3 A practical case of crop protection strategies in the Southwest of the Netherlands

W. Sukkel & J.A.J.M. Rovers
Applied Plant Research (PPO), Lelystad, The Netherlands

3.1 Introduction

The Dutch integrated vegetable farming systems are located in Westmaas, which is in the South-western clay region of the Netherlands. Approximately 18% of the Dutch field-grown vegetable surface area (7 466 ha in 1996) is located in this region. The main vegetable crops in this region are onions, chicory, winter carrots, Brussels sprouts, and celeriac. The amount of iceberg lettuce and various other vegetable crops such as fennel, cauliflower and broccoli being grown is smaller, but increasing rapidly. The main types of farms are the specialised vegetable farms (mainly Brussels sprouts) and arable farms with vegetable crops. Specifically in Southwest region, but also nation-wide, there is a growing tendency to include vegetable crops in arable rotations. This is accomplished by either by specialised farms leasing land from arable farms or by arable or organic farmers growing vegetable crops. This tendency could also be benefit the existing intensive vegetable rotations. The research on the integrated and organic systems variations in Westmaas tries to answer the specific sustainability issues that are a result of this development.

Two types of integrated extensive vegetable systems and one organic extensive vegetable system were tested at one location. The choice of crops in both systems was based on the region and soil. For both systems, the same main crops were planted.

The basis for proper crop protection in the integrated systems in Westmaas is a four-year arable rotation, in comparison to six year long rotation in the organic system. In the integrated systems, cereals and potatoes are the arable crops and either Brussels sprouts or iceberg lettuce is the main vegetable crop. The second vegetable crop is either celeriac, fennel or cauliflower. This set up led to seven system variations for the two cropping plans for the main vegetable crops, which covers the range of cultivation types (from early (spring) to late (autumn) cultivations) within the vegetable crops (Table 3.1, see Manual on Prototyping Methodology and Multifunctional Crop Rotation for more details).

Table 3.1 General scheme of the two integrated rotation types in NL

	NL INT 1 (Brussels sprouts) (4 variations)	**NL INT2 (Iceberg lettuce)** (3 variations)
1	potatoes	potatoes
2	**Brussels sprouts**	fennel/celeriac/cauliflower
3	winter wheat/spring barley	winter wheat/spring barley
4	fennel/celeriac/iceberg lettuce	**iceberg lettuce**

3.2 Weed control strategies

3.2.1 General weed control strategy

General
The strategies for weed control are aimed at minimising the number of hours of manual weeding. Manual labour for weeding is expensive and available labour is limited. The specific situation at the experimental farm influenced the possibilities for weed control and had to be taken into account. Weed pressure is quite low and strategies were aimed at maintaining this situation. The soil type is middle-heavy and crust-forming clay. This determined whether or not the soil could be worked after wet periods and the type of mechanical weed control tools that can be used. Weed control machinery has to work quite aggressively on this soil to be able to remove the weeds.

Prevention
The strategy starts with the design of the crop rotation. Whenever possible, aspects of weed control were taken into consideration. The following effects were used in the design of the crop rotation:
- Planted vegetable crops (preferably a brassica) after potatoes because it is easier to control potential potato volunteers.
- A cereal crop helps to eliminate volunteer weeds and provides a clean start for the next crop.

Another important prevention strategy was to make a clean start for the crop cultivation. Aspects of this strategy are:
- Preventing weed seeds from establishing themselves in the crop and in the field margins as much as possible. Actually most manual weeding hours are not used to prevent the risk of competition and yield loss, but to prevent weed seeds from getting established.

- The main soil cultivation technique is ploughing, which gives a much cleaner start than mixing soil cultivations.
- Mechanical control, just before cultivation. Whenever possible and necessary, weeds are controlled before crop cultivation in order to make a clean start. One of the options used is the false seedbed technique.

Control aspects
If control in a crop is needed, various means of mechanical and physical control are first utilised. Of course, control costs also play a role in this choice. Only when mechanical control is considered insufficient or mechanical control results in too many hours of manual weeding, chemical control will be used. In some cases, herbicides are used for emergency applications, for example, if weather circumstances have been extreme and this made mechanical control impossible. If possible, mechanical control is utilised in a very early stage of weed development. This requires regular and close inspection of weed germination and development.

If chemical control is used, herbicides with low emission risks will be chosen also taking into consideration, of course, the efficacy of the herbicide in controlling the weed population. Furthermore, chemical control is utilised at an early stage of weed development, which makes it possible to lower the dose of the herbicide and use low dose techniques.

3.2.2 Weed control strategies for each crop

Table 3.2 is an overview of the available machinery for physical weed control, Table 3.3 represents a summary of the weed control strategies.

Brussels sprouts and cauliflower
Brussels sprouts (integrated and organic) and cauliflower (integrated) are crops in which weeds can be controlled by fully mechanical methods. Due to the crops' quick development, two or three treatments (harrowing, hoeing, hoeing and ridging) are sufficient. Before the late planting period of Brussels sprouts, pre-planting treatments can control many types of weeds. In the integrated systems, this is only possible in very wet periods with chance of structural damage. This pre-cultivation control was done with ***glyphosate***.

Celeriac
Celeriac (integrated) is planted late and a weed-free start is important. The weeds before planting were removed with a few mechanical treatments (in emergencies with ***glyphosate***). Celeriac is a crop that stays open until the end of the growing period so a long control period is necessary. Two strategies were tested: completely mechanical (harrowing and ridging hoe) or a combination of mechanical and chemical. The second strategy included mechanical applications of harrow and hoe in the row combined with a LDS row application (0.25 kg ha^{-1} ***linuron*** + 0.25 kg ha^{-1} Agral; Agral is an adjuvant).

Table 3.2 Overview of available machinery in the integrated and organic system in the Netherlands

Machine	Type	Width m	Row spacing m	Crops
Inter row cultivator for nursery tractor	Hoe	1.50	0.50, 0.32, 0.26	fennel, celeriac, iceberg lettuce, barley, wheat
Inter row cultivator in front of tractor	Hoe (with ridging strips)	3.00	0.75 0.50	cauliflower, Brussels sprouts, celeriac
Mini harrow behind each hoe	Harrow	1.50 3.00	0.50, 0.75	cauliflower, Brussels sprouts, celeriac
Soil crumbling cultivators (pre seedbed operations, two types)	Cultivator with crumbling roles	3.00		all crops
Ridging rotary cultivator	Cultivator	3.00		potatoes
Flexible chain harrow	Harrow	3.00		potatoes
Angle blade with ridging (covered)	Hoe and ridger	3.00	0.75	potatoes
Spring tine harrow	Harrow	6.00		Brussels sprouts, fennel, celeriac, cauliflower, wheat, barley
Weed flamer	Weed flamer	1.50		pre-emergence (contractor)

Table 3.3 Overview of weed control strategies per crop, integrated and organic system, number indicates number of treatments unless otherwise indicated

Crop	System	Row distance m	Mechanical control: Harrow	Hoe	Ridged hoe	Chemical control: Spray application[1]	Herbicide type[2]	Low dose technique	Expected additional manual labour[3]
Brussels sprouts	Int. + Org.	0.75	0-1	1	1-2	–	–	–	1
Cauliflower	Int.	0.75	–	1-2	–	–	–	–	1
Celeriac 1	Int.	0.50	–	3	–	–	C/S	X	2
Celeriac 2	Int.	0.50	2	4	–	–	–	–	2
Fennel planting (cover)	Int.	0.50	–	-	–	FF	C/S	–	1
Fennel sowing	Int.	0.50	–	1	–	FF	C/S	X	2
Fennel planted	Int. + Org.	0.50	–	1	–	–	–	–	2
Iceberg lettuce	Int. + Org.	0.32	–	x	–	–[4]	–	–	2
Potatoes	Int. + Org.	0.75	1	x	–	–[4]	–	–	1
Winter wheat	Int.	0.13	3	–	–	FF	C	X	1
Spring barley	Int.	0.13	2	–	–	FF	C	X	1
Spring wheat	Org.	0.26	1	1	–	–	–	–	1

1. FF = full field, R = row or band spray, SP = spot-wise
2. C = contact herbicide, S = soil herbicide
3. additional manual labour needed: 1 = < 20 hours ha^{-1}, 2 = 20-40, 3 = 40-60, 4 = 60-80, etc.
4. standard no chemical application except in emergency cases in integrated

Fennel
In the planted fennel (integrated and organic) hoeing between the rows provided good control. Because of the long growth period, 3-4 treatments were necessary. Remaining weeds in the row have to be removed by hand. For the late planting period, a pre-planting treatment can control many types of weeds. Experimentally, the use of the harrow was tested.
In the early covered (fleece) fennel (integrated), the use of mechanical weed control was limited because of the extra labour and plant damage due to removing the fleece during the treatment. Therefore in this cultivation type, a chemical spray of 1 kg ha^{-1} ***linuron*** shortly after planting was used.
For the sown fennel (integrated), a basic row application was not enough. Because of this, a full field application of 0.5 kg ha^{-1} ***linuron*** was used. This application made the soil weed-free in the first four weeks. Next, a Low Dose System (LDS; 0.25 kg ha^{-1} ***linuron*** + 0.5 kg ha^{-1} Agral LN) was used in combination with hoe treatments between the rows. Before the late sowing period, a pre-planting cultivation controlled a large amount of weeds.

Iceberg lettuce
Weeds were controlled mechanically in iceberg lettuce (integrated and organic) crops. The first hoe treatment had to be carried out 7-10 days after planting. Usually two treatments were necessary. Extra attention had to be paid to weeds in the row. Only in the early covered crop of iceberg lettuce (integrated), the use of 4 l ha^{-1} ***chlorpropham*** due to weed pressure or unfavourable conditions was used as an emergency application.

Potatoes
In potatoes (integrated and organic), late weed control was completely done by building ridges in combination with hoe. In the integrated system, a chemical application of Titus was used when conditions were very unfavourable for mechanical control.
Winter wheat and spring barley
In winter wheat and spring barley, hoeing was the main mechanical treatment. In the integrated system, only if black-bindweed, chamonile and cleavers were insufficiently controlled, then a low dose chemical application of ***metsulfuron*** + ***fluroxypyr*** was applied.

3.3 Disease and pest control strategies

3.3.1 General disease and pest control strategies

General
Pests and diseases can cause very high or complete yield and quality losses in vegetable crops much more than in arable crops. Small defects on the product can make the product unmarketable. These high quality requirements play an important role in the necessity of controlling pests and diseases. Moreover, yield losses also mean large financial losses because investments in seeds, plants and labour are high. A stable strategy and delivering a marketable product is the most important limiting condition for the pest and disease control strategies developed.

Prevention
The strategy starts with the design of the crop rotation. Whenever possible, aspects of disease control are already taken into consideration in the crop choice and rotation. The following issues were used in the design of the crop rotation:

- Crop choice. The rotation is composed, as much as possible, of crops from different plant families. Also in the choice of catch crops, this principle has been taken into account. When genetically related species are used, cultivation in succeeding years is avoided.
- Field adjacency. If it is possible, it is preferable to avoid planting crops on fields adjacent to the fields where they were planted the previous year.
- Enhancement and preservation of natural predators: Attention is paid to the development of an ecological infrastructure on the farm in which the choice for a species that provides food and shelter for natural predators plays a role. Moreover, if possible, selective pesticides are used in order protect natural predators.
- Choice of variety. If possible, varieties are used which are resistant or tolerant against the main pests and diseases. Even if yield or quality aspects are lower than non-resistant varieties. In the organic system, these choices are more important than in the integrated systems.
- Plant material or seeds. In order to make a clean start, plants and seeds have to be healthy and free of infection. Plant material is visually controlled before planting. Good and reliable suppliers or producers of plants and seeds are important (quality guarantees).

Farm hygiene is another important strategy in the prevention of pests and diseases. Important aspects are the quick incorporation of crop residues after cultivation and cleaning of machinery. In fertilisation, the crop protection aspect is also considered. Abundant crop growth as well as irregular crop growth due to fertilisation is avoided. In some cases, physical barriers such as insect nets are used to protect the crop from harmful species.

Need for control
Before methods of control are applied, the need for control has to be established. Whenever available and manageable, warning systems, damage thresholds and guided control systems are used. Regular crop inspection and weather forecasts are necessary instruments in establishing the need for control.

Control aspects
When control in a crop is needed, first the possibilities of physical or biological control are utilised. Of course, control costs also play a role in this choice. Some antagonist and natural predators have been applied on an experimental basis (see Chapter 7), but these strategies are for several reasons (efficacy, stability and costs) not yet included in a standard strategy. 'Organic pesticides' such as ***azadiractin***, pyrethroids or ***Bacillus thuringiensis*** are not applied in the organic system.

The residual problems in the integrated systems are controlled with pesticides. For chemical control, pesticides with low emission risks are chosen. Of course, the efficacy of the pesticide in controlling the disease or plague is taken into consideration. The most optimal physical (weather) conditions for application are used to increase the application's effectiveness and/or to be able to lower the advised dosage. Every crop-pesticide-pathogen combination has its own optimal application conditions. Weather forecasts within and outside the region are essential for these considerations.

3.3.2 Disease control strategies for each crop
The crop-specific protection in the organic systems is the same for the non-chemical part as for the integrated systems unless otherwise indicated. However, in organic farming, the focus on this non-chemical crop protection is more important and higher costs for non-chemical protection are acceptable. The strategies presented are for the most important diseases, all of which can cause considerable damage. Strategies are summarised in Table 3.4.

Brussels sprouts
For Brussels sprouts, the basis for control of *Mycosphaerella brassicicola, Albugo candida, Erysiphe cruciferarum* and *Alternaria brassicae/brassicicola* is prevention through choice of variety. Differences in varieties of resistance to these diseases are present, however, not always very well known.
Especially for *Mycosphaerella*, crop residues are worked into the ground directly after harvest because spores can be easily dispersed from old infected leaves. A guided control system is available for *Mycosphaerella*. With the aid of a thermo-hygrograph, the infectious periods are examined. Chemicals are applied for *Mycosphaerella* only after appearance of the first spots and only when the conditions for infection are favourable. The product used

Table 3.4 Overview of the most important disease control strategy per crop

		Prevention					Need for control				Chemical control in integrated systems			
Crop	Disease	Crop rotation[1]	N-Ferti-lisation[2]	Seeds/plants[3]	Variety choice[4]	Incorporation/removal of residues[5]	Signal[6]	Damage threshold[7]	Guided control[8]	Physical control	Seed plant treatment[9]	Preventive or curative	Fulfield/row/spot[10]	Low dose[11]
Brussels sprouts	*Mycosphaerella brassicicola*	X	-	-	X	XX	XX	-	XX		-	P/C	FF	XX
	Albugo candida	X	XX	-	XX	X	XX	-	-		-	P/C	FF	X
	Alternaria brassicicola	X	-	-	X	X	XX	-	-		-	-	-	-
	Erisyphe cruciferarum	X	-	-	XX	X	XX	-	-		-	-	-	-
Cauliflower	*Mycosphaerella brassicicola*	X	-	-	X	XX	XX	-	-		-	-	-	-
Celeriac	*Septoria apiicola*	X	X	X	X	X	XX	-	X		-	P/C	FF	-
Iceberg lettuce	*Bremia lactucae*	-	-	-	XX	X	-	-	-		(X)	(P)	(FF)	(X)
	Bottom-rot complex	XX	-	-	-	X	-	-	-		-	-		-
Potato	*Phytophthora infestans*	-	X	X	XX	XX	-	-	-	B[12]	-	P	FF	XX
Barley	Divers airborne diseases	-	X	-	XX	-	XX	XX	XX		-	C	FF	XX
Wheat	Divers airborne diseases	-	X	-	XX	-	XX	XX	XX		-	C	FF	XX

All chemical control only applied in the integrated systems
XX = very effective or very frequent
X = limited effective and/or manageable
\- = not relevant or not possible

1. Is crop rotation effective as a preventive measure?
2. Is nitrogen limitation effective as a preventive measure?
3. Is infestation control or selection of seeds and plants effective?
4. Are there resistant or tolerant varieties available and used?
5. Is quick removal or incorporation of residues of the crop used?
6. Does control only takes place after detection of the disease and is this effective?
7. Is a damage threshold used?
8. Are there any guided control systems used?
9. Is planting or seed treatment used?
10. Are pesticides applied in the field: FF = full field, R = row or band application, SP = spot-wise?
11. Is the applied dosage lower than that advised on the package?
12. B = Burner

for treatment is the curative and preventive pesticide ***pyrifenox***. ***Pyrifenox*** provides also partial control for powdery mildew and *Alternaria*. There are no benzimidazoles used because of their toxicity for the environment. For the prevention of *Albugo candida*, a steady and controlled growth is essential. A chemical application ***(chlorothalonil)*** is used when occurrence and weather conditions are expected to lead to yield or quality losses. No damage thresholds or guided control systems are available. *Erysiphe cruciferarum* is usually not a problem with the use of tolerant and resistant varieties. Only if there is high chance of disease and/or a severe infection, is *Erysiphe* chemically controlled with ***pyrifenox*** (if possible together with control of *Mycosphaerella*). *Alternaria* is only controlled chemically ***(iprodione)*** when there is a very high chance of disease and an infection in the crop.

Cauliflower

In cauliflower, fungal diseases cause fewer problems than in Brussels sprouts. However, in autumn plantings, *Mycosphaerella* can cause a severe infection. The control system is the same as for Brussels sprouts. A higher incidence for fungal diseases can be tolerated because there is almost no damage to the product. In the four years of testing, no chemical control against diseases was utilised.

Celeriac

In celeriac, *Septoria apiicola* is a large problem. First, partial resistant and tolerant varieties are chosen. In addition, a thermo-hygrograph is used to establish leaf-wet duration and predict the infectious periods. There is no curative chemical available, therefore, as soon as the first spots are detected, the disease is chemically controlled. There is a preference for ***chlorothalonil*** above ***carbendazim*** because of its reduced effect on the environment. A guided control system for *Septoria apiicola* is being developed.

Fennel

In fennel there are, due to a wide rotation, hardly any problems with fungi. There is no chemical control needed.

Iceberg lettuce

In iceberg lettuce, the fungi that cause bottom rot-complex *(Sclerotinia, Pythium spp., Rhizoctonia)* and *Bremia lactucae* are the main problems.
In the four-year rotation, smut was not a problem, so there was no need for a preventive chemical control. Bremia lactucae was not a problem as long as resistant varieties were available. However, this resistance was broken occasionally. Without resistant varieties, one treatment with ***fosethyl-aluminium*** was used on the plant material. Two weeks after planting, a treatment with ***fosethyl-aluminium*** was used in the field. However, this strategy does not always lead to a completely marketable product.

Potatoes

In the potatoes, the starting point in the control of late blight is the variety of choice. In the organic system, an early variety was chosen. In this strategy, the crop can partially escape from the highly infectious periods. When local infection was found, these spots were burned with the weed burner. After the infection exceeded a certain threshold, the full crop was burned to prevent the crop being a source of infection for the region. In the integrated system, an intermediate resistant for market reasons was chosen in combination with preventive chemical control with ***fluazinam***. Depending on the weather, 6 to 12 applications were necessary. Under dry weather and crop conditions, a low dosage of ***fluazinam*** was used.

Cereals

In cereals, tolerant or resistant varieties were chosen. Abundant crop development was avoided with a moderate fertilisation. Moreover, a guided control with damage thresholds was used. On average, two applications against diverse diseases in wheat and barley were necessary.

3.3.3 Pest control strategies per crop

The non-chemical strategies for organic and integrated production are similar if not otherwise indicated. Nematodes are not mentioned in the strategies. Nematodes are regularly monitored and no problems are expected. The strategies are summarised in Table 3.5.

Brussels sprouts

For integrated Brussels sprouts, caterpillars and aphids are successfully controlled with the help of guided control and damage thresholds. However, damage thresholds for *Plutella xylostella* and *Brevicorne brassicae* still need some adjustments.
The control of *Contarinia nasturtii* is based on registration of the insects' flights together with the use of a weather model. This method, however, still needs some improvement.
The first generation of the *Delia brassicae* is completely controlled by seed coating. At the moment, there is no valid method available for targeted control of the next generations. The chemical control is combined with applications for aphids and caterpillars.
For chemical control of caterpillars, ***deltamethrin*** and ***acephate*** are preferred, and for the control of aphids, the insecticides ***pirimicarb***, ***oxydemeton-methyl*** and ***thiometon*** are preferred.
Slugs can cause a lot of damage. Much attention is given to prevention before cultivation (control of weeds, soil cultivation). If necessary, the slugs can be controlled by ***metaldehyde*** or ***methiocarb***.
For organic Brussels sprouts, slugs and larvae of *Plutella xylostella* lead to very high quality losses. Stable and economically viable strategies are still not available. Therefore, focus has been on tests and improvements of several options. Focus on the control of *Plutella xylostella* and other insects have been on covering the crop with insect nets. To control slugs, focus has been on rotation, creating unfavourable conditions for survival and biological control with nematodes and predators. The results of testing various methods are given in Section 3.1.3.

Cauliflower

For integrated cauliflower, damage caused by insects is much lower than in Brussels sprouts. Cabbage fly, caterpillars, aphids and cabbage gall midge are controlled in the same way as in Brussels sprouts, however, damage thresholds are generally higher.

Celeriac

In celeriac, insects are not much of a problem. With help of close monitoring (visual and sticky traps), insects can be easily controlled with a limited amount of insecticides. The insecticides ***pirimicarb***, ***heptenophos*** and ***mevinphos*** are preferred. ***Propoxur*** is only used when ***mevin-***

Table 3.5 Overview of the most pest control strategies per crop

			Prevention			Need for control			Chemical control in integrated systems		
Crop	Disease	Crop rotation[1]	Selection seeds/plants[3]	Variety choice[4]	Crop cover[5]	Signal[6]	Damage threshold[7]	Guided control[8]	Seed/plant treatment[9]	Fulfield/row/spot[10]	Low dose[11]
Brussels sprouts	*Delia brassicae*	X	–	–	X (org.)	–	–	XX	XX	–	
	Plutella xylostella	–	–	–	X (org.)	X	X	–	–	FF	X
	Slugs	X	–	–	–	XX	–	–	–	FF	X
	Brevicorne brassicae	X	–	X	X (org.)	X	X	X	–	FF	X
Cauliflower	*Delia brassicae*	X	–	–	–	–	–	–	XX	–	–
	Noctuids, caterpillars	–	–	–	–	XX	XX	XX	–	FF	X
	Brevicorne brassicae	X	–	–	–	XX	XX	X	–	FF	X
Celeriac	Aphids	X	–	–	–	XX	–	X	–	FF	X
	Lygys-sp	X	–	–	–	X	–		–	FF	X
Fennel	Aphids	–	–	–	–	XX	–		–	FF	X
Iceberg lettuce	Aphids	–	–	XX	–	XX	–	–	–	FF	X
	Noctuids, caterpillars	XX	–	–	–	XX	–	–	–	FF	x
Potato	Aphids	–	–	–	–	XX	XX	–	–	FF	X
Barley	Aphids	–	–	–	–	XX	XX	XX	–	FF	X
Wheat	Aphids	–	–	–	–	XX	XX	XX	–	FF	X

All chemical control only applied in the integrated systems

XX = very effective or very frequent

X = limited effective and/or manageable

- = not relevant or not possible

1. Is crop rotation effective as a preventive measure?
2. Is nitrogen limitation effective as a preventive measure?
3. Is infestation control or selection of seeds or plant effective?
4. Are there resistant or tolerant varieties available and used?
5. Is quick removal or incorporation of residues of the crop used?
6. Does control only takes place after detection of the disease and is this effective?
7. Is a damage threshold used?
8. Are there any guided control systems used?
9. Is planting or seed treatment used?
10. Are pesticides applied in the field: FF = full field, R = row or band application, SP = spotwise?
11. Is the applied dosage lower than advice on package?

phos is not effective enough against Lygys species. Flights of the carrot fly have been monitored, but control has not been necessary yet.

Fennel

In fennel, insects are not much of a problem. Aphids can cause a problem in a young growth stage of the crop. In this period, extra attention needs to be paid to monitoring aphids. With the help of damage thresholds, the aphids can be easily controlled. *Thrips tabacii* can cause some quality damage and is therefore regularly monitored. Chemical control of thrips has not been necessary yet.

Iceberg lettuce

In the cultivation of iceberg lettuce, the control of aphids has been much improved by the availability of *Nasonovia ribisnigri* resistant varieties. In both the organic and the integrated systems, these resistant varieties are used. With the use of resistant varieties and damage thresh-

Table 3.6 Pest and disease causes of shortfall in quality production				
System	Crop	Quality reduced by	Disease/pest cause	Shortfall in strategy
NL INT1	Brussels sprouts	QLP, spots and coloration on product	*Mycosphaerella, Alternaria,* diverse Fungi	Control timing and frequency
NL INT1	Iceberg	QNP, Insufficient development,	*Bremia lactucae*	Control frequency,
NL INT2	lettuce	loss of plants QLP, coloration or lesions on product		choice of fungicide Availability of resistant variety
NL ORG	Potato	QNP, Loss leaf area	*Phytophthora*	No efficient control available
NL ORG	Brussels sprouts	Insects feeding damaged product	Slugs	Green manure, preceding clover, humid soil conditions
NL ORG	Brussels sprouts	Insects feeding damaged product	*Plutella xylostella*	Insufficient cover, insect nets
NL ORG	Iceberg lettuce	QNP Insufficient development, loss of plants QLP coloration or lesions on product	*Bremia lactucae*	Availability of resistant variety

olds, chemical control is applied in one or two applications usually with ***pirimicarb*** or ***dimethoate***. The choice of the insecticide is dependant on the aphid species and the necessity to alternate insecticides. The use of seed coating is not yet allowed, however promising for the future. Caterpillars can be a problem, but can be easily controlled with the use of damage thresholds. Most of the time chemical control is not necessary.

Potatoes
In potatoes, insects are not much of a problem. With the help of damage thresholds, the insects can easily be controlled.

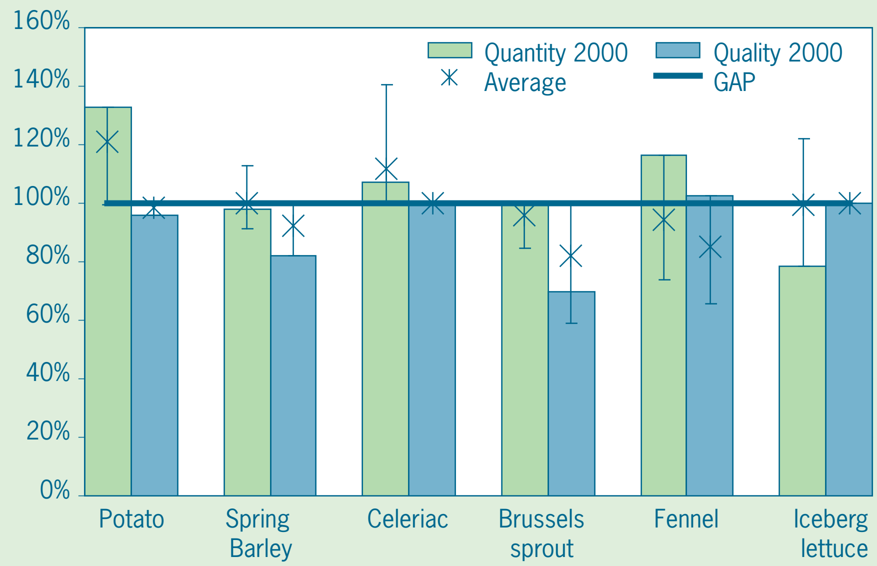

Figure 3.1 Level of quality per crop compared to GAP production (100%) in NL INT1

Cereals
In cereals, aphids can be controlled easily. With help of damage thresholds and guided control, insects can easily be controlled.

3.4 Testing and improving

3.4.1 Control strategies, quality production costs and manual weeding

Quality production can be greatly affected if disease control strategies are insufficient to control harmful species. The quality production achieved (Figures 3.1 to 3.3) is compared with the defined levels according to conventional Good Agricultural Practice.

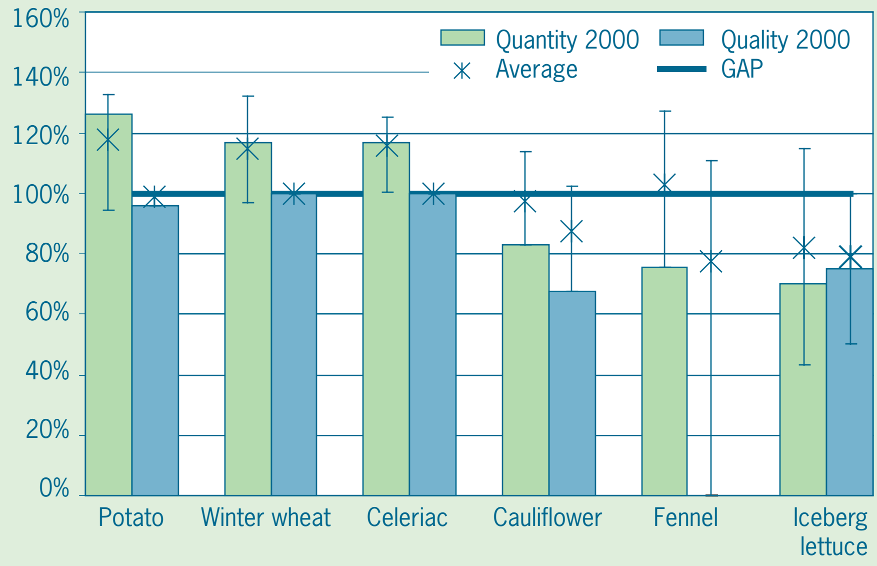

Figure 3.2 Level of quality per crop compared to GAP production (100%) in NL INT2

The level of quality production in average conventional practice normally achieved is about 90% of GAP. The level achieved in the system compared with the level achieved in average practice is, however, difficult. For organic production, there is large difference in quality production compared to conventional GAP. Therefore, the level of quality production achieved is also compared with a target specific for organic production.
The deficit in level of quality production caused by pests and diseases in the integrated system was mainly found in iceberg lettuce and Brussels sprouts (Table 3.6). For organic production, this was the case for Brussels sprouts, iceberg lettuce and potatoes. The deficit in the other crops was caused either by the fertilisation strategy or by unfavourable weather conditions.

In the integrated Brussels sprouts, the quality loss was mainly caused by spots and coloration on the product, which are usually caused by a complex of fungi. Brussels sprouts are a very vulnerable product and only very slight damage during sprout development can cause severe quality damage. Varieties that are more resistant were not available, but would help a great deal. The exact timing (weather conditions, damage thresholds) of chemical control measures still has to be improved to prevent damage. As a last option, the control frequency could be increased. In the integrated iceberg lettuce, quality and quantity loss was partly caused by unfavourable weather conditions. In practice, quality production is variable for this reason too. Another cause is the reduction of resistance against downy mildew in 1999. Especially under humid conditions (autumn cultivations), the strategy of two applications of ***fosethyl-aluminium*** could not completely prevent loss in quality production. However, in practice even with an intensive chemical control, quality losses due to downy mildew do regularly occur.

In the organic system, the quality of the produce is judged against conventional quality requirements for class 1. However, in practice, quality class 2 is very often marketable and receives a good price. Brussels sprouts is the most problematic crop regarding quality production. Both pests and diseases cause reduction in quality production. The main problems are slugs and the back diamond moth. Insect nets were able to prevent most damage caused by the back diamond moth, but this strategy is still not completely safe. Moreover, the use

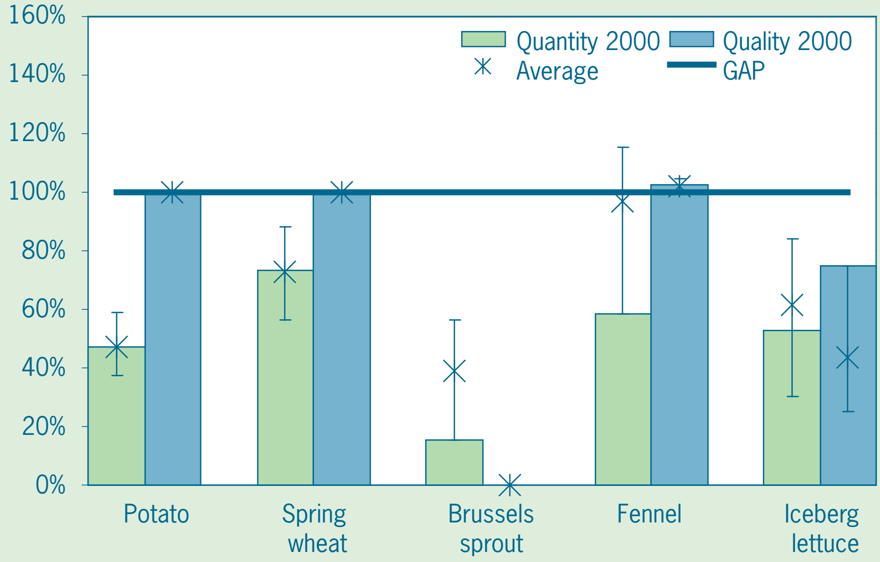

Figure 3.3 Level of quality per crop compared to GAP production (100%) in NL ORG

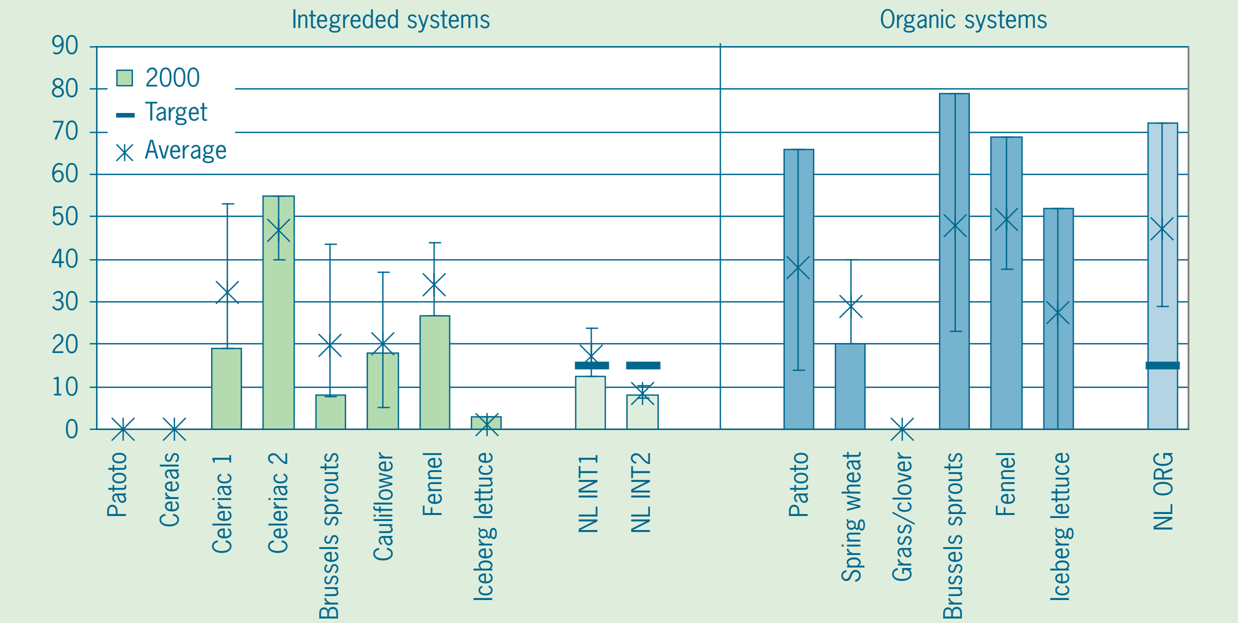

Figure 3.4 Hours of manual weeding per crop (hours ha^{-1})

of insect nets is quite labour intensive, costly, hinders weed control and causes humid conditions in the crop. This last effect can lead to the faster development of diseases.

Also the control strategy for slugs in the organic system was not sufficient. Development of a sufficient strategy is still ongoing. Different strategies for slug prevention were also tested such as changes in the preceding crop and green manure use. In addition, different slug control measures were tried such as the use of ducks and nematodes. The experiments did not yet lead to a sufficient strategy.

In iceberg lettuce in the organic system, the deficit in quality production was partly caused by insufficient nitrogen availability. Another reason for this deficit was the reduction in resistance against downy mildew. The control of aphids in iceberg lettuce with a Nasonovia resistant variety was very successful.

There were no negative effects on quality production identified for the weed control strategy. Another parameter for quantifying the success of the weed control strategy is the amount of labour needed for hand weeding (HHW). In the integrated system (Figure 3.4), HHW in vegetable crops was restricted to one or two times of walking through the crop and removing some remaining weeds. The combination of chemical and mechanical weed control in celeriac 1 proved to be more effective than the complete mechanical control in celeriac 2.

In the organic system, hours of manual weeding were higher than in the integrated system. However, the results are comparable with estimations for the average organic practice. The results of 2000 were negatively influenced by unfavourable weather conditions in most cases, as HHW in 2000 was the highest for the four years of testing. This was partially caused by the previous use of organic parcels that resulted in the appearance of thistles and *Raphanus*. The problems with the biannual thistle increased throughout the period.
Moreover, the success of mechanical weed control on clay soil is very dependent on the weather conditions, which causes a large variation in the results from different years. Other causes of the differences between the organic and integrated systems are the sometimes slow or irregular development of the canopy (potato, lettuce and Brussels sprouts) and, of course, the use of herbicides (fennel). Diverse alternative strategies, for example the use of the finger weeder, have been tested, but have not been found stable enough.

3.4.2 Pesticide use, emission and damage risks

In the organic system, no ‘organic’ pesticides such as copper, sulphur or ***Bacillus thuringiensis*** were used. In Dutch practice, the use of bio pesticides is very low as well.
In the integrated systems, the applied strategies strongly reduced use, emission and damage risks of pesticides compared to average practice (Table 3.7). The pesticide input for average practice was based on the registration of a group of conventional farmers. This group of farmers can be classified as environmentally conscientious and are as such not expected to perform worse than average practice. In the region, many fields border waterways, which present the risk of pesticides emissions to

Table 3.7 Realisation of parameters related to pesticide use and emission

	number of applications no ha^{-1}	pesticide input kg ha^{-1}	EEP air kg ha^{-1}	EEP groundwater ppb	EEP soil kg days ha^{-1}	EYP surface water no. appl. > 10
NL INT1						
Conventional 2000	21.8	11.9	1.5	6.23	801	13.4
Actual 1997	12.9	3.3	0.6	5.98	250	10.1
Actual 2000	10.1	2.5	0.7	0.01	167	6.1
VEGINECO target	-	5.9	0.5	0.50	240	0
% reduction 2000 - conventional	54	79	57	99.9	79	54
NL INT2						
Conventional 2000	19.0	8.1	1.4	8.01	479	9.3
Actual 1997	9.8	2.6	0.7	7.96	217	6.2
Actual 2000	8.2	2.3	0.4	0.01	156	3.9
VEGINECO target	-	4.0	0.4	0.5	144	0
% reduction 2000 - conventional	57	72	69	99.9	67	58

Table 3.8 Main differences in herbicide inputs between conventional and realisation in VEGINECO 2000

Crop	Application type	Conventional pesticide	Pesticide 2000	Difference in strategy
Potato	Full field in crop	***metribuzin***+ ***prosulfocarb***	-	Complete mechanical control
Potato	Defoliation	***diquat***	-	Mechanical defoliation
Fennel		***glyphosate***	-	Mechanical pre-crop control
Fennel	Full field in crop	***linuron***	***linuron***	Lowe Dose System with ***linuron***
Brussels sprouts	Full field in crop	***metazachlor***	-	Lowe Dose System with ***linuron***
Brussels sprouts	Pre-planting control	***glyphosate***	-	Mechanical pre-planting control
Celeriac	Full field in crop	***linuron***	***linuron***	Low Dose System
Iceberg lettuce	Pre-planting control	***chlorpropham***	-	Complete mechanical control

water life and this is used as a local parameter. The risk to water life is called Environmental Yardstick Points for Water life (EYP wl). EYP wl expresses whether a pesticide application is a risk that can lead to damage of water life. The minimum value of 10 points for a specific application corresponds with the concentration level of a pesticide that has no effect. All applications with an EYP wl > 10 exceed the accepted level of risk for water life. EYP wl is dependant on the choice of pesticide, application technique and buffer zone between waterway and crop.
The main reduction was found in the input of fungicides and of herbicides. The a.i. input in the integrated system in 2000 was minimal (0.07 – 0.18 kg ha^{-1}) for herbicides. Fungicides caused the highest input of 3.0 kg ha^{-1} for NL INT1 and 2.2 kg ha^{-1} in NL INT2.
The reduction in pesticide use did not lead in all cases to a comparable reduction of emission and risk of damage.

The reduction of EEP groundwater was large because the differences between pesticides in their capacity to leach were large. Using the option to replace leachable pesticides, EEP groundwater was reduced by almost 100%.

Different aspects of the applied strategy (Tables 3.8 to 3.10) caused the reductions in emission and use. Important elements in the reduction of use and emissions were close observation, damage thresholds, choice of pesticide, lower doses and the use of non-chemical control methods. The effect of preventive measures on pesticide input reductions are difficult to assess. However, prevention is an integral element in the integrated control strategies.
For weed control (Table 3.8), the main reduction in use and emission was achieved by the replacement of chemical control by mechanical control and the use of low

Table 3.9 Main differences in fungicide inputs between conventional and realisation in VEGINECO 2000

Crop	Disease	Conventional fungicide	Fungicide 2000	Difference in strategy
Potato	Late blight	***fluazinam*** ***cymoxanil+ mancozeb***	***fluazinam*** -	Lower dosages Replaced by preventive strategy with fluazinam
Potato	Late blight	***chlorothalonil+ propamocarb-hydrochloride***	-	
Brussels sprouts	Ring spot	Dorado ***carbendazim***	***pyrifenox*** -	Lower doses Strategy with pyrifenox is sufficient
Brussels sprouts	White blister	***chlorothalonil***	***chlorothalonil***	Lower frequency
Brussels sprouts	*Alternaria*	***iprodione***	-	Close observation, no application necessary
Celeriac	*Septoria*	***maneb fentin acetate*** ***chlorothalonil***	- ***chlorothalonil***	Strategy with only ***chlorothalonil*** Lower frequency

dosage systems applied in a very early weed development stage.
For disease control, most of the reduction in use and emission comes from lower frequencies and lower dosages usually based on close observation of disease infection and development. In the case of white blister in Brussels sprouts and *Septoria* in celeriac, the less preferable ***chlorothalonil*** is still used in the VEGINECO strategy. However, now there are no better alternatives. This item also relates to another growing problem in vegetable crops, which is the availability of allowed pesticides in the relatively small vegetable crops. For some crops, there are no more pesticides available for the control of specific harmful organisms or the allowed pesticides that are left over lead to higher inputs and emissions. For example: there will be no insecticide left in celeriac, ***chlorothalonil*** will also be banned as fungicide against *Septoria* in celeriac, the rather soft fungicide ***pyrifenox*** will be withdrawn which will lead to the use of environmentally less favourable compounds such as ***benomyl*** and ***carbendazim***.
For insect control (Table 3.10), the most important causes of reduction in use and emission are choice of pesticide, lower frequency and to a smaller extent a lower dosage. The lower frequency is based on close observations, damage thresholds, guided control and optimising efficacy. Lower dosage and/or optimisation of efficacy is mainly achieved by choosing the right pesticide for the right weather conditions.

Table 3.10 Main differences in insecticide inputs between conventional and realisation in VEGINECO 2000

Crop	Pest	Conventional pesticide	Pesticide 2000	Difference in strategy (2000)
Potato	Divers aphids	***dimethoate*** ***lambda-cyhalothrin*** ***deltamethrin***	-	Close observation, no application necessary in 2000
Fennel	Divers aphids	***deltamethrin*** ***pirimicarb***	***(pirimicarb)***	Damage thresholds, only occasional input in sown fennel in early stage; no application necessary in 2000
Brussels sprouts	Back diamond moth, *Brevicoryne brassicae* Other insects	***lambda-cyhalothrin*** ***pirimicarb*** ***acephate*** ***dimethoate*** ***heptenophos*** ***deltamethrin***	***acephate*** ***deltamethrin*** ***thiometon*** ***pirimicarb***	Selection of pesticides with reduced emissions; choice of pesticide dependant on temperature; lower frequency of applications. Applications are usually for a combination of insects with focus on back diamond moth and Brevicoryne. In VEGINECO, back diamond moth is signalled with pheromone traps
Brussels sprouts	Slugs	***metaldehyde*** ***methiocarb*** ***aldicarb***	***methiocarb***	Choice of pesticides with reduced emissions; close observation leads to lower frequency and lower dose.
Celeriac	Aphids Lygys species	***mevinphos*** ***pirimicarb***	-	No control, because of future withdrawal of allowed pesticides
Iceberg lettuce	Aphids	***dimethoate*** ***pirimicarb*** ***heptenophos***	***dimethoate*** ***pirimicarb***	Lower frequency, starting point is *Nasonovia* resistant variety.
Iceberg lettuce	Diverse caterpillars	***deltamethrin***	***deltamethrin***	Lower frequency