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Summary

This introductory paper focuses on pesticides; use, regulation, impact on nature, economics, and interactions with pests, non target organisms as well as society in the periurban environment and with an international context. With an increasingly skeptical society to pesticides it is important that scientists and non-specialists (farmers and neighbours) meet and discuss their ideas about insecticide use and risks. This is necessary because the public's perception of risks may well diverge significantly from that of specialists. In the periurban areas (the urban fringe) these problems and divergent opinions are likely to be more pronounced than in the rural areas. This review paper is also discussing the insect pest migrations and trap cropping with a view to find out whether insecticide application in field crops (e.g. oilseed rape) affects pest density in the adjacent garden crops (e.g. radish).

Preface

This introductory paper is a review based on references from libraries, internet and personal communication. It elucidates pesticide use and its interactions with nature as well as society in the periurban context but with an international perspective. This review gives a background to a coming PhD-study on pesticide use, interactions between farmers and neighbour gardeners and insect pest situation of farmers field and nearby garden crops. Oilseed rape and radish are used as examples of farmers field and neighbour garden crops, respectively, with flea beetles and cabbage root flies as common insect pests of both crops. Interactions between farmers and neighbours use of pesticides in two societies, Bangladesh, one of the most densely, and Sweden, sparsely populated will be studied.

Contents

Introduction

Agriculture, a term which encompasses farming, is the process of producing food, feed, fiber and other goods by systematic raising of plants and animals. The human history is closely related to the history of agriculture. Development of agriculture has been a crucial factor resulting in social change and specialization of human activities (Wikipedia). The agricultural activities generally occur in rural, urban and periurban areas. They consist mainly of producing crops, fish, meat and egg. Processing and marketing also takes place, especially in the urban region in order to get higher prices. A large part of the urban vegetable market supply is accounted for by the periurban and urban productions. For example, in the capital city of Hanoi, 80% of the vegetables are from the Province of Hanoi and in Brazzaville, 65% of the marketed vegetables come from the urban gardens (Moustier 1999; Bon de 2001).

Periurban Definition and Concept

The periurban interface is a transitional area between city and countryside, meaning not a discrete zone, but rather a diffuse territory. The area is identified by combinations of features and phenomena, generated largely by activities within the area (Adell 1999). The area is a zone of mixed land use elements and characteristics. The area is sometimes also termed the rural-urban fringe. Within the area, rural activities are in rapid change and not only residential, but also commercial, educational, recreational, public services and other largely extensive uses of land are intruding (Thomas 1974). Periurban agriculture takes place on the fringe of a town, a city or a metropolis while urban agriculture is located within the town, city or metropolis. Within the urban and periurban agriculture (UPA), a diversity of food and non-food products are grown or raised, processed and distributed. Also, human and material resources, products and services found in and around that urban area are largely (re)-used. In turn UPA supplies human and material resources, products and services primarily to that urban area (Mougeot 2000). UPA systems include aromatic and medicinal herbs, all types of crops such as cereals, root crops, vegetables, fruit as well as livestock of all types. Also, some systems include plants like ornamentals and tree seedlings. Food and non-food production is often mutually complementary. As for food crops, relatively high-valued, perishable vegetables and animal products and by-products are more common. Although medium sized and larger enterprises are present, the main urban farmers are small-scale family enterprises. Therefore, urban agriculture is carried out additionally to other types of employment. Urban agriculture is found beneficial since it leads to increased food security as well as income levels, both for individuals and at household levels (Zeeuw & Lock 2000).

In many developed countries periurban areas are presently undergoing major transformations. The expansion of urban areas into the surrounding landscape entails the transformation of land use, population composition and business structures. Periurban areas made on scarce land resources are therefore dynamic landscapes, areas of tension and conflicts, with various clashes of interests, and contradictory demands (Busck *et al.* 2006). The processes of urbanization affect land use and social systems of rural communities near urban agglomerations (Bryant & Johnston 1992). Farm properties in periurban areas may attract newcomers with little or no relation to agricultural production. The reason might be a cheap housing alternative, a pleasant living environment away from pollution and social problems of the city, more space for hobby activities or other qualities (Berg & Wintjes 2000). The new landowners' lifestyle may still be strongly attached to nearby urban areas in terms of social, cultural and occupational relationships, made possible by improved infrastructure and mobility. Also, former full-time farmers often seek stronger relations to nearby urban areas e.g. by commuting to off-farm work or engaging in agro-tourist activities (e.g. bed and breakfast) due to the structural development within the agricultural sector. The conventional agricultural areas as suppliers of agricultural products are in other words contested and urban values and lifestyles are encroaching upon agricultural areas (Antrop 2000).

In developing countries agricultural policies have focused strongly on rural areas, aiming to achieve self sufficiency in food production and to reduce rural poverty. Urban food needs are also expected to be fulfilled by production in rural areas. The UPA is a major source of produce in developing countries, leading to improved food security and enhanced livelihoods of poor producers (Bakker *et al*. 2000). Much of the evidence for this has been gathered from African, Latin American, Caribbean and some Asian and Eastern European countries (Lintelo *et al*. 2001).

Criteria defining periurban agriculture differ and relate to population sizes, density thresholds, official city limits (Gumbor & Ndiripo 1996), municipal boundaries of the city (Maxwell & Armar-Klemesu 1998), agricultural land zoned for other use (Mbiba 1994) or agriculture within the legal and regulatory purview of urban authorities (Aldington 1997, also cited by Mougeot 2000). One determination of the outer boundary of periurban zones is based on varying ratios of buildings and roads and increasing ratios of open space per km^2 (Losada *et al*. 1998). Maximum distance away from city centre in which farms can supply the city on a daily basis is another way (Moustier 1998, also cited by Mougeot 2000). Additionally, areas that people living within the city's administrative boundaries can reach, in order to engage themselves in agricultural activities, is used (Lourenco-Lindell 1995). Demographic and economic expansion of cities, through migration and industrialization, tend to be accompanied by spatial expansion, resulting in encroachments by cities upon adjacent periurban areas. Areas that were then earlier distant from the city and rural in character subsequently start falling within the cities' reach or "band of influence". The rural–periurban–urban continuum is thus dynamic in nature. Changes will be more marked around cities that are rapidly urbanizing or growing both economically and spatially, as compared to slower-growing or stagnant urban cores (Lintelo *et al*. 2001).

UPA might affect the environment as well as the health of the urban population both negatively and positively. Intensive urbanization is creating extreme ecological disturbances, caused by sewage water, city garbage, industrial waste etc. Spread of different type of hazardous elements in the UPA region might take place due to e.g. use of chemical fertilizers and pesticides. However, proper agro-ecological solutions can offer mutual benefits both to farmers and to the city population. Such solutions might be; recycling of sewage water for irrigation, changing garbage into compost and industrial waste into animal feeds, and the use of precision agriculture in the periurban environment (Zeeuw & Lock 2000).

Pesticides and Pests

Chemical-based strategies have been the preferred form of pest control in agriculture since the 1950s and have contributed to an unprecedented growth in agricultural production and productivity (Pimentel 1978; 1991; Pimentel & Greiner 1997; Anonymous 1990). Since the end of the 1970s, the on-farm benefits of pesticide use has been weighed against concerns over the off-farm costs of pesticide risks to human health and the environment. The wider perspective prompted many regulatory agencies, at both national and international levels, to implement different types of pesticide risk management policies. These policies ranged from liability rules to market-based instruments and from command and control approaches to incentives for voluntary action including moral persuasion. Still, management of pesticide risks is a difficult task for policy makers (Smith *et al*. 1998; Travisi *et al*. 2006).

Pests are the main constraints of a successful crop production. Worldwide crop losses due to agricultural pests are estimated to be about 15-25% and potential losses 30-40% (Sherwood *et al*. 2003; FAO 2005a). The crop loss varies due to the particular crop, place, time and farmers' knowledge. To address the pest problems a variety of methods can be used e.g. resistant variety, cultural and physical control, biological control, botanical control as well as chemical control. The principle of integrated pest management (IPM) is to primarily utilize other control methods and only as the last choice the chemical method. Crop researchers often advice farmers to use pesticides when pests are reaching the economic threshold level (ETL). However, sometimes these advices are not followed but instead pesticides are used indiscriminately and at substandard or higher doses. The latter might be especially common in developing countries with a lower degree of education among farmers. The indiscriminate use of pesticides may result in pest resurgence, and polluted soil, air and water. Though pesticides control pests, they also commonly kill natural enemies of pests. Main user of pesticides in developing countries is farmers within rural societies (FAO 2005a). In urban and periurban societies including farms and agriculture, the proper use of pesticides is of utmost importance due to the often relatively densely populated surroundings (Ferrier *et al*. 2006).

A. Pesticide Use and Social Attitude

Definition and History of Pesticide

The US Environmental Protection Agency (EPA) defines a pesticide as "any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest or intended for use as a plant regulator, defoliant or desiccant". A pesticide may thus be a chemical substance or biological agent (such as fungus or bacteria) used against pests including insects, plant pathogens, weeds, molluscus, birds, mammals, fish, nematodes (roundworms) and microbes that compete with humans for food, destroy property, spread disease or are a nuisance. Many pesticides are poisonous to humans (Greene 1994; US EPA 2007; Wikipedia).

Elemental sulfur dusting, the first known pesticide, was used in Summer about 4,500 years ago. Later, e.g. in the 15th century, toxic chemicals such as arsenic, lead and mercury were found useful applied to crops to control pests and diseases. Tobacco leave extracts containing nicotine sulphate was used as an insecticide in the 17th century. During the 19th century, two other natural pesticides were introduced, pyrethrum and rotenone which are derived from chrysanthemums and roots of tropical vegetables, respectively (Miller & Tyler 2002; Wikipedia). In 1939, Paul Hermann Müller discovered that Dichloro-diphenyl-trichloroethane (DDT) was a very effective insecticide. It quickly became the world's most widely used pesticide. However, in the 1960s, DDT was found to be a huge threat to biodiversity by preventing many fish-eating birds from reproducing. In May 1962, biologist Rachel Carson alerted the public to the side effects of pesticide use in her best-selling book, *Silent Spring* (Carson 1962). Questions were raised about the actual (rather than the perceived) benefits of pesticides. Also, environmental and public health risks (biological magnification or bioaccumulation of DDT) were discussed. At present, DDT is banned in about 86 countries. However, it is still used to prevent malaria and other tropical diseases in some developing nations as it kills mosquitoes and disease-carrying insects (Lobe 2006). Since 1950, there has been a 50 fold increase in pesticide use, and now 2.5 million tons of industrial pesticides are used every year (Miller & Tyler 2002; Wikipedia). The total expenditures on pesticides in the world were higher than $US32.5 billion in 2000 and more than a thousand active ingredients are commonly used world-wide (Miller & Tyler 2002; US EPA 2004a & 2004b).

Pesticide Use in Agriculture and Surroundings

The use of pesticides has increased over the last five decades and has resulted in higher yields of crops. The main reasons for this are that they are effective (control >90% of susceptible pests rather easily), posses immediate action, are effective over wide and diverse areas, not too dependent on special conditions of weather, temperature etc., convenient to transport, manufacture, distribute and apply, do not require much pest monitoring and need only little pest knowledge (Wang 2003). In developed agricultural systems, most emphasis has been directed towards weed management. Also, in developing countries, use of herbicides is increasing in response to greater awareness of weed competition and labour constraints at a critical period of crop establishment (CropLife 2007). Careful use of pesticides has not only improved crop production, by provision of healthy food, but also contributed to increased life expectancy as stated by Avery (1997). However, environmental concerns have led to greater regulation of the use of pesticides, although in contrast to the investment in developing new pesticides, relatively less research has been directed at improving their application. Furthermore, globally, little investment has been made in ensuring that pesticides are applied by trained persons, although in many EU countries, there is an obligatory training and certification for those applying pesticides on farms (Matthews & Thomas 2000).

Apart from in agriculture, herbicides are used on roadsides, public lands, railroads, golf courses, along canals, power lines, of schools etc. to improve safety, and for clean and good looking surroundings. Also, pesticides are used for controlling pest infestations in homes and institutions, and for lawn maintenance (Coppin *et al*. 2002).

Pesticide Use in Public Health

Beside the agricultural application, pesticides play a vital role in public health programmes across the world. Pesticides help to eliminate pests that often cause serious illness or cause billions of dollars of property damage. Pesticides are used for household control of insects but also for large-scale control of vector-borne diseases (CropLife 2007).

Vector-borne diseases (including a number that are mosquito-borne) are a major public health problem internationally. Dengue and malaria are endemic in many tropical and subtropical countries. Malaria, most likely the number one vector-borne disease worldwide, continues to increase in many areas. Malaria is estimated to cause 300 to 500 million cases worldwide each year, with 1.5 to 2.7 million deaths, most fatalities occurring in Africa (Gratz 1999). Since 1975, the mosquito-carried disease dengue has surfaced in huge outbreaks in more than 100 countries, resulting in 100 million cases each year (Gubler 1998). The flea-transmitted disease plague has reemerged and a definite trend of increase has occurred worldwide since 1981 (Dennis 1998). Other vector-borne diseases continue to pose a public health threat and new vector-borne threats continue to emerge. In 1999, West Nile virus was first recorded in New York signaling the potential for similar outbreaks in the Western Hemisphere (Nosal & Pellizzari 2003).

Pesticides traditionally used in response to epidemics, have a role in public health also for the prevention of vector-borne diseases. Mosquito control may include insecticide application for control of adult mosquitoes, and integrated pest management programs that include surveillance, source reduction, larvicide, and biological control (CropLife 2007). Pesticide use, while widely criticized, is an essential part of the multi-faceted efforts needed to control diseases (Goddard 2002).

Impact of Pesticides in the Environment

Environment and health might be strongly influenced by heavy agricultural reliance on synthetic chemical fertilizers and pesticides. For example, atrazine, one of the main herbicides used for weed control by e.g. 90% of US corn farmers is also one of the commonly found pesticides in streams and ground water (Pimentel *et al*. 1993; Pimentel *et al*. 2005; USGS 2001). Pesticides are poisons and can be dangerous when misused. Fish kills, reproductive failure in birds, and acute illnesses in people have all been attributed to exposure to or ingestion of pesticides. Pesticide losses from areas of application and contamination of non-target sites such as surface and ground water represent a monetary loss to the farmer as well as a threat to the environment. Thus careful management of pesticides in order to avoid environmental contamination is desired by both farmers and the general public. There are basically two ways properly-applied pesticides may reach surface and underground waters; through runoff and leaching. Two other pathways of pesticide are through removal in the harvested plant and by vaporization (volatilization) into the atmosphere. Probably loss by runoff is less than 5%, amount of losses by leaching is less than 1% and volatilization may account for 40-80%, depending on physical properties and environment. Losses to the atmosphere may also occur during the process of application (Plimmer 1992).

Crop or Foodstuff

Uptake of pesticides by plant as well as the transfer into the edible plant parts is an obvious phenomenon. The amount found in the edible parts depends on pesticide and plant types. A large amount of evidence shows the association between pesticides and illness of different types (Solomon *et al*. 2000). The presence of residues in fruits and vegetables can be a significant route to human exposure (EC 1990).

Governments and international organizations are regulating the use of pesticides, setting the acceptable Maximum Residue Limits (MRLs) in foods. When pesticides are applied according to good agricultural practices, MRLs should not be exceeded. Incorrect application may leave harmful residues, leading to possible health risk and environmental pollution (CropLife 2007). Especially in developing countries, residue problems are gaining increasing importance, due to the lack of government inspections and awareness of the producer and consumer. As a consequence, food consumers are faced with food products which might have high residue levels (Cengiz *et al*. 2007). Residue levels of organochlorine pesticides (hexachlorocyclohexane, aldrin and DDT) have been determined in raw fruits, vegetables and tubers from markets, e.g. in Nigeria (Adeyeye & Osibanjo 1999). Similar types of residues have also been found in a range of vegetables (carrots, lettuce, radish and cabbage) and food products (milk, bread menus and coffee) from other countries e.g. Romania (Hura *et al*. 1999).

Residues of several pesticides are found in food and also within raw materials for e.g. baby food production. Although residues are detected and quantified, the raw material can still be used for e.g. baby food production, if the residues are below MRL for the specific use (Domotorova *et al*. 2006).

Natural Enemy Community

Pesticide use may result in pesticide resistance (Hansen 2003) and harmful effects on non-target organisms (Greig-Smith 1990). For example, alpha-cypermethrin and cartap hydrochloride treatments against brown planthopper, *Nilaparvata lugens* (Stal.) have led to pesticide resistance and thereby to resurgence of the pest in rice in India (Misra 2005). A nearly 100% mortality in both the predatory beetle species, *Cybocephalus nipponicus* Endrödy-Younga and *Rhyzobius lophanthae* Blaisdell, were found in fields treated with methidathion, dimethoate, and malathion (Smith & Cave 2006). One application of Ripcord 10EC, Dimecron 100EC and Diazinon 60EC reduced parasitoids populations of yellow stem borer eggs of rice over control plots by 65-76% and parasitism rates by 69-75% (Ahmed *et al*. 2002).

Soil and Soil Microorganisms

Soil consists of a variety of micro and macro flora and fauna, thereby being a dynamic living system. The primary activities of micro and macro flora and fauna are degradation of plant and animal residues in the environment which contributes to the nutrient cycle (Doetsch & Cook 1973). Pesticide residues especially insecticides are known to have an impact on microbial populations (Zhang *et al.* 1984; Ambrogioni *et al*. 1987) in soil. Microbial activities like those of *Azotobacter chroococcum*, actinomycetes and fungi (Milosevic *et al*., 2006; He YoungHua *et al*. 2006), bacteria, aminoheterotrophs and *Azotobacter* spp. (Cvijanovic *et al*. 2006) may be decreased. Changes in microbial populations may influence soil biological processes such as nitrification (Heinonen-Tanski *et al*. 1985; TUCM 1995), ammonification (Schuster & Schroder 1990), respiration (Anderson *et al*. 1981; Zelles & Bahig 1984), ATP (TUCM 1982; Malkomes & Wohler 1983), and other processes (Heinonen-Tanski *et al*. 1985; Vig *et al*. 1999).

Water

Ground and surface waters have been contaminated by chemical run-off from fields that has led to destroyed freshwater ecosystems with damaged fishes. Drain from agricultural regions has also created “dead zones” in ocean areas outside river mouths (Tardiff 1992; Pimentel & Lehman 1993). Originally, chemical run-off was considered as a local problem. However, nowadays run-off pesticides have been found to be a global problem, with toxic compounds accumulating in food chain from the oceans all the way to “untouched” zones, such as the Polar Regions (Blais *et al*. 1998).

When aquatic organisms and fishes were assessed for nine active ingredients of carbamate pesticides, only oxamyl 24% SL showed low potential risk for aquatic organisms (Sun 2006). High concentrations of commonly used rice pesticides have been found in Japanese rivers. The found pesticides are causing adverse effects on these aquatic ecosystems (Ishihara *et al*. 2005).

The occurrence of pesticides in Swedish aquatic environments was initially observed during the mid 1980's. The monitoring studies revealed frequent findings of agricultural pesticides in streams and rivers (Kreuger & Brink 1988). A total of 39 pesticides (31 herbicides, 4 fungicides and 4 insecticides) and 3 herbicide metabolites have been detected in the stream water samples collected over a 10-year period (1989 to 1999) in Sweden. The pesticide residues have been shown to enter streams also without preceding rainfall. This is a result of accidental spillage when filling or cleaning the spraying equipment on surfaces with drainage in direct connection to the stream (Kreuger & Nilsson 2001). Also, pesticide application for weed control on farmyards contributed to ~ 20% of the overall pesticide load in stream water.

Air

It has long been recognized that pesticides are one of the potential air pollutants (Daines 1952). Pesticides can be carried by wind and deposited through wet or dry deposition processes in remote areas or undergo atmospheric degradation, once they become airborne. Depending on their persistence in the environment, pesticides can travel tens, hundreds or thousands of kilometres and can revolatilize repeatedly (Majewski & Capel 1995; Gouin *et al*. 2004; Shen *et al*. 2005). Levels of currently used organochlorine (OC) pesticides are typically highest in agricultural areas with endosulfans dominating air concentrations. However, OCs like endosulfans and lindane has been detected in artic samples (Garbarino *et al*. 2002; Hung *et al*. 2002). Endosulfan is a contact insecticide used worldwide on a variety of vegetable crops, fruits, cereals and tobacco (Antonious & Byers 1997). Endosulfan isomers are oxidized in the environment to form endosulfan sulfate, which is also persistent and bioaccumulative. Lindane is a persistent organochlorine insecticide which has been used for decades throughout the world (Li *et al*. 2004). The most persistent pesticides are of greatest concern because they can be bioaccumulated and biomagnified through the food chain and ingested by humans. This is for example true for the older OCs, which are found in fat tissues of marine mammals (e.g. seals, whales or polar bears) (Dietz *et al*. 2004) and terrestrial mammals such as caribou (Elkin & Bethke 1995). Ideally, pesticides should remain where they have been applied and their toxicity should be very well assessed before being approved for sale (Tuduri *et al*. 2006).

From a large-scale passive air sampling survey conducted in Asia, elevated concentrations of PCBs (polychlorinated biphenyls), DDTs, and HCB (hexachlorobenzene) was found at sites in China. Chlordane was highest in samples from Japan (which also had elevated levels of PCBs and DDTs). South Korea and Singapore generally had low concentrations (Jaward *et al*. 2005).

For the Great Lakes basin as a whole, on an annual basis, the southeast US sources made the largest contribution to the toxaphene, one of the most heavily used OC pesticides (Ma JianMin *et al*. 2005). Large urban centers, such as Chicago and Toronto, normally have the highest levels of PCBs and PBDEs (polybrominated diphenyl ethers) (Gouin *et al*. 2005).

Health

If not managed and carried out properly, both rural agriculture and UPA entails risks to health and environment. There is a need to protect consumers from contaminated foods as well as people working on the farm from occupational hazards (Zeeuw & Lock 2000). The use of chemicals in agriculture is associated with elevated risks of eye diseases (Jaga & Dharmani 2006) and prostate cancer (Dich & Wiklund 1998). Also, exposure to high levels of many pesticides creates acute and long-term neurologic consequences (Kamel *et al*. 2005). Agrochemicals can cause acute poisoning and in such cases a range of symptoms might appear, difficult to diagnose correctly. Also, agrochemical ingestion is found to be a common way to commit suicide. Residues in food such as vegetables, red meat, poultry and eggs might cause chronic illnesses and also such residues have been found in human milk (FAO & WHO 1988).

In many developing countries, serious health and environmental problems have been created during the last three decades due to indiscriminate uses of agricultural chemical pesticides. Poisoning by pesticides is also most common in developing countries. Pesticide poisoning rate in the world is estimated to be 2-3 per minute and causalities 20000 workers every year (World Resources 1998-99; WHO 1990; Rosenstock *et al*. 1991; Pimentel *et al*. 1992; Kishi *et al*. 1995; Dasgupta *et al*. 2005a).

An increase of agrochemicals in the ground water is comes with intensive use. Intensive commercial horticulture elevates the risk of groundwater pollution compared to traditional and/or subsistence farming due to the intensive use of chemicals (WHO Commission on Health and Environment 1992).

Economics of Pesticide Use

Farmers have increased their use of chemical inputs to cropland (Miller & Tyler 2002). The use of chemical pesticides has been associated with increased yields, lower pest damage, higher quality products, and a more stable income stream to the farmer. Returns have been shown to increase by two to four dollars, per additional dollar of pesticide use (Sutherland *et al*. 1971). Chemicals have been seen as the productive and efficient choice for the agricultural sector to deliver the food and fiber needed by consumers at a very low cost, thus a gain to society (James & Ronald 1974).

The economy of the farmers as well as of their suppliers will be influenced by large cut-downs in uses of chemicals in agriculture. Also, the overall economy of consumers will be influenced by such curtails (Knutson *et al*. 1990). E.g. for middle-income consumers in USA, a ban of chemical use in agriculture will lead to 12% increase of the food bill. Such a ban will also lead to a 50% reduction of exported grain and cotton from USA. Furthermore, 10% increased erosion within cultivated land might be an additional outcome (Mary 1996).

However, costs for using pesticides mostly not calculated on are: health costs, defined as medical expenses plus the value of time loss, livestock losses due to intoxication and costs for destroying obsolete pesticides (Houndekon *et al*. 2006). For every £1 gained by farmers in a move from conventional to integrated wheat and apple production, a £6 worth of benefits to society have been found. Therefore, the government maybe should have a role in the promotion of reduced pesticide use strategies (Bowles & Webster 1995; Webster & Bowles 1996; Webster *et al*. 1999). In USA, pesticide use has been found to amount about $8.3 billion every year (roughly $30 in terms of environmental and socio-economic values per person per year). This clearly is higher than the purchase value of all pesticides, which is about $6.5 billion per year (Webster *et al*. 1999). The highest costs was found to arise from bird losses, followed by costs of groundwater contamination, costs of pesticide resistance and public health impacts. Also it is not possible to measure the full environmental and social costs of pesticide usage and thereby the total cost would be significantly greater than the estimated $8.3 billion/year in the USA (Pimentel & Greiner 1997).

Replacement of chemical pesticide treatment by biological control methods would bring huge socio-economic benefits to the society. Biological control methods are not known to pose any health hazards neither to the applicators, nor to the consumers due to the fact that there are no toxic residues on the products. Neither, does this type of control usually give any negative impacts on the environment, or other socio-economic values similar to those associated with the use of chemical pesticides (Pimentel & Greiner 1997; Hokkanen & Hajek 2003; van Lenteren *et al*. 2003; 2006).

During recent years, farming industry has been under enormous financial pressures as farm incomes have dropped in conjunction with the move towards global trading and pricing (Lunn *et al*. 2001). Arable farmers have long recognized the need to make efficient use of inputs, such as insecticides, fungicides, fertilizers, seeds and energy (Walters *et al*. 2003).

Herbicides are the largest part of the pesticides followed by insecticides, fungicides, and other pesticides, respectively (Table 1; US EPA 2004a). At present North America uses about 30% of the world total pesticides, Europe about 27%, Japan about 12% and approximately 31% is used in developing nations, including China (Muir 2004). Although developing countries account for a relatively small portion of the pesticide consumption globally, the use is growing rapidly (Miller & Tyler 2004). Insecticides are dominating, also showing higher acute toxicity than herbicides (WRI).

Table 1. World pesticide use annually as related to active ingredient (AI), expenditures (value) and pesticide type (type)

Type	Year					
	2000		2001		2004*	2005*
	AI M lb	Value M $	AI M lb	Value M $	Value M $	Value M $
Herbicide	1944	14319	1870	14118	14660	14882
Insecticide	1355	9102	1232	8763	7690	7704
Fungicide	516	6384	475	6027	7330	7491
Others	1536	2964	1469	2848	1045	1133
Total	5351	32769	5046	31756	30725	31190

*Source: CropLife 2007. Special biocides and chlorine/hypochlorites as used for woods are not included in the table. Herbicides= herbicides and regulators of plant growth. Other= anythings else than the other stated types. M= million.

At present, cost of preparing the application for a new active substance is considerable. In addition there are research and development costs (CropLife 2007). Overall pesticide marketing and economics by region and year are shown in figures 1 & 2.

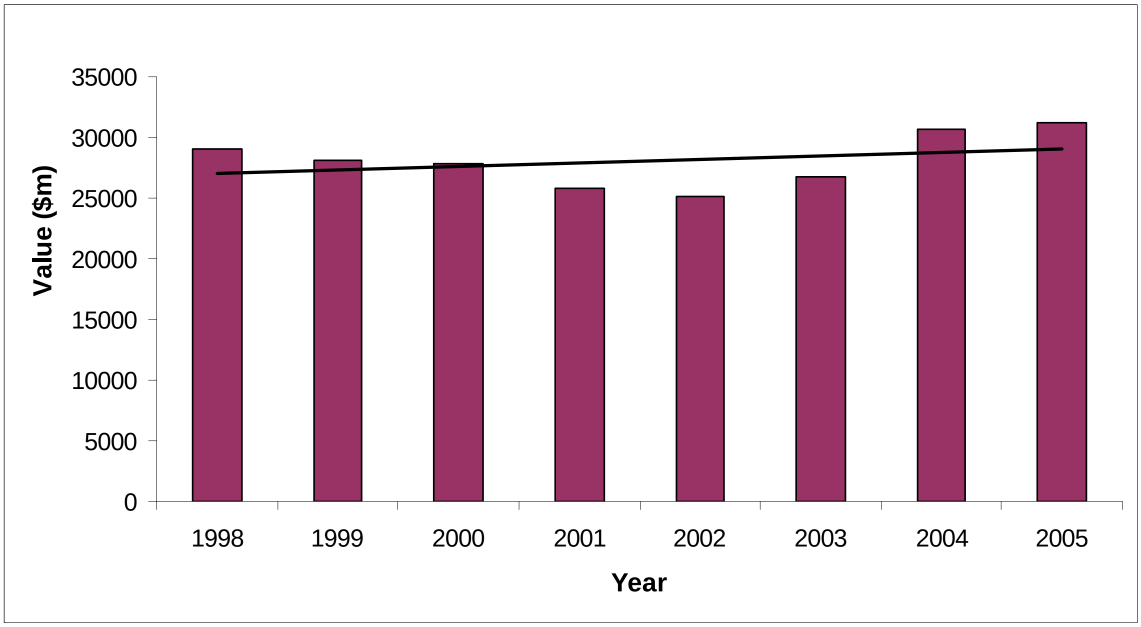


Figure 1. Worldwide pesticide market trends (Source Data: Phillips McDougall 2006)

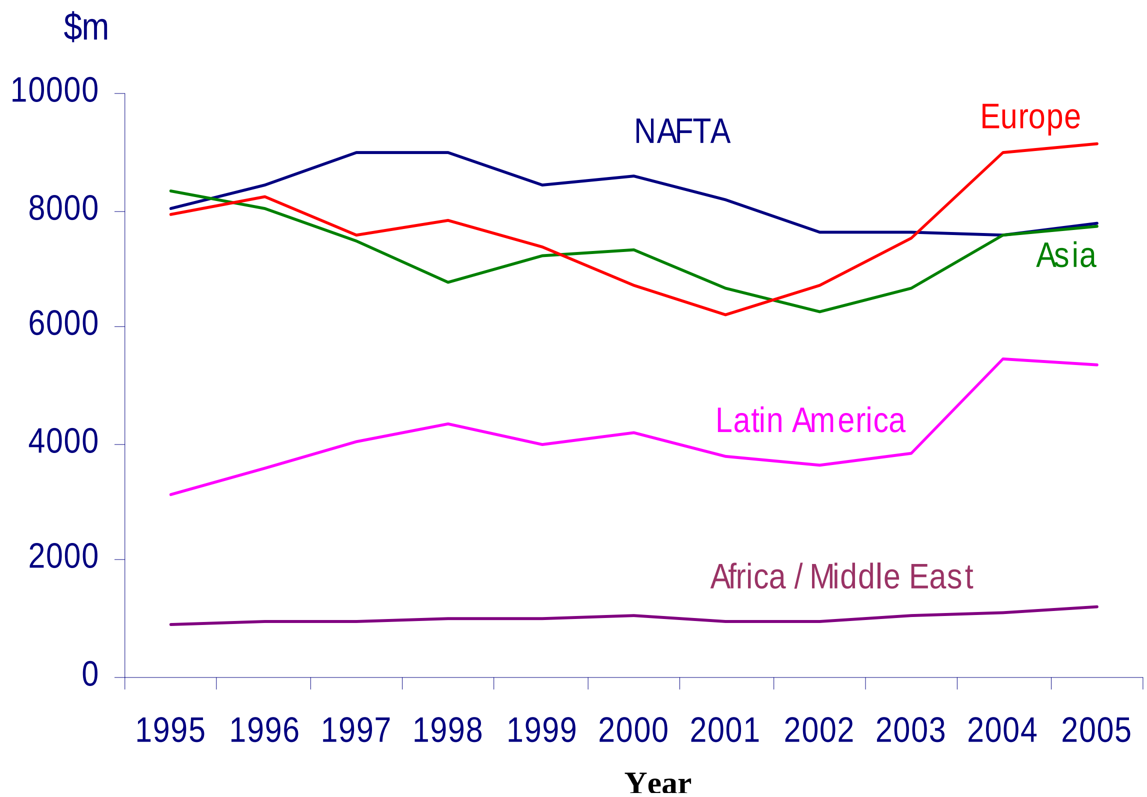


Figure 2. Pesticide marketing trends in region (Source: Phillips McDougall 2006)

Alternatives to Pesticide Use

Pesticides have provided a reliable and cost-effective approach to control pests in arable crops (Alford 2003). However, alternative ways to manage insect pests are now investigated. By improving management techniques or through development of new classes of pesticides, development of resistance to pesticides within pest populations has often been addressed. Improvements in management techniques have included several aspects, such as strategic selection and integration of pesticide products, establishment of effective pest assessment methods, adoption of optimal timing for pesticide applications, introduction of improved farm machinery and the development of computer models that offer improved integration of the range of information upon which decision making is based (Green *et al*. 1991; Hardwick 1998; Morgan *et al*. 2000).

For high-value greenhouse crops, such as tomatoes, classical biological control techniques and their integration within crop production systems were developed in Europe (Alford 2003). There is now widespread use of bio-control in many horticultural commodities, particularly on protected or greenhouse crops, and a range of bio-control agents (BCAs) are commercially available (Copping 2001). Some of these agents can be integrated with chemical pesticides (Head *et al*. 2000), and their performance compares well with that of conventional approaches (Williams & Walters 2000). A wide range of alternatives, such as parasitoids, predators and to a lesser extent, pathogens have considerable potential for limiting or reducing pest populations (Alford 2003). Generally, bio-control strategies in arable crops focus on ways of preserving and enhancing the activity of this kind of naturally occurring BCAs (Kromp 1999). Within Europe, the International Organization of Biological Control (IOBC) has published guidelines for integrated production (Titi El *et al*. 1993).

Pheromones are sometimes used as alternatives of insecticides. The term "pheromone" was introduced by Peter Karlson and Martin Lüscher in 1959, based on the Greek *pherein* (to transport) and *hormon* (to stimulate). A pheromone is any chemical or set of chemicals produced by a living organism that transmits a message to other members of the same species. There are *alarm pheromones*, *food trail pheromones*, *sex pheromones*, and many others that affect behavior or physiology (Karlson & Lüscher 1959).

Pollen beetles (*Meligethes aeneus* Fab.) in oilseed rape are conventionally controlled using pesticides (Walters *et al*. 2003). But some of the alternative strategies, for example, push-pull strategies (Miller & Cowles, 1990) and the use of trap crops (Hokkanen *et al*. 1986; Cook *et al*. 2002; Büchs & Katzur 2003; Frearson *et al*. 2004) can be applied to minimize the use of chemical inputs (Hokkanen 1991). Nilsson (2004) suggested that rape seed mix with 2% turnip rape could be used to avoid chemical control against pollen beetle in oilseed rape production. Plants like neem (*Azadirachta indica*) alone or in combination with pesticide are used to control pests e.g. *Helicoverpa armigera* of cotton (Sridhar & Suganthy 2006).

The reliance on agrochemical inputs can be reduced by using integrated pest and nutrient management systems (IPNM) or certified organic agriculture, also making agriculture more environmentally and economically sound. Sound management practices thereby reduce pesticide inputs while similarly ensuring high crop yields and improved farm economics. For example, pesticide use could be reduced by 50-65% without sacrificing high crop yields and quality in Sweden, Canada and Indonesia (Pimentel & Pimentel 1996; Pimentel *et al*. 2005; BANR/NRC 2003).

Allelopathy or Biological Control of Weed

Nearby plants can directly interfere with each other through competition or allelopathy. Allelopathy is thus an interference mechanism in which a living or dead plant releases bio-molecules or allelochemicals exerting an effect (mostly negative) on the associated plants. Allelopathy plays an important role in natural and managed ecosystems (Weidenhamer *et al*. 1989; Fitter 2003; Inderjit & Duke 2003). In cropping systems, the mechanism of allelopathic interference can develop new, environmentally safe strategies for sustainable agriculture. The allelopathic potential of e.g. maize (*Zea mays*), sorghum (*Sorghum vulgare*) and sunflower (*Helianthus annuus*) as weed suppressants has been determined. The reduction of dry mass/m^2 of weeds was highest in sunflower, medium in sorghum and low in maize (Garcia Castillo 2005).

Safe Use of Pesticides

Human Safety

Before a pesticide can be marketed, regulatory authorities should be satisfied that it poses no unacceptable risks to human health. Also, the plant science industry should be a signatory to and follow the UN FAO Code of Conduct (FAO 2002). Safe Use and Integrated Pest Management projects aim to make pesticide application inherently safer through the training and education of farmers and other parties (CropLife 2007).

Chemicals that persist i.e. take a long time to break down, or bioaccumulate i.e. build up as residues in the body, are a particular problem. The Intergovernmental Forum on Chemical Safety (IFCS) operates a committee on Acutely Toxic Pesticides (ATP = crop protection products classified under the WHO's classifications based upon acute toxicity) (CropLife 2007).

Environmental Safety

Environmental safety must be demonstrated to the satisfaction of the regulators before a product can be licensed for sale. This is normally done through an assessment of potential risk. Risk assessments are generally based upon a comparison of potential exposure and the inherent toxicity (also known as hazard) of the product under a standard set of conditions. If this ratio meets the regulator's definition of "acceptable risk", the product may be registered. In some cases, the potential risk may be managed through the use of risk mitigation techniques (e.g., buffers, spray drift reduction, etc.) (SNFS 1997; CropLife 2007; IFC/WB 2007).

Regulatory Framework

The plant science industry is regulated by a comprehensive framework ensuring consumers, users and environment safety in terms of pesticide. Procedures of re-registration together with quality assurance schemes are maintaining the security of not allowing products of inferior quality on the market, thereby keeping global standard levels (CropLife 2007). The framework is aiming at keeping the minimum standards during the whole chain from manufacture over to marketing. In order to assure quality of food on supermarket shelves, the permission of pesticide residues in produce is limited. By the present regulatory framework only very few of the chemicals that are evaluated by research and development, actually becomes true pesticides reaching the farmer's fields. Major international bodies like Organization for Economic Co-operation and Development (OECD) and World Health Organization (WHO) function as a forum for discussions about regulations of pesticides, thereby contributing towards an internationally similar regulatory framework all over the world (Flynn 2002; FAO & WHO 2006a).

Product Registration

Pesticide products must obtain national government approval before they can be sold, supplied, stored, advertised or used. This approval process is governed by national and possible regional/federal laws depending on locally applicable regulations. Companies seeking approval have to submit safety and efficacy data to their national regulatory authority, which may be a government agency or a division of the Ministry of Agriculture (FAO 1988). The data can be generated or commissioned by the company itself, derived from published material or purchased from third parties (Flynn 2002; CropLife 2007).

Getting an approval and registration from the national authority allows a pesticide product to be sold and used but it is subject to periodic review. Depending on the prevailing national regulations, authorities may review approvals at set intervals or at any time if new information comes to light (EC 1993; CropLife 2007).

Each country has different requirements for product registration, and this can be a daunting prospect for manufacturers seeking to offer their product for sale in many countries. Moves are underway to reduce this burden and time to market by harmonising registration requirements across regions (EU) or other bodies (such as Association of South-east Asian Nations, ASEAN) (EC 1993; Flynn 2002).

Regulatory Harmonisation

Global harmonisation of regulatory test guidelines, assessments and Maximum Residue Level (MRL) setting have traditionally been driven by international organizations such as the FAO, WHO, Codex Committee on Pesticide Residues (CCPR) and OECD (FAO 2005b; UN/SCEGHS 2006). In 2004, OECD member governments and pesticide regulators agreed to take a number of steps towards full harmonisation of data requirements by 2014 (OECD 2004; CropLife 2007). In addition to these initiatives from the OECD and other international bodies, harmonisation is also being driven via trade agreements between individual countries or trading blocks. For example, the North American Free Trade Association, NAFTA, governed cooperative efforts to harmonise pesticide regulatory requirements between the USA, Canada and Mexico (US EPA, 2004b). Similar agreements are in place in Latin America (Mercosur) and Asia Pacific (ASEAN) (Flynn 2002; CropLife 2007).

Codex Maximum Residue Levels

The Codex Committee on Pesticide Residues (CCPR) develops and maintains acceptable pesticide maximum residue limits for food commodities in international trade. FAO considers available data on recognized/registered use patterns of pesticides, fate of residues, animal and plant metabolism data, analytical methodology and residue data developed through supervised trials. Based on these data, maximum residue levels are proposed for individual pesticides in individual food and feed items or well-defined groups of commodities (Flynn 2002; FAO & WHO 2006b). Although these could, in principle, form the basis of globally accepted standards, the major trading blocks in practice set their own independent standards (CropLife 2007).

FAO Pesticide Specifications

Procedures for establishment of specifications for insecticides used in public health programs for insect control were first instituted by the WHO in 1953. The corresponding process for crop protection products was initiated by FAO in 1963. The Food & Agriculture Organization of the United Nations has published specifications for pesticides (referred to as the FAO Specifications) and their related formulations, in addition to a manual on the development of these specifications (FAO & WHO 2006a). The separate processes in WHO and FAO continued in parallel until 2002, at which point FAO and WHO collaborated to merge the two processes (FAO & WHO 2006a).

Pesticide Management

Pesticide management is embodied by a number of national and international regulations and policy conventions that govern all aspects of pesticide manufacturing, distribution, use and disposal. The UN FAO Code of conduct is the most comprehensive of these conventions, and although its provisions are voluntary, the plant science industry is committed to adherence to its 12 clauses. The Stockholm Convention (POP) and Rotterdam Convention (PIC) are international conventions that seek to eliminate persistent organic pollutants and better control trans-boundary shipment of listed chemicals (FAO 2006).

Pesticide Regulations in Bangladesh and Sweden

Pesticide use and regulation is here compared between a developing country, Bangladesh and a developed, Sweden.

Pesticide Use in Bangladesh

Agricultural pesticides have been in use since early sixties. The Pesticide Ordinance was promulgated in 1971 to regulate import, manufacture, formulation and distribution and use of pesticides. In 1980, the Ordinance was amended to accommodate the provision for licensing and the trade was handed over to the private sector (FAO 2005a).

The Ordinance extends to all pesticides, whether used for agriculture, public health or any other purpose and it is administered by the Ministry of Agriculture. The Ordinance provides the basic framework for the regulation and control conform to the proposed guidelines of the FAO (Pesticide Ordinance 1985; FAO 2005a).

Different authorities are involved for enforcement of pesticide rules and regulation according to the Ordinance (Figure 3).

Despite the presence of a regulatory framework in Bangladesh, there are gaps between the policies and implementation. Generally there is a lack of facilities and trained analysts to allow proper monitoring. Thus, specification of pesticides on the market may differ from those registered and residues in food are not properly controlled. In addition, the country has not yet established legal limits for residues and depends upon FAO's Codex of allowable limit which are not always present for all crops and major pesticides used within the country (FAO 2005a; http://www.fao.org/world/regional/rap/meetings/2005/Jul26/Documents/Bangladesh%20 Presentation.ppt).

Bangladesh, like many other developing countries, has promoted the use of pesticides to expand agricultural land and increase output per acre through extension services and significant subsidies (Rasul & Thapa 2003; Hossain 1988). As a result, pesticide use has more than doubled between 1992 and 2001 (Dasgupta *et al*. 2005a) and again almost doubling of formulated pesticides was seen from 2003 to 2006 (Figure 4). The most common type of pesticide in Bangladesh is fungicides (71%) followed by insecticides (23%) (Figure 5, BCPA 2007).

Ministry	**Legislation**	**Registration**	**Licensing**	**Enforcement**	**Testing**	**Training**	**Monitoring**	
							ENVRT	**Health**
Agriculture	PPW	PPW	PPW	PPW	NARI (BARI, BRRI etc.)	DAE	PPW	PPW
Environment								
Health								

Figure 3. Involvement of different authorities for regulation and monitoring of pesticides in Bangladesh (FAO 2005a)

PPW- Plant Protection Wing, DAE- Department of Agricultural Extension, NARI- National Agricultural Research Institute, BARI- Bangladesh Agricultural Research Institute, BRRI- Bangladesh Rice Research Institute

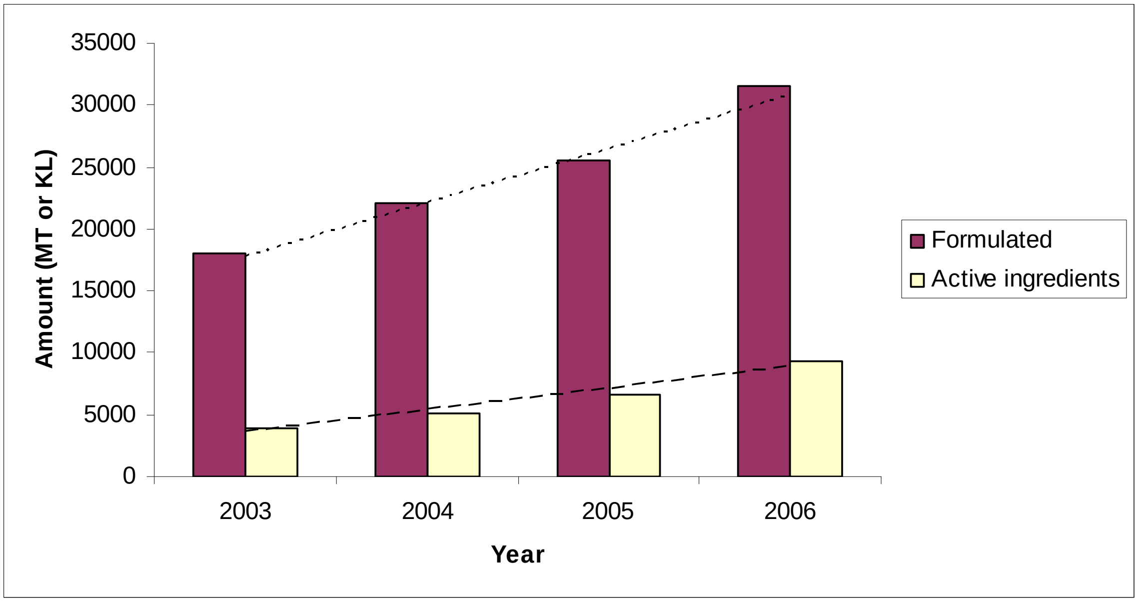


Figure 4. Recent pesticide use trends in Bangladesh (Source: BCPA 2005; 2006 & 2007)

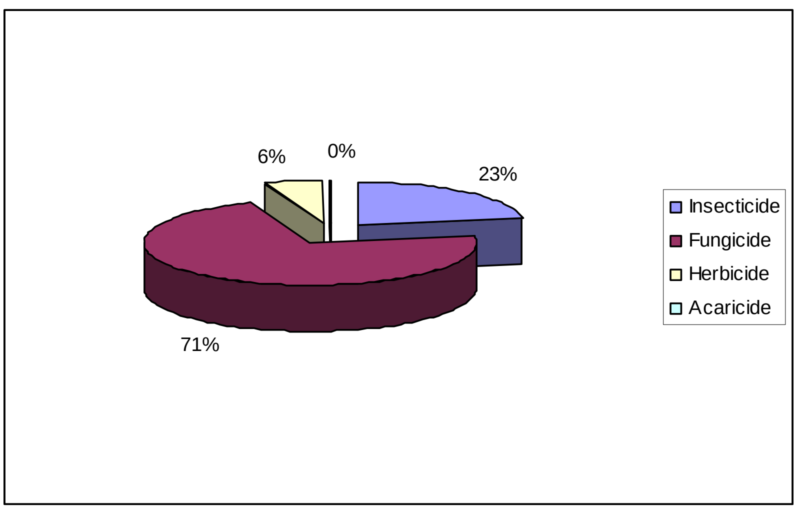


Figure 5. Proportion of pesticides used in Bangladesh in 2006 (Active ingredients as of type) (Source: BCPA 2007)

Pesticide Use in Sweden

In Sweden, agricultural pesticides have been in use since shortly after the World War II. Since then, the pesticide use increased to an average use of around 13500 metric tones active substances per year in case for 1981-85 (Figure 6). The Swedish Government first ‘Plant Protection Law’ was initiated in 1953 (Personal communication with Dr Christer Nilsson, Sweden, Christer.Nilsson@ltj.slu.se).

The Swedish pesticide reduction programme was later initiated by an environmentally active government in mid-1980, responding to broad public concern over the environmental and health impacts of pesticides (Sandrup 2005). The targets of the action plans (based on the average of consumption during the period 1981-85) were a 50% reduction in use by 1990 and a further 50% i.e. in total a 75% reduction in use by 1997. In the two phases a 49 and 64% use reduction were achieved, respectively (Figure 7, Sandrup 2005). Both pesticide-hectare doses and kg-active ingredient has been gradually reduced from 1982 to 2005 (Figure 8, KEMI 2006). There is at present no pesticide manufacturing industry in Sweden (Hurst 1992).

Manufacturers and importers must register their chemical products with the National Chemicals Inspectorate's (KEMI) Products Register. The Register is a central database on the contents of chemical products. The Swedish Chemicals Inspectorate has developed two systems intended to track risk trends over time by calculating pesticide risk indicators. Pesticide Risk Indicators are calculated at National level (PRI-Nation) and at Farm level (PRI-Farm). The first system, PRI-Nation, was initiated in 1996 with the main objective to monitor impact of pesticide policies established in the national risk reduction programme (OECD 1999). It has been in use since 1997 with annual updating and reporting on the national progress. The second system, PRI-Farm, was developed during 2003 and 2004 with the main purpose to follow up pesticide risk trends at individual farms and to compare pesticide risks of different production systems (Hurst 1992; Bergkvist 2004).

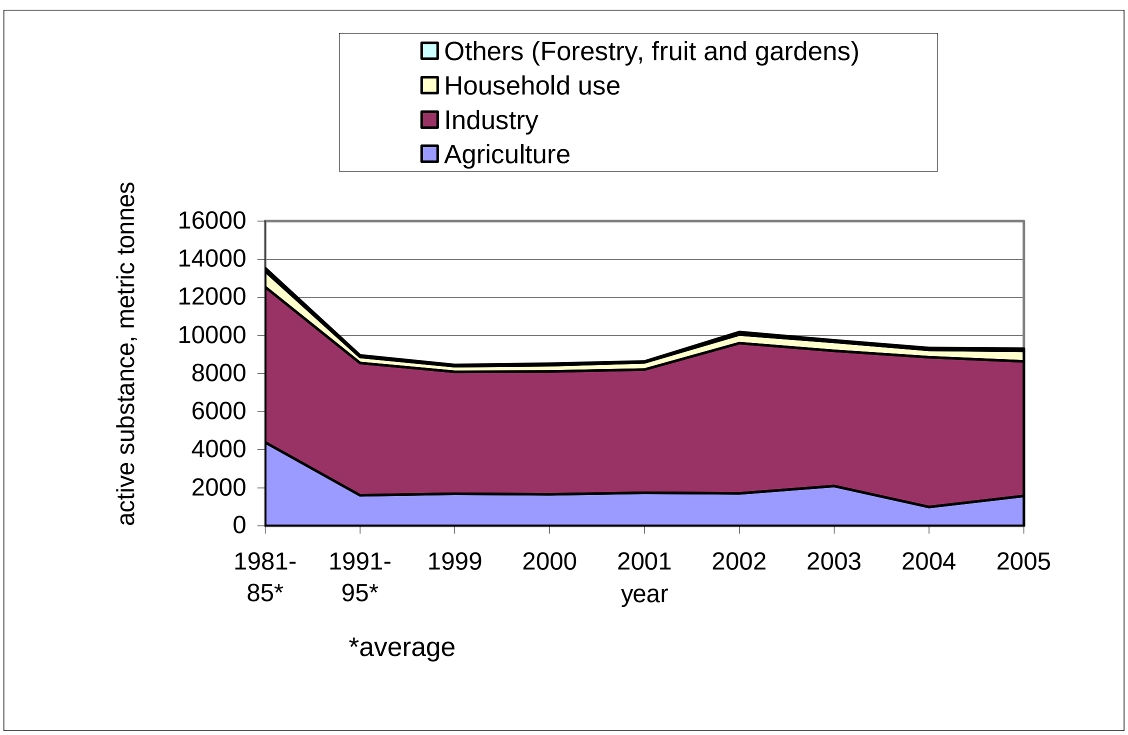
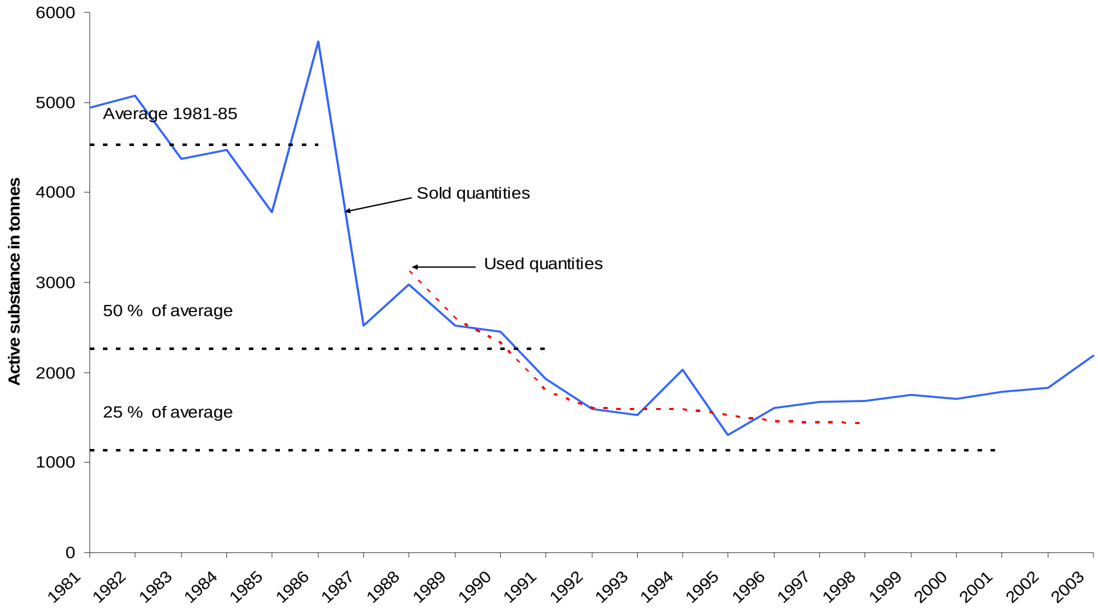
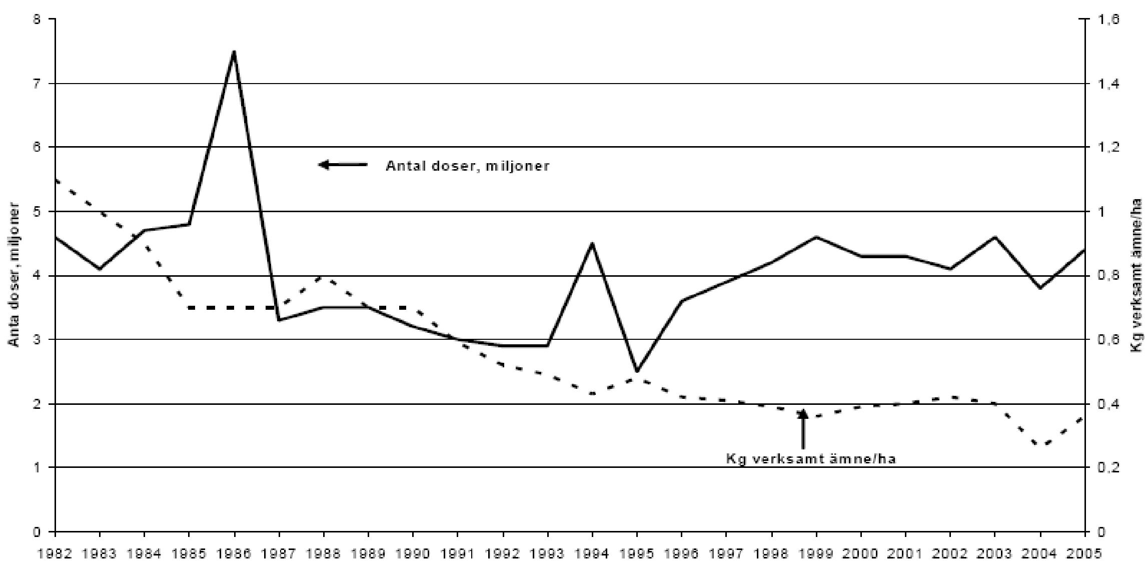


Figure 6. Trend of sold pesticides for agricultural use in Sweden as of active ingredient (Source: KEMI 2006)



Year

Figure 7. Trend of sold and used quantities of pesticides for agriculture use in Sweden as of active ingredient (Source: Schönning, 2005)



Year

Figure 8: Trend of number of pesticide-hectare doses and amount of active compounds in agriculture, Sweden (Source: KEMI 2006)

Beside the Swedish Chemical Inspectorates PRI system, the Government of Sweden has designated 15 environmental objectives. Several of the Targets in these environmental objectives are to reduce the risk presented by chemical substances in both chemical preparations and other products. The Government's proposal means that newly manufactured goods must be as free as possible from carcinogenic, mutagenic, reproduction-toxic, persistent and bio-accumulating substances. The heavy metals mercury, cadmium and lead must also be phased out. The presence and use of substances that impede recycling of materials must also be reduced (KEMI 2002).

Agriculture and horticulture along with households account for 24% of total pesticide use and the rest, 76%, are used by the industry, primarily for wood treatment using pressure and vacuum technology (Figure 6). By type, herbicide accounts for about 84% of pesticide use in agriculture, mainly in cereal production (Figure 9, KEMI 2006).

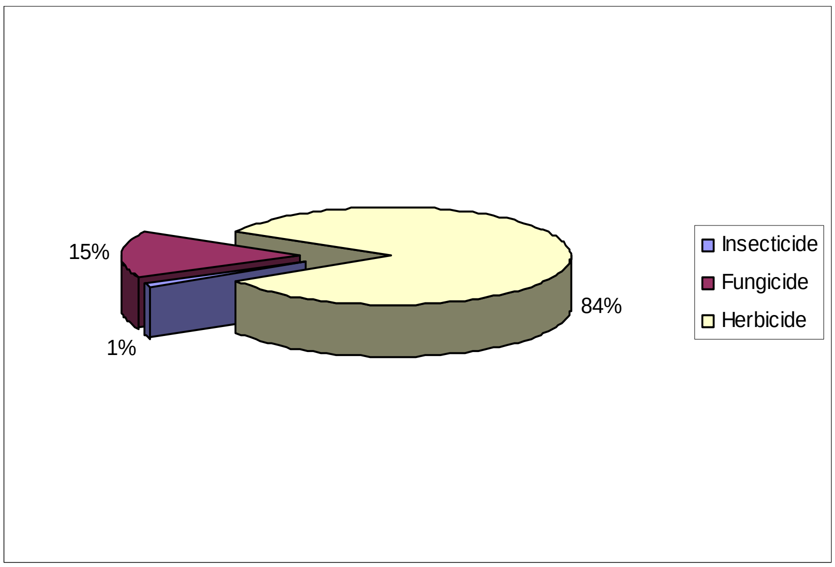


Figure 9. Proportion of Sold pesticides as active ingredient in Sweden 2005 (Source: KEMI, 2006)

Pesticide Marketing System

Pesticide marketing is generally governed by the countries laws and situation. Below the systems within Bangladesh and Sweden are described.

Bangladesh

Bangladesh only imports and formulates the pesticides, but does not produce any active ingredients. In Bangladesh, the marketing channel of pesticides consists of pesticide companies, distributors, wholesalers, wholesaler-cum-retailers, retailers and farmers (Sabur & Molla 2000). At present, approximately 66 officially registered companies, with six of these being multinational in nature exist and of them 10 produce the granular and emulsifiable concentrate formulation (FAO 2005a). Pesticide companies sell almost all of their products to the distributors. But wholesalers can buy directly from the pesticide companies. Wholesalers-cum-retailers, retailers and large farmers can buy the product from distributors. Retailers as well as farmers can buy from wholesalers too. Generally retailers sell their product to farmers, but large farmers frequently buy directly from the distributors as well as wholesalers. A simplified representation of these channels is presented in figure 10 (Dasgupta *et al*. 2005b) and pesticide legislation, information, monitoring and marketing are shown in figure 11.

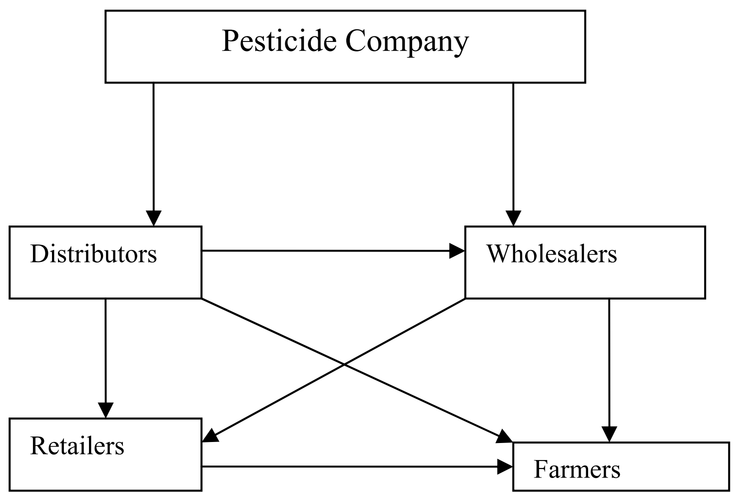


Figure 10. A simplified representation of pesticide marketing channels in Bangladesh (Source: Dasgupta *et al*. 2005b)

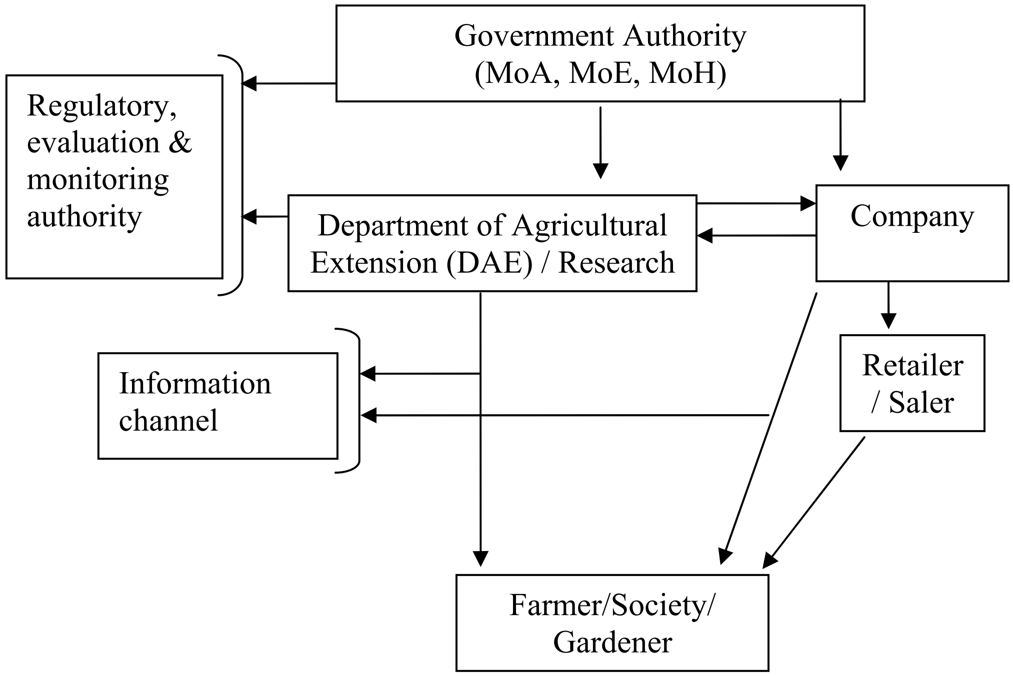


Figure 11. A simplified representation of pesticide legislation, information, monitoring and marketing channels in Bangladesh (as per Pesticide Ordinance 1985)
MoA- Ministry of Agriculture, MoE- Ministry of Environment, MoH- Ministry of Health

Sweden

In Sweden, pesticides marketing system involves several public authorities and private companies, farmers organizations (LRF, GRO) as well as county administrations and local municipalities. The public authorities execute the decisions made by the Riksdag. The distributors (e.g. Lantmännen, Svenska Foder and Gullviks) sell the pesticides to the farmers and end-users. The Swedish Environment Protection Authority (Naturvårdsverket) is monitoring the environmental aspects with the help of the Swedish University of Agricultural Sciences (SLU). Regarding food-stuffs the monitoring is done by the National Food Administration (Livsmedelsverket). Extension services regarding pesticide use is done by the Swedish Board of Agriculture (Jordbruksverket) and also by the Rural Economy and Agricultural Societies (Hushållningssällskapet). Pesticides registration and selling statistics are maintained by the Swedish Chemicals Inspectorate (Kemikalieinspektionen) and pesticides handling, workers health and working environment are monitored by the Swedish Work Environment Authority (Arbetsmiljöverket) (Personal communication with Dr Jenny Kreuger, SLU, Sweden, Jenny.Kreuger@mv.slu.se). A simplified representation of these channels is presented in figure 12.

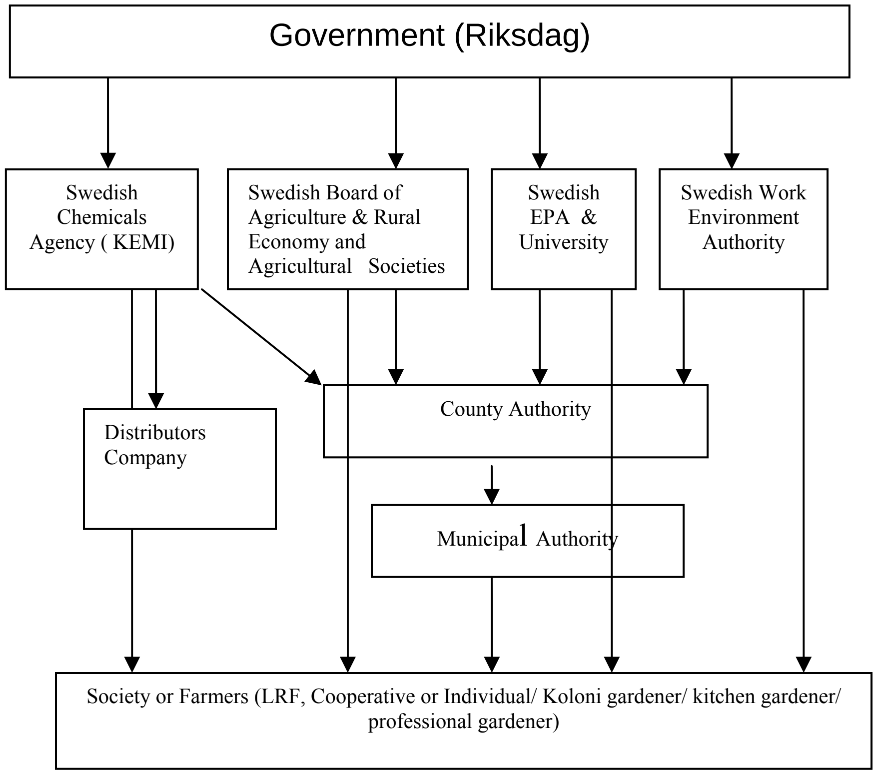


Figure 12. Schematic flow of pesticides legislation, monitoring & marketing process in Sweden (based on the public authorities and private companies information and above discussion)

Society and Pesticides

Although research indicates long-term increases in public concern on pesticides still its use remains extensive (Sachs 1993). Also, pesticide regulation as a whole has found a strong support among the general public (Horowitz 1994).

Pesticide use, its acceptability and environmental influence (i.e., adverse effect on the environment) clearly involves societal values. Use should be based upon consultations with a wide group of stakeholders, including environmental scientists, government regulators and pesticide manufacturers (Crane & Giddings 2004). Also, representatives from the wider community and environmental non-governmental organizations should be involved in the discussions (Crowfoot & Wondolleck 1990). Social acceptability is important for implementation of environmental policies as well as for day-to-day management practices (Brunson 1993; Winston 1997). Political researchers assert that there is a relationship between public opinions on issues and the establishment of public policies both in USA (Page & Shapiro 1983) and abroad in democratic nations (Petry 1999). The concept of the 'acceptability' of pesticide effects in Europe has been developed and defined largely by scientists from the regulatory and business communities. Scientists have since long been seen as experts who could provide an unbiased opinion on scientific matters and whose advice would be accepted by decision makers on the basis of that acknowledged expertise. Nowadays, research has shown a more complex relationship between scientific results and assessment, trust and public perception (Douglas 2000; Crane *et al*. 2006).

With the increasingly skeptical society it is important that scientists or specialists and non-specialists communicate and, in particular, discuss complex ideas. This is necessary because the public's perception of risks might well differ significantly from that of specialists (Frewer 2004; Hansen *et al*. 2003). An individual's perception of risk depends upon an often innate judgment of the probability of occurrence and the severity of the consequences. Even if individuals agree on the degree of risk they may still disagree on its acceptability because of differences in their level of expertise and education, their gender or their personal values. For example, the wholesale rejection of genetically modified crop technology by the British public was significant although many scientists chose to see the technology as safe and controllable (Frewer 2003; Frewer *et al*. 2004; Tait 2001). Additionally, motives within science can itself be questioned. The ongoing pressures of funding, essential to the continuation of particular research lines, requirement for novelty in research in general, essential to publication and career development in science, means that there is a strong science agenda which may be at considerable variance with wider societal wants and needs (Crane *et al*. 2006).

Perceptions of civil society on rice biotechnology research have been found to vary between groups in Bangladesh. Agriculturists and Universities teachers gave the highest support for use of biotech research to incorporate iron and vitamin A in rice (88-90% positive) while least support was received from Environmentalists (63%). Also, 40% of NGO personnel and policy makers in Bangladesh considered pesticide use in rice as a very serious problem, 45% considered it as a serious problem and 13% as a marginal problem (Husain *et al*. 2003).

Pest management decisions provide benefits and costs to the farmer, and also affect the society at large (Hokkanen 2006). Human health can be affected by pesticide use; particularly at risk are those who apply pesticides, bystanders, and the consumers of food containing pesticide residues (Bowles & Webster 1995). Focus groups with residents of low-income, urban neighborhoods in Northern Manhattan decided household pest (cockroaches and rodents) control should be one of three top neighborhood priorities (Green *et al*. 2002) and 69 million households in USA store and use pesticides in and around the home (Goldman & Koduru 2000).

B. Exchange of Pests between Insecticide Treated Farmers' Field and Garden Crop

Gardens neighbouring farmers' fields may exchange pests with the farmers fields via migrations. Depending on the characteristics of the crops and host specificities of the herbivorous insects, emigration or immigration may take place. The crop and crop management of fields adjacent to gardens might influence the pest situation in the garden. In my example I am studying whether *Brassica* oilseeds might influence the pest densities on radish and whether insecticide treatment in the oilseeds makes a change to the frequencies of pests in radish.

Oilseed rape

Introduction

Edible oil is produced from many vegetable seeds but, unlike soya, cotton seed, groundnut and sunflower oils, which are produced from single plant species, rapeseed oil is produced from several species of Brassicaceae, all of them in the genus *Brassica*. The small spherical seeds of rapeseed are harvested and crushed to separate the oil, which makes up approximately 40% of the seed, by weight, from the remaining meal. From about the mid-nineteenth century until the Second World War, throughout Europe, the production of oil from rapeseed declined, as mineral oil and coal gas increasingly replaced rapeseed oil as a fuel. A large increase in European oilseed production began during the Second World War when continental Europe was blockaded and imported vegetable oils were almost impossible to obtain. Area sown each year by oilseed rape within the European Economic Community (EC) since 1970 has been much influenced by subsidies for oilseeds and tariff barriers against imported oils, mainly from Third World countries (Winfield 1992). Most rapeseed oil is now used as a foodstuff but increasingly also as a bio-fuel.

The expanded use of the crop, and the consequent increase in production, occurred when plant breeders changed the chemical composition of the seed. First the fatty acid composition of the oil was altered to reduce the level of erucic acid and then the levels of glucosinolates in the meal were reduced. Erucic acid (one of the fatty acids in rapeseed) was a potential hazard for humans consuming the oil (Daun 1984). Glucosinolates in the meal are repellent or toxic to some farm animals (Robbelen & Thies 1980). The changed rapeseed crop is commonly referred to in Europe as 00rape, i.e. signifying the goal of reducing the levels of erucic acid and glucosinolates in the seed to nearly zero. Glucosinolates act as antifeedants for many polyphagous herbivores, but most insect pests of *Brassica* crops are specialists and use glucosinolates or their fission products as attractants or feeding stimulants (Feeny 1977; Ekbom 1995). Also, the increase in production has offered new areas for insects (Lamb 1989).

One of the most important limiting factors for production of *Brassica* oilseeds is the complexity of insect pests associated with the crop. The necessary insecticide input to secure acceptable production levels may not only be high in any given year but is often essential each season (Ekbom 1995).

Origin

Although agriculture and food industries treat rapeseed as a single commodity, the crop is a composite of seed from two or three species (Downey 1983, Prakash & Hinata 1980). *B. rapa* and *B. juncea* are widely grown in Asia. In Europe, Canada, New Zealand and Australia *B. napus* is mostly grown, although *B. rapa* is grown to a lesser extent. *B.*

juncea probably has arisen as a natural hybrid between *B. rapa* and *B. nigra*, and *B. napus* has arisen as a natural hybrid of *B. rapa* and *B. oleracea*. Genetic relationships among the members of the genus *Brassica* is shown in figure 13 (Morinaga 1934; Nagaharu 1935). In this figure, the origin of the AABB, AACC and BBCC species are shown and also the chromosome sets from their AA, BB and CC ancestors (Morinaga 1934; Nagaharu 1935; Holmes 1980). Probably, *B. rapa* has been domesticated as a source of oil in central Asia or adjacent northwestern India but is native throughout Europe, central Asia and the Near East. *B. napus* does not occur in wild populations and was probably domesticated in southern Europe. The species differ morphologically and chemically and they grow at different rates; these differences complicate the study of pests associated with the crops. Furthermore, the annual forms of *B. napus* and *B. rapa* are sown in the spring in most of Canada and in northern Europe, but in central and southern Europe winter-dormant, biennial forms are sown in the late summer (Downey 1983). Differing phenologies of the two forms and the three species affect the synchronies of insect life histories with the crop (Lamb 1989).

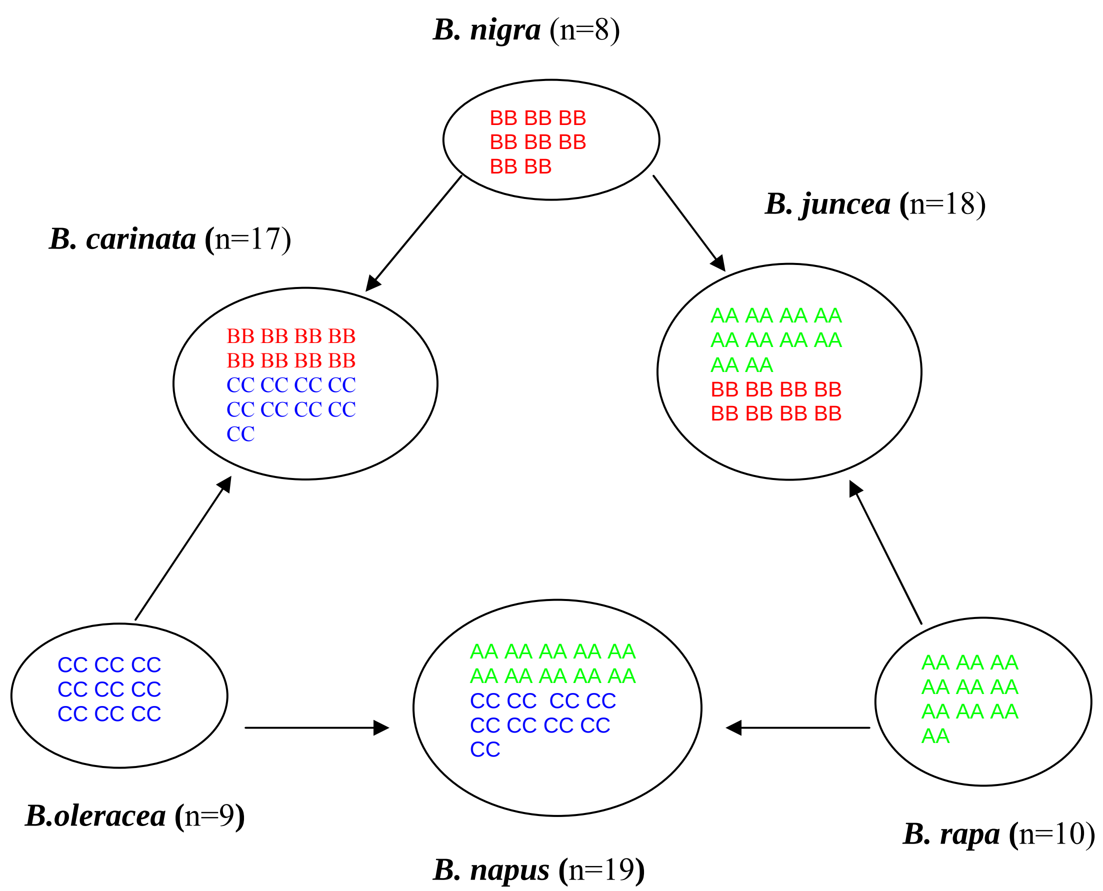


Figure 13. A diagram of genetic relationship among certain members of the genus *Brassica* (Source: Morinaga 1934; Nagaharu 1935; (http://en.wikipedia.org/wiki/Triangle_of_U).

Rapeseed is also known as Rape, Oilseed Rape, Rapa and Rapaseed. In Canada, the spring type that is low in erucic acid and glucosinolates is called Canola (Wikipedia).

Scientific classification

Kingdom: Plantae
Division: Magnoliophyta
Class: Magnoliopsida
Order: Brassicales
Family: Brassicaceae
Genus: *Brassica*
Species: *B. napus* L., *B. juncea* L., *B. rapa* L.

Importance

Rapeseed (*B. napus*) is very widely cultivated throughout the world for the production of animal feed, vegetable oil for human consumption, and bio-diesel. Leading producers of rapeseed include the European Union, Canada, the United States, Australia, China and India. China and India is accounting for as much as 25 and 14% of world production, respectively. In the countries of the northern hemisphere with cool and humid climates oilseed rape is a very important oil- and protein-crop. No other crop under these climatic conditions produces such high yields of both oil and protein. Thus, Canada (20% of the world production) and the European countries Germany, France, and the UK are among the main producers of oilseed rape. Canada, in particular, is the main exporting country onto the world market. Compared with 20 years ago, there has been an impressive increase in rate of annual production of rapeseed by over 200% in nearly all important oilseed rape producing countries (Gianessi *et al*. 2003; Orlovius 2003).

FAO reported that 36 million tones of rapeseed was produced in the 2003-04 season, and 46 million tones in 2004-05, the highest recorded total (Kazachkova 2007). Worldwide production of rapeseed is shown below (Table 2).

According to the United States Department of Agriculture, rapeseed was the third leading source of vegetable oil in the world in 2000, after soybean and oil palm, and also the world's second leading source of protein meal, although only one-fifth of the production of the leading soybean meal. Processing of rapeseed for oil production provides rapeseed animal meal as a by-product. The by-product is a high-protein animal feed, competitive with Soya. Rapeseed is a leading option for Europeans to avoid importation of GMO products (USDA 2002a; 2002b; 2003; EU 2002a; 2002b; Gianessi *et al*. 2003; Orlovius 2003).

Rapeseed oil is usually blended with other vegetable oils for the production of various cooking oils, margarines, and salad dressings. Rapeseed leaves and stems are also edible, and are sold as greens, primarily in Asian groceries. Rapeseed is a heavy nectar producer, and honeybees produce a light colored, but peppery honey from it. Rapeseed growers contract beekeepers for pollination of the crop. (Gianessi *et al*. 2003). The crop is also grown as a winter-cover crop. It provides good coverage of the soil in winter, and limits nitrogen run-off (http://en.wikipedia.org/wiki/Rapeseed).

Table 2. Production of rapeseed in the world

Year	Worldwide Rapeseed Production (MT)	Country	Top Rapeseed Producers 2005 (MT)
1965	5.2	China	13.0
1975	8.8	Canada	8.4
1985	19.2	India	6.4
1995	34.2	Germany	4.7
2005	46.4	France	4.4
		UK	1.9
		Poland	1.4
		Australia	1.1
		World Total	46.4

Source: Raymer 2002; FAO 2005c; http://en.wikipedia.org/wiki/Rapeseed, MT= Million tones

Management

Plant growth and productivity are influenced by the air and soil temperatures. Spring-type oilseed rape grows well from 12° to 30°C but for maximum growth and development the optimum temperature is just above 20°C. From emergence to flowering, oilseed rape desires cool temperatures. Also, at flowering, high temperatures accelerate plant development, thereby reducing time from flowering to maturity. *Brassica* species show the highest demand of sulphur among the cultivated crops (OECD 1997).

At present, minimal or no-till *B. napus* production is advised as a result of increased awareness of soil conservation issues. Reduced tillage leads to snow trapping, less run-off of melted snow, less soil erosion caused by wind and water; enhancing water storage capacity in the soil. The positive effects are created by the fact that crop residues and stubble are left on the soil at reduced tillage. However, in order to get positive effects, weed control programmes need to be effective and systematic (Lenssen *et al*. 2007; Alford 2003; OECD 1997).

Weeds are one of the most limiting factors for oilseed rape production. The most problematic weeds are the cruciferous weeds, closely related with rapeseed. Examples of such weeds are ball mustard (*Neslia paniculata*), common peppergrass (*Lepidium densifolium*), flaxweed (*Descurainia sophia*), hare's ear mustard (*Coringia orientalis*), shepherd's purse (*Capsella bursa-pastoris*), stinkweed (*Thlaspi arvense*), wild mustard (*Sinapis arvensis*), wormseed mustard (*Erysimum cheiranthoides*) etc. Weed problem is more severe for spring-type than the winter-type oilseed rape. Spring-type rapes compete less well with weeds in the early growth stages due to slow-growing, leading to slow covering of the ground. Weed control at early stages is therefore a necessity in spring oilseed rape in order to avoid competition causing yield loss. In order to reduce unnecessary and costly pesticide applications, resulting in build-up of resistance in weeds and insects as well as damage to pollinators, it is important to design pests management programmes. Also, diseases are greatly influenced by cultivation practices and environmental factors, furthermore calling for such programmes (Lutman 1989; SAC 2001; Gianessi *et a*l. 2003).

B. napus can be harvested when the first siliques begin to shatter. The use of desiccants reduces shattering thereby allowing direct combining (OECD 1997).

In order to prevent build-up of diseases, insects and weeds in oilseed rape, the same field should not be used more often for such production than once every three to four years (Alford 2003). When sites are selected for oilseed rape production, chemical residues from herbicides as well as volunteer growth from previous crops should be considered. Volunteer growth can be reduced by suitable soil treatments following harvest (OECD 1997).

Radish

Introduction

Radish, *Raphanus sativus* L., an edible vegetable belonging to the Brassicaceae family, has been in cultivation for thousands of years. Mostly the napiform taproot is eaten, although tops can be used as vegetable and thus the entire plant is edible. Radishes are available in a range of colours, shapes and sizes. The most common type is the red-skinned round one, although types longer than parsnip also exists. Most commonly bulb of the radish is eaten raw, although tougher specimens also exists that are normally steamed. The texture of raw flesh is crispy and the flavour is pungent and peppery. The typical taste is caused by glucosinolates combined with the enzyme myrosinase. When these compounds are brought together by chewing, they form allyl isothiocyanates. Similar chemicals are also present in mustard, horseradish and wasabi (Walter 1984; Nonnecke 1989; Swiader *et al*. 1992; Wikipedia).

The Greek word *Raphanus*, meaning ‘quick appearing’, alludes to its rapid germination and growth. There are in principle four categories of radishes: summer, fall, winter and spring. Spring radishes mature in 20-30 days. They can be grown throughout the season in cool climates and during all but the hottest months in the warmer areas. Successive planting can be made every 10-14 days beginning in spring as soon as the soil can be worked and until a month before expected frost. Winter radishes grow slower, these require a 45-75 days growing period and are usually grown as a fall crop (Walter 1984).

Origin

Cultivation of radish has a long history, depicted already in the wall of the pyramids 4000 years ago (Crisp 1995). Despite the long history, the botanical origin of radish is still unclear (Lewis-Jones *et al*. 1982; Kaneko & Matsuzawa 1993). Either the cultivated radish might have originated from just one single wild species. The suggestion of such a species is either *Raphanus raphanistrum* or *Raphanus maritimus*. The other idea is that radish has originated by an inter-specific hybridization from *Raphanus landra* × *R. maritimus*, two wild species. A third idea exists that an extinct ancestral species is the common ancestor of both *R. sativus* and *R. raphanistrum*. Anyhow, most of the ideas are based on morphological observations, thereby being no definitive evidence as they are not based on either genetic or cytological or molecular data. There is also the hypothesis that cultivated radish has a multiple origin from several wild progenies of *Raphanus* is, however, the dominating one (Pistrick 1987; Yamagishi & Terachi 2003).

Scientific Classification

Kingdom: Plantae
Division: Magnoliophyta
Class: Magnoliosida
Family: Brassicaceae
Genus: *Raphanus*
Species: *R. sativus* L.

Importance

Radish is cultivated and distributed worldwide. The variation in the cultivated radish is large both in relation to morphological and agro-ecological characters. In Europe, the most common type of radish is a small-rooted and short-season type, mainly produced for salads. In Asia, the large-rooted types eaten raw, after cooking or pickling, fodder type, oil-seed type, and long-pod type are present and bred for various purposes (Kaneko & Matsuzawa 1993). Radishes are a popular choice for home garden cultivation in Sweden and abroad, as they are fairly easy to grow. Eating radish is positive for many reasons. Nutritionally, they are rich in vitamin C, folic acid, potassium, vitamin B6, riboflavin, magnesium, copper and calcium. Simultaneously, they are low in calories (One cup = two servings = provides approximately 20 kilocalories or less). Some sources list radishes as being rich in dietary fiber; and used as an alternative treatment for a variety of medical conditions (USDA 2006; Acharya & Sancheti 2007). In USA area harvested radishes (excluding daikon) totaled 17,056 acres in 2002. Domestic consumption of radishes averaged an estimated 141 million pounds annually during 2001-03 and the USA consumers spend about $60 million annually to purchase radishes in supermarkets (Lucier & Jerardo 2004). The production of radish in Europe amounts to 120000t from France and Greece. The Netherlands, Italy and Spain are the main producers (Vogel 1996; Muminović 2004).

Management

With its shallow root system and short life span, the radish is not highly demanding of any specific soil type. It grows well on sandy soils or muck lands and everything in between. However, for the best growth, full sun and moist, fertile, acidic to neutral soil is the best conditions. In Sweden and countries with similar cool climates, radishes are best sown in early until late spring and from late summer until early autumn. The seeds should be planted around 1 cm deep (Nonnecke 1989; Masalkar & Keskar 1998).

Radishes are always grown from seed. The emergence rate is controlled by temperature. At 20^0C, the seeds take about 4-6 days to germinate (Masalkar & Keskar 1998) and that is seen as the optimum germination time (Nonnecke 1989).

Radishes require 35-50kg/ha of N, 70-100kg/ha of P, and 70-100kg/ha of K (Lorenz & Maynard 1980 also cited by Nonnecke 1989). They are sensitive to boron (B) deficiency but tolerant to manganese (Mg) deficiency (Nonnecke 1989).

Pests of Oilseed Rape and Radish

Pests of Oilseed Rape

The increase in arable areas devoted to the production of *Brassica* oilseeds has provided crucifer specialists with an enormous resource for feeding and reproduction (Lamb, 1989). Presence of spring (annual) and winter (biennial) varieties of the crop in the same area is enhancing the temporal availability of host plants for insect pests. Plant breeding has drastically reduced the glucosinolate levels in the seed. However, these secondary compounds are still occurring in sufficient quantities to act as attractants and stimulants to insects in other plant parts (Ekbom 1995). Oilseed rape is attacked by a wide range of insect pests. Of them, some occur virtually wherever the crop is grown, whereas others have a more limited distribution. Several rape pests are brassica or crucifer specialists and attack e.g., seed crops, forage crops, vegetable brassicas and wild hosts such as charlock (*Sinapis arvensis*) (Alford *et al*. 2003). The major insect pests of oilseed rape in Europe are brassica pod midge (*Dasineura brassicae*), cabbage seed weevil (*Ceutorhynchus assimilis*), cabbage stem flea beetle (*Psylliodes chrysocephala*), cabbage stem weevil (*Ceutorhynchus pallidactylus*), pollen beetle (*Meligethes* spp. especially *M. aeneus*) and rape stem weevil (*Ceutorhynchus napi*). The minor insect pests are cabbage aphid (*Brevicoryne brassicae*), cabbage flea beetle (*Phyllotreta* spp), cabbage root fly (*Delia radicum*), peach/potato aphid (*Myzus persicae*), rape winter stem weevil (*Ceutorhynchus picitarsis*) and turnip sawfly (*Athalia rosae*) (Alford *et al*. 2003). Additional incidental pests are turnip moth (*Agrotis segetum*), crane flies (*Tipula oleracea*), mirid bugs (*Closterotomus norvegicus* and *Lygus rigulipennis*) and click beetle (*Agriotes lineatus*) (Alford *et al*. 2003).

Oilseed rape is either grown as winter rape (sown in late summer) or spring rape (sown in spring); and winter rape has a higher potential to compensate for pests damage as it is more vigorous than the spring type. Spring type oilseed rape is grown in Finland and Sweden mainly due to the regular extreme winter condition in these areas. *Phyllotreta* flea beetles are economically important pests for the spring type oilseed rape (Ekbom 1995; Alford 2003). Cabbage root fly (*Delia radicum*) can be a problem at crop establishment (Alford *et al*. 2003). Depending of the sowing time, cabbage root fly (*Delia radicum*), slugs, wood pigeons and some foliar diseases might also be important pests of oilseed rape.

Management of Oilseed Rape Insect Pests

Well-planned insecticide applications are economically justified, but nevertheless costly. A number of alternative control measures have been investigated for the important pests of oilseed *Brassica* crops e.g., trap cropping, biological control and host plant resistance and used in various parts of the world such as in Finland, Canada and India (Gerber 1978; Lamb 1980; Lamb 1984; Lamb 1988; Turnock & Bilodeau 1984; Hokkanen *et al*. 1986; Wylie 1988, Hokkanen 1989).

Control of pollen beetles is particularly important in northern Europe because the yield reduction by this pest can be as high as 70% in oilseed spring rape and somewhat lower in winter oilseed rape (Nilsson 1987). One main problem with pollen beetles in Denmark and Southern Sweden, in contrast to many other European countries, is the growing of both winter and spring rape. This prolongs the period with green bud stages and the period for pollen beetles to breed (Hansen 2003).

Chemical control of pollen beetles is often necessary to secure yields. Economical thresholds separate for winter and spring varieties, are used in Scandinavia (Nilsson, 1987). Several parasitoids are common and cultivation methods, such as avoiding ploughing can increase parasitoid numbers (Nilsson 1985). Another possibility to manage pollen beetle is combined application of insecticides and foliar fertilizers to improve tolerance at green bud stage (Seta & Mrowczynski 2004).

Pests of Radishes

The most serious insect problems of radishes are flea beetles, cabbage root fly (Walter 1984; Nonnecke 1989; Finch *et al*. 1989), peach/potato aphid (*Myzus persicae*) and mustard sawfly (*Athalia proxima*) (Swiader *et al*. 1992; Masalkar & Keskar 1998). Major pests of radishes are shown in table 3. Rotation of the planting location in the garden from year to year is one way to help to control many diseases and cabbage root flies (Ohio State University Extension 2000).

Common Insect Pests of Oilseed Rape and Radish

There are many insect pests common to oilseed rape and radish. Among those, flea beetle and cabbage root fly are some of the dominating ones (Drost & Bitner 2004).

Table 3. Major Pests of Radishes in USA

Diseases	**Insects**	**Weeds**
Damping off	Cabbage root fly	Annual grasses
Powdery mildew	Flea beetles	Annual broadleaf weeds
Downy mildew	Aphids	Perennial weeds
Club Root	Wireworms	
Rhizoctonia	Imported cabbageworm	
	Diamondback moth	
	Cabbage looper	

Source: Radish IPM Definitions (Ohio State University Extension 2000)

Cabbage Root Fly

The cabbage root fly (*Delia radicum*) is over-wintering in the soil as a pupa. When spring is coming, the adult flies are emerging, starts searching host plants and are able to travel considerable distances during that search. The flies are 5-7mm long rather delicate, hump-backed and grey-brown. The eggs are laid a certain time after beginning of the flight. The eggs are 1/8-inch long, white and torpedo-shaped. Eggs are laid at the base of the stem of cruciferous plants, or close to the stem of young plants in the soil. A damaging population density is likely to be around 1 egg/stem in oilseed rape. Eggs may be more abundant in wetter areas of the field (Jones & Jones 1984; Hazzard 2004; Agriculture & Agri-Food Canada http://www.inra.fr/internet/Produits/HYPPZ/RAVAGEUR/6delrad.htm).

In plants belonging with fleshy roots, the cabbage root fly larvae tunnels through or eat the total roots off. Thereby, it is possible to find tunnels of the maggot in such crops. In other crops, such as broccoli or cauliflower, the first sign of cabbage root fly larvae are wilting during sunny days and thereafter the plant will die (Hazzard 2004). The cabbage root fly has 3-4 generations during a year. Thus, the flies are present almost the entire growing season. However, in July and August, high temperatures together with diseases may suppress the populations. At seasons with cooler temperature e.g. September and October, damage starts occurring again. Several crops e.g. chinese cabbage, mustard, radish, rutabaga and turnip are attractive than cabbage for the cabbage root fly, being more severely injured (Jones & Jones 1984; Hazzard 2004; Agriculture & Agri-Food Canada http://www.inra.fr/internet/Produits/HYPPZ/RAVAGEUR/6delrad.htm). Radish damaged by cabbage root fly is shown in figure 14. In the figure also the bacterial rot which is part of the damage by cabbage root fly feeding is clearly visible.

Picture: N. Ahmed, SLU
Cabbage root fly larva comes out from radish root

Picture: N. Ahmed, SLU
Cabbage root fly larva and damage to radish root

Figure 14. Cabbage root fly larvae and damage in radish

Degree days can be used to predict emergence of cabbage root fly. However, degree day accumulations for emergence of cabbage root fly vary greatly across locations (Hazzard, 2004; Agriculture & Agri Food Canada).

In some seasons, cabbage root fly (*D. radicum*) infestations can kill 90% of the plants in untreated *Brassica* crops (King & Forbes 1954; Coaker & Finch 1971) although normally losses are about 25% (Strickland 1965 and also cited by Finch 1989). The different stages of cabbage root fly are shown below figure 15 after Hazzard (2004).

Captured cabbage root fly, *Delia radicum* L.

Cabbage root fly (Adult)

Cabbage root fly larvae

Cabbage root fly larvae and pupae (brown) with damaged roots and stem

Figure 15. Different stages of cabbage root fly, *Delia radicum*
(With kind permission of R Hazzard, rhazzard@umext.umass.edu, http://www.umassvegetable.org/soil_crop_pest_mgt/insect_mgt/cabbage_maggot.html)

Flea Beetle

Flea beetles of the genus *Phyllotreta* are well-known pests of brassicaceous plants, especially vegetable Brassicas e.g. white turnip, radish, cabbage, swede, kale etc. Several species belonging to *Phyllotreta and Psylliodes chrysocephala* are also known as major pests of oilseed rape in Europe and North America (Newton 1928; Nielsen, 1989; Demirel, 2003). In the UK, Saynor (1985) described several flea beetles life history, morphology and control on field and garden crops. Flea beetle damage to oilseed *Brassica* crops amounts more than $300 million annually in North America (Knodel & Olson 2002).

Kinoshita *et al*. (1979) described the biology of *Phyllotreta cruciferae* (Goeze) in the laboratory and field in Ontario and reared it for 8 generations in the laboratory on plants of radish, rape and swede (rutabaga). The mean pre-oviposition period ranged from 3.8 days at 32 ^{0}C to 22 days at 20 ^{0} C, and the duration of development from egg to adult from 24 days at 30 ^{0} C to 54 days at 20 ^{0} C. Temperature sums of 61 day-degrees above a threshold of about 17 ^{0} C, and 456 day-degrees above a threshold of 11 ^{0} C, were needed for oviposition and development. Adults over-wintered in leaf litter in the top 2.5 cm of soil, in windbreaks, fencerows and cultivated areas. Adults appeared in early spring. Peak adult movement occurred at this time, primarily within 2m above the ground. Using temperature sums calculated from soil temperatures, adult emergence from eggs set out in the field at various times was predicted with an accuracy of plus or minus 3.7 days. Population studies and temperature-sum calculations indicated that there was one generation in 1974 and two in 1975. Adults occurred mainly on cruciferous crops, with swede and chinese cabbage as the preferred food-plants. Economic threshold of crucifer flea beetle is 25% defoliation of cotyledons and first true leaves for seedlings of canola (Knodel & Olson, 2002). The life cycle of crucifer flea beetle is shown in figure 16 after Knodel & Olson 2002 and Hazzard *et al*. 2004.

Pest Resistance to Insecticides

Resistance to insecticides was first documented by A. L. Melander in 1914. Additional cases of resistance to inorganic insecticides were recorded between 1914 and 1946. By the development of organic insecticides, such as DDT, the hope grew that insecticide resistance was an issue of the past. However, housefly resistance to DDT was documented in 1947. By introduction of new insecticide classes additional cases of resistance have generally been developed within two to 20 years (www.sripmc.org; Daly *et al*. 1998). A number of 447 species of insects and mites have been shown resistant to at least one insecticide (Georghiou 1986). Of these resistant species, 56% are crop pests, 39% are medical/veterinary pests and 5% are beneficial species (Kazachkova 2007). Genetic variation of the pests and intensive application of insecticides are important for the rapid development of the resistances. Selection by the insecticide allows insects with resistance to survive and the proportion of resistant insects in a population continues to increase as the susceptible insects are eliminated by the insecticide (www.sripmc.org).

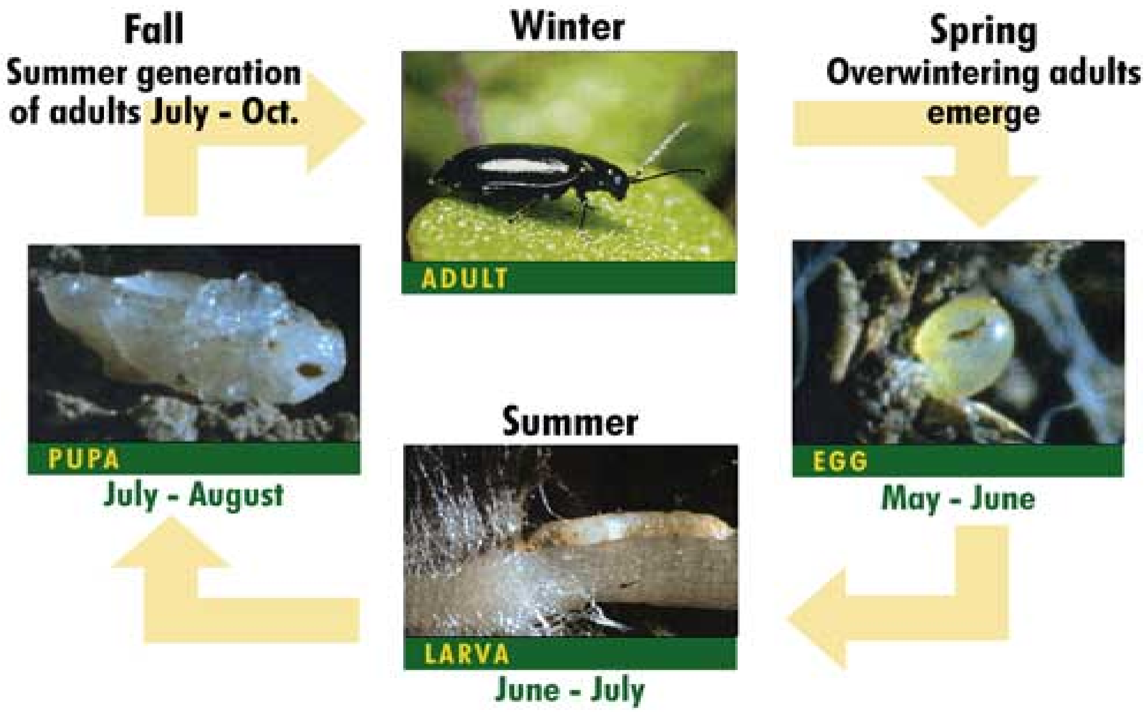


Figure 16. Life cycle of the crucifer flea beetle (With permission of Ruth Hazzard, rhazzard@umext.umass.edu**, and Becky Koch,** becky.koch@ndsu.edu **and the original photos by** Syngenta Crop Protection, Inc.**)**

The rate of development of insecticide resistance depends on factors such as how rapidly the insects reproduce, the insects' level of resistance, the migration and host range of the insects, the insecticide's persistence and specificity, and the rate, timing and number of applications of insecticide made. The use of insecticides on a large scale will speed up the selection process for individuals with pesticide resistance, as demonstrated by the development of resistance in such pests as Colorado potato beetle (*Leptinotarsa decemlineata*) and tobacco budworm (*Heliothis virescens*) (Georghiou 1986).

Due to additional treatment costs and lost yields insecticide resistance adds to the total insecticide bill. This bill can be reduced and the use of insecticide products more effective through better season-long management of pesticides by growers and the crop experts assisting them (Riley & Spark's 2006).

In 1977, Lakocy (1977) reported widely distributed insecticide resistance in populations of pollen beetles in Poland against a wide range of chlorinated hydrocarbon, organophosphorus and carbamate insecticides. Until the late 1990s no further insecticide resistance in pollen beetles in either Poland or other European countries has been reported. Thereafter, pyrethroid resistance has been recorded e.g. in France in 1997 and in Sweden in 2000 (Hansen 2003). In 2000, a small pilot test was performed in Denmark on one population of pollen beetles. The result showed about 90% surviving pollen beetles after treated with pyrethroids in Danish standard doses (Hansen 2003).

In 2001 and 2002 a survey for resistance to pyrethroids in pollen beetles was carried out covering the winter and spring oilseed rape acreage in Sweden. Resistance was widespread in a small area in Central Sweden during 2001 but was lower in this area during 2002. Signs of emerging resistance were observed in most of the other areas surveyed (Nilsson *et al*. 2003).

Migration of Insect Pests

Migration is a key process in the population dynamics of many insects, including some of the most damaging pests. One of the fundamental steps in the formulation of pest management strategies is the development of effective monitoring tools which depends on a comprehensive understanding of the ecology and behavior of the insect pest (Foster & Harris 1997). For example, an important aspect of pest behavior that can be exploited by pest management practitioners is the manner by which a pest approaches natural resources e.g., food, mates, or egg-laying sites (Hausmann *et al*. 2004). The type and timing of movement into an area (immigration) and out of an area (emigration) by a pest individual is also vital for understanding the dynamics of the pest population (Pedigo 2001).

Also, migration is a key process for understanding the epidemic spread of pest-transmitted plant viruses. The timing in relation to host plant age and the quantity of pest migration are thought to be the driving forces in the epidemiological system within field crops (Maelzer 1986; Riley *et al.* 1996).

Trap cropping

Trap cropping is the planting of a trap crop to protect the main cash crop from a certain pest or several pests. The trap crop can be from the same or different family group as the main crop, as long as it is more attractive to the pest. Certain crop cultivars or wild plants are particularly attractive to insect pests and can be used to concentrate the pests in non-crop areas, thus reducing pest incidence in adjacent fields (Hokkanen 1991). When pests are diverted successfully to (and concentrated in) such areas, these can be treated with pesticides or other agents, reducing the amount of pest ingredient even further (Walters & Hardwick 2000). Strips of turnip and winter rape established in crop margins have resulted in 28.4% to 80.3% of the total population of pollen beetles in the field being concentrated in the trap crop during the early immigration phase (Büchi 1995). Such strips have also contributed to the enhancement of parasitoid numbers in and around the field (Walters *et al*. 2003). Examples of trap crops that have been used are e.g. turnip rape for controlling pollen beetle and cabbage seed weevil in oilseed rape (Cook *et al*., 2004) and alfalfa for controlling the lygus bug (Brown 2004) and radish for controlling nematode in sugar beet (Held *et al*. 2000).

There are two types of trap cropping, perimeter trap cropping (PTC) and row intercropping. PTC means planting the trap around the cash crop field so that it completely surrounds the main cash crop (border trap cropping). It prevents pest attacks coming from all sides of the field. It works best on pests found near the borderline of the field. Row intercropping means planting the trap crop in alternating rows within the main crop. Growers using PTC have stated that this system improve and simplify pest control, reduce pesticide use (93%) and crop loss, and save time and money compared to conventional programs (Boucher & Durgy 2004). Others have shown that yield and damage levels were similar in PTC sunflower fields and full sprayed fields, but the trap crop system was more economical (Brewer & Schmidt 1995). Papaya fruit fly damage was almost eliminated in an unsprayed papaya planting in Mexico by using a PTC system (Aluja *et al*. 1997).

Trap crops have been shown to have a potential to contribute to the management of flea beetles on organically-grown crops, e.g. swede (Howard & Parker 2000).

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