Pendimethalin's testament

Impact assessment of the use of pendimethalin in agricultural weed control

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Preface

In 2009, the EU introduced a new Regulation (EC) No. 1107/2009, concerning the placing of plant protection products on the market. Amongst others, this regulation defines more stringent approval criteria for the risk assessment of active substances. This will have consequences for the future availability of active substances currently on the market, as the approval of substances not meeting the criteria may be withdrawn or renewed for a limited period.

Among these active substances is pendimethalin, produced by BASF. Pendimethalin is used in weed control in arable crops and flower bulbs. To obtain insight into the consequences of a potential withdrawal of pendimethalin's approval for Dutch crop production, BASF has asked LEI to perform an impact assessment. This report presents the results of the assessment, which is restricted to farm- and sector-level economic impacts and focuses on onions and flower bulbs as case studies.

The authors would like to thank the experts that have been consulted throughout the project for their willingness to share thoughts and reflect on results. In particular, we acknowledge the contribution of the crop protection advisors who participated in the workshops. We also thank Mrs A. Bulle and Mr H. Hoek from Applied Plant Research, Mr A. Venhuizen from Agrifirm and Mr F. van den Berg from Wiskerke Onions for their expert input, and Mr R. Vijftigschild from Statistics Netherlands for his assistance in data collection.

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Summary

S.1 Important outcomes

Withdrawing the authorisation of pendimethalin decreases the gross margin of onion cultivation with 15 to 17%. For tulip bulbs, gross margin decreases 1 to 5%.

Pendimethalin is commonly used in weed control in onions and flower bulbs, as well as winter cereals and certain outdoor vegetables. (see Chapter 3).

In absence of pendimethalin, growers of onions and tulip bulbs will increase dose rates and spray frequencies, and use substitutes. If this is not possible or causes crop damage, an integrated weed control strategy including hoeing and hand weeding may be applied. In tulip bulb production, an integrated strategy is unfeasible (see Chapter 4).

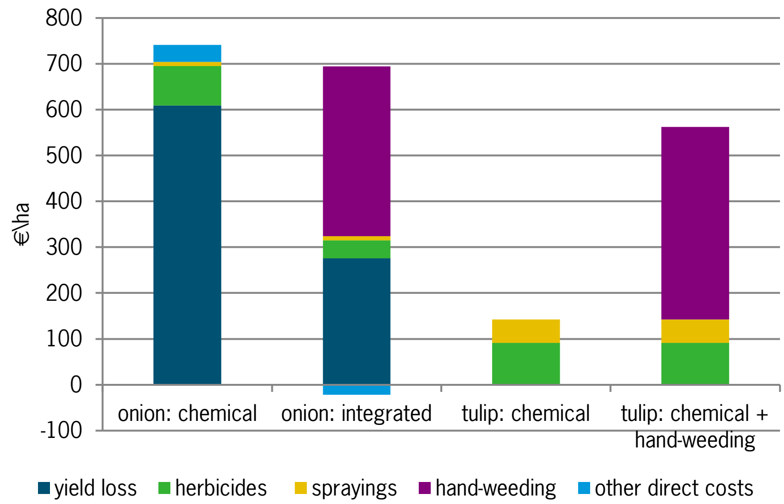
In onions, the loss in gross margin is mainly attributable to yield loss as a result of phytotoxicity, which is partly avoided in an integrated weed control strategy (Figure S.1). For tulip bulbs, losses are solely attributable to increased dosage and frequency of spraying. If additional hand weeding is required, the extra costs of weed control increase fourfold (see Section 5.2.1 and Section 5.3.1).

S.2 Complementary outcomes

The reductions in gross margin cause a loss of €1.5m to €6.2m per year for the tulip bulb sector (see Section 5.3.2). In the onion sector, this loss amounts to €19.7m per year (see Section 5.2.2). While absolute losses per hectare are highest in onions, the relative impact may differ per farm and crop depending on aspects such as cropping plan and cost structure (see Section 6.3).

In flower bulb sectors other than tulip bulb, the number of available herbicides decreases with decreasing total acreage. As a result, the need for hand-weeding, and thus a higher loss in gross margin, becomes more likely (see Section 4.3.3 and Section 5.3.2). In carrots and leeks, expected losses are of similar relative importance as in onions. In winter cereals, sector level losses are estimated at €1.8m per year (see Section 5.4).

Figure S.1 **Costs and benefits of weed control strategies without pendimethalin in onions and tulip bulbs.**



S.3 Method

Due to changes in EU crop protection legislation, the approval of active substances currently on the market may be withdrawn. One active substance for which this possibly applies is pendimethalin. BASF would like to know which economic consequences this will have at farm and sector level and has requested LEI to perform an economic impact assessment (see Section 1.1). The assessment should provide insight into the current position of pendimethalin in weed control, the changes in weed control if its approval would be withdrawn, and the economic impacts of these changes for farmers (see Section 1.2). The impact assessment was performed according to a methodology developed at LEI in a previous, similar study (see Section 1.3). Upon request of BASF, onions and flower bulbs were selected as case studies.

Samenvatting

Het testament van pendimethalin; impact assessment van het gebruik van pendimethalin in agrarische onkruidbestrijding

S.1 Belangrijkste uitkomsten

Intrekking van de toelating van pendimethalin verlaagt het saldo binnen de uienteelt met 15 tot 17%. Bij tulpenbollen daalt het saldo met 1 tot 5%.

Pendimethalin wordt doorgaans gebruikt voor onkruidbestrijding bij uien, bloembollen, wintergranen en bepaalde buitengroenten.

Bij afwezigheid van pendimethalin zullen telers van uien en tulpenbollen de dosering en spuitfrequentie opvoeren en substituten gebruiken. Als dit niet mogelijk is of gewasschade veroorzaakt, kan een geïntegreerde strategie worden toegepast die onder meer uit schoffelen en handwieden bestaat. Bij de teelt van tulpenbollen is een geïntegreerde strategie niet haalbaar.

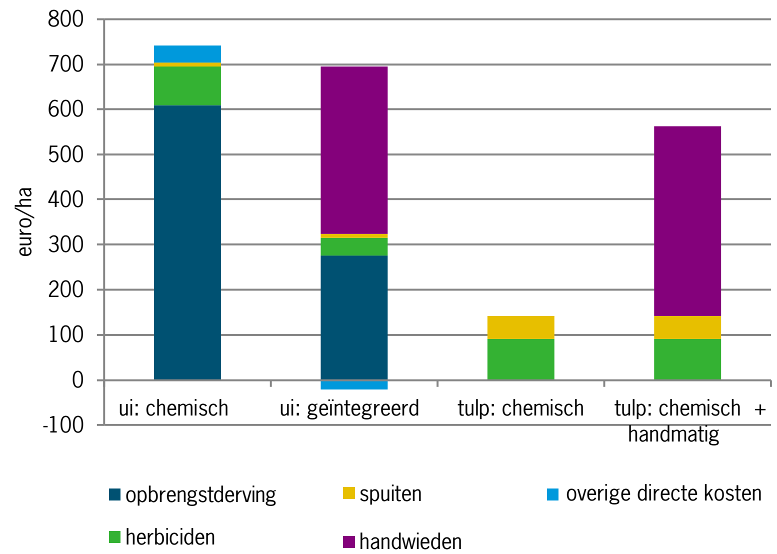
Bij uien wordt het verlies in saldo voornamelijk veroorzaakt door opbrengstderving als gevolg van fytotoxiciteit, die gedeeltelijk wordt vermeden bij een geïntegreerde onkruidbestrijdingsstrategie (afbeelding S.1). Bij tulpenbollen wordt het verlies volledig veroorzaakt door een hogere dosering en spuitfrequentie. Als bovendien handwieden nodig is worden de extra kosten van onkruidbestrijding vier keer zo hoog.

S.2 Overige uitkomsten

De verlaging van het saldo leidt tot een verlies van € 1,5 tot € 6,2 miljoen per jaar voor de tulpenbolsector. In de uiensector bedraagt dit verlies € 19,7 miljoen per jaar. Terwijl het absolute verlies per hectare het hoogste is bij uien, kan het relatieve effect per agrarisch bedrijf en gewas verschillen, afhankelijk van aspecten zoals bouwplan en kostenstructuur.

Bij andere bloembollen (naast de tulpenbol) daalt het aantal beschikbare herbiciden met het totale teeltareaal. Als gevolg hiervan worden de noodzaak van handwieden, en dus een hoger verlies aan saldo waarschijnlijker. Bij wortel en prei is het relatieve verlies naar verwachting van vergelijkbare orde als bij uien. Bij wintergranen wordt het verlies op sectorniveau geschat op € 1,8 miljoen per jaar.

Figuur S.1	Kosten en baten van onkruidbestrijdingsstrategieën zonder pendimethalin bij uien en tulpenbollen



S.3 Methode

Door wijzigingen in Europese wetgeving op het gebied van gewasbescherming kan de toelating van actieve stoffen die momenteel op de markt verkrijgbaar zijn, worden ingetrokken. Pendimethalin is een van de actieve stoffen waarvoor dit mogelijk geldt. BASF wil graag weten welke economische gevolgen dit voor agrarische bedrijven en de sector heeft en heeft LEI verzocht een economische impact assessment uit te voeren.

Deze beoordeling moet inzicht geven in de huidige positie van pendimethalin binnen de onkruidbestrijding, de wijzigingen in onkruidbestrijding als de toelating zou worden ingetrokken en de economische gevolgen van deze wijzigingen voor agrariërs.

De impact assessment is uitgevoerd volgens een methode die in een eerder, gelijksoortig onderzoek door LEI is ontwikkeld. Op verzoek van BASF zijn uien en bloembollen als casestudies geselecteerd.

1 Introduction

1.1 Context and background

In 2009, the new Regulation (EC) No. 1107/2009 concerning the placing of plant protection products on the market entered into force. A major element of this regulation is the introduction of fate and environmental cut-off criteria for risk assessments of active substances. These criteria imply that substances will not be approved if they are considered to be a (1) persistent organic pollutant (POP), (2) persistent bioaccumulative and toxic (PBT) substance, or (3) a very persistent and very bioaccumulative substance (vPvB). Another, ecotoxicological cut-off criterion is that a substance should not be approved if it has an endocrine adverse effect to a non-target organism in the ecotoxicological area, which is not negligible under the proposed conditions of use.

Active substances that are currently approved for use in crop protection products will in principal remain so until the end of the approval period, i.e. they will not be re-evaluated according to the new regulation. An exception is made for substances characterised by the EU as candidates for substitution. These substances are subject to accelerated comparative risk assessment, to evaluate whether the substance can be replaced by an alternative that is safer for human and the environment. Amongst other reasons, substances are qualified as substitution candidate if they meet two of the three PBT criteria mentioned above. Substitution candidates can be approved or renewed for a period of at maximum seven years, as opposed to the default approval and renewal periods of respectively 10 and 15 years. For the moment, it remains unclear which substances will be placed on the substitution list.

One of the active substances that may not be approved anymore under the new regulation is pendimethalin. Pendimethalin is likely to be qualified as a substitution candidate because it possibly meets two out of the three PBT criteria. It may even meet all three criteria, in which case it will not be approved anymore. Pendimethalin is the active substance of the crop protection product Stomp (400) SC, produced by BASF. Stomp is a herbicide currently authorised for the use in many crops, including ware potatoes, cereal crops, maize, flower bulbs, and field vegetables. It is effective against a broad spectrum of weeds and also very selective as it causes no damage to the crop. If the authorisation of Stomp is to be withdrawn, growers in many agricultural sectors will from then on be dependent on alternative herbicides or other measures, such as mechanical weed control. Apart from Stomp, other pendimethalin containing products will be affected as well.

1.2 Research objective

This report aims to provide insight into the economic consequences for agricultural sectors in the Netherlands if pendimethalin will not be approved anymore as active substance. Specifically, economic impacts will be quantified for two Dutch plant production sectors.

To achieve this objective, the following research questions are addressed:

- Which role does pendimethalin currently play in weed control in Dutch crop production?
- How is weed control affected if pendimethalin is omitted from the spraying schedule?
- What are the economic impacts of a change in weed control towards a strategy without pendimethalin?

These research questions are answered quantitatively for the onion and flower bulb production sectors. These sectors were selected by the client based on relevance with respect to use of pendimethalin and relative importance in Dutch crop production. For other sectors using pendimethalin, the questions are addressed in a more qualitative way.

1.3 Approach and demarcations

The approach applied in the current study was developed in a methodological study on impact assessment of a reduction in approved active substances (Van der Knijff et al., 1998). This approach comprises the following steps:

1. Inventory of current use (amount and purpose) of pendimethalin in Dutch agricultural sectors. This is done based on time series data from Statistics Netherlands, LEI's Farm Accountancy Data Network and BASF.

For the two case sectors onions and flower bulbs:

2. Quick scan of the role and relative importance of pendimethalin in weed control. Using expert knowledge on weed control and use instructions of crop protection products, a reconstruction of weed control in onions and flower bulbs was made.

3. Inventory of chemical and non-chemical alternatives for pendimethalin per selected crop-weed(s) combination and definition of the next-best alternative (chemical or technical measure) scenario per crop. Based on a workshop with crop protection advisors, alternative weed control strategies were formulated and cross-checked with the participating advisors as well as crop protection researchers.
4. Quantification of technical and economic consequences at farm level and crop (group) level. Through partial budgeting, costs and benefits were calculated per hectare. Using the output of step 2, these were extrapolated to farm and sector level.

For all sectors:

5. Qualitative extrapolation of the results of the two case studies to other crops and to macro-level. This was done by integrating knowledge on relative and absolute use of pendimethalin in different sectors (including results of step 1), crop sensitivity to weed pressure, and trade and market characteristics of different sectors.
6. Synthesis of results to draw conclusions on the relative importance of pendimethalin in weed control in Dutch crop cultivation and the economic consequences of its withdrawal.

1.4 Outline of the report

The remaining chapters of this report are organised as follows. In Chapter 2, the use of pendimethalin in Dutch agricultural sectors, and in onions and flower bulbs in particular, is characterised. In Chapter 3, alternative strategies weed control without pendimethalin are defined on the basis of a prototype 'reference' strategy representative for the current situation. Chapter 4 provides an overview of the economic impacts of the alternative strategies as compared to the reference strategy, at farm and sector level. Also, impacts for other crops and macro-level are qualitatively addressed. Chapter 5 contains conclusions as well as a discussion on interpretation of results and potential other, non-economic impacts.

2 Method

2.1 Analysis of the status quo

To obtain insight into the current use of pendimethalin in Dutch agriculture, data on the use of pendimethalin in previous years at national, sector, farm and field level were analysed and interpreted. To do so, data were collected from the Dutch Farm Accountancy Data Network (Bedrijveninformatienet, 2013), national survey on pesticide use (Statistics Netherlands, 2013) and BASF (De Bever, 2013). These data sources are complementary, as each has specific strengths and weaknesses regarding this particular type of data:

Table 2.1 Characteristics of data sources

Source	Level of detail	Representativeness	Accuracy	Frequency
FADN	High (data available at farm, field, and regional level)	High for large sectors e.g. onions; low for small (sub)sectors e.g. flower bulbs	High (direct communication with farmers)	Yearly
Pesticide use survey	Moderate (data available at farm and field level) a)	High for all sectors and most subsectors (e.g. specific types of flower bulbs)	Moderate (data collection through questionnaires)	Approx. once in four years
BASF	Low (data available at national level)	Moderate (estimated shares of sectors in total sales)	High (based on actual sales information)	Yearly

a) The Agricultural Census allows for a higher level of detail, but the analyses required for this were not feasible within the available time and resources.

In addition, the use of pendimethalin was qualitatively investigated in terms of its role in weed control management, such as its scope (major weeds to be controlled), relative importance in different sectors, and position with respect to other weed control chemicals.

2.2 Design of weed control strategies

To determine the changes in weed control after withdrawal of the approval of pendimethalin, different weed control strategies were defined. First, a reference strategy was developed, based on analysis of the status quo of pendimethalin, current use of weed control chemicals (data from FADN and Statistics Netherlands), use instructions of crop protection products, and expert knowledge. As weed control varies considerably among the different types of flower bulbs, tulips were selected as a model crop as these cover by far the largest acreage. Results for tulip were then qualitatively extrapolated to other flower bulbs. Regarding onions, weed control is quite comparable among the different subsectors (seed onions, 1^{st} and 2^{nd} year plant onions, silverskin onions).

The strategies were validated in two workshops (one for each case crop), each with three crop protection advisors, who were selected for their expertise in weed control in the respective crop. The crop protection advisors represented different major onion or flower bulb producing areas in the Netherlands and had no conflicts of interest with respect to the research objectives.

In the same workshop, possibilities for weed control without pendimethalin and their consequences for crop yield and quality were discussed. In doing so, two options were explored:

1. Chemical strategy: substitution of pendimethalin with alternative sprayings and higher doses; a risk of this strategy is that crop loss due tophytotoxicity occurs.
2. Integrated strategy: substitution of pendimethalin with alternative sprayings and hand weeding; a risk of this strategy is that weed control is suboptimal.

Based on the acquired information, alternative weed control strategies were designed and validated in an iterative process through (re)consultation of the workshop participants and crop specialists from the Applied Plant Research institutes of Wageningen UR.

2.3 Quantification of economic impacts

A partial budget was developed to quantify the differences in costs and benefits between the reference strategy and alternative strategies. The partial budget was made at field level for a representative farm union or tulip bulb grower in the

Netherlands. It includes the costs of weed control (both chemicals and labour) and revenue of the harvested crop (based on yield and price). Required data were obtained from Quantitative Information on arable crops and outdoor vegetables (KWIN-AGV, 2012) and Quantitative Information on flower bulbs (KWIN-bloembollen, 2005), FADN (Bedrijveninformatienet, 2013), other relevant literature (Hendrix and Looije, 2001; Buurma, 1987), workshop results, and through expert consultation.

To calculate the economic consequences at sector level, the average costs and benefits per hectare are calculated per scenario. *Average* is not the same as *representative*, as the average corrects for the fraction of fields that is sprayed with a particular chemical while a representative farmer either sprays or not. The average costs and benefits per hectare can then easily be extrapolated to sector level by multiplying with the total acreage.

As was the case for the design of control strategies, tulip bulbs are used as a model crop and impacts for other flower bulbs are discussed relative to the results for this crop.

2.4 Extrapolation of results

To get an impression of the impacts at the level of the Dutch economy, results for the onion and flower bulb case studies are qualitatively extrapolated to other sectors based on the qualitative and quantitative characterisation of pendimethalin use in these sectors, as was done in the analysis of the status quo.

3 Status quo

3.1 Introduction

In this section we take the sales data for pendimethalin in the Netherlands as a starting point. These data were provided by BASF and show the volumes used in cereals, flower bulbs, onions and vegetables. Then for onions and flower bulbs a reconstruction of the use is made in terms of crop areas and dose rates, using data from Statistics Netherlands and the Farm Accountancy Data Network of LEI.

3.2 Use of pendimethalin at national level

BASF provided data on the volumes of Stomp 400SC sold over the years 2005-2012 and the percentages of four crop groups in the total. Starting from these data we calculated the active ingredient use (a.i.) in the four crop groups. The result is presented in Table 3.1.

Table 3.1 **Use (kg a.i.) of pendimethalin per year and crop group in the Netherlands over the years 2005-2012**

Year	Cereals	Flower bulbs	Onions	Vegetables	Total
2005	n.a.	n.a.	n.a.	n.a.	33,720
2006	n.a.	n.a.	n.a.	n.a.	48,720
2007	n.a.	n.a.	n.a.	n.a.	46,080
2008	12,628	17,794	21,812	5,166	57,400
2009	20,046	13,561	20,046	5,306	58,960
2010	13,851	11,962	31,480	5,666	62,960
2011	24,738	12,768	35,112	7,182	79,800
2012	17,300	19,300	31,652	6,948	77,200

Source: BASF + calculation LEI.

The active ingredient use of pendimethalin increased from 33,720 kg in 2005 to 79,800 kg in 2011. The increase in 2006 results from the authorisation in flower bulbs in October 2005. Onions have a share of 35-45% in the total. Flower bulbs have a share of 20-25%.

3.3 Use of pendimethalin in onions

The use of pendimethalin in onions depends on crop area, share of crop area treated and dose rate. Crop areas were extracted from the Agricultural Census of Statistics Netherlands. Shares of crop areas treated and dose rates were derived from the Farm Accountancy Data Network of LEI. The results for 2003, 2007, 2011 and 2012 are presented in Table 3.2.

Table 3.2 Reconstruction of pendimethalin use in onions in the Netherlands

Year	Crop area (ha)	Share treated (%)	Area treated (ha)	Dose rate (kg/ha)	Use (kg of a.i.)
2003	23,243	98.4	22,871	0.89	20,355
2007	26,178	96.2	25,183	0.98	24,680
2011	29,841	96.4	28,767	1.18	33,945
2012	27,234	98.2	26,744	1.18	31,558

Source: Statistics Netherlands and Farm Accountancy Data Network of LEI.

About 96-98% of the crop area is treated with pendimethalin. The crop areas and the dose rates increased in the period 2003-2011. As a result the use of pendimethalin increased correspondingly.

3.4 Use of pendimethalin in flower bulbs

As in onions, the use of pendimethalin in flower bulbs depends on crop area, share of crop area treated and dose rate. Crop areas are extracted from the Agricultural Census of Statistics Netherlands. Shares of crop areas treated and dose rates are derived from the national survey on pesticide use.

The shares of crop areas treated in the survey were corrected for a shortcoming due to the recording system. The respondents were invited to record their pesticide applications in monthly forms from January till December. Most flower bulb crops are planted in autumn and in a considerable part of the cases pendimethalin is applied shortly after planting. Thus the early applications (before January) escape from the survey. The shares treated were increased to levels that are needed to meet the BASF sales data for flower bulbs. The results for 2008 and 2012 are presented in Table 3.3 and Table 3.4.

Table 3.3	Reconstruction of pendimethalin use in flower bulbs in the Netherlands in 2008				
Crop	**Crop area (ha)**	**Share treated (%)**	**Area treated (ha)**	**Dose rate (kg/ha)**	**Use (kg of a.i.)**
Tulip	11,390	88.3	10,062	0.79	7,988
Lily	4,970	90.2	4,485	0.80	3,583
Daffodil	1,974	95.6	1,886	0.78	1,472
Hyacinth	1,383	92.8	1,283	0.77	992
Gladiolus	1,167	90.6	1,057	0.83	875
Crocus	534	92.0	491	0.80	393
Iris	415	92.1	382	0.84	319
Others	2,497	90.0	2,247	0.80	1,798
Total	*24,330*		*21,895*		*17.420*

Bron: Statistics Netherlands + calculations LEI.

Table 3.4	Reconstruction of pendimethalin use in flower bulbs in the Netherlands in 2012				
Crop	**Crop area (ha)**	**Share treated (%)**	**Area treated (ha)**	**Dose rate (kg/ha)**	**Use (kg of a.i.)**
Tulip	11,248	97.1	10,920	0.83	9,103
Lily	5,090	97.6	4,966	0.84	4,165
Daffodil	1,777	98.9	1,757	0.82	1,439
Hyacinth	1,448	98.2	1,422	0.81	1,154
Gladiolus	1,113	97.7	1,087	0.87	945
Crocus	400	98.0	392	0.84	329
Iris	288	98.0	282	0.88	248
Others	2,124	97.5	2,071	0.84	1,740
Total	*23,488*		*22,897*		*19,123*

Bron: Statistics Netherlands + calculations LEI.

The use of pendimethalin in flower bulb production increased from 17,240 kg in 2008 to 19,123 in 2012. The increase is due to higher area shares treated and higher dose rates. Pendimethalin was first applied in flower bulbs in 2006 (after authorisation in October 2005). This may explain why the area shares treated in 2008 were still closer to 90% than to 100% (as in 2012).

3.5 Use of pendimethalin in other crop groups

In addition to onions and flower bulbs, pendimethalin is applied to control weeds in winter cereals and in outdoor vegetables. The use (kg of a.i.) in these crop groups was already specified in Table 3.1. According to this table the winter cereals accounted for 25% of total use of pendimethalin and vegetables for 10%.

The national survey on pesticide use in 2008 reported a minor use of pendimethalin in these crop groups, which conflicts with the data from BASF. The difference is explained by the bias in the survey recording system towards crops planted in autumn, which was already explained in the section on flower bulbs. Winter cereals include winter wheat and winter barley. According to farm advisers the use of pendimethalin in these crops amounts to 50% of the crop areas.

The most important outdoor vegetables with application of pendimethalin are winter carrots, wash carrots and leeks. The use of pendimethalin in these crops is specified in Table 3.5 and Table 3.6. The data from Statistics Netherlands on these crops were corrected for omissions in the recording system, analogous to the system applied for flower bulbs in Section 3.4.

The use of pendimethalin in outdoor vegetable crops increased from 5,192 kg in 2008 to 6,954 kg in 2012. The increase is due to higher area shares treated and higher dose rates in 2012 compared to 2008.

Table 3.5 **Reconstruction of pendimethalin use in outdoor vegetables in the Netherlands in 2008**

Crop	Crop area (ha)	Share treated (%)	Area treated (ha)	Dose rate (kg/ha)	Use (kg of a.i.)
Winter carrots	5,286	82,0	4.333	0.72	3.112
Wash carrots	2,379	73,6	1.751	0.68	1.188
Leeks	3,012	85,8	2,583	0.35	893
Total	*10,677*		*8.666*		*5.192*

Source: Statistics Netherlands + calculations LEI.

Table 3.6	**Reconstruction of pendimethalin use in outdoor vegetables in the Netherlands in 2012**				
Crop	**Crop area (ha)**	**Share treated (%)**	**Area treated (ha)**	**Dose rate (kg/ha)**	**Use (kg of a.i.)**
Winter carrots	6,176	91,0	5,619	0.82	4,612
Wash carrots	2,196	86.8	1,906	0.78	1,478
Leeks	2,426	90.1	2,187	0.40	864
Total	*10,798*		*9,712*		*6,954*

Source: Statistics Netherlands + calculations LEI.

4 Weed control strategies

4.1 Introduction

This chapter presents different weed control strategies for onions and flower bulbs. For each of the crops, a reference strategy including pendimethalin represents current practice. In addition, two alternative strategies for weed control in absence of pendimethalin are discussed, one of which follows a chemical approach and the other an integrated approach.

4.2 Weed control in onions

4.2.1 Reference strategy

Table 4.1 comprises a spray schedule of current average weed control in onions. The schedule represents the average spray schedule for weed control in onions, either sown or planted. This average follows from 100 observations in the Farm Accountancy Data Network of LEI in 2011 and represents a normal distribution due to differences in farm management, soil type (sandy or clay soil), weed pressure, previous crop, etc. In this reference strategy, pendimethalin is applied in three out of nine sprays, in the following crop stages:

- Pre-emergence stage
- First true leaf stage
- Second true leaf stage

In fact pendimethalin contributes to a good alternation with other herbicides like chlorpropham, chloridazon and ioxynil-octanoate. These herbicides together offer an effective and adequate line of defence against the different weed types. Pendimethalin and chlorpropham are especially effective in controlling annual weeds, chloridazon effectively controls a broad spectrum of weeds and ioxynil-octanoate effectively controls annual dicotyledons. Most sprays comprise combinations of two, three or four products. In the younger stages the onion plants are susceptible to herbicide damage. For that reason the dose rates and numbers of products applied in one spray are mostly kept lower. An exception to this rule is chlorpropham. Chlorpropham is considered mild for onions, and therefore applied at relatively high dose rates during the flag leaf stage.

Table 4.1 Current spray schedule for chemical weed control in onions in the Netherlands

Crop stage	Weed type	Compound	Product (e.g.)	Dose rate (l/ha)	Area share (%)	# Sprays
Pre-emergence	Annual weeds	pendimetalin	Stomp 400SC	1.25	100	1.0
	Weeds	glyphosate	Glyphosaat 2	3.00	50	
Radicle stage	Annual weeds	chlorpropham	Chloor IPC	0.50	80	0.8
	Weeds	chloridazon	Pyramin DF	0.25	80	
	Annual dicotyledons	ioxynil-octanoate	Totril	0.15	80	
Flag leaf stage	Annual weeds	chlorpropham	Chloor IPC	1.00	80	0.8
1st true leaf, 3 cm	Annual weeds	pendimethalin	Stomp 400 SC	1.00	80	0.8
	Weeds	chloridazon	Pyramin DF	0.25	80	
	Annual dicotyledons	ioxynil-octanoate	Totril	0.25	80	
1st true leaf, 3-6 cm	Annual weeds	chlorpropham	Chloor IPC	0.50	80	0.8
	Annual weeds	s-metalochlor	Dual Gold 960EC	0.50	80	
	Annual dicotyledons	pyridate	Lentagran	0.40	80	
2nd true leaf	Annual weeds	pendimethalin	Stomp 400SC	1.00	80	0.8
	Weeds	chloridazon	Pyramin DF	0.50	80	
	Annual weeds	bentazon	Basagran	0.75	80	
	Annual dicotyledons	ioxynil-octanoaat	Totril	0.50	80	
3rd true leaf + later	Weeds	chloridazon	Pyramin DF	1.00	80	0.8
	Annual weeds	s-metalochlor	Dual gold 960EC	0.50	80	
3rd true leaf + later	Annual weeds	prosulfocarb	Boxer	2.50	60	0.6
Full crop stage	Grasses	cycloxidim	Focus Plus	2.00	20	1.0
	Grasses	tepraloxydim	Aramo	1.50	80	
						7.4

Table 4.2	Spray schedule for chemical weed control without pendimethalin in onions (alternative 1)					
Crop stage	**Weed type**	**Compound**	**Product (e.g.)**	**Dose rate (l/ha)**	**Area share (%)**	**# Sprays**
Pre-emergence	~~Annual weeds~~ Weeds	~~pendimethalin~~ glyphosate	~~Stomp 400SC~~ Glyphosaat 2	~~1.25~~ 4.00	~~100~~ 50	~~1.0~~ 0.5
Radicle stage	Annual weeds Weeds Annual dicotyledons	chlorpropham chloridazon ioxynil-octanoate	Chloor IPC Pyramin DF Totril	1.00 0.25 0.15	80 80 80	0.8
Flag leaf stage	Annual weeds	chlorpropham	Chloor IPC	1.00	80	0.8
1st true leaf, 3 cm	~~Annual weeds~~ Weeds Annual dicotyledons	~~pendimethalin~~ chloridazon ioxynil-octanoate	~~Stomp 400SC~~ Pyramin DF Totril	~~1.00~~ 0.25 0.25	~~80~~ 80 80	0.8
1st true leaf, 3-6 cm	Annual weeds Annual weeds Annual dicotyledons	chlorpropham s-metalochlor pyridate	Chloor IPC Dual Gold 960EC Lentagran	1.00 0.50 0.40	80 80 80	0.8
2nd true leaf	~~Annual weeds~~ Weeds Annual weeds Annual dicotyledons	~~pendimethalin~~ chloridazon bentazon ioxynil-octanoaat	~~Stomp 400SC~~ Pyramin DF Basagran Totril	~~1.00~~ 0.75 1.00 0.50	~~80~~ 80 80 80	0.8
2nd true leaf	Annual weeds Annual weeds Annual dicotyledons	chlorpropham s-metalochlor pyridate	Chloor IPC Dual Gold 960EC Lentagran	1.00 0.50 0.50	80 80 80	0.8
3rd true leaf + later	Weeds Annual weeds	chloridazon s-metalochlor	Pyramin DF Dual gold 960EC	1.00 0.50	80 80	0.8
3rd true leaf + later	Annual weeds	prosulfocarb	Boxer	2.50	60	0.6
Full crop stage	Grasses Grasses	cycloxidim tepraloxydim	Focus Plus Aramo	2.00 1.50	20 80	1.0
						7.7

Table 4.3	Spray schedule for chemical weed control without pendimethalin in onions (alternative 2)					
Crop stage	**Weed type**	**Compound**	**Product (e.g.)**	**Dose rate (l/ha)**	**Area share (%)**	**# Sprays**
Pre-emergence	~~Annual weeds~~	~~pendimethalin~~	~~Stomp 400SC~~	~~1.25~~	~~100~~	~~1.0~~
	Weeds	glyphosate	Glyphosaat 2	3.00	50	0.5
Radicle stage	Annual weeds	chlorpropham	Chloor IPC	0.50	80	0.8
	Weeds	chloridazon	Pyramin DF	0.25	80	
	Annual dicotyledons	ioxynil-octanoate	Totril	0.15	80	
Flag leaf stage	Annual weeds	chlorpropham	Chloor IPC	1.00	80	0.8
1st true leaf, 3 cm	~~Annual weeds~~	~~pendimethalin~~	~~Stomp 400SC~~	~~1.00~~	~~80~~	0.8
	Weeds	chloridazon	Pyramin DF	0.25	80	
	Annual dicotyledons	ioxynil-octanoate	Totril	0.25	80	
1st true leaf, 3-6 cm	Annual weeds	chlorpropham	Chloor IPC	0.50	80	0.8
	Annual weeds	s-metalochlor	Dual Gold 960EC	0.50	80	
	Annual dicotyledons	pyridate	Lentagran	0.40	80	
2nd true leaf	~~Annual weeds~~	~~pendimethalin~~	~~Stomp 400SC~~	~~1.00~~	~~80~~	0.8
	Weeds	chloridazon	Pyramin DF	0.50	80	
	Annual weeds	bentazon	Basagran	0.75	80	
	Annual dicotyledons	ioxynil-octanoaat	Totril	0.50	80	
2nd true leaf	Annual weeds	chlorpropham	Chloor IPC	1.00	80	0.8
	Annual weeds	s-metalochlor	Dual Gold 960EC	0.50	80	
	Annual dicotyledons	pyridate	Lentagran	0.50	80	
3rd true leaf + later	Weeds	chloridazon	Pyramin DF	1.00	80	0.8
	Annual weeds	s-metalochlor	Dual gold 960EC	0.50	80	
3rd true leaf + later	Annual weeds	prosulfocarb	Boxer	2.50	60	0.6
Full crop stage	Grasses	cycloxidim	Focus Plus	2.00	20	1.0
	Grasses	tepraloxydim	Aramo	1.50	80	
						7.7

Not all farmers are applying weed control in all stages. Depending on the weed pressure and the weed spectrum in the field they may skip one or two control options in the course of the growing season. On average the onion grower applies 7.4 herbicides sprays in a season. The average use (in kg of a.i.) amounts to 6.1 kilogram.

Most farmers apply one time of hoeing in the 3rd true leaf stage. This operation is meant to improve aeration of the soil and to complete weed control.

4.2.2 Alternatives

Chemical strategy
Table 4.2 shows the chemical strategy (as mentioned in section 2.2) for weed control without pendimethalin (~~strikethrough~~) in onions. The idea behind this strategy is prevention of weed growth in the crop as much as possible. For that reason the dose rates of some herbicides were increased and an additional herbicide spray (<u>underlined</u>) was included. This increase and addition should fill the gaps which are left behind by pendimethalin. As a result the volume of active ingredients used increases from 6.1 kg per ha in the current situation to 6.5 kg per ha in the alternative situation. In addition one time of hoeing is applied in the 3rd true leaf stage to improve soil aeration and to remove the last weeds.

Integrated strategy
Table 4.3 shows the integrated strategy (as mentioned in section 2.2) for weed control without pendimethalin (~~strikethrough~~) in onions. The idea behind this strategy is that the onion grower accepts some mechanical weed control rather than accepting yield loss resulting from phytotoxic side-effects of high dose rates. For that reason the dose rates of the herbicides applied in Table 4.2 are reduced to their current levels. The extra herbicide application in the 2nd true leaf stage (<u>underlined</u>) is maintained. The eventual gaps in weed control will be filled through hoeing (end of 2nd leaf stage and end of 3rd leaf stage) or hand weeding (beginning of full crop stage). As a result the amount of active ingredients used decreases from 6.1 kg per ha in the current situation to 5.6 kg per ha in the alternative situation.

4.3 Weed control in flower bulbs

4.3.1 Reference strategy for tulips

Table 4.4 comprises the spray schedule that is representative for current weed control in tulips. The schedule is representative for an average tulip bulb production field in the Netherlands, although deviations will appear in practice due to differences in farm management, soil type (sandy or clay soil), crop rotation plan, etc. In this reference strategy, pendimethalin has a central position in pre-emergence weed control, together with glyphosate and/or gluphosinate. Pendimethalin inhibits the germination of annual weed seeds. Glyphosate and gluphosinate remove the weeds that are already present before the emergence of the onions. Applying this spraying scheme results in adequate control of weeds.

Since May 2011, another product is on the market for pre-emergence weed control in tulips, which has dimethanamid-P as active ingredient. As this product was only recently authorised, no representative data are available on its use in the tulip production sector, and the product is not included in the reference spray schedule.

Table 4.4 **Spray schedule for chemical weed control with pendimethalin in flower bulbs (reference strategy)**

Crop stage	Weed type	Compound	Product (e.g.)	Dose rate (l/ha)	Area share (%)	# Sprays
pre-emergence	Annual weeds	pendimethalin	Stomp 400 SC	2.00	100	1.0
pre-emergence	weeds	gluphosinate	Basta 200	1.00	10	1.0
pre-emergence	weeds	glyphosate	Glyphosate 2	5.00	90	
emergence	Annual weeds	chlorpropham	Chloor IPC	2.00	80	0.8
emergence	Annual weeds	s-metalochlor	Dual Gold 960 EC	1.50	80	0.8
emergence	Annual weeds	metamitron	Goltix 70 WG	0.25 a)	20	0.2
emergence	dicotyledons	chloridazon	Pyramin DF	2.00	80	0.8
Early post-emergence	Annual weeds	chlorpropham	Chloor IPC	2.00	80	0.8
Early post-emergence	dicotyledons	asulam	Asulox	4.00	80	0.8
Late post-emergence	Annual/perennial weeds	cycloxydim	Focus Plus	1.00	40	0.4
						6.6

a) Dose rate lower than advised as metamitron is applied locally in the field.

Table 4.5	Spray schedule for chemical weed control without pendimethalin in flower bulbs (alternative 1)					
Crop stage	**Weed type**	**Compound**	**Product (e.g.)**	**Dose rate (l/ha)**	**Area share (%)**	**# Sprays**
~~pre-emergence~~	~~Annual weeds~~	~~pendimethalin~~	~~Stomp 400 SC~~	~~2.00~~	~~100~~	~~1.0~~
pre-emergence	weeds	gluphosinate	Basta 200	1.00	10	1.0
pre-emergence	weeds	glyphosate	Glyphosate 2	5.00	90	
pre-emergence	Annual weeds	dimethenamid-P	Spectrum	1.40	90	0.9
pre-emergence	Annual weeds	chlorpropham	Chloor IPC	2.00	90	0.9
emergence	Annual weeds	chlorpropham	Chloor IPC	2.00	90	0.9
emergence	Annual weeds	s-metalochlor	Dual Gold 960 EC	1.50	90	0.9
emergence	Annual weeds	metamitron	Goltix 70 WG	0.25	20	0.2
emergence	dicotyledons	chloridazon	Pyramin DF	2.00	90	0.9
Early post-emergence	Annual weeds	chlorpropham	Chloor IPC	2.00	90	0.9
Early post-emergence	dicotyledons	asulam	Asulox	4.00	90	0.9
Late post-emergence	Annual/perennial weeds	cycloxydim	Focus Plus	1.00	40	0.4
Late post-emergence	Annual/perennial weeds	tepraloxydim	Aramo	1.50	40	0.4
						8.3

4.3.2 Alternatives for tulips

Chemical strategy

Effective pre-emergence weed control is crucial for weed control at later stages of the growing season. To compensate for the absence of pendimethalin, four alternative sprayings are applied, while application of chloridazon is reduced to one spraying due to overlap with the included sprayings.

On most fields, the spray schedule is considered to be as effective in weed control as the reference scheme. On fields with a relatively high weed pressure, however, additional hand-weeding may be required. It takes approximately 72 hours (Buurma, 1987) to hand weed one hectare of flower bulbs once. Experts expect on average minimal crop damage due to phytotoxicity, although incidental qualitative yield loss (smaller bulb sizes) may occur.

Integrated strategy

Reduction of the number of applications compared to the chemical control strategy will lead to increased weed pressure. Particularly in flower bulb production, weeds are very undesirable, as they have a number of negative effects:

- Yield reduction (smaller bulb size) due to competition with weeds; smaller bulb sizes are not marketable so a larger fraction of bulbs needs to be replanted in the next year;
- Increased virus pressure due to presence of host weeds; most flower bulbs are sold as propagation material on the condition that they are virus-free;
- Harvesting and post-harvest activities (drying, sorting) are more time-consuming, require extra energy (gas), and cause more damage to the bulbs;
- Nematode populations are maintained or increased due to presence of host weeds; as a consequence, fields decrease in value or can less easily be hired for flower bulb production;
- Production in nets becomes complicated because the roots of weeds grow through the nets. Also, recycling of nets becomes infeasible.

As these effects are unacceptable for flower bulb growers, additional mechanical or hand weeding is inevitable. Flower bulbs are grown on flower beds in which mechanical weeding is not feasible. Thus, an integrated strategy will require intensive hand-weeding several times during the growing season. Growers are not very keen on this, not only because of corresponding labour costs but also because the work is physically demanding and labour capacity is difficult to find. Therefore, the integrated strategy is considered not realistic for flower bulbs.

4.3.3 Strategies in other flower bulbs

Tables 4.6 and 4.7 show the active ingredients that are (or can be) applied at different stages of flower bulb cultivation in the Netherlands, under the current and alternative strategy. As can be seen in the two bottom rows, the number of active ingredients available throughout the growing season decreases with crop acreage.

In tulips, a withdrawal of pendimethalin is largely compensated by adding dimethenamid-P and chlorpropham in the pre-emergence stage. Dimethenamid-P is not approved in other flower bulbs, while the use of chlorpropham is restricted to two times per season in lily, hyacinth and gladiolus. Particularly in the latter two of these crops, the spectrum of active ingredients is already quite narrow. In these crops, fewer (post-) emergence weed control options are available. Removing pendimethalin from the spray schedule in these crops will make weed control more sensitive to critical timing (humidity, temperature) and application of remaining pre-emergence treatments. Including aramo later in the season will only give some relief on part of the acreage, as already illustrated in the alternative spray scheme of tulip bulbs.

On the other hand, the limited availability of active ingredients for weed control in the 'smaller' flower bulbs is not new. Thus far, damage due to weed pressure in these crops did not structurally differ from that in other flower bulbs. Daffodils, hyacinths and crocuses are mainly grown in the dunesand area, in rotation with tulips. An effective weed control in tulips will thus at least partly compensate for any reduced effectiveness of weed control in these crops.

Overall, we conclude that for all flower bulbs, active substances remain available at each crop stage. Nevertheless, effective weed control will become increasingly dependent on craftsmanship and good spray practices based on years of experience. Where this is lacking, a narrower spectrum of active substances will more frequently require additional hand weeding.

Table 4.6 **Herbicide applications currently authorized in different stages of flower bulb cultivation**

Crop stage	Weed type	Compound	Product (e.g.)	tulip	lily	daffodil	hyacinth	gladiolus	crocus	iris
pre-emergence	Annual weeds	pendimethalin	Stomp 400 SC	x	x	x	x	x	x	x
pre-emergence	weeds	gluphosinate	Basta 200	x	x	x	x	x	x	x
pre-emergence	weeds	glyphosate	Glyphosate 2	x	x	x	x	x	x	x
pre-emergence	Annual weeds	dimethenamid-P[1]	Spectrum	x						
emergence	Annual weeds	chlorpropham	Chloor IPC	x	x	x	x	x	x	x
emergence	Annual weeds	s-metalochlor	Dual Gold 960 EC	x	x					
emergence	Annual weeds	metamitron	Goltix 70 WG	x	x	x				x
emergence	dicotyledons	chloridazon	Pyramin DF	x	x	x	x	x	x	x
Early post-emergence	Annual weeds	chlorpropham	Chloor IPC	x	x	x	x	x	x	x
Early post-emergence	Annual weeds	metamitron	Goltix 70 WG		x					
Early post-emergence	Annual weeds	fenmedifam	Kontakt 320 SC							x
Early post-emergence	dicotyledons	asulam	Asulox	x	x		x			
	Broadleaf weeds	MCPA	MCPA					x		
Late post-emergence	Annual/perennial weeds	cycloxydim	Focus Plus	x	x	x	x	x	x	x
# applications				11	11	8	8	8	7	9

Table 4.7 **Herbicide applications currently authorised in different stages of flower bulb cultivation, in absence of pendimethalin.**

Crop stage	Weed type	Compound	Product (e.g.)	tulip	lily	daffodil	hyacinth	gladiolus	crocus	iris
~~pre-emergence~~	~~Annual weeds~~	~~pendimethalin~~	~~Stomp 400 SC~~	~~x~~	~~x~~	~~x~~	~~x~~	~~x~~	~~x~~	~~x~~
pre-emergence	weeds	gluphosinate	Basta 200	x	x	x	x	x	x	x
pre-emergence	weeds	glyphosate	Glyphosate 2	x	x	x	x	x	x	x
pre-emergence	Annual weeds	dimethenamid-P	Spectrum	x						
pre-emergence	Annual weeds	chlorpropham	Chloor IPC	x	x	x	x	x	x	x
emergence	Annual weeds	chlorpropham	Chloor IPC	x	x	x	x	x	x	x
emergence	Annual weeds	s-metalochlor	Dual Gold 960 EC	x	x					
emergence	Annual weeds	metamitron	Goltix 70 WG	x	x	x				x
emergence	dicotyledons	chloridazon	Pyramin DF	x	x	x	x	x	x	x
Early post-emergence	Annual weeds	chlorpropham	Chloor IPC	x	~~x~~	x	~~x~~	~~x~~	x	x
Early post-emergence	*Annual weeds*	metamitron	Goltix 70 WG		x					
Early post-emergence	*Annual weeds*	fenmedifam	Kontakt 320 SC							x
Early post-emergence	dicotyledons	asulam	Asulox	x	x		x			
	Broadleaf weeds	MCPA	MCPA					x		
Late post-emergence	Annual/perennial weeds	cycloxydim	Focus Plus	x	x	x	x	x	x	x
Late post-emergence	Annual/perennial weeds	tepraloxydim	Aramo	x		x	x	x		
# applications				12	10	9	8	8	7	9

5 Economic impacts

5.1 Introduction

In chapter 4, different weed control strategies with and without pendimethalin were described. Here, we present the economic impacts of the strategies without pendimethalin as compared to their reference strategy including pendimethalin. In Section 5.2 and Section 5.3, farm and sector level impacts are calculated for onions and flower bulbs (specified for tulips). Section 5.4 discusses the impacts for other crops.

5.2 Impacts for onion cultivation

5.2.1 Farm level

Farm level economic impacts were quantified for seed onions, 1st year plant onions, 2nd year plant onions and silverskin onions. A partial budget was developed in which changes in the following in costs and benefits were considered:
- Revenue, based on yield quantity and quality (size grade);
- Seed costs;
- Chemical costs;
- Machinery and equipment costs (including fuel) for weed control;
- Labour costs (chemical, mechanical and hand weeding) for weed control;
- Drying and storage costs;
- Sales costs;

The costs of fertilisers, pest control, custom work and other direct costs do not vary between the strategies.

Table 5.1 provides an overview of the average gross margin for seed onions per hectare under the reference strategy and the two alternative strategies.

Table 5.1	**Gross margin of seed onions in three scenarios (in €/ha)**			
	Units	**Reference Strategy**	**Alternative 1: chemical control**	**Alternative 2: integrated control**
Revenue				
Yield	Kg/ha	64,750	59,075	62,265
Onions >60mm	%	36%	44%	38%
Price	€/ha	12.04	12.16	12.07
Total returns	€/ha	7,793	7,184	7,517
Costs				
Weed control				
- Herbicides	€/ha	317	403	356
- Spraying	€/ha	222	231	231
- Hand weeding and hoeing	€/ha	150	150	520
Seeds		860	946	860
Energy		611	575	595
Sales costs		139	126	133
Other direct costs	€/ha	1,144	1,144	1,144
Total direct costs	*€/ha*	*3,443*	*3,575*	*3,678*
Gross margin	*€/ha*	*4,350*	*3,609*	*3,678*
Difference	€/ha		-741	-672
In % gross margin	*%*		*-17%*	*-15%*

Reference strategy

Seeds are sown at an initial density of 90 plants per m^2. Due to the 'normal' phytotoxicity of the usual weed control chemicals approximately 15% of the plants does not survive. It is assumed that any growth reduction can be compensated by extending the growing season (Hoek, 2013).

The harvested yield is estimated at 64.750 kg per ha. The long-term average price is €12.00 per 100 kg. Based on consultation of market experts, the prices of coarse onions (>60mm) and fine onions (<60mm) were set at €13.00 per 100 kg and €11.50 per 100 kg, respectively (Van den Berg, 2013). This yields an average return of €7,793 per ha.

The costs for weed control, assuming the commercial products mentioned in chapter 4 as example, add up to €689. This value is composed of chemical costs (€299), application costs (€270) and costs of some mechanical hoeing and hand weeding (€150).

Including the other direct costs such as fertiliser costs and storage costs, the total direct costs for growing seed onions add up to €3,443 per ha. The gross margin, defined as the difference between the total returns and the direct costs, is €4,350 per ha.

Alternative 1: chemical strategy

The use of more chemicals and higher dosages increases the risk of phytotoxicity, leading to damage of onion plants. Moreover, since the weed control spectrum is narrower compared to the reference strategy, more sprayings are required (as shown in chapter 4) and particular weeds may survive.

The increased phytotoxicity will lead to a substantial yield reduction. On the other hand size grade of the onions will change towards coarser onions, which is favourable for the price setting. According to crop protection advisors, it may be assumed that a grower will sow 10% more seeds to anticipate on the foreseen loss of plants. The net effect is an estimated yield reduction of about 9% as compared to the reference strategy, while the fraction of coarse onions increases to 44% (Table 5.1). Total return is expected to reduce with €600 per ha (-8%). The costs will increase as expenses for weed control and for seeds will be higher. Small cost savings are experienced for drying, storage and transport due to lower yields. The net effect on gross margin is a reduction of €741 per ha, which equals 17%.

The financial effects for first and second year plant onions and for silverskin onions are derived from the calculations for seed onions. Assumed is that the same weed control strategy is carried out and the same relative yield reduction is incurred. For first year plant onions the lack of pendimethalin leads to a lower financial return (€568 per ha), higher costs for weed control (€95 per ha) and lower other direct costs (€21 per ha). The total negative effect is calculated at €642 per ha. For second year plant onions the lack of pendimethalin also leads to lower financial returns (€570 per ha), higher costs for plants (€105 per ha), weed control (€95 per ha) and lower other direct costs (€15 per ha). The total negative effect is calculated at €755 per ha.

For silverskin onions a lower financial return (€526 per ha) and higher costs for weed control (€95 per ha) are expected. The total negative effect is calculated at €621 per ha.

Alternative 2: integrated strategy

When applying the spray schedule for alternative 2 as developed in chapter 4, substantially more weeds will survive. In order to destroy the weeds an extra mechanical control is done, consisting of hoeing between the rows and weeding by hand within the rows. In addition, it is assumed that two times hand weeding are required, each of which takes about 35-40 hours per ha.

Table 5.1 shows that the yield in this scenario will not drop as much as is does in scenario 2. That total returns are estimated at €7,517 per ha; this is about halfway between the other two scenarios.

The total costs for weed control add up to €1,107 per ha, which is much more than in the other two strategies due to the hand weeding. However, less extra seed needs to be bought due to lower phytotoxicity levels than in alternative strategy 1. Total direct costs are €3,839 , and the gross margin equals €3,678 per ha. With a total loss of €672 per hectare compared to the reference, this strategy performs slightly better than alternative 1.

For first year plant onions and silverskin onions hoeing and hand weeding are very difficult to realise, so the integrated strategy is not calculated.
For second year plant onions the same strategy is defined as for seed onions. This leads to a financial loss of €802 per ha (lower yield: 249, higher weed control costs: 568, more young plants: 105 and less other costs:-15)

5.2.2 Sector level

The consequences on sector level are calculated by multiplying the Dutch areas of different onion types by the effects per ha on farm level (Scenario 2 compared with scenario 1). The total financial losses from withdrawal of pendimethalin are estimated at €19.7m (table 5.2).

We can express these losses relative to the total volume of pendimethalin. Based on a use of 31,652 kg active ingredient, the value of 1 kg pendimethalin for the onion production sector was €622 in 2012.

Table 5.2	**Economic impact of a ban of pendimethalin for onion cultivation, at farm and sector level.**				
	Seed onions	**1st year plant onions**	**2nd year plant onions**	**Silverskin onions**	**Total onions**
Area (2012)	21,000	1,500	4,300	400	27,200
% with use of pendimethalin	98.20%	98.20%	98.20%	98.20%	
Chemical strategy					
Farm level (€/ha)	-741	-642	-755	-621	
Sector level (€1,000)	-15,300	-1,000	-3,200	-200	-19,700
Integrated strategy					
Farm level (€/ha)	-672	n/a	-802	n/a	
Sector level (€)	-13,800	n/a	-3,400	n/a	n/a

5.3 Impacts for flower bulb cultivation

5.3.1 Farm level

Farm level economic impacts were quantified for tulip bulbs, and qualitatively extrapolated to other bulbs. A partial budget was developed which includes changes in the following costs and benefits:

- Net revenue following from marketable crop yield;
- Chemical costs;
- Machinery and equipment costs (including fuel);
- Labour costs (chemical and hand weeding);

The costs of planting material, fertilisers, pest control, energy for field work, drying and storing, sales costs, custom work and other direct costs do not vary between the strategies.

Table 5.3 provides an overview of the average gross margin for seed onions per hectare under the reference strategy and the two alternative strategies.

Table 5.3	Gross margin of tulip cultivation in two scenarios (in €/ha)			
	Units	**Reference strategy**	**Alternative 1: chemical control**	**Alternative 1a: chemical control + handweeding**
Revenue				
Yield (saleable)	Pcs/ha	376,000	376,000	376,000
Price	€/pc	0.05	0.05	0.05
Total returns	€/ha	18,800	18,800	18,800
Costs				
Weed control	€/ha			
- Herbicides	€/ha	237	328	328
- Spraying	€/ha	198	249	249
- Hand weeding	€/ha	0	0	420
Other direct costs	€/ha	6,653	6,653	6,653
Total direct costs	*€/ha*	*7,088*	*7,226*	*7,647*
Gross margin		*11,712*	*11,570*	*11,150*
Absolute difference			-142	–562
Relative difference			*-1%*	*-5%*

Reference strategy
The yield in the current practice is estimated at 376,000 marketable tulip bulbs per ha, which are sold at an average price of 5 cent per bulb. The costs for weed control are €431 per ha, which is composed of chemicals (€233 per ha) and application costs (€198 per ha). Including the other direct costs, the total direct costs for growing tulip bulbs add up to €7,088 per ha. The gross margin is €11,712 per ha.

Alternative: chemical strategy
For the flower bulb cultivation the phytotoxicity of all allowed herbicides is considered negligible (Bulle, 2013). Thus, consequences of this strategy are limited to (1) higher spraying costs and if necessary (2) costs of additional hand weeding in order to remove remaining weed plants and to minimise the risk of increasing weed pressure.

The costs for chemical weed control in this strategy are €573 per ha, consisting of €328 per ha for chemicals and €249 per ha for their application. In case hand weeding is required, the extra costs for hand weeding are estimated at €420 per ha. In absence of pendimethalin, the gross margin is reduced with €142 per ha in most cases. This loss can increase to €562 per ha hand weeding is necessary, e.g. in years with poor spraying circumstances or on fields with high weed pressure. The need of hand weeding will be higher in the dune sand area where the weed pressure is heavier and the crop rotation only consists of flower bulbs, which means that any remaining weed cannot be destroyed in the next crops.

For other flower bulbs, the changes in costs of chemical weed control are likely to be smaller than for tulips, because there are fewer possibilities for alternative sprays as substitute for pendimethalin. On the other hand, the likelihood of a need for additional hand weeding increases as the withdrawal of pendimethalin can less easily be compensated.

5.3.2 Sector level

The consequences for the tulip production sector level are calculated by multiplying the Dutch tulip bulb production area by the impacts per ha (Table 5.4). It cannot be predicted which acreage of tulips is subject to hand weeding, as this depends on numerous aspects such as crop rotation, soil type, and weather circumstances at times of herbicide applications. Therefore, impacts for Dutch tulip cultivation are calculated for the two extremes that no fields vs. all fields require hand weeding. Using these extremes, sector level impacts on tulip bulb cultivation range between €1.55m and €6.17m . In 2012, total use of pendimethalin in the tulip bulb sector was 9,103 kg. Expressed in a different way, the value of 1 kg pendimethalin for the tulip bulb sector was between €170 and €677 in 2012.

For flower bulbs other than tulips, no sector-level values can be derived from the analyses performed in this study. The absolute impact in these sectors will be lower due to a smaller total acreage. However, particularly for the 'smaller' crops this scale effect will be at least partly compensated by a larger share of the acreage requiring hand weeding, since fewer active substances are available to these crops.

Table 5.4	Calculation of the financial effect of a ban of pendimethalin for the flower bulb sector, no hand weeding	
	chemical control	chemical control + hand weeding
Area (2012)	11,300	11,300
% with use of pendimethalin	97.1	97.1
Farm level impact (€/ha)	-142	-562
Sector level impact (€1,000)	-1,558	-6,166

5.4 Impacts in other crops

In this section we estimate the economic impacts of pendimethalin for winter cereals and outdoor vegetables. For that purpose we start from the status quo as described in Section 3.5.

The estimated use of pendimethalin in winter cereals amounts to 50% of the crop area. In 2012, an alternative weed control product was placed on the market: Herold. This product is considered an appropriate substitute, although its timing of application is more critical (Venhuizen, 2013). We expect that farmers can effectively use this product, once they are familiar with the characteristics of Herold. For that reason we assumed the economic impact consists of the difference in herbicide costs when substituting Stomp with Herold, which equals €30 per ha:

- Stomp: 3.25 l/ha x €13 /l = €42 /ha
- Herold: 0.60 l/ha x €120 /l = € 72/ha

The acreage of winter cereals in the Netherlands amounts to 120.000 ha. Application on 50% implies a total impact of €1.8m.

In outdoor vegetables pendimethalin is mainly used in carrots and leeks. The area of these crops treated (Table 3.6) amounts to 10.000 ha. Reasoning from the characteristics of the crops and experiences of farm advisors we hypothesise that the relative economic impacts in outdoor vegetables are of comparable magnitude as those of onions.

6 Conclusions and other considerations

6.1 Conclusions

Pendimethalin contributes to a good alternation with other herbicides like chlorpropham, chloridazon and ioxynil-octanoate. These herbicides together offer an effective and adequate line of defence against the different weed types.

An eventual withdrawal of pendimethalin will tempt pest control advisers and farmers to increase the dose rates and -where possible- the spray frequencies of the remaining herbicides. Also, substitutes will be used if available, to compensate for the loss of effectiveness in weed control. In case of harmful effects of increased dose rates, part of the farmers will keep dose rates on current levels and control the weeds through hoeing and hand weeding.

In onions, the withdrawal of pendimithalin reduces the gross margin per hectare by €620 to €800 per ha (15-17%), depending on type of onions and choice of alternative strategy. Losses are lower when combining chemical control with hoeing and hand weeding than in a purely chemical strategy, mainly because crop damage due to phytotoxicity is reduced. Total losses for the onion sector are almost €20m per year.

In tulips, the withdrawal of pendimethalin reduces the gross margin per hectare by 1% (about €142 per ha), provided that chemical weed control is fully effective. In situations where this is not the case, hand weeding is required, which increases the impact to €563 . For the total tulip production sector, the impact on tulip bulb cultivation ranges between 1.55 and €6.2m per year. For flower bulb production in general, impact per hectare is likely to increase as the total crop acreage decreases because smaller crops have fewer available substitutes.

Apart from onions and flower bulbs, significant sector level impacts are to be expected in cereals, carrots and leeks. In cereals, impact per hectare is only minor, but cereals are a major crop in the Netherlands. Carrots and leeks cover a smaller acreage, but weed control in these crops is more dependent on pendimethalin.

6.2 Position of hand weeding

The economic impacts presented here were quantified based on a number of assumptions regarding weed control and possible consequences. One important difference between the two case studies is that, following the experience of farm advisors, we assumed that onions are susceptible to damage due to phytotoxicity, whereas flower bulbs are not. As a result, the losses incurred in the alternative strategy for tulip bulbs are fully attributable to extra costs of chemical application. Since hand weeding is more expensive than these extra costs, there is no economic incentive to switch to an integrated strategy. A break-even point is reached if damage due phytotoxicity reduces the number of marketable bulbs or price per bulb (due to poorer quality) with 2.2%, i.e. 10,000 bulbs or €0.0011, respectively.

In onions, the assumption on phytotoxicity leads to revenue loss of €609 per ha in the chemical alternative and €276 per ha in the integrated alternative. In the total impact, the loss of revenue in both strategies has a share of 82% and 41%, respectively. Setting the phytotoxicity effect of the alternative strategies at zero would thus reduce the impact considerably and cause the chemical strategy to be the economically preferable alternative. In both case studies, the occurrence of crop damage is thus a crucial factor in determining when whether or not to consider hand weeding, when reasoning purely economically.

6.3 Interpretation of economic impacts

Above, the economic impacts for farmers of withdrawal of pendimethalin are provided. For farmers, however, the absolute financial loss per hectare is not the only thing that matters. In our study, we distinguished two alternative strategies: one in which the loss of pendimethalin was compensated by using more and/or other chemicals, and one in which a change in use of chemicals was combined with hoeing and/or hand weeding. Farmers are often not very keen on hand weeding, as this is very time-consuming and the farmer does not have the required labour capacity available. In onions, this may be a valid reason for farmers to opt for alternative strategy 1, even though this is the more expensive one. In flower bulbs, an integrated strategy was not even included as most farmers consider several times of hand-weeding unacceptable.

Another aspect that should be taken into account is the position of a particular crop in the portfolio of the farmer. Onions are generally grown by arable farmers as part of a crop rotation plan including amongst others cereals and potatoes. If cultivation of onions becomes technically or financially unattractive, the farmer may decide to substitute onions in the cropping plan with an alternative arable crop. Flower bulbs, on the other hand, are often grown on farms specialised in flower bulb cultivation. Flexibility with respect to crops grown is much smaller on these farms.

The impacts for flower bulbs are fully attributable to an increase in costs. Thus, absolute losses are quite constant over time as long as product prices of chemicals do not change very much. In onions, revenue loss has a large share in the impact per hectare. As the price of onions varies considerably between years, the impact per hectare will also show large fluctuations over time, being larger in years with high prices and lower if prices are below average.

Recent analysis of FADN data on farm income and cost structure revealed that the relative impact of a change in gross margin on farm income differs among sectors. Based on the years 2007-2011, a 1% decrease in gross margin causes a decrease in farm income of 7% for a flower bulb farm and 3% for an arable farm. The relative impact on flower bulb farms is larger because of higher fixed costs (e.g. machinery and equipment, land). Based on the same data, for the two alternative weed control strategies in tulips (Table 5.3), the gross margin reductions of 1 and 5% would lead to a reduction in farm income of 7 and 32%, respectively. On an average arable farm with onions in the cropping plan, onions comprise about one tenth of the total acreage. Assuming an equal share of all crops to the gross margin, the calculated gross margin reduction of 15 to 17% (Table 5.1) causes the farm income to decrease about 5%. In practice, this percentage will vary per year as the profitability of onions varies considerably between years.

6.4 Other impacts

This study focused on the farm- and sector-level economic impacts. One should realise that impacts at these levels can lead to macro-economic impacts as well. Other stakeholders in the supply chain may experience consequences to a greater or lesser extent (e.g. change in production and supply of seeds and chemicals, shifts in available size grades). Moreover, if changes in the quality or volume of marketable product occur at a large scale, this may induce price effects. The Netherlands is a large exporter of onions. However, onions are a speculative crop and the Dutch share in the global onion market is too small to cause structural price effects due to reduced supply, unless other major onion exporting countries experience similar consequences. Flower bulbs are a unique export product of the Netherlands. For several types of bulbs, prices have been low in the past decades due to overproduction compared to demand. A reduced supply of marketable flower bulbs may have a positive price effect; however, we cannot state based on results of this study that withdrawal of pendimethalin has an effect of supply of flower bulbs. Moreover, such effects would have to be put into perspective of other factors influencing supply and prices, such as the general trend of farm discontinuation and changing phytosanitary requirements of importing countries.

Apart from economic impacts, withdrawal of pendimethalin will also have social and environmental consequences. While not attempting to give a complete overview, we will mention some examples here. As mentioned already in section 6.2, labour is an important issue in plant production. Given the amount of time required for hand weeding, the farmer will have to hire labour capacity. It is difficult to fulfill this capacity as it concerns only temporary work. Moreover, hand weeding is physically demanding. Also the application of chemicals brings along health and safety risks to the farmer as well as consumers (residues on harvested products); however, legislation in the Netherlands is such that these risks will be minimal irrespective of the strategy considered.

Regarding environmental impacts, a change in application of chemicals will lead to changes in emission to the soil, ground water and surface water. The environmental burden of chemicals is generally expressed in terms of mbp (milieu belastingspunten), for which information is available per crop protection product. Yet, quantification of the change in mbps under the assessed strategies goes beyond the scope of this study.

A potential undesired side effect of withdrawal of pendimethalin is the development of resistance to active substances among weeds. As a part of resistance management, farmers should alternate the active substances they use in weed control. Withdrawal of pendimethalin reduces the flexibility for doing so and increases the frequency of use of particular products. As long as crops like onion and flower bulbs are grown in rotation with crops in which other chemicals are used, the effect on resistance development will be minimal.

However, on fields with monocultures of flower bulbs, which are particularly common in the dunesand area in the Netherlands, repeated application of the same set of herbicides may lead to selection and establishment of resistant weeds. An in-depth analysis of weed resistance development is required to test this hypothesis.

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Appendix 1

Workshop participants

Table A1.1	Affiliation and production region represented by crop protection advisors participating in the onion workshop	
Participant no.	**Company**	**Region**
1	Albert Groot bv	North-west NL
2	CropSolutions	South-west NL
3	Profytodsd	Central NL

Table A1.2	Affiliation and production region represented by crop protection advisors participating in the onion workshop	
Participant no.	**Company**	**Region**
1	Albert Groot bv	North-west NL
2	van Gent van der meer Nuyens	West NL
3	Heyboer bv	Central NL

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