Grower Summary

Headline

- A literature review and surveys have been carried out to assess the risk that the lily beetle poses to horticulture in the UK.
- The surveys indicate that the lily beetle is a problem for some suppliers (providers) of lilies and some professional gardeners.
- The lily beetle problem is likely to get worse.

Background and expected deliverables

The scarlet or red lily beetle (*Lilioceris lilii*), is a bright red leaf beetle which has become a pest of lilies (*Lilium*: Liliaceae) in the UK and parts of North America. The report below is a preliminary assessment of the risk this beetle poses to UK horticulture. In addition to a review of the literature, the assessment has been made by conducting surveys of commercial providers of the beetle's host plants and the end user, both professional and amateur.

The primary aims of the surveys were:

- To determine the current problems with lily beetle in the UK, for the providers of plants, the amenity horticulturist and amateur gardener.
- To quantify how lily beetle host plants are grown in the UK, and the extent of the industry.
- To gain an insight into control measures used against the beetle.
- To assess the likely future effect of the lily beetle on horticulture in the UK.

Other work is in progress out to meet the following additional project objectives:

- To investigate the chemical ecology of both the lily beetle and its parasitoids.
- Using the results gained to develop integrated pest management strategies for the control of the red lily beetle for the amateur gardener, amenity horticulturist and the horticultural industry.

Summary of the project and main conclusions

Background (Information from the literature)

- Both the adult and larval stages of the lily beetle can cause foliar damage to host plants throughout the growing season (March to October). No stage in the beetle's life cycle attacks or is attached to the bulb.

- The beetle has only one generation a year. Inaccurate earlier literature stating that there is more than one generation is often repeated in modern pest control texts.
- Plants at risk are limited to *Lilium, Fritillaria* and *Cardiocrinum* (referred to as lilies), despite statements in earlier literature listing up to 20 genera. There is some evidence that not all plants in these genera are equally susceptible; more research is needed to assess these differences.
- Lily beetle is distributed throughout Eurasia. It is an alien pest in North America and the UK. It has been established in England since 1939, but has only become common outside the south-east during the past 17 years. It has recently become established in parts of Scotland and Northern Ireland, and is becoming widespread in Wales.
- Generalist predators are unlikely to have a significant effect on the lily beetle.
- There are four species of parasitic (parasitoid) wasp that attack and kill lily beetle larvae in Europe. Two species occur in the UK. It is thought that a combination of three or more parasitoids in mainland Europe can reduce lily beetle populations below damaging levels.
- The proportion of enquiries about lily beetle to the Royal Horticultural Society has risen from 0.5% of all pest enquiries in the 1970s to 3% in the 2000s. It is now consistently a top 5 pest.
- There is a risk to native lilies in the USA and it is thought that it poses a threat to the *Lilium* industry in the USA (worth $65 million in 2003).
- The risk to native populations of *Fritillaria meleagris*, which is now a rare UK wildflower should be assessed.
- Current control methods for the beetle are inadequate. Manual removal is time consuming and the use of broad spectrum insecticides expensive and considered by many to be environmentally damaging.
- Biological control using three parasitoids in the USA is being attempted. One species is now established and reductions in lily beetle infestation have been observed.
- It has been suggested that introducing a further parasitoid to the UK may have an effect on the lily beetle problem. However the research required to satisfy the necessary safety tests and legislation would take many years and the cost of work under quarantine conditions is likely to be prohibitive.
- Research into the interaction of the beetle and its parasitoids with chemicals naturally occurring in the environment (e.g. volatile chemicals released by lily plants) may provide improved control measures.

- The lily beetle is a significant problem for the amateur lily grower throughout England and Wales and it is likely to expand from its current localised distribution in Scotland and Northern Ireland.

Risk assessment survey part 1: Effect of the lily beetle in amateur gardens.

In order to gain some insight into consumer confidence, members of the RHS who phoned, e-mailed or visited a pest advisor at one of the RHS shows were asked (after advice was given about control of *L. lilii*): "If you continue to have a lily beetle problem would you stop growing lilies (fritillaries) in the future?"

- Between March 2005 and August 2006, 148 people with a *L. lilii* problem had responded: 26% (39) said they would not continue to grow lily beetle hosts in the future.
- If the result is representative of the lily-growing public it indicates that *L. lilii* could cause a decline in the sales of lilies and may already be restricting sales.

Lily beetle risk assessment survey part 2: providers of lily beetle host plants.

In order to gain an insight into the current and perceived impact that the lily beetle has on the lily-supplying industry (lily providers) in the UK, survey forms were sent to 682 potential providers of lilies (HDC members and providers listed in the RHS Plant Finder). Responses were received from 102 providers of lilies. A range of different provider types responded; from growers providing 10 plants per year to those providing 2 million cut flowers; including wholesalers, retailers and those propagating plants. The 102 providers represented nearly 7 million plants sold in the UK during 2005, and more than 300 *Lilium, Fritillaria* and *Cardiocrinum* species, varieties and cultivars.

- A third (35, 34%) of lily providers stated that the lily beetle had been a problem. These providers represent 9% (nearly 600 000) of the plants covered by the survey.
- Almost all sectors of the industry are vulnerable to the lily beetle. Lily beetle was reported by at least one provider under each category of growing regime (including under protection). The source of the plants (own propagation, purchased externally or imported) or how plants are propagated does not appear to affect whether or not lily beetle is a problem.
- Pesticides were probably used as a control measure against the beetle on most (up to 84%) of the lilies that were infested.
- Most providers think that lily beetle will decrease sales of lilies. Despite this perception, most growers have seen sales increase or stay the same over the past five years.

- Lily beetle is the second most frequent pest (after aphids) encountered by providers but has largely been a problem for small-scale growers.

Lily beetle risk assessment survey part three: professional users of lily beetle host plants.

A survey of gardens open to the public has provided some insight into the problems faced by the professional user of lilies. Surveys were sent to 330 gardens open to the public; these were National Trust, RHS partner gardens and English and Scottish Heritage properties. Responses were received from 135 gardens (41%), 115 of which grew lilies.

- Fifty-one (43%) of gardens growing lilies reported that lily beetle had been a problem, 16 (14%) of which were in 10 km grid squares where lily beetle had not previously been reported, including some areas of Scotland and Wales.
- All 43 gardens that took control measures against the beetle used manual removal, including 4 (8%) that also used insecticides. Thus insecticide use against the beetle in gardens open to the public is limited, however staff time is being spent on removing the beetles.
- A quarter of gardens would reduce or stop planting lilies if lily beetle becomes a problem.
- Most (over 70%) of responding gardens source lilies from UK suppliers, and primarily as bulbs (over 70%).
- Almost all gardens (98%) grew at least some plants outside, but lily beetle could still be a problem whether the plants were in pots, open ground or under protection.
- Lily beetle was reported as the second most frequent pest (after slugs) on lilies. A different set of pests appears to affect lilies in gardens compared to those affecting the providers.
- Only 16% of gardens currently use any chemical inputs on lilies.
- Of the 135 survey forms returned, 91 (70%) sold plants on site, 45 of which sold lilies. Most (28, 24%) stated that sales of lilies were increasing.

Conclusions.

- The beetle's recent rapid spread in England and Wales, survival in Scotland and Northern Ireland and its worldwide distribution indicate that it will eventually become distributed throughout the UK, wherever its host plants are grown.
- A considerable proportion of professional gardeners and providers of lilies have experienced a problem with the beetle.

- Lily beetle can be a problem under almost any growing regime, including under protection.
- Based on current knowledge the lily beetle problem is likely to worsen, and it can be expected that more providers and gardeners will experience infestations.
- Lily beetle infestations are unlikely to increase chemical inputs in gardens open to the public, although the time spent removing the beetles manually is likely to increase.
- In commercial production, lily beetle infestations are likely to increase the use of broad-spectrum insecticides and staff time in maintaining lily crops, resulting in increases in production costs.
- The likely effect of the beetle on lily sales is unclear. Both amateur and professional gardeners have indicated that fewer lilies would be planted / bought if lily beetle becomes a problem. However the surveys have indicated that sales of lilies have increased during the past five years, despite the increasing beetle problem faced by amateur gardeners.
- It has often been suggested that the lily industry may be spreading the beetle throughout the UK through distribution of potted plant material. There is no evidence from these surveys for or against this theory. It is likely that most of the beetles spread in England and Wales has been due to other factors, although these remain unknown (natural spread).
- Many lily providers import lilies from abroad, most frequently from Holland. It should also be considered that if the lily beetle does affect sales the industry outside of the UK may also be affected.

Other work in progress

- Laboratory and field based scientific work has largely built on work carried out in 2005 (see 2005 annual report).
- Greater insights to the behavioural responses of the beetle to odour streams have been gained.
- Investigations using combined gas chromatography-electroantennogram (GC-EAG) to identify potentially behaviourally active compounds have commenced.
- Following a visit to CABI bioscience (Switzerland) protocols have been established for the rearing of the beetles parasitic wasps (parasitoids) for use in experimental work in 2007.
- A field trial of six lilies has continued.
- The results of the above work will be reported in full in the final report.

Financial benefits

- There are currently no financial benefits to be gained by growers from this work.

Action points for growers

- It is recommended that lily providers and professional gardeners remain vigilant and take action against the beetle as necessary.
- For lily providers, currently the most successful action is likely to be the use of a broad spectrum foliar insecticide; this may need repeating throughout the natural growing season of susceptible plants.
- Providers who supply lilies in pots should take care that all outgoing stock is free of the beetle and its damage. This is especially important for those providers supplying lilies to large retail outlets where contamination with beetles can result in significant economic penalties and rejected shipments.
- Overwintering survival of one species of parasitic wasp that kills lily beetle larvae is reduced by the presence of mulch. It is therefore advisable that, where possible, lilies in gardens are not mulched.

Science Section

Part 1.

Risk Assessment: The effect of the Red Lily Beetle, *Lilioceris lilii* (Scop.) on horticulture in the UK: Results of two surveys of professional horticulturalists in the UK.

1. Introduction.

The scarlet or red lily beetle, *Lilioceris lilii* (Scopoli) is a bright red leaf beetle (Coleoptera: Chrysomelidae. Fig. 1.1) which has become a pest of lilies (*Lilium*: Liliaceae) in the UK and parts of North America. This report provides a preliminary assessment of the risk this beetle poses to UK horticulture. In addition to a review of the literature, the assessment has been made by conducting surveys of commercial providers of the beetle's hosts plants and the end user, both professional and amateur.

The primary aims of the survey were.

- To determine the current problems with lily beetle in the UK, both for the providers of plants, the amenity horticulturist and amateur gardener.
- To quantify how lily beetle host plants are grown in the UK, and the extent of the industry.
- To gain an insight into control measures used against the beetle.
- To assess the likely future effect of the lily beetle on horticulture in the UK.

Fig. 1.1. Red lily beetle adult (R. Key)

2. Review of the literature.

2.1. Beetle description.

Adult lily beetles (*Lilioceris (Crioceris) lilii*) are 0.8-cm long, bright red with a black head and legs (Fig. 1.1). It is the only *Lilioceris* species occurring in the UK, but two others occur elsewhere in Europe, *L. meridiana* (L.) and *L. tibialis* (Villa); which are both similar in appearance to lily beetle but *L. lilii* is the only species with a black head and legs (Berti and Rapilly 1976). Adults can fly (Cox 2001) but this behaviour is not well studied.

The eggs of *L. lilii* are 1-mm long and elongate (Fig. 2.1). Immediately after they are laid they are bright orange, but they darken as they mature (Cox 2001).

The larvae (Fig. 2.2) are humped, dirty orange-red with dark heads and legs and usually covered in their own mucilaginous excreta. There are four larval instars and mature larvae are up to 1.0-cm long (Cox 2001).

Pupation occurs in the soil beneath the host plant where a 'silken' cocoon incorporating soil particles is constructed (Nolte 1939).

Fig. 2.1. Red Lily Beetle eggs on a *Lilium* leaf (photo Royal Horticultural Society (RHS)).

Fig. 2.2. Lily beetle larvae on lily leaves.

2.2. Life cycle.

Lilioceris lilii adults have been recorded in every month of the year (Cox 2001) and it is this stage that overwinters in soil and similar hibernacula, but not necessarily near host plants (Haye and Kenis 2004). Adults have been observed on host plants from early spring (Haye and Kenis 2004), but may continue to emerge until June (Halstead 1989).

Eggs have been observed from late March until September, are laid in linear groups of 2-16 on the ventral leaf surface, and hatch after 4-10 days (Haye and Kenis 2004). Each female can produce 200 to 367 eggs in one season (Fox Wilson 1942). It was thought adults could produce eggs in a second season (Lataste 1932) but this has been shown to be untrue (Haye and Kenis 2004).

Hatchling larvae feed together on the lower leaf surface, leaving the upper surface intact; later larval stages consume the entire leaf (Cox 2001). Larvae will also feed on flowers, seed capsules and the epidermis of the stem; after heavy attacks only the desiccated woody stem remains (Fox Wilson 1942). Larvae feed for 10-24 days before entering the soil and constructing a silken cocoon at a depth of 3 to 4-cm, this subterranean phase lasts 16-23 days (Haye and Kenis 2004).

The first new adults emerge in July (Haye and Kenis 2004). It used to be thought that new adults produce a second generation and that three generations are possible in a year (Lataste 1932). It is now clear that the beetles need to overwinter before mating and egg production can occur so there is only a single, protracted generation (Haye and Kenis 2004).

Much of the available works on the life cycle of *L. lilii* are based on observations made during the early part of the 20th century and the data provided are often unsubstantiated and later contradicted. Several of these early misconceptions on *L. lilii* life cycle are still widely reported in pest control books and articles, for example Alford (1995) refers to two generations of *L. lilii* a year.

2.3. Host range.

At least one life stage of *L. lilii* has been observed on 20 plant genera (Table 2.1). However a distinction should be made between those plants on which eggs are laid and the life cycle can be completed and those on which adults are able to feed. Adult *L. lilii* are often observed on plants with no damage occurring or damage has been wrongly attributed to *L. lilii*. Fox Wilson (1942) shows a *Polygonatum* said to have been damaged by *L. lilii*, but the damage is more likely to have been caused by slugs (A. Halstead, *pers. com.*). Additional inaccuracies may have occurred due to confusion with other *Lilioceris* species (Section 2.1). It is possible that references to *Convallaria, Allium* and *Polygonatum* as hosts concern other related beetles (Labeyrie, 1963). In the laboratory larval feeding and survival has only been observed with *Lilium* and *Fritillaria*, (Livingston 1996, Salisbury 2000). Thus only *Lilium* and *Fritillaria* should be considered true hosts, with *Cardiocrinum* included as both larvae and extensive damage have been observed on this genus by several authors (Table 2.2).

Lilioceris lilii has been observed on 57 hybrid *Lilium*, 30 *Lilium,* one *Cardiocrinum* and four *Fritillaria* species. Within *Lilium* the beetle has been observed on species and

hybrids from all the major groups (Tables 2.2, 2.3, 2.4). Casual observation is the source for most of the information on these hosts and the largest contribution to the list was made at RHS Garden Wisley between 2000 and 2003 (Salisbury 2004a). This indicates which plants are hosts for *L. lilii*, particularly if larvae are present, but cannot give any indication of levels of resistance. In a field trial of several *Lilium* cultivars, variation in their susceptibility was found, although all *Lilium* in the trial were attacked by adult *L. lilii* (C. Conjin *pers. com.* Table 2.3). There are approximately 100 *Lilium* species and more than 7000 hybrids (McRae 1998), three *Cardiocrinum* species (Synge 1980) and at least 100 species of *Fritillaria* (Pratt and Jefferson-Brown 1997). It is clear that further work and a more systematic approach is required to assess the resistance of *Lilium* spp. or *Fritillaria* spp. to *L. lilii*.

Plant family	Genus	Adult	Larva	Reference(s)
Amaryllidaceae	Narcissus	Y	?	Livingston 1996
Alstroemeriaceae	Alstromeria	Y	N	Coghill 1946
Campanulaceae	Campanula	N	N	Casagrande and Livingston 1995
Convallariaceae	Convallaria	Y	N	Livingston 1996
	Maiamthemum	Y	?	LeSage 1983
	Polygonatum	Y	N	Fox Wilson 1942
	Tricyrtis	Y	?	RHS data
Hostaceae	Hosta	Y	?	Livingston 1996
Hemerocallidaceae	Hemerocallis	O	N	Cox 2001
Hyacinthaceae	Muscari	Y	?	Livingston 1996
Iridaceae	Crocus	Y	?	Livingston 1996
	Iris	Y	?	Livingston 1996, Cox 2001
Liliaceae	Cardiocrinum	Y	Y	See table 2.2.
	Fritillaria	Y	Y	See table 2.2
	Lilium	Y	Y	See table 2.2
	Nomocharis	Y	Y	Fox Wilson 1943
	Smilax	Y	?	Livingston 1996
	Tulipa	Y	?	Livingston 1996
Solanaceae	Nicotiana	O	?	Cox 2001
	Solanum	Y	N	Halstead 1990

Table 2.1. Plant genera on which lily beetle has been observed.

O = Observed (no feeding noted) Y = Will feed; N = No feeding in non-choice tests (Salisbury, 2000; Scarborough, 2002); ? = No observation.

***Species*/ Variety**	**Group***	**Adults**	**Eggs/ Larvae**
Cardiocrinum giganteum (Wallich)	n/a	4, 9, 11	8, 11
Fritillaria imperialis L.	n/a	8, 9, 11	9, 9
F. meleagris L.	n/a	8, 9	8, 9
F. pontica Wahlenberg	n/a	8	-
F. pyrenaica L.	n/a	8	-
Lilium hansonii Moore	1	9, 10	9, 10
L. martagon L.	1	1	1, 7, 9, 10, 11
L. tsingtauense Gilg	1	10	9, 10
L. occidentale Purdy	2	9	9
L. pardalinum Kellogg	2	4, 7, 9, 10	7, 9, 10
L. superbum L.	2	9, 10	9, 10
L. bulbiferum L.	3	11	11
L. candidum L.	3	2, 4, 5, 9	5, 9, 10
L. monadelphum Bieberstein	3	9	9
L. pomponium L.	3	9	9
L. pyrenaicum Gouan	3	9	-
L. auratum Lindley	4	5, 7	5
L. rubellum Baker	4	10	9, 10
L. speciosum Thunberg	4	6, 10	6, 9, 10
L. concolor Salisbury	5		10
L. davidii Elwes	5	7, 9, 10	9, 10
L. duchartrei Farnchet	5	9	9, 10
L. henryi Baker	5	4, 5, 6, 9, 10	4, 5, 6, 9, 10
L. lancifolium Thunberg	5	3, 5, 6, 7, 9, 10	3, 5, 6, 9,
L. leichtlinii Hooker	5	10	10
L. nepalense Don	5	9	9
L. pumilum de Candole	5	5	5
L. formosanum Wallace	6	9, 10	9, 10
L. leucanthum Baker	6	9, 10	9, 10
L. longiflorum Thunberg	6	7, 9, 10	7, 9, 10
L. regale Wilson	6	2, 3, 4, 5, 6, 9	3, 4, 5, 6, 9
L. sargentiae Wilson	6	10	9, 10
L. sulphureum Baker	6	9	-
L. dauricum Ker-Gawler	7	5	-
L. 'Amber Gold'	I	9	9
L. 'Butter Pixie'	I	9, 10	9, 10
L. 'Connecticut King'	I	6, 8	6
L. 'Enchantment'	I	6, 7, 9, 10	6, 9, 10
L. 'George Soper'	I	10	-
L. 'Karen North'	I	10	9, 10
L. 'Karmen'	I	10	10
L. 'King Pete'	I	9	-
L. 'Ladykiller'	I	9, 10	-
L. 'Marie North'	I	9	-
L. 'Matchless'	I	10	-
L. 'Mont Blanc'	I	6	6

Table 2.2. Part 1 of 2. Summary of observations made on the presence of lily beetle on *Lilium* and *Fritillaria*

***Species/* Variety**	**Group***	**Adults**	**Eggs/ Larvae**
L. 'Montreaux'	I	6	6
L. 'Nutmegger'	I	10	10
L. 'Orange Pixie'	I	-	9
L. 'Orange Triumph'	I	10	10
L. 'Pandora'	I	-	9, 10
L. 'Peggy North'	I	9	9
L. 'Pink Tiger'	I	9	9
L. 'Prins Constatjn'	I	9	4, 5
L. 'Red Lion'	I	9	-
L. 'Rosemary North'	I	9, 10	9, 10
L. 'Santorin'	I	9, 10	9, 10
L. 'Vanguard'	I	9	9
L. 'Yellow Blaze'	I	9, 10	9, 10
L. x *hollandicum*	I	10	10
L. 'Brocade'	II	9, 10	9, 10
L. 'Mrs R.O. Backhouse'	II	9	9, 10
L. x *dalhansonii*	II	9	9, 10
L. 'Afterglow'	IV	9	9
L. 'Kirschroter Tänzer'	IV	-	10
L. Bellingham Group	IV	9, 10	9, 10
L. San Gabrial Group	IV	9, 10	9, 10
L. 'Casa Rosa'	V	6	6
L. 'Bright Star'	VI	9, 10	9, 10
L. 'Green Magic'	VI	9	9
L. 'Moonlight'	VI	9	10
L. Pink Perfection Group	VI	9	9, 10
L. 'Thunderbolt'	VI	-	9, 10
L. 'Vico Queen'	VI	10	10
L. Golden Splendor Group	VI	9, 10	9, 10
L. 'Arthur Grove'	VII	9, 10	9, 10
L. 'Cover Girl'	VII	9	9
L. 'Mona Lisa'	VII	6	6
L. 'Showbiz'	VII	9, 10	10
L. 'Star Gazer'	VII	6, 7	6, 7
L. Everest Group	VII	-	9
L. 'Smoky Mountain'	VIII	9	9

Table 2.2. Part 2 of 2. Summary of observations made on the presence of lily beetle on *Lilium* and *Fritillaria*. * see Table 2.4.

1 = Beitrag 1932, 2 = Barton 1941, 3 = Fox Wilson 1943, 4 = Coghill 1946, 5 = Southgate 1959, 6 = Livingston 1996, 7 = Cox 2001, 8 = Anderson and Bell 2002, 9 = Salisbury 2003b, 10 = Salisbury 2004a, , 11 = Haye and Kenis 2004.

Most resistant	Group*	**Most susceptible species and cultivars**	Group*
L. henryi	5	*L. auratum*	4
L. 'Black Beauty' (Most resistant)	VII	*L.* 'Acapulco'	VII
L. 'Donau'	VII	*L.* 'African Queen'	VI
L. 'Lollypop'	I	*L.* 'Berlin'	VII
L. 'Reinesse'	I	*L.* 'Casa Blanca'	VII
		L. 'Grand Cru'	I

Table 2.3. Lilies investigated for resistance to lily beetle (after C. Conjin, *pers. com.*). * see Table 2.4.

Species group		**Hybrid groups**	
1	*martagon*	I	Asiatic hybrids
2	American	II	Martagon hybrids
3	*candidum*	III	Candidum hybrids
4	Oriental	IV	American hybrids
5	Asian	V	Longiflorum hybrids
6	Trumpet	VI	Trumpet hybrids
7	Dauricum	VII	Oriental hybrids
		VIII	Miscellaneous hybrids

Table 2.4. Lily species groups and hybrid groups following Comber 1949 and the lily register (http://www.lilyregister.com/register/).

2.4. Worldwide distribution.

Lilioceris lilii has been reported from almost everywhere lilies (*Lilium*) grow (natural or cultivated), across the northern temperate zone (Fig. 2.3. Fox Wilson 1942, Berti and Rapilly 1976, Cox 2001, Gold et al. 2001). *Lilioceris lilii* is an established alien in the UK (Fox Wilson 1942) and North America (Brown 1946, Casagrande and Livingston 1995). The origin of *L. lilii* is unclear. It has been speculated that the beetle originated in China, but records from China are sparse and a centre of origin there is now considered unlikely (Yu et al. 2001).

In North America, *L. lilii* was established in Montreal, Canada by 1945 (Brown 1946) and by 2002 it had been reported across five Canadian provinces (Casagrande and Kenis 2004). *Lilioceris lilii* was first reported in the USA from Massachusetts in 1992 and has spread rapidly, occurring in seven north-eastern states by 2004 (Casagrande and Kenis 2004, Maier 2005). It is thought that *L. lilii* could become much more widely distributed in North America, based on its Eurasian distribution and the establishment of other leaf beetles of European origin (LeSage 1983, Gold et al. 2001).

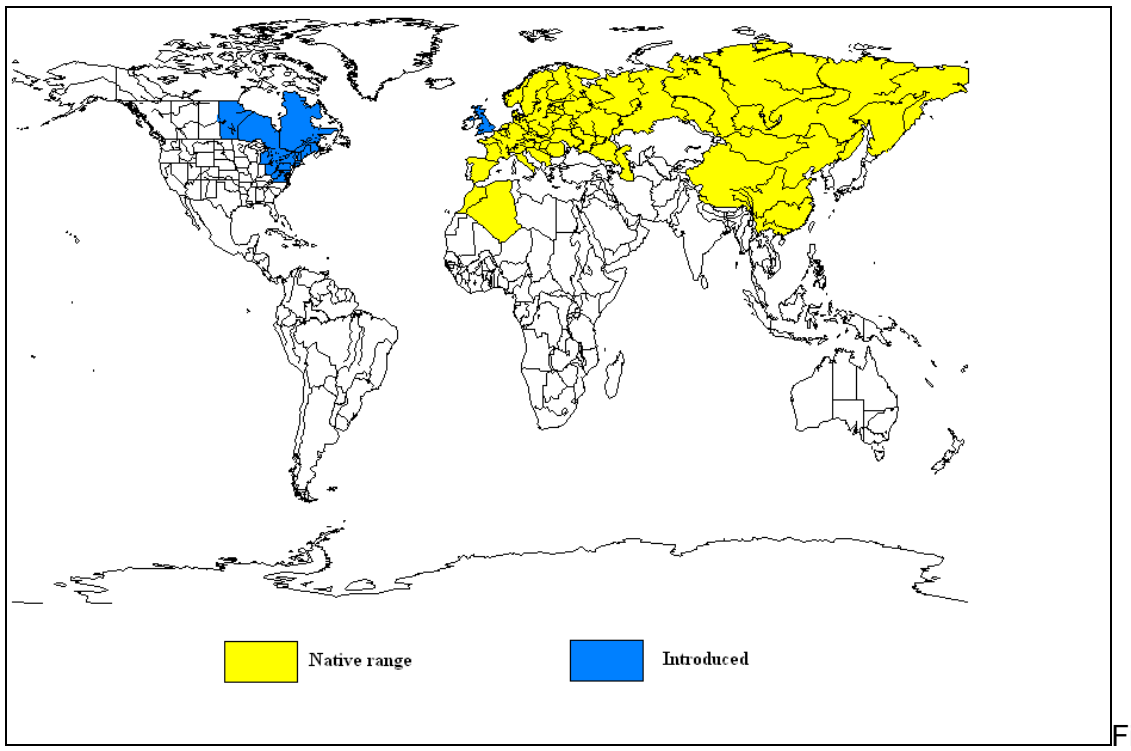


Fig. 2.3. Worldwide distribution of the red lily beetle *Lilioceris lilii* (Scop.).

2.5. Distribution in Great Britain (Fig. 2.4).

Before 1839 *L. lilii* was recorded from London and Swansea and considered rare (Fowler 1890). *Lilioceris lilii* was reported in Flintshire in 1945; the infestation may have originated with bulbs imported from Holland and was probably destroyed by applications of DDT (Coghill 1946). Single specimens were recorded in the 1940s from Carlisle (Richards 1943) and Cheshire (Southgate 1959) and adults and larvae from Chobham, Surrey in 1939 (Barton 1940). The lack of records from Flintshire, Carlisle and Cheshire between the 1940s and 1989 indicates a failure to establish in these areas at that time (Halstead 1989).

In addition to Chobham, by 1943 *L. lilii* had been reported from two sites in Surrey and one in Middlesex (Fox Wilson 1943). By 1959 *L. lilii* was widespread in Surrey and occurred in the surrounding areas of Hampshire and Berkshire (Southgate 1959). The continued presence of *L. lilii* in Chobham and its apparent spread outwards from the town indicates that this was probably the site of establishment in the UK (Halstead 1989). By the late 1970s *L. lilii* was established in four counties adjoining Surrey and during the 1980s its range extended to most counties in southeast England (Halstead 1989). By August 2006, *L. lilii* was present in almost every county in England and was becoming widespread in Wales (RHS data. Fig. 2.5). *Lilioceris lilii* was reported from Scotland and Northern Ireland in 2002 (Anderson and Bell 2002, Hancock 2002) and continues to survive in these areas (RHS data). The beetle's distribution in England and Wales,

survival in Scotland and Northern Island and its worldwide distribution indicate that it will become distributed throughout the UK wherever its host plants are grown.

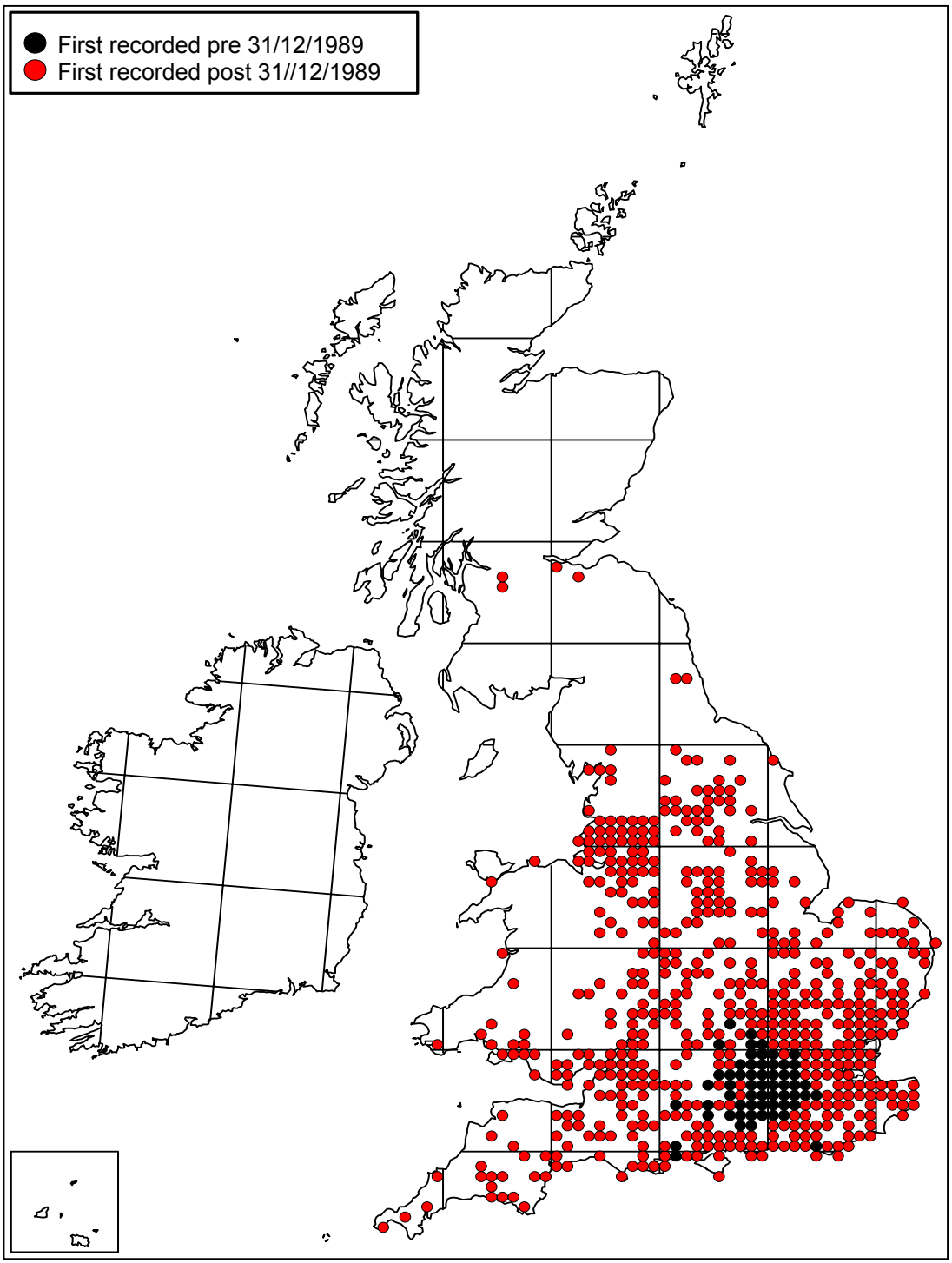


Fig. 2.4. Post 1939 10 km dot distribution map of the lily beetle from RHS data (at 31/07/06). Produced using DMAP©.

2.6. Generalist predators.

Carnivorous bugs (Hemiptera) and lacewing larva have been observed feeding on lily beetle larvae (Nolte 1939, Salisbury unpublished). In laboratory tests with predatory ground beetles a low level of egg predation was observed (Salisbury 2000). Therefore predation by generalist predators may be limited.

2.7. Specialist predators – Parasitoids (Parasitic wasps).

Four hymenopteran larval parasitoids, one hyperparasitoid and one egg parasitoid of *L. lilii* have been identified (Table 2.5). Combined, the parasitoids infect 25 to 94% of *L. lilii* larvae in mainland Europe (Kenis et al. 2002, Haye and Kenis 2004). None of the larval parasitoids kills *L. lilii* larvae before they are mature, and are therefore unsuitable for rapid control.

Two of the parasitoids occur in the UK. *Tetrastichus setifer* (Fig. 2.6) was first reported from East Kent in 1987, and has since been recorded in Essex, Surrey, Sussex, Middlesex, Suffolk, Cambridge and East Yorkshire (Salisbury 2003b, Fig. 2.7). It may be as widely distributed as its host because it is present in areas where *L. lilii* has only recently become established (Section 2.5). *Lemophagus errabundus* (Fig. 2.5) was reared from *L. lilii* larvae collected from Essex in 1998, and has since been recorded in Surrey (Salisbury 2003a), Sussex and Middlesex (RHS data, Fig. 2.7) The hyperparasitoid *Mesochorus lilioceriphilus* has been recorded from Surrey (Salisbury 2004b). Neither of the parasitoids can be native to the UK as they are specific to the genus *Lilioceris* (Table 2.5): *L. lilii* is the only representative of the genus in the UK and is an established alien (section 2.5).

Fig. 2.5. Adult *Lemophagus errabundus.* A. Salisbury.

Fig. 2.6. *Tetrastichus setifer* adult. A. Salisbury

Family: *Species*	**Distribution**	**Life cycle (Adult occurrence)**	**Host range***
Ichneumonidae			
Lemophagus errabundus (Gravenhorst) Fig. 2.5.	Belgium, France, Germany, Netherlands, Switzerland, UK	Univoltine, Solitary. May -June.	*Lilioceris* spp.
Lemophagus pulcher (Szepligeti).	Throughout mainland Europe	Multivoltine. July-August	Criocerinae
Diaparsis jucundus (Holmgren).	Throughout mainland Europe	Univoltine. July.	*Lilioceris* spp.
Mesochorus lilioceriphilus Schwenke.	France, Holland, Switzerland, UK	Solitary hyperparasitoid	*Lemophagus* spp.
Eulophidae			
Tetrastichus setifer Thomson. Fig. 2.6.	Central Europe, UK	Univoltine. May-August. Gregarious	*Lilioceris* spp.
Mymaridae			
Anaphes sp. (undescribed).	France, Switzerland	Egg parasitoid. Multivoltine, gregarious	Unknown

*Under laboratory conditions

Table 2.5. Characteristics of hymenopteran parasitoids of *Lilioceris lilii* in Europe (Haye and Kenis 2000, Gold et al. 2001, Kenis et al. 2001, Gold 2003, Haye and Kenis 2004)

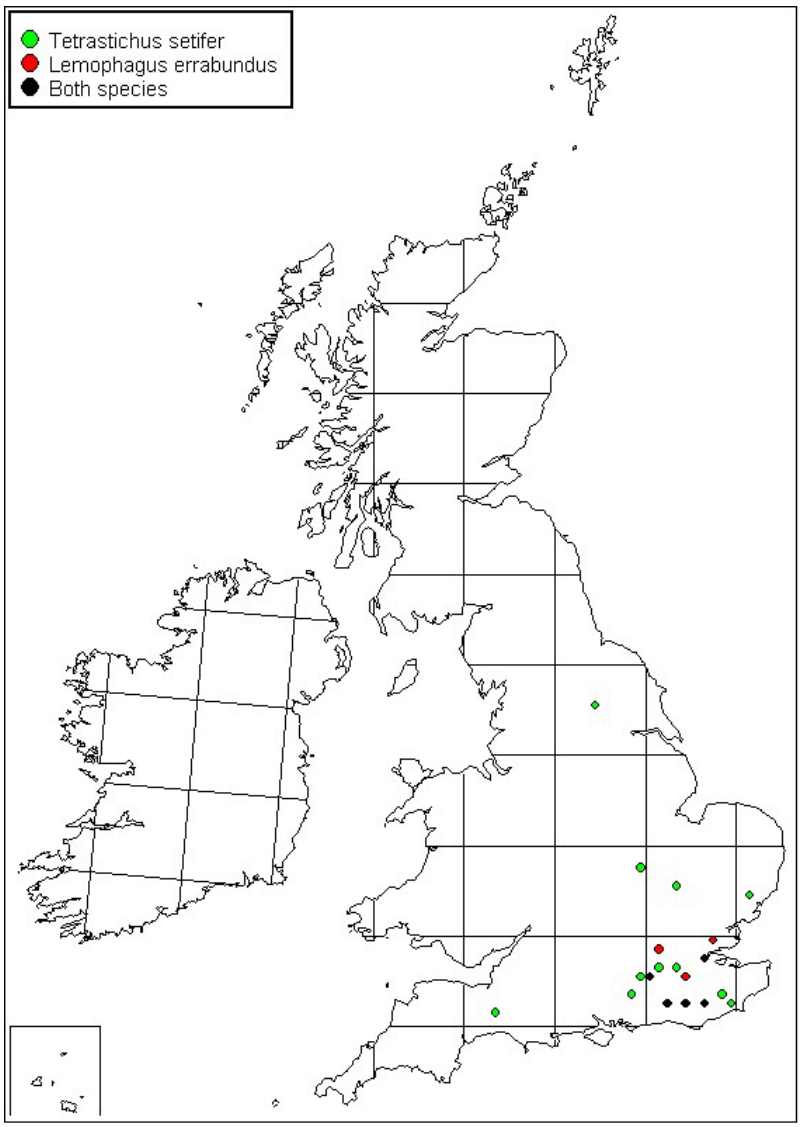


Fig. 2.7. Distribution of lily beetle parasitoids in the UK (RHS data at 31/07/2006). Produced using DMAP©.

2.9. Defence against predation.

The bright red colouration of *L. lilii* adults is assumed to act as a warning to predators (Jolivet and Verma 2002). Adult *L. lilii* make a squeaking sound by contracting and extending the abdomen, which could either be a defence behaviour (Emmel 1936) or a means of communicating with other lily beetles (Schmitt 1994). Adult beetles show a feigned death defence when disturbed, falling to the ground and remaining motionless (Livingston 1996). The presence of the excrement cover (known as a faecal shield) of *L. lilii* larvae was shown to reduce predation by the earwig *Forficula auricularia* L. (Schaffner and Kenis 1999). Whilst such defensive secretions can provide protection against generalist predators, specialists can exploit them. An investigation of the foraging behaviour of the parasitoid *Lemophagus pulcher* found that adults moved towards the odour of larvae and their faecal shields and to lilies with larval damage (Schaffner and Müller 2001). In the laboratory *L. pulcher* females probed faecal shields with their ovipositor (used for laying eggs). This suggests that the shield plays a primary role in

short-range host location and host acceptance, and that the stimulus is chemical. Initial work with the other parasitoids indicate that these may have similar responses (Scarborough 2002).

2.10. Pest status.

Lilioceris lilii in the UK, North America and the Netherlands is a problem for the amateur gardener, as well as in public parks and gardens, but it may also be a risk to the native lilies of North America (Haye and Kenis 2000, Gold et al. 2001). This pest may also threaten lily production in the USA, an industry worth $65 million in 2003 (Gold, 2003). Damage does occur in commercial lily fields in central Europe, but it is usually for the first few years following a new planting after which it is presumed that parasitoids keep *L. lilii* populations in check (Kenis et al. 2001). The UK has rare native populations of the snake's head fritillary (*Fritillaria meleagris*) and beetles have been observed adjacent to fields where it occurs (RHS data); the risk to these plants should be considered (Sutton 2004).

RHS data indicate the rise of *L. lilii* as a problem to the gardener since 1967 (Fig. 2.8). A mean of four *L. lilii* enquiries per year (0.5% of total pest enquiries) were received during the 1970s; in the 1980s the mean rose to 26.7 (1.8% of total), in the 1990s rose to 76.1 (3.0% of total); in the new millennium (up to December 2005) the figure is 104 (3.3% of total).

Before the commencement of the surveys reported below no information was available on problems *L. lilii* causes to the professional grower in the UK, and the risk *L. lilii* poses to commercial production had not been assessed.

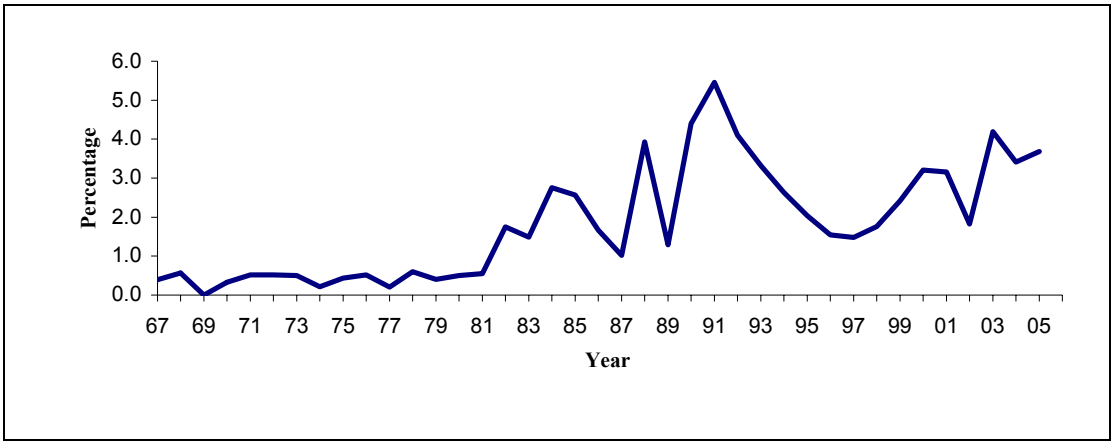


Fig. 2.8. Lily beetle enquiries as a proportion of all pest enquiries received by the RHS (1967 to 2005).

2.11. Management in the UK.

Management of *L. lilii* currently relies on hand picking or the use of pesticides (Alford 1995). These measures often need to be repeated throughout the growing season due to the long period of beetle activity. The excrement-covered larvae, the adult behaviour of

dropping to the ground when disturbed, and the time consumed can make hand picking undesirable (RHS 2005). In 2006, two synthetic insecticide foliar sprays are available to amateur gardeners to control beetle pests on ornamental plants in the UK: active ingredients bifenthrin and imidacloprid. The latter is the only insecticide to carry a specific label recommendation for *L. lilii* (Bayer Provado Ultimate Bug Killer). Both insecticides are broad spectrum and not suitable for use on plants in flower. Two insecticides (active ingredients imidacloprid and azadirachtin) were found to repel adults but not to cause significant adult mortality (Livingston 1996). These data support the conclusion of LeSage (1992) that no insecticide at present can completely eradicate the adults or larvae of *L. lilii.* Thus it is clear that existing management methods against the beetle are inadequate.

2.12. Biological control.

Following extensive host testing, parasitoids have been introduced against *L. lilii* in the USA. *Tetrastichus setifer* was released in Massachusetts from 1999 to 2003 (Tewksbury et al. 2005). Three thousand female *T. setifer* were released in trial plots; initially up to 60% parasitism was recorded, but low winter survival was observed, as the bark mulch used on the plots was unsuitable for the overwintering parasitoids (Tewksbury et al. 2005). By March 2005, *T. setifer* had been established for three years near Boston and Rhode Island and declines in *L. lilii* had been seen as a result (Tewksbury et al. 2005). This parasitoid has also been released in Maine and New Hampshire (Tewksbury et al. 2005). The first releases of *L. errabundus* and *D. jucunda* occurred in 2004; evaluation of success is scheduled until 2007 (Kenis and Rohner 2004).

It has been suggested that it is a complex of three or more parasitoid species that reduce *L. lilii* populations to non-damaging levels in mainland Europe and that in the UK *L. lilii* may be managed by introducing an additional parasitoid (Casagrande and Gold 2002). However such an introduction requires extensive quarantine testing in a registered UK laboratory to satisfy a plethora of government advisory bodies before a release licence can be granted (Sections 14 and 16 of the UK Wildlife and Countryside Act 1981, HMSO 1981). Data collection would take many years, the cost of quarantine facilities can be prohibitive and it is still possible that a licence will not be granted. In the event that a licence is granted, there is no guarantee that the addition of a further parasitoid will control *L. lilii* in the UK.

2.13. Conclusions.

It is clear that there is much that can still be learned about *L. lilii*. Inaccuracies from the early literature on *L. lilii* life cycle are still repeated in the pest management literature and its phenology is not thoroughly understood. The beetle's host range, in particular the preferences it may have for different types of *Lilium* or *Fritillaria* has shown potential in the

search for resistant varieties but rigorous investigation is lacking. *Lilioceris lilii* has shown considerable range expansion in the UK since its establishment in 1939 and it can be assumed that the beetle will continue to spread in the UK.

No stage of the beetle attacks or is attached to the bulb, therefore the beetle is unlikely to be transported with dry bulbs, although there is a risk of spreading the beetle with potted plants.

Current management options for *L. lilii* are unsatisfactory. In the USA biological control with parasitoids is being attempted, yet despite two of these parasitoids being present in the UK, *L. lilii* continues to be a problem for many gardeners and the introduction of further natural enemies to the UK is unlikely, unless they arrive accidentally.

3. Risk assessment survey part 1: Effect of the lily beetle in amateur gardens.

3.1. Introduction and methods

The prevalence of a pest such as *L. lilii* may have a deleterious effect on consumer confidence, for example declines in sales of roses are widely believed to have been due to the rise of black spot (C. Prior pers. com.). In order to gain some insight into consumer confidence, members of the RHS who enquired about the lily beetle by phone, e-mail or in person during 2005 and 2006 were asked (after advice was given about *L. lilii*) "If you continue to have a lily beetle problem would you stop growing lilies / fritillaries) in the future?"

3.2. Results and discussion

Between 13 March 2005 and 9 August 2006, there were 148 responses (Fig 3.1): 26% (39) said they would not continue to grow lily beetle hosts in the future if lily beetle continued to be a problem. This result is likely to be biased towards the keen gardener, those replying being primarily RHS members. However, if considered representative of the lily-growing public, it indicates that *L. lilii* problems could cause a decline in the sales of lilies and fritillaries, if it is not already restricting sales.

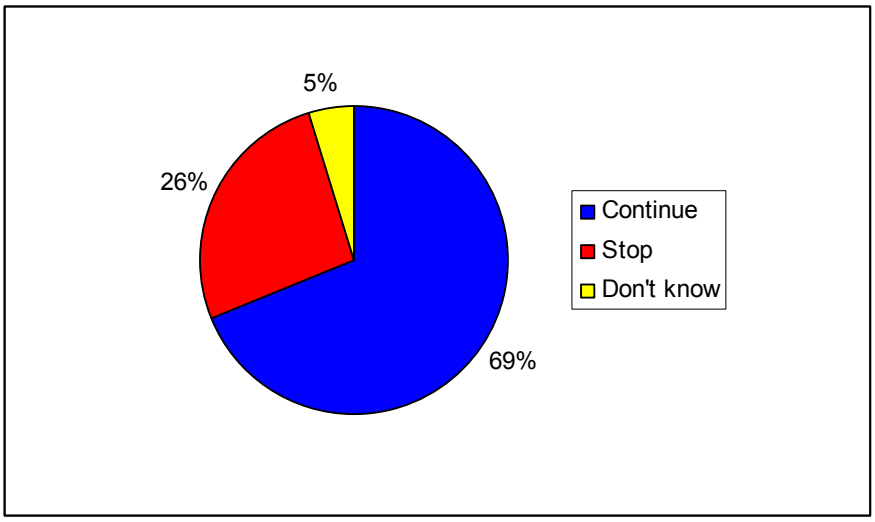


Fig 3.1. Replies from 148 enquirers who were asked "If you continue to have a lily beetle problem would you stop growing lilies (fritillaries) in the future?"

4. Lily beetle risk assessment survey part 2: providers of lily beetle host plants.

4.1. Introduction.

Reviewing the literature (Chapter 2) provided information on the biology and distribution of the lily beetle (*Lilioceris lilii*), including published control methods. An analysis of RHS enquiries (Section 2.10) and a question asked of enquirers (Chapter 3) shows that the beetle is an increasing problem for the amateur gardener and that a proportion (26%) would stop growing lily beetle host plants (*Lilium, Fritillaria* and *Cardiocrinum,* referred to as lilies) because of a beetle problem. However this does not provide information on problems or the risk the beetle may give professional growers, wholesalers and retailers (the providers) of lilies. Thus a survey of providers of lily beetle host plants was instigated.

Limited information is publicly available on providers, the only recent statistic is that 20 million lilies were grown under glass in registered agricultural holdings in England and Wales in 2003 (DEFRA, 2004). Thus the survey not only assessed the current problems, control measures and perceived risk of the beetle but attempted to quantify the industry in the UK.

4.2. Methods.

Survey forms were despatched in February 2006, each form was sent with a freepost envelope for return and lily beetle information sheet (Appendix 9.1 and 9.2). The survey was sent to lily providers listed in the RHS Plant Finder (134 surveys) and to Horticulture Development Council (HDC) members (448 surveys), not all of whom were necessarily providers of lilies. The surveys had a return date of 10 March 2006.

Responses have been summarised by the number of providers responding to each question/ category, with numbers who reported a lily beetle problem indicated (Q2a). Where appropriate, comparisons have also been made with the number of lilies produced (Question 6b). It should be noted that if a provider reported a problem with lily beetle it does not indicate that the problem is ongoing or that all stock was infested and comparisons given should be treated as only as a guide.

4.3. Results.

Response rate.

The response rate was 22%, 126 of the 582 surveys were returned 102 of which were from lily providers. Proportionally more responses were received from providers listed in the plant finder (56, 42%, all providing lilies) compared to HDC members (70, 16%, 46 were lily providers). The lower response rate from HDC members may have been partially due to the fact that not all provided lilies, as demonstrated by the 24 returned surveys from this group stating that lilies were not grown. The results below refer to the 102 providers

who supply lilies. Responses received after the due date have been included in the results. Of the 102 producers 81 (79%) indicated how many plants they produced (Question 6b) and represent 6 700 225 lilies sold in 2005.

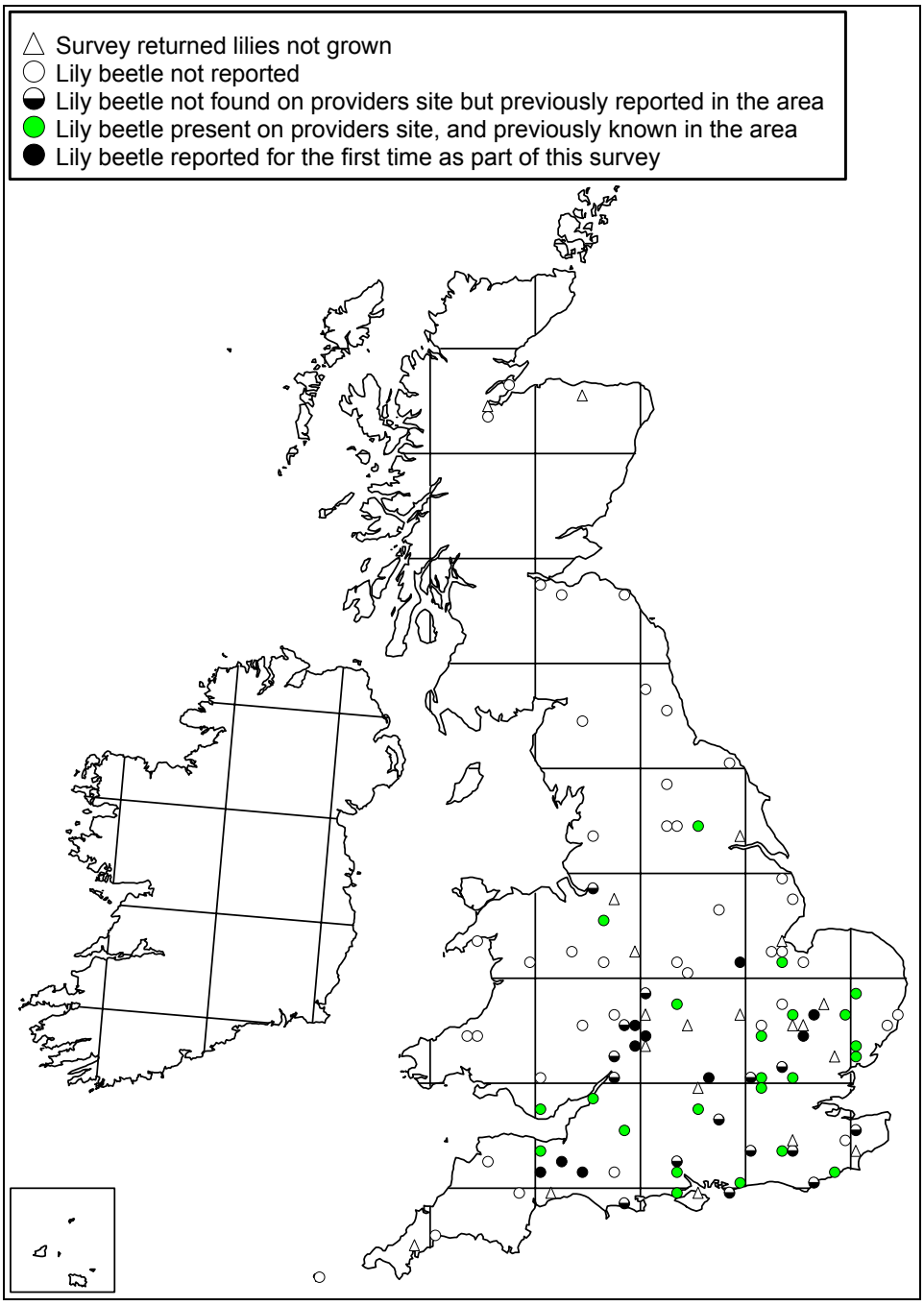


Fig. 4.1. Distribution of returned surveys and presence of the lily beetle.

SECTION B. *The lily beetle.*

Q2a. *Have you ever had a problem with lily beetle?*

Thirty-five providers reported that lily beetle had been a problem, all but one of these providers were in England (Fig. 4.1). Ten of the reports were from 10 km grid squares where *L. lilii* had not been previously reported, although these were all within the known range of the beetle (see Fig 2.5).

Twenty-four providers reporting lily beetle specified the number of lilies sold per year; 593 670 lilies, 9% of the lilies represented in the survey (Q6b).

Q2b. *What control measures were taken against lily beetle?*

Most (19, 54%) of the 35 providers relied on hand picking alone as a control measure, only four (11%) relied on chemicals alone (Fig 4.2) and two providers stopped growing lilies because of the beetle. Whilst manual removal was the most frequent method of controlling the beetle by number of providers, by number of lilies produced pesticide is most commonly used (Fig. 4.3).

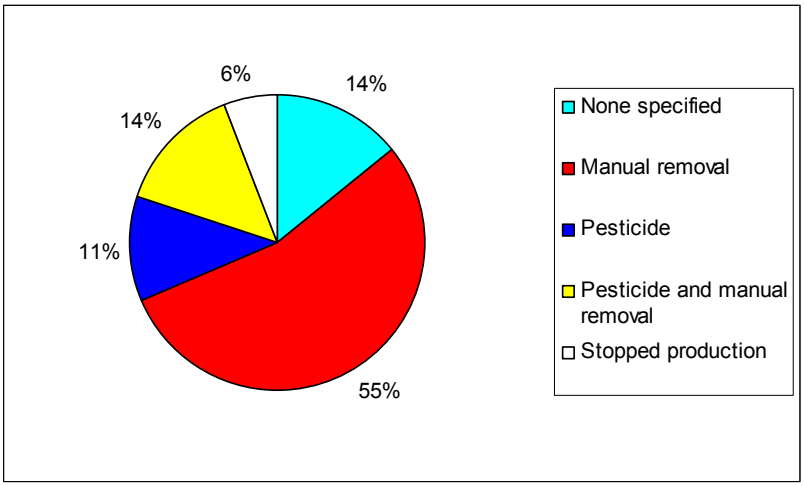


Fig 4.2. Control measures taken by 35 providers against lily beetle.

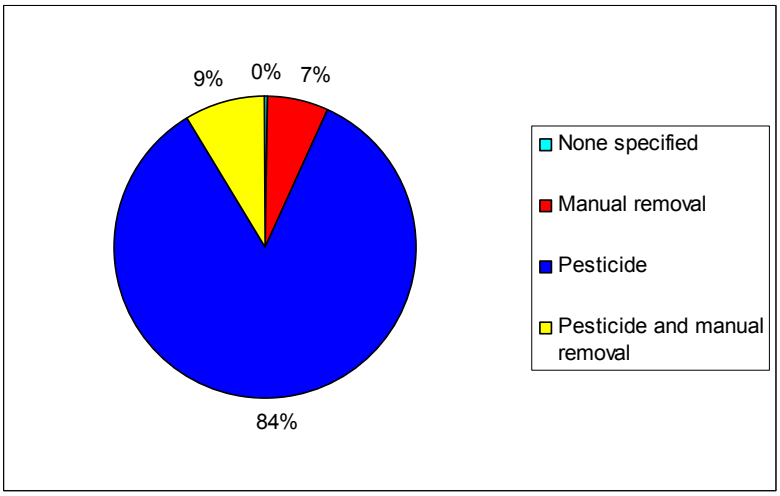


Fig 4.3. Control measures taken against lily beetle, percentage of 591 850 lilies sold by 24 providers.

Q2c. *Have you ever had enquiries or complaints from customers about the lily beetle?*

Thirty of the providers had enquiries or complaints about the beetle, 16 of these had not had a problem with lily beetle. Therefore even if lily beetle is not a problem on site for a provider, they are being made aware of the problem by customers.

Q2d. *To your knowledge, is lily beetle present in other gardens locally (within 5 miles)?*

Of the 56 providers stating that the beetle was known locally (all within the known distribution of the beetle, Figs 2.5 and 4.1), 21 did not have a problem with lily beetle themselves. Thus a provider based in an area where lily beetle is present does not necessarily have a problem with this pest, although a high proportion (35 of the 56, 63%) had reported a problem.

Q2e. *A number of those who contacted the RHS for advice on lily beetle in 2005 will not purchase any new lilies or fritillaries for their garden due to the beetle problem. In light of this information and the other information provided with this survey, what impact do you think the beetle may have on the lily or fritillary part of your business?*

Almost half of providers (48) representing 66% of plants in the survey thought the lily beetle would have no effect or even increase sales (Figs 4.4 and 4.5). However 54 providers expected to see a decrease in sales, representing 34% of plants in the survey. A minority (3) of producers would stop growing lilies if they had a beetle problem.

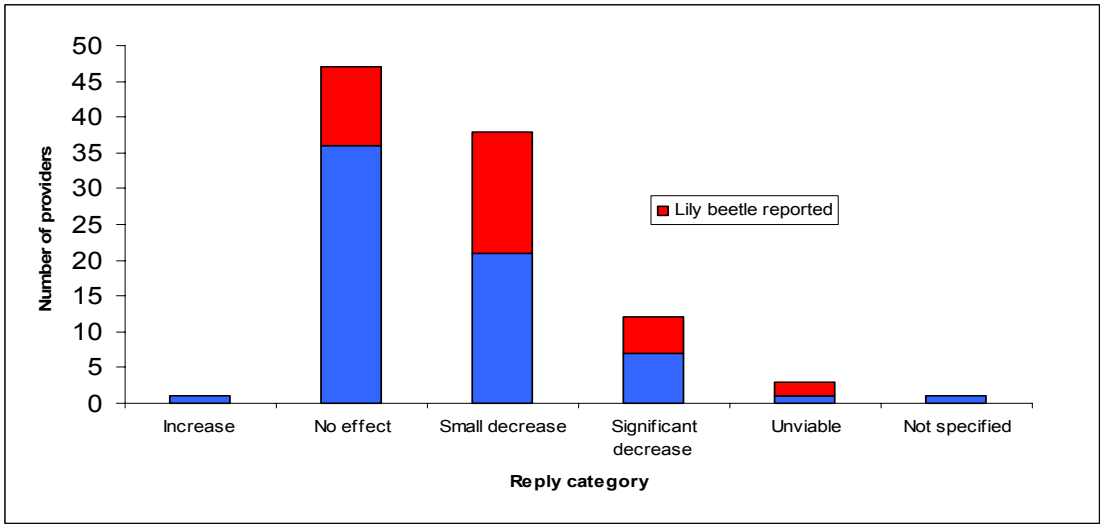


Fig. 4.4. Perceived impact of the lily beetle on lily sales.

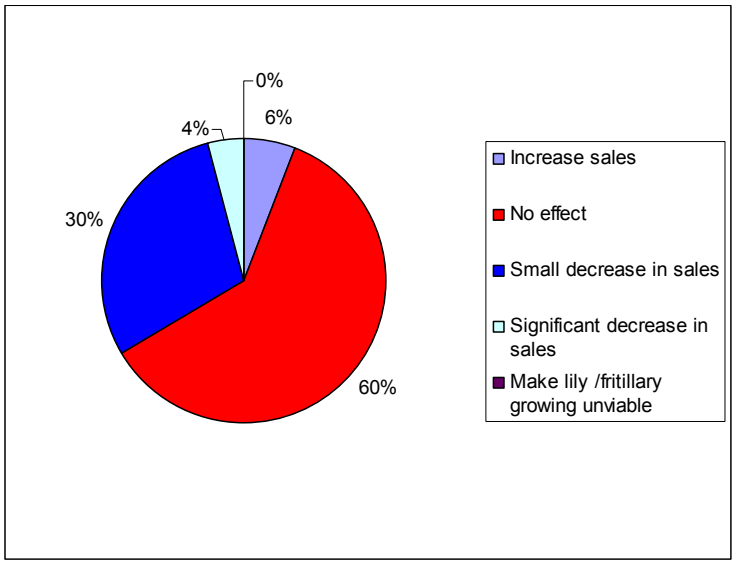


Fig. 4.5. Perceived impact on plant sales of the lily beetle by plants sold (of 6 700 225).

Q3. *Please list the* Lilium/ Fritillaria/ Cardiocrinum *that you supply.*

Over 300 plant types are represented in the survey, including lilies from all major taxonomic and hybrid groups (Table 4.1), thus the survey is representative of plant types provided in the UK. The largest group of providers (38) are those that supply *Lilium* alone, accounting for 83% of the plants represented in the survey (Figs 4.6 and 4.7). It is clear that lily beetle has been a problem for providers in most groups.

	Cardiocrinum	***Fritillaria***	***Lilium***
Species	3	57	48
Cultivars / varieties/ hybrids	4	35	175
Total	7	92	223

Table 4.1. Summary of the plants supplied by providers surveyed.

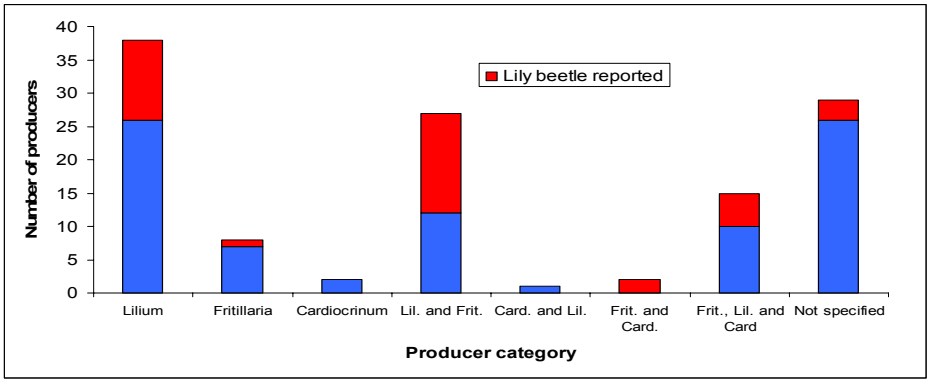


Fig. 4.6. Plants produced by providers of lilies

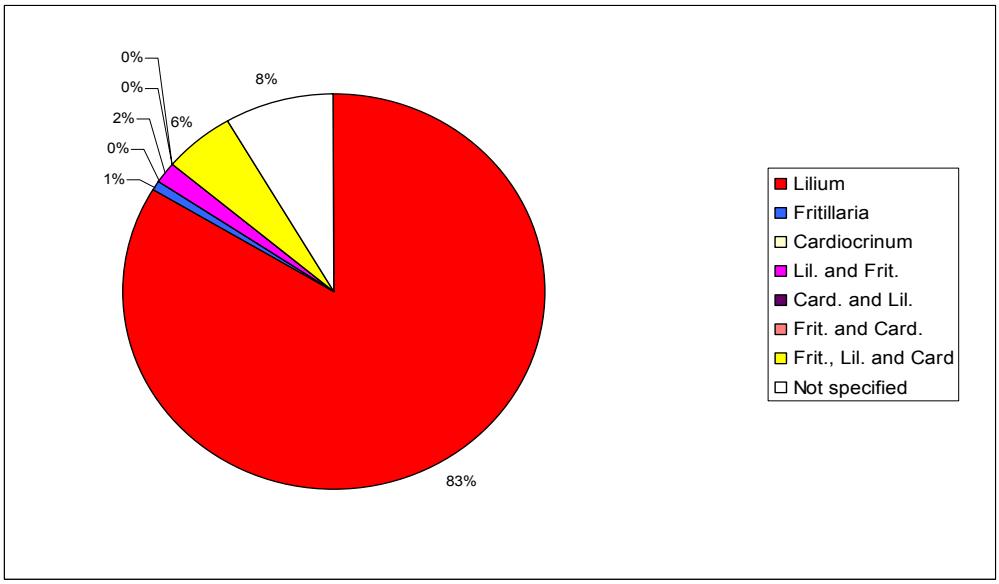


Fig 4.7. Percentage of each plant type sold (of 6 700 225)

Section C. Lily production

Q4a. *Are you a producer, retailer or wholesaler of* Lilium/ Fritillaria/ Cardiocrinum*?*

Overall 79 providers grew at least some of their own plants for retail or wholesale (Fig 4.8), 14 of which relied on their own production as the sole source of plants. Most of those surveyed were at least in part retail (74) and/ or producers (88). With the exception of wholesalers, lily beetle was reported by at least one provider in all categories. Considering the replies by the number of lilies sold, most are from producers alone or producers and wholesalers (92%, Fig 4.9).

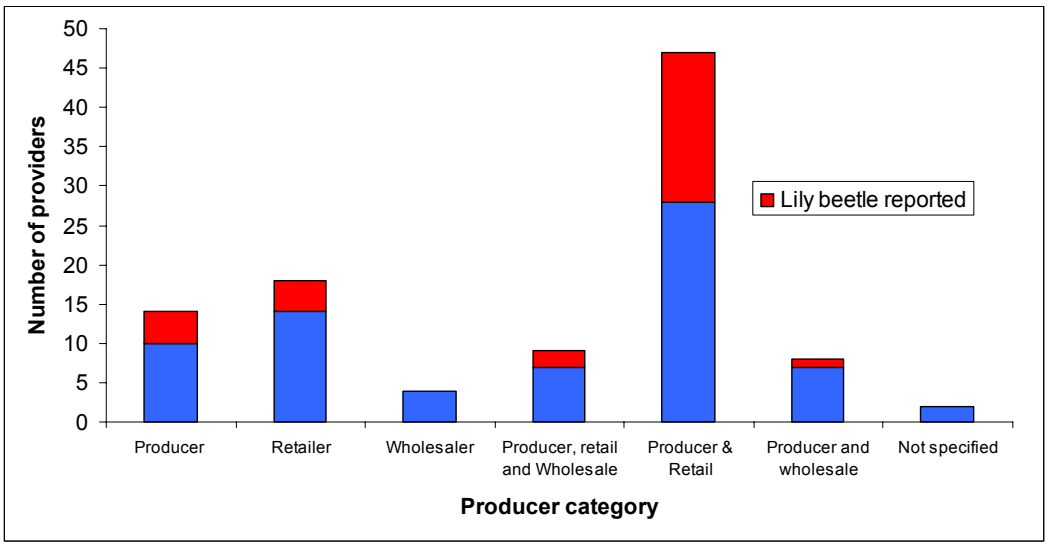


Fig 4.8. Provider types.

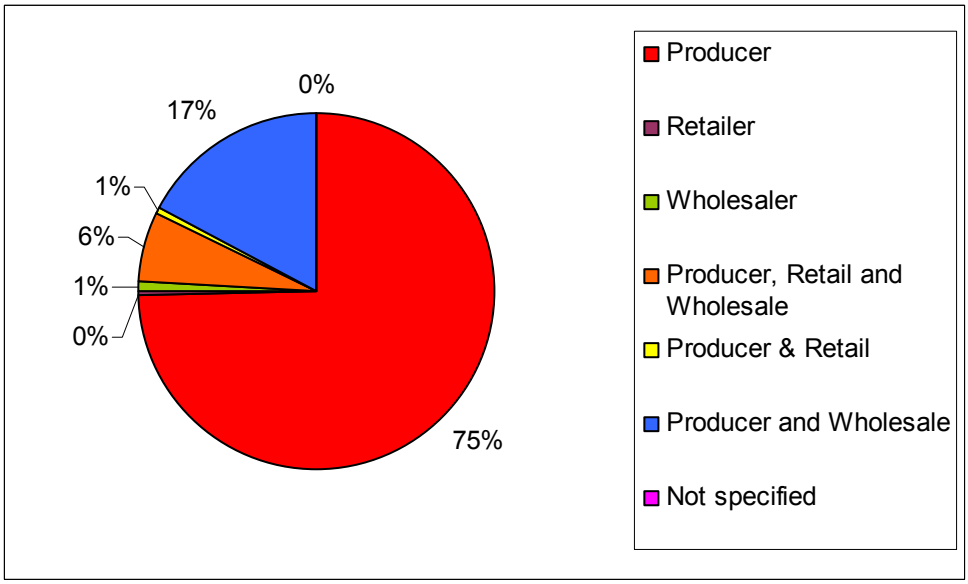


Fig 4.9. Type of provider by number of plants sold (of 6 700 225).

Q4b. *Where do you source new stock?*

Most (68) of the 82 providers responding bought in plants as a partial source of new stock, 36 of which exclusively purchased plants from other providers. Propagation of stock was carried out by 47 providers, 32 of which also purchased plants externally (Fig. 4.10). Comparing the number of plants represented in this survey, those propagating alone

represent 1% of the plants with over 75% plants represented being purchased externally (Fig 4.11). Providers in all categories had a lily beetle problem.

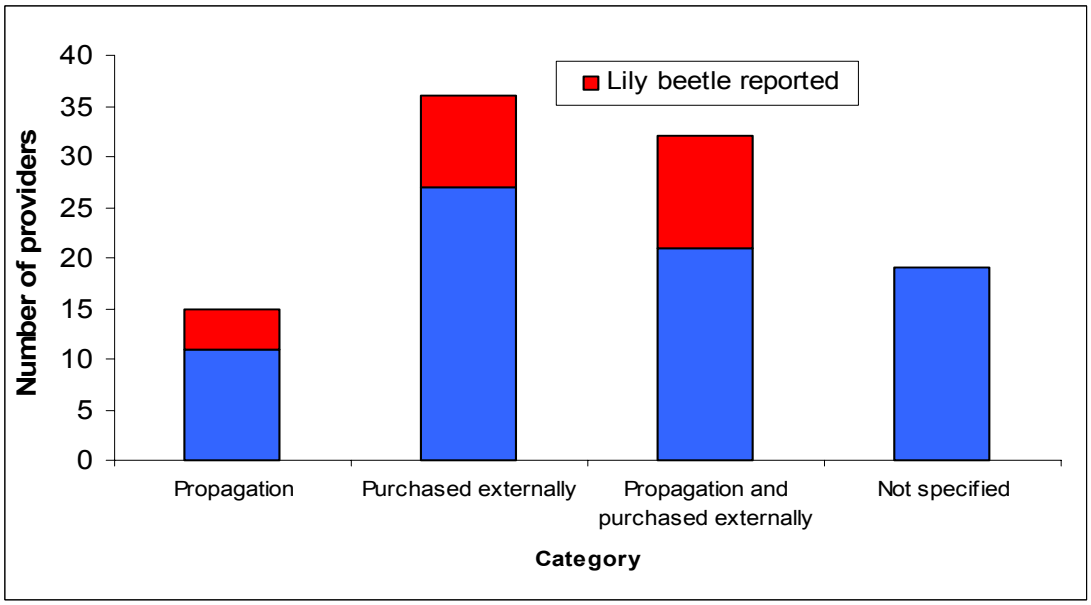


Fig 4.10. Where lily providers source of new stock.

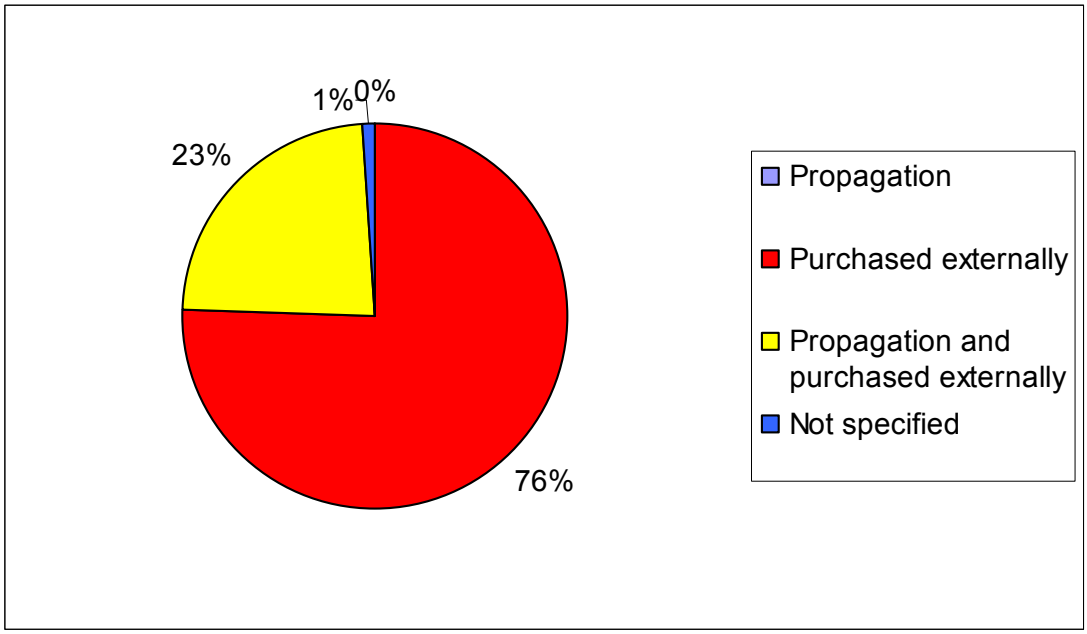


Fig. 4.11. Source of new plant stock, by number of plants sold (of 6 700 225).

Q4c. How do you propagate?

Of the 47 providers who were propagating lilies 36 responded (Fig 4.12). A combination of propagation methods is often used in lily production and with the exception of tissue

culture, all published methods of lily production are used in the UK. In almost all categories at least one provider has had a problem with lily beetle.

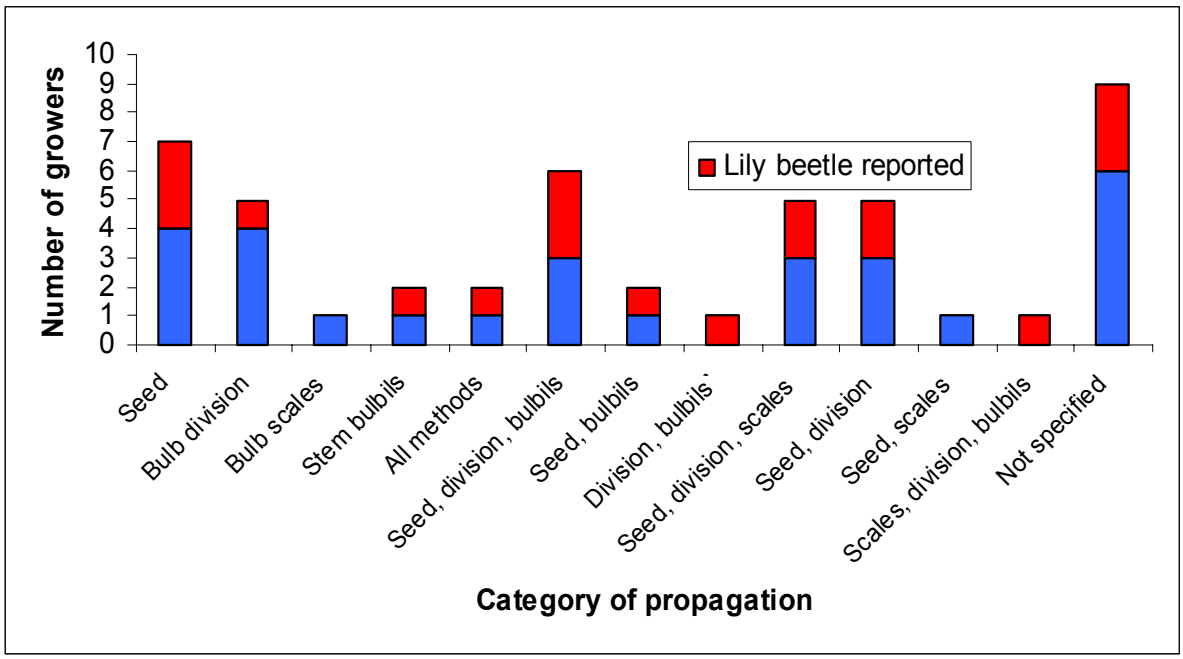


Fig. 4.12. Methods of lily production in the UK.

Q4d. *Are you breeding new varieties/ cultivars?*

Four providers accounting for 1 515 400 (23%) of plants represented in the survey were breeding new varieties of lilies, and three reported a problem with lily beetle.

Q4e. *What is your current growing regime?*

Providers that used polytunnels, bulb frames or glasshouses were categorised as 'grown under protection' (Fig. 4.13). The 88 responses indicate that lily beetle can be a problem both under protection and out of doors, in potted plants and those in the open ground. The only situation where no provider reported lily beetle were those that grow under protection with additional heat/ light. Most of the lilies represented by this survey (Fig. 4.14) are grown at least partly under protection.

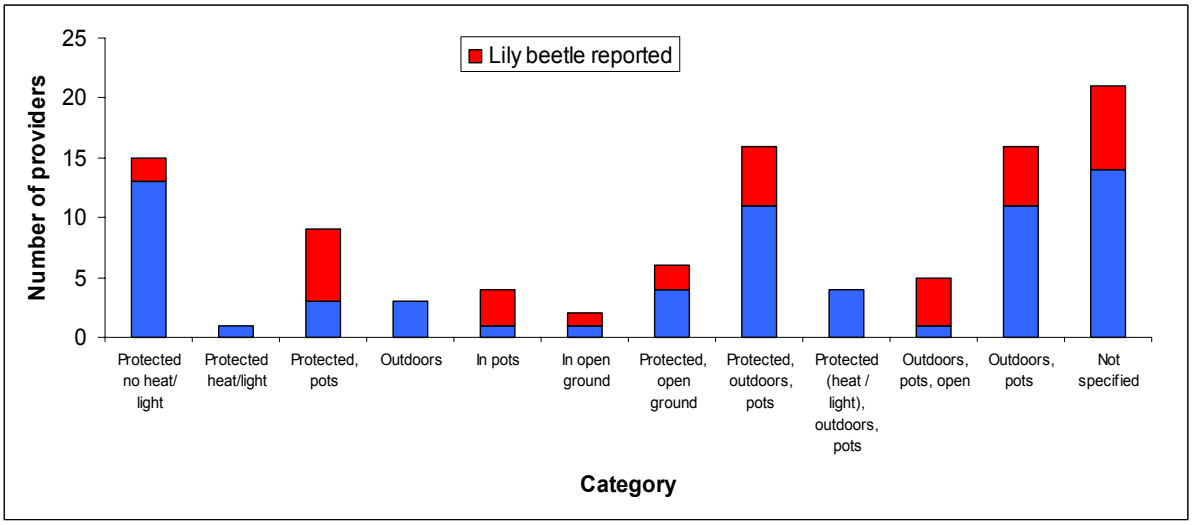


Fig 4.13. Providers' growing regimes for lilies in the UK.

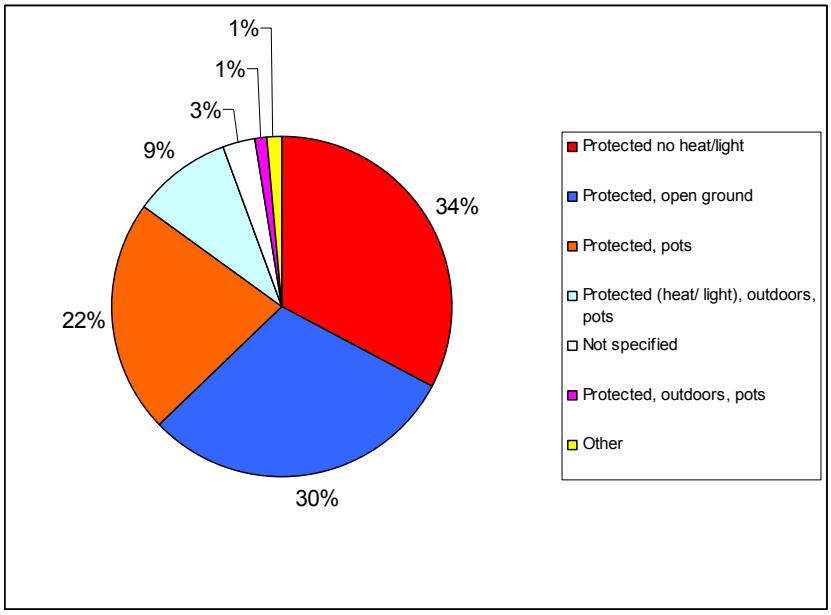


Fig 4.14. Providers' growing regimes for lilies in the UK, proportion of plants sold (of 6 700 225).

Section D – Source of stock

Q5a. *Where do you source new stock?*

There were 94 responses (Figs 4.15, 4.16); the largest group of providers sourcing new stock exclusively from the UK (45), although these providers accounted for less than 1% of all plants sold. Holland was the biggest source of supply by number of plants represented. There may be some circular referencing of these figures as many who obtain plants from UK suppliers may have bought plants from other providers in the survey.

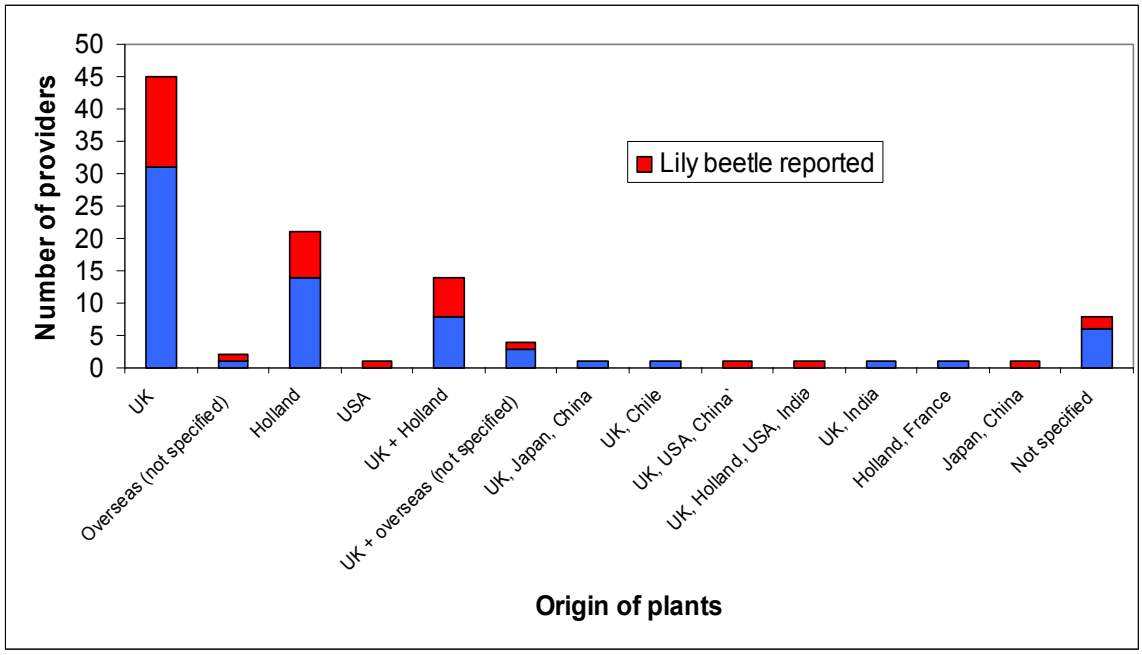


Fig 4.15. Where plants are sourced by number of providers.

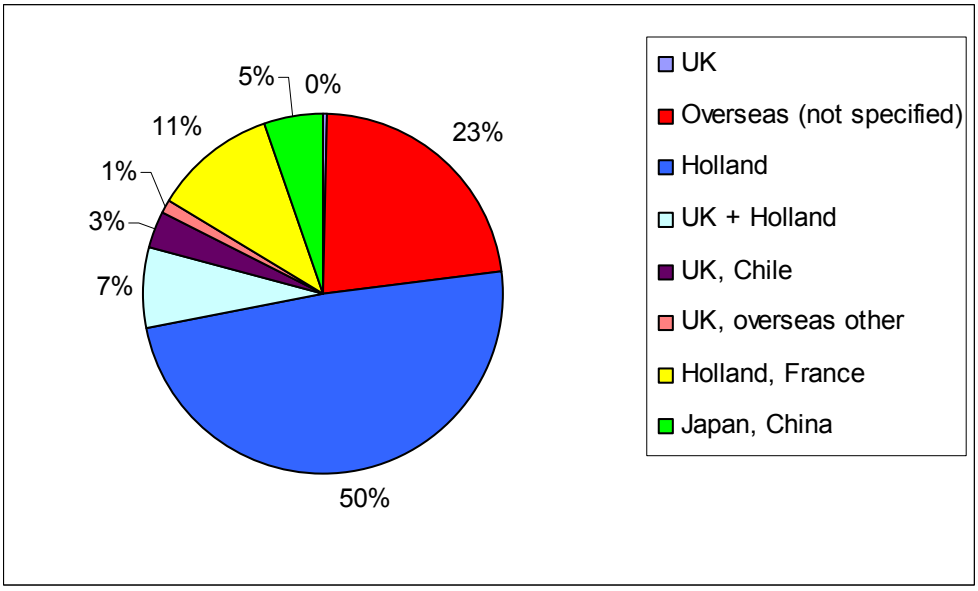


Fig 4.16. Where plants are sourced by the number of plants sold (of 6 700 225)

Q5b. *What stage of plants do you source?*

The most likely man-made (anthropogenic) dispersal of lily beetles is movement of plants in pots, which may contain pupae or adults in the growing medium or adults, eggs or larvae on foliage. There were 94 responses to this question, most (51) indicated that plants were brought as stages unlikely to contain the beetle (seed, bulbs or bulbils); overall those buying bulbs accounted for more than 94% of the plants represented (Figs 4.17, 4.18). Five providers sourced plants in pots alone, accounting for 6% of the plant sales in the survey; two of these imported plants, but neither has had a problem with the beetle.

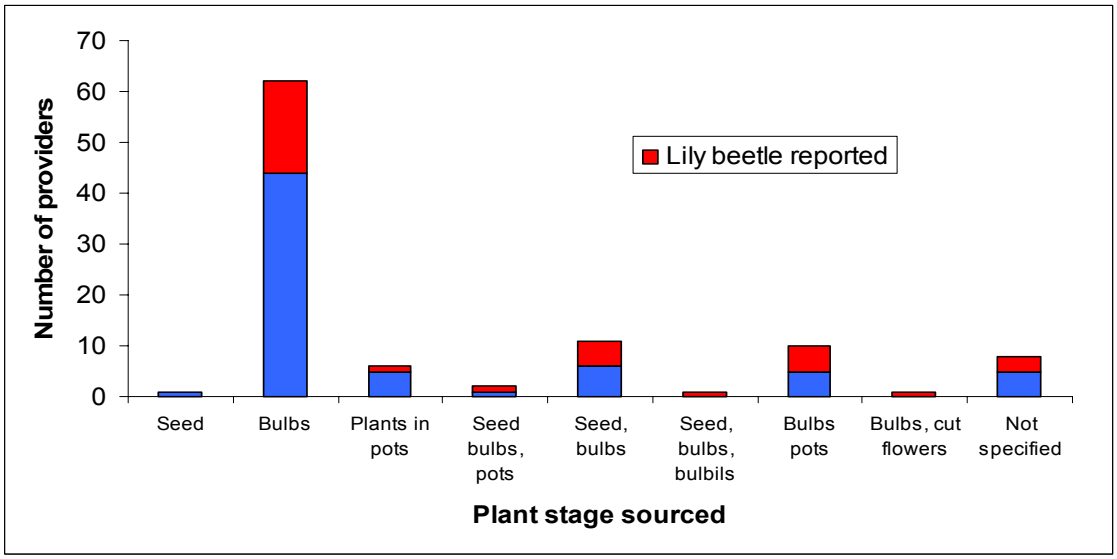


Fig. 4.17. Number of providers sourcing each stage of lilies.

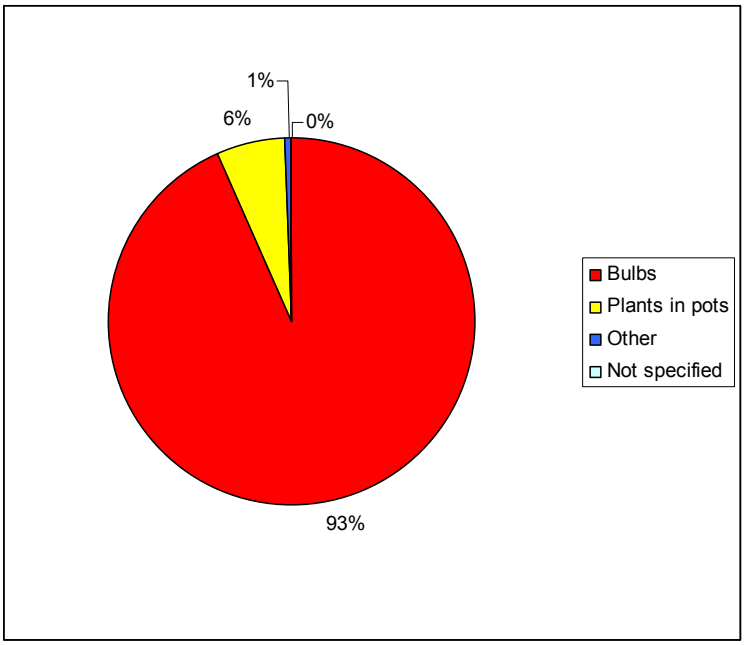
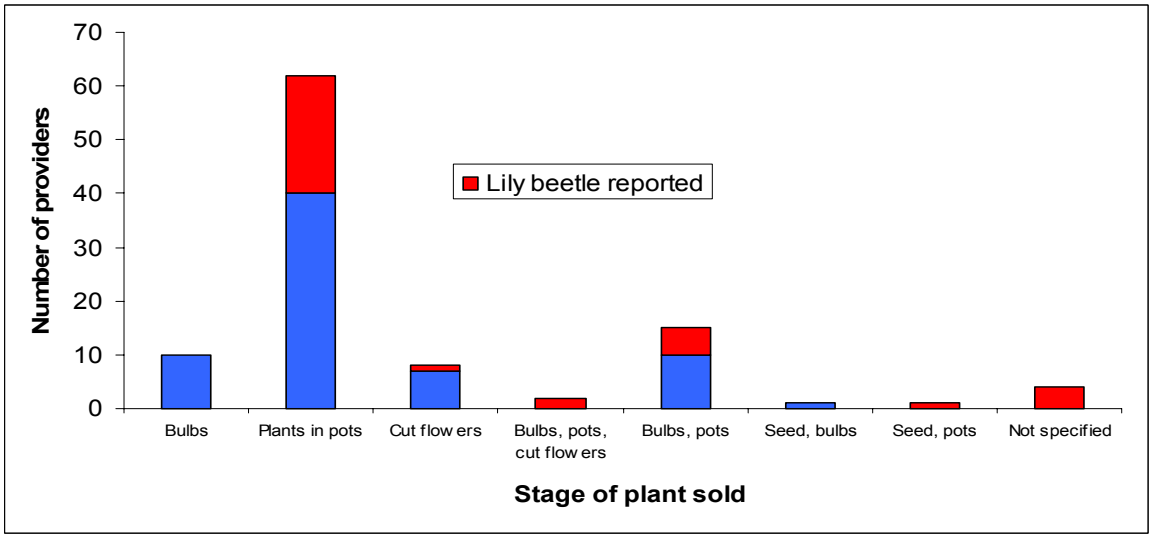


Fig. 4.18. Source of plants by number of plants sold (of 6 700 225)

SECTION E – Plant sales

Q6a. *At what stage do you sell plants?*

There were 98 responses, the majority sold plants in pots (62, Fig 4.19) and plants sold at this stage accounted for 33% of all plants represented (Fig 4.20). Only 7 providers sold cut flowers alone, yet this accounted for 60% of plants represented. In most categories at least one provider reported lily beetle. Whilst the risk of spreading the beetle by selling dry bulbs is small, it is possible that any stage of the beetle could be transported in potted plants. In theory eggs, larvae or adults could be transported with foliage in the cut flower trade; however it is unlikely that eggs or larvae will develop on these cut flower stems, as the stems will be disposed of and larvae will have nowhere to pupate (unless disposed of on a compost heap). However beetles or their damage would result in complaints and un-



saleable stock.

Fig 4.19. Number of providers selling each stage of lily beetle host plants.

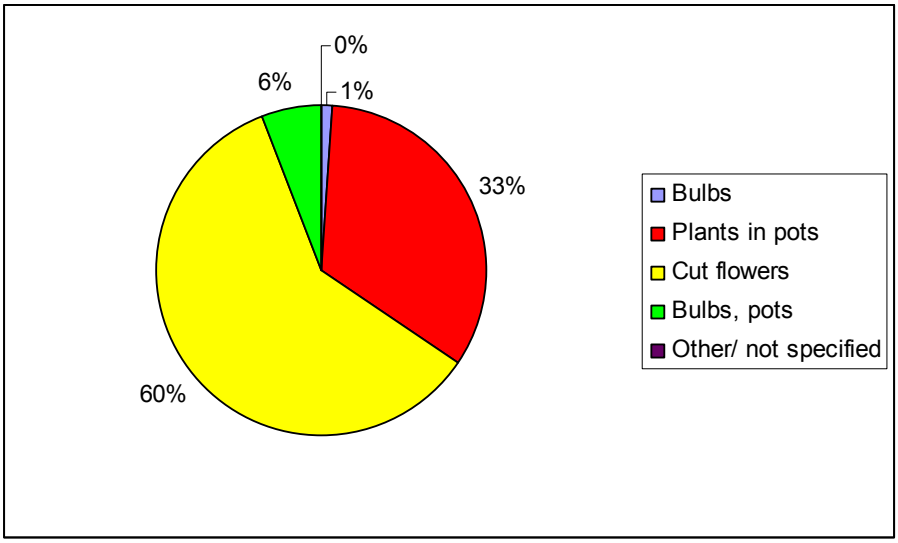


Fig. 4.20. Percentage of plants sold by stage (of 6 700 225).

Q6b. *What is your approximate turnover of plants (number of bulbs, seeds or stems) each year?*

A total of 6 700 225 plants are represented by the survey results, 81 providers specifying the number of lilies sold. The providers ranged from selling just 10 plants a year to 2 000 000. The mean number of plants sold per provider was 82 719. Most providers (66) sold less than 10000 plants per year, but these growers combined supplied less than 1% of all plants represented (Figs. 4.21, 4.22). Two providers produced 52% of the plants represented, therefore care should be taken when interpreting results presented by number of plants produced as the response by large providers will skew the results. The survey has covered a wide range of provider sizes and in all categories at least one grower has had lily beetle with the exception of those growing more than a million plants.

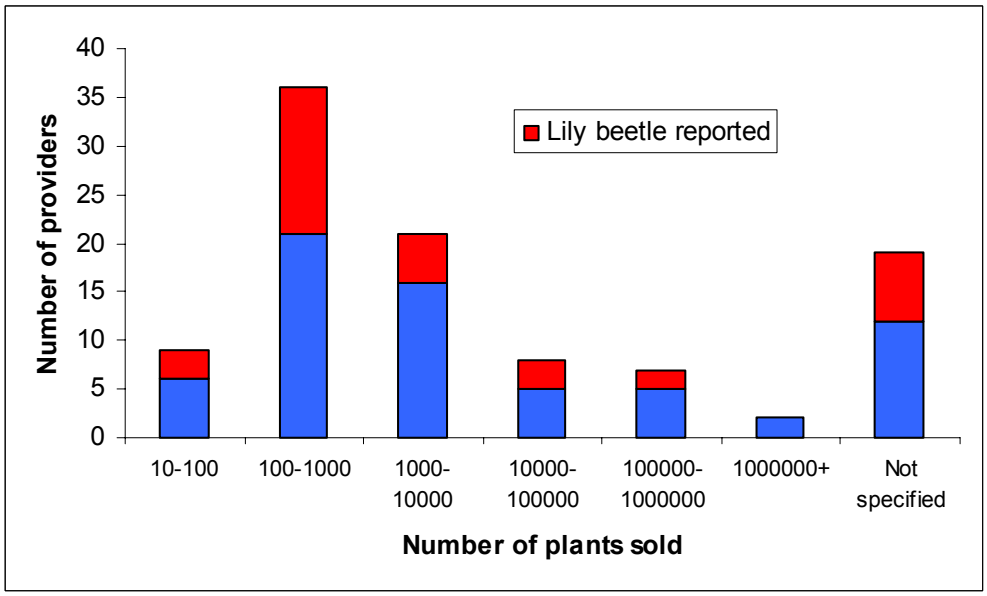


Fig. 4.21. Provider size by number of plants sold.

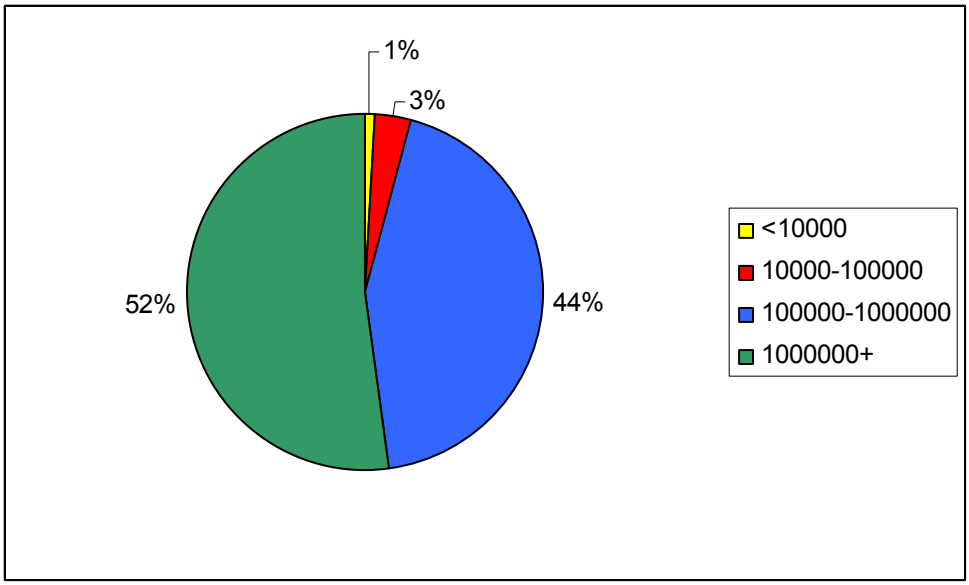


Fig. 4.22. Categories of provider size by number of plants sold (of 6 700 225)

Q6c. *Has this volume been increasing or decreasing over the past five years?*

Of the 89 responses, most (70) providers stated that plant sales had increased or stayed the same (Fig. 4.23); when compared with the number of plants sold, 58% have seen an increase, 5% staying the same. Nineteen providers have seen sales decrease, corresponding to 6% of plant sales. The responses to this question appear independent of the presence of lily beetle (Fig. 4.23). Overall it can be concluded that the sales of lilies are currently increasing.

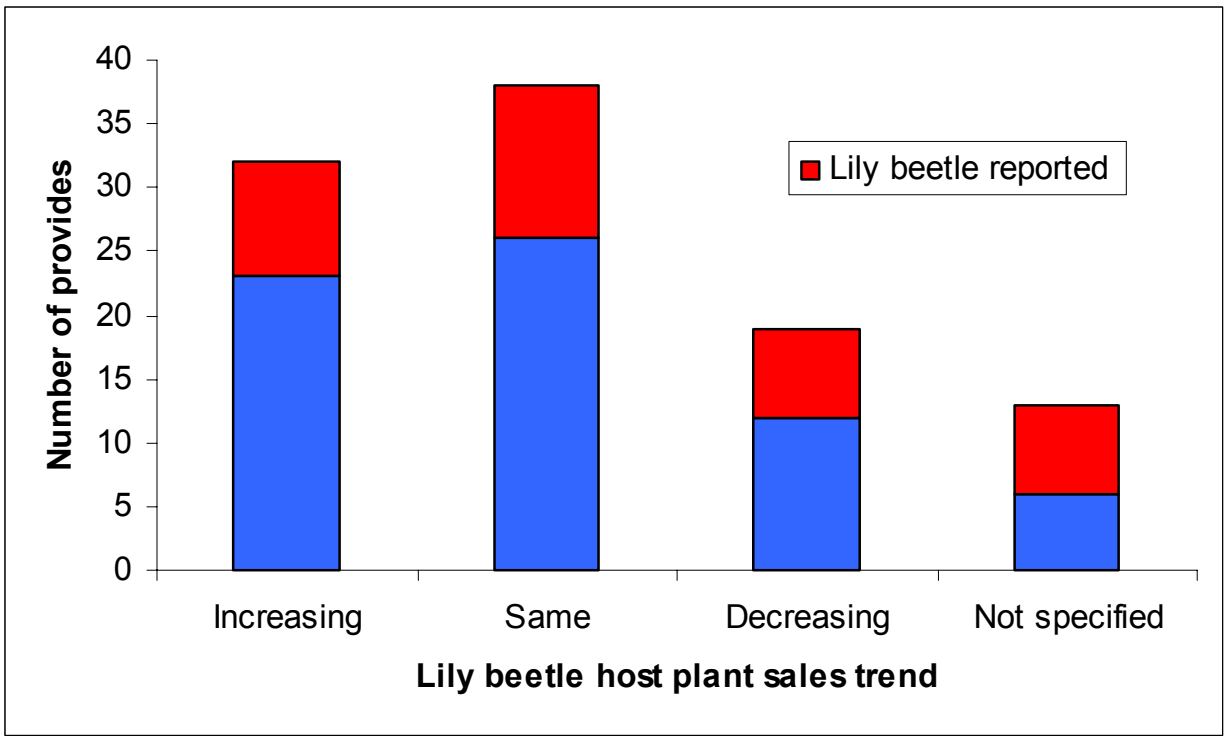


Fig. 4.23. Sales trend over the past five years, by number of responses.

6d. *Who do you sell plants to?*

Of the 100 responses, the largest group sold plants on site (32 exclusively, 70 at least partly, Fig. 4.24). In most circumstances at least one provider had a problem with lily beetle, although notably the two largest providers by number of lilies sold (supplying large retail outlets and flower pickers) had not had a lily beetle problem (Fig 4.25). This is fortunate as large retailers (e.g. B&Q) have strict quality control and will reject and even fine suppliers if any stock received is infested with pests.

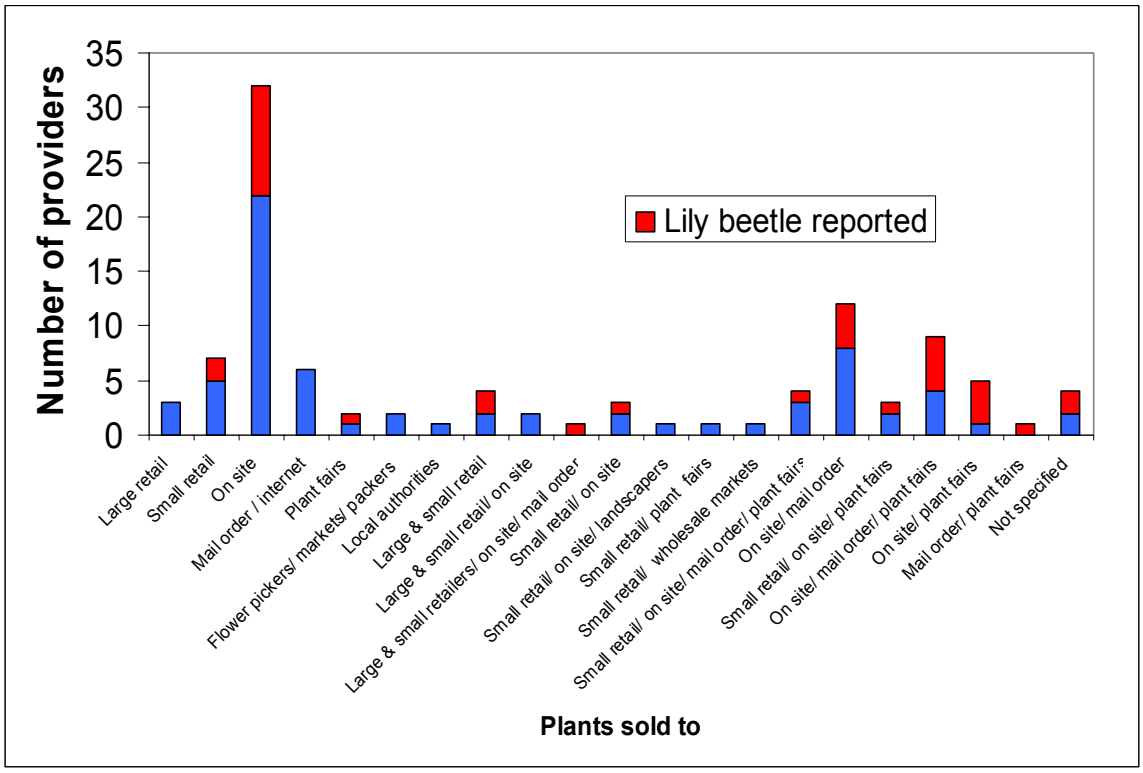


Fig 4.24. Who providers supply

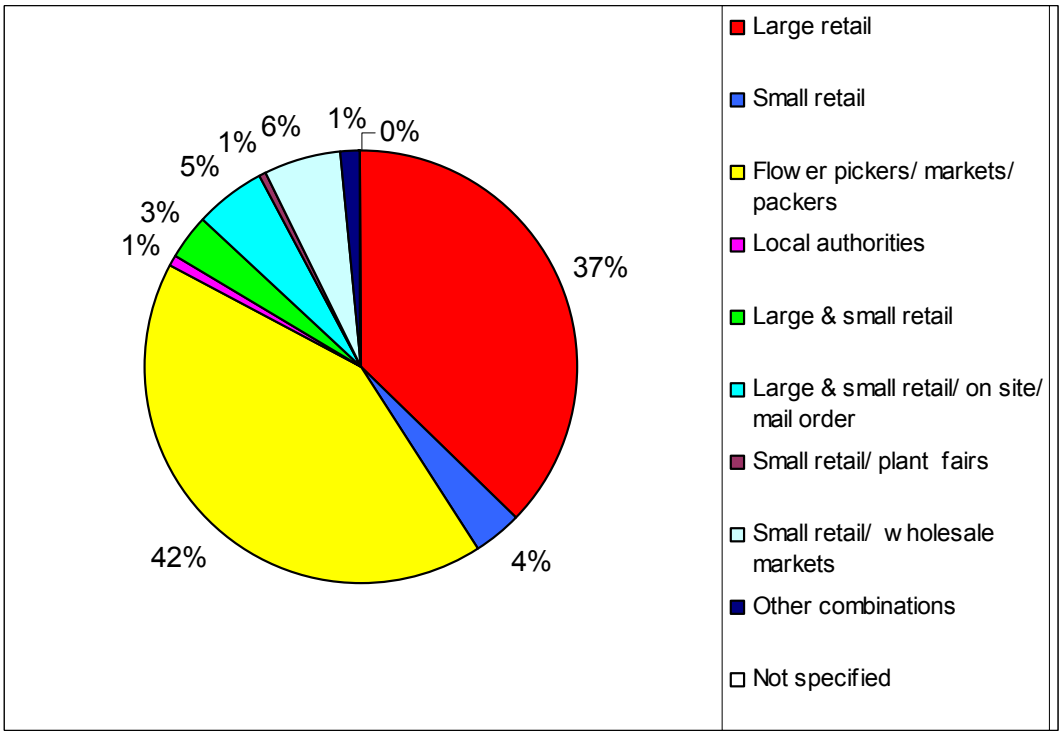


Fig 4.25. Percentage of plants in survey supplied to each category of outlet (of 6 700 225)

Section F – Pest and disease control

Q7a *Have you had any pest or disease problems?*

Pests

Over half of the providers (55) indicated that pests other than the lily beetle had been a problem. The most frequent pest by number of providers (45) and proportion of plants produced (89%) was aphids (Figs 4.26 and 4.27). Second in terms of number of providers affected was lily beetle (35), however this only affected providers selling 9% of the plants represented, and was behind thrips (29%), vine weevil (23%) and fungus gnats (22%). The aforementioned pests were found by providers growing over 90% of the plants represented in this survey. Other pests had affected 17 providers, however combined these providers represent less than 1% of plants sold. One provider had a problem with bulb mites and considered that they were a greater economic problem than the lily beetle. One provider found a grub imported with bulbs from China, indicating that insects can be introduced with imported bulbs.

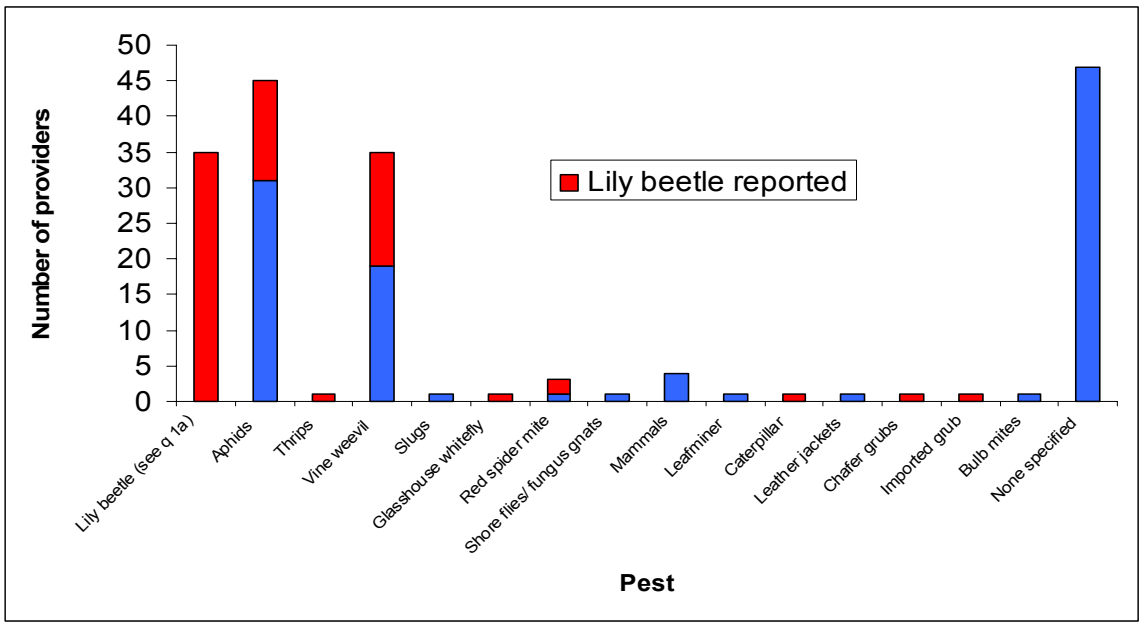


Fig. 4.26. Lily providers pest problems

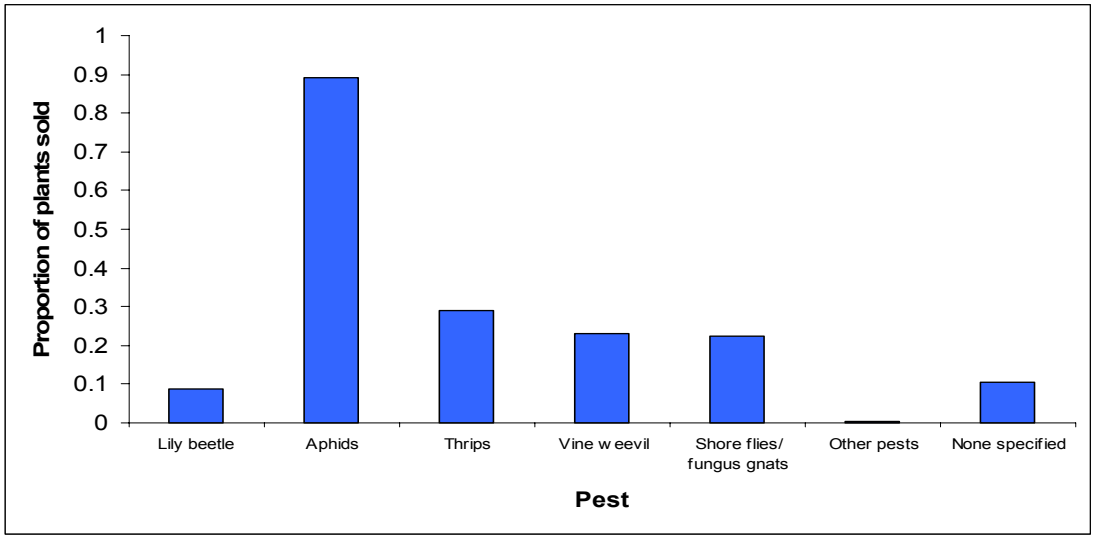


Fig 4.27. Providers with pest problems, by proportion of plants sold (of 6 700 225).

Diseases

Most providers (73) did not respond to this question accounting for over 50% of the plants sold (Fig 4.28). Therefore it can be concluded that diseases are a lesser problem than pests. Bulb rots are the most frequently encountered diseases both by number of providers and plants sold, followed by virus which is likely to be spread by aphids.

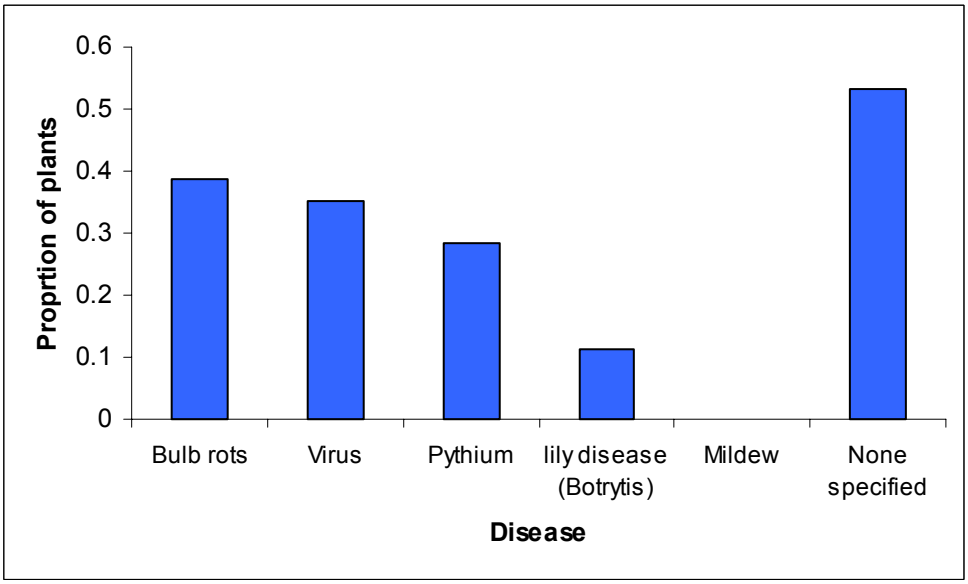


Fig 4.28. Diseases encountered by providers, proportion of plants sold (of 6700225).

Q7b What chemicals are used in production / storage?

Over half of the providers (56) stated that pesticides were used. Nine of these producers used an insecticide but did not specify pests as being present. The most frequently used were the neonicotinoid compounds (imidacloprid and thiocloprid) used by 22 growers (Fig 4.29). These are broad spectrum systemic insecticides used to control a variety of insect pests. However when considering plants represented by the survey (Fig 4.30) pirimicarb, a selective insecticide for aphids is the most commonly used, which will not have an effect

on lily beetle. Thus if lily beetle does become a wider problem it is likely to increase the use of broad spectrum insecticides.

More providers used pesticides (56) than fungicides (21) or fertilizer (47), and the number of plants sold corresponds to these figures (Fig 4.31).

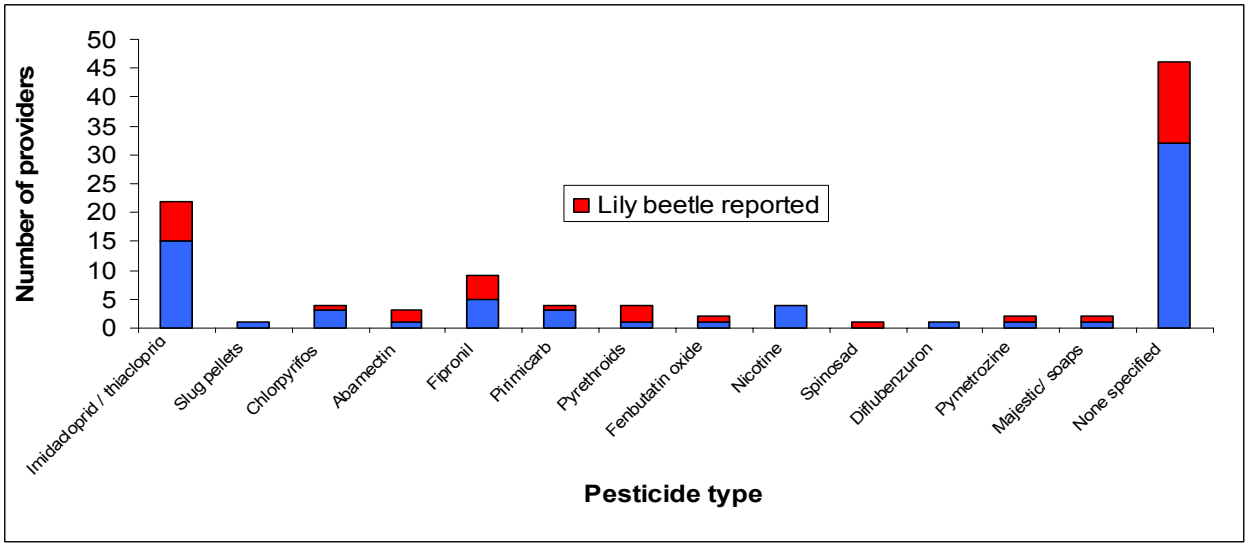


Fig 4.29. Pesticide use amongst the providers of lilies

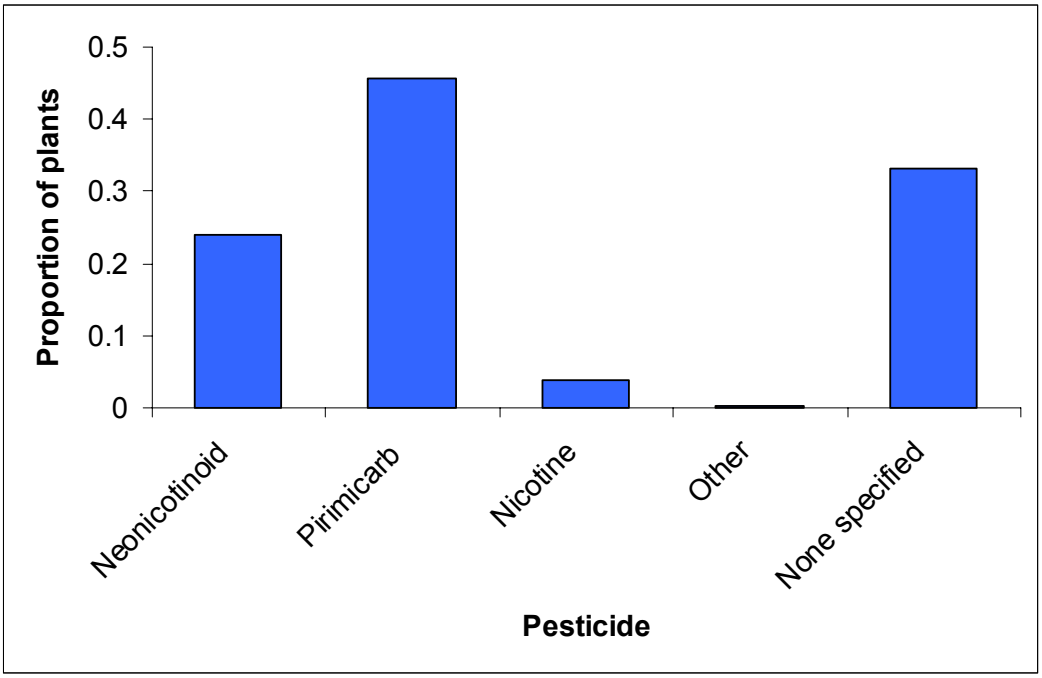


Fig 4.30. Pesticides used by proportion of plants sold (of 6 700 225)

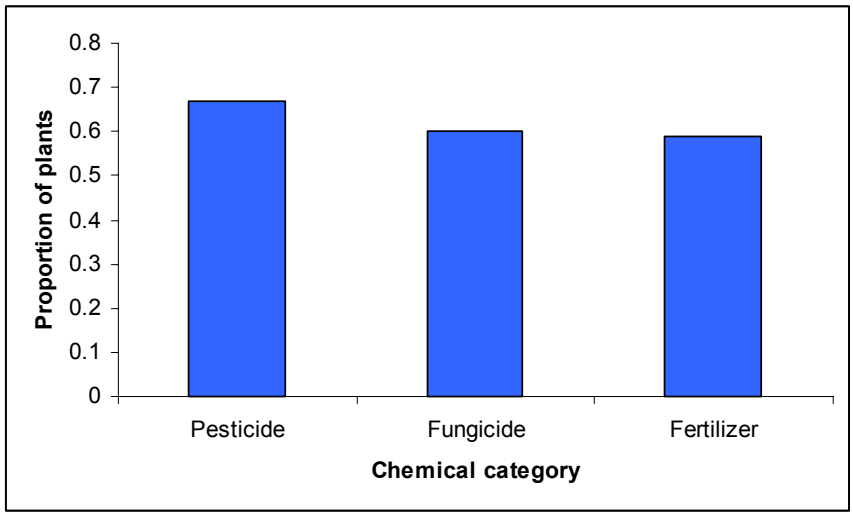


Fig 4.31. Chemical inputs as a proportion of plants sold by those providers specifying (of 6 700 225).

7c. What other pest / disease control strategies are used?

Of 88 responses 33 used methods other than chemical to control pests and diseases. The most commonly used was manual control, be that manual removal/ destruction of the pest itself or the infested crop. Biological control was used by ten producers, primarily against vine weevil (Fig. 4.32). However when the number of plants represented is taken into account these numbers are outweighed by those who used chemical control (57); manual control accounts for less than 1% of the plants produced (Fig. 4.33).

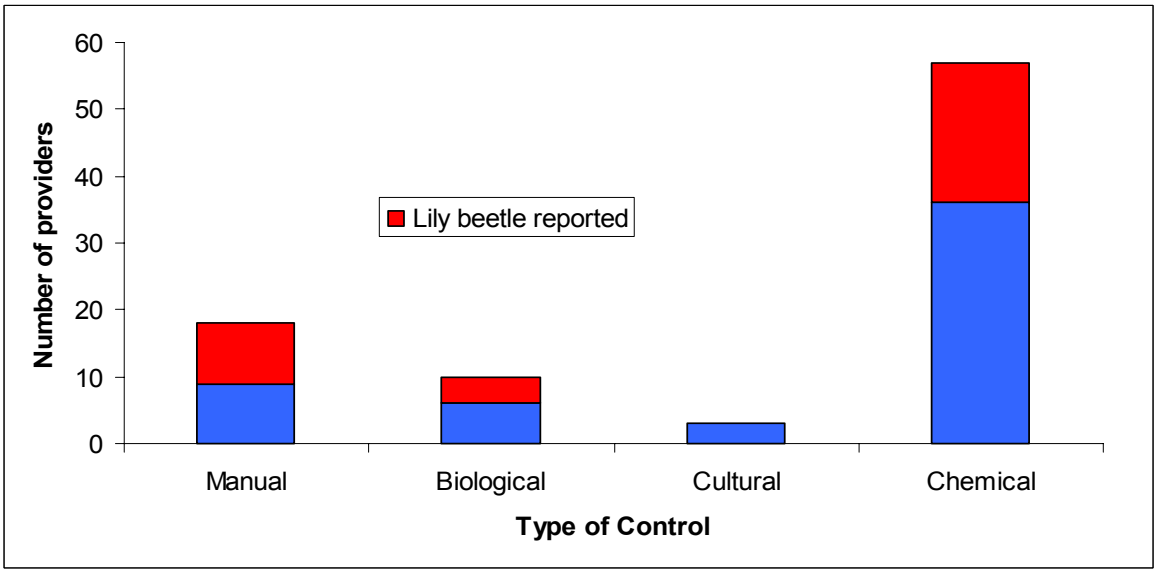


Fig 4.32. Other control measures taken by providers.

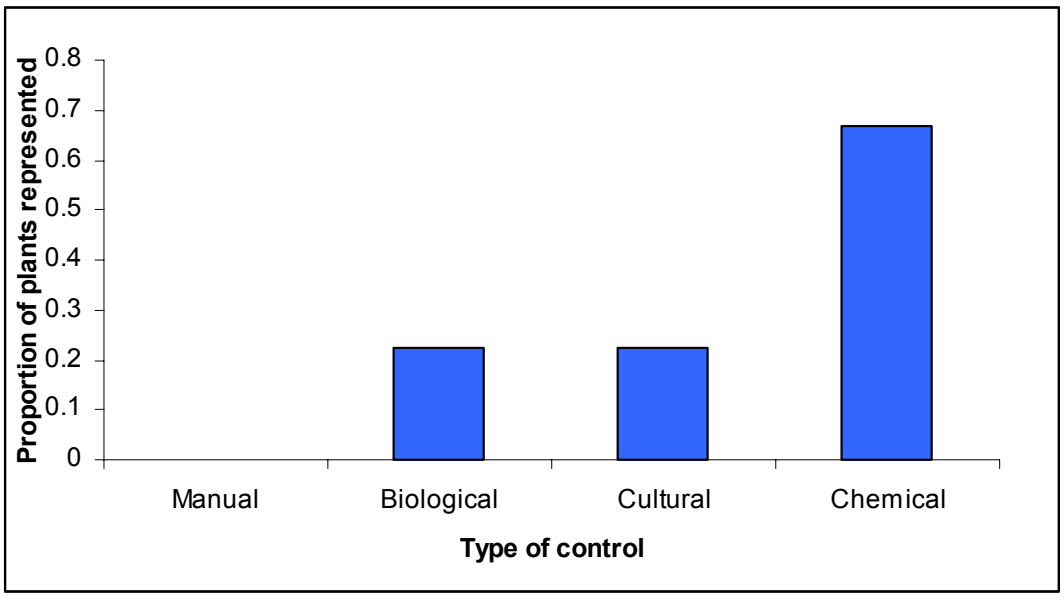


Fig. 4.33. Other control measures by number of plants sold (of 6700225).

Please add any other comments or information which you consider important

A few providers gave comments, all of these were relevant and are covered by one of the questions reported above.

5. Lily beetle risk assessment survey part 3: professional users of lily beetle host plants.

5.1. Introduction.

A survey of providers of lilies has given insights into the status of the beetle for professional growers, wholesalers and retailers (the providers) of lilies (Chapter 4). Another group in the horticulture industry are the amenity horticulturists. This group consists of those that use plants in gardens open to the public, local authority parks and gardens and other amenity plantings. The results of the survey presented below provide an indication of the effects of lily beetle provided by a section of these professional users, those who operate gardens open to the public.

5.2. Methods.

To represent professional users of lily beetle host plants (referred to as lilies) gardens open to the public were surveyed. Survey forms were sent in February 2006, each was sent with a freepost envelope for return and lily beetle information sheet (Appendix 9.1 and 9.3). Forms were sent to properties with gardens throughout the UK run by the National Trust, English and Scottish Heritage, and Royal Horticultural Society (RHS) partner gardens, 330 gardens in total. The surveys had a return date of 10 March 2006, but returns after this date have been included in the results.

Responses to the questions have been summarised by number of gardens responding to each question with those that stated they had had a lily beetle problem indicated (Question 2b, Fig 5.2). It should be noted that if a garden indicated that there was a beetle problem, there is no indication of the severity of the problem or that the problem is ongoing.

5.3. Results/ Discussion.

Response rate. The response rate was 41% (135 surveys returned).

Q1a. *Are Lilium/ Fritillaria/ Cardiocrinum grown in the garden?*

Most responding gardens (115, 85%) grew lilies, therefore it can be assumed that these are popular plants in gardens open to the public. The fact that 20 (15%) gardens did not grow lilies but still returned the surveys gives an indication that the survey is representative. Responses to the questions below are related only to those gardens that grew lilies.

Q1b. *Approximately how many varieties and bulbs of lilies/ fritillaries are grown*?

All 115 gardens growing lilies responded. Most gardens grew only a few plants/ varieties (81% less than 50), and it could be concluded that damage to these plants from the beetle will not have a big impact on the appearance of these gardens. However 16 (15%) gardens grew more than 100 plants/ varieties; here the appearance of large numbers of plants and presumably areas of the gardens could be affected by the beetle. However as the survey gives no indication of the size of the garden, this conclusion should be considered with care.

The lily beetle has been reported from all categories in this section, indicating that the beetle is able to find its hosts no matter how many or few are grown (Fig 5.1).

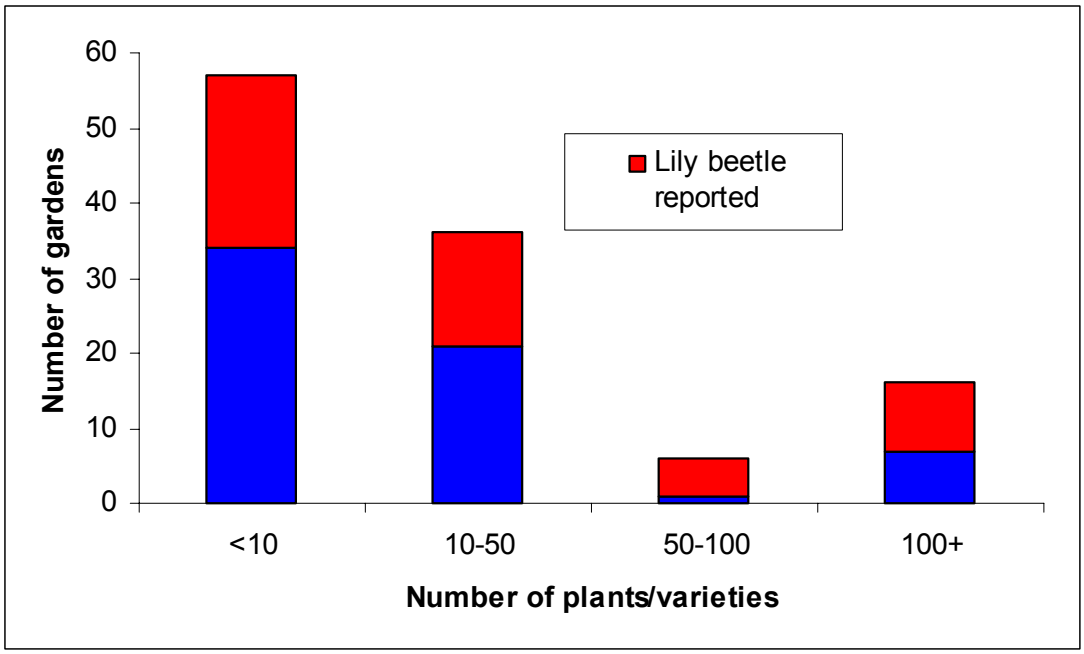


Fig 5.1. Number of lilies grown by gardens in the survey.

Q2. *The lily beetle*

Q2a. *Have you ever had a problem with lily beetle?*

Fifty-one (43%) of gardens growing lilies reported that lily beetle had been a problem, 16 (14%) of which were in 10 km grid squares where lily beetle had not previously been reported (Fig 5.2). Most of the new records were from parts of England within the beetle's known range (see Fig 2.5), however the survey has provided additional records for Wales and Scotland.

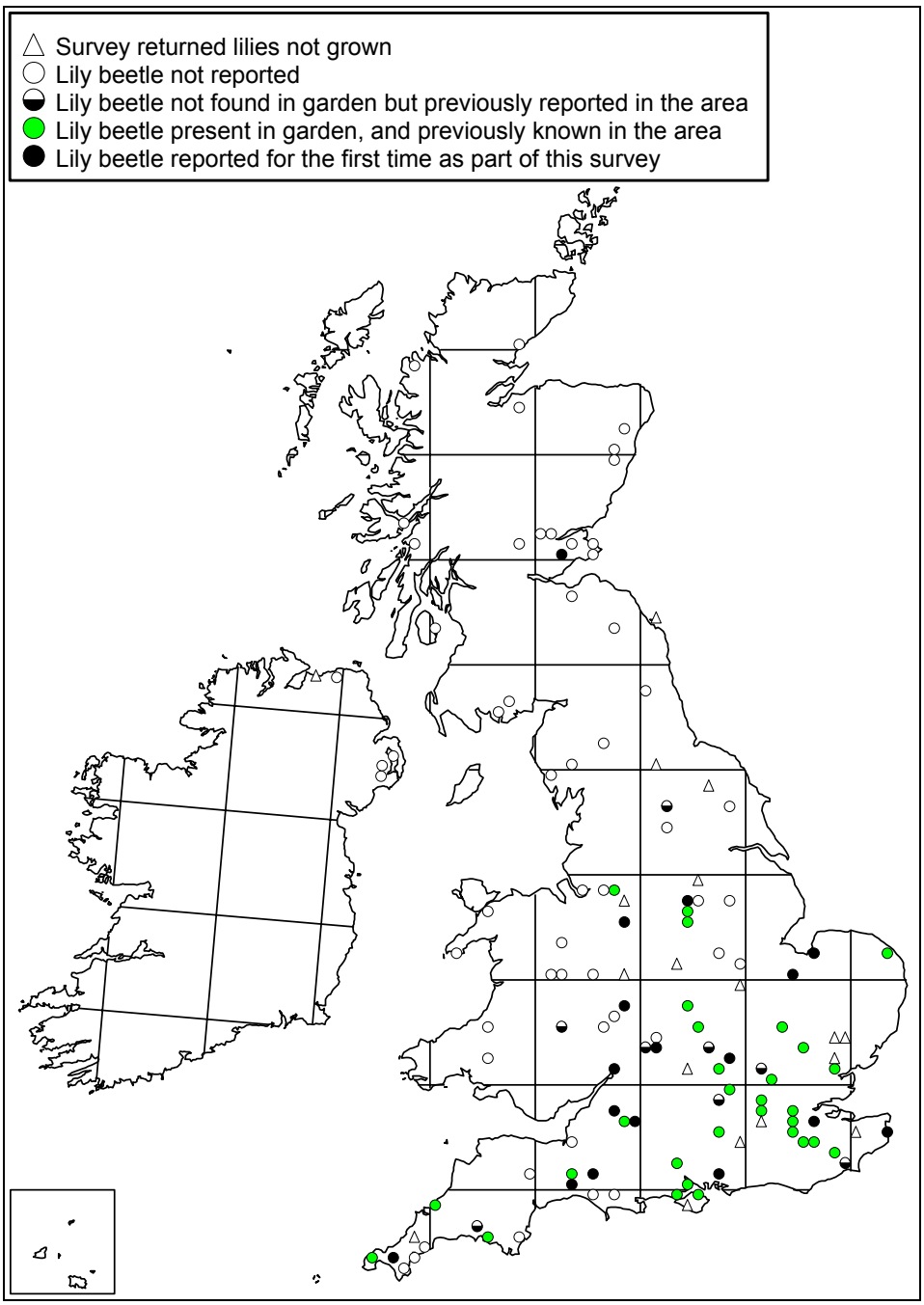


Fig. 5.2. Distribution of the lily beetle and surveys returned from gardens open to the public.

Q2b. *What control measures were taken against lily beetle?*

Most (47, 94%) gardens with a lily beetle problem responded (Fig. 5.3). All 43 (85%) gardens that took control measures against the beetle used manual removal, including the 4 (8%) that also used insecticides. This Indicates that insecticide use against the beetle in gardens open to the public is limited, even though staff time is being spent on removing the beetles. Three of the gardens that used pesticide specified the type used; one used soapy water, one Provado Ultimate Bug Killer (active ingredient imidacloprid) and one Derris (active ingredient Rotenone).

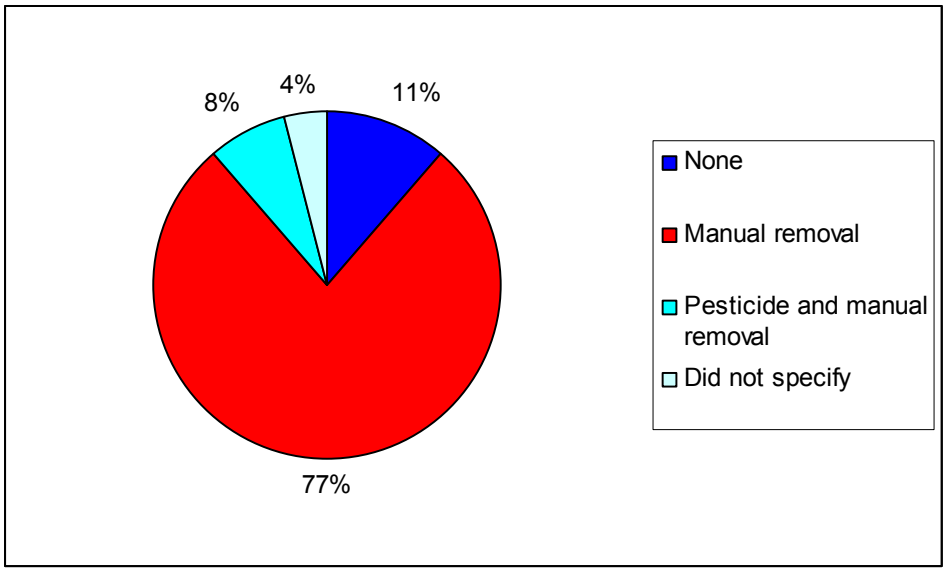


Fig. 5.3. Control measures taken by 51 gardens against lily beetle.

Q2b. *To your knowledge, is lily beetle present in other gardens locally (within 5 miles)?*
Of the 28 (21%) returns stating that the beetle was known locally, two gardens did not have lily beetle themselves although they grew lilies. Comparing their localities with current records (Fig 2.5), none of the gardens provided new distribution records for the beetle. Nine of the gardens who did not have lily beetle and did not know of it locally were in areas where the beetle has been reported to the RHS, suggesting that some are unaware that the beetle is present locally.

Q2c. *If lily beetle becomes a problem (or is already a problem) what effect will this have on lily/ fritillary use in the garden?*
All but one of the gardens that grew lilies responded (114, 99%, Fig 5.4), and a majority (65%) indicated that they would not change future plans due to the beetle. However, over a quarter of gardens will reduce or no longer grow lily beetle host plants, with the obvious drop in plant purchases. Experience with the beetle did not appear to affect the results.

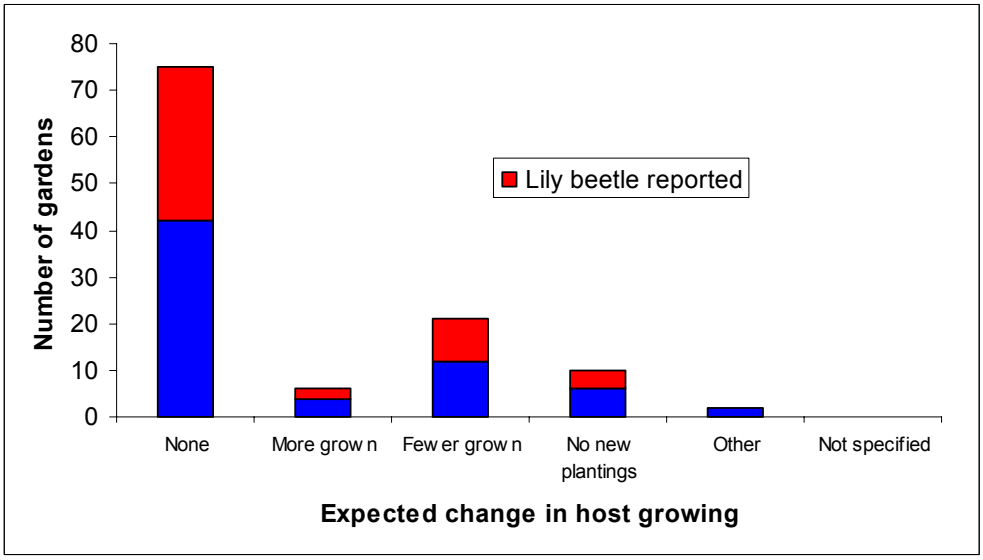


Fig. 5.4. Likely effect of lily growing if lily beetle becomes established in gardens open to the public.

Q3. *Lily growing*

Q3a. *Where do you source new stocks of lilies/ fritillaries for the garden?*

The responses have been compared with responses to question Q2c. A majority of gardens bought at least some plants from UK wholesalers (80, 70%) or retailers (32, 28%). Of this group 28 (27%) indicated that they would reduce or stop growing lilies if lily beetle becomes or remains a problem (Fig 5.5). If this survey is representative this may cause a significant drop in lily sales to this sector from lily providers.

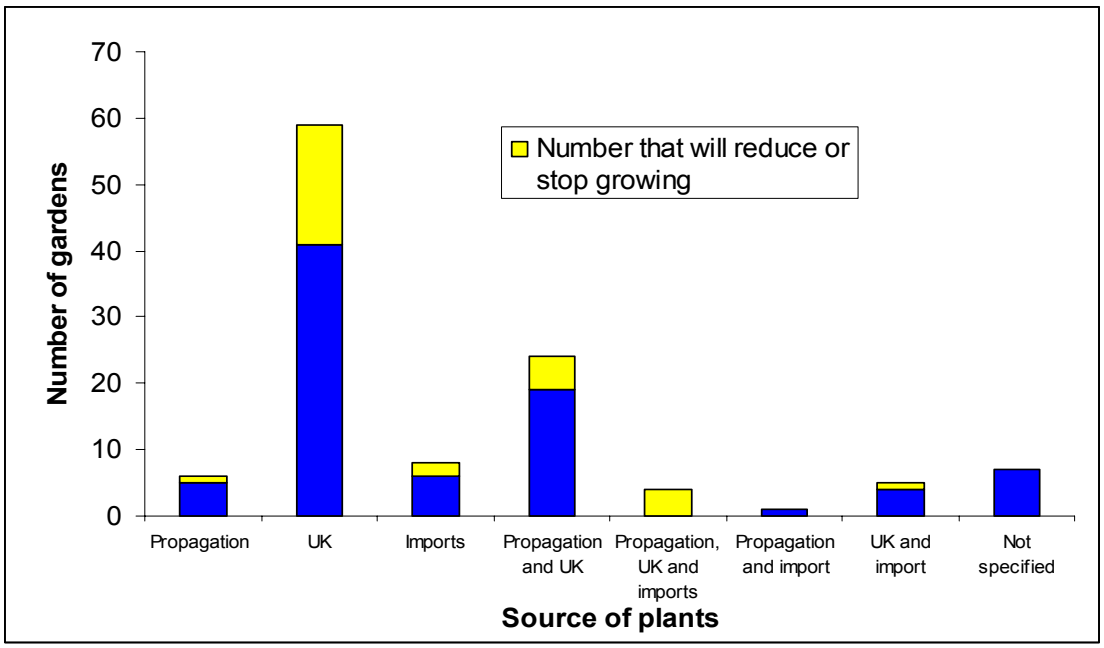


Fig 5.5. Where gardens source lilies and the effect lily beetle may have on plant purchases.

Q3b. *What stage of plants do you source?*

Human-aided introduction of beetles is most likely with plants in pots (see section 2.13). Most (71, 63%) of the 111 gardens replying sourced plants as bulbs alone, whilst only 23 (21%) gardens sourced at least some plants in pots (Fig 5.6). Under most reported circumstances at least some gardens had a problem with lily beetle, indicating that the beetle does not necessarily arrive in a garden with plant purchases.

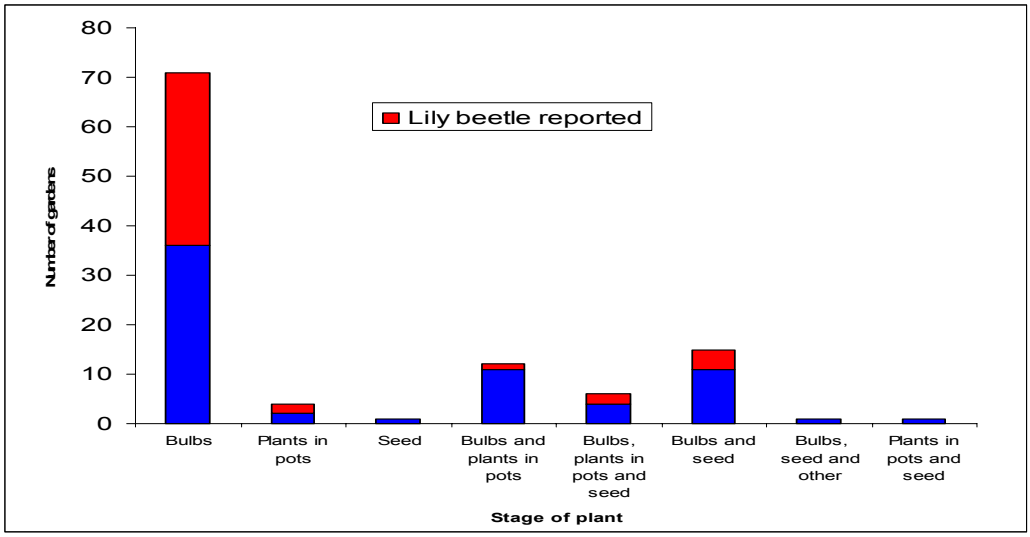


Fig 5.6. Stage of lilies sourced by gardens.

Q3c. *How do you grow lilies/ fritillaries?*

Of the 115 gardens that responded almost all (113, 98%) grew at least some plants outside. Whether in pots or in the open ground, some gardens had a problem with lily beetle (Fig 5.7). Only two gardens grew lilies exclusively under glass, and one of these had a problem with lily beetle.

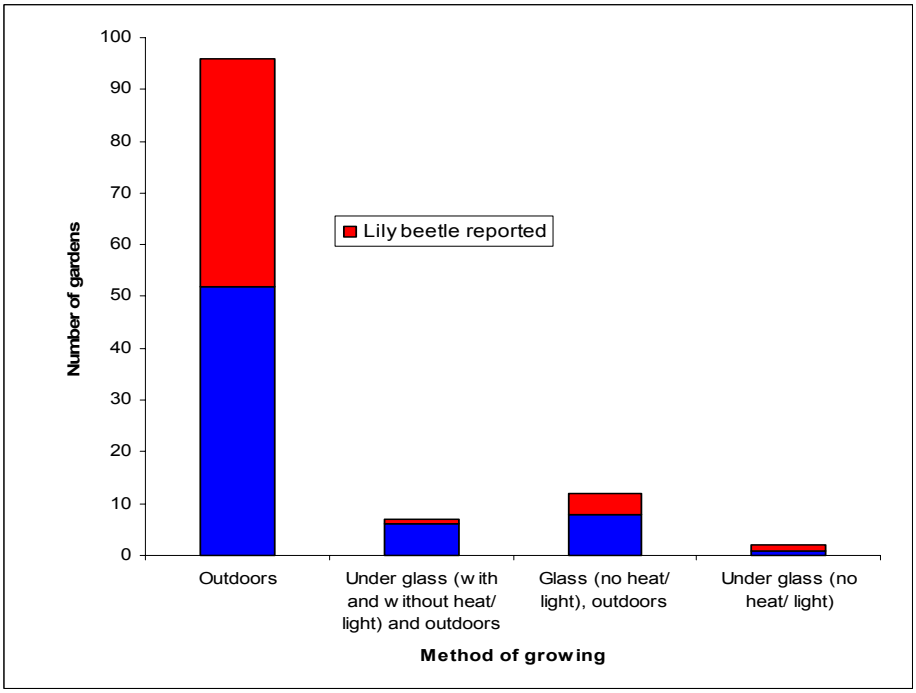


Fig. 5.7. How lilies are grown in gardens open to the public.

Q4. *Pest and disease control*

Q4a. *Have you had any pest or disease problems other than lily beetle on lilies/ fritillaries?*

Pests

Combined with those with a lily beetle problem (Question 2a), 95 gardens responded to this question. The most frequently reported problem was slugs (54, 47%), second most reported pest was lily beetle (51, 44% gardens, Fig. 5.8). A different set of pests affect lilies in gardens compared to that affecting the producers where aphids are the most frequent problem (Chapter 4 Q7a).

Diseases

Fewer gardens 31 (26%) had problems with lily diseases, the biggest problem being bulb rots which affected 23 (20%) gardens (Fig 5.9). Thus, as with lily providers (Chapter 4 Q7a), pests are a bigger problem than diseases.

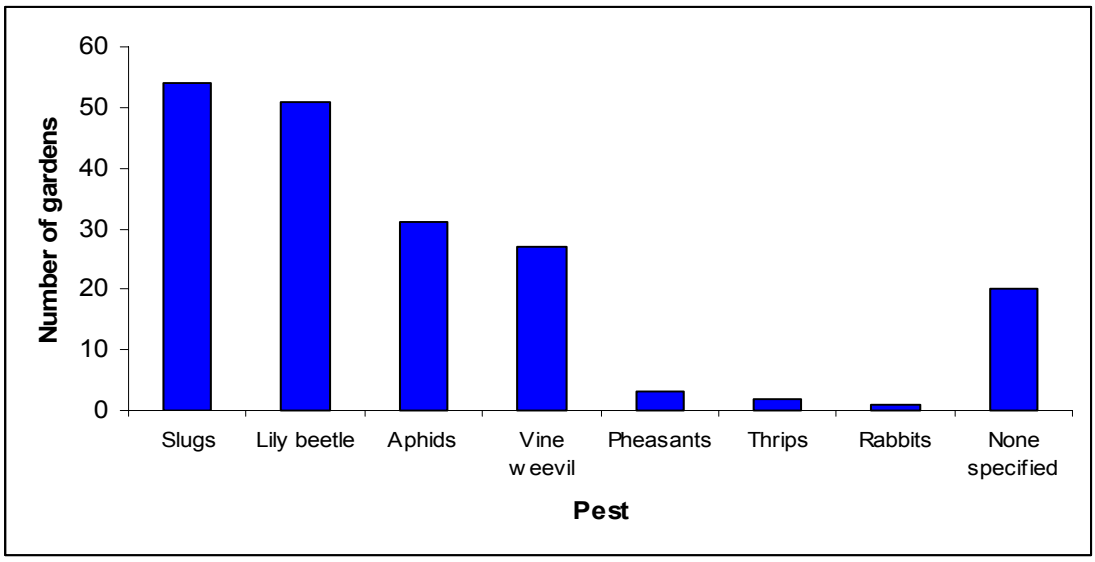


Fig 5.8. Pests experienced on lilies in gardens open to the public

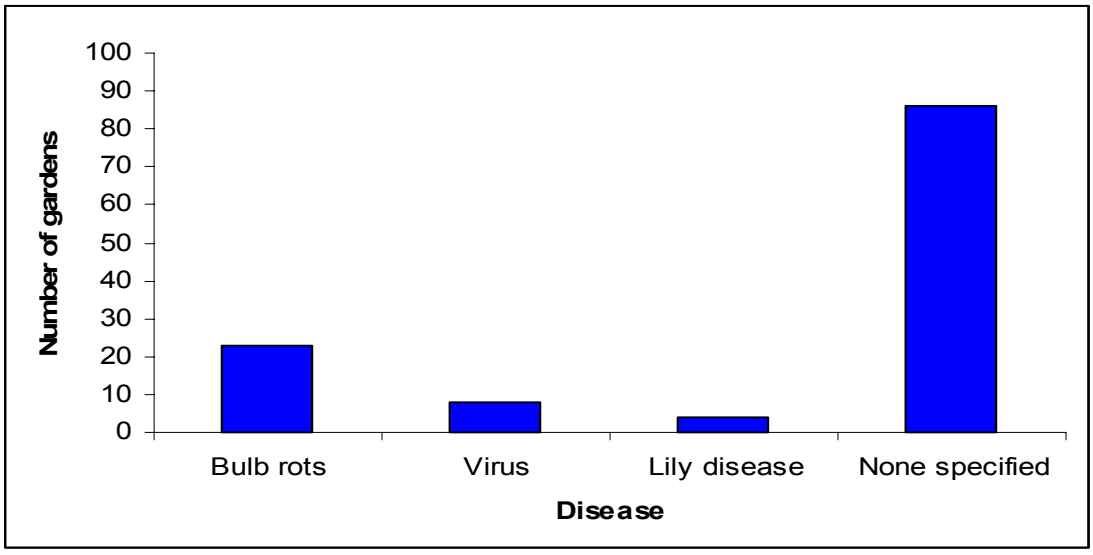


Fig. 5.9. Diseases experienced on lilies in gardens open to the public

Q4b. *Are there any chemical inputs into lily/ fritillary growing?*

Of the 115 responses, 86 (75%) did not use any chemical inputs on lilies, with only 16 (13%) using pesticides, 10 of which specified the chemical used (Fig 5.10). Imidacloprid/ thiocloprid was the most popular chemical, primarily against vine weevil. The most common chemical input was fertilizers with 22 (19%) gardens using these products. Only 4 (3%) gardens used fungicides on lilies. It appears that in gardens open to the public, chemical inputs into lily growing are low and, despite the lily beetle, are likely to remain low (see question 2b), as even those gardens that have a problem with the beetle tend not to use chemicals to attempt control.

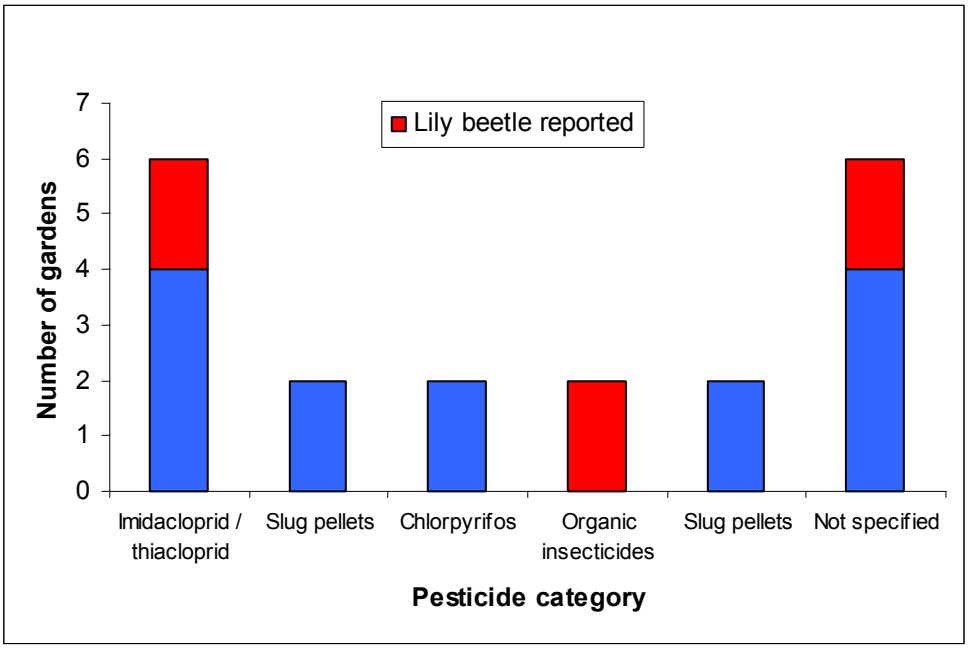


Fig 5.10. Chemical inputs from 16 gardens that used pesticides on lilies.

Q5. Plant sales

Q5a. *Do you have a plant centre on site?,*

Of the 135 survey forms returned, 129 responded, 91 (70%) of these gardens sold plants on site.

Q5b. *Does the plant centre sell lilies/ fritillaries?*

Of the 91 gardens, 77 (86%) responded, of which 45 (49%) sold lilies, indicating that these are popular in plant sales. Most (42, 55%) of these gardens sold lilies in pots (Fig 5.11); as has been stated above it is selling plants in active growth that presents the biggest risk for spreading the beetle.

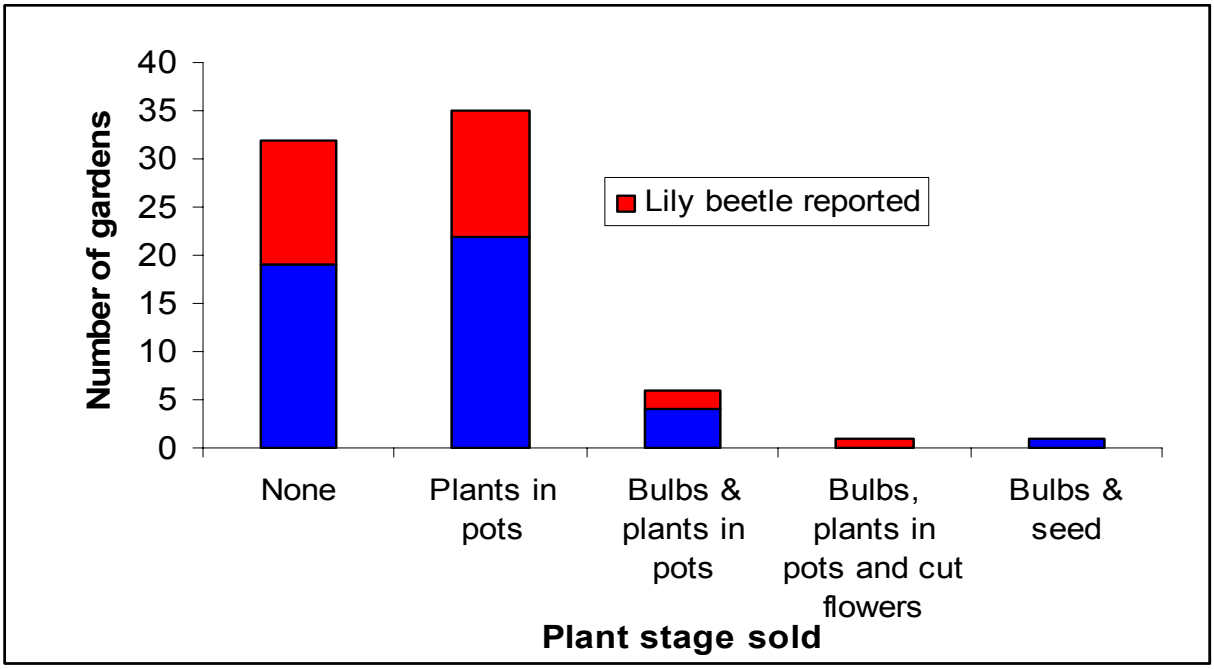


Fig. 5.11. Lily beetle host plants: stage sold by gardens.

Q5c. *Has the volume of sales of lilies/ fritillaries been increasing or decreasing over the past five years?*

There were 33 responses, most (28, 73%) stated that sales of lilies were increasing or staying the same (Fig. 5.12). Five gardens stated that lily sales had been decreasing, but it is not known if this is due to the beetle.

Q5d. *Have plant sales staff received queries about the lily beetle from customers?*

Of the 53 gardens that responded to this question 13 had had enquiries relating to the lily beetle.

Q6. *Please add any other comments or information which you consider important.*

Three responses indicated that the problem with lily beetle varied from year to year, with 2004 worse than 2005.

Two responses stated that they would now be more vigilant for the beetle's presence, suggesting that the survey has increased awareness of the lily beetle problem.

Two comments were made on the unpleasantness and time consumed (often by volunteers) in hand picking the beetle and its larvae from host plants.

Other comments and questions given in this section are covered in other areas of the report

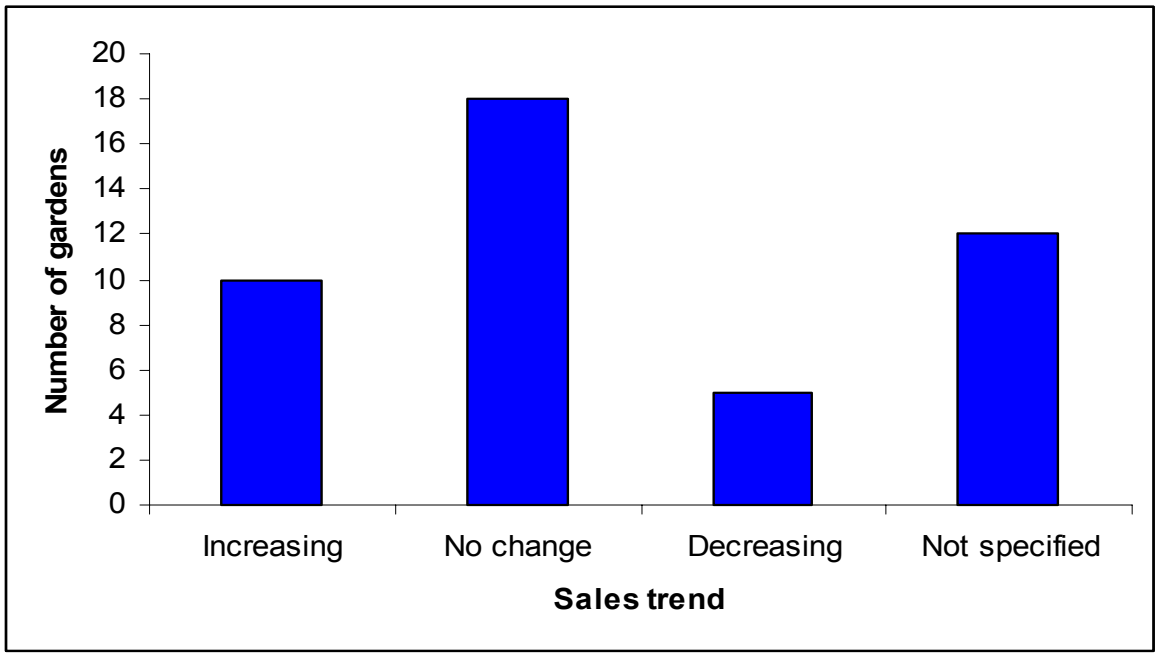


Fig. 5.12. Trend in lily sales in gardens with plant centres over the past five years.

6. Conclusions and recommendations.

It is clear that the lily beetle is a significant problem for the amateur lily grower throughout England and Wales and it is likely to expand from its current localised distribution in Scotland and Northern Ireland. A considerable number of professional gardeners and providers of lilies have also experienced a problem with the beetle. It can be a problem under almost any growing regime, including plants grown under protection and is currently the second most important pest for lily providers and professional gardeners. Based on our current knowledge the problem is likely to worsen, and it can be expected that more providers and gardeners will experience infestations. Lily beetle infestations are unlikely to increase chemical inputs into gardens open to the public, although the time spent removing the beetles may increase significantly. For the provider of lilies it is likely to involve greater use of broad-spectrum insecticides and time maintaining the crop, resulting in production cost increases.

The effect of the beetle on lily sales is less clear. Whilst both amateur and professional gardeners have indicated that fewer lilies would be planted / bought, the surveys have indicated that sales of lilies have increased during the past five years.

It has often been suggested that the lily industry may be spreading the beetle throughout the UK through distribution of potted plant material. There is no evidence from these surveys for or against this theory. Whilst the beetle was introduced into England in the 1930s, most probably with plant material, and the infestations in Scotland and Northern Ireland are likely to have been imported with plant material, it is likely that most of its spread in England and Wales has been due to other factors, although these remain unknown (natural spread).

Many lily providers import lilies from abroad, most frequently Holland. There is some evidence that pests are imported infrequently with plant material. It should also be considered that if the lily beetle does affect sales, the industry outside of the UK may also be affected.

It is recommended that lily providers and professional gardeners remain vigilant and take action against the beetle as necessary. For lily providers, currently the most successful action is likely to be the use of a broad spectrum foliar insecticide; this may need repeating throughout the natural growing season. Providers who supply lilies in pots should take particular care to make sure all outgoing stock is free from the beetle and its damage. This is particularly important for those providers supplying lilies to large retail outlets where contamination with beetles can result in significant economic penalties and rejected shipments.

In gardens, the ground around lilies should not be mulched, as this reduces the overwintering success of one of the beetle's parasitoids. Gardeners should remain vigilant

and attempt to reduce populations, by either hand picking or pesticide. However with large collections of lilies it may prove impossible to control the beetle.

7. Glossary and definitions of terms.

Chemical ecology. The study of the chemicals involved in the interactions of living organisms, including the production of and response to signalling molecules, toxins, and other organic compounds.

Criocerinae. Sub-family of the Chrysomelidae (leaf beetles) containing the lily beetle (Lilioceris lilii).

Hibernacula. Hibernacula are the locations used by an animal for hibernation.

Hymenoptera. Order of insects containing the bees, ants, wasps, parasitic wasps and sawflies.

Hyperparasitoid. A parasitoid (see below) that uses another parasitoid as a host.

Lilies. In most instances in this report referring to the three genera of plants that are lily beetle hosts; *Lilium, Fritillaria* and *Cardiocrinum.*

Multivoltine. Organisms that have more than two generations per year.

Parasitoid. An organism that spends a significant portion of its life history attached to or within a single host organism which it ultimately kills (and often consumes) in the process. In a parasitoid relationship, the host is killed before it can produce offspring.

Providers. In the context of this report these are all commercial operators who sell lilies; this includes retailers, wholesalers, importers and propagators of plants.

Univoltine. Organisms having one generation per year.

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9. Appendix.
9.1. Lily beetle fact sheet sent with surveys

Lily beetle survey 2006 - Fact sheet

The lily beetle (*Lilioceris lilii*) can be a serious pest of lilies (*Lilium* and *Cardiocrinum*) and fritillaries (*Fritillaria*). Both adults and larvae cause damage, primarily by defoliation, but heavy infestations can damage flowers, seed capsules and stems. The beetle became established in England during the 1940s and until the early 1990s was largely confined to Surrey. However, over the past 15 years the beetle has spread rapidly and is now found in every English county from Yorkshire southwards, has become widespread in Wales and is established in Glasgow and Belfast. Despite its increasing occurrence very little scientific work has been carried out on the beetle, and the current and future impact on the *Lilium* industry in the UK has not been assessed.

The adult beetle (Fig. 1) is 8 mm long, bright red with a black head and legs. The fully grown larvae (Fig. 2) are 8-10 mm long, dirty orange-red with a black head, but they are normally covered by their own slimy black excrement and could be mistaken for birds' droppings. Adult beetles are active from late March through to October, larvae are found between May and September.

At present management of this pest relies on chemicals or hand picking, however the long period over which the beetle is active can make this difficult. Adequate control may only be gained if measures are repeated regularly in areas where the pest is abundant.

Research joint funded by the HDC and RHS. A three year Ph.D. research project is being undertaken which could pave the way for improved management of the lily beetle. Part of the project is investigating the chemical ecology of the beetle to get an understanding of, among other things, how it is able to locate lilies when they are planted together with a range of other plants in the garden. A field trial is also underway, nearly 1000 lily bulbs representing six lily groups have been planted to investigate whether any display resistance to the beetle. The work is being done in collaboration with Rothamsted Research in Hertfordshire and Imperial College London.

How you can help. One of the primary aims of the project is to ascertain the risk that the lily beetle poses to the lily and fritillary industry in the UK. A large part of this assessment will be made using results from the attached survey, therefore the more growers that fill in the survey, the more accurate and useful this assessment will be.


Fig 1. Adult lily beetle


Fig 2. Lily beetle grubs on lily

9.2. Survey form sent to lily providers.

Lily beetle risk assessment Survey 2006

Imperial College London

Royal Horticultural Society

ROTHAMSTED RESEARCH

HDC

Section A

1 Contact details

Your name/ nursery	
Address	
Post code	
Telephone	
E-mail	

Section B – The lily beetle

2a Have you ever had a problem with lily beetle? If so, please state what was done.

……...

……..

2b Have you ever had enquiries or complaints from customers about the lily beetle? If possible please give details.

……..

……..

2c To your knowledge, is lily beetle present in gardens locally (within 5 miles)? ……...

Yes	**No**

2d A number of those who contacted the RHS for advice on lily beetle in 2005 will not purchase any new lilies or fritillaries for their garden due to the beetle problem. In light of this information and the other information provided with this survey, what impact do you think the beetle may have on the lily or fritillary part of your business?

Factor	**Please tick one**	**Additional notes**
Increase sales		
No effect		
Small decrease in sales		

Significant decrease in sales		
Make lily /fritillary growing unviable		

Lily beetle risk assessment survey 2006

3 Please list the *Lilium/ Fritillaria/ Cardiocrinum* that you supply

……..

……..

……..

Section C – Plant production methods

4a Are you a producer, retailer or wholesaler of *Lilium*/ *Fritillaria*/ *Cardiocrinum*? Please tick all appropriate

Producer (including growing on)	**Retailer**	**Wholesaler**

If retail or wholesale only please go to question 5.

4b Where do you source new stock? Please tick all appropriate

Propagation	**Purchased externally**

If only purchase externally please go to question 4e.

4c How do you propagate? Please tick all appropriate

Seed	**Bulb division**	**Bulb scales**	**Stem bulbils**	**Tissue culture**	**Other** (please specify)

4d Are you breeding new varieties/ cultivars?

……

Yes	**No**

4e What is your current growing regime? Please tick all appropriate

Under glass (no artificial	**Under glass** (with heat/	**Outdoors**	**In pots**	**In open ground**	**Other**

heat/ light)	light)				(please specify)

Lily beetle risk assessment survey 2006

Section D – Source of stock

5a Where do you source new stock? Please tick all appropriate

UK	**Overseas** (please list country(ies) of origin)

5b What stage of plants do you source? Please tick all appropriate

Seed	**Bulbs**	**Plants in pots**	**Other** (please specify)

Section E – Plant sales

6a At what stage do you sell plants? Please tick all appropriate

Seed	**Bulbs**	**Plants in pots**	**Cut flowers**	**Other** (please specify)

6b What is your approximate turnover of plants (number of bulbs, seeds or stems) each year?

……..

6c Has this volume been increasing or decreasing over the past five years?

……..

6d Who do you sell plants to? Please tick all appropriate

Large retailers (eg B&Q)	**Small retailers** (independent plant centres)	**On site** (open to the public)	**Mail order / internet**	**Other** (please specify)

Lily beetle risk assessment survey 2006

Section F – Pest and disease control

7a Have you had any pest or disease problems? Please tick all appropriate

Pests:

Aphids	**Thrips**	**Vine weevil**	**Other** (please specify)

Diseases:

Bulb rots	**Virus**	**Other** (please specify)

7b What chemicals are used in production / storage? Please list

Chemical	**Product name**
Pesticides	
Fungicides	
Fertilisers	
Other	

7c What other pest / disease control strategies are used? Please list

……..

……..

Completion and return of this form

Please add any other comments or information which you consider important

.....

.....

.....

.....

Please check that you've completed all sections and return in the pre-paid envelope provided to the RHS Wisley by Friday 10 March 2006.

Thank you for your co-operation.

9.3. Survey form sent to gardens open to the public.

Lily beetle risk assessment survey 2006

Once completed please return to Andrew Salisbury, Entomology Laboratory, **Freepost**, RHS Garden Wisley, Woking, Surrey, GU23 6BR in the envelope provided.

Contact name: **Address:**   **Post code:** **Tel:** **E-mail:** **Date:**

1a. Are *Lilium/ Fritillaria/ Cardiocrinum* grown in the garden? **Yes** **No** If no please go to question 5
1b. Approximately how many varieties and bulbs of lilies/ fritillaries are grown. **<10** **10-50** **50-100** **100+**

2. The lily beetle.

2a. Have you ever had a problem with lily beetle?

Yes **No** (Go to question 2c.)

2b. What control measures were taken against lily beetle. (Please circle all appropriate).

None **Manual removal** **Pesticide** (Please specify product used)

Other **(Please specify)**

2c. To your knowledge, is lily beetle present in other gardens locally (within 5 miles)?

2d. If lily beetle becomes a problem (or is already a problem) what effect will this have on lily/ fritillary use in the garden. Please circle.

No change (Plants will be replaced as necessary or as new planting demands)

More lilies/ fritillaries will be planted

Fewer lilies/ fritillaries will be planted

Lilies/ fritillaries will no longer be planted in the garden

Other (Please specify)

3 Lily growing

3a. Where do you source new stocks of lilies/ fritillaries for the garden? Please circle all appropriate.

Own propagation (UK) **Purchased wholesale/ direct from grower**

Imported from outside UK ***Purchased from retail outlets***

Other *(Please specify)*

3b. What stage of plants do you source? Please circle all appropriate.

Bulbs **Plants in pots** **Seed**

Other (Please specify)

3c. How do you grow lilies/ fritillaries? Please circle all appropriate.

Under glass (no artificial heat/ light) **Under glass** (with heat/ light)

Outdoors ***In pots*** ***In open ground***

Other (Please specify)

4. Pest and disease control

4a. Have you had any pest or disease problems other than lily beetle on lilies/ fritillaries? Please circle all appropriate.

Pests: ***Aphids*** ***Thrips*** ***Vine weevil*** ***Slugs***

Other (Please specify)

Diseases: **Bulb rots** **Virus** **Lily disease** **Other** (Please specify)

4b. Are there any chemical inputs into lily/ fritillary growing? Please list.

None

Pesticides:

Fungicides:

Fertilizers:

Other:

5. Plant sales

5a. Do you have a plant centre on site? (If no go to question 6)

5b. Does the plant centre sell lilies/ fritillaries? If so please circle all appropriate stages sold.

No **Bulbs** **Plants in pots** **Seed** **Cut flowers**

Other (please specify)

5c. Has the volume of sales of lilies/ fritillaries been increasing or decreasing over the past five years?

5d. Have plant sales staff received queries about the lily beetle from customers?

6. Please add any other comments or information which you consider important

Please check that you've completed all sections and return in the pre-paid envelope provided to the RHS Wisley by Friday 10 March 2006.

Thank you for your co-operation.

Andrew Salisbury
Entomology Laboratory, RHS Garden Wisley, Woking, Surrey, GU23 6QB