

2 Integrated and Ecological Crop Protection (I/ECP)

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2.1 Analysis and diagnosis

2.1.1 Crop protection and pesticide use in Europe

In modern agriculture, crop protection has become increasingly synonymous for pesticide use. The use of pesticides in Europe varies strongly in each country (Figure 2.1) and for each crop.

The total use in the European Union is about 300 000 ton (1996). Fungicides make up the largest pesticide group sold in the 15 countries of the European Union, accounting for 41% of total weight of active ingredients in 1996, followed by herbicides (39%), insecticides (12%) and other pesticides (8%)

(http://europa.eu.int/comm/agriculture/envir/report/en/pest_en/report_en.htm). However the situation varies from one country to another due to different climatic conditions and different types of crops. For example, in countries in which a large quantity of cereals is cultivated, pesticide input tends to be much lower.

Specific data on the use of pesticides in field-grown vegetables does not exist for most countries. However, the estimated active ingredient input for field-grown vegeta-

bles is expected to be at least equal to the average input in agriculture considering crop intensity and the large variety of harmful organisms.

Despite all efforts to reduce pesticide use, the total use is rather stable especially for fungicides and insecticides:

- A high intensity of cultivation and narrow one-sided rotations resulting in an increase in pest and disease pressure, especially from soil-borne pests and diseases.
- Decreasing effectiveness of pesticides caused by more resistant pest, disease and weed populations.
- The introduction of new exotic pests and diseases.
- Market standards demanding stable and high cosmetic quality.
- The relatively bad economic situation of vegetable farmers combined with the absence of financial incentives to reduce pesticide use.
- Relatively low costs for pesticide input compared to the high value of the crop and high risks for complete crop loss caused by pests and diseases.

Pests and diseases can cause very high or complete yield and quality losses in vegetable crops. Small defects in the product can make the product unmarketable.

These high quality demands and the large financial risks cause most farmers to use very conservative crop protection strategies with low risks.

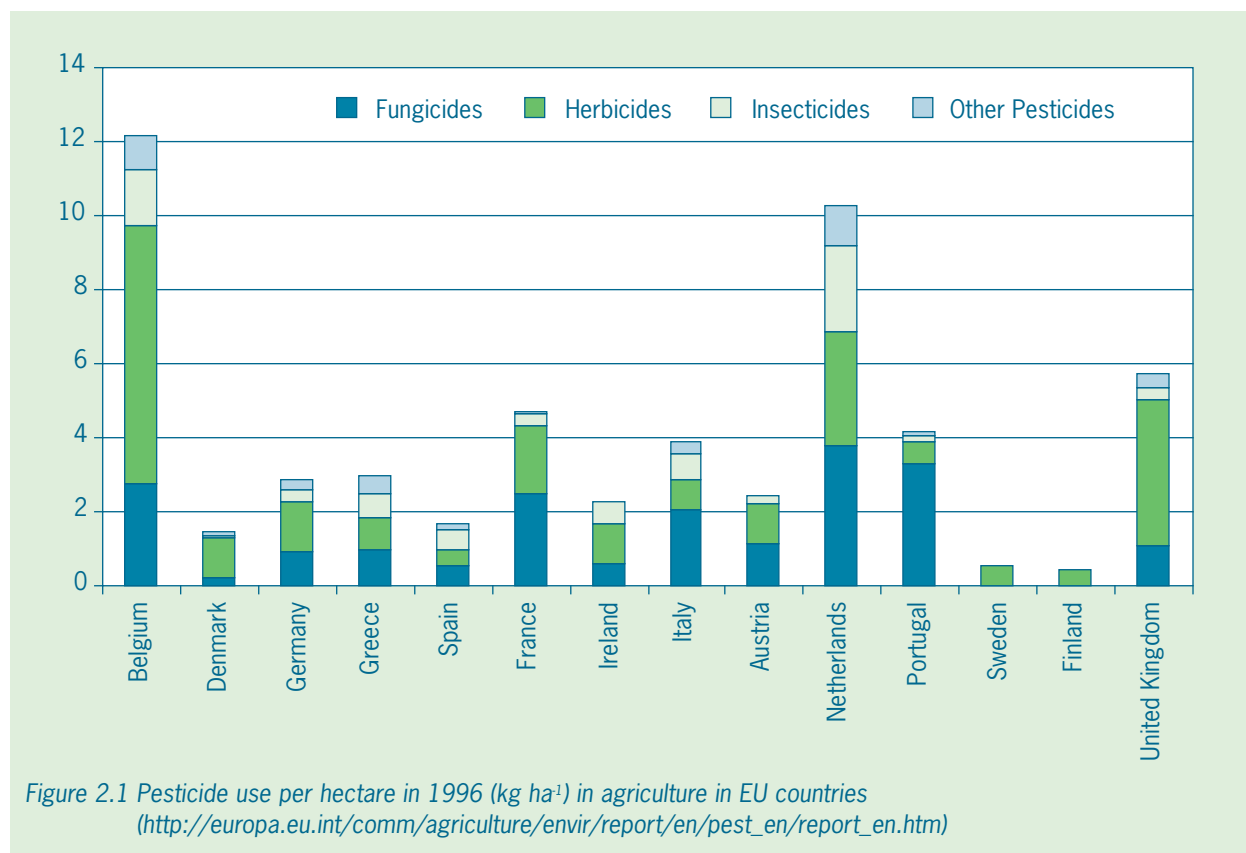


Figure 2.1 Pesticide use per hectare in 1996 (kg ha^{-1}) in agriculture in EU countries (http://europa.eu.int/comm/agriculture/envir/report/en/pest_en/report_en.htm)

In general, production of vegetable crops has been increasingly rationalised for the past decades in Europe. Scale enlargement, specialisation, increase in level of farmers' expertise and restrictive legislation are the leading factors for this development. However, there is still a large dependency of pesticides mainly because the risks of financial yield loss are high compared to the costs of the pesticide input. Frequent periodic treatments are commonly used against many pests and diseases, and when effective pesticides are available, the cultivar choice is more based on their potential yield and quality than on their resistance to pest and diseases. This dependency is stronger in the Mediterranean countries, such as Italy or Spain, than in Northern Europe. The warmer climate in southern countries and, therefore, the possibilities for all-year round crops are important because of the higher pressure of pests and diseases. Soil disinfections are normal practice in the most intensive areas. In addition, the small size of fields and a lack of adequate machinery are usually the biggest obstacles for mechanical weeding.

In Northwestern Europe, the weed control in field-grown vegetable crops tends towards the use of mechanical control and the use of low dose systems. However, there is still a preference for the use of herbicides compared to mechanical control. In agriculture, the use of herbicides in the Netherlands has been reduced 33% in the last 15 years (anonymous 2001). Concerning fungicides and insecticides, pesticide use has been stable for the past decade. The humid Dutch climate, world market prices and quality requirements makes farmers more dependent on the availability of fungicides. The application of fungicides and insecticides in practice is the balance between a rational control based on observations and weather conditions, and a preventive control as an "insurance policy". The use of chemical soil disinfection has been reduced with 88% in the past two decades mainly because of restrictive legislation.

2.1.2 Undesirable side-effects of pesticide use

Pesticide use has many undesirable side effects such as emission, damage to non-target biota and risks for human health. These side effects are discussed in more detail in this section.

Emission to the environmental compartments air, soil and water

Volatilisation is the major cause of pesticide loss. Volatilisation losses up to 80-90%, within a few days after application, have been reported (Taylor and Spencer, 1990). A study in the Netherlands (as part of the evaluation of the crop protection policy) estimates that some 50% of the total pesticide used volatilises (Anonymous, 1996). What happens to pesticides in the atmosphere is relatively unknown. However, atmospheric transport and deposition (global distillation) may distribute many pesticides all over the earth (Schomburg and Glotfelty, 1991;

Gregor and Gummer, 1989; Atlas and Schauffler, 1990; Simonich and Hites, 1995).

Pesticide concentrations exceeding the permitted amount are regularly found in ground and surface waters. A study in four countries within the European Union (Isenbeck-Scröter et al. 1997) shows that the pesticides most frequently detected in water analyses are **atrazine**, **simazine** and **bentazone**.

Damage to non-target biota

The presence of pesticides in the abiotic environment is potentially a threat for all of the biota (non-target). The magnitude of this threat is only partially known and quantification is difficult because of the several emission routes. Although the poisoning of non-target wildlife is regularly recorded (water life, birds, predators), a proper evaluation of the ecotoxicity of a substance is virtually impossible since it involves thousands of different species that react differently when exposed to a certain substance. It does not only involve direct toxicity but also mid-term and long-term effects on, for instance, fertility, vitality and population dynamics.

An indirect effect of pesticide use is the selection of resistant and competitive genotypes, which out-compete non-target species. The selection of aggressive and resistant weeds by the intensive use of herbicides has been reported to influence biodiversity in field margins and hedgerows.

Risks for public health

The risk for human health due to pesticides use is different depending on the population. The groups with the highest risk are farmers and other professionals working with the pesticides. On the other hand, a distinction can be made between acute and chronic toxicity, which mainly depends on pesticides characteristics, and amount and length of exposure.

In the last 10-15 years, another long-term effect has been detected for certain pesticides. It is the endocrine disruption, and it can be summarised as the capacity of certain pesticides and other compounds to change the hormonal equilibrium (endocrine functions) affecting the health of an organism or its offspring. Exposure to endocrine disrupting chemicals is particularly serious for pregnant or nursing women and their developing fetuses or babies (Smolen, 1996). Legal measures are expected to be taken concerning these kinds of substances in the near future. It could lead to a major change in the environmental concept of the pesticides.

On the other hand, Public Administrations regulate pesticide use and set MRLs (maximum of residue level) for the authorised pesticides on crops to decrease the risk of pesticide contamination. The main problem with MRLs is that there are many differences between the legislation among the different countries, and many times, this can be an obstacle for international trade. Legislation within the EU member states is continuously progressing because the residue limitations are being brought into

line. Control programmes are usually run to control that these residues are not higher than permitted amounts. According to different vigilance plans set up in several European countries (Coscollá, 1999), the range of samples with residues above the MRL is from 0.7% (Germany '96, national market of fruits and vegetables) to 9.3% (Finland '97, imported fruits and vegetables). In every case, the amount of samples with residues is always much higher. For example in the Valencian region of Spain, the average percentage of samples with pesticide residues was 56.2%, and samples with residues over the MRL were 2.6% (SSCV de Silla, 2001). In every case, these figures are useful only as an estimate for two reasons: the difficulties in analysing the methodology and not all the compounds are usually analysed.

2.1.3 Policy, legislation and label guidelines

Policy and legislation

The current EU policy, in particular directive EU 414/91, and most of the EU countries pesticide policies focus on regulations, which define minimum requirements and the same standards for quality, and application of agricultural pesticides. The uniform EU principles for the admission procedure were set in 1994. Maximum levels were set for factors such as persistence, risk of groundwater contamination and the bio-concentration factor. The progress of EU legislation being implemented into national legislation is continuing very slowly.

The EU intends to add pesticide policies in addition the current regulatory framework. Under the EU's Fifth Environmental Action program (1992), the EU has set for itself the objective of achieving by 2000 a "significant" reduction of pesticide use. Actions identified as necessary to reach the target are registration of sales and use of pesticides (EU 414/91). There is also a move towards policies that aim to provide assistance to agriculture, targeted to specific (environmental) outcomes (cross compliance, agri-environmental programmes). Payments or other financial benefits to farmers for environmental purposes are increasing (for instance, Council Regulation 2078/92 EC about agro-environmental programmes).

EU Directive 83/91 of 3 November 1998 on the quality of drinking water has set the maximum admissible concentrations of each substance at 0.1 ppb and the total concentration of all pesticides at 0.5 ppb. Concerning food safety, the EU guidelines EU 642/90 and EU 362/86 standardise the residue tolerance of pesticides in foodstuff.

Pesticide use in organic production in Europe has been regulated in Council Regulation EU 2092/91 (revised by Commission Regulation EU 436/2001).

At a national level, diverse action plans have been or are running to reduce pesticide use in Sweden, Denmark,

Finland, Austria Switzerland, and the Netherlands. All pesticides are re-evaluated in line with the European standards for application of pesticides. This means that the number of allowed pesticides will decrease and the most environmentally harmful applications will be eliminated. The aims of the policies concerning pesticide pollution are the reduction of dependency, emission and damage. These policies have resulted in legislation, subsidies and agreements within the agricultural sector.

The MJPG policy in the Netherlands, completed in 2000, involved an agreement with the agronomic sector to reach certain targets for pesticide use and emission. One of these targets was the reduction of pesticide use by 40% from 1995 to 2000. Based on the evaluation of the MJPG policy, a new policy is being developed for the coming period, which possibly will include tax benefits for farmers who can fulfil certain requirements for pesticide use. There is also legislation being developed (probably active starting in 2002) which requires a licence for production. This legislation involves certification of producers, complete registration of pesticide inputs and restrictions on pesticide use.

In Switzerland, the federal board for agriculture supports different eco-programmes, for example, the IP-program and the Bio-program. The legislation consists of article 31b of the law for agriculture and it establishes that by 2005, 90% of all farms should be registered as integrated or organic producing farms. The reform of agricultural policy in Switzerland ("Agrarpolitik 2002") requires the farmers to fulfil some requirements in order to receive direct payments. These requirements are connected to common integrated farming practices. For instance, chemical soil disinfection is not allowed.

Integrated labels

There are several IP labels in the EU countries, promoted either by the Public Administrations or the supermarket chains. Crop protection is established in these protocols by creating for each crop a short list of pesticides that can be used and others that can only be applied with restrictions. Recording all farming activities is required, especially pesticide applications (even those applied after the harvest). Other important requirements are connected to protective clothing for working with pesticides, spray equipment (annual calibration is needed), residues analysis, pesticides storage, and handling of empty containers and obsolete pesticides. In general, nothing is stated about specific limitations of pesticides inputs or residues.

Nevertheless, not all field-grown vegetables have specific protocols in every EU country. Furthermore, requirements can vary quite a lot within the different labels because there is no international standard for integrated food production. The new EUREP GAP protocol for Good Agricultural Practices is the first attempt to standardise

one IP label in Europe. Some European retailers (mainly Dutch and British) have targeted the EUREP GAP label to become a reference point for the near future. The protocol has been set out for the global production of horticultural products. Therefore, the requirements are very general and based on national legislation. As legislation in different European (and world) countries on crop protection is diverse and standardisation is continuing very slowly, EUREP GAP lacks a solid base of requirements and different interpretations will appear. However, certain basic elements for crop protection are required in certification schemes:

- Attention to prevention such as choice of appropriate crop or variety, crop rotations, use of resistant varieties, creation of habitats for the beneficial predators, and good hygienic practices.
- Methods to determine when action is required.
- Preference of non-chemical methods (cultural, physical and biological) over chemical methods.

For example, according to EUREP GAP 2001, “growers must...seek to employ crop rotations whenever practicable”. Furthermore, “where rotations are not employed, growers must be able to provide adequate justification”. The chemical fumigation of soils will be avoided wherever possible.

In some Dutch labels, there is a maximum of active ingredients input at a crop level (MBT or milieukeur). In other cases, the chemical disinfections of soils are not allowed (MIGROSSano and SGU in Switzerland, and regional guidelines of Murcia in Spain). In other cases, these labels limit the level of pesticides residues to under the 50% of the MRL, such as NATURANE in Spain.

Organic labels

Most labels for organic production in EU are based on EU Regulation 2092/91. In general, this regulation treats several topics in a general way and, therefore, it is submitted to different interpretations that will be reflected in national guidelines. For example, in the list of authorised “bio-pesticides”, the use of some (copper or **azadiractin**) is conditional based on the need to be recognised by the inspection body or authority. The protection of natural predators will have to be reinforced through the “care of hedges, nests, and so on” (different interpretations may appear). Genetically modified organisms or the derivatives are specifically banned in organic farming. The list with approved organic pesticides differs between countries. Some pesticides will be forbidden in most countries due to the negative effects on both the environment and human health such as copper, **metaldehyde**, mineral oil and **nicotine**. In almost every case, most organic pesticides somehow affect not only the environment and human health, but also the equilibrium of the farming systems.

In the Netherlands, the pesticide policy for organic farm-

ing is stricter than in other countries. For instance, copper is allowed in all partner countries except the Netherlands, although a reduction in use is predicted. In Switzerland, only non-synthetic (natural) pesticides registered in an official list (FiBL, 2000) can be used if cropping strategies and biological control are not successful.

2.2 The theoretical background of I/ECP

Definition

Integrated and Ecological Crop Protection (I/ECP)

Integrated/ecological crop protection is the prevention or minimisation of economical damage to crops caused by harmful species with a minimum of negative effects on the environment.

Integrated and organic crop protection focuses on sustainable production, producing high quality food and other products, diminishing the impact on the environment by minimising emission and damage to non-target biota caused by crop protection products and measures. Natural resources and regulating mechanisms are used as much as possible to replace polluting inputs. Only the residual harmful species that are expected to cause economic damage to the crops are controlled with the input of pesticides.

Minimising emission and damage provides adequate food safety. Residues on food products from the crop protection products used should be avoided or at least be below the legal limits.

The terms “integrated and ecological” in the method name stands for the prototype in which the crop protection method is used. The general principles of the method are basically the same for prototypes of both organic and integrated farming systems. The difference is that in organic systems, contrary to integrated systems, no “synthetic” pesticides are used. Therefore the focus of the crop protection methods can be on different factors for different prototypes.

Connection to other farming methods

Crop protection does not function independently of other farming methods. In addition to Nutrient Management and Ecological Infrastructure Management, Multifunctional Crop Rotation (MCR) interacts closely with I/ECP. In defining the rotation of a farming system, the basis is laid for optimal prevention against pests and diseases based on the choice of crops and varieties and the layout in time and space.

The relationship of I/ECP with Nutrient Management is laying in the growth of healthy crops: both nutrient deficiency and surplus can make crops susceptible to pests and diseases. Ecological infrastructure Management influences I/ECP by giving food and shelter to beneficial and/or harmful species.

Relationship with different themes

The themes criteria used to assess the performance of farming systems were given in paragraph 1.2. Crop protection has a strong relationship with the themes quality production, farm continuity and clean environment.

- Clean environment is strongly influenced by the emission of pesticides in different environmental compartments and by the damage that can be done to non-target species.
- Quality-production is influenced by the prevention of yield and quality reduction by harmful species, pesticide damage to the crop (herbicides) and pesticide residues on the product.
- Farm continuity is influenced indirectly through the effect on quality production and directly by the costs of crop protection and extra labour input (manual weeding) caused by insufficient crop protection.

In addition to these main relationships, crop protection can influence 'sustainable use of resources' by the accumulation of pesticide residues in the soil (for example, copper). Also the management of the natural habitats on farms can influence crop protection because natural enemies can use it for food and shelter. In Annex 2, an overview shows the common set of parameters.

2.3 Design of crop protection strategies

2.3.1 Main elements of an integrated strategy

To design crop protection strategies, a three-step approach is followed. These steps should be followed in sequence. The last step, actual treatment or control measures, is only taken after all other options in the previous steps have been used or considered.

1. Prevention:
 - a. Strategic:
 - farm hygiene and legal measures,
 - agro-ecological lay out and crop rotation,
 - stimulation of bio-diversity,
 - soil structure and water management.
 - b. Tactical:
 - variety of choice,
 - healthy seeds and plant material,
 - adapted planting time or plant spacing,
 - optimal nutrient supply,
 - soil cultivation.
2. Establish need of treatment:
 - a. Regular crop inspection.
 - b. Prediction of economic loss (thresholds, guided control systems).
3. Treatment measures (crop protection: physical, biological and chemical):
 - a. Non-chemical.
 - b. Chemical:
 - pesticide choice,
 - dose, timing and technique.

Prevention is considered the basis of integrated ecological crop protection. In prevention, strategic and tactical elements can be distinguished. Strategic measures are usually long-term and are often basic choices in the total farm design. Crop choice, rotation and agro-ecological layout are some of these strategic elements. The tactical elements are usually short-term actions mostly in connection with the cultivation technique.

Structural elements (preventive measures) will not usually completely eliminate the occurrence of noxious organisms. However their occurrence does not necessarily have to lead to economical damage. Appropriate tools and expertise must be available and used to determine whether it is necessary or not to take any action to control these organisms. Regular crop inspection is the basic action.

In the end, when the need to intervene is clear, the most adequate action must be chosen. Of course, treatments must be effective and practical. However, treatments must also be judged on their environmental, ecological and economic merits. From an ecological and environmental point of view, physical or biological control is generally preferred above chemical control.

For every combination of a crop and harmful species, an optimal strategy can be designed consisting of the elements that are mentioned. Especially for the structural elements of the strategies for different crops, it is vital that they are adjusted to each other in a complete strategy. The different possible elements of integrated crop protection strategies are treated in detail in the next section.

2.3.2 Prevention

Prevention can be summarised as measures for reducing the probability of damage. The so-called preventive pesticide inputs are not included in prevention strategies. Next the main elements of prevention will be treated below:

1. Prevention of initial inoculum:
 - legal measures,
 - farm hygiene and healthy seeds and plant material.
2. Enhancing (bio) diversity:
 - crop rotation and variety choice,
 - design of the agro-ecological layout,
 - other means of bio-diversification.
3. Creating unfavourable conditions for noxious organisms:
 - cultural methods,
 - nutrient management.

Legal measures

All the members of the EU have legislation to eliminate introduction of new exotic organisms and dispersal in their countries. With the elimination of borders in the EU, this legislation has become even more difficult to regu-

late. At this time, the EU legislation should be capable of eliminating introduction of these exotic organisms as much as possible and their possible dispersal through the different countries.

There are many examples of the import of exotic organisms: *F. occidentalis* in vegetable crops, or *P. citrella* in citrus crops are some the most recent and most important cases. At the same time, new viruses are continuously appearing almost every year. Rigid and strict legislation could save a lot of money and make the farming systems more sustainable. For this legislation to become more efficient, it is necessary to have (Ripollés, 1988):

- an actual and clear legal base,
- public services that can regulate this legislation quick and efficiently,
- appropriate technical and economic means.

The two most important legal means for prevention are quarantines and inspections of nurseries.

Farm hygiene, healthy seeds and plant material

Farm hygiene and the use of healthy seeds and plant material are important instruments to avoid or minimise the initial introduction of harmful species. This can completely eliminate infection or slow down their development. Farm hygiene involves:

- Eliminating pest and disease survival in crop residues or on host plants by removing them.
- Avoiding contamination of fields and plants due to transport on machines, humans, or other means of dispersal.
- Avoiding initial introductions by using disease and weed-free seed or plants and organic fertilisers (composts, manure).

Legislation only partially guarantees the use of healthy and disease-free material. Some pests and diseases cannot be detected on seeds and planting material. For other harmful species, it is not required to deliver disease-free plant and seed material. Careful selection of especially vegetative propagated crops and plantings can be very useful.

Crop Rotation and variety of choice

The main cause of the high pressure from and the fast propagation of harmful species is the cultivation of continuous monocultures. Crop rotation on farms can be highly effective to break this monoculture in time and space. The main principle is

to follow one crop by another genetically unrelated one so that the pests of the first crop are unable to feed or propagate on the following crop. This means diversification at the farm level between plant families and/or plant species, or even between plant varieties. However, such techniques may or may not coincide with good agronomic practices and each case must be decided on its own merits. The composition of the cropping plans, the order of the crops in the rotation, the numbers of years between crops of the same family, species or varieties are factors that need to be considered

Figure 2.2 depicts the role of crop rotation in the prevention and control of pests, diseases and weeds (after Vereijken, 1994). Pests and diseases are placed along two axes. On the x-axis, the organisms range from non-mobile, mainly soil-born to very mobile, mainly airborne. On the y-axis, the organisms range from very specific (monofageous) to non-specific (polyfageous). Crop rotation is of increasing importance as the line moves from the lower right corner to the upper left corner.

1. Specific and non-mobile pests and diseases (upper, left corner): mostly soil-born, such as the cyst nematodes and *Rhizoctonia* spp. Infrequent planting of the organisms' favourite crop is usually sufficient to suppress these pests and diseases. The use of resistant and tolerant cultivars supports this approach. Specialised nematodes, such as the potato cyst nematode, can be controlled well with crop rotation.
2. Non-specific and non-mobile pests and diseases (lower left corner): these also mainly soil-born pests and diseases such as *Sclerotinia* and root knot nematodes. The composition of the crop rotation is important; which crops are grown and in which sequence. Support for this approach can be found in the crop-

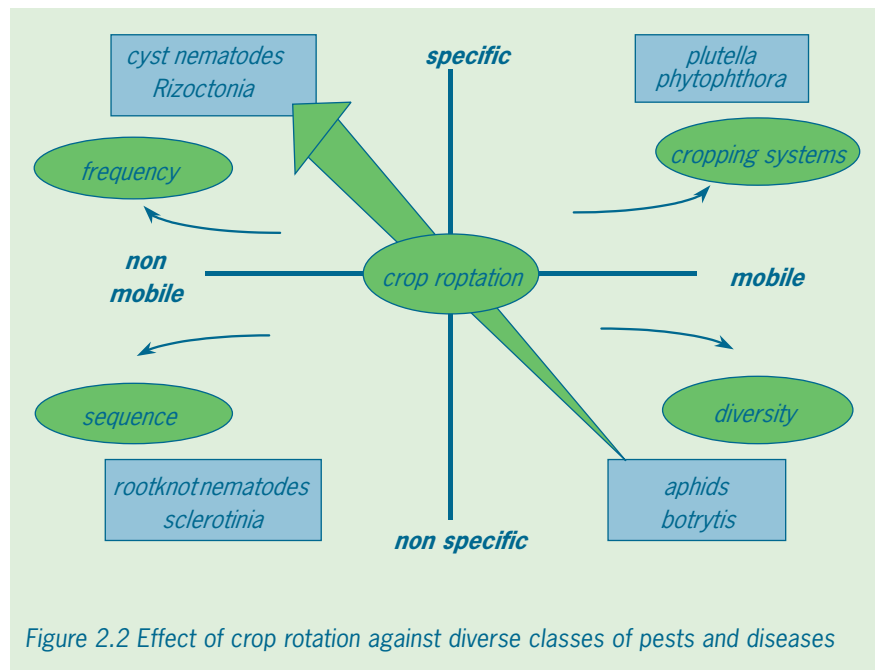


Figure 2.2 Effect of crop rotation against diverse classes of pests and diseases

ping systems and cultivation measures (sowing or planting date, cultivar choice) depending on the organism involved.

3. Specific and mobile pests and diseases (upper, right corner): these are organisms such as *Plutella* and *Phytophthora*: classical crop rotation at the farm level is not helpful here, although spatial crop rotation can contribute to the control of semi-mobile, specific pests and diseases. Other solutions might be found in the cropping systems (cultivar choice, sowing or planting date, crop structure). Control measures during cropping might be necessary.
4. Non-specific and mobile pests and diseases (lower, right corner): many pests and diseases. Crop rotation is of little or no use, although crop diversification might be helpful. Again, the design of cropping systems and cultivation measures can contribute to prevention.

In these two last cases, natural predators might help to protect the crop. Natural predators must be stimulated with a carefully designed and managed ecological infrastructure on the farm that offers year-round shelter and food (functional biodiversity). Also factors such as shape and size of fields and the total farm (parcel) layout are increasingly important, this is the agro-ecological layout of the farm.

Variety of choice can be considered as an important factor in crop rotation. (Partially) resistant varieties stop or slow down the propagation rate of the harmful species. Tolerant varieties show little (economic) damage from pest and disease pressure. Cultivating resistant or tolerant varieties can be a very powerful and effective preventive tool in crop protection. However, monogenetic resistance against mobile and fast propagating pathogens often is broken quite rapidly.

Crop rotation also can play a role in the prevention of weeds. Crops differ in their capacities to cover the soil and their different speed of development. Crop diversification can help to prevent the development of weed populations adapted to a specific crop. Also the mechanical control alternatives are considered in the design of the crop rotation. In specific crops, (specific) weeds can be very efficiently controlled, which gives a cleaner starting point for the following crop. In the Manual on Prototyping Methodology and Multifunctional Crop Rotation, the design of multifunctional crop rotations (MCR) and agro-ecological layout (see next section) is discussed in more detail.

The design of an agro-ecological layout

The design of an optimal agro-ecological layout in time and space can be an additional preventive element. Its function is also based on prevention of monoculture in time and space. This concerns not only the choice of a multifunctional crop rotation (see Manual on Prototyping

Methodology and Multifunctional Crop Rotation), but also the agro-ecological identity of the farm.

Additional criteria are formulated with regard to the layout such as adjacent fields, field size, field length and width, adjacency of subsequent crop rotation blocks and the ecological infrastructure. These ensure a maximum contribution of the MCR to the prevention of pests and diseases (Vereijken, 1994). The adjacent fields in a crop rotation refer to the proximity of the same crop or the distance between crops belonging to the same group, both in time and space.

Plots with diversified vegetation in non-productive parts of the farm or in strips will generally result in enhanced diversity and abundance of natural predators. The specific species will vary depending on the diversity and availability of primary and alternative hosts or prey, location and size of the field, plant composition, floral diversity, surrounding habitat and land management technologies. The increase of natural enemies in fields can be achieved through several methods:

- *Hedgerows and field margins:*
Hedgerows and field margins serve as refuge sites for many animal species and increase the number of beneficial arthropods. They eliminate drifting of pesticides from or to surrounding fields or bodies of water. Plant species should be nectariferous and offer a microclimate favourable to natural predators. First, an assessment must be made that they are not an alternate host for the pest species.
- *Sown strips of weeds.*
The presence of weed strips can increase the numbers of natural enemies near the crops. For example, the strips sown with *Galinsoga ciliata* and *Stellaria media* have been studied in cereals. These strips increase the number of aphid predators, such as syrphids.

Other methods of increasing bio-diversification

Bio-diversification is widely recognised as a factor of equilibrium not only in agro-ecosystems, but also in any of the environments that are found in nature. The more homogeneous they are, the more biotypes will be affected by any incidence. In farming systems, bio-diversity can be increased at different levels: the design of a crop rotation increases bio-diversity at a field level, and the design of an agro-ecological layout works at a farm level. Also different scales can be distinguished within bio-diversity. Bio-diversity refers to the number of species and the diversity within a species (for example, the genetic diversity of cultivars or subspecies). The presence of different predator and competitor species can help to bring about a balance among the potential harmful organisms in farming systems. Intercropping and mixed cropping is an agronomic alternative for breaking monocultures and increasing biodiversity, and is gaining interest in research institutions. However, up until now, these have too many technical difficulties to overcome in modern agriculture.

The natural predators hypothesis states that both generalists and specialists will be more abundant in polycultures than in monocultures. Larger numbers of polyphagous predators, such as carabids, sirfids have been found in polycultures more than in monocultures. The effect of using polycultures on specialists is less clear. There is no unequivocal proof that increasing natural predator activity causes a decrease in the density of the herbivore population. An example of intercropping is the combination of alfalfa and cereals. Parasitic *Hymenoptera*, specifically *Ichneumonoidea*, needs water and cool temperatures and are, therefore, always collected in the alfalfa. Intercropping cabbage or leek with clover (*T. repens* and *T. subterraneum*) has shown good results in terms of suppression of oviposition and larval populations of various pests, although competition for nutrients, water and light reduced marketable yield.

Water management and soil structure

A good water purity and soil structure maintains the vitality and health of crops by providing optimal growing conditions for the crop. Concerning pests and diseases, these elements prevent the occurrence of specific diseases such as *Phytium spp.* and the soil biodiversity is also potentially enhanced (see also effects of biodiversity).

Cultural methods

Cultural measures involve altering the habitat to make it less favourable for pest reproduction and survival. The application of cultural methods must be based on a biological and ecological foundation, just as much as any other technique. A thorough knowledge of life history and habits of the pest is particularly essential. At the same time, an understanding of the ecosystem is necessary because habitat modification may be harmful for one pest, but could well favour one or more others. Altering plant density and plant spacing, for example, is used to control relative humidity within the crop and also the possibility of infection and propagation of diseases.

The right timing of sowing or planting dates to avoid favourable conditions for infection or periods with high disease pressure in the plant's susceptible stages can be included in a specific agronomic practice. Several examples can be given: weed control is much more difficult in summertime because of watering for farms in the Mediterranean regions; in Eastern Spain, weed control is much easier from October to February. The incidence of viruses is also dependent on the time of the year. Also in Northwestern Europe, the cabbage fly has specific periods that the different generations disperse. The first dispersals can be predicted quite accurately and planting dates can be adjusted to these flights.

Timing and method of harvesting can be manipulated as well to reduce pest populations. Strip cutting of alfalfa is a classical example. Row distance can be adapted to the

available machinery and equipment. Accurate and regular rows and an even surface are an important agronomic practice to make the mechanical control of weeds easier.

Another agronomic aspect that can influence pest and disease development and damage is timing and amount of irrigation. Irrigation influences the crop microclimate and as such, it influences the development of pests and diseases. Washing the pests of the susceptible plant parts is another technique that is sometimes used.

The objective of soil tillage is to establish and preserve soil's condition. This provides optimum conditions for the cultivation and growth of crop plants, and maintains its long-term productive capacity. Soil tillage can indirectly reduce the chance of damage by creating the optimum growing conditions for the crop. However, there are also some examples of the direct action against harmful organisms. The most impressive result of soil tillage is weed control. The use of various types of soil tillage before and after crop cultivation can play a large role in the prevention of weeds during cultivation. Effects of soil tillage on pests and diseases can be the control of pests in susceptible stages (pupae or eggs) and the spreading of pests through soil tillage (see also farm hygiene). Insufficient soil tillage can create favourable conditions for a wide range of soil pathogens. For example, compacted, wet soil provides very favourable conditions for *Phytium*, *Phoma*, *Erwinia* and *Fusarium* species.

Nutrient management

The aim of nutrient management is providing an optimal supply of nutrients to a crop. Sub-optimal nutrient supply can cause losses because of nutrient deficiency, but also can cause a higher susceptibility to harmful species. Fertilisation levels that are too high as well as too low can cause the crop to be more susceptible to pests and diseases. Nitrogen supply can influence the microclimate within a crop, which can cause a higher risk of infection of diseases. Poorly grown plants, on the other hand, are often also more susceptible to pests and diseases. Application of organic manure can have, in addition to the increased nutrient supply, a positive effect on the anti-phytopathogenic potential of the soil. On the other hand, weed seeds can be imported with organic manure.

2.3.3 Monitoring and need of controls

Several steps could be followed to establish whether it is or not necessary to take any action to control the potentially "harmful organisms":

- determine if organisms are harmful,
- monitor,
- prognosis of infestation or infection,
- prognosis of economic loss.

Determine if organisms are harmful

First of all, it has to be determined which harmful organisms can influence normal growth or cause a decrease in

yield or quality. The set of potential harmful organisms is different for every crop, for every region and for every field in the case of weeds. This step is essential because expertise about what needs to be detected simplifies monitoring.

Monitoring

Detection of the initial infection can be site-specific or regional, depending on the pathogen. In some cases, the harmful organisms are known to be always present in small quantities (for example, *Botrytis cinerea*). In other cases, it must be detected by monitoring. Regular monitoring in vegetable crops is very important because many organisms can colonise and damage the crop very quickly. The frequency of checking and the sampling size in the field is dependent on many factors such as the stage of crop growth, the potential danger of the organisms and their development, and climatic conditions. Once or twice a week can be considered the correct frequency when the risks are high.

While monitoring, all the areas in the field must be inspected, zigzagging through the entire field and choosing plants to be sampled randomly. Usually, there are no guidelines indicating how many sample sites are needed for an effective monitoring. In each case, sampling the edges of the field is important because infestations often begin in these areas. It is important to distinguish between the different developmental stages of the harmful organism because each organism has different behaviours regarding the crop, pesticides and growing cycles. Pheromones, food and sticky traps are commonly used to detect the presence of certain pests, although they are sometimes used to determine the need for control (for example, in some cases of Lepidoptera or wireworms). The monitoring of weeds consists basically of determining their occurrence, development and their level of infestation in the field.

Prognosis of infection or infestation and economic loss

Once the pest or disease is detected in the crop, the need for control involves the prognosis of infestation or infection and development, and prognosis for potential economic loss. Before taking measures to control the organisms, it has to be established whether there is a chance for infection or infestation and whether this can cause economic loss (including the costs of control). In order to carry out this prognosis, an expert level of epidemiological knowledge about the harmful organisms is required, including symptoms, pest and disease cycles, natural enemies, ecological niches and optimal conditions for its development.

There are several factors that must be taken into account in order to predict whether the pathogen will cause economic damage or not. Examples are the levels of infestation or infection together with the stage of crop develop-

ment, the number of natural enemies and the climatic conditions.

In case of diseases, their rate of development and the resulting damage are influenced by the genetic characteristics of the plant, its stage of growth when infection or stress occurs, other stresses occurring at the same time and environmental conditions, especially temperature and humidity (Flint, 1987).

When symptoms are detected, the diagnosis is usually difficult because different diseases can cause the same symptoms or the similarity between symptoms of different diseases can be minimal. Analysis in specialised laboratories is frequently required to find out the identity of a specific disease. In monitoring diseases, it is important to record the distribution of the symptoms (scattered plants, concentrated in certain areas or generally distributed). Soil and climatic conditions, as well as the humidity within the canopy should be recorded because the development of pathogens (especially initial infection) is often dependent on these microclimatic conditions.

Various monitoring systems as well as economic or treatment thresholds have been developed to establish the need for control of pests and diseases in the most important crops. However, this is not the case for a large range of pathogen-crop combinations in less important vegetable crops. The main reason is probably the relatively small area of vegetables in the whole group of crops, and the large variety of vegetable crops and their pathogens.

Thresholds for pests and diseases can be established, but in weed control, tolerance to weed seed density should in principle be set to zero. Especially when the seed bank is still rather small. For some weeds, this is, however, almost impossible in practice. Establishing species and size of the weeds is important to decide which type of control is the best to be used. For instance, doses of herbicides have to be higher when weeds are larger.

2.3.4 Physical methods of control

In physical methods of control, one should distinguish between weed control and pest and disease control. For mechanical weed control, a variety of tools are available, which have reduced the dependency on chemical control and minimise the need for manual labour.

The right choice of tools and timing are essential for the success of mechanical control. No general recommendations can be given for mechanical weed control. The strategies are very much dependant on soil, crop and climatic conditions. There are various alternatives for mechanical control of weeds between the rows. Control of weeds within the rows, especially in sown crops with fine seeds (onion, carrots), however, is still problematic. Sometimes, physical control of weeds is not possible because of weather conditions, which makes an addition-

al treatment of chemical control or manual weeding necessary. Proper seedbed preparation is also important for successful mechanical weed control. It may be necessary to adapt planting or seeding distances to the available mechanical tools.

False seedbed technique is another physical alternative for mechanical weed control. It consists basically of pre-plant ploughings and seedbed preparation, preceded by irrigation (or profiting from rain) that causes the germination of weed seeds. This technique will help to lower the weed seed bank of the field, however, it must be repeated as often as possible for an optimal result.

Mulching is also considered as another physical method for weed control. Covering the soil with polythene (in combination with fertigation) is a standard practice in the cultivation of crops, mainly in the Mediterranean countries. The advantages and disadvantages of this must be evaluated for every crop.

The alternatives for physical control of pests and diseases are limited. In some cases, identification and removal of infested plants can be successful. For soil-borne diseases, techniques such as steaming, inundation, anaerobic decomposition of organic matter (bio-fumigation) or solarisation can be successful. It is important to point out that the last two techniques should be applied only in extreme cases, when no other solution is available because these can potentially have the same effect as chemical soil disinfections by causing disequilibrium in the biota of soils.

Physical barriers are used to stop the harmful organisms from reaching the crop or crop parts where they can do damage. There is a wide range of possible physical barriers, often very specific for individual pathogen-crop combinations. The advantages (effective control, environment) and disadvantages (costs, labour, agronomy) need to be thoroughly considered. A few types of physical barriers are quite commonly used. Insect nets, for example, can be used as protection against pests, as well as against diseases (often viruses) that these insects can transmit. Again the agronomic advantages have to be weighed against costs, possible extra labour and agronomic disadvantages such as problematic weed control and susceptibility against diseases (higher humidity in the crop).

2.3.5 Biological control

Classical Biological Control can be defined as the regulation of the population of a harmful organism's density using natural enemies to a lower rate than would otherwise occur naturally. This definition implies that man's activity manipulates the environment to favour of the presence and activity of natural enemies. Biological control could be divided into three different types: use of entomopathogen micro-organisms, use of antagonist micro-organisms and use of entomophagus (Ripollés, 1986).

The use of fungus, bacteria or virus (entomopathogen micro-organisms) can cause an epidemic in the organism that needs to be controlled. Formulations of viruses are only occasionally used for the control of pests in vegetable crops. The most important and most used bio-insecticide is the bacteria *Bacillus thuringiensis* against several species of *Lepidoptera* and *L. decemlineata*. Because *Bacillus thuringiensis* is formulated with toxic crystals included in the bacteria, it is questionable whether it should be considered as a biological or a chemical control, because the organisms do not reproduce in the field. The fungus *Beauveria bassiana* is used mainly for the control of white flies in some vegetable crops.

The use of antagonists for the control of diseases is still in an early stage, although it is expected that its use will be increased in the coming years. These antagonist organisms usually are fungi or bacteria that do not damage the crop, but eliminate or restrain the development of the disease. As examples, the bacteria *Streptomyces* sp. is used for the control of *Fusarium* sp. and the fungus *Trichoderma* spp. are active on *Acremonium*, *Fusarium*, *Rhizoctonia* and *Sclerotinia*, in addition to others.

Entomophagus insects can be used in two ways: the introduction of exotic natural enemies and the addition of parasites and predators. It must be stated that, in addition to these two practices, the best option will always be to promote conservation or the enhancement of the autochthonous natural enemies (see Chapter 2.3.2, Prevention).

- *The introduction of exotic natural enemies:* This should be done very carefully and only with those known to be specific. Unfortunately, this is usually not the case in vegetable crops. For instance, aphid parasites are generalists as well as leaf miner parasites. Exotic white flies are controlled by native parasites too. The only exception is in sweet corn: *Ostrinia Trichogramma*.
- *Augmentation of parasites and predators:* This augmentation to increase their effectiveness involves their direct manipulation either by mass releases or periodic colonisation. Species of the egg parasite *Trichogramma* have been utilised more than any other entomophagous enemies for inoculative or inundative releases have been utilised. Currently, this modality is being used in greenhouses and infrequently in field-grown vegetable crops.

Regarding the inundative releases, the efficiency of predaceous coccinellids in natural or managed systems is difficult to determine given their mobility and their polyphagous nature. The role of naturally occurring *Coccinellidae* in suppressing pest populations is significant, but poorly documented. The insects are generally released as adults in augmentation programs, but non-target effects have not been examined. The concentration

of large number of coccinellids in augmentative releases is likely to increase cannibalism.

2.3.6 Chemical control

In an IECF strategy, pesticides are used only when there is no other feasible alternative to control the dangerous organism. If pesticides are chosen, then two main aspects have to be taken into consideration: effectiveness in controlling the target organism(s) and their effects on the environment (emissions and damage). The chosen pesticide has to be effective against the harmful organism(s) that have to be controlled. Aspects such as selectivity, resistance of the harmful organism(s), weather conditions (temperature, humidity) and the developmental stage of the crop and target species have to be taken into account. Within the range of effective, acceptable pesticides, a choice can be made for the most environmentally safe pesticide. The physical properties of the pesticide play an important role in this choice.

For the proper use of pesticides, it is necessary to follow the directions on the label, giving special attention to dosage, dangers to users, harvest intervals, toxicity for man, wildlife, and natural predators, authorised crops and possible phytotoxicities, and expiry dates. Their working capacity should be optimised and, at the same time, their use minimised, preventing the pesticide emission and undesirable side effects as much as possible.

Selectivity

Obviously, the choice of a pesticide will first depend on how well it works in controlling the target harmful organism. This can be improved for pests and diseases with the selectivity of a pesticide because this property helps to maintain the equilibrium between natural enemies and pests or between antagonist and pathogen micro-organisms. The selectivity of a pesticide can be physiological or ecological. The first one is a characteristic inherent to the active ingredient and the second one depends on its use, that is to say, on the timing, dose, application technique, type of formulation, and persistence (Ripollés, 1986). In herbicides, the selectivity will be necessary not only with regard to the growing crop, but also to the following crops if residues of herbicides remain.

Pest resurgence and/or secondary pest outbreaks
Therefore, the effects of selected pesticides on the different natural enemies should be very well known to avoid pest resurgence and/or secondary pest outbreaks. Pest resurgence occurs when pesticide destroys the natural enemies of a target pest. Because the natural enemies depend on the pest for food, they take much longer than the pest to build up to their former numbers. Meanwhile, the pests that survive the treatments breed without being restrained by natural enemies, sometimes building up to a greater number than existed before the treatment (Flint, 1990). The secondary pest outbreak happens when certain species usually do not reach critical numbers due to the action of natural enemies. If these natural enemies are removed by a treatment, the secondary species is

released from their pressure and may reach damaging numbers. It is very common with spider mites, but it can happen also with weeds when herbicides allow a few tolerant species to survive. When the competing weeds are removed, the tolerant species grows easier. Also, colonisation with soil-borne diseases in disinfected soils is much easier than in well-balanced soils.

Resistance to pesticides

Pesticides' efficiency will increase if the resistance of harmful organisms to pesticides is eliminated as much as possible. Therefore, it is necessary to alternate the applications with different active ingredients. If possible, these active ingredients should belong to different classes. Resistance develops more quickly under the selective pressure of repeated pesticide application. In addition, lower doses than recommended are in some cases the reason certain resistances develop. On the other hand, developing cross-resistance to several pesticides is not rare, even though they belong to different chemical groups. Resistance has been reported in aphids, spider mites, worms, leaf miners and several other diseases.

Pesticide choice and reducing emissions and damage

In addition to minimising the use of pesticides and optimising their efficacy, there are other techniques to reduce the emissions and damage of pesticides. The choice of pesticide according to its different levels of emissions to air, groundwater or soil is very effective if this can reduce the effect on the environment, as it has been demonstrated in the different VEGINECO systems (see Chapters 3-6).

To quantify the emissions in the (a-biotic) environment independently, PPO developed a concept called Environment Exposure to Pesticides (EEP). EEP is quantified by taking into account the active ingredient's physical properties (DT50, soil half-life; VP, Vapour pressure and Kom, bonding to organic matter) and the amount used. Emissions are calculated for the routes to the air, groundwater and soil (see Annex 5).

This concept fits into the strategy of integrated farming systems. In the development of these systems, the use of this property aims at minimising any potential effect of pesticides on flora and fauna. Therefore, the exposure of the environment to pesticides (EEP) should be minimised. This can be accomplished by minimising the farming systems' pesticide requirements (Integrated Crop Protection). Consequently, the pesticides are carefully selected while taking into account the extent to which the environment is exposed to pesticides. If more than one pesticide is available to control an organism, the pesticide with the lowest emissions is chosen. Emissions to the air are considered as the most important route that needs to be reduced, emissions to the soil the least important route. Therefore, a pesticide with a low risk of

emissions to the air and high risk of emissions to the soil is preferred above a pesticide with high risk of emissions to the air and low risk of emissions to the soil.

Each year, a list should be made of the highest scoring pesticides for each emissions route, then solutions should be sought to prevent the use of these pesticides either by being replaced with another pesticide or by changing the crop protection strategy. In this way, total emissions from pesticides can be reduced from year to year.

Pesticides damage the crop and to other non-target organisms in and out of the fields. Damage can be caused by the use of obsolete pesticides, excessive dosage, incompatible mixes, inadequate climatic conditions or an incorrect application technique. Damage to the crop can also be caused by the lack of crop tolerance. With herbicide applications, the crop can sometimes be protected from damage by the use of screens or caps next to the nozzles. Using hedges or zones that are not sprayed can reduce damage to non-target organisms outside the field. In addition, neighbouring crops can be protected with these steps as well. Wearing appropriate protective clothing and cabins on tractors can prevent damage to farm worker's health. Respecting the legally set interval between the last application and harvest can prevent damage to consumers.

In organic farming, natural pesticides are used. These 'organic' pesticides can also have the same effects as synthetic pesticides on environment, biota and human health. Therefore, the use of "bio-compounds" such as **azadiractin** or **rotenone**, and mineral compounds such as copper or sulphur will be absolutely considered as chemical controls in organic farming. Because of this, organic farmers in the Netherlands hardly use any 'organic' pesticides at all. In the Dutch organic system, no pesticides are used at all (see Chapter 3).

Optimising efficacy and minimising use

After choosing the right pesticide, an optimal combination between its efficacy and effectiveness on the environment, and its application can be optimised. Again both efficacy and effectiveness on the environment have to be taken into account. Aspects such as timing, dosage and application technique also play an important role

Timing

Timing is an important factor to improve the efficacy of pesticides. In the case of pests, it is necessary to know the cycle of the different pests and their natural enemies, as well as the crop characteristics to determine the best time to spray (when the pest is most vulnerable). In this way, fewer applications are needed and the efficacy of applications can be improved. On the other hand, herbicides are applied more efficiently in a lower amount per hectare in low dose systems (LDS). With these systems,

herbicides are applied in a very early growing stage of the weeds and with lower doses than conventionally used. This low dose treatment should be repeated if the effect of first treatment was not good enough. The advantages of LDS system are:

- weed species are more vulnerable in a young growth stage (even strengthened by repeated applications),
- applications are less selective at a young growth stage,
- the degree of weed control increases,
- the accumulative amount used to control weeds is often substantially lower than the conventional high dose approach,
- crop damage is lower because of lower doses (lower phytotoxicity).

Naturally this technique demands sophisticated sprayers. On the other hand, climatic conditions are most important to determine the best timing of treatments. Wind, for example, may considerably reduce the efficacy and increase the emissions of pesticides.

Application techniques

Different application techniques influence the efficacy of pesticides and reduction of use. With a hand sprayer or more conventional techniques, larger quantities of water are usually necessary (higher than 400 l ha⁻¹). For large-scale farming, the use of these large quantities of water is more time consuming and costly, and therefore, medium to low volume techniques have been developed. At the same time, these techniques have enabled much more accurate and uniform dosing and a better adaptation of the application technique to the specific pest, crop and pesticide (pressure, droplet size, types of nozzles). However, these technically improved machines are often not suited or economically not feasible for small-scale vegetable farming. In some cases, pests or weeds can be sprayed through spot-wise application because of their limited distribution, and therefore a smaller amount of pesticide is applied. In these cases, the application must be done manually. In each case, the machinery must always be well calibrated for the correct distribution of the pesticide.

Pesticide doses

The use of the proper pesticide dose is another way to minimise its use and optimise its efficacy. There are different methods to determine the pesticide dose. One can find two types of advice on the label:

- concentration of the application solution (and also the solution amount) or
- amount of product per surface unit.

The first type of advice is usually used in situations when the dosage is not (only) dependent on surface area, but also on crop size such as tomatoes or green beans, for example. Another situation, where a fixed concentration is used, is if an exact dosage per ha is difficult to

achieve (small-scale applications, spot-wise applications). In these cases, the dose depends on the amount of spray liquid that is applied.

The second type of advice is more predominant in crops with a closed canopy and two-dimensional crops, arable crops and many open field vegetable crops. The last type of advice has become predominant in the Netherlands because of the improved technical possibilities to apply an exact dosage. In this case, a fixed amount of water per ha is used. In theory, both methods have to lead to the same used amount for the same crop-disease combination. In practice, the first method tends to give more variations in use.

Mixtures of pesticides with bioactive foliar feeds or urea sometimes allow doses of systemic pesticides to be lowered. In the same way, the mixtures of contact and feed pesticides with mineral oil are used to reinforce the effect and persistence of pesticides, allowing also for a reduction of the pesticide dose.

Other factors

Other factors that influence pesticides are weather conditions, physical properties of pesticides, soil characteristics for herbicides and the characteristics of the crops. In general, there are interactions between these factors that influence the pesticides' efficacy. The following are several examples of interactions between pesticide properties and these factors:

- The a-polar compounds are generally less weather dependent.
- Transport and uptake in gaseous form is very dependent on temperature.
- Systemic pesticides have to be taken up by the plant and this process is weather and plant dependent.
- Non-systemic pesticides in general need finer dispersion than systemic pesticides. A finer dispersion can mean more water and/or a smaller droplet size.
- Soil herbicides are very much influenced by soil (surface conditions (humid-dry), and rainfall).

The interaction between pesticide properties and weather conditions is quite important. Applied Plant Research, DLV and Opticrop in the Netherlands have linked both together in a computer program called (GEWIS) developed. The program uses weather conditions and forecasts inside and outside the crop to predict how well an application of a certain pesticide will work. This program provides an extra tool to support decisions in pesticide choice and timing of the application. For some pesticides, it also gives advice about pesticide dose.

2.3.7 Testing and Improving

After crop protection strategies have been designed, they need to be tested in practice. The layout of the prototype requires that the model be tested and improved until the objectives have been reached. Because this stage is the

most labour intensive and expensive step, at least a full rotation of the prototype on each field (4-6 years) is required; it is useful to take a critical inventory of all the methods previously designed before developing a new prototype (Vereijken, 1999). It is important to check the compatibility of the crop protection strategy with the other methods used. This can be done by estimating the parameters that are used to test and improve the model. The parameters that can be used to evaluate I/ECP can be divided in three groups. The first group of parameters is greatly influenced by I/ECP. The second group of parameters is partially influenced by I/ECP. However, other methods are important as well to the parameter values. The third group is slightly influenced by I/ECP. In Table 2.1, the major objectives that are quantified by I/ECP related parameters are shown. A short description of the parameters can be found in Annex 2. In the manual on prototyping methodology and multifunctional crop rotation (Chapter 4), the reason why these parameters were chosen is explained.

Parameters can only be used to test and improve farming systems if target values are established. In Chapter 4, the justification for parameters and target values is discussed. In addition, the EEP parameters are prioritised. The parameter, EEP air, is considered the most important, followed by EEP groundwater and EEP soil.

The crop protection strategy is evaluated by calculating the amount of pesticides used and the environmental effects of the pesticides. When target values are not reached, changes in the strategies need to be made. Therefore, it is necessary to determine the problematic combinations of pesticide, crop and pest, disease or weed. First, the five most important pesticides that contribute to the total parameter values are determined for each pesticide exceeding the target value. Secondly, a list can be made with the pesticides, which need to be replaced first. Finally, replacement or reduction in use needs to be considered. If possible, pesticides in the list should be replaced by preventive measures. If preventive measures are insufficient, more environmentally friendly pesticides should be chosen. If no alternative pesticides are available, reducing use should be considered either by establishing the need for control or the use of different application techniques, which require reduced use (low dose systems, row sprayings or spot wise applications).

An example of this testing and improving strategy is given in Figure 2.3. The figure depicts the improvement in the EEP air in the Integrated Fresh Market system (Italy, I INT2). Large reductions were already achieved in the first year compared to previous years, and in the following years, the results continued to improve. The main improvements were:

- the substitution of Butisan for Ramrod (resulting in a lower EEP groundwater as well) and the use of mechanical weed control (ridging),
- fewer treatments with Hostaquick (better choice of