Neonicotinoids in European agriculture

Main applications, main crops and scope for alternatives

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The project has benefited from the insight of many experts and intermediaries, mainly from the case-study countries. They contributed by sharing their network and knowledge on crops and crop protection with and without neonicotinoids. The experts tirelessly answered our questions by phone and e-mail and provided valuable comments on the draft report. A full list of those who supplied input into the project can be found in Annex 2. We thank all these people who contributed to our study by providing data, studies, names of experts or in any other way.

Please note that the content and conclusions in this report are entirely the responsibility of CLM.

Content

Preface

The group of systemic pesticides called neonicotinoids is subject to public and political debate in Europe. Beekeepers and bee researchers are concerned that these chemicals are connected to the decline of wild bees as well as honeybees. This concern has led the EU to put a partial ban on the use of some neonicotinoids.

Such developments raise the question how indispensible neonicotinoids really are. How often are they used? And are there viable less harmful alternatives? Because what we need is real understanding of what can be done today to protect the environment and produce food sustainably. After all, farmers do not use pesticides to harm bees, they want to protect their crop. They are convinced neonicotinoids are a better alternative to chemicals used previously, and indeed some beekeepers think so too. But now that we have learned what harm neonicotinoids do, our aim should be to minimize the use. Especially when they are used as a prophylactic or without a serious threat to crops. Or indeed where viable, bee-friendly alternatives are at hand.

This CLM-report, pointing the way in an objective and pragmatic manner, could well be the start of a fruitful debate. And it may help agriculture move towards practical, more environmentally benign crop-protection.

Ted van den Bergh

Director Triodos Foundation
and beekeeper

Summary

Which neonicotinoids are used most in European agriculture, and in which crops? And in which cases are there viable alternatives to these pesticides? These are the questions we aim to answer in this study.

The group of systemic insecticides called neonicotinoids are under public and political scrutiny. They have become an increasing concern to beekeepers and bee researchers in recent years with many of them suspecting that they may be connected to current bee decline. In 2013 these concerns led to partial bans on the use of some neonicotinoids and fipronil for specific crops in the EU. This study steers clear of the debate about the harmfulness, focusing instead on the use and possible alternatives for neonicotinoids.

Methodology
The study covers the five neonicotinoids that have authorization in the European Union (EU): imidacloprid, chlothianidin, thiamethoxam, thiacloprid and acetamiprid, complemented with the systemic insecticide fipronil. Four countries and ten crops were chosen for the investigation, divided as follows.

	Apple	Cereal	Citrus	Leave salads	Maize	Melon	Olives	Potato	Rapeseed	Sugar beet
Germany	✗	✗						✗	✗	✗
Netherlands	✗				✗			✗		✗
Spain			✗	✗		✗	✗			
United Kindom		✗			✗			✗	✗	✗

We collected data through literature and making use of experts in the four case study countries. It took substantial effort to find reliable data, especially at the level of individual neonicotinoids and crops.

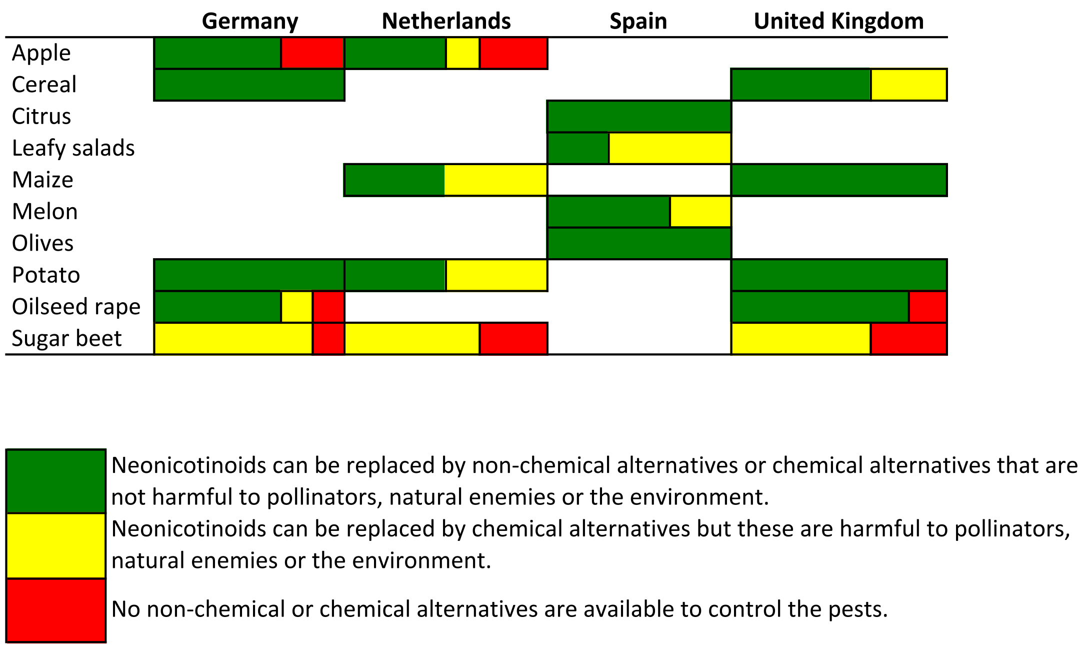
Use of neonicotinoids
The total use of neonicotinoids in 2012 compared to the total agricultural area ranged between 12.2 g/ha in Germany to 30.5 g/ha in the Netherlands. The total volume of use in 2012, ranged between 13.0 metric tonnes in the United Kingdom to 146.8 tonnes in Germany. For Spain the total use of neonicotinoids via spray application was low compared to the other countries. No information was available on the amount used as seed treatment in Spain and hence no total amount applied could be determined.

Viable alternatives to neonicotinoids

In this study viable alternatives to neonicotenoids were analysed in a number of crops in four EU countries. Among the topics considered were main pests in the crops, environmental impact of the alternative as compared to neonicotinoids, risk of resistance development in the pest to active ingredients, effectiveness of the alternative including restrictions on when and how to apply and the costs compared to neonicotinoid application.

The table below summarises in which cases there are alternatives to neonicotinoids. Two colours per crop mean that the results concern part of the active ingredients applied in that crop.

In about half of the situations that we analysed, neonicotinoids can be replaced by an alternative that has no or little environmental impact. This means that either non-chemical alternatives can be used, or that neonicotinoids can be replaced by pesticides that have a lower environmental impact. In over one third of the crop-country combinations, the chemical alternatives that are currently on the market to replace neonicotinoids have a high environmental impact as well. For seven pest species in three crops (about one-sixth of the instances) no reliable alternative is available at present for at least one of the neonicotenoids and an immediate ban may lead to loss of crop and extra costs. It is important to distinguish different cases – for instance in rapeseed in Germany neonicotinoids are very important to combat cabbage root fly, but not in the United Kingdom, where the fly is not a major pest.



Economic impact

We performed a quick-scan on farm-level income effects for those crops in which there are no effective alternatives for pest control by neonicotinoids. A total ban on neonicotinoids will have economic consequences for apple, maize, sugar beet and oilseed rape growers. Income losses due to pests vary from 3.3% for oilseed rape in United Kingdom to 50% in apple production should such a ban come into force immediately. It should be noted that experience shows that once a ban is announced, the future lack of the pesticide becomes driver for innovation. New technical solutions appear and existing options become feasible through decreasing costs. Thus, the actual economic impact of a ban may be lower than calculated in this study.

Recommendations

1. Improving the availability of pesticide use data in Europe is indispensable to allow for better analysis of use and environmental impact.
2. Market authorization of "green pesticides", e.g. pesticides with low environmental impact, should be enhanced and accelerated.
3. Integrated pest management should be developed further, ranging from use of resistant varieties to mulching for crop protection.
4. Arable rotation should be further encouraged. Most pest problems can be reduced when crops are rotated. Areas in Germany or England with high density of oilseed rape may profit from more crop rotation; areas with less intensive production of oilseed rape, such as the Netherlands, have little or no problems with cabbage stem flea beetle.
5. Monitoring on the occurrence of pests in specific regions should be further developed. When pest incidence is low, farmers may choose not to apply seed coating, as sugar beet growers do in the Netherlands. And in case damage does occur, collective crop insurance such as developed for maize production in the Po Valley in Italy may compensate for the loss.
6. Circumstances in which natural enemies (predators) of pests thrive should be stimulated. This means for instance avoiding the use of broad-spectrum pesticides and stimulating the presence of natural vegetation around the fields and orchards.

1

Introduction

In this study, the use of a number of systemic insecticides (neonicotinoids and fipronil) to control pests in a number of main crops in four EU countries is analysed. In addition a quick-scan of alternative crop protection methods is performed, in order to assess the impact of banning the use of the systemic insecticides.

Unlike contact pesticides, which remain on the surface of the treated foliage, systemic pesticides are taken up by the plant and transported to all tissues (leaves, flowers, roots and stems, as well as pollen and nectar). Products containing these systemic active ingredients can be applied at the roots (as seed coating or soil drench) or sprayed onto crop foliage. The insecticide toxin remains active in the plant for many weeks, protecting the crop during the growing season.

Prevention of emissions is very important when using pesticides. This is also crucial for neonicotinoids, since these active substances are –in general- very detrimental to aquatic life. Emission to water has to be prevented when spraying, but also on the farm when filling or cleaning the sprayer. Seeds coated with pesticides provide another route through which neonicotinoids enter the environment. Bees and other non-target organisms may be exposed to neonicotinoids via pollen and nectar of the flowers of plants that had their seed coated with neonicotinoids. For plants that are harvested before flowering, such as sugar beets, pollinators are not exposed to neonicotinoids via nectar and pollen. However, neonicotinoid-treated seeds may be a source of contamination to nectar and pollen in wild flower species bordering the fields, but only when contaminated dust abraded from the treated seeds is blown to the field edges. Evidence for these contaminations have been demonstrated in wild flowers bordering oilseed rape and winter wheat (David et al. 2016). Secretion of small droplets from the pores of plants (guttation) is another route through which insects can be exposed to neonicotinoids that have been used for seed coating. Neonicotinoids are active against a broad spectrum of economically important crop pests, including aphids (Aphidae), whitefly (Aleyrodidae), leafhoppers (Cicadellidae), Chrysomelidae (among others western corn rootworm), wireworms (Elateridae), planthoppers (Fulgoroidea), mealybugs (Pseudococcidae) and phytophagous mites (Simon-Delso, 2015).

Since the introduction in the early nineties neonicotinoids have become the most widely used insecticides of the five major chemical classes (the others being organophosphates, carbamates, phenyl-pyrazoles, and pyrethroids) on the global market. Systemic insecticides have become of increasing concern to beekeepers and bee researchers in recent years with many of them suspecting that they may be connected to current bee decline (Grimm et al. 2012). These concerns have led to partial bans on the use of some neonicotinoids and fipronil for specific crops in European countries, starting in September 2013. EFSA has announced an update on the risk assessments of clothianidin, thiamethoxam and imidacloprid en fipronil for January 2017. However, due to large amounts of data that need to be studied, the planning of EFSA is delayed. Now it has been announced for autum 2017 (Farming online, 2017).

Since the partial ban on neonicotinoids there has been a vigorous debate focusing on the scientific evidence that neonicotinoids harm pollinators (Godfray et al. 2015). Some studies focus on whether neonicotinoids are harmful to bees and bee colonies (e.g. Moffat et al., 2016), while other studies focus on the question whether bee species are exposed to concentrations that are harmful (Long and Krupke 2016). In this report we do not intend to enter into this debate. We concentrate on the question how use of neonicotinoids can be reduced with reliable alternatives.

2

Objectives of the assessment

The objectives of the assessment of neonicotinoids in European agriculture are the following:

- An analysis of the crops where neonicotinoids are generally applied most in the EU.
- An estimation of the amount and types of use of neonicotinoids applied in a number of major crops (major defined as those crops where neonicotinoids are used in relatively large quantities).
- A quick-scan impact assessment of a (partial) switch to alternative pest control in these major crops based on an inventory of alternative crop protection methods in chosen countries and crops.

3

Methodology and choices

3.1 Methodology

The study is based on literature search supported by input from experts from the countries concerned. The list of experts can be found in the Annex.

Please note that the contents and conclusions in this report are entirely the responsibility of CLM.

3.2 Choice of neonicotinoids

The neonicotinoids that have authorization in the European Union (EU) are covered by this study. It concerns the following substances: imidacloprid, chlothianidin, thiamethoxam, thiacloprid and acetamiprid, complemented with the systemic insecticide fipronil. The systemic insecticide sulfoxaflor is not included in this study because it has been permitted only recently as an active substance (18/08/2015). There are a number of other neonicotinoids on the world market that are not included in this study (table 3.1). Table 3.1 gives a general estimation of the importance of neonicotinoids worldwide based on sales in 2009 (Jeschke, 2011 and EU Pesticides Database, 2016).

Table 3.1 Neonicotinoids, authorization in the EU, the number of crops where used and sales world wide in 2009

Product	# EU Countries with authorization	# Crop uses world wide	Sales world wide (US $million) in 2009
Imidacloprid	28	140	1091
Thiamethoxam	25	115	627
Clothianidin	21	40	439
Acetamiprid	25	60	276
Thiacloprid	28	50	112
Dinotefuran	not approved in EU	35	79
Nitenpyram	not approved in EU	12	8
Sulfoxaflor	authorisation in progress in 5 countries	?	?
Guadipyr	not approved in EU	?	?
Huanyanglin	not approved in EU	?	?
Paichongding	not approved in EU	?	?
Cycloxaprid	not approved in EU	?	?
Imidaclothiz	not approved in EU	?	?
Nithiazine	not approved in EU	?	?

3.3
Choice of countries

For the choice of countries the following variables have been taken into account: zonal distribution of the countries in the different climate zones of the European Union, usable agricultural area per country, use of pesticides/ha and availability of data on neonicotinoids. Considering these parameters the chosen countries are: Germany, the Netherlands, Spain and the United Kingdom. Although France is an important agricultural country bearing in mind the agricultural area and the share in pesticide use in the EU, this country could not been included in this study because of lack of data on neonicotinoids.

Table 3.2 gives an overview of arable land, use of pesticides, insecticides and neonicotinoids in Europe (28 countries), Germany, the Netherlands, Spain and the United Kingdom.

Table 3.2 General statistics about agricultural area and sales of pesticides, insecticides and neonicotinoids in Europe and four member states for 2012. For Europe and Spain no data were available on the total sales of neonicotinoids. For source of the data see the references section.

	Agricultural area	Pesticides	Insecticides	Neonicotinoids
	ha	**tonne**	**tonne**	**tonne**
Europe	114.379.051	369.441	24.208	-
Germany	12.073.796	45.521	1.029	342
Netherlands	1.075.286	11.349	247	28
Spain	15.331.545	63.490	7.641	?
United Kindom	6.308.487	20.243	454	88

3.4
Choice of crops

The parameters used for the choice of crops are total area of the crop in a specific country, total use of neonicotinoids in a crop and the use/ha of neonicotinoids in a crop and the availability of data on the use. In paragraph 4.1 the selection process is described. The use of neonicotenoids has been analysed in 10 crops in four EU countries (Table 3.3).

Table 3.3 Result of the selection process of crops in Germany, the Netherlands, Spain and the United Kingdom.

	Apple	Cereal	Citrus	Leave salads	Maize	Melon	Olives	Potato	Rapeseed	Sugar beet
Germany	✗	✗						✗	✗	✗
Netherlands	✗				✗			✗		✗
Spain			✗	✗		✗	✗			
United Kindom		✗			✗			✗	✗	✗

4

Inventory and analysis of the use of neonicotinoids

4.1 Introduction

To gather information on the use of neonicotinoids in the chosen crops the websites of the authorisation boards, departments of agriculture and statistical institutes of the various countries have been checked. Also information on pesticide surveys has been obtained. In this way insight was acquired in the authorisation and use of neonicotinoids in the different crops per country. For a detailed overview see References. We present data on the use of neonicotinoids for the year 2012. We choose this year as reference because it is the year just before neonicotinoids were partly banned and thus shows a situation without a ban on neonicotinoids. For Spain, data on the use of neonicotinoids were only available for 2013, hence these data are used in the report.

First, data are presented on the amount of neonicotinoids applied in three of the four countries during the past years (Figure 4.1). Spain was not included in the figure due to a lack of data from before 2013. For the Netherlands the volume is determined from the sales of pesticides. Then the total use of active ingredients of neonicotinoids in Germany, Netherlands, Spain and the United Kingdom for 2012 is accounted for (Table 4.1). For Germany the quantity of neonicotinoids sold (342 t) is much higher than the quantity that is applied (102 t). Partly, this is due to missing data on the amount of neonicotinoids applied as seed coating in crops other than oilseed rape and sugar beet and because for Germany the quantity sold includes the amount that is used for coating seeds that were exported (mainly sugar beet and oilseed rape).

Then the total amount of active ingredient per crop and country is listed (Table 4.2). Per crop and country the average amount applied per hectare is calculated by dividing the total amount applied by the respective cropping area in a certain year. This quantity allows comparing the relative amount of active ingredients applied in a crop between countries. The average amount applied per hectare is not the same as the average dose that is applied, which is the amount applied divided by the treated area per application.

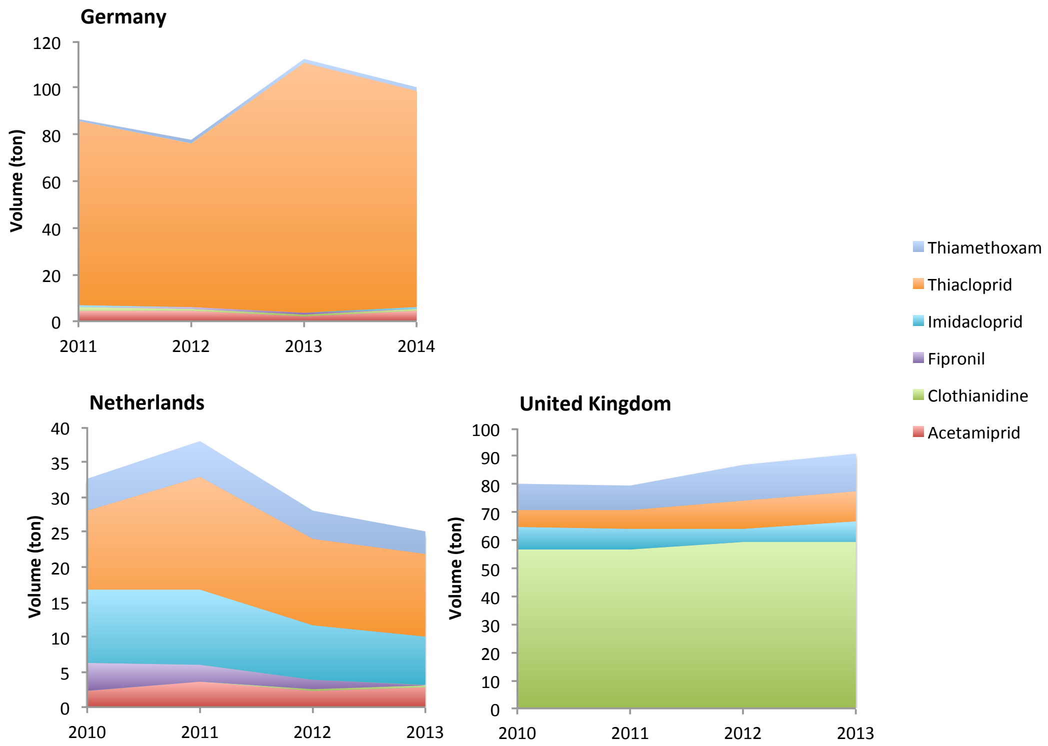


Figure 4.1: Amount of neonicotinoids applied in three countries during the past years. For the Netherlands the volume is determined from the sales of pesticides. Spain only has data for 2013 (see Table 4.1).

Table 4.1 Total domestic sales of neonicotinoids (incl. fipronil) and the amount applied in spraying or as seed coating per country for 2012. In the last column the total amount applied is divided by the total agricultural area from Table 3.2. Data for seed coating in Germany is only for oilseed rape and sugar beet.

	Domestic sales	Applied in spraying	Applied as seed coating	Total applied	Total applied per area
	tonne	**tonne**	**tonne**	**tonne**	**g / ha**
Germany	342,0	77,7	69,1	146,8	12,2
Netherlands	28,0	26,4	6,4	32,8	30,5
Spain	?	23,0	?	-	-
United Kingdom	88,0	11,7	70,6	82,3	13,0

Table 4.2 Amount applied [tonne] of active component for the main crops per country that we included in our study. For DE, NL and UK data are for 2012; for SP data are for 2013. Shaded cells are for active ingredients that fall (partly) under the ban. Note: Only for crops and countries that were included in the study data is presented.

	Acetamiprid	Clothianidin	Fipronil	Imidacloprid	Thiacloprid	Thiamethoxam	**Total neonicotinoids**
Germany							
Apple	0,4			0,1	2,6		**3,1**
Cereal					5,3		**5,3**
Potato		0,8	0,8		6,8	0,6	**9,1**
Oilseed rape	3,9	43,3		0,2	55,5	1,6	**104,4**
Sugar beet		12,5		6,3		5,1	**24,0**
Netherlands							
Apple	0,1			0,1	0,5		**0,7**
Maize					2,4	0,6	**3,0**
Potato	1,1			1,2	3,8	1,3	**7,4**
Sugar beet		2,7			<0,1		**2,7**
Spain							
Citrus	5,5			2,6			**8,1**
Olive				2,1			**2,1**
Vegetables[1]	0,8			8,0	1,0		**9,8**
United Kingdom							
Cereal		50,9		0,5			**51,4**
Maize		0,4		2,1		<0,1	**2,5**
Potato	0,4				5,3	<0,1	**5,6**
Oilseed rape	<0,1	0,6		1,0	1,5	7,4	**10,5**
Sugar beet		1,7		0,4		5,5	**7,6**

[1]) For Spain no individual information is available for lettuce and melon. These crops are grouped under 'hortalizas' (vegetables) together with several other horticultural crops. Most neonicotinoid use in this group, however, is in lettuce and melon (expert opinion of Javier Arizmendi Ruiz, from ZERYA Spain).

In September 2013 the European Commission has banned three neonicotinoids for use in crops attractive to bees, because a high risk for bees could not be excluded (EU 2013a). These neonicotinoids are clothianidin, thiamethoxam and imidacloprid. Seed treatment, soil treatment, as well as some foliar applications of these neonicotionids were banned in a number of crops. Use of these substances in greenhouses and as spraying application after flowering is permitted. In The Netherlands it was estimated that (for the three neonicotenoids clothianidine, imidacloprid and thiametoxam) the ban is only relevant for 15% of the use in 2012 (van Vliet et al. 2013).

In addition to the ban on the use of clothianidin, thiamethoxam and imidacloprid the use of fipronil was prohibited in December 2013 by the European Commission for the same reason, possible high risks for bees (EU 2013b). Currently it is not allowed to use this substance as a seed treatment anymore. There are two exceptions: seeds used to be sown in greenhouses and seeds of leeks, onions, shallots and of the group of *Brassica vegetables* that are sown outside and harvested before flowering.

The following part of this chapter contains detailed information on the use of neonicotinoids in 2012 in the chosen crops in Germany, the Netherlands and the United Kingdom and for Spain in 2013. For Spain only data for 2013 were available.

4.2 Apple

Germany
In Germany acetamiprid, imidacloprid and thiacloprid were used in a spraying application in 2012 in apple. The average amount of these three neonicotenoids applied per hectare was 98 g for Germany. In 2012 thiacloprid covered 84% of the total amount of neonicotinoids in apple in Germany.

Netherlands
In the Netherlands the same neonicotinoids are used in apple as in Germany: acetamiprid, imidacloprid and thiacloprid. The average amount applied per hectare is lower than in Germany, namely 86 g. Thiacloprid covers 71% of the total amount of neonicotinoids used, contrary to 84% in Germany.

4.3 Cereal

Germany
In cereals in Germany 5,3 tonnes thiacloprid were used in spraying applications. The average amount applied per hectare is 0,8 g.

Cereal in The Netherlands: thiacloprid in 2016
In 2012, neonicotinoids were not allowed in cereals in The Netherlands and this crop is therefore not included in our study. However, currently Calypso (thiacloprid) is authorised for and used in cereals against aphids and *Lema cyanella* [graanhaantje]. No data are available yet on the amount of thiacloprid used in cereals. This example shows that the authorisation of neonicotenoids can extend to more crops, although there is a partial ban on three of them.

United Kingdom
In the United Kingdom clothianidin and imidacloprid were used as seed treatment. Because of the ban, these neonicotinoids have no authorization for use in spring cereals, which comprised in 2012 about 25% of the total cereal production area (Defra 2015). The average amount applied per hectare in winter cereals is 16 g.

4.4 Citrus

Spain
In 2013 a total of 8,1 tons of neonicotinoids were used in citrus. Acetamiprid had the highest use with 5,5 tons, followed by imidacloprid with 2,6 tons. The average amount of neonicotinoids applied per hectare was 26,8 g.

4.5
Leafy salads

Spain
No information is available on the specific use of neonicotinoids in leafy salads, as this crop is grouped under 'hortalizas' (vegetables). Total use in 'hortalizas' was 9,8 tons, of which 8,0 tons imidacloprid. The average amount applied per hectare in leafy salads could not be calculated due to lack of information about the produced area, as they are grouped under 'hortalizas'.

4.6
Maize

Netherlands
In 2012 thiamethoxam was used as seed coating, but is currently not allowed anymore in maize due to the ban. Thiacloprid was and is still used as a coating. By far most of the neonicotinoids use in maize is used in seed coating. However, there are no registered data on the amount of pesticides used in this type of application. The amount of thiacloprid in Table 4.2 is based on an estimated area of 10% on which coated seeds are used (personal information G. Bouman, Plantum, 2016). The average amount applied per hectare is 12 g.

United Kingdom
In the United Kingdom mainly imidacloprid and a small amount of clothianidin and thiamethoxam are used as seed treatment in 2012. The average amount applied per hectare is 14 g. In 2016 this application is part of the ban.

4.7
Melon

Spain
No information is available on specific use of neonicotinoids in melon, as this crop is grouped under 'hortalizas' (vegetables). Total use in 'hortalizas' was 9,8 tons, of which 8,0 tons imidacloprid. The average amount applied per hectare could not be calculated due to lack of information about the produced are of vegetables grouped under 'hortalizas'.

4.8
Oilseed rape

Germany
In oilseed rape 59,3 tons neonicotinoid were applied as foliar spray consisting of acetamiprid, imidacloprid and thiacloprid. The remainder (45,1 t) is probably used as seed coating (U. Heimbach, Julius Kühn Institute, pers. comm.). Percentages are based on the total area of oilseed rape production in 2012 (1.458.000 ha). The average amount applied per hectare as foliar spray was 40,7 g and as seed coating was 30,9 g.

United Kingdom
In the United Kingdom imidacloprid, thiamethoxam and clothianidin are used as seed coating and thiacloprid and a small amount of acetamiprid are used in spraying. The average amount applied per hectare is 13 g.

4.9 Olive

Spain
In 2013 2,1 tons imidacloprid was used in olives. The average amount applied per hectare was 0,8 g.

4.10 Potato

Germany
In Germany mainly thiacloprid and a small amount of clotinadinin, fipronil, and thiamethoxam are used for spraying potato. The average amount applied per hectare is 36 g.

Netherlands
In potatoes the neonicotinoids acetamiprid, imidacloprid, thiacloprid and thiamethoxam are used for spraying. In 2012 a total of 7,4 t of these neonicotinoids were applied on potatoes for consumption, seed potatoes and potatoes for starch. The use of active ingredients is largest for seed potatoes with an average dose applied of 1500 g ha^{-1}. On consumption and starch potatoes the average dose applied is 200 g ha^{-1}. The average amount applied per hectare is only 50 g because not the total crop area is treated with neonicotinoids.

United Kingdom
In the United Kingdom mainly thiacloprid and a small amount of acetamiprid and thiamethoxam are used for spraying. Average amount applied per hectare is 38 g.

4.11 Sugar beet

Germany
In Germany clothianidin, imidacloprid and thiamethoxam are used for seed coating. The total use of these active ingredients was calculated based on the average dose applied (Table 1 in Hauer et al. 2016) and the sugar beet cultivation area (360.000 ha). The average amount applied per hectare is 67 g.

Netherlands
In the Netherlands clothianidin is used as seed coating and a small amount of thiacloprid is used for spraying. The amount used as seed coating was calculated based on the area that used coated seeds and a dose of 45 g/ha (bietenstatistiek.nl). The average amount applied per hectare (divided by the total area sugar beet) is 37 g.

United Kingdom
In the United Kingdom only clothianidin, imidacloprid and thiamethoxam are used as seed coating. The average amount applied per hectare is 64 g.

5

Analysis of crops and pests

5.1 Introduction

For the analysis of crops and pests various cultivation manuals have been consulted. Also guides on crop protection and websites of manufacturers of pesticides proved to be useful to gather information on crops and their pests. The crop experts who were consulted have given a very worthwhile contribution to this chapter. In addition expert knowledge of CLM was used to finalize the results. Only pests that are controlled by neonicotinoids, are included in this section. Dutch, English, German and Spanish species names are taken from the EPPO Global Database (gd.eppo.int).

5.2 Apple

Germany
In Germany three aphid species may cause damage in apple: **rosy apple aphid** [Mehlige Apfelblattlaus] (*Dysaphis plantaginea*), **green apple aphid** [Grüne Apfelblattlaus] (*Aphis pomi*) and the **green citrus aphid** [Grüne Zitronenlaus] (*Aphis spiraecola*).

Rosy apple aphid is one of the major pests in apple in Germany. It is present in all apple orchards and requires regular control. It causes shoots and leaves to curl, and small, deformed fruits to form. It may cause up to 50% yield loss. The economic damage threshold is 1% of infected flower bushes.

The **green apple aphid** is in most parts of Germany often associated with the **green citrus aphid**. Both species occur after flowering and have their peak in early summer. They cause damage to leaves and shoots. The damage threshold is 10 colonies per 100 shoots. In contrast to the green apple aphid, the green citrus aphid is difficult to control.

The **apple saw fly** [Apfelsägewespe] (*Hoplocampa testudinea*) and the **apple fruit weevil** [Rotbraune Apfelfruchtstecher] (*Caenorhinus aequatus*) cause damage to the blossom and the young fruit and thus can locally lead to considerable loss of harvest. The larvae of the **apple sawfly** burrow beneath the surface of the fruits, migrating from fruitlet to fruitlet. It is important to keep track of the damage because it can locally lead to considerable loss of harvest. When 2% of the fruits were affected before thinning, or 1% at harvest, chemical control should be used the following year (DLV Plant, 2014; Groenkennisnet, 2016).

The **apple blossom weevil** [Apfelblütenstecher] (*Anthonomus pomorum*) eats from the petal base, causing capped blossoms. These flowers with dried petals contain the larvae, which has eaten away the pistil and stamens. Without chemical control this pest can become widespread and destructive. Generally control measures should be taken when 10-20 weevils for 100 beat samples are present when checking for the weevil in early spring (DLV Plant, 2014; Groenkennisnet, 2016).

Economically less important pests for which neonicotinoids are used include the **codling moth** [Apfelwickler] (*Cydia pomonella*) and leaf miners such as the **apple leaf miner** [Obstbaumminiermotte] (*Leucoptera malifoliella* and *Lyonetia clerkella*), **spotted tentiform leaf miner** [Apfelblattblütenmotte] (*Lithocolletis blancardella*) and the **banded apple pigmy** [Apfelminiermotte] (*Stigmella malella*). Caterpillars from the **codling moth** cause damage to the fruits from which they eat. **Leaf miners** may cause substantial damage by leave fall if they occur in high densities.

The **summer apple psylla** [Sommerapfelblattsauger] (*Cacopsylla picta*) is the most important vector of apple proliferation [Apfeltriebsucht], a phytoplasma bacteria of apples. The overwintering adults can transfer the phytoplasma bacteria in spring very effectively. In Germany there is no registration of products with sufficiently effects on this pest.

Netherlands

Four of the six economically important pest species that were described for Germany, **rosy apple aphid**, **green apple aphid**, **apple sawfly** and **apple blossom weevil**, also cause damage to apple in the Netherlands. In addition to these species the Netherlands has four additional pest species in apple: **apple grass aphid**, **rosy leaf curling aphid**, **woolly apple aphid** and **common green capsid**. The Dutch and Latin names of the pest species are given below.

Four aphid species may cause problems. These include the **rosy apple aphid** (*Dysaphis plantaginea*), **apple-grass aphid** [appelgrasluis] (*Rhopalosiphum insertum*), **green apple aphid** [groene appeltakluis] (*Aphis pomi*), and **woolly apple aphid** [appelbloedluis] (*Eriosoma langerium*) (Groen Kennisnet, 2016).

Damage caused by aphids occurs on branches and fruits. The **woolly apple aphid** can cause cancer like growths on twigs, obstructing circulation (Syngenta, 2016). The **green apple aphid** and **apple-grass aphid** cause leaf curling (DLV Plant, 2014).

The threshold to start control depends on the aphid species. Control of the **rosy apple aphid**, being one of the most damaging pests in apple, starts as soon as infestation is detected. Also the **woolly apple aphid** justifies treatment when a single tree is affected in June. The **green apple aphid** should only be controlled when absolutely necessary, at 50% of blossom trusses infested, as they are a good source of sustenance for natural enemies (DLV Plant, 2014; Groenkennisnet, 2016).

The **common green capsid** [groene appelwants] (*Lygocoris pabulinus*) is a pest that can cause damage to the shoots and fruits of apple trees. It hibernates in shoots of woody plants, so rootstock sucker growth should be removed during the winter. When larvae or shoot damage are found shortly before flowering, treatment should be applied. The treatment timing is crucial for its effectiveness and should be performed shortly before or during flowering (Groenkennisnet, 2016; AHDB Horticulture, 2016)

The **apple sawfly** [appelzaagwesp] and the **apple blossom weevil** [appelbloesemsnuitkever] were already described for Germany and may also cause damage to apple in the Netherlands.

5.3 Cereal

Germany
The main pests in cereals that are controlled by neonicotinoids include the **grain aphids** [große Getreideblattlaus, bleiche Getreideblattlaus, Haferblattlaus] (*Sitobion avenae, Metopolophium dirhodum, Rhopalosiphum padi*) and the **cereal leaf beetle** (*Oulema melanopus*) [graanhaantje].

Grain aphids can cause substantial damage when they occur in high densities. Control measures should be taken when 30% of the stems are occupied before flowering or 70% after flowering. **Grain aphids** may also transmit the *Barley Yellow Dwarf Virus*. Mainly in wheat this virus may cause yield reduction.

The **cereal leaf beetle** may cause yield loss by the larvae that feed from leaves. The threshold for control measure for this beetle is between 10 and 20% damaged leaves (Luske et al., 2014).

United Kingdom
In the United Kingdom the main pest species in cereals that are controlled by neonicotinoids include the **bird-cherry aphid** (*Rhopalosiphum padi*), **English grain aphid** (*Sitobion avenae*), **Rose-grain aphid** (*Metopolophium dirhodum*) the **orange wheat blossom midge** (*Sitodiplosis mosellana*) and **wireworm** (*Agriotes* spp.). The United Kingdom and Germany only have the **bird-cherry aphid** in common as major pest species.

Two wheat blossom midge species occur in the UK: **orange wheat blossom midge** and **yellow wheat blossom midge** (*Contarinia tritici*). **Orange wheat blossom midge** is usually the most significant and economically important species. Larvae feed on the developing seeds, causing small, shrivelled grains with poor germination. Damage to the outer layer of the grain (pericarp) allows water to enter, resulting in sprouting in the ear and facilitating secondary attack by fungi causing fusarium and septoria. This affects both the yield and quality of grain harvested. **Orange wheat blossom midge** can be found in any cereal field in which susceptible varieties have been grown for the past four years." (Orange wheat blossom midge leaflet).

5.4 Citrus

Spain
Citrus includes several citrus fruits, such as orange, lemon and tangerine, as most important pests affect more than one citrus species. The main pest species in citrus include **Mediterranean fruit fly** [mosca del mediterráneo] (*Ceratitis capitata*), **woolly whitefly** [mosca blanca de los citros] (*Aleurothrixus floccosus*), **citrus whitefly** [mosca blanca de los cítricos] (*Dialeurodes citri*), **cotton aphid** [afido del algodón] (*Aphis gossypii*), **green citrus aphid** [Pulgón Amarillo] (*Aphis spiraecola*) and the **citrus leaf miner** [minador de las hojas dos cítricos] (*Phyllocnistis citrella*). Information on the pest species was obtained from Abrol, (2015), Gil and Climent (2014) and Agrologica (www.agrologica.es).

Mediterranean fruit fly females puncture ripening fruit to lay eggs. Feeding combined with fungal and bacterial infection from the puncture holes result in premature fruit fall. Tolerance level for this pest is very low. Treatment starts at 0,5 flies per trap per day or at presence of punctured fruits.

Woolly whitefly is one of the most important pests in citrus. The sap-sucking nymphs secrete honeydew and flocculent wax, which causes a black sooty mould. Treatment starts when over 20% of shoots sampled are affected.

Citrus whitefly nymphs and adults suck sap from the plants. Then they secrete honeydew that can cause the development of sooty mould. Fruits turn black and have insipid taste.

Several **aphids** affect citrus, but only two need control. **Cotton aphid** can transmit **citrus tristeza virus**. This **virus** can ruin large areas of citrus and is problem in citrus all around the world. Pest pressure is highest in spring and treatment starts when 25% of buds are infected. The **green citrus aphid** deforms leaves and buds, which stops development of affected shoots. All **aphid** species suck plant sap and produce large quantities of honeydew, which can cause black sooty mould.

Citrus leaf miner is an important pest for young or recently grafted orchards and nurseries. Females lay eggs on young leaves of which the larva burrows through the leaves. The leaves dry out and lose their photosynthetic capacity. Treatment starts at two affected shoots in young plants or grafts. No treatment is necessary in producing orchards.

5.5
Leafy salads

Spain
'Leafy salads' is a group of horticultural crops, including several types of lettuce and spinach. The main pests in leafy salads include several species of aphids, whitefly and caterpillars.

Aphids are one of the most important pests in lettuce. Several species affect the crop, the most important ones being **green peach aphid** [pulgón verde del melocotonero] (*Myzus persicae*) and, especially in the past few years, **lettuce aphid** [pulgón rosado de la lechuga] (*Nasonovia ribisnigri*). Also frequent are the **cotton aphid** [afidio del algodon] (*Aphis gossypii*), **black bean aphid** [piojo del frijol] (*Aphis fabae*) and **potato aphid** [afidio pulgon de la papa] (*Macrosiphum euphorbiae*). The **green peach aphid** and **black bean aphid** are also present in spinach. Aphids suck sap from the plants, reducing plant vigour, and produce honeydew, which causes sooty mould (Sanchez, 2014). Aphids are also vectors to viruses, like LMV (Lettuce Mosaic Virus), which can cause deformed and mottled leaves in lettuce and spinach (dpvweb.net). During periods of high risk of infection, with good weather conditions and susceptible crop, the treatment starts when aphids are encountered (Sanchez, 2014).

Two whitefly species affect lettuce, the **cabbage whitefly** [mosca blanca del repollo] (*Aleyrodes proletella*) and the **tobacco whitefly** [mosca blanca del tabaco] (*Bemisia tabaci*). Whitefly cause debilitated plants, by sucking the sap, and fungus through honeydew excretion. Also, **tobacco whitefly** is a vector to several viruses (agrologica.es).

During summer and autumn several caterpillar species cause damage in lettuce. The **cotton leafworm** [rosquilla negra] (*Spodoptera littoralis*), **beet worm** [lambda] (*Autographa gamma*), **golden twin-spot moth** [camelleros camello] (*Chrysodeixis chalcites*) and **beet armyworm** [gardama verde] (*Spodoptera exigua*) are some of the more damaging species. In recent years the **corn earworm** [gusano bellotero del algodon] (*Helicoverpa armígera*) has become more damaging due to it migrating deep in the foliage and being difficult to control. Aside from feeding damage, caterpillars have a low threshold for control due to excrements on the leaves, causing development of funguses and the presence of individuals (alive or dead) on the commercialised crops.

5.6
Maize

Netherlands, United Kingdom
The main pest species in maize in the Netherlands and the United Kingdom that are controlled by neonicotinoids include **frit fly** [fritvlieg], (*Oscinella frit*) and **wireworm** [ritnaalden] (*Agriotes* spp.).

Frit fly larvae can cause much damage to corn in the early development of the plant when they eat from the shoot apex. The species overwinters on cereals and grasses, but the extent of damage is not strongly related to the previous crop.

Wireworms live in the soil and eat from dead organic material, but when conditions are dry they switch to consuming living plants. They have a development time of about five years before they pupate and emerge as adult beetles. Adult beetles have a preference for grassland and clover fields to lay eggs. The larvae frequently occur in old grasslands (> 10 year) and may cause damage to crops in the second year after ploughing because in the first year they can still live on the organic material from the grass sods.

5.7
Melon

Spain
The main pest species in melon include **two-spotted spider mite** [ácaro común] (*Tetranychus urticae*), **glasshouse whitefly** [mosca blanca de los invernadores], [mosquita blanca del Tabaco] (*Bemisia tabaci*), **cotton aphid** [afidio del algodón] (*Aphis gossypii*) and **peach-potato aphid** [afidio verde] (M*yzus persicae*). Information on the pest species was obtained from the website of AgroLogica (www.agrologica.es) and InfoAgro (www.infoagro.com).

The **two-spotted spider mite** is a fairly common pest, being found all over the world, with a wide host range. It spins webs that can cover all surfaces of the plant and sucks the sap from the leaves, which become brittle and fall prematurely. At high temperatures (around 30 °C) the pests develops in little more than a week, quickly killing infested plants. When the mites affect the fruit, dark spots appear on the skin.

Two whitefly species affect melon, the **glasshouse whitefly** and the **tobacco whitefly**. They weaken the plants and cause plant yellowing. Also they produce honeydew, which can cause fungus infection. The **glasshouse whitefly** is vector to the Cucurbit Yellow Stunting disorder Virus. The **tobacco whitefly** is vector to a large number of viruses, including the Cucumber Vein yellowing Virus.

The **cotton aphid** and **peach-potato aphid** are the most abundant aphid species in greenhouses. They suck the sap and produce honeydew, which in turn can cause sooty mould. The aphids are vectors for a large number of debilitating viruses.

5.8
Oilseed rape

Germany
The major pest in oilseed rape in the north of Germany the **cabbage root fly** [kleine Kohlfliege] (*Delia radicum*). In the south the most important pest is the **rape stem weevil** [großer Kohltriebrüssler] (*Ceutorhynchus napi*). Other pests include the **cabbage stem flea beetle** [Rapserdfloh] (*Psylliodes chrysocephala*) and the **rape beetle** [Rapsglanzkäfer] (*Meligethes aeneus*). The **cabbage aphid** [Mehlige Kohlblattlaus] (*Brevicoryne brassicae*) can cause damage as virus vector.

Four minor pests include the **cabbage seed weevil** [Kohlschotenrüssler] (*Ceutorhynchus obstrictus*), **brassica pod midge** [Kohlgallmücke] (*Dasineura brassicae*) and the **cabbage stem weevil** [kleiner Kohltriebrüssler] (*Ceutorhynchus quadridens*).

The **cabbage root fly** is a wide spread pest in oilseed rape in Germany. Intensive soil cultivation after rape harvest, however, significantly reduces the hatching of the first generation of the flies.

The rape stem weevil is an important pest in South Germany. At present it also spreads towards the north, although Niedersachsen and Schleswig-Holstein are not affected yet. In certain, years when the population of the **rape stem weevil** has increased and environmental conditions are not favourable for the plant, this pest can cause considerable damage. Control can be achieved by sustaining the population of natural enemies.

The **cabbage stem flea beetle** is a pest in oilseed rape in Central Europe. The holes made by the larvae causes water to enter the plant that as a result of freezing in winter causes damage. Furthermore, the holes are an entry point for fungal pathogens. It occurs in all oilseed rape fields.

The **rape beetle** is also an important pest in oilseed rape. When the crop has an early development, this pest may cause significant losses. In general pest infestations are less in summer oilseed rape than in winter oilseed rape.

The **cabbage aphid** may cause economic loss of 20-30% when population numbers are high in autumn. Apart from this, the aphid may cause damage by transmitting viruses. The pest occurs in all oilseed rape fields. During summer it can be strongly suppressed by natural enemies. In autumn natural enemy activity is in general too low for effective control.

Cabbage seed weevil occurs in all oilseed rape fields. Direct damage of this pest is usually low, but indirect it may cause locally severe damage by probing holes in the seeds through which the **brassica pod midge** can lay her eggs.

The **brassica pod midge** occurs in all oilseed rape fields. It can locally become a severe pest in high cabbage seed weevil infestations, but mainly at the headlands.

Cabbage stem weevil occurs in all oilseed rape fields. An infestation is difficult to detect because there are no clear symptoms. Yield loss of 20% is possible if no control measures are taken. The threshold for control is 10 beetles per yellow water trap during a period of three days, until mid April, but this threshold is not very reliable.

United Kingdom
The major pest species in oilseed rape in the United Kingdom include flea beetles, among which the **cabbage stem flea beetle** (*Psylliodes chrysocephala*), and the **rape beetle** (*Meligethes aeneus*). The

peach-potato aphid (*Myzus persicae*) can be a damaging pest by transmitting the **turnip yellows virus**.
Other less important pests include the **cabbage gall weevil** (*Ceutorhynchus assimilis*), **rape stem weevil** (*Ceutorhynchus napi*), **rape winter stem weevil** (*Ceutorhynchus pictarsis*) and the **cabbage root fly** (*Delia radicum*).

The **cabbage stem flea beetle** can cause severe damage to oilseed rape in both larvae and adult form. The adults feed on the foliage, sometimes destroying the apex. A female can lay up to 1000 eggs, which hatch 35-70 days later. The larvae feed on the surviving plants, boring into petioles. They cause crop stunting, loss of vigour and destruction of the growing point (Nicholls, 2015). Control of the beetles starts as soon as infestation is detected (Delphy gids akkerbouw en veehouderij, 2016).

Rape beetle can cause up to 5-20% when not treated. Exceptionally yield losses of 70% yield losses are possible (Williams, 2010). In oilseed rape, adult and larvae feeding by **rape beetles** can lead to bud abortion and reduced pod set. This damage rarely results in reduced yields for winter crops but spring crops can be vulnerable as the susceptible green/yellow bud stage often coincides with beetle migration. The plant is only susceptible al long as the buds are closed. When the flowers begin to open, the beetles become a pollinator instead of a pest. The control thresholds depend on plant density. A low plant density (<30 plants/m^2) allows 25 beetles per plant, while a high plant density (>70 plants/m^2) only allows 7 beetles per plant. Monitoring should be done periodically throughout the susceptible green-yellow bud stage (AHDB 2013 info sheet 18).

Other flea beetles, such as the **turnip flea beetle** and **large striped flea beetle**, can cause damage when pest pressure is high. Feeding on the cotyledons, stems and young leaves by adult beetles causes most of the damage. No threshold has been established, so chemical control should be based on similar criteria as the cabbage stem flea beetle (Bayer expert guide). So control of the beetles starts as soon as infestation is detected

The **peach-potato aphid** is a vector for the turnip yellows virus. The aphids rarely cause direct feeding damage, but the virus can cause yield losses up to 30% (AHDB oilseed rape guide, 2015). The aphids migrate from their summer hosts to oilseed rape in late September to early October and can remain active during winter. They prefer relatively low-density populations, so migrate often, spreading the virus further (Bayer expert guide).

The **cabbage gall weevil** is widespread in the UK, but it rarely results in economic damage. The crop can compensate for pod losses up to 60%. Chemical control is advised during flowering if the threshold of 0,5/plant in Northern Britain or 1/plant in the rest of the country is exceeded (Cereals.ahdb).

The **brassica pod midge** lays eggs through **seed weevil** holes in developing pods. The larvae cause swelling and eventually the pod burst. Generally, damage is greatest on headlands, but it is not necessarily a great threat. Spring oilseed rape yields can be severely reduced (Cereals.ahdb).

Cabbage root fly is a potential pest of establishing rape in the UK but is generally only a problem in early-sown crops, particularly those that emerge in late August.

Cabbage stem weevil is frequently recorded in oilseed rape but only occasionally causing economic damage. Damage can be caused by feeding adults, as well as larvae.

Rape winter stem weevil adults lay their eggs on petioles close to the stem and larvae feed within the stems over winter. If severe, the crop can be stunted. There are no thresholds for this pest and it only appears to be a problem locally in certain parts of the country.

5.9 Olive

Spain
In olives there are four pest species controlled by neonicotinoids that can cause serious damage in Spain: **olive fruit fly** [la mosca del olivo] (*Bactrocera oleae*), **black scale** [caparreta negra] (*Saissetia oleae*), **olive kernel borer** [polilla del olivo] (*Prays oleae*) and the **Jasmin moth** [Glifodes/Polilla del Jazmín] (*Palpita unionalis/vitrealis*) (www. agrologica.es).

The **olive fruit fly** is one of the most challenging pests in olives. The pupae overwinter below the soil surface. The females lay up to 250 eggs during their life span, one egg per fruit. Its larvae tunnel through the fruits, which can cause fungal or bacterial infection. For table olives, the fruits lose their commercial value. For olives produced for oil, **olive fruit fly** damage causes the oil to taste poorly, due to the fungal or bacterial infection. Even without fungal or bacterial infection, a loss of 20% can be expected. Regular monitoring is important to take timely control measures to prevent a pest outbreak (Gil&Torres, 2014).

The **black scale** feeds on leaves, shoots and sometimes fruits, causing photosynthesis and plant vigour loss, resulting in lower yields. The young scales also produce honey-like substances, which may cause *Capnia* fungal infection. The species has one or two generations depending on weather conditions, pruning and pest control. The insect has a preference for cool and humid conditions. Treatment starts when one adult is found per 10 shoots or if 5% of shoots are affected (Gil&Torres, 2014).

Olive kernel borer is the pest that requires most attention in olive crop protection. The pest has three stages in its life cycle. Each stage causes different damage. The adults lay eggs in autumn, from which the filophague generation hatches. The larvae of this generation eat burrows in the leaves where it overwinters. The larvae of the final stage are so large that they also eat the exterior leave. After pupation, the filophague generation adults lay eggs in the flower buttons, from which the antophague generation hatches. The larvae of this generation feed on the antennas and stigmas of the developing flowers. After a month the larvae pupate into adults, which lay eggs on the fruits. The larvae of the third generation burrows into the fruits, feeding on the seed (Gil&Torres, 2014). The damage caused by the first generation is not relevant, except in young trees. The second generation reduces the number of flowers and thus the potential yield. The third generation is most damaging because it feeds directly on the fruits.

The **Jasmin moth** is a secondary pest, as it only affects young shoots and generally does not need control in producing orchards.

5.10 Potato

Germany / Netherlands / United Kingdom
In potatoes **colorado potato beetle** [Kolorado-Käfer; coloradokever] (*Leptinotarsa decemlineata*) and five aphid species may cause problems, including the **black bean aphid** [zwarte bonen, schwarze

Bohnenblattlaus luis] (*Aphis fabae*), **peach-potato aphid** [groene perzikbladluis, grüne Pfirsichblattlaus] (*Myzus persicae*), the **potato aphid** [aardappeltopluis, gestreifte Kartoffelblattlaus] (*Macrosiphum euphorbiae*), and the **buckthorn-potato aphid** [vuilboomluis, gemeine Kreuzdornblattlaus] (*Aphis nasturtii*) (wiki.groenkennisnet.nl).

The aphid pests that are tackled in Germany, the Netherlands and the United Kingdom don't differ. So they are treated in the same section. In the United Kingdom **green peach aphid** and **potato aphid** are most common and **colorado potato beetle** is not a pest in the UK.

In seed potatoes **aphids** may cause economic damage by transmitting **viruses** to the plant. Especially when the plant is in early development it is vulnerable for **viruses**. In consumption and starch potatoes virus transmission is not an issue, but in these crops aphids may cause damage by sucking from the phloem or deformation of the top leaves by the **potato aphid** or indirectly by **black fungi** that grow on the honeydew on the leaves.

Aphid control measures in consumption and starch potatoes are in general only necessary when there are on average more then 50 aphids on a mature full sized leave or 25 aphids in case of the much harder to control **buckthorn-potato aphid** (Veerman, 2003).

Colorado potato beetles may cause great damage to potato plants by the larvae and adults that eat from the leaves. Adult beetles overwinter in the soil and lay their eggs on the leaves in spring. In optimal conditions the beetle can have two generations a year. When no timely measures are taken **colorado potato beetles** may destroy a whole potato field leaving only the stem of the plant and its petiols. The optimal time for control is when the larvae appear on the leaves (Veerman, 2003).

5.11
Sugar beet

Netherlands, Germany, United Kingdom
The pests that are tackled in Germany, the Netherlands and the United Kingdom don't differ. So they are treated in the same section.

The main pest species in sugar beet include **flea beetles** [aardvlo, Rübenerdfloh] (*Chaetocnema* spp.), **pygmy mangold beetle** [bietenkevertje, Moosknopfkäfer] (*Atomaria linearis*), **beet leaf miner** [bietenvlieg, Rübenfliege] (DE: *Pegomya hyoscyami/Pegomya betae;* NL: *Pegomya betae*), **black bean aphid** [zwarte bonenluis, schwarze Bohnenblattlaus] (*Aphis fabae*) and the **green peach aphid** [groene perzikbladluis, grüne Pfirsichblattlaus] (*Myzus persicae*).

Other pests of less significance include **leather jackets** [emelten, Schnaken] (*Tipula* spp./*Nephrotoma* spp.), **wireworms** [ritnaalden, Schnellkäfer] (*Agriotes* spp.), **springtails** [springstaarten, Springschwänze] (*Sminthurus viridis / Onychiurus armatus*), **thrips** [trips, Fransenflügler] (*Thrips tabaci/T. angusticeps*), **snake millipede** [roodstip, Tüpfeltausendfuß] (*Blaniulus guttulatus*) and **garden centipede** [wortelduizendpoot, gewächshaus Zwergfüssler] (*Scutigerella immaculata*). **Trips** and **springtails** are not a pest in sugar beet for Germany.
Flea beetles eat from the cotyledons and the first true leaves. They predominantly occur on sandy soils and young peat soils (raised bog residues) and may suddenly affect young plants when weather is dry and windy.

Pygmy mangold beetle eat from the root and hypocotyl that may cause plants to die in the early development. At temperatures above 15 °C they may also cause damage to the leaves. They predominantly cause damage on clay or loess soils, especially in fields were beets were sown in the previous year or fields that border other beet fields.

Larvae of the **beet leaf miner** mine in the leaves. If no seed coating with neonicotinoids is used this pest can cause yield losses. Without seed coatings the threshold for control in the Netherlands is 4-20 eggs depending on the growth stage of the plant (2-6 leaves) (www.wiki.groenkennisnet.nl).

The main species of aphids that may cause damage are the **black bean aphid** and the **green peach aphid**. The first causes mainly feeding damage, while the second may also transmit **viruses**. Control of the **black bean aphid** in the Netherlands is profitable in May and June when 50% of the plants are occupied with more than 50 aphids. In July it is lucrative when more than 75% of the plants are occupied with more than 200 aphids. After July control of the black bean aphid is not profitable anymore because parasitic fungi and other natural enemies will control the aphid (website IRS).

In the Netherlands control of the **green peach aphid** is lucrative in May and the first half of June when there are found more than 2 aphids per 10 plants. From half June it is when there are more than 5 aphids per 10 plants and in the first two weeks of July when there are more than 10 aphids per 10 plants. After half July control of the green peach aphid is not profitable anymore. Then the costs are higher than the damage the aphids may cause (www.irs.nl).

Leather jackets live in the soil, but eat during the night from the leaves. The risk of damage is high when there are more then 100 larvae per square meter (Dutch standard). The larvae can be counted by dissolving several soil samples from the field of 10x10x cm^3 in a solution of water with salt. Currently, there are no effective measures to control **leather jackets**. Neonicotinoids applied in the seed pellet give some protection, but are not sufficient for control.

Wireworms eat from the roots, which may cause the plants to wilt and die. Neonicotinoids applied in the seed pellet provides protection when density of the pest is not too high. At high pest infestation neonicotinoids cannot prevent substantial damage because wireworms only die after they have eaten from plants. Wireworms infestation can best be avoided by controlling the adult beetles in the pre-crop.

Of the two **springtail** species especially *Onychiurus armatus*, which lives below ground, may cause damage to the seedling. This species predominantly occurs on moist heavy clay and on clay soil with high organic matter content.

Thrips are tiny insects that pierce the leaves of plants and may cause damage during a cold and dry spring. More damage can be expected on fields with peas, onion or linseed as pre-crop.

Snake millipede feeds on dead organic materials but can also feed on aboveground living plant tissue. Especially seedlings and young plants are vulnerable. This pest mainly occurs on heavy clay and loess soils.

Garden centipede uses existing holes and cavities in the soil and can live up to 150 cm deep. Sandy soils with little humus have little cavities and **garden centipede** usually does not occur on these soils. Apart from dead material and fungi they eat from living root tissue that can retard the plants development and makes the plant vulnerable to infections by bacteria or fungi.

6

Inventory of alternatives to neonicotinoids

6.1 Introduction

Integrated Pest Management (IPM) is an important way to control pests. Since 2009 IPM is a corner stone of the EU policy on pesticides and part of the Directive 2009/128/EG. Under this directive EU member states are obliged to stimulate integrated pest management. The directive defines integrated pest management as follows:

Definition Integrated Pest Management from Directive 2009/128/EG the sustainable use of pesticides:

'Integrated pest management' means careful consideration of all available plant protection methods and subsequent integration of appropriate measures that discourage the development of populations of harmful organisms and keep the use of plant protection products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimise risks to human health and the environment. 'Integrated pest management' emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.

The preferential sequence of integrated measures is:
- Prevention of pests
- Scouting
- Non-chemical control methods
- Chemical control methods
- Prevention of emission of pesticides

In the following section of this report this sequence will be followed, when discussing the alternatives for neonicotinoids.

When discussing the availability of alternatives, development of resistance is an important issue, an issue that is also taken into consideration by EPPO, the European and Mediterrenean Plant Protection Organisation. EPPO warns against using too few types of plant protection products (PPPs). See the EPPO standard in the box below.

From EPPO Standard PP 1/213 Resistance risk analysis (EPPO, 2017a):

Care should be taken to avoid dependence on too few product types in IPM programmes, as this can ultimately accelerate resistance development and result in use of non-IPM-compatible products.

In the EPPO guidance (PP 1/271) for comparative assessment it is recommended that agronomic risks should be taken into consideration when considering substitution. Furthermore, it is recommended that two to four modes of action or resistance groups must be available, when substituting one active ingredient by another to have a sustainable resistance management strategy (see box below). In the European Union, comparative assessment is required for authorization of a plant protection product (PPP), which contains an active substance that has been identified as a candidate for substitution. In the authorization process, comparison with safer alternatives may be considered when a safer and effective alternative is available.

From EPPO Standard PP 1/271 Guidance on comparative assessment (EPPO, 2017b)

Based on expert judgment it is recommended that in a low resistance risk situation a sustainable resistance management strategy includes at least two modes of action. However, in case there is evidence of a medium risk of resistance to one or more of these PPPs or a medium risk of resistance in the target organism, at least three modes of action are recommended. In case there is evidence of a high risk of resistance to one or more of these PPPs or a high risk of resistance in the target organism, at least four modes of action are recommended (Rotteveel et al., 2011). Current resistance situation should be considered when evaluating the required number of mode of actions.
In considering the effect of substitution for a resistance management strategy other factors of inherent risks (e.g.target site resistance versus metabolic resistance, cross resistance) or agronomic risks should be taken into consideration (see EPPO Standard PP 1/213).

The Dutch authorization authority Ctgb considers the availability of five resistance groups necessary, when carrying out a comparative assessment (personal comment J. Edens, NVWA, 2017). However Milieukeur growers in the Netherlands are able to grow for example potatoes without neonicotinoids and with fewer alternatives than are recommend by EPPO or Ctgb. No resistance has developed, probably thanks to careful pest management, for example by minimal use of insecticide sprayings using thresholds before spraying (personal comment P. Leendertse, CLM, 2017).

The non-chemical alternatives that we present below include agronomic measures, resistant varieties, changing location of field, trapping, natural enemies, and green crop protection products that are based on natural substances and do not harm natural enemies or pollinators. The chemical alternatives with low impact include crop protection products that have a 'green' score on the Environmental Yardstick for Pesticides (Reus & Leendertse 2000, www.milieumeetlat.nl) and are not harmful to natural enemies or pollinators. A green score means that the expected toxicity to soil and water organisms are below the threshold set for these organisms and that the expected concentration in the ground water is below the threshold set for drinking water in the Netherlands and Europe. A green score also means that the active substance is not harmful to pollinators and natural enemies. The chemical alternative with high impact include products that score 'orange' or 'red' on the Environmental Yardstick for Pesticides (are above the threshold) or that are harmful to natural enemies or pollinators.

6.2
Several generally occurring pests treated by neonicotinoids

Aphids and **wireworm** are among the pest species for which we discuss alternatives and occur in all or several crops. The alternatives for control by neonicotinoids of these pests are not different between crops and are therefore discussed here in general for all products. At each section of the particular crop reference will be made to the information provided here. Information on alternative pest control strategies was obtained from van Schooten *et al.* (2015).

Neonicotinoids are not specific and therefore also often harm natural enemies of pest species. **Aphids** are among the pests that can be suppressed by natural enemies below the economic threshold for most crops. Among the natural enemies of **aphids** are several species of ladybird, true bugs, neuropterans, hoverflies, gall midges, parasitic wasps, predatory beetles, ground beetles and spiders. Parasitic wasps can detect aphids at low densities, while ladybirds are attracted by high aphid densities.

Parasitic wasp and other flying predators also need nectar and pollen from flowers as food source. Apart from alternative food sources natural enemies need protective environment for hibernation. These resources are naturally available in a landscape that is characterized by natural elements. In landscapes in which these elements are lacking, due to e.g. large fields, effectiveness of natural enemies for pest control is often poor. In such landscapes the effectiveness must be accomplished by a region wide adoption of measure to enhance biodiversity.

In general no pesticide application is required when the ratio of natural enemies to aphid colonies is larger or equal to 1:10 (Visser *et al.,* 2014). In case **aphids** need to be controlled, aphid specific products, such as flonicamid or pymetrozine, should replace neonicotinoids or other broad working insecticides to enable natural enemies to survive pesticide applications. Flonicamid and pymetrozine are relatively safe products for pollinators and have little to no detrimental effect on the environment (www.milieumeetlat.nl). Pesticide application can be reduced if scouting of the crop for presence of aphids precedes it. In case **aphids** are absent or below the economic threshold level no application is required.

Wireworms are difficult to control once the field is infested. At the Po Valley in Italy farmers use decision support systems based on monitoring adult beetles to control the larvae of **wireworms**. Locations were **wireworm** densities are expected to exceed the economic damage threshold are limited and only on those locations farmers use chemical control. When risk of **wireworm** infestation is low farmers are advised to rely on their IPM strategies and not to use chemical control. For situations that IPM failed to prevent damage from **wireworm** farmers have organised an insurance fund to compensate for pest damage (Ferrari et al. 2015). For the countries that we cover in this study no such insurance fund or monitoring system for **wireworm** is in place yet. Alternatively, to test for presence of larvae on twenty places along the field edge and on the parcel half a potato should be buried at a depth of about 5 cm shortly before planting (Veerman 2003). When after ten days, upon checking the buried potatoes, larvae are present control measures can be taken or another field, free of **wireworm** should be chosen for planting. Drying the soil by cultivation in late summer may help to reduce the pest by killing the eggs, especially under dry conditions in cereal stubble. Leguminous crops are less sensitive to **wireworm** and farmers that have included lupine or peas in their crop rotation have fewer problems (PPO, 2005). A chemical alternative for control by neonicotinoids is to control adult beetles in the preceding crop using a pheromone trap (KniptorKit) to determine the optimal timing for spraying with pyrethrins (Spruzit) (DLV Plant, 2013). Pyrethrins, however, have no authorization yet for professional use in the Netherlands. In Germany and United Kingdom pyrethrins are authorized for professional use.

6.3 Apple

For all pests affecting apple, cultural control can reduce or prevent infestation. Natural enemies, such as parasitic wasps and earwigs, can be encouraged by providing shelter and food sources, and by avoiding the use of broad-spectrum insecticides. By providing alternative food sources such as flowering plants that provide pollen and allowing less harmful aphid species like the **apple grass aphid** to remain, populations of natural enemies are fostered. To promote earwigs and other natural enemies, artificial refuges like bottles and rolls of cardboard can be provided. These measures are important when small numbers of pests can be tolerated without much economical damage. If conditions are right, the natural enemies aid in keeping pest pressure low. However, if the economical damage threshold is low, as for example for **rosy apple aphids**, natural enemies may not keep populations low enough.

Germany
Pest species controlled by neonicotinoids in Germany include **rosy aphid**, **green apple aphid**, **green citrus aphid**, **apple sawfly**, **apple fruit weevil**, **apple blossom weevil**, **codling moth** and **leaf miners** (Table 6.1). Information on alternative pest control strategies was obtained from Hees *et al.* (2016) and the Apple Best Practice Guide (apples.ahdb.org.uk).

Table 6.1 Overview of neonicotinoids currently authorized (2016) for pest control in apple in Germany and the non-chemical and chemical alternatives (authorization imidacloprid only after flowering).

Apple – Germany			
Neonicotinoids	**Non-chemical alternative**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Rosy apple aphid			
- thiacloprid (Calypso) - imidacloprid (e.g. Confidor) - acetamiprid (e.g. Mospilan)	- azadirachtin (Neem) - rape seed oil (Micula) - soap (Neudosan Neu)	- flonicamid (Teppeki)	- pirimicarb (Pirimor)
Green apple aphid / Green citrus aphid			
- imidacloprid (Confidor)		- flonicamid (Teppeki)	- pirimicarb (Pirimor)
Apple sawfly /Apple fruit weevil			
- acetamiprid (Mospilan) - thiacloprid (Calypso)			
Apple blossom weevil			
- thiacloprid (Calypso)			- pyrethroid (Spruzit Neu)[1]
Codling moth			
- thiacloprid (Calypso)	- Granulosevirus-Präparate		- chloranthraniliprole (Coragen) - indoxacarb (Steward)
Leaf miners			
- thiacloprid (Calypso) - imidacloprid (Confidor)			- chloranthraniliprole (Coragen) - indoxacarb (Steward)

[1] Not sufficiently effective

Potassium salts of fatty acids (Neudosan), azadirachtin (Neematazal) and rape seed oil (Micula) are non-chemical alternatives for control of **rosy apple aphid**. In Sweden the extract of the plant *Quassia amara* is used in organic orchards to keep populations from increasing (Sjöberg *et al.*, 2015), but this product has no authorization in the Germany. Chemical alternatives with a low environmental impact include flonicamid (Teppeki). However, when at the same time the **apple blossom weevil** needs to be controlled, the official advise is to use Calypso 480 SC (thiacloprid), because this is the only effective product against the **apple blossom weevil**. The pyrethroid Spruzit Neu is also allowed against the **apple blossom weevil**, but cannot effectively control this pest.

The **green apple aphid** and the **green citrus aphid** are both controlled by imidacloprid (Conifor). Flonicamid (Teppeki) and pirimicarb (Pirimor) are the only alternative product of which flonicamid has less environmental impact. Flonicamid and pirimicarb are less effective in controlling the **green citrus aphid** than imidacloprid**.**

The **apple blossom weevil** is controlled before flowering by thiacloprid (Calypso). The alternative product Spruzit Neu (pyrethroid) can only reduce the attack, but is it not sufficiently effective. Natural enemies also do not provide an adequate alternative for this pest in Germany.

For the **apple saw fly** and the **apple fruit weevil** are controlled by neonicotinoids at the end of flowering. No alternative products are available to control these pests. In organic orchards a special provision is given for control of **apple saw fly** by Quassia plant extract (*Quassia amara*).

For control of the **codling moth** three alternative products are available of which Coragen (chloranthraniliprole) is the most effective. The other products include indoxacarb (Steward) of which re-admission is questionable and Granulosevirus-Präparate. Steward and Granulosevirus-Präparate are less effective than Calypso or Coragen. Coragen is not harmful to natural enemies and bees, but may only be applied twice a year. In practice Coragen is used first in intervals of three weeks followed by one application of Calypso to control the first generation moths.

Leaf miners are controlled at the same time when Calypso is applied against the **codling moth** in summer. Leaf miners are a less important pest in the last decade, but there is always a risk that they occur in high numbers.

CONCLUSION
- The **rosy apple aphid**, **green apple aphid**, **green citrus aphid** and **codling moth** can be effectively controlled without neonicotinoids.
- For the other pests, **apple saw fly**, **apple fruit weevil** and **apple blossom weevil,** effective control without neonicotinoids is difficult due to the lack of effective alternatives.

Netherlands
In the Netherlands neonicotinoids are allowed for control of the following pest species in apple: **apple-grass aphid**, **green apple aphid**, **rosy apple aphid**, **woolly apple aphid**, **apple sawfly**, **common green capsid** and **apple blossom weevil** (Table 6.2). Information on alternative pest control strategies was obtained from Hees *et al.* (2016) and the Apple Best Practice Guide (apples.ahdb.org.uk).

Table 6.2 Overview of neonicotinoids currently authorized (2016) for pest control in apple in the Netherlands and the non-chemical and chemical alternatives (authorization imidacloprid only after flowering).

Apple – Netherlands			
Neonicotinoids	**Non-chemical alternatives**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Rosy apple aphid			
- imidacloprid (Admire) - thiacloprid (Calypso) - acetamiprid (Gazelle)	- potassium salts of fatty acids (Savona) - *Ephedus persicae* - Earwig - azadirachtin (Neemazal)	- flonicamid (Teppeki)	- pirimicarb (Pirimor) - spirotetramat (Movento)
Apple-grass aphid / Green apple aphid			
- imidacloprid (Admire) - thiacloprid (Calypso) - acetamiprid (Gazelle)	- potassium salts of fatty acids (Savona)	- flonicamid (Teppeki)	- pirimicarb (Pirimor) - spirotetramat (Movento)
Woolly apple aphid			
- acetamiprid (Gazelle)	- potassium salts of fatty acids (Savona) - *Aphelinus mali*	- flonicamid (Teppeki)	- pirimicarb (Pirimor) - mineral oil - spirotetramat (Movento)
Apple sawfly			
- imidacloprid (Admire) - thiacloprid (Calypso) - acetamiprid (Gazelle)	- *Lathrolestes ensator* - *Aptesis nigrocincta*		
Apple blossom weevil			
- thiacloprid (Calypso) - acetamiprid (Gazelle)	*Scambus pomorum* *Syrrhizius delusorius*		- indoxacarb (Steward) - deltamethrin (Decis)
Common green capsid			
- imidacloprid (Admire) - thiacloprid (Calypso) - acetamiprid (Gazelle)	Culture control: keeping orchard clean of weeds and rootstock suckers, foster natural enemies, insect nests	- flonicamid (Teppeki) - VBC Ultra - NeemAzal-T/S	- indoxacarb (Steward) - Mineral oil

Rosy apple aphid can be suppressed by natural enemies such as earwigs and lady beetles but these predators, currently, do not provide effective control in the Netherlands due to the very low economic damage threshold (expert Matty Polfliet). In Sweden the extract of the plant *Quassia amara* is used in organic orchards to keep populations from increasing (Sjöberg *et al.*, 2015), but this product has no authorization in the Netherlands. Potassium salts of fatty acids (Savona) and azadirachtin (Neematazal) are other non-chemical alternatives for control of **rosy apple aphid**. Chemical alternatives with a low environmental impact include flonicamid (Teppeki). These products need to be applied after an early harvest of apples to suppress the population for next year. If the population is kept low, no control is necessary in the following growing season (expert

Mattie Polfliet). This strategy is used in Elstar apples, as it is an early cultivar. Chemical alternatives that have a high environmental impact include pirimicarb (Pirimor) and spirotetramat (Movento).

Apple-grass aphid and **green apple aphid** can be controlled by potassium salts of fatty acids (Savona). A chemical alternative that has low environmental impact and is effective is flonicamid (Teppeki). Chemical alternatives that have a high environmental impact include pirimicarb (Pirimor) and spirotetramat (Movento). Pirimor, is not allowed for 90% of the orchards (due to strong restrictions in application methods to reduce emission to surface water) and also has limited effect against the apple-grass aphid. Pirimor and Movento are not allowed before the 1st of May, which is too late to control the **apple-grass aphid**. Spruzit was allowed until 2014.

Woolly apple aphids are currently difficult to control. Also acetamiprid (Gazelle) is not sufficiently effective and may even promote the pest because it suppresses the parasitic wasp *Aphelinus mali* and earwigs. *Aphelinus mali* and earwigs are the most successful in controlling the **woolly apple aphid**. Potassium salts of fatty acids (Savona) are another non-chemical alternative that suppress **woolly apple aphid.** Chemical alternative (Table 6.2) flonicamid (Teppeki) is not sufficiently effective in controlling the aphid. The use of pirimor (Pirimor) is very restricted. Spirotetramat (Movento) in combination with mineral oil can control the hibernating aphids before the buds open and only after mild winters. If the winter is cold the aphids hibernate next to the roots, where they are protected from the pesticide.

Non-chemical alternatives for control of **apple sawfly** include parasitic wasps *Lathrolestes ensator* and *Aptesis nigrocincta.* The latter two are not sufficiently effective. In Sweden and Germany Quassia extract (*Q. amara*) is used in organic orchards to control **apple sawfly** (Psota *et al.*, 2010). A recent experiment demonstrating effectiveness of Quassia extract against **apple sawfly** is presented in Sjöberg *et al.* (2015). Quassia extract is currently not allowed in the Netherlands.

Non-chemical measures available for control of the **apple blossom weevil** include parasitic wasps *Scambus pomorum* and *Syrrhizius delusorius.* None of these natural enemies is able to control the population below the economic threshold level. Chemical alternatives to the effective neonicotinoids for control **apple blossom weevil** include deltamethrin (Decis) and indoxacarb (Steward), which have a high impact. Low-impact plant extracts, such as Quassia and Derris, are currently not authorised in the Netherlands, although good results were obtained in other countries. In organic apple production a special authorization was provided to control this pest with rapeseed oil and pyrethrinen (Raptol) (G. Brouwer, Delphy).

Pest infestation by **common green capsid** can be reduced if the area surrounding the orchard does not contain potato fields. Other non-chemical measures include keeping the orchard clean of weeds and rootstock suckers and to foster natural enemies by proving nesting sites. None of the chemical alternatives listed in Table 6.2 have much effect or its effect is decreasing, in case of mineral oil. Also neonicotinoids cannot sufficiently control **common green capsid** but only suppress the pest population. Only NeemAzal-T/S has a moderate control efficacy.

CONCLUSION

- **Aphids** and **common green capsid** can be controlled without neonicotenoids.
- For control of the **apple sawfly** and the **apple blossom weevil** thiacloprid is needed to correct in the case the threshold level is exceeded.

6.4 Cereals

Germany

In Germany **grain aphids** and **cereal leaf beetle** are the only two pests in cereals currently controlled by neonicotinoids. Information on alternative pest control strategies was obtained from Luske et al. (2014) and AHDB (2016).

Table 6.3 Overview of neonicotinoids currently authorized (2016) for pest control in cereals in Germany and the non-chemical and chemical alternatives.

Cereal – Germany			
Neonicotinoids	**Non-chemical alternative**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Grain aphids			
- thiacloprid (Biscaya)		- flonicamid (Teppeki)	- pyrethroids# - pirimicarb - dimethoate
Cereal leaf beetle			
- thiacloprid (Biscaya)	- crop rotation - resistant crop varieties - saving natural enemies by applying flonicamid (Teppeki) against aphids - providing habitat for natural enemies - using threshold levels and scout regularly		- pyrethroids#

Pest has developed (widespread) resistance against active ingredient.

Because the damage caused by the **cereal leaf beetle** is not substantial and because the population of beetles does not grow exponentially within a season, there is a high potential for integrated crop protection methods to control this pest. These methods include:

- A divers crop rotation will reduces the risk for damage caused by the **cereal leaf beetle** because during years without cereals the population size decreases.
- **Cereal leaf beetles** do not like to lay eggs on leafs with long and dense hairs. Choosing a crop variety with hairy leaves will help to reduce infestation levels.
- The eggs and cocoons of the **cereal leaf beetle** are being parasitized by a wide variety of common natural enemies in cereal fields. Several of these natural enemies are also important for natural control of **grain aphids**. Choosing selective products against aphids (e.g. Teppeki) will save the natural enemy population.
- Providing habitat for natural enemies by sowing flowers margins will increase the population of natural enemies.
- Observing regularly for **cereal leaf beetle** larvae and **grain aphids** and only taking control measures when infestation levels are above the damage threshold level. With a no-tolerance attitude there is no change for survival of natural enemies.

Providing habitat for natural enemies is also beneficial for control of **grain aphids**, however adding natural habitat is only effective in landscapes that contain some reservoir of natural enemies.

A region wide adoption of an action plan to increase natural habitat might be necessary before measures such as sowing flower margins are yielding to pest control. Adding natural habitat should be accompanied by using selective products for control of **grain aphids** so that the population of natural enemies can re-establish. Instead of neonicotinoids a grower can chose between products based on pyrethroids, pirimicarb, flonicamid or dimethoate. Of these products only flonicamid (Teppeki) is not harmful for bees and natural enemies and has a low environmental impact (CLM Environmental Yardstick for pesticides 2016). Using a product from one chemical group is not recommended because of the risk of resistance. Recently, resistance has been observed in the **grain aphid** (*Sitobion avenae*) against pyrethroids.

CONCLUSION

- Both pest species **cereal leaf beetle** and **grain aphids** in cereals in Germany can be controlled by non-chemical or chemical alternatives.

United Kingdom

In the United Kingdom clothianidin seeds treatment are used to control **grain aphids** (as **virus vector**) and **wireworm**. Thiacloprid is used against **orange wheat blossom midge**. Information on alternative pest control strategies was obtained from AHDB Ecyclopaedia (2014) and AHDB (2016).

Table 6.4 Overview of neonicotinoids currently authorized (2016) for pest control in cereals in the United Kingdom and the non-chemical and chemical alternatives (authorization clothianidine for winter cereals only).

Cereal – United Kingdom			
Neonicotinoids	**Non-chemical alternative**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Grain aphids			
- clothianidin (e.g. Deter)		- flonicamid (Teppeki)	- pyrethroids[#] - dimethoate
Orange wheat blossom midge			
- thiacloprid (Biscaya)			- pyrethroids
Wireworm			
- clothianidin (e.g. Deter)	- avoid grass or cereal as pre-crop - soil cultivation to dry-out soil		- tefluthrin (Austral Plus) - cypermethrin (Signal) - pyrethrins (Spruzit)

[#] Pest has developed (widespread) resistance against active ingredient.

For all these pest species except for **bird-cherry aphid** as **virus vector** non-chemical alternatives are available. Flower margins are effective to control aphids in summer if farmer or agronomist properly monitors populations. See for more details 6.1. A chemical alternative with low environmental impact includes flonicamid (Teppeki). As a third option a grower can choose for pyrethroids, pirimicarb or dimethoate (Table 6.4.). However, resistance to pyrethroids in **grain**

aphid (*Sitobion avenae*), have been observed and pirimicarb will loose its authorization for use in cereals.

For control of the **orange wheat blossom midge** a grower can chose for a resistant variety, because many wheat varieties have resistance to this pest. Soil sampling for egg and cocoon numbers can be used to help predict risk where it has been a pest previously. An alternative chemical control option includes pyrethroids (Table 6.4).

For non-chemical control of **wireworm** see section 6.2. The chemical alternative for the United Kingdom is to control the adult beetles in the pre-crop with pyrethrins (Spruzit) in combination with a pheromone trap for optimal timing. Pyrethrins are also harmful for bees and natural enemies and cannot control the **wireworm** itself. Also the other chemical control options have high environmental impact (Table 6.4).

CONCLUSION
- **Orange wheat blossom midge** and **wireworm** can be controlled by chemical alternatives with environmental impact.
- **Grain aphids** as **virus vector** is difficult to control without the neonicotinoid clothianidin (Deter) because of pyrethroid resistance in the aphids.

6.5
Citrus

Spain
Pests that are controlled by neonicotinoids in citrus include **mediterranean fruit fly**, **woolly whitefly**, **citrus whitefly**, **cotton aphid**, **green citrus aphid** and **citrus leaf miner**. Information on alternative pest control strategies was obtained from Gil and Climent (2014), the website of Agrologica (www.agrologica.es), the website of the ministry of agriculture, fishery and environment of Spain (www.mapama.gob.es) and the website of the ministry of agriculture of the Dominican Republic (www.agricultura.gob.do).

Table 6.5 Overview of neonicotinoids currently authorized (2016) for pest control in citrus in Spain and the non-chemical and chemical alternatives (authorization imidacloprid only after flowering).

Citrus - Spain			
Neonicotinoids	**Non-chemical alternatives**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Mediterranean fruit fly			
- imidacloprid (Gaucho WS)	- azadiractin (Neem) - Sterile males - Cultural: clean away infected fruit and other host trees - spinosad	-[aceite amonico] (traps – biolure) - lufenuron [traps] (Adress) - deltamithrin [traps] (e.g. Decis)	lambda-cyhalothrin (e.g. Karate Zeon) - deltamethrin [spray] (e.g. Decis) - phosmet (Phosdan) - etofenprox (Shark)
Woolly whitefly			
- imidacloprid (Gaucho WS) - acetamiprid (Gazelle)	- Parasitoids and predators when no other chemical control	- spirotetramat (Movento)	- mineral oil - deltamethrin [spray] (e.g. Decis)

	is applied - pruning		
Citrus whitefly			
- acetamiprid (Mospilan) - imidacloprid (Confidor 200)	- Parasitoids and predators - Sticky traps - Aeration - Removal of excess plant material - Fly traps - azadiractin (Neem) - Soap (Neudosan)		- deltamethrin [spray] (e.g. Decis)
Cotton aphid/ green citrus aphid			
- acetamiprid (Gazel Plus SG) - imidacloprid (Confidor 200) - thiamethoxam (Memory)	- Parasitoids, predators and fungi - Sticky traps to catch adults and monitor populations - azadiractin (Neem) - potassium salts (Jabon potassico)	- spirotetramat (Movento)	- alpha-cypermethrin (e.g. Fastac ME) - pirimicarb (Pirimor) - etofenprox (Shark) - deltamethrin [spray] (e.g. Decis) - Mineral oil
Citrus leaf miner			
- acetamiprid (Gazelle) -imidacloprid (Gaucho WS) -thiamethoxam (Actare)	- Protective nets - *Bacillus thuringiensis* - azadiractin (Neem) - *Citrostichus phyllocnistoides* - abamectin (Vertimec Gold)		- chlorantraniliprole (Coragen) - diflubenzuron (Dimilin-25)

Natural enemies can effectively suppress all pests that are controlled by neonicotinoids in citrus, except for **Mediterranean fruit fly**, for which natural enemies currently are not sufficient for pest control. Pest levels can be limited by cultural measures such as clearing away affected fruits and removal of other host tress (figs and loquat) on the perimeter of the orchard. Also liberation of large numbers of sterile males can be used to reduce the pest pressure. The sterile males compete with fertile males, reducing the number of offspring. For optimal effectiveness, one sterile male per m^2 or ten sterile males per fertile male are used. Food or pheromone traps are effective, especially when combined with a chemical pesticide such as deltamethrin or lufenuron. Both active substances are harmful to pollinators and natural enemies, but when used in combination with traps these pesticides are not harmful for insects other than the pest. Alternatively, chemical control is possible (see Table 6.5) with spraying application, but all these products have a high environmental impact or are harmful to pollinators and natural enemies, except for azadiractin and spinosad, which are plant extracts used in organic orchards.

Woolly whitefly rarely causes a problem because it can be effectively suppressed by the parasitoid *Cales noacki* when no chemical control is applied on the orchard. When chemical control is applied against other pests, the parasitoid may not be able to control **woolly whitefly** and additional control may be necessary for this pest. In this case acetamiprid can be replaced by spirotetramat, which also has a relatively low environmental impact. Also high impact products deltamithrin can be used. Chemical control of **woolly whitefly**, however, is difficult because the secreted wax from the insect combined with honeydew causes a coat that is impermeable to insecticides. Mineral oil is more effective, as it forms an asphyxiating coat around the wax and whitefly.

Citrus whitefly is generally controlled by the parasitoid *Encarsia strenua* and by generalist predators, but when non-specific chemical pesticides are applied, these natural enemies are killed too. Aeration of the orchard and removal of excess plant material help in the control of pest populations. In addition flytraps with a chemical pesticide and sticky traps can also be used to monitor and suppress the pest. Deltamethrin is a chemical alternative, but has high impact on bees. Azadiractin and potassium soaps are therefor more suitable alternatives and do have a good effectiveness against the pest.

A large number of predators, funguses and parasitoids can reduce **cotton aphid** and **green citrus aphid**. In tangerines, which are susceptible to citrus Tristeza virus that is transmitted by aphids, natural enemies may not be sufficiently effective. Non-chemical alternatives to control **aphids** include azadiractin (Neem) and potassium salts (Jabon potassico), which are quite effective. Additionally, a large number of high-impact chemical products are available (Table 6.5).

In producing orchards no treatments are necessary against the **citrus leaf miner** due to the effectiveness of the parasitoid *Citrostichus phyllocnistoides*. In organic orchards with young shoots the non-chemical product azadiractin (Neem) is available. In nurseries protective nets are recommended to keep the miner out. When chemical treatments are necessary abamectine, clorantranipirol and diflubenzuron are available. All these products are harmful for pollinators and natural enemies.

CONCLUSION
- For **citrus whitefly** and **aphids** several effective low-impact alternatives to neonicotinoids are available.
- **Woolly whitefly** and **citrus leaf miner** can be controlled by natural enemies in case no broad-working pesticides are used. When broad-working insecticides are used chemical control is also necessary for these pests. In that case **woolly whitefly** can be controlled by a chemical alternative with low environmental impact and **citrus leaf miner** by chemical alternatives with high environmental impact.
- **The Mediterranean fruit fly** is difficult to control by non-chemical alternatives. The use of high-impact chemical products such as deltamithrin and lufenuron in traps is a relatively environmental-friendly alternative to neonicotinoids.

6.6
Leafy salads

Spain
Pest species controlled with neonicotinoids in leafy salads in include **aphids**, **whitefly** and **caterpillar**. Information on alternative pest control strategies was obtained from Sanchez (2014), the website of the ministry of agriculture, fishery and environment of Spain (www.mapama.gob.es) and the website of Agrologica (www.agrologica.es).

Table 6.6 Overview of neonicotinoids currently authorized (2016) for pest control in leafy salads in Spain and the non-chemical and chemical alternatives.

Leafy salads: lettuce (L) and spinach (S)			
Neonicotinoids	**Non-chemical alternatives**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Aphids			
-acetamiprid (Gazelle) (L/S) - imidacloprid (Confidor energy) (L/S) -thiamethoxam (cruiser) (L) spray and seed treatment	-azardiractin (Neem) (L/S) -sticky traps in different colours -trap crops (combined with natural enemies)		-alpha cypermethrin (Fastac) (L) -cypermetrin (Sherpa) (L/S -deltamethrin (Confidor) (L/S) -lambda cyhalhotrin (Axiendo) (L)
Whitefly			
-acetamiprid (Gazelle) (S) - imidacloprid (Confidor 200) (L)	-Several predators, parasitoids and fungi -azardiractin (Neem)		-alpha cypermethrin (Fastac) (L) -lambda cyhalothrin (Axiendo) (L)
Caterpillar			
-imidacloprid (Gaucho WS) (L)	-*Bacillus thuringiensis* (L) -Mass pheromone trapping (10/ha) (L) -azardiractin (Neem)	-tebufenozide (Mimic 2 F) (L)	-alpha cypermethrin (Fastac) (L) -cypermethrin (Sherpa) (L/S -deltamethrin (Confidor) (L/S) -lambda cyhalothrin (Axiendo) (S) -indoxacarb (Steward) (L)

Although there are a large number of natural enemies against **aphids**, they are not able to successfully control the populations. Consumers don't want to find any **aphid**, or other insects, on the product, so even a low threshold is not tolerated. A combination of coloured sticky traps and trap crops on the border of the fields can help in controlling pest levels, but some form of chemical treatment is necessary. The only non-chemical alternative is the plant extract azardiractin, which is effective. The other chemical alternatives to neonicotinoids are of high impact to bees: alpha cipermetrin, cipermethrin, deltamethrin and lambda-cihalothrin.

Several parasitoids, predators and fungi are capable of controlling **whitefly** populations, but due to the zero-tolerance level for insects on the final product, these are not sufficient for effective control. As for aphids, the only non-chemical alternative is the plant extract azardiractin, which is an effective measure. However, even with a complex action mechanism, a single product leads to resistant populations. The other chemical alternatives to neonicotinoids are of high impact to bees: alpha cipermethrin and lambda-cihalothrin.

For the control of **caterpillars** mass trapping with pheromones to attract and kill male Lepidoptera can be used. Also sexual confusion can be used to avoid **caterpillars** in the crop. In lettuce *Bacillus thuringiensis* is a non-chemical alternative to control **caterpillars**. Tebufenicide is a chemical alternative with low impact, but it is not allowed in spinach. The other available alternatives to neonicotinoids are of high impact: alpha-cipermethrin, cipermethrin, deltamethrin, lambda-cihalothrin and indoxacarb.

CONCLUSION

- **Caterpillars** can be controlled in lettuce without the use of neonicotinoids by Bacillus, pheromone trapping and sexual confusion.
- For spinach, it is possible to control **caterpillars** without neonicotenoids, but mainly by using other pesticides that also pose a risk to bees.
- **Aphids** and **whitefly** are difficult to control without chemicals because of a zero-tolerance level for any insect, natural enemies included. Non-chemical measures such as natural enemies, combined with a border of trap crops, or sticky traps reduce populations of these pest but cannot guarantee that the crop is free of any insect. The non-chemical product azardiractin is effective against **aphids**, **whitefly** and **caterpillars**, but is not a long-term solution due to resistances. Other chemical alternatives are available but have equal or higher impact on bees and natural enemies.

6.7 Maize

Netherlands, United Kingdom

In the Netherlands thiacloprid is used as seed coating for control of the **frit fly** and in both the Netherlands and the United Kingdom thiacloprid is used for control of **wireworm**. Information on alternative pest control strategies was obtained from van Schooten et al. (2015).

Table 6.7 Overview of neonicotinoids currently authorized (2016) for pest control in maize in the Netherlands and the non-chemical and chemical alternatives.

Maize – Netherlands			
Neonicotinoids	**Non-chemical alternative**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Fritfly			
- thiacloprid (Sonido)			- tefluthrin (Force 20) - methiocarb (Mesurol FS)
Wireworm			
- thiacloprid (Sonido)	- avoid grass or cereal as pre-crop - soil cultivation to dry-out soil - no use of seed coating in low risk areas (and insurance in case of damage)		- methiocarb (Mesurol FS)*

* Not sufficiently effective

Table 6.8 Overview of neonicotinoids currently authorized (2016) for pest control in maize in the United Kingdom and the non-chemical and chemical alternatives.

Maize – United Kingdom			
Neonicotinoids	**Non-chemical alternative**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Wireworm			
- thiacloprid (Sonido)	- avoid grass or cereal as pre-crop - soil cultivation to dry-out soil - no use of seed coating in low risk areas (and insurance in case of damage)		- methiocarb (Mesurol FS)* - pyrethrins (Spruzit)

* Not sufficiently effective

For control of **frit fly**, no non-chemical alternatives are currently available. The chemical alternatives include tefluthrin (Force 20) and methiocarb (Mesurol FS), both products, however, are also harmful to bees (CLM Environmental yardstick for pesticides 2016). In the United Kingdom methiocarb (Mesurol) seed dressing is the only product available for control of **frit fly**.

For non-chemical control of **wireworm** see section 6.2. The chemical alternative for the United Kingdom is to control the adult beetles in the pre-crop with pyrethrins (Spruzit) in combination with a pheromone trap for optimal timing. Pyrethrins are also harmful for bees and natural enemies and cannot control the **wireworm** itself. Alternatively, methiocarb (Mesurol FS) can be used but this product is not very effective.

Another approach to deal with the situation where no neonicotinoids can be used is that farmers make use of a decision support system for pest control and have an insurance in case of damage in low risk areas. This approch is currently developed in Italy (Agenzia Veneta per l'Innovazione nel Settore Primario, in prep).

CONCLUSION THE NETHERLANDS AND UNITED KINGDOM

- The pests in maize can be controlled without neonicotenoids, but mainly by using other pesticides that also pose a risk to bees.

6.8
Melon

Spain
Pest species that are controlled by neonicotinoids in melon include **two-spotted spider mite**, **glasshouse whitefly**, **tobacco whitefly**, **cotton aphid** and **peach-potato aphid**. Information on alternative pest control strategies was obtained from the website of Agrologica (www.agrologica.es), the website of the ministry of agriculture, fishery and environment of Spain (www.mapama.gob.es) and Infoagro (www.infoagro.com).

Table 6.9 Overview of neonicotinoids currently authorized (2016) for pest control in melon in Spain and the non-chemical and chemical alternatives.

Melon - Spain			
Neonicotinoids	**Non-chemical alternatives**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Two-spotted spider mite			
Acetamiprid	- *Phytoseiulus persimilis* - *Amblyseius californicus* - Clear away weeds and plant debris	- Spirodiclofen (Envidor) - Spiromesifen (Oberon) - Tebufenpyrad (Masai)	- Mineral oil - Abamectin (Vertimec Gold) - Etoxazol (Borneo)
Glasshouse whitefly, tobacco whitefly			
- acetamiprid (Gazel Plus SG) - thiacloprid (Calypso) - thiamethoxam (Memory)	- Clear away plant debris - Nets in greenhouses - Traps - *Encarsia Formosa* - *Eretmocerus californicus* - *Eretmocerus sineatis*	- Buprofezin (Applaud) - Pymetrozine (Plenum) - Potassium salt (Castalia) - Spiromesifen (Oberon)	- Mineral oil - Pirimifos-methyl (Actellic)
Cotton aphid, peach-potato aphid			
- acetamiprid (Polysect Ultral) - thiacloprid (Calypso) - thiamethoxam (Memory)	- Remove weeds and virus-affected plants) - Several parasitoids and predators - Funguses *Verticillium lecanii* and *Beauveria bassiana*	- pymetrozine (Plenum)	- Mineral oil - Esfenvalerate (Sumicidin) - Pirimifos-methyl (Actellic) - Deltamethrin (Decis)

To avoid infection with the **two-spotted spider mite** during the more susceptible early crop stages, it is important to clear away plant debris and weeds and monitor regularly, especially on plots with previous infestations. Natural enemy predatory mites *Phytoseiulus persimilis* and *Amblyseius californicus* occur naturally in fields, but can also be released when the pests are detected. Mineral oil can asphyxiate the mites, but the leaves need to be wet for the oil to be effective because otherwise the insects are protected by their webs. To control the mite chemically spirodiclofen (Envidor), spiromesifen (Oberon), tebufenpyrad (Masai), mineral oil, abamectin (Vertimec Gold) and etoxazol (Borneo) are available as alternatives to acetamiprid. Spirodiclofen, spiromesifen and tebufenpyrad have low environmental impact and are not harmful to pollinators and natural enemies.

To control the **glasshouse whitefly** and **tobacco whitefly**, it is important to clear away new shoots after harvest, as young shoots attract adult whitefly. Crop rotation with non-host plants, traps and nets in greenhouses can reduce pest pressure. Several parasitic wasps can be released to control whitefly populations, including *Encarsia formosa, Eretmocerus californicus* and *Eretmocerus sineatis*. There are several chemical alternatives to the neonicotinoids acetamiprid and thiamethoxam. Mineral oil and pirimifos-methyl (Actellic) are very harmful to bees. Buprefezin (Applaud), pymetrozine (Plenum), potassium salts (Castalia) and spiromesifan (Oberon) have low impact and are thus good alternatives to the neonicotinoids.

To control the **cotton aphid** and **peach-potato aphid** several predators and parasitoids, as well as funguses can be used. Also practices like removing weeds and removal of virus-infected plants can help reduce pest-pressure. These measures may not be sufficient when pest pressure is high. Of the alternatives, only pymetrozine has a relatively low impact, which can lead to resistance on the long term. Mineral oil, esfenvalerate, pirimifos-methyl and deltamethrin are available, but have high impact on bees and other polinators.

CONCLUSIONS

- There are several alternatives to neonicotinoids against the **two-spotted spider mite** and **whiteflies**, such as spirodiclofen and tebufenpyrad**.**
- One chemical alternative with low environmental impact is available against **aphids** in melon, which can lead to resistance on the long term if only this product is being used.

6.9 Oilseed rape

Germany

Pest species that are controlled by neonicotinoids in oilseed rape in Germany include **rape beetle**, **brassica pod midge** and **weevils**. **Cabbage root fly** and the **cabbage stem flea beetle** were controlled by neonicotinoid coated seeds before the ban in 2013. Information on alternative pest control strategies was obtained from Bayer Expert guide (2012), AHDB Cereals & Oilseeds (2013), AHDB oilseed rape guide (2015), Invasive Species Compendium (2016).

Table 6.10 Overview of neonicotinoids currently authorized (2016) for pest control in oilseed rape in Germany and the non-chemical and chemical alternatives.

Oilseed rape – Germany			
Neonicotinoids	**Alternative products**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Rape beetle			
acetamiprid (Mospilan) thiacloprid (Biscaya)	- early flowering cultivar - early drilling - stimulating predatory wasps (in unsprayed crops) - trap cropping with turnip rape		-indoxacarb (Avaunt) -pyrethroid class I# -pyrethroid class II#* -pymetrozine (Plenum)*
Brassica pod midge			
thiacloprid (Biscaya)	- keep distance to last years' oilseed rape field		- pyrethroids
Weevils			
thiacloprid (Biscaya)			-pyrethroids
Cabbage root fly			
moratorium on neonicotinoid	- early drilling - soil cultivation		
Cabbage stem flea beetle			
moratorium on neonicotinoid	- crop rotation - early drilling - minimum tillage - drilling the crop in stands with cereal straw		-pyrethroids#

Pest has developed (widespread) resistance against active ingredient.

* Not sufficiently effective.

To avoid damage caused by **rape beetle**, which only occurs before the flowers open, early flowering varieties and early drilling can be effective. Parasitic wasps can kill 25-50% of larvae in unsprayed crops or when spraying has occurred before the presence of the **rape beetle** in the green bud stage. A non-chemical alternative is trap cropping with turnip rape. In this method an alternative crop that flowers before oilseed rape is planted next to or around an oilseed rape field. Emigrating adult beetles will inhabit this trap crop rather than the actual crop and because **rape beetles** can only fly for a finite period, it is anticipated that once in the trap crop, they will stay there. Further experimental work is currently being done to improve this method.
For chemical control of the **rape beetle** pymetrozine (Plenum 50 WG) and indoxacarb (Avaunt) are available until the first open flowers of the crop or weeds. Both products can only be applied ones. When the plants are flowering thiacloprid (Biscaya) and acetamiprid (Mospilan) are used. These neonicotinoid pesticides can be replaced by pyrethroids, but these are also harmful to pollinators and natural enemies. Moreover, some products based on pyrethroids should be avoided because of problems with resistance.

For control of **brassica pod midge** pyrethroid insecticides may be used. Furthermore, keeping distance to last years' oilseed rape can reduce infestation pressure of **brassica pod midge** because adult beetles do not fly long distances.

Also for control of **weevils** pyrethroid insecticides may be used.

Cabbage root fly is the most important pest in the main oilseed rape production areas in Germany. Before 2014 seed coating containing neonicotinoids controlled this pest. Currently, there are no chemical alternatives. Soil cultivation and late planting can suppress this pest species, but these measures are not fully reliable because in some years **cabbage root fly** may have a late flight, which means that plants are attacked when they are small and vulnerable.

Unlike in the United Kingdom, **cabbage stem flea beetle** is not a major pest in Germany, because it can still be controlled with pyrethroids insecticides. However, this is not a long-term solution because of expected resistance problems. Before 2014 seed coatings containing neonicotinoids controlled this pest. Culture measures can help to reduce pest infestation but need to be combined with other IPM strategies to be an effective alternative.
Minimum tillage has the potential to reduce mortality of natural predators, such as the carabid beetle *Trechus quadristriatus* and the parasitoid *Tersilochus microgaster*. These natural enemies are very vulnerable to pyrethroid insecticides, which should be avoided when relying on natural pest control. Drilling early reduces crop vulnerability to early attacks as the crop developed past the susceptible stage when beetles migrate to the crop. And when the crop is drilled in stands with white cereal straw the attack rate by **cabbage stem flea beetle** can be reduced (pers. comm. P. Dews, Agrovista).
Alternating crops, e.g. maize, can reduce **cabbage stem flea beetle** infestation as well. In general reducing the oilseed rape cultivation area within larger areas, not only on farm scale, can reduce infestation pressure for most pest insects. In Germany the crop rotation in the main oilseed rape production areas is 1:3 and sometimes 1:2 (pers. comm. U. Heimbach), which means that one-third to halve of the cultivated area in a region consists of the oilseed rape.

CONCLUSIONS GERMANY

- **Cabbage stem flea beetle** is not a major pest in Germany and can still be controlled by culture measures in combination with IPM. Pyrethroids can also be used.
- For **cabbage root fly** currently no effective and reliable control strategy is available.

- For **rape beetles** non-chemical measures are available. Indoxycarb is the only reliable chemical alternative to neonicotinoids.
- **Weevils** can be effectively controlled by alternative products with a high environmental impact.
- **Brassica pod midge** can be effectively controlled without neonicotinoids by keeping distance to last years infestation or by using pyrethroids which have a high environmental impact.

United Kingdom

Pest species that are controlled by neonicotinoids in oilseed rape in the United Kingdom include **rape beetle**, **cabbage gall weevil**, **summer aphids** and **peach-potato aphid**. Before the ban on neonicotinoids **cabbage stem flea beetles** were also controlled by neonicotinoid coated seeds. Information on alternative pest control strategies was obtained from Bayer Expert guide (2012), AHDB Cereals & Oilseeds (2013), AHDB oilseed rape guide (2015), Invasive Species Compendium (2016).

Table 6.11 Overview of neonicotinoids currently authorized (2016) for pest control in oilseed rape in the United Kingdom and the non-chemical and chemical alternatives.

Oilseed rape – United Kingdom			
Neonicotinoids	**Non-chemical alternative**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Cabbage stem flea beetle			
- clothianidin (emergency authorization only)	- crop rotation - minimum tillage - early drilling - drilling the crop in stands with cereal straw		- pyrethroids#
Rape beetle			
- thiacloporid (Calypso)	- early flowering cultivar - early drilling - stimulating predatory wasps (in unsprayed crops) - trap cropping with turnip rape		- pyrethroids# - indoxycarb (e.g. Steward) - pymetrozine (Plenum)*
Cabbage gall weevil / summer aphids			
- thiacloprid (Calypso)	- parasitoids - ground beetles and spiders		- pyrethroids
Peach-potato aphid (vector of turnip yellows virus)			
- thiacloprid (Calypso)	- Resistant variety Amalie - Late drilling		- pyrethroids# - pymetrozine - pirimicarb#
Cabbage root fly			
- thiamethoxam (Actare) (emergency authorization only)	- do no sow crop before August		

* Not sufficiently effective

Pest has developed (widespread) resistance against active ingredient.

There are several options for culture control to reduce the damage caused by **cabbage stem flea beetle**. However, many of these measures are limited by weather conditions, as structural damage may occur when the soil is too wet or too dry. Some companies market varieties with good early growth vigour as a way to reduce the impact of **cabbage stem flea beetle** damage. In the field, however, there is not much difference in damage between varieties (pers. comm. P. Dews, Agrovista). Minimum tillage has the potential to reduce mortality of natural predators, such as the carabid beetle *Trechus quadristriatus* and the parasitoid *Tersilochus microgaster*. These natural enemies are very vulnerable to pyrethroid insecticides, which should be avoided when relying on natural pest control. Drilling early reduces crop vulnerability to early attacks as the crop has developed past the susceptible stage when beetles migrate to the crop. And when the crop is drilled in stands with white cereal straw the attack rate by **cabbage stem flea beetle** can be reduced (pers. comm. P. Dews, Agrovista). Further experimental work is needed to improve this method. Alternating crops, e.g. maize, can reduce **cabbage stem flea beetle** infestation as well. In general reducing the oilseed rape cultivation area within larger areas, not only on farm scale, can reduce infestation pressure for most pest insects. In The Netherlands pest pressure in oilseed rape is low. Oilseed rape is – compared to Germany and United Kingdom– only a minor crop in the Netherlands. In the United Kingdom, oilseed rape is commonly cultivated in a rotation of 1:3 or 1:4 (pers. comm. P. Humphry). In Germany the crop rotation in the main oilseed rape production areas is 1:3 and sometimes 1:2 (pers. comm. U. Heimbach).

Pyrethroid broad-spectrum insecticides are the only chemical option, but widespread resistance has been identified across populations. Two types of resistance occur in the UK. Knock-down resistance is found throughout Europe, while an unknown type of metabolic resistance is found only in the UK. Due to the resistance, currently no viable chemical control option exists as an alternative to neonicotinoids (AHDB impact assessment 2015). An emergency authorization for seed treatment with clothianidin was provided in autumn 2015 for the counties with highest **cabbage stem flea beetle** infestation: Suffolk and Bedfordshire.

To avoid damage caused by **rape beetle** early flowering, early drilling and trap cropping with turnip rate can be applied (see the text under Germany). Chemical alternatives with authorization to control **rape beetle** include pyrethroids, indoxycarb and pymetrozine. Resistance to pyrethroids have been widely established but it can sometimes still be effective. These active substances, however, are all harmful for natural enemies and pollinators. Pymetrozine is not effective for control of **rape beetle**, which leaves only indoxycarb as a reliable alternative.

Peach-potato aphid is mainly a problem because of the transmission of **turnip yellows virus**. Amalie is a variety with resistance to **turnip yellows virus** and a reliable crop protection strategy that can replace thiacloprid. Another preventive measure is to delay drilling in late summer to avoid the spread of the **virus** to the seedlings (Bayer Expert guide (2012); AHDB oilseed rape guide, 2015), but this is counterproductive for control of the **cabbage stem flea beetle**. Due to widespread resistance to pyrethroids and pirimicarb the only effective alternative to control **peach-potato aphid** is pymetrozine (Table 6.6). Crop monitoring and decision support systems on aphid pressure provide best timing information for any insecticide treatment if required.

The **cabbage gall weevil** and **summer aphids** rarely need treatment. The **cabbage gall weevil** is controlled mainly by parasitoids such as *Trychomalus perfectus, Mesopalobus morys* and *Stenomalina gracilis*. **Aphids** are predated by ground beetles and spiders in autumn and by parasitoids during mild weather. Minimum tillage and field margins can harbour natural enemies, although they can also harbour aphids. If chemical control is necessary a grower only can use pyrethroids, which is counterproductive for next year's pest control because it reduces the reservoir of natural enemies.

Unlike in Germany, **cabbage root fly**, is not a problem in the United Kingdom, unless crops are sown before august.

CONCLUSIONS UNITED KINGDOM

- For **cabbage stem flea beetle** currently is no effective and reliable control strategy.
- For **rape beetles** non-chemical measures are available. Indoxycarb is the only reliable chemical alternative to neonicotinoids.
- For **cabbage seed weevil** and **summer aphids** no neonicotinoids insecticides are necessary because this pest can be controlled reliably by alternative products.
- For **peach potato aphid** planting resistant variety against **turnip yellows virus** is a reliable control strategy.
- **Brassica pod midge** can be effectively controlled without neonicotinoids

6.10
Olive

Spain

Pest species that are controlled by neonicotinoids in olives include **olive fruit fly**, **black scale**, **olive kernel borer** and **jasmin moth**. Information on alternative pest control strategies was obtained from the website of the ministry of agriculture, fishery and environment of Spain (www.mapama.gob.es), Abrol (2015) and Gil and Torres (2014).

Table 6.12 Overview of neonicotinoids currently authorized (2016) for pest control in olive in Spain and the non-chemical and chemical alternatives (authorization imidacloprid only after flowering).

Olives - Spain			
Neonicotinoids	**Non-chemical alternatives**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Olive fruit fly			
- acetamiprid (Epik 20 SG) - imidacloprid (Confidor 200) - thiacloprid (Calypso SC) - thiamethoxam (Actare)	- pheromone traps - traps with 'fosfato biamonico' - early harvest - spinosad (Spintor) - kaolin (Surround) - copper		- deltamethrin (e.g. Decis) - dimethoate (e.g. B58) - cypermethrin (e.g. Fastac ME) - phosmet (Supramin)
Black scale			
- imidacloprid (Gaucho WS)	Parasitoids: - *Scutellista cyanea* - *Metaphicus flavus* - *Hyperaspis spp* Pruning/ open canopy	- buprofezin (Applaud)	- phosmet (Supramin)
Olive kernel borer			
- thiamethoxam (Actare)	*Chrysoperla carnea*[c] *Bacillus thuringiensis* - kaolin (Surround)	- metil clorpirifos (Reldan) - etofenprox (Shark)	- dimethoate (e.g. B58) - cypermethrin (e.g. Fastac) - zeta-cypermethrin (Fury) - chlorpirifos (Chas 48) - phosmet (Supramin)

Jasmin moth			
- thiamethoxam (Actare)	Sucker eradication *Bacillus thuringiensis* Pruning/ open canopy	- carbaryl (Sevin 80S) - methidathion (Supracide 25WP)	- cypermethrin (e.g. Fastac ME) - phosmet (Supramin)

Olive fruit fly can be controlled by releasing x-ray sterilized males or using a chemical repellent for females. Another method is to treat the fruits with kaolin, which impedes the females to reach the fruit. Furthermore, an early harvest of oil olives can reduce the damage done to the fruits. In organic orchards copper is used, which kills the bacteria that attract females. The parasitoid *Psystalia concolor* is not sufficiently effective, as its development is slower than that of the **olive fruit fly**. There are two alternative options for chemical **olive fruit fly** control. When pest incidence is low (three adults per trap), **olive fruit fly** can be attracted with an attractant and killed with an insecticide like deltamethrin. This method works only on a small scale. When pest incidence is higher the whole orchard can be treated with an insecticide with low impact, such as spinosad, or with high impact, like deltamethrin, phosmet or dimethoate.

Parasitoids such as *Scutellista cyanea* and *Metaphicus flavus* and ladybug predators of the genus *Hyperaspis* can effectively suppress **black scale**. In organic farms therefor generally no treatment is necessary. Pruning also reduces damage and infestation levels as it creates more dry and warm conditions which **black scale** does not like. Due to their scale, chemical treatment of **black scale** is most effective during the crawler stage, when 90 to 100% of the larvae are hatched. Alternatives for control by imidacloprid include phosmet (high impact) and buprofezin (low impact). Buprofezin has low to no environmental impact and is not harmful for pollinators and natural enemies. It is therefor a good alternative to neonicotinoids, although the use of a single product can lead to resistance on the long term.

Olive kernel borer can be suppressed by lacewing larvae of *Chrysoperla carnea*, which are commercially available. The lacewing larvae are only effective against the initial larval stages of **olive kernel borer** of the first and third generation. *Bacillus thuringiensis* is another effective non-chemical alternative against **olive kernel borer** larvae. In addition to these natural enemies female sex pheromones can be used to disrupt reproduction of adults. Also pruning to make open canopies will help to reduce the pest population.

Chemical treatment of the **olive kernel borer** generally starts from the second generation onwards. Chemical treatment can be done with thiamethoxam or dimethoate, although this reduces the number of natural enemies. Alternatively to the products with high impact, several low impact products are available, such as kaolin or etofenprox.

Jasmin moth larvae can be controlled with *Bacillus thuringiensis*. Removing suckers also reduces the pest because the insect prefers to lay eggs on suckers. The **jasmin moth** is a secondary pest, as it only affects young shoots and generally does not need control in producing orchards. However, when plants are weakened or natural enemies are reduced by control measures against other pests, they may become a pest.

CONCLUSION

- **Olive fruit fly** can be controlled effectively through non-chemical methods if incidence is low. When incidence becomes too high, sometimes a chemical alternative is necessary. Spinosad is available as low-impact alternative, but it is generally too expensive to be used on a large scale. High-impact insecticides are available, but are not a viable alternative.

- Buprofezin is a good alternative against **black scale** when non-chemical measures are not sufficient, but a single alternative can lead to resistance.
- Several non-chemical and low-impact chemical alternatives to neonicotinoid thiamethoxam are available against the **olive kernel borer** and **jasmin moth**.

6.11 Potato

Germany / Netherlands / United Kingdom
Both in Germany and the Netherlands **aphids** (as **virus vector**) and **Colorado potato beetle** are controlled by neonicotinoids and the alternatives are very similar for both countries. Information on alternative pest control strategies was obtained from Sukkel et al. (2004).

Table 6.13 Overview of neonicotinoids currently authorized (2016) for pest control in potato in Germany and the non-chemical and chemical alternatives.

Potato – Germany			
Neonicotinoids	**Non-chemical alternative**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Aphids			
- acetamiprid (Danjiri, Mospilan SG) - imidacloprid (Monceren G) - thiacloprid (Biscaya) - thiamethoxam (Actara) - clothianidin (Dantop)	- Add mulch to the soil - for seed potato only: produce potatoes in areas with low aphid flight activity (e.g. windy coast line)	- flonicamid (Teppeki) - pymetrozine (Plenum)	- pirimicarb (Pirimor)*
Colorado potato beetle			
- acetamiprid (Danjiri, Mospilan SG) - imidacloprid (Monceren G) - thiacloprid (Biscaya) - thiamethoxam (Actara) - clothianidin (Dantop)	- *Bacillus thuringiensis* (Novodor) - azadirachtin (Neem Azal) - keep distance to previously infested field		- chlorantraniliprole (Coragen) - pyrethrin (Spruzit)

* Not sufficiently effective.

Table 6.14 Overview of neonicotinoids currently authorized (2016) for pest control in potato in the Netherlands and the non-chemical and chemical alternatives.

Potato – Netherlands			
Neonicotinoids	**Non-chemical alternative**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Aphids			
- acetamiprid (Gazelle) - thiacloprid (Calypso/Dadian) - thiamethoxam (Actara)	- add mulch to the soil - stimulate natural enemies by flower margins - produce seed potatoes in areas with low aphid flight activity (e.g. windy coast line)	- flonicamid (Teppeki) - pymetrozin (Chess)	- pirimicarb (Pirimor)
Colorado potato beetle			
- thiacloprid (Calypso/Dadian) - acetamiprid (Gazelle)	- keep distance to previously infested field		- chlorantraniliprole (Coragen) - pyrethroiden

Table 6.15 Overview of neonicotinoids currently authorized (2016) for pest control in potato in the Netherlands and the non-chemical and chemical alternatives.

Potato – United Kingdom			
Neonicotinoid	**Non-chemical alternative**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Aphids			
-thiacloprid (7 products, including Biscaya) -thiamethoxam (2 products, including Actara) -acetamiprid (4 products)	- add mulch to the soil - produce seed potatoes in areas with low aphid flight activity (e.g. windy coast line or at higher altitude)	- pymetrozin - flonicamid	- pirimicarb (Pirimor)#

Pest has developed (widespread) resistance against active ingredient.

For non-chemical alternative control of **aphids** by natural enemies in starch and consumption potato see the information in 6.1 Introduction. Natural enemies do not protect against the transmission of **viruses** in seed potatoes. **Virus** transmission in seed potato can be reduced by putting mulch, i.e. straw, on the soil surface when potato leaves begin to emerge. The mulch reduces the number of alate (winged) aphids trying to settle down by making such areas less optically attractive for them. This has been shown in trials. Another alternative is to produce seed potatoes in areas with low aphid flight activity (e.g. near to the windy cost line or at higher altitude). Also scouting before applying pesticides can help to reduce pesticide applications. Chemical alternatives for control of **aphids** include flonicamid (Teppeki), pymetrozine (Plenum) and pirimicarb (Pirimor). Pirimicarb is not very effective, has a high environmental impact and is harmful to pollinators and natural enemies. Moreover, pirimicarb has resistance problems, particular when used against *Myzus persicae*. Flonicamid and pymetrozine have little environmental impact and are not harmful to pollinators and natural enemies.

In the Netherlands flower margins that stimulate natural enemies of **aphids** help to reduce **aphid** numbers below the economic threshold, but may take one year to be effective. In potato fields next to flower margins the number of aphids declined in the course of three years making it unnecessary to spray against **aphids** in the second and third year of the trial (van Rijn et al. 2008). Similar results were obtained by a large group of farmers that participated in the Dutch project 'Bloeiend Bedrijf'. Up to 70% of farmers that had sown field margins along potato fields reduced or did not apply pesticides at all (Steenbruggen et al., 2015). In Germany flower margins are not yet reliable for crop protection and also in the UK there are no good examples of flower margins contributing to suppression of aphids in potatoes. More research is needed to understand why flower margins do not seem to contribute to pest control in these countries, and what is needed to improve their effectiveness. Developing a region wide action plan to enhance natural habitat to restore the natural enemy population may be one of the measures needed together with replacing broad working insecticides by **aphid** specific products.

Pest infestation by **Colorado potato beetle** can be reduced by keeping distance to previously infested field because the beetles overwinter near and in these fields. Adult beetles are able to fly up to several kilometres and a distance of 1-2 km to the previously infested field would be enough to reduce risk of re-infestation. In areas with more than one potato farmer this requires coordination and planning at the region level, which famers are not used to do at the moment. In Germany other non-chemical alternatives include control by *Bacillus thuringiensis* (Novodor) and azadirachtin (Neem Azal). In the Netherlands these products have no authorization for potato. For both Germany and the Netherlands the chemical alternatives include chlorantraniliprole (Coragen) and for Germany pyrethrine (Spruzit); both have a high impact on the environment. Coragen is not harmful for beneficial insects, but has a leaching risk to groundwater.

CONCLUSION

- For control of pests in starch or consumption potato neonicotinoids are not necessary since non-chemical and chemical alternatives are available.

6.12
Sugar beet

Neonicotinoids in seed treatments are used as a precautionary measure against most of the pest species in sugar beet in Germany, Netherlands and United Kingdom. For the Netherlands and United Kingdom the alternatives are the same and the results for these countries are therefore combined. Information on alternative pest control strategies was obtained from IRS (2016).

Germany
Pest species for which neonicotinoid seed treatments are used include **flea beetle**, **pygmy mangold beetle**, **beet leaf miner**, **aphids** (as **virus vector**), **wireworm** and **millipede**.

Table 6.16 Overview of neonicotinoids currently authorized (2016) for pest control in sugar beet in the Germany and the non-chemical and chemical alternatives.

Sugar beet – Germany			
Neonicotinoids	**Non-chemical alternative**	**Chemical alternative with low impact**	**Chemical alternative with high impact**
Flea beetle			
- thiamethoxam (Cruiser 600 FS, Cruiser 70 WS)			- lambda-cyhalothrin (e.g. Karate Zeon)
Pygmy mangold beetle			
- thiamethoxam (Cruiser 600 FS, Cruiser 70 WS) - imidacloprid (Gaucho WS) - clothianidin (Janus, Poncho Beta, Poncho ungefärbt)	- crop rotation - keeping distance to other beet fields		- alpha-cypermethrin (e.g. Fastac ME) - deltamethrin (e.g. Decis forte) - tefluthrin (e.g. Force 20 CS)*
Beet leaf miner			
- thiamethoxam (Cruiser 600 FS, Cruiser 70 WS) - imidacloprid (Gaucho WS) - clothianidin (Janus, Poncho Beta, Poncho ungefärbt)			- lambda-cyhalothrin (e.g. Hunter) - dimethoate (e.g. B58)
Aphids / Beet Yellowing Virus			
- thiamethoxam (Cruiser 600 FS, Cruiser 70 WS) - imidacloprid (Gaucho WS) - clothianidin (Janus, Poncho Beta, Poncho ungefärbt)			- pirimicarb (e.g. Pirimax) - lambda-cyhalothrin (e.g. Hunter)
Wireworm			
- thiamethoxam (Cruiser 600 FS, Cruiser 70 WS) - imidacloprid (Gaucho WS) - clothianidin (Janus, Poncho Beta, Poncho ungefärbt)	- avoid grass or cereal as pre-crop - soil cultivation to dry-out soil		- tefluthrin (Force)*
Millipede			
- imidacloprid (Gaucho WS) - clothianidin (Poncho Beta)	generally does not cause severe damage and do not require control		

* Low efficacy.

The main pests species include **black bean aphid**, **green peach aphid** as **virus vector** and **beet leaf miner.** None of these pest can currently be controlled effectively otherwise then with insecticides. Alternative chemical products for **black bean aphid** and **green peach aphid** include pirimicarb (Pirimax) and lambda-cyhalothrin (Hunter). For control of **beet leaf miner** lambda-cyhalothrin (Hunter) and dimethoate (B58) are available, but are also either harmful to bees and natural enemies or have a high environmental impact (CLM Environmental yardstick for pesticides 2016). Moreover, these products are more likely to get into contact with natural enemies and bees since they are applied as spray.

Pygmy mangold beetle infestation can be reduced by crop rotation and keeping distance to other beet fields (IRS, 2016). Alternative chemical control products for this pest include alpha-cypermethrin (Fastac), deltamethrin (Decis forte) and tefluthrin (Force 20 CS). Tefluthrin is applied as seed coating but is less effective than neonicotinoid coated seeds (pers. comm. IRS). Alpha-cypermethrin and deltramethrin are applied in spraying application for adult beetles and cannot control larvae, which cause most of the damage.

For **flea beetle** no non-chemical control measure is available. An alternative chemical control product is lambda-cyhalothrin (Karate Zeon). The alternative chemical products are harmful for pollinators and natural enemies and have a high environment impact (CLM Environmental yardstick for pesticides 2016).

Millipede generally does not cause severe damage and do not require control.

Neonicotinoids as seed treatment are used as a precautionary measure against most of the pest species in sugar beet. Not in all cases, however, the pest causes actually damage. In the Netherlands pest incidence is much lower on sandy than on clay soil. Therefore growers are advised to use only neonicotinoid seed treatments on clay (see below).

In Germany the area of sugar beet production on sand is very small (< 5% according to Mrs Stockfisch of the Institute of Sugar Beet Research (IfZ) in Germany). Most sugar beets are produced on silty soil. Moreover, it is unknown whether pest incidence is also lower on sand in Germany because this is not being monitored. Overall, pest incidence is lower in Germany than in the Netherlands (Hauer et al. 2016, Table 3). Monitoring pest occurrence in Germany has potential to reduce the area in which neonicotinoid treated seeds are used or to reduce the dose applied per hectare.

CONCLUSIONS

- For the main aboveground pests no non-chemical alternatives are currently available. Chemical alternatives are available but these pose a high risk for pollinators and natural enemies and have a high environmental impact.
- For belowground pests no non-chemical alternatives are available. Teflutrin is a chemical alternative that can be applied as seed coating, but has lower efficacy as neonicotinoid coated seeds.
- Monitoring pest occurrence in Germany has potential to reduce the area in which neonicotinoid treated seeds are used or to reduce the dose applied per hectare.

Netherlands, United Kingdom

Neonicotinoids in seed treatment are used as a precautionary measure against eight pest species including **flea beetle**, **pygmy mangold beetle**, **beet leaf miner**, **aphids** (as **virus vector**), **leather jacket**, **wireworm**, **springtails** and **thrips**. Information on alternative pest control strategies was obtained from IRS (2016).

Table 6.17 Overview of neonicotinoids currently authorized (2016) for pest control in sugar beet in the Netherlands and the non-chemical and chemical alternatives.

Sugar beet – Netherlands			
Neonicotinoids	**Non-chemical alternative**	**Alternative with low impact**	**Alternative with high impact**
Flea beetle			
- imidacloprid (Sombrero) - clothianidin (Poncho Beta)	- no chemical control needed on sand		- lambda-cyhalothrin (e.g. Karate Zeon)
Pygmy mangold beetle			
- imidacloprid (Sombrero) - clothianidin (Poncho Beta)	- no chemical control needed on sandy soils - crop rotation - keeping distance to other beet fields		- tefluthrin (Force)* - deltamethrin (e.g. Decis forte)
Beet leaf miner			
- imidacloprid (Sombrero) - clothianidin (Poncho Beta)	- no chemical control needed on sandy soils		- lambda-cyhalothrin (e.g. Karate Zeon)
Aphids / Beet Yellowing Virus			
- imidacloprid (Sombrero) - clothianidin (Poncho Beta) - thiacloprid (Calypso)			- pirimicarb (Pirimor)# - lambda-cyhalothrin (e.g. Karate Zeon)
Leather jacket			
- imidacloprid (Sombrero) - clothianidin (Poncho Beta)	- avoiding grassland, grass seeds, cereals or a cover crop as pre-crop - dry out topsoil in autumn		- oxamyl (Vydate)* - tefluthrin (Force)*
Wireworm			
- imidacloprid (Sombrero) - clothianidin (Poncho Beta)	- avoid grass or cereal as pre-crop - soil cultivation to dry-out soil		- tefluthrin (Force)*
Springtails			
- imidacloprid (Sombrero) - clothianidin (Poncho Beta)	- no chemical control needed on sandy soils		- tefluthrin (Force)*
Thrips			
- imidacloprid (Sombrero) - clothianidin (Poncho Beta)	- avoid peas, onion or flax as pre-crop		- pyrethroids (e.g. Karate Zeon)

Pest has developed resistance against active component in crop protection product.

* Low efficacy.

Table 6.18 Overview of neonicotinoids currently authorized (2016) for pest control in sugar beet in the United Kingdom and the non-chemical and chemical alternatives.

Sugar beet – United Kingdom			
Neonicotinoids	**Non-chemical alternative**	**Alternative with low impact**	**Alternative with high impact**
Flea beetle			
- clothianidin (Poncho Beta) - thiamethoxam (Cruiser SB)			- lambda-cyhalothrin (e.g. Clayton Lambada)
Pygmy mangold beetle			
- clothianidin (Poncho Beta) - thiamethoxam (Cruiser SB)	- crop rotation - keeping distance to other beet fields		- tefluthrin (Force)* - deltamethrin (e.g. Decis forte)
Beet leaf miner			
- clothianidin (Poncho Beta) - thiamethoxam (Cruiser SB)			- lambda-cyhalothrin (e.g. Clayton Lambada)
Aphids / Beet Yellowing Virus			
- clothianidin (Poncho Beta) - thiamethoxam (Cruiser SB) - thiacloprid (Calypso)			- pirimicarb (Pirimor)# - lambda-cyhalothrin (e.g. Clayton Lambada)
Leather jacket			
- clothianidin (Poncho Beta) - thiamethoxam (Cruiser SB)	- avoiding grassland, grass seeds, cereals or a cover crop as pre-crop - dry out topsoil in autumn		- oxamyl (Vydate)* - tefluthrin (Force)*
Wireworm			
- clothianidin (Poncho Beta) - thiamethoxam (Cruiser SB)	- avoid grass or cereal as pre-crop - soil cultivation to dry-out soil		- tefluthrin (Force)*
Springtails			
- clothianidin (Poncho Beta) - thiamethoxam (Cruiser SB)			- tefluthrin (Force)*
Thrips			
- clothianidin (Poncho Beta) - thiamethoxam (Cruiser SB)	- avoid peas, onion or flax as pre-crop		- pyrethroids

* Low effecacy.
\# Pest has developed (widespread) resistance against active ingredient.

Unlike in potatoes and cereals, flower margins that facilitate natural enemies do not provide adequate control of **aphids** in sugar beet because the **black bean aphid** can grow so rapidly in spring that it is difficult to suppress by natural enemies. For the **green peach aphid** there is a very low tolerance because of virus transmission – only few aphids are tolerated, which makes it hard to suppress by natural enemies alone.

For **black bean aphid** growers have pirimicarb (Pirimor) and lambda-cyhalothrin (Karate Zeon) as alternative chemical products to control this pest. For **green peach aphid** and virus yellows transmission pirimicarb may not provide enough protection because pirimicarb can only be applied twice a year, while the tolerance level for this species is very low and more applications may be necessary. Furthermore, first signs of resistance in the **green peach aphid** to pirimicarb have been observed.

Flea beetle and **beet leaf minder** are mainly a problem on clay and not on sandy soil (IRS, 2016). On sandy soil a farmer could do without neonicotinoids. This, however, needs careful monitoring and when pest incidence increases, neonicotinoid coated seeds may still be necessary. In some regions pest incidence is low probably because a majority of growers uses neonicotinoid coated seeds. In the Netherlands **flea beetle** damage does in general not lead to economic damage. A chemical alternative for both pests is lambda-cyhalotrin (Karate Zeon).

Pygmy mangold beetle infestation can be reduced by crop rotation and keeping distance to other beet fields because the pest has only few host plants (IRS, 2016). Avoiding grassland, grass seed, cereals or a cover crop as pre-crop may reduce occurrence of **leather jackets**. In addition, it may help to dry out the topsoil in autumn because the larvae of **leather jackets** are sensitive for dehydration (IRS, 2016). For **wireworm** see section 6.2 for non-chemical alternatives. All soil pests mentioned above can be controlled by seed coating with tefluthrin (Force). Seeds coated with tefluthrin, however, are currently (2016) not on the market in the Netherlands and are less effective than neonicotinoid coated seeds. For control of **leather jackets** also oxamyl (Vydate) is availabe but this product is not 100% effective.

Thrips infestation is usually not a problem. When it does pose a problem, populations can be reduced by avoiding peas, onions or flax as a pre-crop (IRS, 2016). A chemical alternative is to spray with pyrethroids.

All aforementioned chemical alternatives are harmful for pollinators and natural enemies or have a high environmental impact. Since beet crops do not flower exposure of natural enemies and pollinators to tefluthrin is questionable.

In 2012 on 23% of the sugar beet area in the Netherlands no neonicotinoid coated seeds were used (bietenstatistiek.nl). Especially on sandy soils the risk for pest infestations is low and the union of sugar beet growers 'Suiker Unie' encourages using non-treated seeds in these areas. The main pest on sandy soils is **black bean aphid** for which farmers have a chemical alternative. On clay soils the major problem is **green peach aphid**, which has a lower tollerance level because of virus transmission. Chemical alternatives to control this pest are available but with the risk that this pest develops resistance to one or more of the active ingredients.

CONCLUSIONS THE NETHERLANDS AND UNITED KINGDOM

- For most of the five aboveground pests no non-chemical alternatives are currently available. Chemical alternatives are available but pose a high risk for pollinators and natural enemies.

- For two of the three belowground pests culture measures can reduce the risk for pest outbreak. For all three pests teflutrin is a chemical alternative that can be applied as seed coating, but has lower efficacy as neonicotinoid coated seeds.

6.13
Conclusions on alternatives for neonicotinoids in ten crops in four countries

In 15 of the 18 crop-country combinations analysed, neonicotinoids can be (partially) replaced by an alternative that has no or little impact on the environment (green bars in Figure 6.1). For 6 crop-country combinations all neonicotinoids currently used can be replaced by an environmental friendly alternative. Not all alternatives can directly be adopted, such as flower margins, and not all alternatives are 100% reliable. The results of this study show that there is a large potential for environmentally friendly crop protection.

In 10 of the 18 crop-country combinations neonicotinoids can (partially) be replaced by other chemical crop protection products (yellow bars in Figure 6.1). In some cases these chemical alternatives have a higher environmental impact than neonicotinoids.

Finally, in 7 of the 18 crop-country combinations part of the neonicotinoids could not be replaced by any alternative (red bars in Figure 6.1). These include apple, oilseed rape and sugar beet. For oilseed rape this is only the case for Germany and not for the United Kingdom, because **cabbage root fly** is a major pest in Germany, but not in the United Kingdom. And for sugar beet this is only the case for the Netherlands and not for Germany or the United Kingdom, because less chemical alternatives are available for pest control in sugar beet in the Netherlands than in Germany or the United Kingdom.

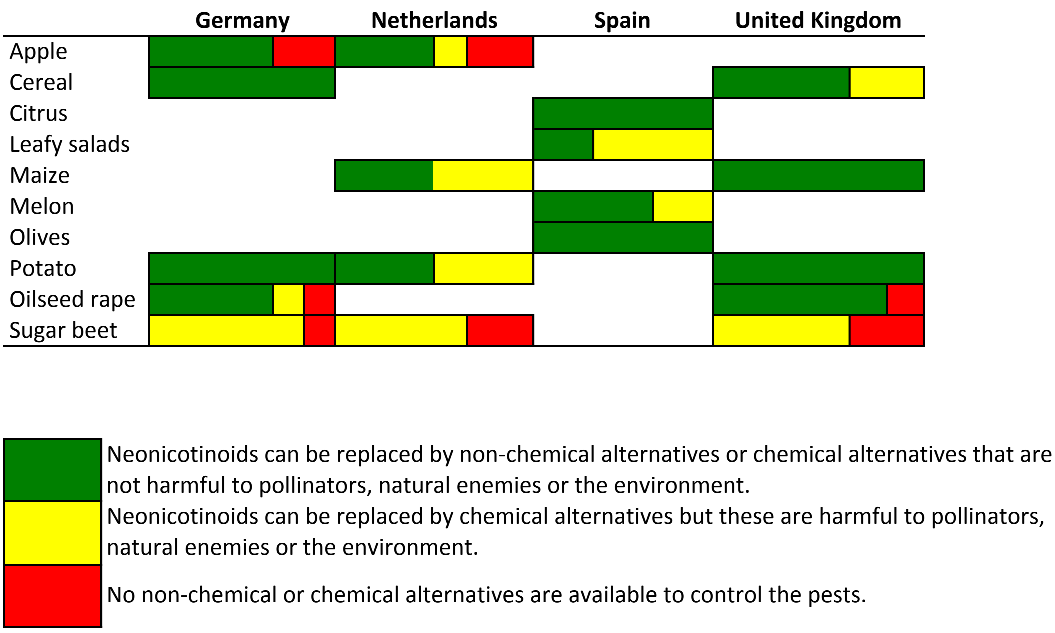


Figure 6.1 Overview of results regarding the question whether neonicotinoids can be replaced by non-chemical or chemical alternatives for the different crops and countries. Two colours per crop mean that the result applies to part of the active ingredients applied in that crop.

7

Quick-scan of the economic impact of a ban of neonicotinoids

7.1 Introduction

For this quick-scan we identified the crops for which currently no alternative is available for one or more active ingredients for a particular pest. These crops are appel, sugar beet and oilseed rape (figure 6.1). For apple and sugar beet our analysis is based on prices in the Dutch market. For oilseed rape we did an analysis for Germany and the United Kingdom separately, based on prices in international studies.

7.2 Apple

The Netherlands

In case no neonicotinoids can be applied in apple, economic loss will result from damage caused by **apple sawfly** and **apple blossom weevil** and in Germany also the **apple fruit weevil**. All three pests are specialized in apple and without control the population can grow unlimited. Natural enemies have little effect on regulation of the population in commercial apple production. Potential loss of production is estimated at 50-90% after several years and depents on the apple variety, bud set and weather conditions (M. Polfliet, Fruitconsult; G. Brouwer, Delphy). The loss rates mentioned are based on experience of organic apple growers when no regulation takes place for several years. Revenue in apple production is on average € 15.000 per hectare (Dutch market). The loss for a farmer could be more than € 7.500 per ha.

Organic apple growers, who of course do not use neonicotinoids, currently use Raptol based on oilseed rape oil and pyrethrin as an alternative to control **apple sawfly**. For the **apple blossom weevil** they have no crop protection and accept any damage caused by this pest (G. Brouwer, Delphy). Raptol has no authorization for use in conventional apple production.

7.3 Oilseed rape

Germany

In 2013, the European Commission banned the use of three of the six neonicotinoids and fipronil for a range of applications and crops for the whole of the EU.

The Humboldt Forum for Food and Agriculture has made an extensive economic impact assessment of the consequences of the Euopean ban for oilseed rape production in Germany (HFFA, 2016) based on studies of Kim et al. (2016) and Marketprobe (2015a, b). According to the study of Marketprobe (2015a) 62% winter oilseed rape production area in 2014 was affected by **cabbage stem flea beetle** and 39% was also affected by **cabbage root fly**. Average yield loss due to cabbage stem flea beetle was estimated at -5.4% (Marketprobe 2015a) and -5.0% (Kim et al. 2016). Given an average production of 3.89 $tonsha^{-1}$ and a revenue of € 355 per tonne (HFFA 2016), an average yield loss of -5.2% amounts to a loss of income of € 71.81 per hectare.
The majority of the respondents in the Marketprobe (2015a,b) study said that quality of oilseed rape has not changed. HFFA (2016), however, reports a loss of € 156 per hectare because oilseed rape did not meet quality standards compared to prior to the ban. Also the Marketprobe (2015c,d) studies for the UK report that quality of oilseed rape was not (much) affected by the ban. We assume for our economic assessment that loss of income due to quality loss was negligible. The number of foliar pesticide applications increased from 2.4 to 3.6 per season - often with pyrethoids, which amounts to an average extra costs of € 30 per hectare; assuming the cost per application to be € 25 (HFFA, 2017).
Furthermore, 12% of farmers also increased monitoring efforts (and thus labour input) and 10% of farmers used higher seed rates (HFFA, 2016). According to the survey of Marketprobe (2015a) overall production costs increased from € 41 to € 61 per hectare and for small farms from € 52 to € 82 and was mainly due to additional foliar applications.

Table 7.3. Costs for control of **cabbage stem flea beetle** in oilseed rape in Germany for a scenario in which no neonicotinoids can be used.

Category	**Loss or extra costs per hectare chemical alternative**
5,2 % yield loss	€ –71,81
1,2 additional foliar applications [1]	€ –30
Savings on neonicotinoids [2]	€ 9,35
Net loss	€ –92,46 (6,7 %)[3]

[1] Unlike in the United Kingdom, foliar pesticide applications are still effective against **cabbage stem flea beetle**. Cost for additional applications are included in the net loss for Germany.
[2] This is the average premium price for neonicotinoid coated seeds in the UK when they where first introduced. For Germany this price was considered market-relevant and could not be shared.
[3] Percentage from balance when neonicotinoids can be used.

United Kingdom

Average yield loss due to pest damage that otherwise could be prevented by neonicotinoids has been recently estimated by five studies for the United Kingdom (Alves et al. 2016; Kim et al. 2016; Market Probe 2015a, b; Nicholls 2016; White 2016) and reviewed in HFFA (2017). The percentage yield loss that these studies report varies between -1.0 and -9.0 % (HFFA, 2017) with an average

yield loss of 3.9%. Between regions and between individual farms the impact on yield varied widely. In the Eastern region 24% of the oilseed rape area exceeded control levels for **cabbage stem flea beetle** while in the South West of Scotland the percentage of the area exceeding the threshold levels was almost zero (Nicholls 2016). Of the oilseed rape production area 56% was not affected at all by **cabbage stem flea beetle** or the damage did not exceed the threshold (Nicholls, 2016).
A yield loss of 3,9% corresponds to a loss of € 58,91 per hectare assuming an average oilseed rape yield of 3,6 t ha^{-1}, a price per tonne of £ 323 (Nicholls, 2016) and an exchange rate from GBP to EUR from before the 'leave' vote of 1.299 (HFFA, 2017). Three of five studies reviewed in HFFA (2017) report additional foliar applications with pyrethoids to combat **cabbage stem flea beetle**. An average of 1,6 additional foliar application can be deduced from the HFFA review, which amounts to average costs of € 33.67; assuming the cost per application to be € 21.04 (HFFA, 2017). This is not included in the net loss because pyrethroids have low efficacy (see text) and are no long-term solution because of widespread resistance of **cabbage stem flea beetle** against pyrethroids. In a study across six counties in the UK agronomists estimated more than 50% control in only four of 34 (12%) foliar applications with pyrethoids (White, 2015).

The cost of seeds, without neonicotinoids, did not change much after the ban, because seed companies added other products to the seeds such as growth regulators. When neonicotinoids where first introduced as seed coating, the price of the seeds increased by £ 1.80 per kg seeds (pers. comm. KWS UK Ltd). Converted to EUR and assuming an average seed rate of 4 kg per ha this amounts to € 9.35 per ha. Farmers could thus save € 9.35 per ha when they use seeds without neonicotinoids.
In areas with high risk of damage due to **cabbage stem flea beetle**, farmers are advised to increase seed density by 10%, which amounts to additional costs of € 40.18 per ha (HFFA, 2017). An increase of seed density is used to compensate for loss until chemical control with pyrethoids can be achieved. Since **cabbage stem flea beetle** has widely developed resistance against pyrethroids chemical control is not effective and also increasing seed density has therefore little effect. We therefore do not include increase of seed density in our assessment.
Sowing the crop in white cereal straw can reduce damage, but this measure has not been investigated yet in field trials, so no estimation of the costs for the farmer can be made. We expect the costs to be lower than what a farmer would spend on foliar applications.

Table 7.4. Costs for control of **cabbage stem flea beetle** in oilseed rape in the UK for a scenario in which no neonicotinoids can be used.

Category	**Loss or extra costs per hectare Chemical control**
3.9% yield loss	€ –58.91
Savings on neonicotinoids [1]	€ 9,.5
Net loss	€ –49.56 (3.3 %)[2]

[1]Average premium price for neonicotinoid coated seeds when they where first introduced.
[2] Percentage from balance when neonicotinoids can be used.

7.4
Sugar beet

The Netherlands
Economic loss in sugar beet in case no neonicotinoids can be used will mainly result from damage caused by **aphids** and **beet yellowing virus**. The loss of production is estimated at 7%, causing a revenue loss of 17% (Tijink et al., 2015). Current revenue for sugar beet production is on average € 2.685. A loss of 17% means a revenue loss of € 456 per ha. Neonicotinoid coated seed cost € 44 – 53 per ha more compared to uncoated seed. If neonicotinoids cannot be used, seed companies will most likely coat seeds with tefluthrin (Force), which is only effective against soil pests. We assume for our assessment no difference in price between neonicotinoid and tefluthrin coated seeds.

Table 7.5. Costs for above ground pests in sugar beet in the Netherlands for a scenario in which no neonicotinoids can be used.

Category	**Loss or extra costs per hectare Chemical control**
7% yield loss	€ –456
Net loss	€ –456

7.5
Conclusions on the economic impact of a ban of neonicotinoids
In this quick-scan we aimed to identify the impact on farm income for those crops in which there are currently no effective alternatives for pest control by neonicotinoids.

For apple production in the Netherlands the losses may be € 7 500 per ha when pests can reproduce unlimited due to lack of neonicotenoids. Availability of the neonicotenoid thiacloprid is sufficient to control the pests. Organic apple growers, who of course do not use neonicotinoids, currently have Raptol based on oilseed rape oil and pyrethrin as an alternative to control **apple sawfly**. For the **apple blossom weevil** they have no crop protection and accept any damage caused by this pest (G. Brouwer, Delphy). Raptol has no authorization for use in conventional apple production.

For oilseed rape losses due to a ban on neonicotinoids are about € 92 per ha for a grower in Germany and about € 50 per ha for a grower in the United Kingdom. The losses are almost two times higher in Germany than in the United Kingdom because in Germany the damage is on average higher than in the United Kingdom and farmers spend more on alternative pesticide applications. In the United Kingdom these applications are not effective and are therefore not included in our analysis.

A sugar beet grower in areas with high pest pressure (i.e. on clay soil) may have an economic loss of € 456 per ha. On sandy soil damage can be much lower or even absent. Similar to maize, insurance for growers in low risk areas might be an option.

The (announcement) of a ban on one or more specific pesticides and the (future) lack of these pesticides can become driver for innovation. New technical solutions appear and existing options become feasible through decreasing costs. Thus the actual economic impact of a ban may be lower than calculated in this study. A well studied example is the ban of azinphos-methyl in controlling codling moth in pear fruit in California. This ban stimulated both the development of the pheromone technique used in mating disruption and the granulosis virus that infects codling moth larvae (O' Brien et al. 2009). Both techniques have been succesfully implementend and the costs of the techniques are acceptable. Another example is the announced ban of glyphosate for use on hardend surfaces in the Netherlands. This strongly stimulated new non chemical techniques to control weeds. The initial higher costs of this control strongly decreased due to optimalisation of the techniques and increasing competition between maintenance companies (Leendertse et al. 2013). This ban is operational from March 2016 onwards.

8

Conclusions and recommendations

8.1 Conclusions

8.1.1 Neonicotinoids and fipronil are used in a number of crops in different European countries

In this study the neonicotinoids imidacloprid, chlothianidin, thiamethoxam, thiacloprid and acetamiprid, complemented with the systemic insecticide fipronil are investigated in a number of important crops in four European countries (Germany, Netherlands, United Kingdom and Spain). These pesticides have authorization for use in the European Union (EU), while three of them (imidacloprid, clothianidine and thiametoxam) have a partial ban in specific crops since 2013. The total use of neonicotinoids in 2012 compared to the total agricultural area ranged between 12.2 g/ha in Germany to 30.5 g/ha in the Netherlands. The total volume of use in 2012, ranged between 13.0 metric tonnes in the United Kingdom to 146.8 metric tonnes in Germany. For Spain the total use of neonicotinoids via spray application was low compared to the other countries. No information was available on the amount used as seed treatment in Spain and hence no total amount applied could be determined.

8.1.2 Data on pesticide use in European countries and crops are not readily available

It is difficult to estimate specific volumes used, since data are not readily available. It took substantial effort to find reliable data, especially at the level of individual neonicotinoids and crops. France -being an important agricultural country- could not been included in this study because of an almost complete lack of data on neonicotinoids.

8.1.3 Alternatives for neonicotenoids are available for part of the crops and countries studied

Neonicotinoids can already be replaced today by an alternative that has no or little environmental impact in about half of the situations that we analysed in the ten crops and four countries (Figure 6.1). This means that either non-chemical alternatives can be used, or that neonicotinoids can be replaced by pesticides that have a lower environmental impact.

In one third of the crop-county combinations, the existing chemical alternatives for neonicotinoids have a high environmental impact as well. In those crops replacement may not be improvement. Neonicotinoid seed coating in sugar beet, for example, may have less environmental hazard than foliar sprays with chemical alternatives.

For six pest species in the three crops apple, oilseed rape and sugar beet (about one-tenth of the instances) no reliable alternative is available for at least one of the neonicotenoids and an immediate ban of all neonicotenoids in these crops may lead to loss of crop and extra costs.

8.1.4
Quick scan shows that a total ban on neonicotenoids may have economic consequences

A total ban on neonicotinoids will have economic consequences for apple, maize, sugar beet and oilseed rape growers if it were installed today. Estimations of a decrease in income due to pests that are at present difficult to control without one or more neonicotenoids vary from 3.3% for oilseed rape in United Kingdom to 50% in apple production.
It should be noted that experience shows that once a ban is announced, the future lack of the pesticide becomes a driver for innovation. New technical solutions appear and existing options become feasible through decreasing costs. Thus the actual economic impact of a ban may be be lower than calculated in this study.

8.2
Recommendations

1. Improving the availability of pesticide use data in Europe is indispensable to allow for better analysis of use and environmental impact.
2. Market authorization of green pesticides, e.g. pesticides with low environmental impact, should be enhanced and accelerated.
   For several pest species green pesticides and alternative crop protection products are available, but these have no authorization yet or only in a few European countries. For example Quassia extract, a biological control agent available in Sweden against several pests in apple, has no authorization in the Netherlands or Germany.
3. Integrated pest management should be developed further.
   Integrated pest management is about integrating all possible methods of reducing pest damage and using pesticides only as a last resort. One aspect of integrated control is the use of resistant varieties. For the crops in this study resistant varieties as an alternative control strategy are avalibale for turnip yellows virus in oilseed rape and for cereal leaf beetle in cereals. There is more potential for breeding-in traits that increase plants' defences against pests. One of such traits is the ability of a plant to emit volatiles that attractant natural enemies – specific for a particular pest.
   Another integrated method that should be further explored is the benefit of mulching for crop protection. For the crops studied positive results for control of aphids in potatoes and of cabbage stem flea beetle in oilseed rape were found.
4. Arable rotation should be further encouraged.
   Most pest problems can be reduced when crops are rotated. (Wide) crop rotation reduces pest infestation and increases soil organic carbon (e.g. by increasing the share of cereals as opposed to root crops), which enhances soil life that can promote plant health. Moreover, crop rotation may increase yields (e.g. winter wheat after oilseed rape).
   Areas in Germany or England with high density of oilseed rape may also profit from more crop rotation. An increase of the rotation scheme of 1:3 to 1:4 will reduce the area covered by oilseed rape by 25%. Areas with less intensive production of oilseed rape, such as the Netherlands, have little or no problems with cabbage stem flea beetle.
5. Monitoring on the occurrence of pests in specific regions should be further developed.
   When pest incidence is low, no control is needed, and farmers may choose not to apply seed coating, as sugar beet growers do in the Netherlands. And in case damage does occur insurance such as developed for maize production in the Po Valley in Italy may compensate for the loss.
6. Circumstances in which natural enemies thrive, should be stimulated.

Natural enemies are a reliable control strategy for several pests in different crops, such as for control of woolly apple aphids in apple or Mediterranean fruit fly in apple. In order to benefit (more) from the control potential of natural enemies we give the following recommendations: The use of broad-spectrum pesticides that have an impact on a range of pests, such as pyrethroids, should be avoided or minimized. In several circumstances this can already be achieved by replacing broad-spectrum pesticides by products that only target the pest. Broad working pesticides are popular because they kill all (potential) pests. But when farmers monitor the pest infestation it may not be necessary to use a broad spectrum product. Projects such as 'Bloeiend bedrijf', in which a large group of Dutch potato and cereal farmers participated, demonstrate that pesticide use can be reduced when farmers make an informed choice whether or not to spray based on monitoring. We see a great potential increase of natural pest control in potato, cereals and oilseed rape when monitoring for pests is integrated in day-to-day farm management.

7. When use of broad spectrum pesticides is minimized, the presence of natural vegetation will further strengthen pest control by predators
   For potato and cereals, installing flower margins along fields promote a range of natural enemies of pests such as parasitic wasps. The species of flowering plants determine effectiveness of the flower strip, and this differs between regions. In some circumstances flower strips do not provide adequate control. Effectiveness of flower strips in promoting natural enemies strongly depends on the landscape context. The margins may have little effect when sown in landscapes that are scarce in natural habitats (e.g. when field size is large).
8. In perennial crops, habitats for beneficials can be created to promote natural pest control.
   In apple, citrus and olive orchards there is large potential for such natural pest control. Hedgerows have several functions including provided habitat and food for natural enemies such as parasitic wasps, lacewings and ladybugs. They also function as a windshield, which is also beneficial to natural enemies of pests. Hoverflies may lay up to 30% more eggs in apple trees behind hedgerows compared to trees that are not protected by a hedgerow (pcfruit, 2017). Hedgerows also attract birds and bats, which will then also hunt insects in the orchard. Herbal or flower margins complement the function of hedgerows. They also provide food and shelter for natural enemies of pests.
9. Facilitate landscape management for pest control. The adoption of region-wide pest management strategies is a relative new area to be explored. Pest infestation by **colorado potato beetle**, for example, can be reduced by a approach at regional scale. Potato fields should be no closer than 2-3 km from fields that were infested by **colorado potato beetle** in the previous year.

Annex 1: References

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Annex 2: List of experts and intermediaries

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The content and conclusions in this report are entirely the responsibility of CLM.

Annex 3: About CLM

CLM Research and Advice is an independent consultancy working in the field of sustainable farming and food and rural development. CLM provides advice to governments at all levels, from European to local. In addition, CLM works with food and retail companies and for farmers' organisations as well as environmental organisations.

Our advisors work with food multinationals but also with farmers in the field. Staff at CLM have a broad range of substantive expertise on sustainable farming and rural areas, for instance on soil, agro-biodiversity, animal welfare and animal health, water quality, energy, climate impacts, footprint etc. We also have extensive experience in communication and facilitation, building bridges between, for instance, companies and environmental organisations.

Part of our work is of an international nature, at different levels and with different angles. It covers policy advice on EU-level, evaluation of EU-policy in the Netherlands but also international tools for food business and farming. For instance, CLM supports the food industry network SAI-Platform in their quest for more sustainable sourcing.

A CLM-specialty: tools for measuring sustainability
One specialty of CLM is developing practical tools for measuring and benchmarking sustainable farming and food. Examples are:

- Gaia Biodiversity Yardstick, a free online tool for measuring on-farm biodiversity.
- The Pesticide Yardstick, consisting of a free online tool, an offline data analysis and reporting tool and scorecards indicating impacts of all pesticides per crop. The Yardstick has been in use in the Netherlands since 1999, but is also in use in Morocco and the USA.
- CLM has helped build the Cool Farm Tool (CFT), in particular the biodiversity module. The CFT is the first international online tool with broad industry support, for calculating farm-level impacts on carbon, water and biodiversity.
- The Climate scale, an interactive on-line awareness-raising tool, helping consumers understand the climate impact of food, online on the site of the Dutch National Nutrition Centre.

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