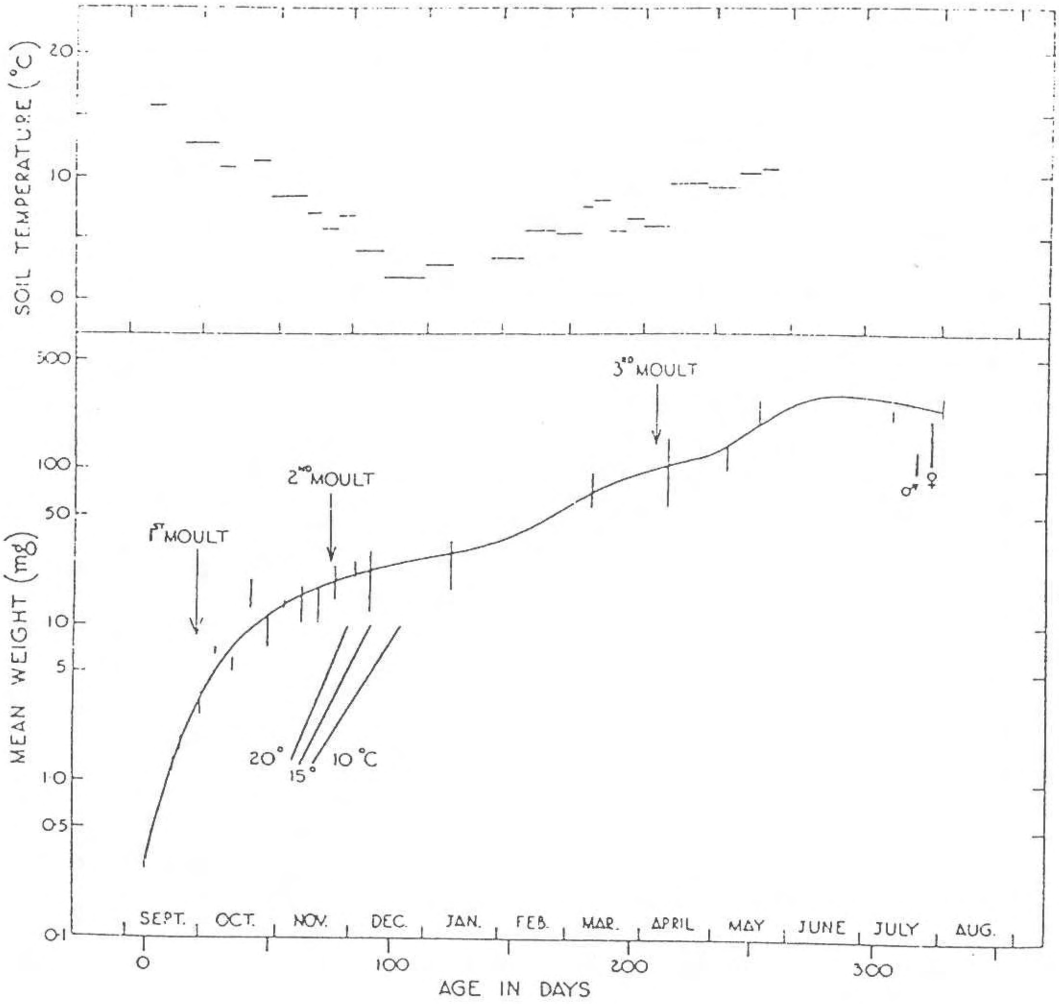

Fig. 3. Growth of *T. paludosa* larvae in cages in the field, 1960-61.

After Laughlin (1967).

THE REVISED LONG TERM ARRANGEMENTS FOR EXTENSION OF USE (1995)

INTRODUCTION

Since 1 January 1990 arrangements have been in place which permit many pesticide products to be used for additional specific minor uses, subject to adherence to various conditions. These arrangements have now been updated to current standards and additional guidance notes have been provided to improve clarity. The revised arrangements are valid until 31 December 1999. Extrapolations at Table 2 are valid only until 31 December 1995.

SPECIFIC RESTRICTIONS FOR EXTENSION OF USE

Certain restrictions of use are necessary to ensure that the extension of use does not increase the risk to the operator, the consumer or the environment. For this reason **the following conditions must be followed** when applying pesticides under the terms of this scheme.

1. All safety precautions and statutory conditions relating to use (which are clearly identified in the statutory box on product labels) must be observed.

2. The method of application must be as stated on the pesticide label and in accordance with the relevant codes of practice and requirements under COSHH (Control of Substances Hazardous to Health).

3. Those planning to use hand held applicators to apply pesticides must ensure that this method of application is appropriate for the on-label uses (Note: unless otherwise stated spray applications to protected crops include hand held uses). Where this is not the case, users must only use pesticides which comply with the conditions at paragraph 11.

4. All reasonable precautions must be taken to safeguard wildlife and the environment.

5. Pesticides must only be used in the same situation as that on the product label i.e. outdoor or protected. Pesticides must not be used on protected crops, i.e. crops grown in glasshouses, poly tunnels, cloches or polythene covers or in any other building, unless the product label specifically allows use on that crop under protection. (N.B. unless specifically restricted to outdoor crops only, pesticides approved for use on tomatoes, cucumbers, lettuce, chrysanthemum and mushrooms include use under protection). Products approved for use only under protection must not be used outdoors.

6. Pesticides must not be used in or near water unless the product label specifically allows such use. Off-label use in or near water is not permitted under these arrangements. (In or near water includes drainage channels, streams, rivers, ponds, lakes, reservoirs, canals, dry ditches, areas designated for water storage. Use in or near coastal waters is also not permitted).

7. Off-label use by aerial application is not permitted under these arrangements.

8. Rodenticides and other vertebrate control agents are not included in these arrangements.

9. Use on land not intended for cropping, land not intended to bear vegetation, amenity grassland, managed amenity turf and amenity vegetation is not included in these arrangements (this includes areas such as paths, pavements, roads, ground around buildings, motorway verges, railway embankments, public parks, sports fields, upland areas, moorland areas, nature reserves etc.).

10. Pesticides classified as harmful, dangerous or extremely dangerous to bees must not be used during flowering on any crop (i.e. from first flower to complete petal fall) nor where bees are actively foraging (NB. If use during flowering is recommended for crops such as peas and oilseed rape this use relates ONLY to the label recommendations for these crops and must not be extrapolated to other crops under these arrangements). Applications of pesticides hazardous to bees must not be made when flowering weeds are present.

11. HAND HELD APPLICATIONS

When planning to use hand held equipment to apply a pesticide under these arrangements, users must ensure that hand held use is appropriate for the current on-label recommendations; spray applications to protected crops include hand held use unless stated otherwise. Where hand held use is not appropriate for the on-label recommendations hand held application should not be made if the pesticide label:

(a) prohibits hand held use;

(b) requires the use of personal protective clothing when using the pesticide diluted to the minimum volume rate recommended on the label for the dose required;

(c) is classified with one of the following hazard warnings:

'Corrosive', 'very toxic', 'toxic', or 'risk of serious damage to eyes'.

In other cases hand held application is permitted provided that:

(i) the concentration of the spray volume for the off-label use is no greater than the maximum concentration recommended on the pesticide label;

(ii) spray quality is at least as coarse as the British Crop Protection Council medium or coarse spray;

(iii) operators wear at least a coverall, gloves and rubber boots when applying pesticides below waist level. Use of a faceshield is also required for applications which are above waist height.

(iv) where there are label precautions with regard to buffer zone restrictions for vehicle mounted use, then users must observe a 2 m buffer zone when applying by hand held equipment.

12. BROADCAST AIR-ASSISTED USE

When planning to apply a pesticide under these arrangements by broadcast air-assisted sprayer (any equipment which broadcasts spray droplets produced by fan assistance and which carry outwards and upwards from the source of the spray), only pesticides with specific recommendations for such use or those currently approved for use on hops or any bush, cane and tree fruit can be used.

13. It is the responsibility of the user to ensure that the use does not result in any statutory UK Maximum Residue Levels (MRLs), as set out in statutory instrument No. 1985 of 1994: The Pesticides (Maximum Residue Levels in Crops, Food and Feeding Stuffs) Regulations 1994 (HMSO publication ISBN 0-11-044985-1) and any subsequent updates, being exceeded. These arrangements do not apply in either of the following situations:

(a) Where the MRL for the crop in column 1 of section IV "Crops used Wholly or Partly for Consumption by Humans or Livestock" is lower than the MRL for the crop in column 2.

(b) Where no MRL is set for the crop in Column 2 of section IV "Crops used Wholly or Partly for Consumption by Humans or Livestock" but a MRL at the limit of determination has been established for the crops in column 1.

In either of the above circumstances use on the crop in column 1 is not permitted.

14. These extensions of use only apply to label recommendations for use. Extrapolations must not be made from specific off-label approvals.

I. NON EDIBLE CROPS AND PLANTS

a) Subject to the specific restrictions for extension of use set out above, pesticides provisionally or fully approved for use on any growing crop may be used on commercial agricultural and horticultural holdings and in forest nurseries on the following crops and plants

(i) hardy ornamental nursery stock, ornamental plants, ornamental bulbs and flowers and ornamental crops grown for seed where neither the seed nor any part of the plant is to be consumed by humans or animals;

(ii) forest nursery crops prior to final planting out.

b) Subject to the specific restrictions for extension of use set out above, pesticides provisionally or fully approved for use on any growing edible crop may be used on commercial agricultural and horticultural holdings on non ornamental crops grown for seed where neither the seed nor any part of the plant is to be consumed by humans or animals. This extrapolation excludes use on potatoes, cereals, oilseeds peas and beans grown for seed. Seed treatments themselves are not included in this extension of use.

c) Subject to the specific restrictions for extension of use set out above, pesticides provisionally or fully approved for use on oilseed rape may be used on commercial agricultural and horticultural holdings on hemp grown for fibre. Seed treatments are not included in this extension of use.

Before making hand held applications see paragraph 11 of the specific restrictions for extension of use.

II. FARM FORESTRY AND ROTATIONAL COPPICING

Subject to the specific restrictions for extension of use set out above <u>herbicides</u> provisionally or fully approved for use on;

i) cereals may be used in the first five years of establishment in farm forestry (including short rotation coppicing) on land previously under arable cultivation or improved grassland (as defined by the Farm Woodland Scheme);

ii) cereals, oilseed rape, sugar beet, potatoes, peas and beans may be used in the first year of re-growth after cutting in coppices (short term, rotational, intensive wood production e.g. poplar or willow biofuel production) established on land previously under arable cultivation or improved grassland (as defined by the Farm Woodland Scheme).

III. NURSERY FRUIT CROPS

Subject to the specific restrictions for extension of use set out above, pesticides provisionally or fully approved for use on any crop for human or animal consumption may be used on commercial agricultural and horticultural holdings on nursery fruit trees, nursery vines prior to final planting out, bushes, canes and non-fruiting strawberry plants provided any fruit harvested for these crops within 1 year of treatment is destroyed. Applications must not be made where there are fruit present. If hand held or broadcast air assisted use is required see paragraphs 11 and 12, respectively, of the specific restrictions for extension of use.

IV. CROPS USED PARTLY OR WHOLLY FOR CONSUMPTION BY HUMANS OR LIVESTOCK

Subject to the specific restrictions for extension of use set out above pesticides may be used on commercial agricultural or horticultural holdings on the crops listed overleaf in the first column if they have been provisionally or fully approved for use on the crop(s) listed opposite them in the second column. These extrapolations do not include use in store which are subject to separate arrangements (at V)

TABLE ONE

Column 1: Minor use	Column 2: Crops on which use is provisionally or fully approved	Additional special conditions
A. ARABLE CROPS		
Poppy (grown for oilseed)	Sunflower	
Sesame	Sunflower	
Mustard	Oilseed rape	
Linseed	Oilseed rape	
Evening primrose	Oilseed rape	
Honesty	Oilseed rape	
Linola	Oilseed rape or linseed	
Flax (oilseed and fibre)	Oilseed rape or linseed	
Borage (grown for oilseed)	Oilseed rape	)Seed treatments are not)permitted
Grass seed crop	Wheat, barley, oats, rye, triticale	)Treated crops must not be)grazed or cut for fodder.)Seed treatments are not)permitted
Grass seed crop	Grass for grazing or fodder	
Rye	Wheat, barley)	) Treatments applied before) second node detectable) stage only
Triticale	Wheat, barley)	
Durum wheat	Wheat	
Lupins	Combining peas or field beans	

ADAS

B. FRUIT CROPS

Almond) Application to	Apple or cherry or plum	) For herbicides
Chestnut) the orchard	Apple or cherry or plum	) used on the
Hazelnut) floor ONLY	Apple or cherry or plum	) orchard floor
Walnut)	Apple or cherry or plum	) ONLY
Quince	Apple or pear	
Crab apple	Apple or pear	
Almond	)Products approved for use on two of	
Chestnut	)the following:	
Hazelnut	)almond, chestnut,	
Walnut	)hazelnut and walnut	
Nectarine	Peach	
Apricot	Peach	
Blackcurrant	Redcurrant	
Blackberry	Raspberry	
Rubus species (e.g. tayberry, loganberry)	Raspberry	
Dewberry	Raspberry	
Redcurrant	Blackcurrant	
Whitecurrant	Black or redcurrant	
Bilberry	Black or redcurrant	
Cranberry	Red or blackcurrant	

C. VEGETABLE CROPS

Parsley root	Carrot or radish
Fodder beet	Sugar beet
Mangel	Sugar beet
Horseradish	Carrot or radish
Parsnip	Carrot
Salsify	Carrot or celeriac
Swede	Turnip
Turnip	Swede
Garlic	Bulb onion
Shallot	Bulb onion
Aubergine	Tomato
Squash	Melon
Pumpkin	Melon
Marrow	Melon
Watermelon	Melon

Broccoli	Calabrese
Calabrese	Broccoli
Roscoff cauliflower	Cauliflower
Collards	Kale
Lamb's lettuce, frise, radicchio	Lettuce
Beet leaves	Spinach
Cress	Lettuce
Scarole	Lettuce
Leaf herbs and edible flowers*	Lettuce or spinach or parsley or sage or mint or tarragon
Edible podded peas (e.g. mange-tout, sugar snap)	Edible podded beans
Runner beans	Dwarf French beans
Rhubarb	Celery
Cardoon	Celery
Edible fungi other than mushroom (e.g. oyster mushroom)	Mushroom

* This extension of use applies to the following leaf herbs and edible flowers: angelica, balm, basil, bay, borage, burnet (salad), caraway, chamomile, chervil, chives, clary, coriander, dill, fennel, fenugreek, feverfew, hyssop, land cress, lovage, marjoram, marigold, mint, nasturtium, nettle, oregano, rocket, rosemary, rue, sage, savory, sorrel, tarragon, thyme, verbena (lemon), woodruff.

V APPLICATION IN STORE ON CROPS USED PARTLY OR WHOLLY FOR HUMAN OR ANIMAL CONSUMPTION.

Subject to the specific restrictions for extensions of use set out above pesticides may be used on commercial agricultural or horticultural holdings on the crops listed below in the first column if they have been provisionally or fully approved for use in store on the crops listed opposite them in the second column. Seed treatments are not covered by this arrangement.

Column 1: Minor Use	Column 2: Crops on which use is provisionally or fully approved.
Rye	Wheat
Barley	Wheat
Oats	Wheat
Buckwheat	Wheat
Millet	Wheat

ADAS

Sorghum	Wheat
Triticale	Wheat
Dried peas	Dried beans
Dried beans	Dried peas
Mustard	Oilseed rape
Sunflower	Oilseed rape
Linola	Oilseed rape
Flax	Oilseed rape
Honesty	Oilseed rape
Poppy (grown for oilseed)	Oilseed rape
Borage (grown for oilseed)	Oilseed rape
Evening primrose	Oilseed rape
Sesame	Oilseed rape
Linseed	Oilseed rape

TABLE TWO

THE FOLLOWING EXTENSIONS OF USE WILL EXPIRE ON 31 DECEMBER 1995.

The following extensions of use are permitted for one year only, until 31 December 1995. After this date it will be a contravention of the Control of Pesticides Regulations 1986 to use these extrapolations.

Column 1: Minor use	Column 2: Crops on which use is provisionally or fully approved.
A: ARABLE CROPS	
Poppy	Oilseed rape
Gold of Pleasure	Oilseed rape
Grass seed crops*	Wheat, barley, oats, rye, triticale,
Oats	Wheat, barley - treatments applied before second node detectable stage ONLY
Durum wheat	Barley
B. FRUIT CROPS	
Redcurrant	Whitecurrant
Bilberry	Whitecurrant
C. VEGETABLE CROPS	
Beetroot	Carrot, radish
Celeriac	Carrot
Horseradish	Potato
Jerusalem artichoke	Potato, carrot, radish, turnip, swede.
Salsify	Potato, radish
Garlic	Salad onion
Shallot	Salad onion
Pepper	Tomato
Squash	Cucumber, gherkin, courgette
Pumpkin	Cucumber, gherkin, courgette

Broccoli	Cauliflower
Calabrese	Cauliflower
Roscoff cauliflower	Broccoli, calabrese
Peas - non-edible podded (harvested green)	Vining peas
Broad beans	Vining peas, dwarf French beans
Runner beans	Edible podded peas
Beans - harvested dry	Peas, dwarf French, runner or broad beans
Peas - harvested dry	Vining peas or dwarf French, runner or broad beans
Fennel (as a vegetable)	Celery, leek
Kohlrabi	Celery, leek, cabbage

* This extension of use will be continuing in the revised Long Term Arrangements for Extension of Use at Table 1, with the proviso that treated grass seed crops are not consumed by livestock and seed treatments are not used.

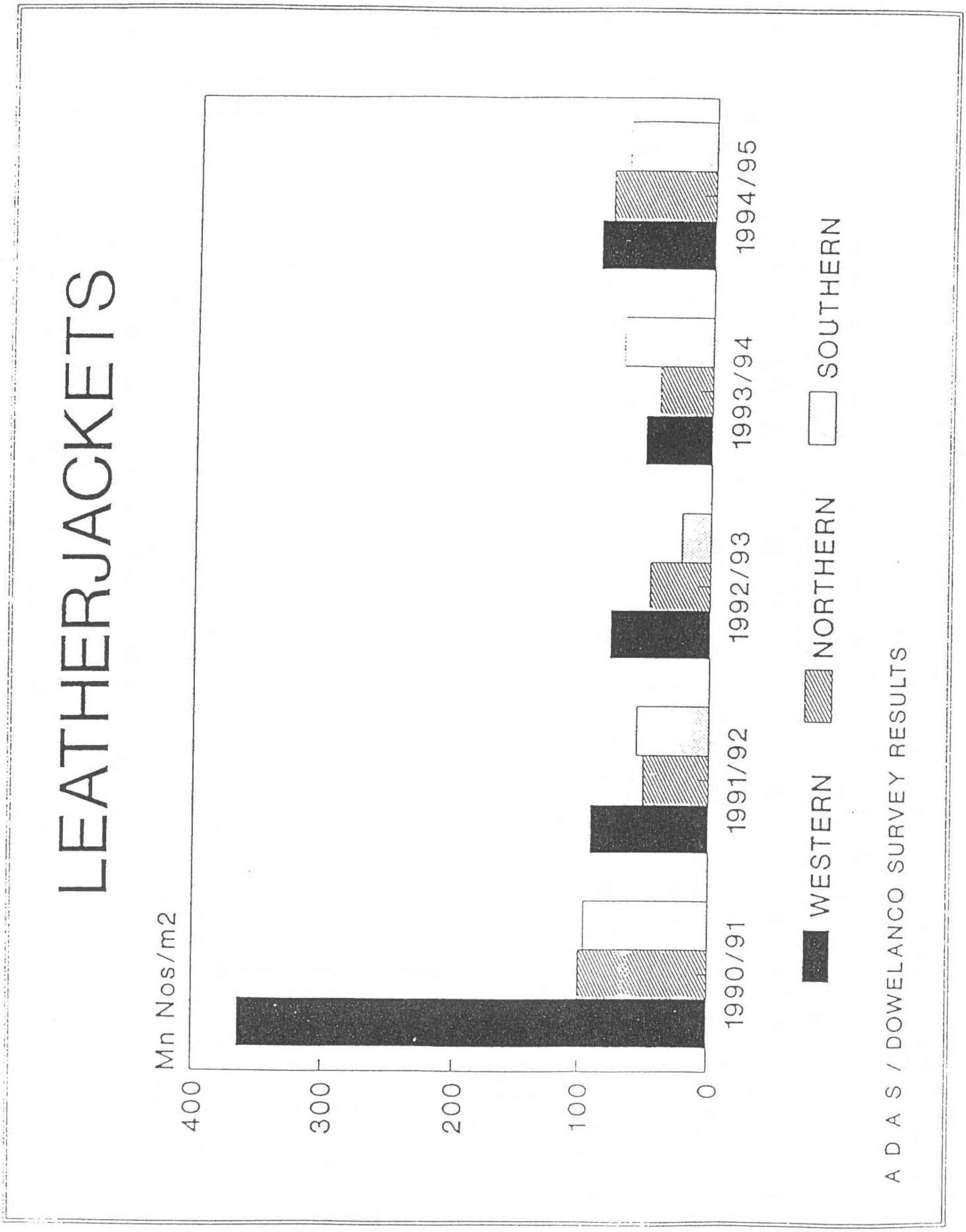

Fig 4. Summary of ADAS/Dow Elanco leatherjacket surveys 1990/91 to 1994/95.

ADAS

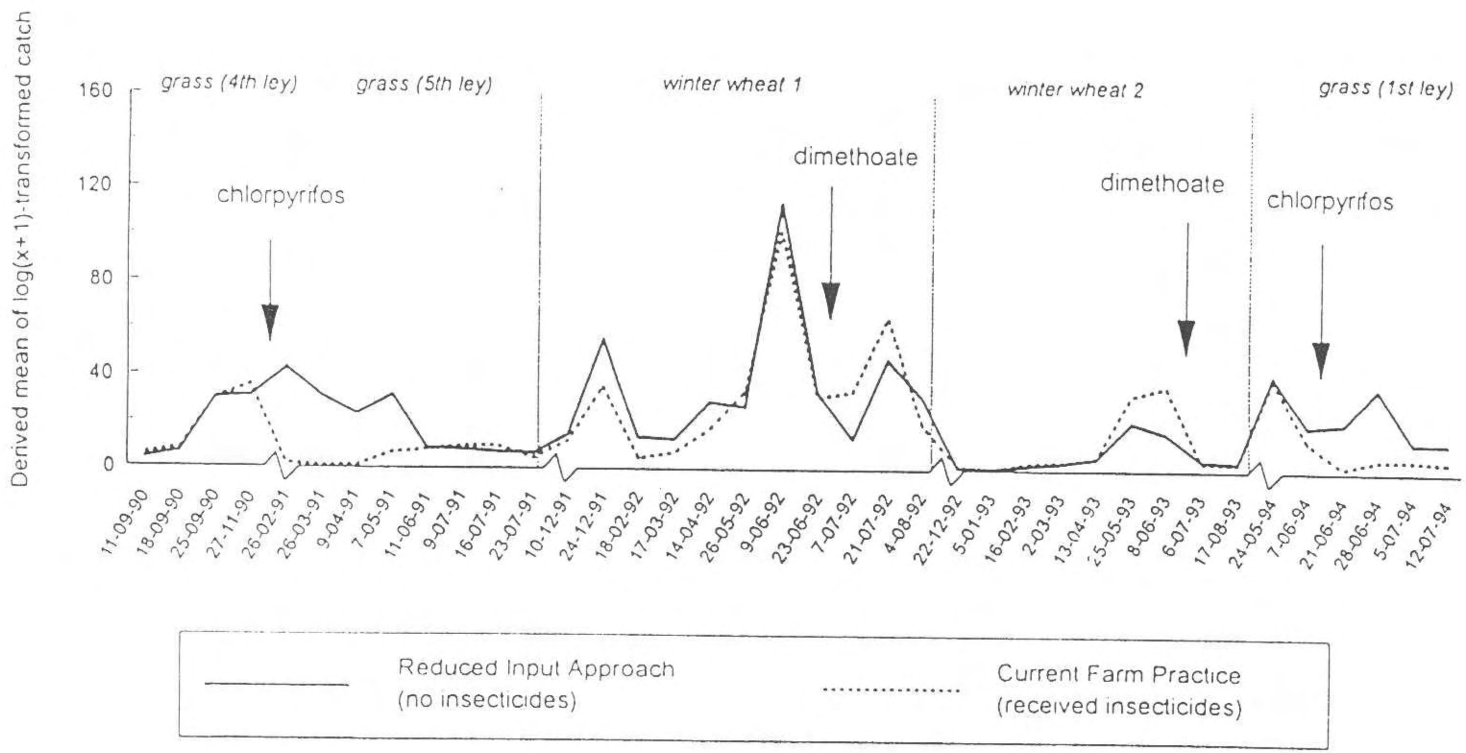

Fig. 5. Pitfall trap catches of Coleoptera (all families grouped together) in SCARAB project Field 5 (ADAS Drayton).

From Cilgi and Frampton (1994)

Contract between ADAS (hereinafter called the "Contractor") and the Horticultural Development Council (hereinafter called "the Council") for a research/development project.

1. TITLE OF PROJECT Contract No: HNS59

A REVIEW OF LEATHERJACKETS ON NURSERY STOCK: BIOLOGY AND CONTROL

2. BACKGROUND AND COMMERCIAL OBJECTIVE

Leatherjackets are a sporadic problem on containerised nursery stock, but when occurring damage can be severe. Symptoms include girdling the stem bases eg of heathers and conifers, and grazing off the foliage of low-growing plants eg Saxifrage. Most incidences of damage seem to occur on plants under polythene tunnels; an increasing number of nursery stock crops now spend some time under protection. The incidence and severity of leatherjacket damage is probably due to several factors, including weather conditions, surrounding crops and choice and timing of pesticides. The species most commonly attacking nursery stock is thought to be *Tipula oleraceae*, although *Tipula paludosa*, the species more common on grasses and cereals, has also been recorded. The life cycle of *T.paludosa* is well-documented but that of *T.oleraceae* is not fully understood. The latter species is thought to have two adult emergence periods; in the spring and in late summer/early autumn, thus, accurate timing of chemical control measures is more difficult for this species. There are no pesticides currently approved for the control of leatherjackets on ornamentals, either outdoors or under protection. Under the long-term off-label arrangements growers of ornamentals can use at their own risk, pesticides approved for leatherjacket control on other crops. Most growers use drenches of gamma-HCH or chlorpyrifos, although the latter can only be used outdoors and can be phytotoxic. Both pesticides are purely contact in action and are only fully effective if the leatherjackets are grazing close to the surface of the compost at the time of application. If the pest is present lower down in the pots, control by pesticide drenching gives poor results. Neither pesticide is compatible with biological control agents; both are not only harmful but persistent for many weeks. For the increasing number of nursery stock growers using or interested in Integrated Pest Management (IPM), there is no compatible method for controlling leatherjackets. There are a number of biological control agents with the potential to control leatherjackets and these are worth evaluating. There is some anecdotal evidence that the controlled release granular formulation of chlorpyrifos, "Suscon Green", could give incidental control of leatherjackets, when used for vine weevil control on nursery stock. However, this has not been substantiated by trials data, and the product has only been on the market for the past year.

3. POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY

The proposed work would summarise information to date on leatherjacket species on nursery stock, their biology and methods of control; chemical, cultural and biological. The results of the review will be used to assess the current importance of leatherjackets as a pest on nursery stock, to identify the most effective control measures and to make recommendations for future research if appropriate. It is difficult to quantify the potential financial benefits to the industry at present, but

ADAS

growers would benefit immediately by being made aware of the best control strategies to date. Future research could potentially develop improved control methods, including those compatible with IPM, which would benefit the increasing number of nursery stock growers responding to the pressures to minimise pesticide usage.

4. SCIENTIFIC/TECHNICAL TARGETS OF THE WORK

(a) To review the species and life cycles of leatherjacket species attacking nursery stock.

(b) To review chemical, cultural and biological methods of control on nursery stock, including any relevant information on other crops.

(c) To include six "case studies" of nurseries experiencing leatherjacket problems, to examine the characteristics of infestations, extent of damage and methods of control.

(d) To assess the significance of leatherjackets as a pest of nursery stock in the UK and identify the most effective control measures currently used.

(e) To make recommendations for future research on the biology and control of leatherjackets on nursery stock.

5. CLOSELY RELATED WORK

To the proposer's knowledge, there is no ongoing work on the biology and control of leatherjackets on nursery stock. Where appropriate, information on leatherjackets on arable crops will be utilised and any relevant findings on integrated methods of control discussed with other researchers in order to make recommendations for future work.

6. DESCRIPTION OF WORK

(a) The literature search will be done in conjunction with the ADAS Library, Wolverhampton, who will carry out an on-line computer based search. Manual searching of any relevant references dated before 1970 may be necessary.

(b) If necessary, other researchers or advisers will be contacted to discuss relevant findings.

(c) The six nurseries chosen for the "case studies" will be selected on the basis of ADAS knowledge of nurseries experiencing leatherjacket problems in recent years. The growers and the appropriate ADAS consultants will be contacted and the following points discussed:-

  (i) Plant species attacked, nature and extent of damage over the past three years.

(ii) Time of year of attack.

(iii) Surrounding crops.

(iv) Control measures used and their efficacy.

(v) Use of, or interest in, IPM on the nursery and extent to which leatherjacket control measures might interfere with the programme.

(d) Other growers/advisers will be contacted to determine the importance of this pest to HNS growers across the country and to indicate whether further investigation using levy funds can be justified.

7. START DATE, DURATION AND REPORTING

Start date 1 September 1994.

Duration five months.

Reporting date 31 January 1995.

8. STAFF RESPONSIBILITIES

Project Leader: Jude Bennison, Senior Consultant, Entomologist, ADAS Huntingdon.

9. LOCATION

ADAS Huntingdon and ADAS Library, Wolverhampton.

10. COST

£4,950.