Pesticide Use in Periurban Areas

Farmers' and Neighbours' Perceptions and Attitudes, and Agricultural Field Influences on Pests in Nearby Garden Plants

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Cover: Oilseed rape field with pollen beetles, ornamental flowers, flea beetle damage on cotyledon, cabbage root fly damage in radish, insecticide application in spring oilseed rape (photos: Nur Ahmed; Inger Åhman)

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Abstract

Public concern about pesticide use is very high, although it varies with social, ethical and political factors. In periurban regions, farmers live close to people with other occupations. Thus farming activities such as pesticide spraying may cause tensions. Pesticide use may also cause changes in pest abundances outside the treated field, on plants in neighbouring gardens.

The first part of this thesis compared perceptions of pesticide use by farmers and their neighbours in two periurban regions in Sweden. Neighbours reported using pesticides, but perceived pesticide use to be more negative than farmers did. Neighbours also perceived themselves as pesticide non-users to a higher extent than farmers, although both categories used pesticides in their home setting to a similar extent. Perceptions of pesticide use differed between farmers and neighbours but also between groups of farmers, depending on farm size, whether pesticides were used or not, number of crops grown and pesticide safety knowledge.

In two field studies, abundances of pests were compared in garden crops adjacent to insecticide-treated and untreated agricultural fields. The garden crops were not subjected to wind drift during insecticide spraying. Despite this, pest abundance and their damage on vegetables and ornamental flowers in nearby gardens decreased with insecticide use in the agricultural fields. The magnitude of this decrease depended on type of insect pests targeted, garden plants tested and timing of pesticide applications.

In general, perceptions and attitudes concerning pesticide use differed between groups of people in the periurban society studied, e.g. with social factors such as gender, age and education. The fact that pesticide use in agricultural fields may actually benefit neighbouring garden crops is a novel finding.

The findings presented here can be of use for policy makers to avoid conflicts regarding pesticide use in periurban environments, since it is important to address variations in the views of different groups of people in society and to communicate both the negative and positive effects of pesticide use.

Keywords: Urban-rural fringe, herbicide, fungicide, insecticide, location, safety knowledge, pollen beetle, flea beetle, cabbage root fly, radish, oilseed rape, vegetables, ornamental flowers, window traps, soil traps

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Dedication

To my parents
And
To my beloved wife, Nasrin, and daughters, Nanjiba and Nazifa

*"It is HE WHO has made the earth a bed for you and the sky a canopy; and HE WHO sends down rain from above for the growth of every kind of food products for your sustenance". (**Al-Quran, Al-Baqarah 2:22**).*

Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Ahmed, N., Englund, J-E., Åhman I., Lieberg, M. & Johansson, E. (2011). Perception of pesticide use by farmers and neighbours in two periurban areas. *Science of the Total Environment* 412-413, 77-86.

II Ahmed, N., Englund, J-E., Åhman I. & Johansson, E. Perception of pesticide use among Swedish farmers (manuscript).

III Ahmed, N., Åhman, I., Englund, J-E. & Johansson E. (2011). Effect on radish pests by application of insecticides in a nearby spring oilseed rape field. *Journal of Applied Entomology* 135, 168–176.

IV Ahmed, N., Englund, J-E., Johansson E. & Åhman, I. Does insecticide application in a winter oilseed rape field influence the abundance of pollen beetle, *Meligethes aeneus* in nearby ornamental flowers and vegetables? (manuscript).

Papers I and III are reproduced with the permission of the publishers.

The contribution of Nur Ahmed (NA) to the papers included in this thesis was as follows:

I NA planned the experiment together with co-authors, developed the survey tools, carried out data collection and analysis and wrote the paper, guided by Englund, Åhman, Lieberg and Johansson.

II NA planned the experiment together with co-authors, developed the survey tools, carried out data collection and analysis and wrote the paper, guided by Englund, Åhman and Johansson.

III NA planned the experiment together with co-authors, performed the field experiment, carried out data collection and analysis and wrote the paper, guided by Åhman, Englund and Johansson.

IV NA planned the experiment together with co-authors, performed the field experiment, carried out data collection and analysis and wrote the paper, guided by Englund, Johansson and Åhman.

Abbreviations

ANOVA	Analysis of variance
BRRI	Bangladesh Rice Research Institute
CABI	Commonwealth Agricultural Bureau International
CS	*Cosmos* sp.
DH	*Dahlia* sp.
EC	European Commission
ENIRO	ENIRO AB, offering search service and directory assistance
EU	European Union
FAO	Food and Agriculture Organization
FAOSTAT	FAO Statistics
GCIRC	International Consultative Research Group on Rapeseed
GMO	Genetically modified organism
ICARDA	International Centre for Agricultural Research in the Dry Areas
IDRC	International Development Research Centre
IFPRI	International Food Policy and Research Institute
ILO	International Labour Organization
IOBC	International Organisation for Biological and Integrated Control of Noxious Animals and Plants
IRRI	International Rice Research Institute
ISBN	International Standard Book Number
ISSN	International Standard Serial Number
IT	Insecticide treated
IWMI	International Water Management Institute
KEMI	Kemikalieinspektionen (in Swedish)
LP	*Leucanthemum* sp., from private garden
LRF	Federation of Swedish Farmers
LS	*Leucanthemum* sp., Snow lady
OILB	Organisation Internationale de Lutte Biologique et Integree Contre les Animaux et les Plantes Nuisibles

SAS	SAS Statistical Software
SCB	Statistiska centralbyrån (in Swedish)
SEQ	South East Queensland
SIDA	Swedish International Development Cooperation Agency
SKOP	**SK**andinavisk **OP**inion (in Swedish)
SLU	Swedish University of Agricultural Sciences
SOSR	Spring oilseed rape
SPSS	SPSS Statistical Software
SROP	Section Regionale Ouest Paleartique
UK	United Kingdom
UNEP	United Nations Environment Programme
USA	United State of America
UT	Untreated
VAS	Visual Analogue Scale
WHO	World Health Organization
WOSR	Winter oilseed rape
WPRS	West Palaearctic Regional Section

1 Introduction

For more than seven decades, pesticides have been used in agriculture to secure high and reliable production. Pesticides are also used to protect humans against the vectors of serious diseases, such as malaria, dengue, West Nile fever, *etc*., and to protect home sites from weeds, pathogens, and arthropod and mammal pests. Regardless of the positive effects that pesticides have on agriculture and human well-being, the use of pesticides also poses several risks to human health, non-target organisms, air, water and the environment as a whole (*e.g.* Cooper & Dobson, 2007; Devine & Furlong, 2007; Travisi *et al.*, 2006; Litchfield, 2005; Wesseling *et al.*, 2005; Spliid *et al.*, 2004; Tilman *et al.*, 2002; Wesseling *et al.*, 2001; Wilson & Tisdell, 2001; Pimentel & Greiner, 1997; Ekstrom *et al.*, 1996; Pimentel *et al.*, 1992; Thrupp, 1991; Pimentel *et al.*, 1978).

Pesticides are amongst the most regulated chemicals. The pesticide as a killing or repellent agent is registered, its development, marketing and uses are monitored and safe use is ensured through a number of rules and regulations by national authorities, *e.g*. KEMI, and international authorities, *e.g*. EU, WHO, FAO and Stockholm convention (WHO, 2010; EC, 2009; Litchfield, 2005; Massey, 2005; Wesseling *et al.*, 2005; Stockholm Convention, 2001). The national and international rules and regulations have been developed to minimise the risks involved in the use of pesticides. The effectiveness of these rules and regulations is dependent on pesticide use acceptability and the influences of societal values. Public concern regarding the environmental hazards of exposure of humans and nature to pesticides has become a crucial issue since the publication of the bestselling book 'Silent Spring' in 1962 (*e.g.* Goldman & Koduru, 2000; Ekstrom *et al.*, 1996; Carson, 1962). Despite the public concern, pesticide use remains extensive in *e.g*. the USA, Canada and other developed and developing countries (Wesseling *et al.*, 2005; 2001; Horowitz, 1994; Sachs, 1993; Thrupp, 1991). Over time, rules for sustainable use of pesticides have become increasingly strict, *e.g.* EU Directive 2009/128/EC, FAO, ILO and WHO Code (EC, 2009; Litchfield, 2005; Wesseling *et al.*, 2005).

Farmers' pest management decisions affect society at large, and also provide both benefits and costs to the farmer using the pesticides. Pesticide use can affect human health negatively. Negative effects have in particular been reported to affect the users of pesticides, bystanders during pesticide application and consumers exposed to pesticide residues in food (Menzler-Hokkanen, 2006; Bowles & Webster, 1995). Beside the use in agriculture, households store and use pesticides in and around the home setting (Whyatt *et al.*, 2002; Goldman & Koduru, 2000).

Adverse effects of pesticides on the environment, their use and the acceptability of such use all involve societal values. Due to the involvement of societal values, pesticide regulation development requires consultations including groups such as government regulators, environmental scientists, pesticide manufacturers and also stakeholders from the wider community (Crane & Giddings, 2004; Coppin *et al.*, 2002; Crowfoot & Wondolleck, 1990). Social acceptability is important for implementation of environmental policies (Winston, 1997; Brunson, 1993). In general, a significant relationship is found in democratic nations between public opinion on issues and the establishment of public policies (Petry, 1999; Page & Shapiro, 1983).

An individual's perception of a risk often depends upon their level of expertise and education, gender and personal values, as well as judgment of the uncertainty and severity of a certain risk (Frewer *et al.*, 2004; Frewer, 2003; Tait, 2001). Therefore perceptions in relation to the use of a number of technologies, *e.g.* GMO technology, depend on the individual's demand, attitude and lifestyle (Mergenthaler *et al.*, 2009; Lehrman & Johnson, 2008; Okello *et al.*, 2007; Husain *et al.*, 2003; Antrop, 2000; van den Berg & Wintjes, 2000). In periurban areas (the rural-urban fringe), confrontations between different groups of individuals are more pronounced than in rural areas, perhaps due to the dynamic characteristics of the periurban area (see periurban definition in section 3.1). In the periurban area, farmers' activities, such as pesticide spraying, take place close to neighbouring non-farmers. The perceptions of such activities can be expected to vary between different groups in the periurban area. Furthermore, the use of pesticides by farmers within the periurban area may also in practice influence the abundance of plants and animals (*e.g.* insects) in the gardens and homes of surrounding neighbours. The strict national rules to protect against pesticides spreading to adjacent land theoretically ensure that there is no pesticide drift from farmers' fields to neighbouring garden crops or ornamental flowers. However, through migration of pests, farmers' fields and neighbouring gardens may still exchange pests. Therefore, the choice of crops and methods of pest control used in farmers' fields may indirectly affect the presence, amounts and damage by pests in neighbouring gardens.

2 Objectives

The general objectives of this thesis were: i) to investigate the perceptions of pesticide use among different groups of people within periurban society; and ii) to evaluate whether pesticide use by farmers in periurban areas influences the abundance of certain pests in neighbouring garden crops.

Four studies were carried out. The first two were based on a self-completed questionnaire sent out to farmers and neighbours in two periurban areas. The objectives of these two studies were: 1) to investigate differences and similarities in perceptions among farmers and neighbours concerning the use of pesticides; and 2) to investigate differences and similarities in perceptions among various groups of farmers concerning the use of pesticides.

The third and fourth studies were based on field trials with the aim of investigating whether insecticide use in field crops influences the amount of insects and insect damage in nearby garden crops.

3 Background and organisms studied

3.1 Periurban definition, characteristics and periurban agriculture

A periurban area is a diffuse territory that is transitional between the city and the countryside. It is a combination of features and phenomena, largely generated by activities within the area (Adell, 1999; Anonymous, 1998). Periurban areas have also been named rurban, urban-rural hinterland, rural-urban fringe, *etc.* Within the periurban areas, rapid changes are generally on going over time, including all types of activities such as residential, educational, commercial, recreational and public services activities, which lead to influences on the use of land (Elgåker, 2011; Thomas, 1974). The area is characterised by mixed land use. In contrast to urban agriculture, which is to be found within a town, city or metropolis, the places for periurban agriculture are on the fringe of a metropolis, a city or a town (Ngigi *et al.*, 2011; Torquati *et al.*, 2008; Mougeot, 1999). The periurban area has also been described as a blended area with urban and rural landscape interests competing with each other. The periurban area is the interface between the highly complex urban area and the more uniform rural landscape area, mainly built on an agricultural economy with similar land use and community values (Low Choy *et al.*, 2007; Mackenzie *et al.*, 2006).

Apart from the general descriptions, the periurban area has been defined in a more quantitative way. For example, Gumbo & Ndiripo (1996) used density thresholds, population sizes and official city limits, while Maxwell & Armar-Klemesu (1998) defined the periurban area on the basis of municipal boundaries to the city. Another definition is based on how much of the agricultural land is used for other uses (Mbiba, 1994). Ratios of buildings, roads and open space (per km^2) have also been used to define the outer boundary of the periurban zones (Losada *et al.*, 1998). Furthermore, the distance within which the farms can supply the city on a daily basis can be used to define the periurban area (Moustier, 1998). Another distance criterion is being within two hours of commuting distance from the nearest metropolitan area (Low Choy *et al.*, 2007; Mackenzie *et al.*, 2006). The Swedish National Rural Development Agency (2008) has defined periurban as being possible to reach in a travel time of 5-45 minutes by car from the nearest city or settlement with more than 3000 habitants. Economic and demographic expansion of cities has resulted in spatial expansion, through industrialisation and migration into adjacent periurban areas. Therefore, the rural-periurban-urban continuum is dynamic in nature (Lintelo *et al.*, 2001). In many developed countries, periurban areas are currently undergoing major transformations, leading to urban agglomerations. This process of urban agglomerations is affecting both the social systems and land use of the rural communities (Elgåker, 2011; Busck *et al.*, 2006; Bryant & Johnston, 1992). Newcomers may be attracted to periurban areas for several reasons although they have no or little relationship to agricultural production. The houses are often cheaper, the living environment is close to nature and further away from human-made pollution and the social problems are less pronounced than in the city. In addition, the space for hobby activities is sometimes greater (van den Berg & Wintjes, 2000). Therefore, conventional agricultural areas are transferred from being used mainly for the supply of agricultural products to being used for urban lifestyles (Antrop, 2000).

The increasing urban populations are thus turning into periurban populations and need more food and housing. In fact urban and periurban agriculture produces the majority of the perishable goods (*e.g*. vegetables, fruits, flowers *etc*.) consumed and used by the urban population. Thus, livelihood opportunities for urban and periurban farmers are generated. Furthermore, periurban farming contributes to the growing, processing and distribution of a diversity of food and non-food products. Periurban agriculture (re-)uses largely human, material resources and products and provides products for input suppliers, traders and other service providers, thereby adding value in the supply chain (IWMI, 2006; Scott *et al.*, 2004; Mougeot, 2000). However, in urban and periurban agriculture there are hazards associated with the fresh produce being contaminated by vehicle exhaust fumes, industrial waste, road dust and fresh (not decomposed) animal manure (Hide *et al.*, 2001).

4 Descriptions of experimental locations, participants, plants and insects studied

4.1 Experimental locations and participants

For the two social studies of pesticide use (**Papers I and II)**, the participants were selected from two periurban areas, the Mälardalen region and the county of Skåne (*Figure 1*). There are considerable differences between these two areas, relating to agriculture, weather, landscape *etc*., although both areas are predominantly agricultural (SCB, 2010; 2008a; 2008b; Anonymous, 1994; **Papers I and II**). The main categories of participants were farmers and non-farmers. The farmers category was defined as those having at least 2 hectares of land for agricultural production in the survey year. From the non-farmers category, neighbours were defined as living at a distance of less than 100 m from the nearest farm land (**Paper I**).

4.2 Plants

For the two studies of influences of pesticide use on the abundance and damage by insect pests in vegetables and ornamental flowers in gardens adjacent to the farmers' fields (**Papers III and IV**), oilseed rape was selected as the crop and is therefore described in some detail in the following. Certain brassicaceous vegetables and ornamental flowers were chosen and studied as examples of garden plants.

4.2.1 Oilseed rape

Oilseed rape (*Brassica napus* L.), also known as canola in North America, has bright yellow flowers and belongs to the family Brassicaceae. In 1866 rapeseed production reached a first peak in Sweden, producing about 3000 tons

(Andersson & Granhall, 1954). Thereafter cultivation declined due to the import of mineral oil for lamps (Baranyk & Fábry, 1999) and other vegetable oils for margarine and soap production (Andersson & Granhall, 1954). After World War II, the production of oilseed crops increased again in Europe to make up for the shortage of edible oils (Appelqvist & Ohlson, 1972). Cultivation of oilseed rape has also been widely adopted in Canada and more recently in the USA and Australia (Baranyk & Fábry, 1999). Cultivation of rapeseed reached over 31 million ha globally in 2009, with Europe having the largest acreage (8.5 million ha), followed by China (7.3 million ha) and Canada (6.1 million ha) (FAOSTAT, 2011). Forecasts predict a continuing increase in demand for oilseed rape production in Europe (Williams, 2010). In Sweden oilseed rape cultivation has shown an increase during recent years and in 2009 was grown on 97 500 ha (FAOSTAT, 2011), which represents more than 3.5% of Swedish arable land (SCB, 2011).

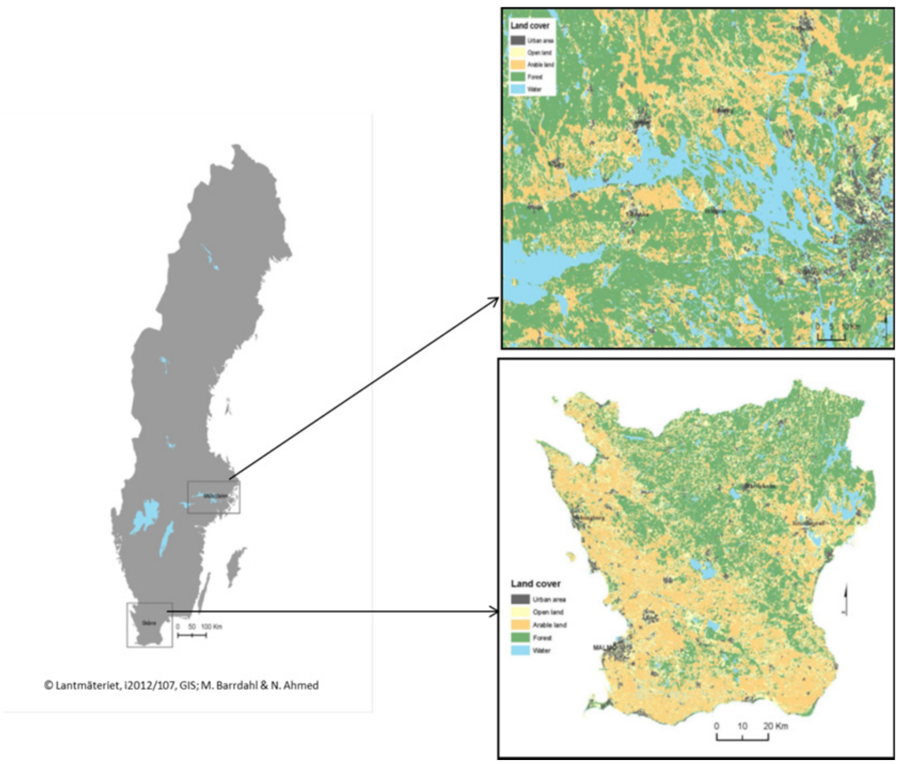

Figure 1. The Mälardalen area including Lake Mälaren (upper box) and the Skåne area (lower box).

Oilseed rape is either annual or biennial; spring oilseed rape (SOSR) is sown in spring and harvested in the same year, while winter oilseed rape

(WOSR) is sown in autumn and harvested in the next year. The main product from oilseed rape is oil used for cooking or technical applications such as fuel and lubricants. A protein-rich meal remains as a by-product and is mainly used as animal feed. Some reasons for the increase in oilseed rape cultivation are the newly developed products from the crop, *e.g*. biodiesel to be used in motor vehicles as well as resins, emulsifying agents, detergents, lubrication oils and waxes (Alford, 2003).

A number of biotic factors cause damage and reduce yield in oilseed rape; fungi, viruses, bacteria, weeds and insect pests as well as other herbivores, *e.g*. nematodes, slugs and pigeons (Alford *et al.*, 2003). Management to reduce the negative impacts of these factors includes crop rotation, the use of resistant plants and the use of chemicals (Rimmer & Buchwaldt, 1995). Flowering oilseed rape normally releases a complex mixture of volatiles, including fatty-acid derivatives, terpenoids, benzenoids and nitrogen-containing compounds (Jakobsen *et al.*, 1994; Tollsten & Bergstrom, 1988). Some of these compounds are probably involved in attraction of pollinators (Westcott & Nelson, 2001). The insect pests are primarily crucifer specialists. A number of these specialist herbivorous insect pests and their parasitoids are attracted to the specific oilseed rape odours (Potting *et al.*, 1999; Bartlet, 1996) that are break-down products of glucosinolates (Hopkins *et al.*, 2009). Crucifer specialists also use glucosinolates as a feeding or oviposition stimuli. However, these same compounds acting as attractants and stimulants for crucifer specialist insects may act as feeding deterrents or toxins for non-cruciferous specialists (Ekbom & Borg, 1996; Ekbom, 1995).

A total of six to eight insects are considered to be the major pests in oilseed rape in Europe. These major oilseed pests are widespread and abundant, cause considerable economic damage and require insecticide application by growers (Williams, 2010; Menzler-Hokkanen *et al.*, 2006; Garbe *et al.*, 2000; Bromand, 1990). Different groups of insects and other pests of Brassica oilseeds cause damage to specific parts of the plants; seedlings, stems, pods or seeds (Ekbom & Borg, 1996; Ekbom, 1995). For example, flea beetles (*Phyllotreta* spp.) attack seedlings, while aphids (*e.g*. *Brevicoryne brassicae*) damage seedlings, leaves and stems, pollen beetles (*Meligethes* spp., particularly *M. aeneus*) attack buds and flowers, diamondback moths (*Plutella xylostella*) attack leaves from bud stage until maturity and nematodes (*e.g*. *Heterodera schachtii*) affect all parts of the plant via the roots. The cabbage root fly (*Delia radicum*) also damages the roots and the pod midge (*Dasineura brassicae*) damages the pods (Ekbom, 2010; Williams, 2010; Erichsen & Hünmörder, 2005; Alford *et al.*, 2003).

4.2.2 Radish

Radish (*Raphanus sativus* L.) has been in cultivation for thousands of years. This taproot vegetable belongs to the family Brassicaceae. The word 'radish' originates from the Greek word '*raphanus*', meaning 'quickly appearing', referring to its rapid germination and growth. The long history of radish cultivation is depicted on the walls of the Egyptian pyramids, built about 4000 years ago (Crisp, 1995), but the origin of radish has not yet been fully determined (Kaneko & Matsuzawa, 1993; Lewisjones *et al.*, 1982). Skin colour, size and shape of radishes vary, *e.g.* there are round, long and oval, red and white types. The most commonly grown type is the round, red-skinned radish. The texture of the taproot is crispy and the flavour pungent and peppery. Radish is usually eaten raw, but it can be steamed. The typical taste is caused by the breakdown products of glucosinolates. During chewing, these compounds come into contact with the enzyme myrosinase and form *e.g.* allyl isothiocyanate, which is also common in horseradish, mustard and wasabi (Swiader *et al.*, 1992; Nonnecke, 1989; Splittstoesser, 1984). Broadly, radishes are categorised into two seasonal types: summer and autumn. The maturation time of summer radish is 20-30 days. Therefore, several sowings can be made during the season in temperate climates. However, summer radish cannot be grown during the hottest months in warm climates. Autumn radishes reach maturity in 45-75 days (Splittstoesser, 1984). Radish is also a very popular vegetable in hobby gardening since it is so easy to cultivate. Its major pest problem is damage to the taproot by the cabbage root fly. *Phyllotreta* flea beetles may also cause considerable damage to emerging plants.

4.2.3 Ornamental flowers

In Europe, Canada and the USA, ornamental or horticultural plants are primarily grown under controlled conditions, *e.g.* in greenhouses and nurseries. Ornamental and horticultural plants are considered speciality, high-value crops. Certain levels of pest damage may be tolerated in agricultural crops, whereas in ornamental plants damage thresholds are normally zero (Bethke & Cloyd, 2009). Pest infestations may therefore cause low market values, with enormous economic losses as a result (Bethke & Cloyd, 2009; Nothnagl, 2006). Hobby gardening of ornamental plants and vegetables is popular in home settings in developed countries. The advantages of using pesticides associated with field production in agriculture are generally understood by the public and homeowners commonly use pesticides to protect certain ornamental plants, such as roses, from arthropod pests, *e.g*. aphids, in order to maintain aesthetic quality (Crane *et al.*, 2006; Henry, 1994; Ravlin & Robinson, 1985). In spite of this, most consumers or homeowners do not understand the procedures required to produce ornamental plants, and are thus unable to perceive, or are unaware of, the immediate benefits of using pesticides in these circumstances (Loureiro *et al.*, 2002). Among the oilseed rape pests, pollen beetles may be a nuisance in garden flowers and for cultivation of cut indoor flowers, since they destroy flower appearance by making holes in buds and petals, which is intolerable for ornamental flowers (CABI, 2011; Bethke & Cloyd, 2009).

4.3 Insects

The insects described in the following paragraphs are those selected for the investigations described in **Papers III and IV**.

4.3.1 Flea beetles, *Phyllotreta* spp.

There are several *Phyllotreta* (Coleoptera: Chrysomelidae) species that are pests of *Brassica* crops. In SOSR, *Phyllotreta undulata* and sometimes *P. atra* dominate, while *P. nemorum* is more often found in vegetable Brassicas and seldom in SOSR (Ekbom, 1990; Sommer, 1981).

Phyllotreta species in Sweden all have one generation per year. The life cycle of the *P. undulata* flea beetle is shown in *Figure 2*. The *Phyllotreta* species commonly found in SOSR are 2-2.5 mm long (Ekbom, 2010). These flea beetles overwinter as adults, often hiding in places away from the fields, in leaf litter and turf beneath trees, in fence rows and grassy areas (Ekbom, 2010; Burgess, 1981; 1977). They leave their overwintering sites between March and May depending on the temperature, *i.e*. when the ground temperature reaches 15 °C (Ekbom, 2010; Ulmer & Dosdall, 2006). In warmer, drier weather, they become active and move to the emerging crops of newly-sown SOSR fields. High numbers of flea beetles can be devastating for crop establishment. Beetle attack in early stages can cause irreversible damage by adults feeding on the cotyledons and stems, sometimes even while plants are below ground, resulting in certain plant death (Ekbom, 2010; Jones & Jones, 1984). The larvae of *P. nemorum* mine and feed on leaves, while those of *P. undulata*, *P. atra*, *P. nemorum*, *P. nigripes* and *P. striolata* are root feeders of oilseed rape and those of *P. vittula* mine stems and leaf petioles of cereals (Ekbom, 2010). Eggs are laid, often in batches, on the soil at the base of the plant. In laboratory conditions, each female is able to lay up to 200 eggs. Larvae have three larval instars. Young larvae are white, but later the head becomes light brown.

Younger larvae feed on fine roots, while older larvae attack larger roots. The larvae normally live on the roots at a depth of 5-30 cm below the soil surface (Sommer, 1981). Fully developed larvae are about 5 mm long. The larvae build soil cells to pupate, and development to pupation takes about 4 weeks (Jones & Jones, 1984). Adults of the new generation emerge in late summer, from mid-August to September, depending on temperature (Ekbom, 2010; Ulmer & Dosdall, 2006). Adult beetles feed on plants during the growing season, but beyond the seedling stage the rapeseed plants are much less sensitive to attack (Gavloski & Lamb, 2000). The type of crop losses from flea beetle attack include reduced crop stands, uneven plant growth and delayed maturity, creating a need for insecticide applications (Dosdall & Mason, 2010; Madder & Stemeroff, 1988).

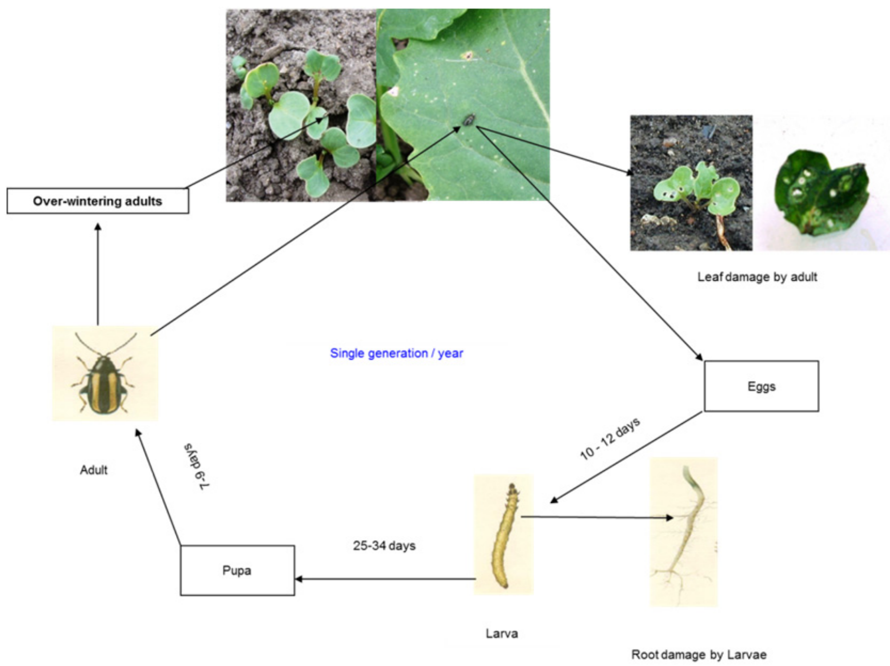

Figure 2. Life cycle of flea beetle *Phyllotreta undulata* Kutschera and its damage.

If only seed dressing with systemic insecticides is used, this treatment is not able to always control flea beetles in areas with high populations in Sweden and Finland. Thus one or more additional insecticide applications are needed. In Sweden, Finland and Canada, the economic threshold is 25-30% damage to the cotyledon area. Use of this threshold is somewhat difficult because attacks occur at high speed during hot and dry weather. Therefore, several insecticide applications might be needed, bringing increased risks of environmental damage and insecticide resistance. To avoid such a situation, it is necessary to check fields every day during periods of warm, sunny weather when plants are beginning to emerge (Dosdall & Mason, 2010; Ekbom, 2010). There are cultural practices that can be used for reducing the risk and severity of flea beetle attack (Dosdall & Mason, 2010). Direct-drilled oilseed rape generally suffers less damage than oilseeds drilled after conventional tillage. Increasing the seed rate or row density provides extra food for the flea beetles and thus more even distribution of the damage (Ekbom, 2010; Dosdall *et al.*, 1999). The same is true if plants emerge at about the same time, then damage to individual plants may be reduced. To get rapid and even germination, proper seeding and optimal depth of sowing are necessary. Rapid growth results in plants quickly passing the most vulnerable cotyledon stage and later the plants tolerate beetle damage (Dosdall & Mason, 2010; Ekbom, 2010; Dosdall & Stevenson, 2005). Several natural enemies (*e.g.* parasitoids) have been found to be effective in suppressing flea beetles in central Europe, Sweden and Turkey (Ekbom, 2010; Lipa & Ekbom, 2003; Yaman, 2002; Ekbom, 1991; 1990; Sommer, 1981; Jourdheuil, 1960).

4.3.2 Cabbage root fly, *Delia radicum* (L.)

Cabbage root fly (*Delia radicum*; Diptera: Anthomyiidae) is a chronic and serious pest of commercial Brassica vegetables grown in the Holarctic region (Dreves, 2007; Biron *et al.*, 2000; CABI, 1989; Finch, 1989). The genus *Delia* consists of 170 species, but only a few species are considered to be economically important pests. Some examples of economically important *Delia* species are the onion fly (*Delia antigua*), which damages the onion bulb, the seed corn fly (*Delia platura*) and the bean seed fly (*Delia florilega*), which feed on the seedlings of vegetables, and the wheat bulb fly (*Delia coarctata*), which attacks cereals (Dosdall & Mason, 2010; Dreves, 2007; Finch, 1989). The cabbage root fly uses a range of crops as host, *e.g.* radish, cabbage, broccoli, cauliflower, Brussels sprouts, kale, collards, swede, turnip and oilseed rape (Dreves, 2007). Marketable edible cruciferous root crops such as radish, horseradish and swede are particularly sensitive to larval damage, which results in reduced market price of root crops (Finch, 1989). Wild crucifers such as yellow rocket, wild radish and black mustard act as larval hosts, maintaining populations of *Delia* root flies (Todd, 1998; Finch & Ackley, 1977).

Radish root damage caused by the larva of *D. radicum* and its life cycle are shown in *Figure 3*. The cabbage root fly overwinters as a pupa within a red-orange puparium (<1 cm long and a few mm wide) in the soil (at maximum 10 cm depth (Coaker, 1966; Hughes & Salter, 1959). The cabbage root fly adults start to emerge when the soil temperature is above 16 °C, which is normally in May, and approximately seven weeks later the second generation of adults emerges (Coaker & Finch, 1971).

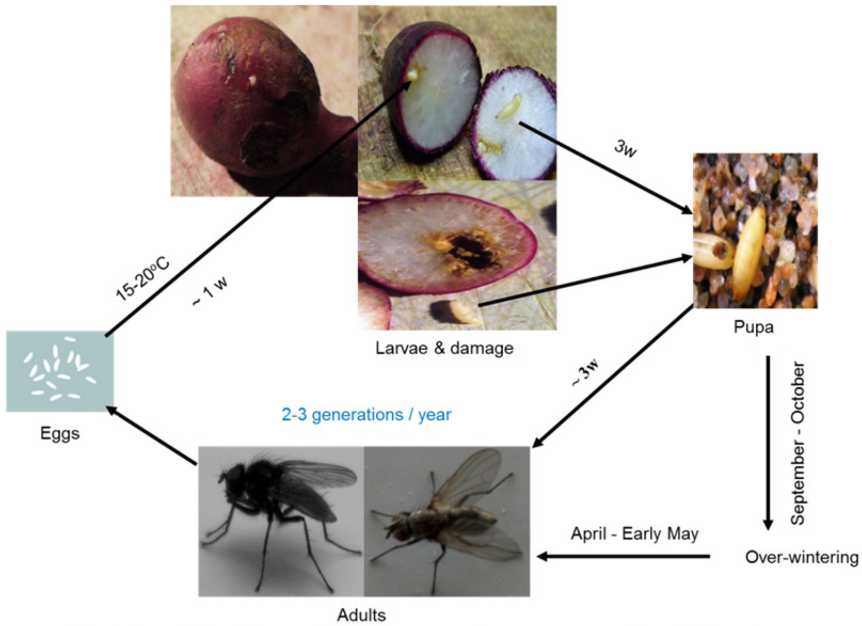

Figure 3. Life cycle of cabbage root fly, *Delia radicum* (L.).

In the early spring, cabbage root flies seek nectar and pollen from the flowers of many different plants (Finch & Coaker, 1969a; Harris & Svec, 1966). After emergence of adults, mating occurs within 4-5 days (Swailes, 1961). On an optimal diet and under laboratory conditions, a female can lay up to 376 eggs (Finch & Coaker, 1969a). In relation to egg laying, a synovigenic habit has been reported for the cabbage root fly, meaning that before laying the first batch of eggs the fly needs only carbohydrates, but for the additional batches, the fly has a requirement for both proteins and carbohydrates (Finch & Coaker, 1969b). Depending on the weather and soil conditions, the average time of cabbage root fly activity ranges from 41-65 days and peaks at temperatures of 19-22 °C (Bracken, 1988; Harris & Svec, 1966). Females search for Brassica crops by using leaf colour, shape and green area and by using odours, *e.g.* volatile isothiocyanates and other glucosinolate products (Prokopy *et al.*, 1983; Stadler, 1978). Females lay oblong, white 1 mm long eggs, on soil near the crown of a host plant down to 2.5 cm below the soil surface and also sometimes up the stem. Approximately 6 days after adult emergence from the pupa (Harris & Svec, 1966), oviposition typically occurs during afternoon hours (Hawkes, 1972). Within 3 to 7 days, the eggs hatch and neonate larvae begin to feed on lateral and main roots. After 2-3 weeks, the larvae pupate in the soil around the plant root and emerge as flies 1-2 weeks later. Fly emergence is sometimes suppressed during warm summer months because of pupal aestivation (Finch & Collier, 1985; Harris & Svec, 1966). In low temperature and short photoperiod conditions, puparia undergo diapause in late autumn (Dosdall & Mason, 2010; Johnsen & Gutierrez, 1997).

In southern Sweden, cabbage root fly has long been identified as an important pest and normally has two generations, although a third generation has been reported in favourable conditions (Lundblad, 1933). A number of cultivated Brassica crops are fed on by the larvae, preferably their roots and stems (Hambäck *et al.*, 2010; Hummel *et al.*, 2009; Parsons *et al.*, 2007; Finch, 1989; Zalom & Pickel, 1985; Coaker & Finch, 1971; Lundblad, 1933). The larval injury provides entries for pathogens causing black leg (*Phoma lingam*), bacterial soft rot (*Erwinia carotovora*), and root rot (*Fusarium* spp.), thus resulting in further yield reductions and quality problems (McDonald & Sears, 1992; Griffiths, 1986a; 1986b). In Nordic conditions, cabbage root fly is not a great problem for oilseed rape, but is a chronic and serious pest of oilseed rape in North America (Dosdall & Mason, 2010; Ekbom, 2010; Williams, 2010). In dry conditions, it is also a problem for oilseed rape in *e.g*. Germany (Erichsen & Hünmörder, 2005).

Insecticidal seed treatments with organophosphate and carbamate products, coated with a polymer for slow release in the soil, only slow the onset of feeding damage to oilseed rape but do not prevent it (Griffiths, 1991). However, seed coating with insecticides, *e.g*. fipronil or spinosad, effectively controls cabbage root fly on Brassica vegetables (Ester *et al.*, 2005). Cultural control strategies are therefore equally important, *e.g*. resistant cultivars (Dosdall *et al.*, 1994), soil tillage prior to sowing (Dosdall *et al.*, 1996a), sowing to achieve relatively high plant densities (Dosdall *et al.*, 1996b), using a wider row spacing (Dosdall *et al.*, 1998), and delaying weed removal until crops are in the four-leaf of development rather than the two-leaf stage (Dosdall *et al.*, 2003). However, biological control holds considerable promise to reduce future crop losses from these pests (Dosdall & Mason, 2010; Nilsson, 2010).

4.3.3 Pollen beetle, *Meligethes aeneus* (Fab.)

The pollen beetle (*Meligethes aeneus*, Coleoptera: Nitidulidae) is a pest of great economic importance in oilseed *Brassica* especially in Fennoscandia (Hokkanen, 1989; Nilsson, 1987). In the rest of Europe, pollen beetle is of less importance, although during latter years the pest has increased because of a higher proportion of SOSR crops being grown in this region. One reason for the pollen beetle being more severe in Denmark and Southern Sweden compared with the rest of Europe is the cultivation of both SOSR and WOSR crops, prolonging the period of suitable host stage for the reproduction of the pest (Hansen, 2003). The beetle migrates to the crop at its most susceptible green bud stage (Ekbom, 2010; Williams, 2010; Ekbom, 1995). Several other *Meligethes* spp. then *M. aeneus* may be found on rape crops in Europe (Karltorp & Nilsson, 1981; Jurek, 1972; Nolte & Fritzsche, 1952), particularly *Meligethes viridescens* (Fabricius) in some spring crops (Fritzsche, 1957). *M. viridescens* emerges later in the spring and requires higher temperatures for oviposition and development than *M. aeneus* (Ekbom, 2010).

Pollen beetle has one generation per year. The adults of the pollen beetle are 2-2.5 mm in size and are black with a metallic lustre and regular punctuations on the elytra. The antennae consist of 11 segments, with a club-shaped end (Kirk-Spriggs, 1996; 1991). The eggs are glossy and elongated. The full grown larvae are yellow-white, elongated, much flattened, covered with light brown dots and 4 mm long, with brown head and legs. The life cycle of the pollen beetle is shown in *Figure 4*. The adult pollen beetles overwinter in the upper soil layer, vegetation and leaf litter, predominantly in field margins, woodlands and hedgerows. They emerge in early spring (March-June), when the temperature exceeds 10 °C (Ekbom & Borg, 1996; Laska & Kocourek, 1991; Nilsson, 1988a). The adults are polyphagous and feed on pollen of many different families for a week or two (Charpentier, 1985; Free & Williams, 1978; Müller, 1941).

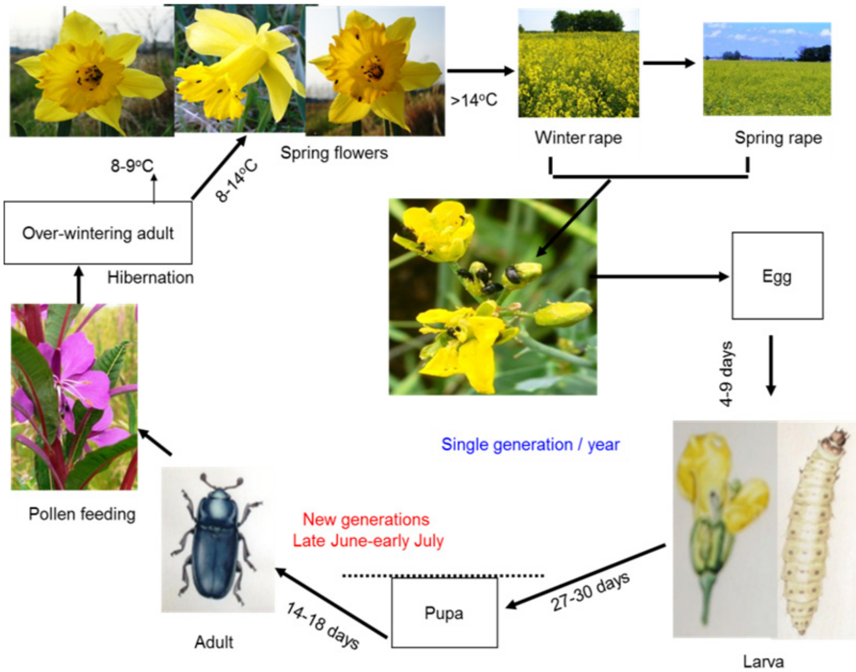

Figure 4. Life cycle of pollen beetle *Meligethes aeneus* (Fabricius).

Pollen beetles then seek cruciferous plants for mating and oviposition when the temperature exceeds 12 °C (Free & Williams, 1978) and they therefore usually arrive in WOSR at the green bud stage, whereupon they feed on developing pollen in the buds and later in the flowers. Female pollen beetles deposit eggs in small holes they have bitten at the base of flower buds (Ekbom & Borg, 1996). They prefer to lay their eggs in buds which are 2-3 mm long (Ekbom & Borg, 1996; Nilsson, 1988b; Scherney, 1953). The eggs are placed either along the anthers or occasionally between the sepals and petals (Scherney, 1953). Single females have laid a mean of 246 eggs each with 2–3 eggs per bud (Scherney, 1953) although up to 10 eggs per bud have been reported (Ekbom & Borg, 1996). Within 4-9 days, the eggs hatch and the neo-natal larvae stay in the flower bud until the flower opens, feeding on pollen in the anthers. The larvae may also feed on the plant stem when the population density is particularly high (Ekbom & Borg, 1996). Pollen beetle has two larval instars (Osborne, 1964). The first instar feeds on pollen within the bud for 5-10 days (Nilsson, 1988c) and the second feeds on pollen from open flowers, moving into younger flowers every few days (Williams & Free, 1978). The fully grown larvae drop to the soil, and pupate just under the soil surface (Ekbom & Borg, 1996). Young beetles emerge 2-3 weeks later from the soil.

Depending on temperature, it takes around one month to develop an adult from an egg (Williams, 2010). Emergence of a new generation of beetles takes place from late June until late July, and they feed on pollen from many plant families (Ekbom & Borg, 1996; Charpentier, 1985; Williams & Free, 1978; Müller, 1941). Pollen beetles also attack cauliflower, calabrese (broccoli) and Chinese cabbage during the autumn, resulting in reduced quality of these vegetables and of ornamental flowers (CABI, 2011; Richter & Michel, 2007; Hokkanen *et al.*, 1986; Wheatley & Finch, 1984).

Pollen beetle attacks at the early bud stage often result in a significant yield decrease (Nilsson, 1994; Axelsen & Nielsen, 1990; Nilsson, 1988d; 1987; Tatchell, 1983; Williams & Free, 1979). WOSR may escape damage if it has passed the susceptible bud stage before the main migration of beetles into the crop. However, without insecticide application, up to 70% yield losses in SOSR crops have been reported (Nilsson, 1987). Both adult and larvae feeding may cause bud abscission, resulting in podless stalks or distorted, weakened pods, but this is mainly caused by the adults (Nilsson, 1988d; Free & Williams, 1978; Gould, 1975). Later the weakened pods are often attacked by the brassica pod midge (Williams, 2010). Oilseed rape plants have the capacity to considerably compensate for pollen beetle attack, and thus damage to the buds does not always result in yield losses (Axelsen & Nielsen, 1990; Lerin, 1987; Tatchell, 1983; Williams & Free, 1979). Furthermore, pollen beetle bud feeding on the terminal raceme leads to increased production of new side racemes and pods. Seed yield may be little affected if the damage occurs early, but seeds from pods on these racemes are often smaller and contain less oil (Axelsen & Nielsen, 1990; Nilsson, 1987; Sylven & Svensson, 1976). Plants may even overcompensate and produce increased yield, although late maturing pods may give a harvested product high in chlorophyll.

Chemical treatment to control pollen beetle may be necessary to ensure economic yields. In Sweden, economic thresholds are in use both for WOSR and SOSR (Nilsson, 1987). Economic thresholds are also in use in the UK (Lane & Walters, 1993) and in many other countries (Williams, 2010; Menzler-Hokkanen, 2006). Pyrethroids are the most commonly used chemicals for control of pollen beetle, although resistance to pyrethroids has been reported (Slater *et al.*, 2011; Zimmer & Nauen, 2011; Ekbom & Kuusk, 2001). A number of natural enemies are present, *e.g.* parasitoids, and protozoans and fungi such as *Beauveria bassiana* can be applied (Hokkanen, 2008; Husberg & Hokkanen, 2001; Hokkanen, 1993). Use of trap crops (*e.g.* turnip rape; *Brassica rapa*) can lower pollen beetle damage to oilseed rape (Nilsson, 2004; Buchi, 1995; Hokkanen, 1991; Hokkanen *et al.*, 1986). Changes in cultivation practices influence the presence of natural enemies, *e.g.* a negative correlation exists between the presence of certain natural enemies and ploughing (Nilsson, 1985). Other protection methods to ensure high yield is, the use of crop varieties resistant to pollen beetle (Melander *et al.*, 2003). However, no such varieties are available (Ahman, 1993). It is advisable to apply chemicals only when necessary according to economic threshold (Ekbom, 1995; Rimmer & Buchwaldt, 1995). Positive results against pollen beetle have also been reported for a treatment combining insecticides and foliar fertilisers at the green bud stage (Seta & Mrowczynski, 2004).

5 Materials and methods

This thesis is based on two studies using surveys to evaluate the perceptions of pesticide use among farmers and non-farmers in two regions, Skåne and Mälardalen (**Papers I and II**), and two field experiments carried out in Lönnstorp (55°40´N, 13°06´E) and Mellangård (55°39´N, 13°3´E), Lomma, Sweden (**Papers III and IV**).

5.1 Survey to evaluate perceptions of pesticide use

Data for the studies of perceptions and attitudes to pesticide use were collected from two different periurban regions in Sweden, Skåne and Mälardalen. These two areas were selected to cover differences in relation to perceptions of pesticide use between people living in different environments. Both areas are situated in the most dense agricultural regions in Sweden, although they differ in many respects. For example, Skåne has a higher proportion of agricultural land, a higher mean temperature and humidity and lower numbers of organic farmers than Mälardalen (SCB, 2010; 2008b; *Figure 1*).

There are several survey methods that can be used when the aim is to collect information on various issues. Such methods include an interviewer-led telephone questionnaire, a postal questionnaire, or a face-to-face interview questionnaire (Morgaine *et al.*, 2005; Kelley *et al.*, 2003; Christensen, 2002; Coppin *et al.*, 2002). Performing a postal questionnaire-based survey is cheaper, more repeatable, minimises interviewer effects and can also cover a wider geographical area compared with the other methods. However, a comparatively higher response rate is usually obtained by the use of face-to-face and telephone interviews (Morgaine *et al.*, 2005; Kelley *et al.*, 2003; Cartwright, 1988). Postal questionnaires often result in more missing data, and possibly less reliable answers to some questions compared with other survey alternatives (Addington-Hall *et al.*, 1998). However, the response rate to postal questionnaires is normally high enough for evaluation and planning purposes (Morgaine *et al.*, 2005). A higher response rate to a postal questionnaire than to a telephone survey has also been reported in certain cases (Hocking *et al.*, 2006). Furthermore, for an international student such as I (not speaking the Swedish language), a survey using a postal questionnaire was easier to carry out than a face-to-face or telephone interview. Considering all the above aspects, for the present investigations I elected to use and send out a postal questionnaire to the participants. Therefore, a self-completed questionnaire was distributed by SKOP (www.skop.se) by post to the participants selected for the studies (**Papers I and II**). The participants were randomly selected from a register of the Federation of Swedish Farmers (LRF; www.lrf.se).

Farmers were selected on the basis of farm size (**Papers I and II**). Non-farmers were randomly selected and divided into four categories. Among these, those living in a house less than 100 m away from the nearest farm land were designated 'neighbours'. The primary aim of the investigation was to compare farmers' and neighbours' perceptions of pesticides, and therefore most comparisons were made between these two groups. A distance of less than 100 m away from farm land was selected as the basis for classifying an individual as a neighbour based on the fact that people living close to farms face some problems that people living further away do not, *e.g*. agro-chemical drift, odours, dust and machinery noise (**Paper I**).

The questionnaire was developed on the basis of aims in relation to perceptions of pesticide use (**Papers I and II**). It consisted of six theme (main) questions: i) Extent of harmfulness to the environment in relation to pesticides, other agricultural inputs and farming; ii) extent of pesticide use in different spaces, *e.g*. houses, gardens *etc*.; iii) attitudes to pesticide use; iv) the question of who uses pesticide in the periurban area; v) influences of pesticide use on production, quality of products and other natural systems; and vi) overall influences of agriculture in the society. The remaining questions (17) in the questionnaire related to basic information about the respondent. Of the 23 questions, 15 were the same for both farmers and non-farmers, while the remaining eight questions were different. One question addressed to both farmers and non-farmers concerned pesticide use in their home setting, *i.e*. in the home, in the garden or on the lawn. One question was used to distinguish farmers from non-farmers. Additional questions were used to categorise farmers according to the crop types grown, pesticide use and knowledge of pesticide-related safety regulations. The answer 'Do not know' was not available in the questionnaire in order to have as many statements as possible (Feveile *et al.*, 2007).

A total of 1200 participants were selected from the LRF register. The categories farmers and non-farmers (particularly neighbours) and different groups of farmers/farms were determined on the basis of LRF and ENIRO data and answers to the questionnaire by the respondents. However, the classification of farmers and non-farmers in the register obtained from the LRF was not completely correct. Some of the respondents (50) primarily classified as farmers turned out to be non-farmers (discarded from all analyses except the factor analyses) and some of the respondents (33) classified as non-farmers turned out to be farmers (included in the farmer group in further analyses) according to how they answered the questionnaire (**Paper I**).

5.2 Field experiments

To evaluate influences of the use of insecticides on neighbouring garden crops, a SOSR crop field was used as an example of an agricultural field, while a radish crop was sown nearby and was considered an example of a neighbour garden crop (*Figure 5*). During the SOSR crop season, several radish sowings were carried out in the vicinity of the SOSR field. Insecticides were applied to half the SOSR field for control of flea beetle and pollen beetle (**Paper III**). Damage by flea beetle and cabbage root fly, number of larvae of cabbage root fly, root cracks, root disease and unspecified leaf damage, root size and root and leaf dry weight were recorded (**Paper III**).

Another study of the influence of insecticide use on the presence of insect pests in nearby garden crops was carried out using a field of WOSR as an agricultural crop (**Paper IV**). Two parts of the WOSR field were treated with insecticide to control pollen beetle, while the other two parts were left untreated. Numbers of pollen beetles in nearby vegetable Brassicas (*Figure 6*) and ornamental flowers (*Figure 7*) were recorded.

Figure 5. Experimental set-up of the agricultural field crop (spring oilseed rape) and the garden crop (radish) in the field trial in **Paper III**.

In order to determine when to apply the insecticide and its effect in the WOSR, immigrated adult pollen beetles were counted repeatedly on the plants and by using soil traps (*Figure 7*, left) to capture the new emerging generation. Emergence time and the secondary effects of insecticide treatment were recorded. Window traps (*Figure 7*, right) adjacent to the field helped record flight directions over time. Pollen beetle catches were collected and preserved for identification and counts. In addition, information about new generation pollen beetle flight peaks was collected from SLU, Alnarp, and weather data were obtained from a weather centre in Malmö, Sweden (**Paper IV**).

Figure 6. Test heads of the Brassica vegetables cauliflower (left) and broccoli (right) placed near the experimental site.

Figure 7. Window (left) and soil traps (right) near the experimental site and in the field.

To estimate the numbers of pollen beetles in vegetables and ornamental flowers near the WOSR field, test heads of cauliflower and broccoli and flowers of *Leucanthemum* sp. (Shasta daisy; *Figure 8a*), *Cosmos* sp. (*Figure 8b*) and *Dahlia* sp. (*Figure 8c*) were placed alongside each part of the WOSR field. Numbers of pollen beetles were counted during the main flight periods. In addition, pollen beetles were counted on two wild flower species (*Matricaria inodora* L. and *Cirsium arvense* (L.)) growing alongside the WOSR field (**Paper IV**).

Figure 8. Flowers positioned to attract pollen beetles as they left the winter oilseed rape field. (a) *Leucanthemum* sp., (b) *Cosmos* sp. and (c) *Dahlia* sp.

5.3 Statistical analysis

In **Papers I and II**, several of the questions in the questionnaire used a Likert-type scale to measure participants' perceptions of, and attitudes to, pesticide use. The Likert scale is a unidirectional (only measures a single feature), psychometric response scale mainly used in questionnaires to obtain data on participants' preferences or degree of agreement with a statement or set of statements. Participants are generally asked to specify their level of agreement with a given statement on an ordinal scale. A 5-point scale ranging from 'strongly agree' at one end to 'strongly disagree' at the other, with 'neither agree nor disagree' in the middle, is usually used in practice (Likert, 1932). However, a 7- or 9-point scale that adds additional divisibility can be used, while a 4-point or even-numbered scale can be used to produce a forced choice measure where no indifferent option is offered. A numerical value or coding, usually starting at 1 and increasing by 1 for each level, is given. In **Papers I and II** a scale from 1 to 10 was also used. This type of scale is generally used in social, psychological or behavioural studies (Broadbent *et al.*, 2006; Flynn *et al.*, 2004; van Laerhoven *et al.*, 2004; Ulleberg & Rundmo, 2003; Coppin *et* *al.*, 2002; Du Toit *et al.*, 2002; Lukasiewicz *et al.*, 2001). A number of other scales can be used to measure social, psychological or behavioural characters. Examples of such scales are simple Visual Analogue Scale (VAS, linear response option) and numerical VAS (numeric response option). However, the Likert scale is the easiest to complete and to use as the basis for calculations and interpretations (van Laerhoven *et al.*, 2004). Furthermore, in capturing coping patterns for emotions, approaches and avoidance of coping functions, the Likert scale has a wider range than VAS (Flynn *et al.*, 2004).

Factor and GLM analysis were carried out to compare the perceptions and attitudes to pesticide use between different groups of respondents by using SPSS (**Papers I and II**; SPSS, 2008). Significant interaction terms were also considered, giving exact information on respondent and location interactions, as well as the influence of social factors (*e.g*. gender, age, education *etc*.; **Paper I**).

Perceived and reported actual use of pesticides was investigated and the *corresponding* and *non-corresponding* perception terminology was used to describe the relationship (**Paper I**). A Tukey's post-hoc test to test for differences between factors within the same questions (**Papers I and II**) and a logistic regression analysis for the dichotomous answers (**Paper I**) were also carried out.

Data in **Papers III and IV** were analysed in ANOVA using SAS (SAS, 2003). When the ANOVA proved to be significant, a Tukey's post-hoc test was carried out to test for significant differences between treatments. Pearson correlation analysis, t-test (**Paper III**), and sign-test (**Paper IV**) were also carried out.

6 Results and discussion

6.1 Response rate and profile

In the social studies, a total of 1200 questionnaires were sent out; 300 each to the groups farmers and non-farmers (neighbours) in the regions Skåne and Mälardalen. In both regions, farmers comprise a relatively large proportion of the population, around 9000 persons per region (SCB, 2008b; Table I). Thus, the questionnaire was sent out to more than 3% of the farmers in each region and 1.8% completed and returned it (Table 1; **Paper II**). The response rate of the farmers was 54% (**Paper II),** and of the farmers and non-farmers combined 51% (**Paper I**). This corresponds to the level that can be expected from a postal questionnaire (Morgaine *et al.*, 2005; Christensen, 2002; **Paper I**). The non-response bias rate was not calculated due to the fact that the response rate was at the expected level and non-respondents did not constitute a homogeneous group (Etter & Perneger, 1997; **Paper I**). However, the response rate was not biased by the unequal amounts of respondents from the farmers and neighbours categories, or by the unequal amounts of respondents from the two different regions. As regards the responding farmers, those with large farms responded to a higher extent than those with small farms (**Paper II**). Furthermore, education level differed between the respondents from the different areas and between farmers and neighbours (**Paper I**).

Table 1. *Information on the farmers group of respondents in Mälardalen and Skåne (SCB, 2008b)*

Region	Farm size category	Total no. of farmers living in the region; percentage of the regional and national total		No. of questionnaires sent out, percentage of farmers in the region surveyed		Questionnaires returned completed, response rate, %	
		No.	%	No.	%	No.	%
Mälardalen[a]							
	Small	3788	5.28	100	2.64	35	35.0
	Medium	2199	3.07	100	4.55	52	52.0
	Large	2853	3.98	100	3.51	65	65.0
Total		8840	12.33	300	3.39	156	50.7
Skåne							
	Small	4749	6.62	100	2.11	46	46.0
	Medium	2030	2.83	100	4.93	50	50.0
	Large	2351	3.28	100	4.25	71	71.0
Total		9130	12.73	300	3.29	169	55.7
Total farmers (Regional)		17970		600	3.34	325	1.81
Total farmers (National)		71693					

[a]Mälardalen including south-west Uppland, south-east Västmanland, northern Södermanland and west of Stockholm.

6.2 Similarities and differences in perceptions of pesticide use among farmers and neighbours

When comparing perceptions of farmers and neighbours relating to pesticide use, it was striking how similar these perceptions were in many aspects (**Paper I**). Both farmers and neighbours generally perceived agriculture to highly affect food prices, food quality, human health, animal health, wild plants and animal welfare, clean water and landscape appearance (*Figure 9*; **Paper I**). Previous investigations have also shown the importance of agriculture for rural, urban, near-city and city inhabitants (Wachenheim & Rathge, 2000).

Both farmers and neighbours perceived that pesticide use in the garden, use of agricultural land for settlement and traffic, use of chemicals in industry, waste in nature and sewage discharges were highly harmful to the environment (*Figure 10*; **Paper I**). Both farmers and neighbours were also of the opinion that the extent of pesticide use was high in gardens and fields and low on pastures, forests, rivers and lakes (*Figure 11*; **Paper I**). This general perception that pesticide use affects and is harmful to the surroundings and the environment has also been reported previously by a number of authors

(Kleftoyanni *et al.*, 2011; Potts *et al.*, 2010; Belfrage *et al.*, 2005; Bengtsson *et al.*, 2005). Furthermore, the perception reported in **Paper I** that the highest use of pesticides occurs in gardens and fields also corresponds with previous findings (Nieuwenhuijsen *et al.*, 2005; Ball & Norton, 2002).

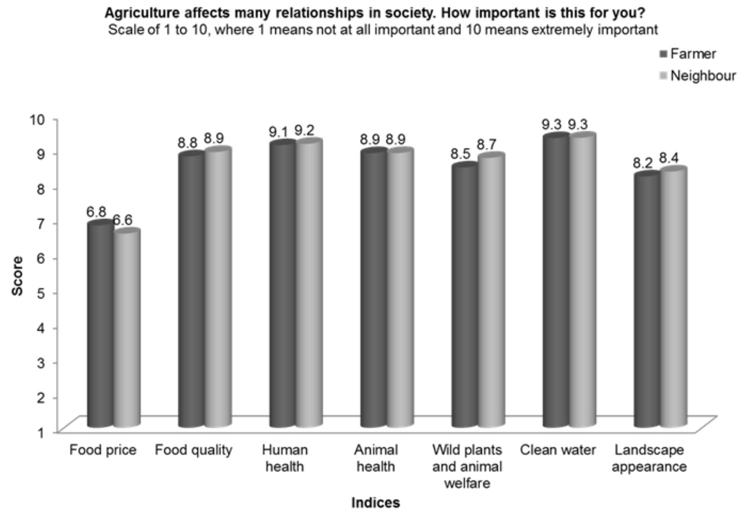

Figure 9. Perceptions of farmers and neighbours concerning the importance of various issues (mean score value) relating to the impacts of agriculture on society.

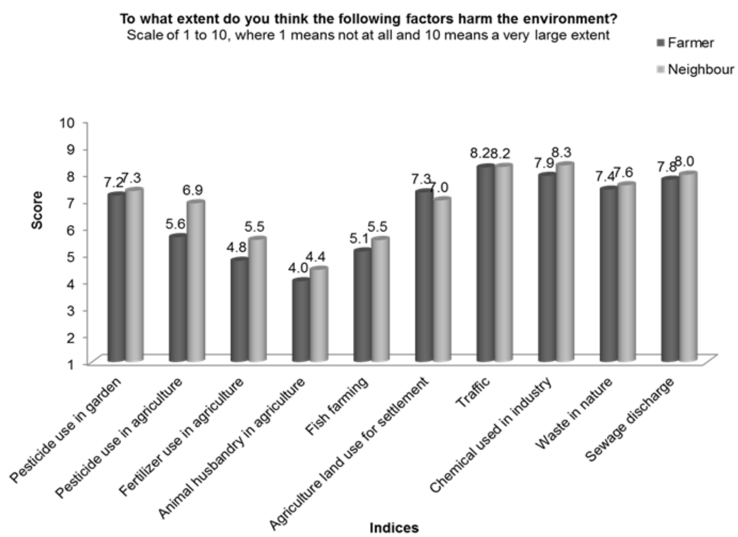

Figure 10. Perceptions of farmers and neighbours concerning the harmfulness of various activities (mean score value) to the environment.

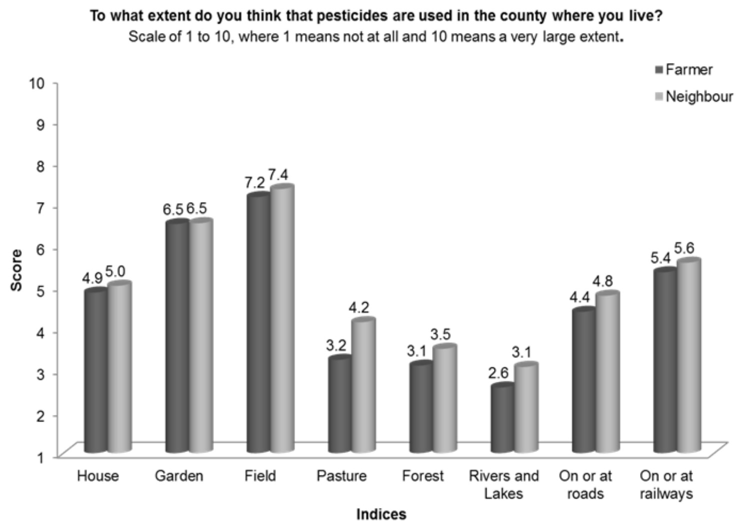

Figure 11. Perceptions of farmers and neighbours concerning the extent of pesticide use (mean score value) in various parts of their local environment.

The farmers and neighbours shared a common perception that the use of pesticides primarily influences crop yield and that growers profit from this (Figure 12; **Paper I**). Both farmers and neighbours perceived that the number of insect species that are not pests, the number of plant species that are not weeds, the number of wild plants and animals in the environment, the good taste of food, the healthiness of the food, farmers' health, neighbours' health, pet and stock animal health, water quality and fish populations were all negatively influenced by the use of pesticides (Figure 12, **Paper I**). However, the neighbours had stronger perceptions on this than the farmers. Information regarding the increase in yield in particular, but also grower profits, through the use of pesticides (Cooper & Dobson, 2007) therefore seemed to be well rooted in the minds of both farmers and neighbours. Similarly, the many negative reports on environmental impacts from the use of pesticides (*e.g.* Kleftoyanni *et al.*, 2011; Potts *et al.*, 2010; Belfrage *et al.*, 2005; Bengtsson *et al.*, 2005) are in accordance with the respondents' perceptions.

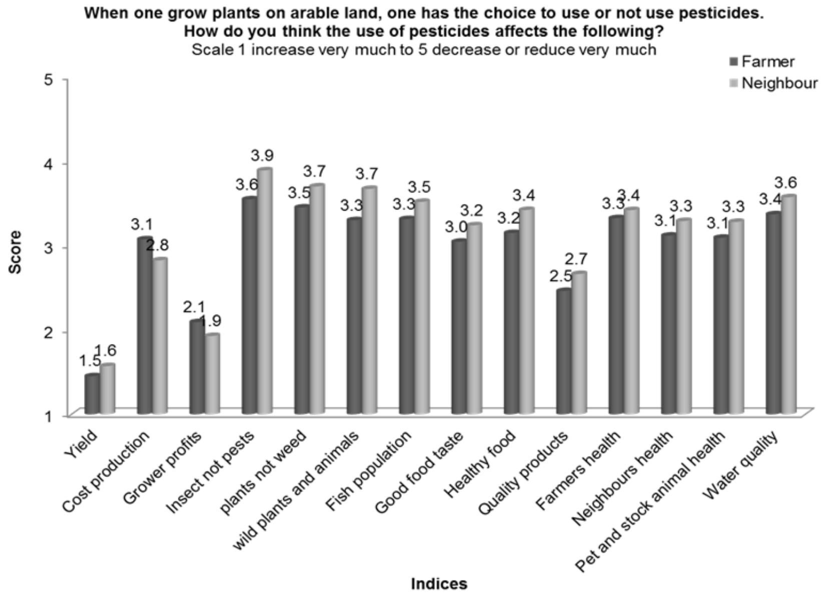

Figure 12. Perceptions of farmers and neighbours concerning the influences of pesticide use (mean score values) on various issues.

It was also found that both farmers and neighbours perceived farmers to be the main users of pesticides (Figure 13; **Paper I**). However, the answers in the questionnaire indicated a high proportion of users in both categories, and the proportion of users in the home setting or garden was not significantly different among farmers and neighbours (Figure 14; **Paper I**). High use of pesticides among neighbours has also been reported in previous investigations, with pesticides being widely used in homes, gardens and lawns (Alumai *et al.*, 2010; Crane *et al.*, 2006; Whyatt *et al.*, 2002; Robbins *et al.*, 2001).

While there were many similarities in perceptions of pesticide use between farmers and neighbours, a number of differences were also seen (**Paper I**). One significant difference between farmers and neighbours was in their attitude to the use of pesticides, with the farmers having a more positive attitude to pesticide use than the neighbours (Figure 15, **Paper I**).

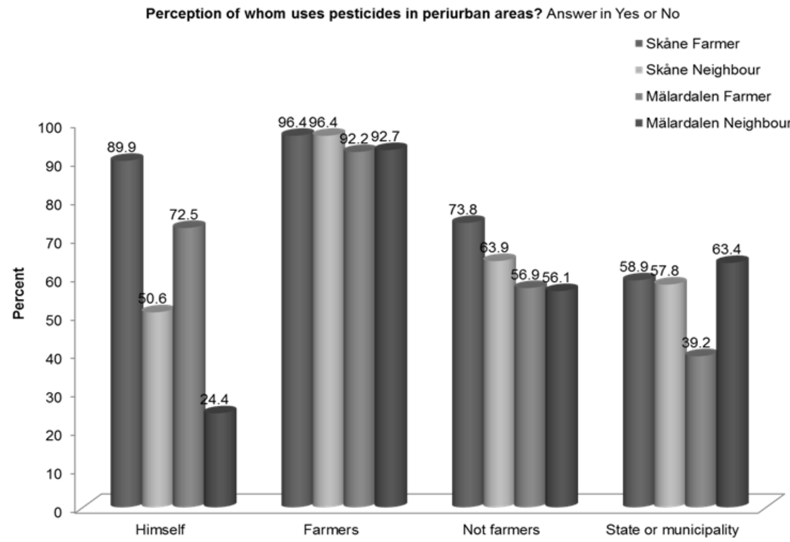

Figure 13. Perceptions of different survey groups concerning who uses pesticides (self, farmer, non-farmer, state; %) in the Mälardalen and Skåne regions of Sweden.

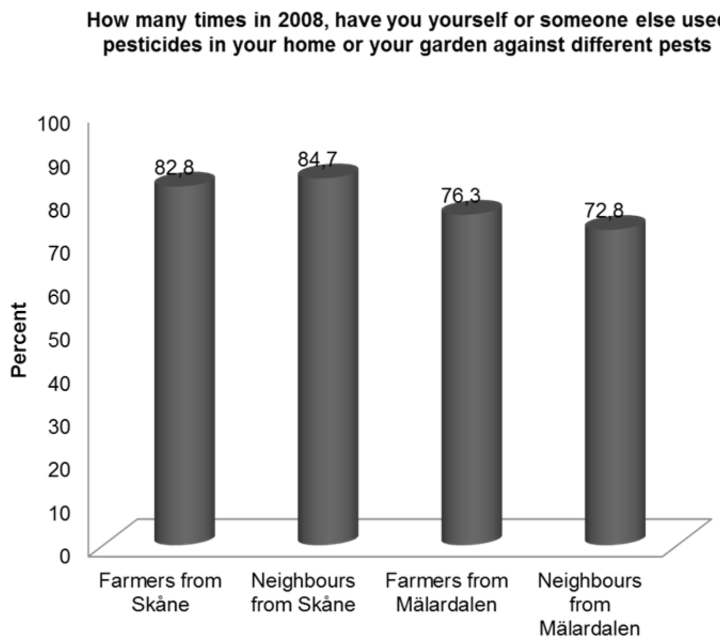

Figure 14. Percentage of reported pesticide use to control various pests in the home setting (*e.g.* house, garden or lawn) among farmers and neighbours in the Mälardalen and Skåne regions of Sweden.

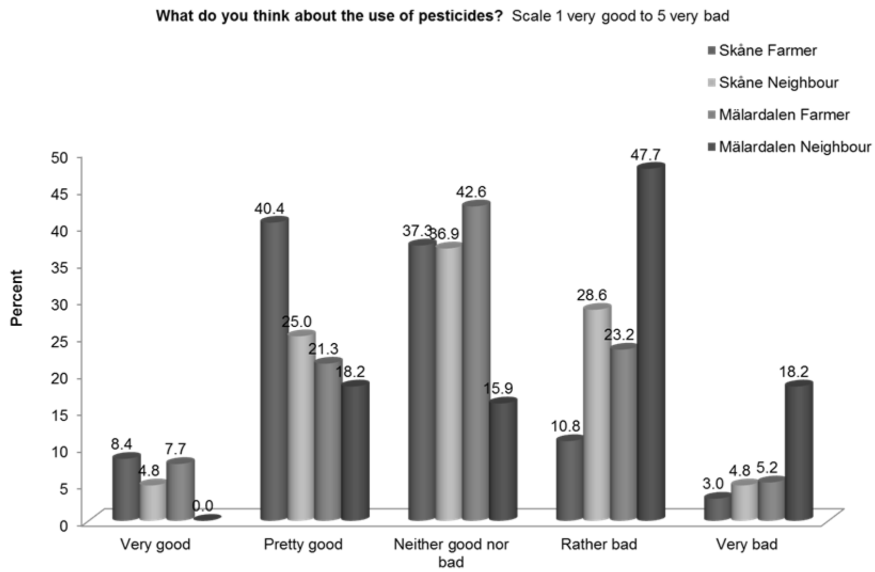

Figure 15. Attitudes of farmers and neighbours (% in different attitude classes) in Mälardalen and Skåne to pesticide use.

Differences in people's attitudes to agricultural activities in general and pesticide use in particular have been reported by other authors too (Kleftoyanni *et al.*, 2011; Potts *et al.*, 2010; Belfrage *et al.*, 2005; Bengtsson *et al.*, 2005; Letourneau & Goldstein, 2001; Hawkes & Stiles, 1986). However, the specific differences in attitudes to pesticide use between farmers and neighbours reported in **Papers I and II** are novel findings. Knowledge relating to perceptions and attitudes to different matters are of relevance for politicians and regulatory bodies setting up new rules and regulations (Cole *et al.*, 2011; Robbins *et al.*, 2001). In the periurban area, where farmers and neighbours live close together, knowledge of attitudes to agricultural activities is highly relevant in order to create a harmonious and functioning society (Birley & Lock, 1998). The farmers surveyed in **Paper I** perceived pesticide use in agriculture, fertiliser use in agriculture, animal husbandry and fish farming to be less harmful to the environment than did the neighbours (*Figure 10*; **Paper I**). This finding, related to variations in perception and risk evaluation of pesticide use from different groups in the periurban setting, is of relevance for policy makers and regulatory authorities (Cole *et al.*, 2011; Kleftoyanni *et al.*, 2011; Birley & Lock, 1998). Furthermore, **Paper I** showed that farmers, especially from Mälardalen, perceived the extent of pesticide use on fields, pastures and forest to be lower than was perceived by the other categories in the study (neighbours in Mälardalen, farmers and neighbours in Skåne). Thus account must be taken of the fact that perceptions, attitudes and risk evaluations may differ between locations and not only between different groups of people. Furthermore, previous investigations have pointed out the necessity of considering the location of a study when making decisions on regulations and laws (SCB, 2010; Fogelfors *et al.*, 2009). As to influences of pesticide use on the environment and food quality (cost of food production, number of insect species that are not pests, number of plant species that are not weeds, number of wild plants and animals in the environment, good taste of food, healthiness of food and quality of products), both farmers and neighbours generally had negative perceptions, although those of farmers were less negative than those of neighbours (**Paper I**). This shows that there may be a general consensus in a society regarding risk and perception of a specific issue, although the level of perception or risk might differ between groups of people in that society. Variation in risk perceptions of various groups of people in society has been reported by several authors (Kleftoyanni *et al.*, 2011; Hammond, 2002; Handel, 1996; Lapping *et al.*, 1989).

The perception of who is the actual user of pesticides varied in **Paper I**. The farmers mainly indicated themselves as being the users of pesticides, while the neighbours generally did not indicate themselves, but farmers (*Figure 13*). However, answers later in the questionnaire showed that both farmers and neighbours were using pesticides to an equal extent in the garden or home setting (*Figure 14*). One might speculate that the neighbours not identifying themselves as users of pesticides generally had a feeling that they are not the main pesticide users. When thinking of pesticide use, they may have related this to large tractors spraying pesticides in the neighbouring fields. Application of pesticides in the home setting is not as obvious. The finding of people not regarding themselves as pesticide users despite actually using pesticides in the home setting has been reported previously by others (Nieuwenhuijsen *et al.*, 2005). Statistics on pesticides sales show that high proportions of pesticides are sold for garden and home purposes and these pesticides can be as toxic as those used the field (KEMI, 2009; Ma *et al.*, 2002). Furthermore, the ethics of using pesticides to create attractive gardens compared with using them in food production can also be debated (Cole *et al.*, 2011; Robbins *et al.*, 2001).

6.3 Similarities and differences in perceptions of pesticide use among groups of farmers

Comparisons of farmers that were pesticide users or non-users, farmers with large, medium and small farms, farmers growing one or several crops and farmers with adequate and less adequate knowledge about certain pesticide regulations showed that their perceptions of certain issues did not differ (**Paper II**). All these groups of farmers perceived agriculture to highly affect food prices, food quality, human health, animal health, wild plants and animal welfare, clean water and landscape appearance (**Paper II**). Previous investigations evaluating perceptions in different groups of farmers have reported both similarities and differences for various issues, although most of these investigations have focused on food-related issues (Yiridoe *et al.*, 2005; Saba & Messina, 2003; Miles & Frewer, 2001).

All groups of farmers surveyed in **Paper II** perceived pesticide use in the garden and use of agricultural land for settlement and traffic highly harmful to the environment. Furthermore, all these groups were of the opinion that agricultural inputs and management (pesticides and fertilisers used in agriculture, animal husbandry in agriculture and fish farming) were less harmful for the environment than infrastructure (pesticide use in gardens, use of agricultural lands for settlements and traffic) and the use of chemicals and waste (chemicals used in industry, waste in nature and sewage discharges). All groups of farmers were also of the opinion that the extent of pesticide use was higher in houses, gardens and fields than in pastures, forest, rivers and lakes and roadside verges (**Paper II**). Prior to **Paper II**, no study had evaluated the perceptions of various groups of farmers regarding the use of pesticides and its relationship to various issues in agriculture and society. However, a number of studies report a general perception of a negative influence of pesticides on surroundings and the environment (Potts *et al.*, 2010; Michel-Guillou & Moser, 2006; Belfrage *et al.*, 2005; Bengtsson *et al.*, 2005; Ball & Norton, 2002; Hansen *et al.*, 2001; Letourneau & Goldstein, 2001). Numerous studies have also actually proven that pesticide use influences the surroundings negatively, especially if such use does not comply with regulations (Potts *et al.*, 2010; Belfrage *et al.*, 2005; Bengtsson *et al.*, 2005; Hansen *et al.*, 2001; Letourneau & Goldstein, 2001).

All groups of farmers surveyed in **Paper II** showed a common perception that the use of pesticides primarily influenced crop yield and farm profits positively. A common perception among all these groups was that the cost of food production, the number of insect species that are not pests, the number of plant species that are not weeds, the number of wild plants and animals in the environment, the good taste of food, the healthiness of the food, the quality of the products, farmers' health, neighbours' health, pet and stock animal health, water quality and fish populations were all negatively influenced by the use of pesticides (**Paper II**). Negative influences of the use of pesticides on non-target organisms and biodiversity have previously been reported in several publications (Potts *et al.*, 2010; Belfrage *et al.*, 2005; Bengtsson *et al.*, 2005; Hansen *et al.*, 2001; Letourneau & Goldstein, 2001).

However, there were also differences between the groups of farmers. The most obvious differences relating to perceptions of pesticide use was between farmers using pesticides and those not using pesticides. Thus, **Paper II** confirmed results from previous studies revealing that people preferring organically produced food differ substantially in their attitudes and perceptions from those not preferring organically produced food (*e.g.* Yiridoe *et al.*, 2005; Saba & Messina, 2003; Miles & Frewer, 2001). However, **Paper II** did not establish whether the farmers not using pesticides were organic farmers, as farmers were only asked about pesticide use during the study year. **Paper II** clearly showed that farmers using pesticides had a more positive attitude to pesticide use than farmers not using pesticides (*Figure 16*). Furthermore, farmers not using pesticides perceived chemicals used in industry, waste in nature and sewage discharges to be more harmful to the environment than did farmers using pesticides (*Figure 17*; **Paper II**). In addition, farmers using pesticides perceived pesticide use to increase crop yield and grower profits more than did farmers not using pesticides. Farmers not using pesticides perceived pesticide use to influence the environment, health and food quality (cost of food production, number of insect species that are not pests, number of plant species that are not weeds, number of wild plants and animals in the environment, good taste of food, healthiness of food and quality of products, farmers' health, neighbours' health, pet and stock animal health, water quality and fish populations) more negatively than did farmers using pesticides (*Figure 18*; **Paper II**). Thus, it was clear from **Paper II** that there was a significant difference between the perceptions related to pesticide use. Previous investigations have shown that the choice of becoming a pesticide non-user or organic farmer is based on attitudes and perceptions (Potts *et al.*, 2010; Belfrage *et al.*, 2005; Bengtsson *et al.*, 2005; Hansen *et al.*, 2001; Letourneau & Goldstein, 2001).

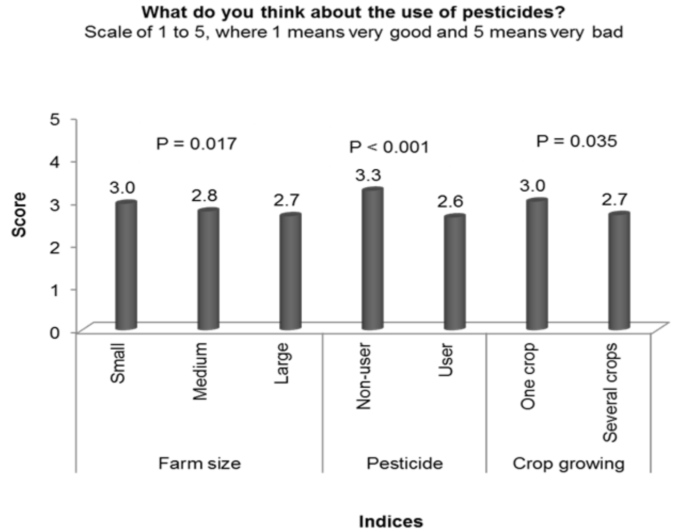

Figure 16. Attitudes to pesticide use (mean score value) among different categories of farmers.

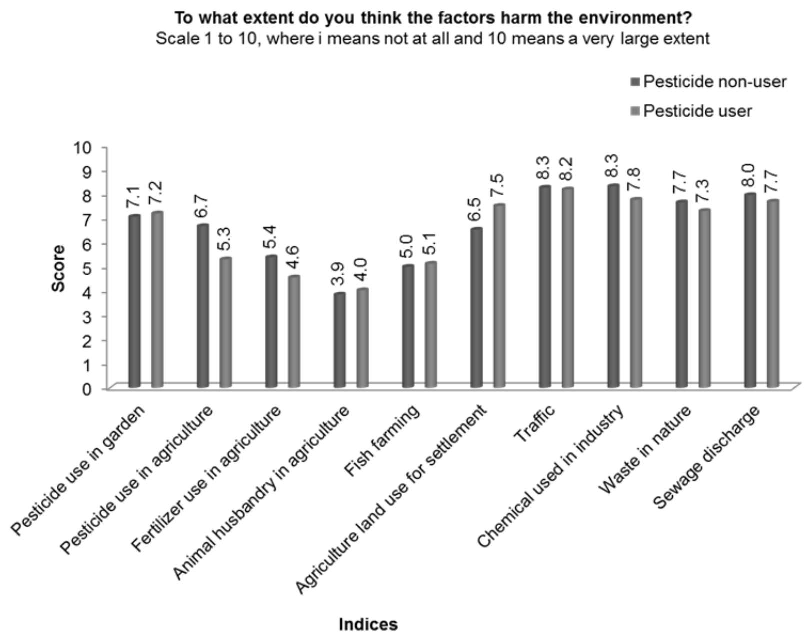

Figure 17. Perception of farmers who were pesticide users or non-users concerning the harmfulness (mean score value) of various activities to the environment.

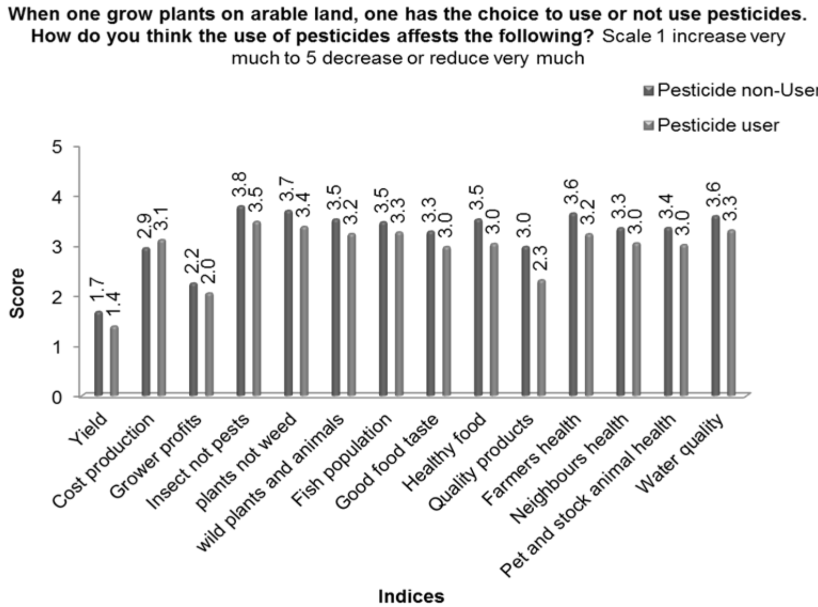

Figure 18. Perceptions of farmers who were pesticide users or non-users (mean score value) concerning the influence of pesticide use on various issues.

Farm size was the second most important factor influencing attitudes and perceptions of pesticide use (**Paper II**). Farmers with large farms had a more positive attitude to the use of pesticides than farmers with small farms (*Figure 16*; **Paper II**). Furthermore, farmers with small farms perceived a significantly higher extent of pesticide use on fields, pastures and forest than farmers with medium size farms (*Figure 19*; **Paper II**). Farmers with large farms perceived a more positive influence of pesticide use on the good taste of food, healthiness of food and quality of products compared with farmers with small or medium size farms (*Figure 20*; **Paper II**). Several previous studies have reported a significant association between farm size and farmers' perception of pesticide use as a risk to the environment (Lehrman & Johnson, 2008; Mauro & McLachlan, 2008; Lichtenberg & Zimmerman, 1999). In general, farmers with large farms tend to take higher risks, but also to have a more economics-based view and technology-friendly approach to farming than farmers with smaller farms (Damalas & Hashemi, 2010; Wilson & Tisdell, 2001). Whether the farmers grew one or several crops in the study year and their level of knowledge of pesticide regulations played a minor role regarding their attitudes and perceptions of pesticide use (**Paper II**). Farmers growing more than one type of crop were more positive to the use of pesticides than farmers growing only one type of the common crops (*Figure 16*; **Paper II**). Furthermore, farmers growing only one type of crop were more negative about the influence of pesticide use on the good taste of food, healthiness of food, quality of products and fish populations than farmers growing several types of crops (*Figure 21*; **Paper II**). Farmers with a lack of knowledge of pesticide safety regulations perceived a higher extent of pesticide use in rivers and lakes and roadside and railway verges than farmers with knowledge of pesticide safety regulations (*Figure 22*; **Paper II**).

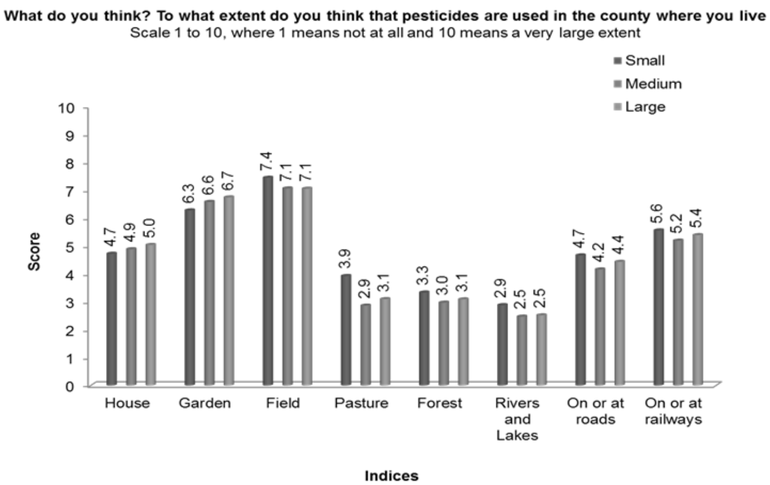

Figure 19. Perceptions of farmers in different farm size classes concerning the extent of pesticide use (mean score value) in various environments.

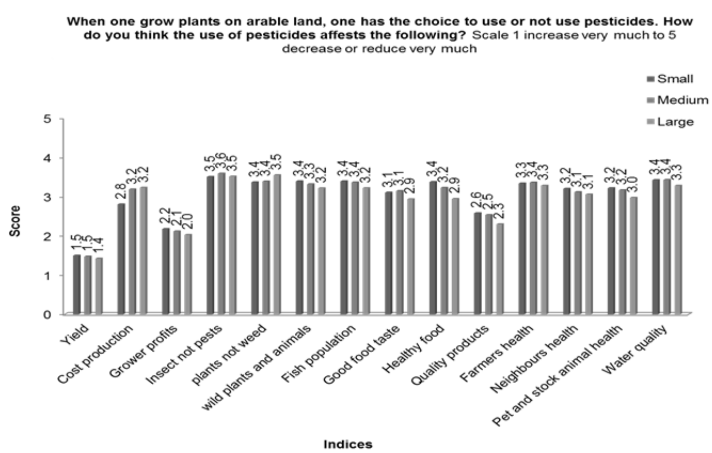

Figure 20. Perceptions of farmers in different farm size classes concerning the influence of pesticide use (mean score value) on various issues.

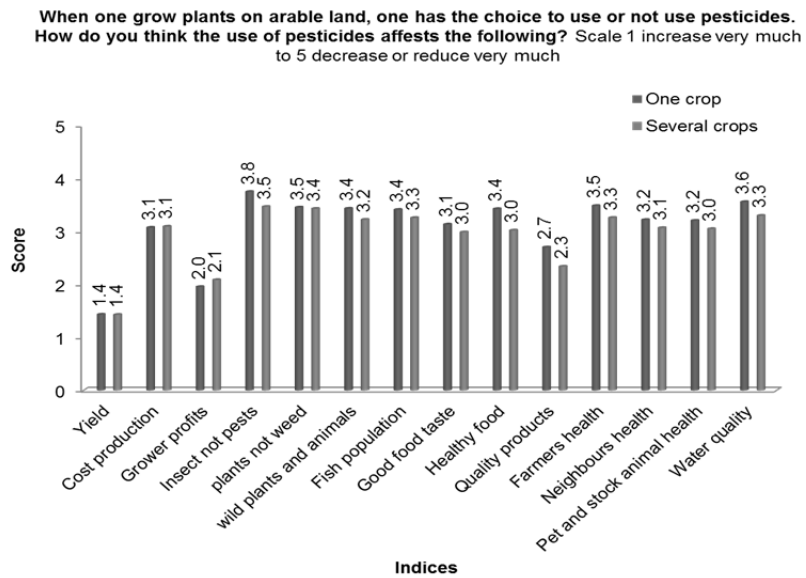

Figure 21. Perceptions of farmers growing only one crop or more than one crop concerning the influence of pesticide use (mean score value) on various issues.

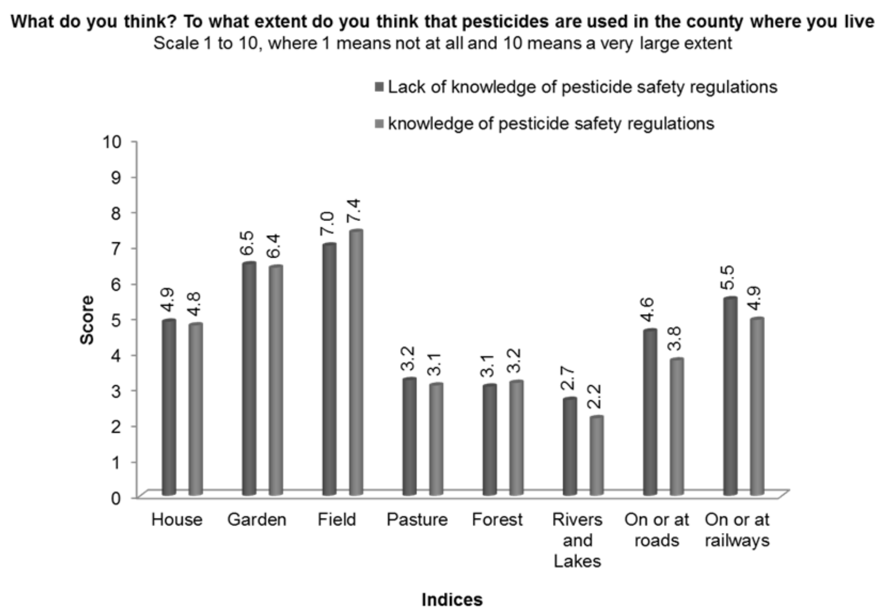

Figure 22. Perceptions of farmers with or without adequate knowledge about certain safety regulations concerning the extent of pesticide use (mean score value) in various environments.

6.4 Contribution of this thesis to understanding perceptions of pesticide use among different groups of people in periurban society

In general, **Papers I and II** revealed differences and similarities in perceptions of pesticide use among different groups of people in periurban society. Differences in perceptions of pesticide use were seen not only between farmers and neighbours, but also among different groups of farmers. The differences in perception among different groups of people within the periurban setting were characterised by variations in attitudes to pesticide use, perception of risk of harm, perception of extent of use and perception of influence on the environment, health and life quality. For some of the attitudes and perceptions evaluated in **Papers I and II**, there was a general consensus regarding whether pesticide use was positive or negative for certain issues. However, even though the perceptions among the groups corresponded, the level of risk and the degree of negative or positive perception often varied. For policy makers and pesticide regulatory authorities, these findings of different attitudes and perceptions, but also of different levels of perception, are important (Cole *et al.*, 2011; Robbins *et al.*, 2001; Birley & Lock, 1998). If people have totally contradictory perceptions, *e.g*. viewing tractors and pesticide spraying as being of high value in producing sufficient yield for economic gains and to fight hunger compared with viewing these as pollution and destroying the calm and friendly environment (Damalas & Hashemi, 2010; Hammond, 2002; Wilson & Tisdell, 2001; Handel, 1996; Lapping *et al.*, 1989), such contradictions have to be taken into account. The debates concerning organic farming and the use of GMO are well known to relate more to ethics, politics and feelings than to scientific evidence (Lehrman & Johnson, 2008; Mauro & McLachlan, 2008). Thus, these two issues clearly show the relevance of documenting perceptions for data support in decision making. The correlation between positive perceptions of pesticide use and actual pesticide use among farmers in **Papers I and II** might be partly related to the fact that some non-pesticide using farmers are organic growers with certain ethical values. Actual levels of risk perception differed, *e.g*. everyone agreed about the negative effects of pesticide use on the environment but some perceived it to be very negative and others perceived it to be only slightly negative, which might influence decisions and regulations (Cole *et al.*, 2011; Robbins *et al.*, 2001; Birley & Lock, 1998).

Location of the periurban area or setting (the areas Skåne and Mälardalen in **Papers I and II**) also influenced the perceptions of pesticide use. The respondents in Skåne were generally more positive to pesticide use than those in Mälardalen and there was a higher proportion of pesticide non-users in

Mälardalen than in Skåne (**Paper I**). A higher proportion of farmers with small farms in both areas were pesticide non-users (**Paper II**). Several previous investigations report similar differences between different study areas (SCB, 2010; Fogelfors *et al.*, 2009; SCB, 2007). Although, the same laws and regulations need to be valid throughout a country. Thus, in the implementation of new laws or regulations, variations in perceptions between locations may play a significant role (Cole *et al.*, 2011; Robbins *et al.*, 2001). For planning purposes, knowledge about variations in perceptions between regions is of significant importance (Cole *et al.*, 2011; Robbins *et al.*, 2001; Birley & Lock, 1998). The higher concern found among respondents in Skåne regarding the harm caused when agricultural land is used for settlements and traffic might be related to the higher dependence on arable or agricultural land in Skåne than in Mälardalen.

Besides the differences in attitudes and perceptions among groups of people and regions of a country, differences due to gender, age and education level have been reported in a number of studies (Franzen & Meyer, 2010; Van Tassell *et al.*, 1999; Davidson & Freudenburg, 1996; Flynn *et al.*, 1994; Dunlap & Beus, 1992). The aim of **Paper I** was not to compare the effects of differences in gender, age and education level on perceptions of pesticide use. However, the data collected in the study revealed that females and older persons perceived pesticide use to increase yield and grower profits more than did males and younger persons. Females generally showed a higher concern for harm to the environment by the use of pesticides than males. These results confirm previous findings that females perceive a higher level of environmental concern than males (Franzen & Meyer, 2010; Davidson & Freudenburg, 1996; Dunlap & Beus, 1992). Previous studies have also shown that older persons perceive pesticides to be less harmful for the environment than do younger persons (Van Tassell *et al.*, 1999; Dunlap & Beus, 1992), although contradictory results show older respondents perceiving a higher health risk from the presence of pesticide residuals in their food (Dosman *et al.*, 2001). In **Paper I**, respondents from Mälardalen had a higher level of education, were less prone to use pesticides and had a more negative view of pesticide use than respondents from Skåne. Another study has reported that non-pesticide users are generally more well educated than pesticide users (Nieuwenhuijsen *et al.*, 2005).

6.5 Influence of insecticide application in agricultural fields on the amount of pests and damage in neighbouring garden crops

Several studies have shown that the use of pesticides influences the environment and the immediate surroundings of the fields in which pesticides are applied (*e.g.* Kleftoyanni *et al.*, 2011; Potts *et al.*, 2010; Devine & Furlong, 2007; Mansfield *et al.*, 2006; Belfrage *et al.*, 2005; Bengtsson *et al.*, 2005; Langhof *et al.*, 2005; Langhof *et al.*, 2003; de Snoo & de Wit, 1998; Inglesfield, 1989; Croft & Brown, 1975). However, most of these studies have focused on: i) pesticide residuals in food (*e.g.* Dressel *et al.*, 2011; Yiridoe *et al.*, 2005; Saba & Messina, 2003; Miles & Frewer, 2001); ii) pesticide residuals in the surrounding water resources (*e.g.* Gonzalez *et al.*, 2012; Ali *et al.*, 2011); iii) wind drift during spraying (*e.g.* Langhof *et al.*, 2005; Langhof *et al.*, 2003; Holland *et al.*, 2000; Davis *et al.*, 1993); iv) negative impacts of pesticide use on wildlife and beneficial insects (*e.g.* Potts *et al.*, 2010; Belfrage *et al.*, 2005; Bengtsson *et al.*, 2005); and v) negative effects on human and animal health (*e.g.* Wesseling *et al.*, 2005; Whyatt *et al.*, 2002; Wesseling *et al.*, 2001). No previous study has evaluated the influence of insecticide use in field crops on nearby garden vegetables and flowers. In this thesis, the influence of pesticide use in field crops on the presence of three different insect pests (flea beetle, cabbage root fly and pollen beetle) in garden vegetables and flowers was evaluated. Oilseed rape was selected as the field crop, as several insect pests are shared between Brassica oilseeds and a number of garden crops and flowers, *e.g*. radish, broccoli and cauliflower and ornamental flowers (Richter & Michel, 2007; Hokkanen *et al.*, 1986; Wheatley & Finch, 1984; Free & Williams, 1978; Müller, 1941). A general finding in Papers **III and IV** was that insecticide treatment in the field influenced the presence of insects in nearby garden crops. The effect of insecticide application in farmers' fields on the numbers of insect pests in nearby garden crops could not be explained by wind drift, since a buffer zone was used between the field and the garden crop and the garden crop was covered by 'winter' fleece during spraying in **Paper III**, while in **Paper IV** the test plants were placed along the field well after insecticide application. **Papers III and IV** clearly showed a reduction in insect pests in garden crops, ornamental flowers and wild flowers adjacent to insecticide-treated farmers' fields compared with garden crops adjacent to untreated farmers' fields. This reduction in insect pests in garden crops adjacent to insecticide-treated farmers' fields was especially apparent for flee beetle (*Figure 23*; **Paper III**) and pollen beetle (*Figure 24*; **Paper IV**), but also for unspecified insect leaf damage (*Figure 25*; **Paper III**).

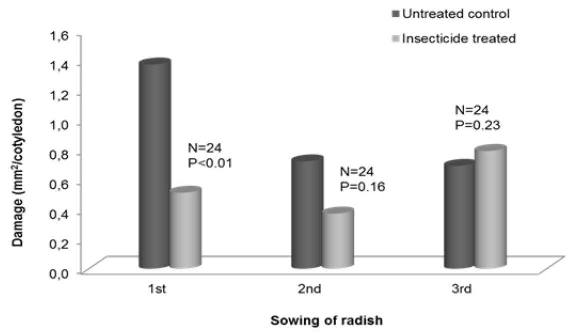

Figure 23. Flea beetle damage to cotyledons of radish grown adjacent to insecticide-treated or untreated spring oilseed rape (N = sample size).

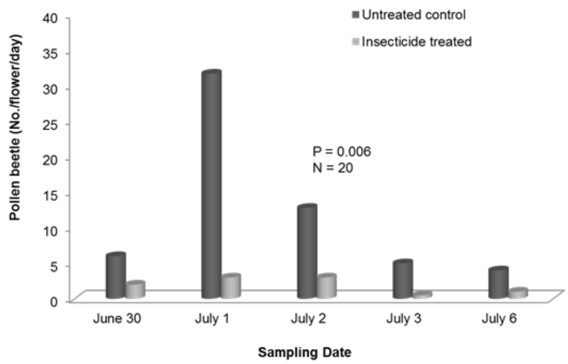

Figure 24. Mean numbers of pollen beetles in ornamental flowers (*Leucanthemum* sp.) placed alongside insecticide-treated and untreated winter oilseed rape (N = sample size).

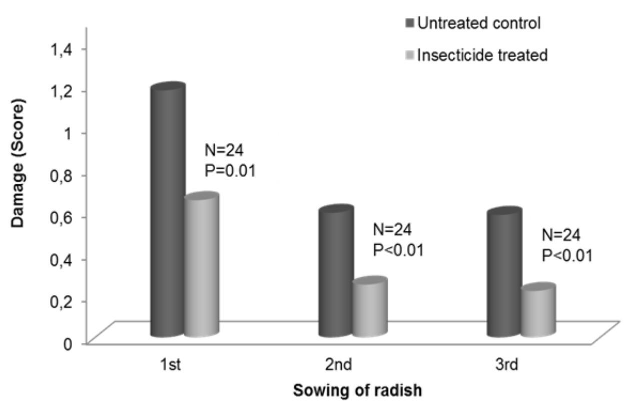

Figure 25. Unspecified damage to true leaves of radish grown adjacent to insecticide-treated and untreated spring oilseed rape (N = sample size).

However, for cabbage root fly, no relationship was found between the use of insecticides in the farmers' field and presence of the insect pest in the garden crop (**Paper III**). One explanation for this is that the pesticides used were pyrethroid deltamethrin, tau-fluvalinate and organophosphate fenitrothion, which specifically target the beetles evaluated in **Paper III** but not the cabbage root fly (Williams, 2010; Erichsen & Hünmörder, 2005; Alford *et al.*, 2003; Ekbom, 1995). Thus, the conclusion can be drawn that pesticide application to control a target insect pest in adjacent farmers' field reduces the numbers of that same insect pest in nearby gardens. However, various insects might also differ in sensitivity to nearby insecticide application, so that will also influence the numbers present in the surroundings. For influences in the surrounding gardens, immigration and emigration patterns of the target insect play a role.

Other factors that might determine the influence of pesticide application in nearby farmers' fields on insect pests in garden crops include: i) the time span of insecticide treatment during the season (Hiiesaar *et al.*, 2003); ii) the time during the season when garden crops and flowers are available for the insect pests (Richter & Michel, 2007; Hokkanen *et al.*, 1986; Wheatley & Finch, 1984; Free & Williams, 1978; Müller, 1941); iii) the kind of crops and/or flowers grown in nearby gardens (Richter & Michel, 2007; Hokkanen *et al.*, 1986; Wheatley & Finch, 1984; Free & Williams, 1978; Müller, 1941); the colour of flower petals (Cook *et al.*, 2006; Blight & Smart, 1999; Giamoustaris & Mithen, 1996); and iv) the direction and distance between farmers' fields and adjacent garden crops and flowers (Williams *et al.*, 2007; Nilsson, 1988a). **Paper IV** showed that when new generation pollen beetles peaked in the farmers' field, insecticide treatment of the old generation reduced the number of beetles in nearby ornamental flowers. Later, when pollen beetle numbers stabilised, no significant difference was found in numbers of pollen beetles in ornamental flowers adjacent to pesticide-treated and untreated farmers' fields. However, at later sampling occasions during the season, the number of pollen beetles was generally rather low in all sampled flowers. Furthermore, few or no pollen beetles were recorded in some of the ornamental flowers used in **Paper IV**, or in the broccoli or cauliflower. Reports from England, Finland and Germany show that pollen beetles attack both cauliflower and broccoli during late summer, causing damage in the form of brown feeding scars (Richter & Michel, 2007; Hokkanen *et al.*, 1986; Wheatley & Finch, 1984; Free & Williams, 1978). A possible explanation for the broccoli and cauliflower not being attacked in the present study is that there may have been enough preferred flowers along the WOSR field for the new generation beetles to feed on during the study period. Another explanation might be that the quality of the test heads of cauliflower and broccoli, which were cut and kept in water, was inferior to that of heads growing normally, causing the test heads to be rejected by the pollen beetles.

6.6 Influence of the direction and distance from agricultural fields to garden crops on the amount of pests and damage in those crops

The direction of the garden crops in relation to the farmers' fields affected the abundance of insect pests in the garden crops (**Paper IV**). The importance of direction was evident both in terms of the number of pollen beetles collected in window traps alongside the field crop and in number of pollen beetles in ornamental flowers and wild-type flowers placed/present in various directions around the farmers' fields (*Figure 26*; **Paper IV**). The prevailing wind direction has previously been found to be significant for pollen beetle movements (Nilsson, 1988c), as confirmed in **Paper IV**. Reports indicate upwind and downwind flying of beetles entering and leaving an oilseed rape field, respectively (Williams *et al.*, 2007).

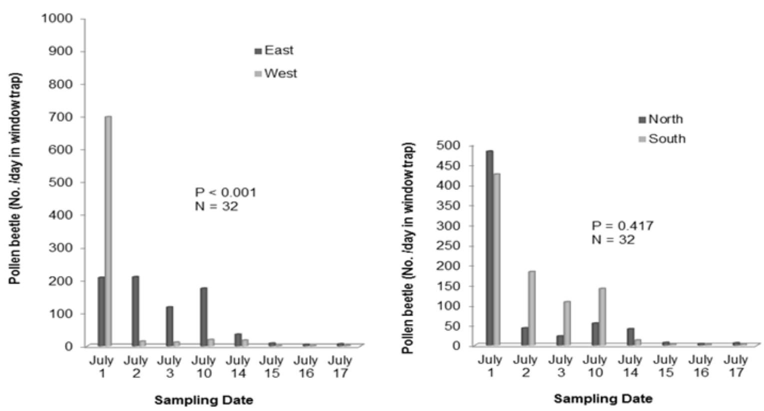

Figure 26. Mean number of pollen beetles in window traps alongside a winter oilseed rape field, presented in relation to direction (N = sample size).

Another important parameter for the presence of insect pests in garden crops was the distance between the garden crop and the agricultural field, especially for some pests. **Paper III** showed that damage by cabbage root fly to the roots of a garden crop of radishes was negatively correlated to the distance to a farmers' field of SOSR, especially early in the season (*Figure 27*; **Paper III**).

However, the distance between the farmers' field and the garden crop did not seem to influence the amount of flea beetle damage to the radish crop (**Paper III**). Thus, the relationship between distance to farmers' fields and presence of insect pests in garden crops depends on the type of insect pest evaluated. Factors that might influence this relationship include variations in the life cycle of different insects and the immigration and emigration behaviour of the insects (Jonsson, 2007; Williams *et al.*, 2007). As for cabbage root fly, the large areas of a rapeseed field might attract immigrating females (Prokopy *et al.*, 1983; Hawkes & Coaker, 1979; Hawkes *et al.*, 1978). Thus, while the immigrating females are flying to the field, they might land on garden crops (radish) nearby. Adult cabbage root flies are good fliers and can migrate more than 2-3 km, often moving 80-100 m/day (Hawkes *et al.*, 1978; Finch & Skinner, 1975).

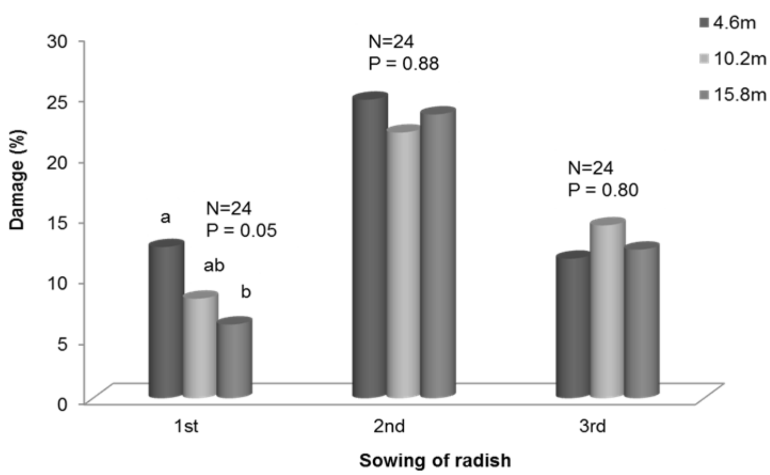

Figure 27. Cabbage root fly damage to radish crops grown at different distances from insecticide-treated and untreated spring oilseed rape (N = sample size).

6.7 Contribution of this thesis to understanding the influence of pesticide use by farmers in the periurban area on the presence of pests in neighbouring crops

Papers III and IV clearly demonstrated that insecticide application in farmers' fields also influenced the numbers of insect pests in nearby garden crops and ornamental and wild flowers. However, a number of factors can affect the amounts of insect pests present in garden crops and flowers. The most relevant of these is the type of field crop grown nearby (Gladbach *et al.*, 2011; Zaller *et al.*, 2008; Valantin-Morison *et al.*, 2007). Oilseed rape shares a number of insect pests with common garden crops and flowers (CABI, 2011; Gladbach *et al.*, 2011; Zaller *et al.*, 2008; Valantin-Morison *et al.*, 2007; Ekbom & Borg, 1996; Hokkanen *et al.*, 1986; Charpentier, 1985; Wheatley & Finch, 1984; Müller, 1941) and was therefore a relevant study object. The next most important factor for the presence of insect pests in garden crops and flowers is that crops and flowers grown in nearby gardens can act as hosts (Hokkanen *et al.*, 1986). Selecting garden non-host crops for the insect pests of the nearby field crops might thus reduce the presence of pests in the gardens (Sarfraz *et al.*, 2010). Another highly relevant factor for the presence of insect pests in garden crops and flowers, as shown in **Papers III and IV**, is the life cycle of the insect pests in relation to the timing and type of pesticide use in farmers' fields. The correct time for pesticide treatment and the 'correct' pesticide for the actual field abundance of insects can be determined using knowledge of life cycles and economic damage threshold values (Williams, 2010; Menzler-Hokkanen *et al.*, 2006; Hiiesaar *et al.*, 2003; Lane & Walters, 1993). Suitable timing and pesticide type are likely to reduce the number of insects in the garden vegetables and flowers as well (**Paper**s **III and IV**). Such a treatment might even be less negative for the pests in the neighbours' environment than applying insecticides directly in the gardens when farmers do not use pesticides on their field crops. Pesticides used for gardens are sometimes more harmful for the environment and are also commonly used in larger doses than pesticides used in field crops (Cole *et al.*, 2011; Crane *et al.*, 2006; Robbins *et al.*, 2001). Pesticide use to produce healthy and tasty food field crops should perhaps also be compared with pesticide use to produce attractive gardens (Bethke & Cloyd, 2009; Nothnagl, 2006; Henry, 1994). In the periurban area, strategies for pesticide use are even more important than in more rural areas, as the population has less space and the environment is sometimes 'overused' (Cole *et al.*, 2011; Robbins *et al.*, 2001; Fleury, 2000; Birley & Lock, 1998). Therefore, in planning and regulatory processes in periurban areas, it is important to know about differences and similarities in perceptions of pesticide use among groups of people living in the area (**Paper**s **I and II**) and about the actual risks and economic benefits of pesticide use (**Papers III and IV**). The work presented in this thesis also shows the importance of direction and distance between garden crops and farmers' fields for prediction of insect pest incidence in garden vegetables and flowers. Including all the above-mentioned factors in predicting the effect of pesticide use in farmers' fields on garden crops and flowers is complicated. However, the knowledge obtained can add to the understanding of conflict issues in the periurban area.

7 Conclusions

Farmers and neighbours and different groups of farmers expressed varying perceptions and attitudes to pesticide use in the periurban area. Neighbours generally perceived pesticide use to be more dangerous and less valuable than farmers. Despite this fact, neighbours used pesticides more commonly than they were aware of, actually as often as their neighbouring farmers when comparing use in the home setting. In addition, neighbours benefited from pesticide use in farmers' fields when their garden pests were the same as those treated in the field. Geographical region, gender, age and education level were also found to influence perceptions and attitudes to pesticide use to various degrees. Different groups of farmers differed in their perceptions and attitudes to pesticide use firstly depending on whether they were pesticide users or non-users and secondly depending on their farm size.

Insecticide application to control specific pests in agricultural fields was shown to reduce pest-related damage in neighbouring garden crops and ornamental flowers. Pest damage and the amount of different insect pests in neighbouring garden vegetables or ornamental flowers was influenced by the type of these vegetables or flowers, the timing and type of insecticide application in the agricultural field, the type of insect pests and their life cycle and peaks of outbreak, insect flight direction and distance between the garden crop and the farmers' field. The most likely reason for the decrease in certain pests in garden crops and flowers was a general decrease in the population of that pest in the agricultural field due to insecticide use.

In periurban planning and regulation of pesticide use, it is important to address variations in views between different groups in society. Such variations may be of particular importance in the periurban area, where farmers and other professional groups are living close together. Further understanding of actual pesticide use by the different groups is also important. Therefore, the results of this thesis regarding the attitudes and perceptions of various groups in a periurban society and insect pest damage in crops neighbouring untreated or insecticide-treated farmers fields are useful for stakeholders and policy makers when prioritising actions to avoid serious social, environmental and pest problems in the future.

8 Future perspectives

- In-depth studies are needed to address farmers' and neighbours' perceptions, attitudes, beliefs, views and opinions and to develop periurban planning. Critical land use for agricultural purposes is important for society.

- It would be interesting to investigate how perceptions and attitudes differ among different groups of neighbours or non-farmers.

- Little is known about influence of pesticide use in domestic gardens on the environment. In developed countries, use of chemicals such as pesticides and fertilisers in gardens is a debatable issue, particularly in periurban and urban areas. Further studies are therefore needed.

- It might be interesting to examine whether shared pests (pest sources) and pest management in garden crops have any influence on agricultural pests. It would be particularly interesting to compare organic and conventional agricultural field systems and gardens in this regard. Other factors such as surrounding crops, presence of trap or other host crops, and crop management might be important too. To strengthen the findings of this thesis, a further large-scale study considering the above factors could be of interest.

- An interesting issue for future research would be to evaluate the relationships between pest-related agricultural practices and perceptions and attitudes.

- Similar studies to this should be carried out in developing countries. For example, in Bangladesh, one of the most densely populated countries in the world, farmers and neighbours live very close together. The agricultural land is fragmented, with small farms and intensive use of chemicals, *e.g*. pesticides and fertilisers, to meet the ever increasing demand for food. It would be interesting to evaluate variations in perceptions and attitudes to agrochemicals, *e.g*. pesticides and fertilisers, among different groups of people in society in developing countries. Finally, comparisons of pesticide use in developed and developing countries might be another interesting issue for future research.

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Appendix

USE OF PESTICIDE

1. Agriculture affects many relationships in society. How important is this for you?

Scale of 1 to 10, where 1 means not at all important and 10 means extremely important

	Not at all important 1	2	3	4	5	6	7	8	9	Extremely important 10
Food prices										
Food quality										
Human health										
Animal Health										
Wild plants and animal welfare										
Clean water										
Landscape appearance										

2. To what extent do you think the following factors harm the environment?

Scale of 1 to 10, where 1 means not at all and 10 means a very large extent

	Not at all 1	2	3	4	5	6	7	8	9	Very large extent 10
Pesticides used in gardens										
Pesticides used in agriculture										
Fertilizer use in agriculture										
Animal husbandry in agriculture										
Fish farming										
Agricultural land used for settlements										
Traffic										
Chemicals used in industry										
Waste in nature										
Sewage discharges										

3. **What do you think? To what extent do you think that pesticides are used in the county where you live**

Scale of 1 to 10, where 1 means not at all and 10 means a very large extent

	Not at all 1	2	3	4	5	6	7	8	9	Very large extent 10
In housing										
In gardens										
On fields										
On pastures										
In the forest										
In rivers and lakes										
On or at the road sites										
On or at the railways										

4. What do you think about the use of pesticides? Is it…..

Very good = 1

Pretty good = 2

Neither good nor bad = 3

Rather bad = 4

Very bad = 5

5. **Which of the following uses pesticides within 10 km from your home?**

You yourself	Yes=1 No=0
Those who are farmers	Yes=1 No=0
Those who are not farmers	Yes=1 No=0
State or municipality	Yes=1 No=0

6. When you grow plants on arable land, one has the choice to use or not use pesticides. How do you think the use of pesticides affects the following?

	Increases very much = 1	Increases small = 2	No difference = 3	Reduce small = 4	Reduce very much = 5
Yield					
Cost of food production					
Grower profits					
Number of insect species that are not pests					
Number of plant species that are not weeds					
Number of wild plants and animals in the environment					
Fish populations					
The good taste of food					
Healthiness of food					
Quality of products					
Farmers' Health					
Neighbours' Health					
Pet and stock animals' health					
Water quality					

7. Have you had a garden of your own for private purposes in 2008? Yes No

8. How many times in 2008, have you yourself or someone else used pesticides in your home or your garden against

	Number of times
Rats and mice	
Ants	
Wasps	
Mosquitoes and black flies	
Cockroaches	
Flies	
Storage pests in food, e.g. mealy worm	
Pests on potted plants	
Snails	
Weeds in garden paths	
In order to protect garden flowers	
In order to protect vegetables	
In order to protect fruit and berries	
Moles and voles	
Game	
Other, What?..	

9. By which of the following ways do you get you information about the pesticides that you or any other person use in your garden and your home?

Neighbours	Yes=1 No= 0
Consultants, e.g. Anticimex	Yes=1 No= 0
Adviser on plant cultivation	Yes=1 No= 0
Authorities	Yes=1 No= 0
Dealers of pesticides	Yes=1 No= 0
The text on the packages/labels	Yes=1 No= 0
Newspapers and magazines	Yes=1 No= 0
Radio and TV	Yes=1 No= 0
Internet	Yes=1 No= 0

10. What year were you born? 19 …….. **11. Are You ...** Female … Male…..

12. How many people including with yourself live in the same household as you do? Number of persons:

13. How many children less than 18 years live in your household? Number of children less than 18 years:……………..

14. How much education do you have?

9 years or less, such as basic public school

10-12 years e.g. gymnasium, professional or girls' school

13 years or more, but not academic

Academic

15. Have you been engaged in commercial agriculture or commercial horticulture in 2008?

Yes, proceed to Question 16!

No, EXIT SURVEY!

THANK YOU FOR YOUR HELP!

If you have run commercial farming or commercial horticulture

16. How big was the total area of arable land and pasture in your operating unit that you or someone else managed in 2008? Include also the rented land. Total number of hectares:

17. How big was the area of the various crops in 2008? Number of hectares:

Winter wheat for harvest in 2008

Winter wheat for harvest in 2009

Spring wheat

Barley

Triticale

Rye

Oat

Pulses

Sugar beet

Winter oilseed rape for harvest in 2008

Winter oilseed rape for harvest in 2009

Spring oilseed rape

Potatoes

Vegetables

Which? ....

Forage for fodder

Pasture only

Fruit / flowers for sale

Set aside land

Catch crops

Other, What? ....

18. How many times have you yourself or someone else used pesticides (including seed application) against fungal diseases in various crops in your farm in 2008?

Number of times

Winter wheat for harvest in 2008
Winter wheat for harvest in 2009
Spring wheat
Corn
Triticale
Rye
Oat
Pulses
Sugar beet
Winter oilseed rape for harvest in 2008
Winter oilseed rape for harvest in 2009
Spring oilseed rape
Potatoes
Vegetables
Forage for fodder
Pasture only
Fruit / flowers for sale
Other , What? ....

19. How many times have you yourself or someone else used pesticides (including seed application) against insects in various crops in your farm in 2008?

Number of times

Winter wheat for harvest in 2008
Winter wheat for harvest in 2009
Spring wheat
Corn
Triticale
Rye
Oat
Pulses
Sugar beet
Winter oilseed rape for harvest in 2008
Winter oilseed rape for harvest in 2009
Spring oilseed rape
Potatoes
Vegetables
Forage for fodder
Pasture only
Fruit / flowers for sale
Set aside land
Catch crops
Other, what? ....

20. How many times have you yourself or someone else used pesticides against weeds in the various crops or before sowing in your farm in 2008?

Number of times

Winter wheat for harvest in 2008
Winter wheat for harvest in 2009
Spring wheat

Corn
Triticale
Rye
Oat
Pulses
Sugar beet
Winter oilseed rape for harvest in 2008
Winter oilseed rape for harvest in 2009
Spring oilseed rape
Potatoes
Vegetables
Forage for fodder
Pasture only
Fruit / flowers for sale
Set aside land
Catch crops
Other, What? ....

21. By which of the following ways do you get information about the pesticides that you or any other person use in your farm?

Neighbours	Yes=1 No= 0
Adviser on plant cultivation	Yes=1 No= 0
Authorities	Yes=1 No= 0
Dealers of pesticides	Yes=1 No= 0
The text on the packages/Labels	Yes=1 No= 0
Newspapers and magazines	Yes=1 No= 0
Radio and TV	Yes=1 No= 0
Internet	Yes=1 No= 0

22. What is the minimum safe distance you should have when you professionally spray pesticides?

	Number of meters:
For drinking water reservers	
For rivers and lakes	
For drainage wells and trenches	

23. What is the minimum safe distance you should have to all kind of water mentioned above when cleaning or filling the spray equipment? Number of meters:

THANK YOU FOR YOUR HELP!