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UNIVERSITY
DEPARTMENT OF AGROECOLOGY

EXTERNAL SCIENTIFIC REPORT

Collection and evaluation of relevant information on crop interception[1]

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DISCLAIMER

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SUMMARY

This project was performed at Aarhus University from November 2011 to May 2013, and the aim was to collect scientific information on crop interception of plant protection products and submit proposals for revision of the existing FOCUS values. The present FOCUS values on crop interception were published by the FOCUS ground water group (FOCUS, 2000; Anonymous, 2011b) and in the FOCUS surface scenarios (Anonymous, 2011a). Limited experimental data were available to the working group at that time, and therefore many of the existing FOCUS values were obtained using indirect data such as crop coverage or by interpolation or extrapolation of data. On the request of EFSA a scientific report on cereals was prepared by van Beinum and Beulke (2010) from The Food and Environment Research Agency (FERA). Besides a collection of literature on cereals, they made a literature database, where references on other crops were collected as well. Thus, the aim of the work reported here was to compile and evaluate references on all other FOCUS crops than cereals.

The literature database was updated with published studies after 2010 by searching in 13 databases. FERA reduced the search to literature published after 1980, but for other crop than cereals the number of papers was limited and it was decided to include also papers published before 1980. In addition, a number of papers were collected by personal contact to people from the network of Aarhus University, Department of Agroecology.
Searches were performed using 7 main search terms. After the search, all references were evaluated in accordance with a set of minimal and exclusion criteria developed by van Beinum and Beulke (2010). The exclusion criterion “non-European” was not used in the study by van Beinum and Beulke (2010); therefore papers rejected as “non-European” were re-evaluated.

In total 51, articles were accepted with studies on one or more of the crops mentioned by FOCUS (appendix A). The largest number of studies was found for apples. For eight of the FOCUS crops no studies fulfilling the criteria could be found. In this report, literature regarding vine, pome fruit, potato, citrus, cotton and sugar beet was evaluated, and the crop interception values reported were employed for revision of the existing FOCUS values (appendix E). For a number of crops (alfalfa, peach, maize, olive, pea, strawberry, tomato, bean and soybean) the data regarding growth stage and crop interception were limited, so data were stated in the report but not used for revision. No studies were found on bush berries, but due to the extrapolation rules it was revised in accordance to data derived from vine. All relevant data from the articles, such as spray equipment, sampling, growth stages etc., were compiled in an Excel file (Annex 2).

In the report from FERA, six methods (M1, M2, M3, M4, M5 and M6) were suggested for calculation of interception factors for which measurements were based on deposition on soil or plants. In vine, it is also common to measure the amount of drift and spray that is collected from recycling, when equipment such as tunnel sprayers are employed. Therefore, three further calculation methods were proposed, M7, M8 and M9. To evaluate the interception values obtained from literature with the values earlier suggested by FOCUS (2000), data were plotted against the growth stage of the crop. For sugar beet, stone fruit and cotton, the FOCUS values seem to be in accordance with the crop interception values derived from most of the experiments reported in the articles. In potato and citrus, the average of crop interceptions values derived from the experimental data was above the FOCUS values, and increasing the values is suggested. In vine and bush berries a decrease of the crop interception (CI) value was suggested. Apples were more difficult to evaluate due to a very large variation between the reported measurements. Evaluation of the average of all data and of the average of data collected on apples that are similar to common modern apple orchards; it is recommended to decrease the CI values by 5% at flowering stage and by 15% at full foliage. Thus, in the present report

the proposal for new CI FOCUS values were given for vine, apple/stonefruit, citrus, bush berries and potato. Calculations can be found in sheet 5.1. – 5.7. calculations, in annex 2.

KEY WORDS: Interception, Spray Deposition, Residues, Pesticides

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BACKGROUND

The purpose of the assignment was to provide scientific information to be used for future scientific opinions and guidance on exposure assessment of pesticides in the environment. Interception by crops reduces the amount of the plant protection product that reaches the ground underneath the crop. Only the plant protection products that reach the ground are taken into account in regulatory calculations of predicted environmental concentrations (PECs) in soil, surface water and groundwater. It is important that the crop interception factors used in the regulatory risk assessment are based on well- documented data and in that way act as robust and representative values.

In the preceding project (CFT/EFSA/PPR/2009/02) a database and a report were prepared by van Beinum and Beulke (2010) from The Food and Environment Research Agency (FERA) and accepted by EFSA in October 2010. In this project the literature searches were performed on 19 databases using 5 main search terms. The literature was evaluated according to a number of selected minimal criteria. The outcome of this evaluation was a database containing 1009 references (listed in 73 eax1). These references were then evaluated based on another set of criteria and divided into two groups: 55 accepted and 954 rejected papers. One of the criteria for omitting the references was if the study was dated before 1980. These studies were not included in the database. Studies from outside the EU were included in the database but placed in the rejected group. In the present study of "other crops than cereals" less literature can be obtained on specific crops and therefore it was proposed by the grant holder in response to the call to incorporate literature based on experiments from before 1980 and from outside the EU if this would fulfil the other criteria. The aim of this follow-up project (CFP/EFSA/PRAS/2011/01) was to continue the work and provide scientific information and proposals for crop interception factors on "other FOCUS crops than cereals" (appendix A) to be used for future scientific opinions and guidance on exposure assessment of pesticides in the environment. The report by van Beinum and Beulke (2010) established crop interception factors on cereals and proposed the crop interception methodology to be applied. The grant holder was requested by the Terms of References to the call to apply the same methodology when revising the values derived by FOCUS.

TERMS OF REFERENCE AS PROVIDED BY EFSA

In the technical specifications to the open call (CFP/EFSA/PRAS/2011/01) EFSA requested the following:

The applicant is to follow up on the scientific report submitted to EFSA on collection and evaluation of relevant information on crop interception for the revision of the Guidance Document on Persistence in soil which resulted from the contract CFT/EFSA/PPR/2009/02, Question number: EFSA-Q-2009-01085. The report is available at this link: http://www.efsa.europa.eu/en/supporting/pub/73e.htm

Methodology to be followed during the project:

- Methodology recommended by the report which resulted from the contract CFT/EFSA/PPR/2009/02 should be used. This report is available at this link:

  http://www.efsa.europa.eu/en/supporting/pub/73e.htm.

Deliverables expected during the project:

- The candidate is expected to provide a **supplementary comprehensive data collection** from publicly available publications, test reports, reviews, guidance documents, guidelines, scientific reports and any other information relevant for estimating the factors determining the crop interception factors from foliar spraying of Plant Protection Products on crops. The quality criteria for insertion into the database are those which are mentioned in the report which resulted from the contract CFT/EFSA/PPR/2009/02. This report can be found at this link:
  http://www.efsa.europa.eu/en/supporting/pub/73e.htm

- To compile a **database** in a format and structure agreed by EFSA of all relevant crop interception measurements. For details of the expected database structure please see the report/database which resulted from the contract CFT/EFSA/PPR/2009/02, at this link http://www.efsa.europa.eu/en/supporting/pub/73e.htm

- To make **suggestions** for possible revision of the currently proposed crop interception factors proposed in the FOCUS reports with the exception of cereals. References are found in point 1.2 above. Proposals for interception factors for crops with limited data should also be provided.

ACKNOWLEDGEMENTS

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Contract/grant title: Collection and evaluation of relevant information on crop interception.

Contract/grant number: CFP/EFSA/PRAS/2011/01.

1. INTRODUCTION AND OBJECTIVES

During pesticide application the spray liquid is atomized into droplets. These droplets can have different fates. The droplets can be deposited on the crop or they can be deposited on the ground. Furthermore a fraction of the spray is lost as spray drift deposited inside or outside the sprayed area. Another loss comes from evaporation during the application. Only the plant protection products that reach the ground are taken into account in regulatory calculations of predicted environmental concentrations (PECs) in soil, surface water and groundwater. It is important that the crop interception factors used in the regulatory risk assessment in Europe are based on well-documented data and that the values are representative across the EU.

The crop interception table currently used for PEC soil and groundwater calculations was determined by members of the FOCUS groundwater group (FOCUS, 2000; Anonymous, 2002; FOCUS, 2009; Anonymous, 2011b) and similar for surface water calculations (Anonymous, 2011a). The intention of the table was to give conservative estimates of interception, taking into account that wash-off is not separately considered. However, the degree of conservatism is not clearly documented. The aim of this project was to collate any data on interception by crops from available sources and to compile a database. Based on the information recommendations are to be provided for reconsideration of the existing FOCUS values. However, only few studies have focused directly on investigating deposition of pesticides on the soil surface during pesticide application. The majority of studies of deposition on crop or soil comes from studies investigating different application techniques. In these studies crop and/or soil deposition and biological efficacy are the parameters used to compare the techniques.

The objectives of this project were:

- To accomplish a supplementary comprehensive data collection on literature related to crop interception after chemical applications in the field
- To document the references in databases
- To collect interception values and relevant data related to the experiments described in the literature. This has to be employed on all FOCUS crops except cereals
- To make suggestions for a possible revision of the currently proposed crop interception factors proposed in the FOCUS reports with the exception of cereals
- To apply the methodology for determining the crop interception factors as requested by EFSA in the call (CFP/EFSA/PRAS/2011/01).

2. LITERATURE SEARCH

2.1. Search engine, terms and logic

The report by FERA (van Beinum and Beulke, 2010) was based on a literature search on studies dated after 1980. A follow-up literature search was performed in February to obtain studies from before 1980 and further to look up studies published after 2010. One additional study (Pergher et al. 2013) was obtained during the regular searches for studies on application technique.

Seven search terms (T1-T7) were employed in the literature search on all databases (Table 1 and appendix B). Five of the terms were employed in the previous FERA report and, as recommended in the FERA report, two new search terms (spray retention and through fall) were added. As in the previous report, it was found that a search on each single term resulted in a high number of references (documented in appendix C).

The search was then narrowed down by combining search terms. It was a stepwise procedure, and when the number of results was below 1000 references the search results were evaluated in accordance with the minimal criteria for the relevance to the matter and listed in Table 2. Combining T1, T4 and T5 or T2, T4 and T5 resulted in the most relevant references when the search was performed on topic Search terms T3, T6 and T7 resulted in less relevant references. Search on keywords in title resulted in many of the same references as found by searching in topic.

Table 1: Search terms for literature search

T1	**interception** or intercepted	Original search words
T2	**deposit?**	Original search words
T3	**crop** or crops or plants or foliar or foliage or leaf or leaves or canopy? or tree? or bush? or shrub? or row? width? or soil or soils or ground?	Original search words
T4	**Pesticide?** or plant protection product? or crop protection product? or active substance? or insecticide? or fungicide? or herbicid? or tracer?	Original search words
T5	**Spray?** or droplet? or application? or apply? or applied or nozzle?	Original search words
T6	**Spray retention**	New search words
T7	**Through fall**	New search words

After evaluating the references in accordance with the minimal criteria, the final number of references was 29 from before 1980, 47 from 2010 to 2012 and 1 from 2013. These 77 references (Annex 1, new search) were then evaluated and divided in accordance with the exclusion criteria in Table 3. The relevance of the references was first determined based on titles and abstracts. At this step some papers were rejected and for others an overview study of the full length papers was needed.

Articles were acquired during the first six months of the project period. In the search of references two new papers were added to the database as “not available” (A524 and C221). The papers were unsuccessfully reserved at many different libraries. Indeed, A524 is in a journal publishing papers about rice and C221 is published in a Japanese journal, so the two papers would probably not be relevant for setting CI for the FOCUS crops.

Besides the literature search explained above, a number of papers were collected by personal contact to people from the network of Aarhus University, Department of Agroecology. These references were collected in the database called Personal contacts (in Annex 1). This database contains 42 references (two of the references, A290 and A282, are also listed in the previous database 73 eax1). To ensure that all relevant data were collected EFSA contacted ECPA (European Crop Protection Association) to provide available data on crop interception. ECPA replied that no relevant data were available from their members (e-mail to EFSA 25-01-2012).

In addition to the references from the two databases, references from the database received from FERA (73 eax1) were collected. The FERA report (van Beinum & Beulke, 2010) used Non-Europe as exclusion criteria. It was agreed with EFSA to include such studies if the cultivation practice yield etc. were considered to be similar to European conditions. A similar cultivation practice implies a cultivation method (row distance, plants per m^2, fertilization) that will generate a crop with crop coverage comparable to a European crop throughout the growing season. The references rejected as NON EUROPEAN were re-evaluated in accordance with the exclusion criteria (Table 3) and later on, it was also decided to re-evaluate papers where data were only presented in graphs or bar plots (DATA IN GRAPH). Data from these papers were only accepted in the database if the data could be assessed accurately. The reason for re-evaluating previously rejected papers was the lack of studies for most of the arable crops. After re-evaluation of papers with data in graphs, there were one paper in maize with 6 measurements and two papers on apple where totally 17 measurements could be read accurately and fulfil the other criteria in table 2 and 3.

Table 2: Overview of minimal criteria for documentation of references in the database

a. The publication does not report measurements of interception or ground deposition (e.g. modelling articles, theoretical publications, reviews)
b. The publication is not related to interception of solutes (e.g. light interception, interception of water during rainfall or irrigation)
c. The publication does not report measurements of deposition on vegetation (e.g. spray deposition on insects or on bystanders, spray deposition on artificial plants or sprayer testing on surfaces without plants)
d. The publication is not related to deposition of spray (e.g. applied by dipping, dropwise application with a pipette or brushed onto the leaves)
e. The publication reports measurements related to spray drift only (e.g. drift deposition outside the field, spray interception by hedgerow or windbreak vegetation, or deposition on water bodies adjacent to the field)
f. The publication is not related to interception by crops (e.g. herbicide interception by weed or by crop residues such as stalks or mulch)
g. The publication is not related to agricultural use (e.g. spraying of insecticides in swamps against malaria)

Table 3: Overview of exclusion criteria for references not included in data collection. A more detailed description of the criteria can be found in the FERA report

AERIAL	Pesticides or tracers were sprayed from an aeroplane or helicopter.
FORESTRY	Pesticide or tracers were applied in forestry or nurseries.
GREENHOUSE	The study was specific for techniques used in greenhouses and not relevant for open fields.
NO FOCUS CROP	The crop was not listed in the FOCUS crop tables for

	groundwater or surface water.
NO FIELD	The conditions of the study were not relevant for field.
CANNOT DERIVE INTERCEPTION	The authors have not measured spray deposition or the measurements were per leaf area or per plant, but there is not enough information given to calculate interception at the field scale as a percentage of applied doses.
NO GROWTH STAGE	Not enough information is given to determine the growth stage of the crop when the spray was applied.
LANGUAGE	The article is written in a language other than English, German, Dutch or Swedish, Norwegian or Danish. Other language such as Spanish and French were considered (translation by colleagues), but no relevant references in these two languages were found and included in this report.
DATA IN GRAPHS	The data reported in a graph or bar plot could not be accurately retrieved. Data from graphs employed in the report are marked with a G* in the tables and data were only accepted if the data could be assessed accurately. Studies with data in graphs are from studies on apples and one in maize.
WASH-OFF FROM CROP	If wash-off from the crop occurred between the time of spray application and when the measurements were taken. (None of the references failed this criterion in our search nor in the FERA search).
DISSIPATION OF PESTICIDE	If dissipation of the pesticide could have occurred in the field before sampling. (None of the references failed this criterion in the FERA search).

3. DEVELOPMENT OF SPRAY INTERCEPTION DATABASE

After a first reading of the articles, the result was 16 references on vine, 28 on apple and 0-6 on the other crops included. When the articles were evaluated in a more detailed manner, a number of the references were rejected due to lack of for instance leaf area index (LAI) or the description of growth stage was not reported in such a way that a BBCH value could be determined. The final number of articles for each crop employed in the database is shown in Table 4. Crops missing in the table are crops where no articles were obtained.

Table 4: Number of articles for each crop.

Crop	Number of articles	Crop	Number of articles
Vine	11	Sugar beet	2
Olive	1	Citrus	3
Pear	2	Tomato	1
Peach	2	Soybean	1
Strawberry	1	Bean	1
Alfalfa	1	Apple	17
Cotton	3	Pea	1
Maize	1	Potato	3

The database containins information on the articles, collated in a file with one Excel spreadsheet for each crop (Annex 2). Alongside the interception data, all information that could influence the interception value of the experiment was entered into the database. The information that was collated in the database was the same as in the FERA report.

4. METHODOLOGIES

During pesticide application, the spray liquid is atomized into droplets. These droplets can have different fates as illustrated in Figures 1a and 1b. The droplets can be deposited on the crop (1) or they can be deposited on the ground (2). A fraction of the spray is lost as spray drift deposited inside or outside the sprayed area (3). Further, a fraction of the spray can evaporate during the application (4). Furthermore, if new equipment such as tunnel sprayers is used, the recycled spray liquid constitutes an additional fraction (5).

The fraction of droplets lost as spray drift typically amounts to a few per cent (of the applied dose) with boom sprayer (Ganzelmeier, 1997; van de Zande et al., 1999), but is considerably larger from orchard sprayers (Heer et al., 1985a; Heer et al., 1985b; Ganzelmeier, 1997). The other source of pesticide loss during application, evaporation, is mentioned by the FOCUS Air Group (FOCUS, 2008). From studies where crop deposition, ground deposition and eventually drift are measured, there can be a significant fraction of the applied pesticide/tracer dose that cannot be accounted for. An example from van de Zande et al. (2002) is illustrated in Figure 2. The study was carried out in potatoes at a late growth stage where the leaf canopy covers the soil surface completely. In this experiment an air-assisted and a conventional boomsprayer were used and respectively 17.1% and 23.1 % of the applied spray could not be accounted for. It is not uncommon in studies to find even larger fractions not accounted for.

The applied pesticide dose is typically very precise with well-calibrated spray equipment. The deviation from the applied dose rate can either be due to methodological problems in studies where the pesticide/tracer cannot be recovered satisfactorily from plants or to artificial collecting objects. Another explanation could be that evaporation during the application can be a significant loss factor. In a study by de Heer (1985a) 90% of the spray could be accounted for when pesticide application was carried out early in the morning, whereas only 68% of the spray could be accounted for when the application was carried out in the early afternoon at weather conditions more favourable for evaporation. Emans et al. (1992) estimated that 10% of the spray is lost as air-emissions during an application (spray drift and evaporation).

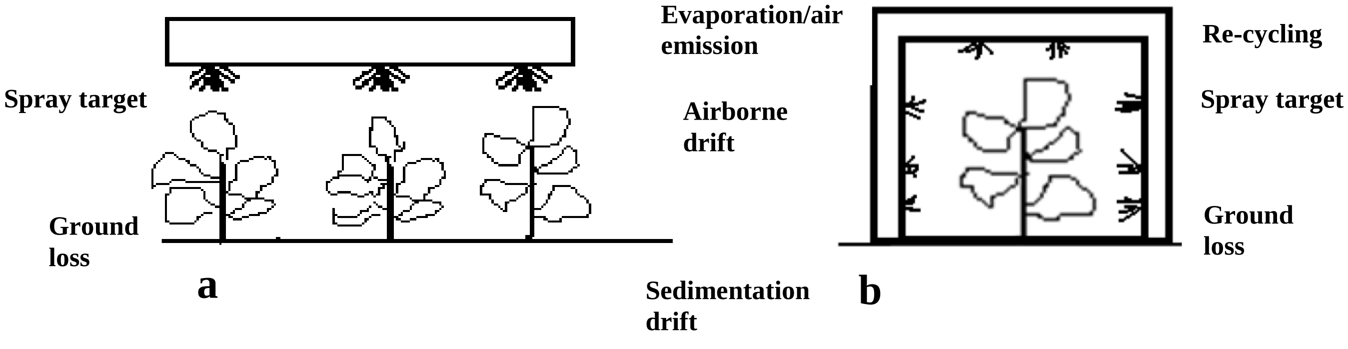

Figure 1: Spray accountability for a) traditional boom sprayers and b) tunnel sprayers

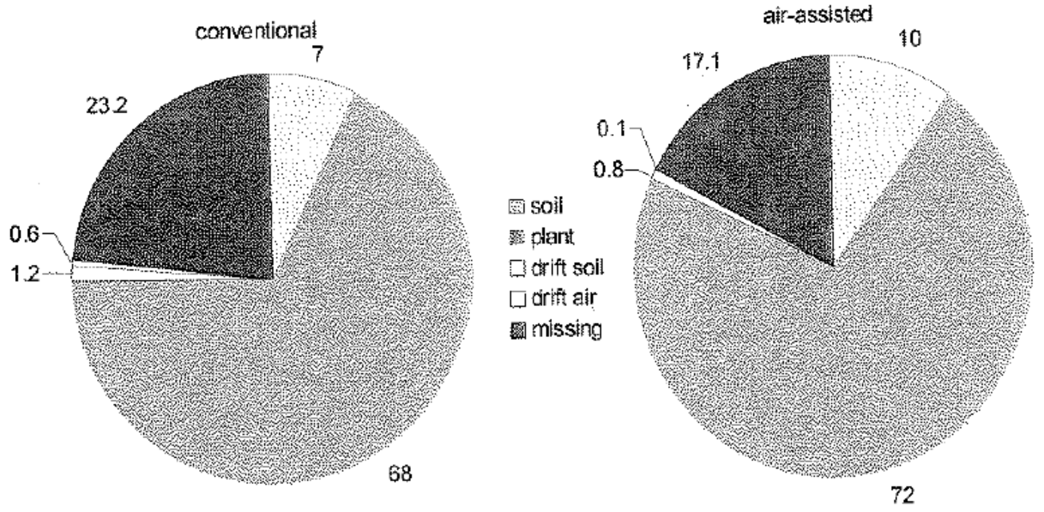

Figure 2: Distribution of pesticide during spraying of potatoes at growth stage 39 (F020, van de Zande et al. (2002).

4.1. Methodology used by FOCUS to derive crop interception factors

The crop interception values recommended by FOCUS (Anonymous, 2002,2011b) were not revised from the original FOCUS Groundwater Scenarios report (FOCUS, 2000), except for winter cereals, where 70% at elongation were added to BBCH 20-39. In the last-mentioned report it is described that studies describing interception of substances by crops at different growth stages are rather limited. Therefore, also indirect data were used to estimate crop interception. The indirect data come from information on crop coverage at different growth stages collected and reported by Becker et al. (1999). In their publication values on crop coverage assessed in 2000 field trials carried out during a four year period in six member states were used to propose crop interception factors in cereals, maize, rape, beet, potatoes and peas. Becker et al. (1999) proposed that an estimate of the crop interception factor should be based on a crop coverage value above the mean value. They proposed to use a value somewhere between the mean values and the mean value + standard deviation of the mean. The crop interception values established in this way were supported by some experimental deposition values from a literature search (van de Zande et al., 1999). Data on ground deposition in vine, fruit and hops were compiled by Ganzelmeier (1997). For crops not covered by these sources, interception was estimated based on information on the LAI of crops using the GLEAMS model (FOCUS, 2000). For those crops where no data were available a set of extrapolation 'rules' for (maximum) interception values were defined as listed below.

Extrapolation rules:

1. Grass: based on cereals

2. Beans, soybeans: based on peas
3. Cabbage, carrots, onions, tomatoes, tobacco: 0.9 * max soil cover
4. Vines, bush berries: 1.5 * soil cover (max = 90%)
5. Sunflower: based on maize

The rules were mentioned by van der Linden and Resseler (2009) in the answer to the EFSA question regarding how to obtain the crop interception values in preparation of the EFSA opinion (2012). Indeed, it has not been possible to find the scientific evidence which justifies the extrapolation rules proposed by FOCUS. However, one study that could support rule number three was found. It was a study on cereals by Gyldenkaerne et al. (1999). Here the relationship between leaf area index (LAI) and soil deposit was examined by the following equation: Ps = Pa exp(k LAI), where k is the pesticide capture coefficient, Ps the soil deposition and Pa the application rate. The correlation was tested on wheat and barley, +/- surfactant, and in one case for wheat the influence of height was included. The regression coefficients ranged from 0.817 to 0.914, which fit to the multiplication factor of 0.9 employed in extrapolation rule number three.
Rule number four can also be changed now because many data are reported on vine. We suggest changing the rule so bush berries is based on vines.

An overview of estimated crop interception for orchards and arable crops is found in Tables 5 and 6. The approach applied to establish crop interception values is very pragmatic and adapted to the situation with very few studies focusing on this aspect and limitations of available data in even major crops. Since the FOCUS crop interception values were established (FOCUS, 2000) environmental issues have received considerable attention. This has increased the number of studies related to the topic and enabled a review of the established crop interception values. A few of the new studies gives CI values obtained with methods adapted directly to the purpose, whereas many still have been carried out with another purpose. For crops which were not mentioned by the FOCUS Groundwater Group (FOCUS 2000) and not listed in Table 5 and 6, the crop interception values were taken from the FOCUS surface water scenarios (Anonymous, 2011a) (see appendix E).

Table 5: Stage description and FOCUS crop interception values (CI) for trees and bushes (FOCUS report 2000).

Vines	Without leaves	First leaves	Leaf development	Flowering	Ripening
CI	40	50	60	70	85
Apple	Without leaves	Flowering	Leaf development	Full foliage	
CI	50	65	70	80	
Citrus			All stages		
CI	70	70	70	70	70
Bush berries	Without leaves	Flowering	Full foliage		
CI	50	65	80		

Table 6: FOCUS crop interception values (CI) for arable crops (FOCUS report 2000).

Crop	Bare emergence	Leaf development	Stem elongation	Flowering	Senescence/ ripening
			BBCH		
	0-9	10-19	20-39	40-89	90-99
Beans	0	25	40	70	80
Cabbage	0	25	40	70	90
Carrots	0	25	60	80	80
Cotton	0	30	60	75	90
Grass	0	40	60	90	90
Linseed	0	30	60	70	90
Maize	0	25	50	75	90
Oilseed rape	0	40	80	80	90
Onions	0	10	25	40	60
Peas	0	35	55	85	85
Potatoes	0	15	50	80	50
Soybean	0	35	55	85	65
Strawberries	0	30	50	60	60
Sugar beets	0	20	70 (rosette)	90	90
Sunflower	0	20	50	75	90
Tobacco	0	50	70	90	90
Tomatoes	0	50	70	80	50

4.2. Measurements and calculation of crop interception

Whole plants, leaf samples or artificial collectors (e.g. filter paper clipped to the leaf, branches or stem) are used to measure the amount of chemical or tracer deposited on plants following an application. If the deposit on whole plants is used for calculation, the plant density (number of plants per hectare) is needed. If calculations are based on leaf samples or collectors, the leaf/collector area and the leaf area index (LAI) are needed for calculation of percentage interception. LAI indicates the total leaf area per ground area, so if LAI is 3, the crop can cover three times the ground area. Measurements of deposit on the ground are done by placing for instand filter papers or Petri dishes on the ground between plant rows and underneath the plants within the rows. The collectors are then taken to the laboratory for extraction and quantification of the chemicals or tracers. In some experiments drift deposition is measured by placing collectors outside the field. The applied dose is typically based on the calibrated and recommended dose rate. In some studies concentration of pesticide/tracer measured on collectors on bare soil or just above the top of the canopy is used as basis for calculating crop and ground deposition. This method can only be used with boom sprayers.

After collation of the reported data (crop, sprayer and experimental details), the interception values were calculated and reported in the database. Formulas for different calculation methodologies are listed in Table 7 and described in Table 8. In the previous report by van Beinum and Beulke (2010) regarding cereals, six methods to evaluate deposition were proposed, as drift is very limited using boom sprayers, and recycling is not relevant for this crop. In Tables 7 and 8 three further methods are described and also reported in the database. These extra methods are included as spray drift can constitute a substantial fraction in orchard spraying and recycling is relevant with new spray technology. In some studies in vine, apples and other orchard crops both data on drift and recycling of spray can be measured. In order to achieve a correct crop interception value it is important to take these fractions into account when the total spray account is calculated. Van Beinum and Beulke (2010) mention a number of uncertainties using the different methodologies. Similar points are highlighted in paragraph 4.4.

Table 7: Methodologies used for calculation of crop interception values.

	Description of method
Calculation based on crop deposition	
M1	$$\text{Interception (\%)} = \frac{100 \text{ x (spray deposit in µg/plant (or µL/plant) x plant density/ha)}}{10^6 \text{ x applied dose in g/ha (or L/ha)}}$$ or $$\text{Interception (\%)} = \frac{100 \text{ x } (10^8 \text{ x spray deposit in µg/cm}^2 \text{ x LAI in ha/ha)}}{10^6 \text{ x applied dose in g/ha}}$$

M2

$$\text{Interception (\%)} = \frac{100 \text{ x (spray deposit in µg/plant x plant density/ha)}}{10^6 \text{ x deposition on bare soil or just above canopy in g/ha}}$$

M3

$$\text{Interception (\%)} = \frac{100 \text{ x (spray deposit in µg/plant x plant density/ha)}}{10^6 \text{ x (deposition on crop + deposition on ground in g/ha)}}$$

Calculation based on ground deposition

M4

$$\text{Interception (\%)} = 100\% - \frac{100 \text{ x } (10^8 \text{ x ground deposition in µg/cm}^2 \text{ (or µL/cm}^2\text{))}}{10^6 \text{x applied dose in g/ha (or L/ha)}}$$

M5

$$\text{Interception (\%)} = 100\% - \frac{100 \text{ x } (10^8 \text{ x ground deposition in µg/cm}^2)}{10^6 \text{ x deposition on bare soil or just above canopy in g/ha}}$$

M6

$$\text{Interception (\%)} = 100\% - \frac{100 \text{ x } (10^8 \text{ x ground deposition in µg/cm}^2)}{10^6 \text{ x (deposition on crop + deposition on ground in g/ha}}$$

M7

$$\text{Interception (\%)} = 100\% - \frac{100 \text{ x } (10^8 \text{ x ground deposition + drift* in µg/cm}^2)}{10^6 \text{x applied dose in g/ha (or L/ha)}}$$

M8

$$\text{Interception (\%)} = 100\% - \frac{100 \text{ x } (10^8 \text{ x ground deposition + recyc. in µg/cm}^2)}{10^6 \text{x applied dose in g/ha (or L/ha)}}$$

M9

$$\text{Interception (\%)} = 100\% - \frac{100 \text{ x } (10^8 \text{ x ground dep. + drift* + recyc. in µg/cm}^2)}{10^6 \text{x applied dose in g/ha (or L/ha)}}$$

* Drift calculated as the integral of the drift deposition curve

Table 8: Methodologies used for calculation of crop interception, described in words.

M1	Crop deposition as percentage of application dose
M2	Crop deposition as percentage of the applied dose, measured as the deposition on bare soil or just above the canopy
M3	Crop deposition as percentage of the total recovered deposition from crop canopy and the ground beneath the crop
M4	Ground deposition as percentage of application dose
M5	Ground deposition as percentage of the applied dose, measured as the deposition on bare soil or just above the canopy
M6	Ground deposition as percentage of the total recovered deposition from crop canopy and the ground beneath the crop
M7	Ground deposition plus drift as percentage of application dose
M8	Ground deposition plus recycled pesticide as percentage of application dose
M9	Ground deposition plus drift and recycled pesticide as percentage of application dose

Table 9: Methods applied to derive crop interception values, reported on respective crops. An x represents one study.

	M1	M4	M3/M6	M7	M8	M9
Vine	xxxxxxxxx	xxxxx	xxxxx	x	xx	x
Potato	x	xxx	x			
Apple	xxxxxxxxxxxx	xxxxxx	xxxx			
Citrus	xxx	xx	xx			
Bean		x				
Soybean		x				
Tomato		x				
Cotton	xxx	x	x			
Sugar beet		xx				
Pea		x				
Alfalfa		x				

Maize		x	
Olives		x	
Peach	x	xx	x
Pears		xx	
Strawberries		x	

In the EFSA call (CFP/EFSA/PRAS/2011/01) the M3/M6 methods were selected as the preference method as proposed in the report by van Beinum and Beulke (2010). However, as shown in Table 9, in a number of crops only ground depositions were measured, resulting in M4 as the only method to determine crop interception. M8 and M9 are of interest when advanced technologies such as recycling sprayers are employed. Those methods can be relevant in the future when these technologies have a larger share of the market. However, for the current environmental exposure assessment for regulatory purposes no distinction is made on spray equipment for pesticide application and therefore methods M8 and M9 are not further considered in the final evaluation. M2 and M5 are not included in Table 9 and not used to report crop interception factors in this report. The reason is that none of the studies found on "other crops" included measurement of spray deposition on bare soil or just above canopy.

4.3. Factors of influence on crop interception

In the FERA report about crop interception in cereals it was mentioned that many publications reported the measured deposition on plants or ground rather than the percentage interception. This was also the case for the other crops included in this report and data were listed in the database (Annex 2) in the same manner as for cereals (database 73 eax2).

4.3.1. Sampling and growth stage

In general, sampling has to be done immediately after spraying and completed in a way that is representative of the crop at the particular growth stage. A common way is to sample a large number of leaves from the plant and combine these into one bulk sample. In vine and orchards there can be a variation between top, middle and bottom of the canopy, and in a very dense crop the deposition on the leaves may vary inside and outside the crown. Both sampling and growth stages depend on the crop species and are important issues that should be taken into consideration. In view of the fact that this report deals with different crop species, further discussion will take place with respect to the different crop types (in chapter 5). Overviews of different growth stages and BBCH scale for the different crop species are given in Tables 5 and 6 together with the FOCUS crop interception values. The BBCH growth stages selected by FOCUS are appropriate based on the morphological development of the plant. The five selected ranges of growth stages varies from almost no soil cover (no germ, small seedlings or naken trees) to full soil cover (full stem elongation and leaf development) to cover the CI development in a sufficient way.

In some articles the growth stage is only described in words and then the BBCH stage was derived in accordance with the examples illustrated in Table 10.

Table 10: Examples from literature in which the development stage is only described verbally, so the BBCH value was set by comparing this information with the BBCH scale.

ID	Reference	Crop	Description	BBCH
F-24	(Pergher and Gubiani, 1995)	Vine	after end of blossom	69
F-24	(Pergher and Gubiani, 1995)	Vine	at full foliage development	19
B-320	(Pergher et al., 1997)	Vine	full foliage development	19

For vineyards the different ways of training the plants also influence the crop interception and therefore the sprayer has to be calibrated in accordance with the height and stage of the vine plants (Pergher and Petris, 2007) (A098).

4.3.2. Spraying equipment

In research studies, it is of interest to find technologies that can improve the targeting ability of the sprayer by optimizing its adjustments according to the canopy characteristics. An innovative technology developed for vineyards and other orchard crops with limited height is the tunnel sprayer. In five out of ten studies on vine and one on apple, spray deposition was reported when tunnel sprayers was used as one of the spraying technologies. With this type of equipment it is possible to collect and recycle a fraction of spray that normally would end as spray drift with conventional sprayers and in that way reduce the drift and ground deposit in comparison with the traditional sprayers. Furthermore, the system is evaluated by using different nozzles and air flow. In the study by Ade et al. (2007) between 20.8 and 48.9% of the liquid was recycled during spraying of a vineyard at different growth stages. However, tunnel sprayers are still not the most common sprayer technology and this is developed especially for tree crops. There are some limitations using this technology, such as expensive investment (if growers should change over from old to new technology), travel speed, problems in hilly orchards and vineyards and restricted tree size and shape (Fox et al., 2008; Pergher and Petris, 2008).

An example on how the crop interception values vary depending on the different spraying technologies is highlighted in Table 11 for vineyards. At the early stage during leaf development, the crop interception value is eight times higher when tunnel sprayer is employed than when using the conventional axial fan sprayer or the over-row sprayer. Using the air blast sprayer gives the lowest CI values in both early and late growth stages. The air blast sprayer is needed when the crops are grown on sheer cliffs.

Table 11: Interception values for vineyards derived by seven different calculation methods (M1-M9) and based on data from Viret *et al.*, (2003) (shown in the first six columns). The experiment was conducted at two different growth stages (BBCH scale) by the use of different spraying technologies. Spray deposition were reported as percentage of applied and measured on plants (leaves + stem etc.), on the ground (within the plots and outside the plots, mentioned as ground drift) and, the percentage of pesticide which was recycled.

BBCH	Sprayer types	Leaves+ stem etc.	Ground within plot	Ground drift	Recycling	M1	M3	M4	M6	M7	M8	M9
14	Tunnel	23	26	1	35	23	47	74	47	73	39	38
14	Over-row sprayer	15	67	11		15	18	33	18	22		22
14	Axial fan	15	26	5		15	37	74	37	69		69
14	Air blast	6	76	2		6	7	24	7	22		22
77	Tunnel	73	23	0,5	4	73	76	77	76	76,5	73	72,5
77	Over-row	68	13	2		68	84	87	84	85		85
77	Axial fan	65	22	2		65	75	78	75	76		76
77	Air blast	35	63	2		35	36	37	36	35		35

4.4. Uncertainties in crop interception values based on results from various studies

As mentioned above, a substantial proportion of the applied doses are often not accounted for in deposition studies. This can be due to methodological problems or it can be caused by the fact that the fraction not measured in the study has a significant magnitude. The different methods proposed by FERA (van Beinum and Beulke, 2010) in the report on cereals (CFT/EFSA/PPR/2009/02) addresses these issues concerning arable crops. In orchard spraying it can be relevant to include further methods as described above. Further in orchard spraying methods M2 and M5 are not relevant due to the application methods used. When the purpose is to investigate the concentration of pesticides deposited on the soil (underneath the crop), measurement of soil deposition is the preferred method (M4), provided that methodology is reasonable. In the present study the purpose was to describe the interception of plant protection products intercepted by the crop, and therefore M1 is suggested as the preferred method, again conditioned on the use of reasonable methodology (as it measures the exact amount of chemical deposited on crop as a percentage of the spraying dose). In studies where both crop and soil deposition are measured one can argue using methods M3/M6. Using these methods the fraction of spray applied not accounted for in the study is added proportionately to crop and soil deposition values, i.e both these values increase. If methodological problems are the reason for the fact that the measured fractions do not add up to 100% of the applied dose, this seems reasonable. However, if other fractions such as spray drift, recycling and eventually evaporation are measured, methods M3/M6 will give an overestimate of crop and soil deposition. In this case it seems more reasonable to use the methods M7, M8 or M9 proposed. Methods M3 and M6 give an overestimate of the chemical intercepted by the crop because the calculations are based on ground deposit and deposit on the crop, assuming that there are no losses (so plant deposit + ground deposit = 100%). Thus spray drift, evaporation and other losses during application as illustrated in Figure 1 are not considered. Further M1 will give an overestimate of soil deposition if the method used to measure deposits on crop plants underestimates the deposition on the crop due to degradation of the applied product/tracer or insufficient recovery of product/tracer. In order to consider some of the other sources in the spray account three further calculation methods are suggested in this report. M7 can be used if drift is measured; M8 is needed if the spraying methods use recycling systems and M9 if ground deposit, drift and recycling are measured. The example illustrated in Table 11 illustrates how very different the interception value can be when M1 or M4 is used.

Thus, the different methods mentioned above (and in Tables 7 + 8) are expected to result in different values for interception. Therefore, the different uncertainties must be considered when crop interception is determined (some points were also mentioned in the previous FERA report).

- In orchards due to the application technique used it is not possible to measure the applied dose from deposition measurements above canopy, so calculation methods M2 and M5 are not relevant.

- It is important that the collectors are placed in such a way that they are representative of the total crop or ground deposition. Spray deposition will be larger between the rows than just below the crop rows. In vine and orchards, deposition on the inner part of the plant will be different from deposition on the outer part of the plant. There can also be a different deposition on the top, middle and bottom of the plant.

- Measurements on individual plants or leaves are extrapolated to deposition on the crop in the field using the estimated LAI or plant density. LAI can vary depending on the method used for measuring. As mentioned above, it is important to collect samples that are representative of the whole crop.

- The estimation of the tracer or pesticide concentration in the spray solution also causes uncertainties in the applied dose. Tank sampling may give variable results due to a heterogeneous tank mixture. Extraction of tracer after spraying may vary depending on the stability of the tracer and how easy it is to wash out.

4.5. Objective criteria for establishment of CI factors

An objective way of evaluating and revising the existing FOCUS CI factors would be to specify the criteria before the literature review and data collection was carried out. This was not done and it would probably also have led to such high quality demands that the studies collected in the review generally would not be able to comply with such criteria. The criteria mentioned below are therefore based on a pragmatic evaluation of what is possible with the available literature and studies. The review of the papers complying with the criteria as potential background literature for revising the crop interception database highlights a large variation in the number of data for the crops. In some crop species there were many references and many measurements (above 10), whereas for other crops the data were limited to 1-6 sample points or no studies at all. In the worst case (where only one relevant article was found) it was decided to compromise with the exclusion criteria regarding growth stage in Table 3, if the spraying time was determined or other descriptions (e.g. LAI and plant height) could be used to determine the growth stage. Based on this fact it was decided that revision will be only suggested for crops with more than 10 data points and where the growth stages are well described. Furthermore, the method used to calculate crop interception varied between studies. In some studies ground deposit was measured and in others plant deposit and in a number of studies both methods were applied. In vine, drift and recycling were also measured contributing to a total spray account. Thus, to make a homogenous proposal for revision of the FOCUS CI factors the following numbers of working criteria's was applied:

- For crop species where no clear growth stage could be determined or where fewer than 10 measurements were reported, no suggestions to change the FOCUS CI values are given. Further for crop species with 10 or more measurements at least 5 measurements should be within the same growth stage interval as the FOCUS value being evaluated. However, the data presented in Figures 17-25 can still give a valuable contribution to the evaluation of the existing FOCUS values.

- As requested in the Terms of References provided by EFSA in the call and in agreement with the FERA report (van Beinum and Beulke, 2010) methods M3 and M6 were applied for crop species in which both ground and soil deposit were measured. If less than 10 measurements was obtained by the use of M3/M6 then the proposal is based on a combination of M3/M6 and M1 or M4.

- The CI value that is compared with the existing FOCUS CI value was calculated taking the arithmetic mean of the measurements in the growth stage interval. The proposed CI value is rounded to the nearest lower value which is divisible by 5 to achieve a conservative approach. For those crops where a new CI value is proposed, the calculations can be found in sheets 5.1. – 5.7. calculations, in annex 2, calculations sheets.

- Figures and tables in the report highlight how M1 underestimates the CI value and M4 overestimates the CI value, in comparison with M3/M6. In studies on apple and potato where data are derived with all four methods (M1, M3/M6 and M4) it can be found that the difference is approximately 20% between M1 and M3/M6 or between M4 and M3/M6 (see Tables 15+18). Thus, in crops in which the proposal is only based on M1 we do not suggest to change the FOCUS value if the measurement results (M1) are less than 20% below the FOCUS value. Likewise, if the proposal is only based on M4 we do not suggest changing the FOCUS value either, unless the CI values derived by M4 are more than 20% above the FOCUS value.

5. Spray interception by crops

5.1. Measurements of spray interception in vineyards

The review study on vine resulted in 11 references and 60 measurements on crop interception, see Table 12. The measurements can either be as crop deposition or as ground deposition, so if both are measured in the experiment it will be counted as two measurements. Common for evaluation of spray deposit was the effect of growth stage, canopy structure (or training systems) and test of different spraying technologies. Data were only included in the database or report if the spraying technology and spray volume were common practice in Europe (air blast, axialfan, overrow and tunnel sprayer).

Table 12: Relevant literature for interception data for vineyards and methods used to derive CI.

ID	Reference	No	Country	Variation	Method
C-46	(Ade et al., 2007)	5	Italy	Various growth stages	M1, M3, M4, M6, M8
F-24	(Pergher and Gubiani, 1995)	8	Italy	Detect loss level and distribution	M1, M3, M4, M6
C-1	(Llorens et al., 2010)	5		Relationship between spray volume savings and canopy structure	M1
A-39	(Pergher and Petris, 2008)	8	Italy	Two growth stages, air flow rate and distribution in plants	M1
A-98	Pergher and Petris (2007)	6	Italy	Deposition in different training systems	M1
A-838	(Viret et al., 2003)	8	Switzerland	Comparison of spraying equipment	M1, M3, M4, M6, M7, M8, M9
B-406	(Baraldi et al., 1993)	2	Italy	Two spraying technologies	M1, M3, M4, M6
B-320	(Pergher et al., 1997)	4	Italy	Comparison of spraying equipment	M1, M3, M4, M6
C-65	(Ade et al., 2005)	4	Italy	Comparison of two spraying equipments	M1, M3, M4, M6, M8
A-495	(Siegfried and Hollinger, 1993)	6	Switzerland	Comparison of two spraying equipments	M1, M3, M4, M6, M7, M8, M9
E-080	(Pergher et al., 2013)	4	Italy	Two spraying technologies	M1
	Number of data in database	60			

Depending on the measurements reported and collected in the database, various methods were employed (Table 7) for calculation of crop interception, and results were plotted against growth stage as illustrated in Figures 3-5. In 37 of the total 56 tests, spray deposits were measured on both crop and soil and M1, M3, M4 and M6 could be employed as calculation methods. The values derived by M3 and M6 are based on the same measurement and are therefore identical, and only presented as one plot (Figure 4).

Results from the axialfan sprayer seem to agree quite well with the FOCUS values when M3, M4 and M6 are employed as calculation methods. When tunnel sprayers are employed, the value increases, telling that if more advanced technologies, such as tunnel sprayers, are used in future, it will be possible to increase the (FOCUS) CI values. Figure 3 shows that the crop interception factors derived with M1 result in lower values than the FOCUS value for most of the measurements.

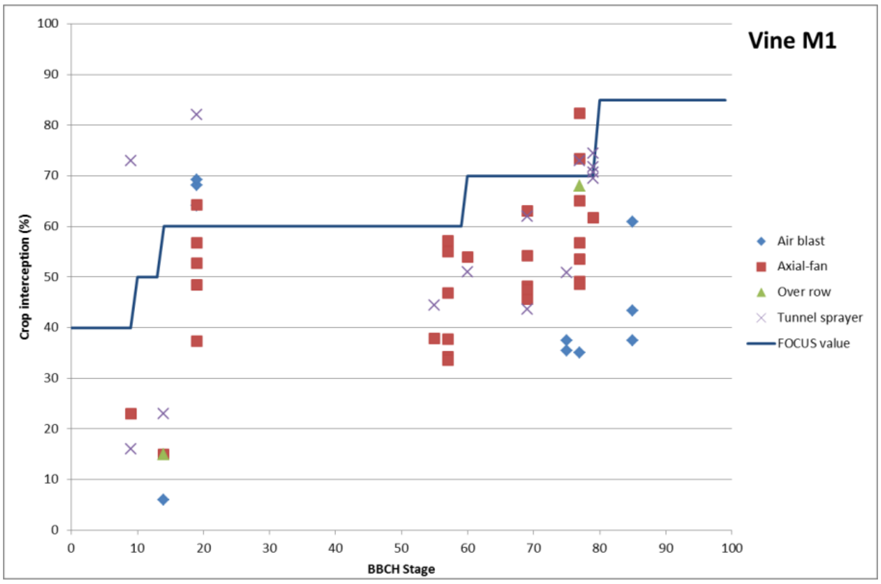

Figure 3: Crop interceptions for vine as a function of growth stage, calculated with M1.

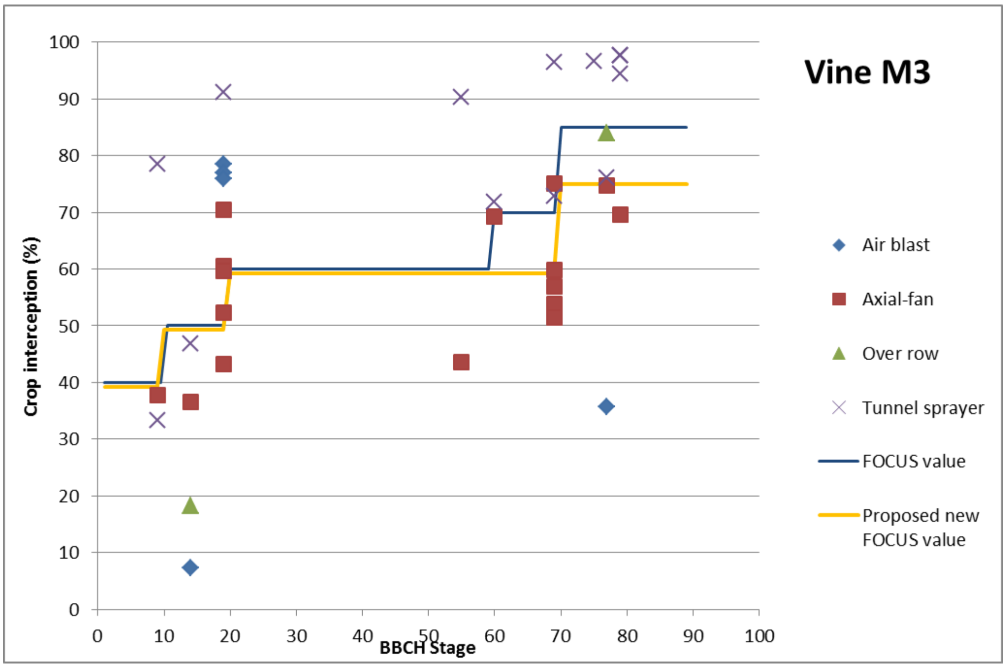

Figure 4: Crop interception values for vine calculated by M3/M6 as a function of growth stage. The proposed new FOCUS value is based on an average of measurements conducted after spraying with traditional sprayers (tunnel sprayers not included).

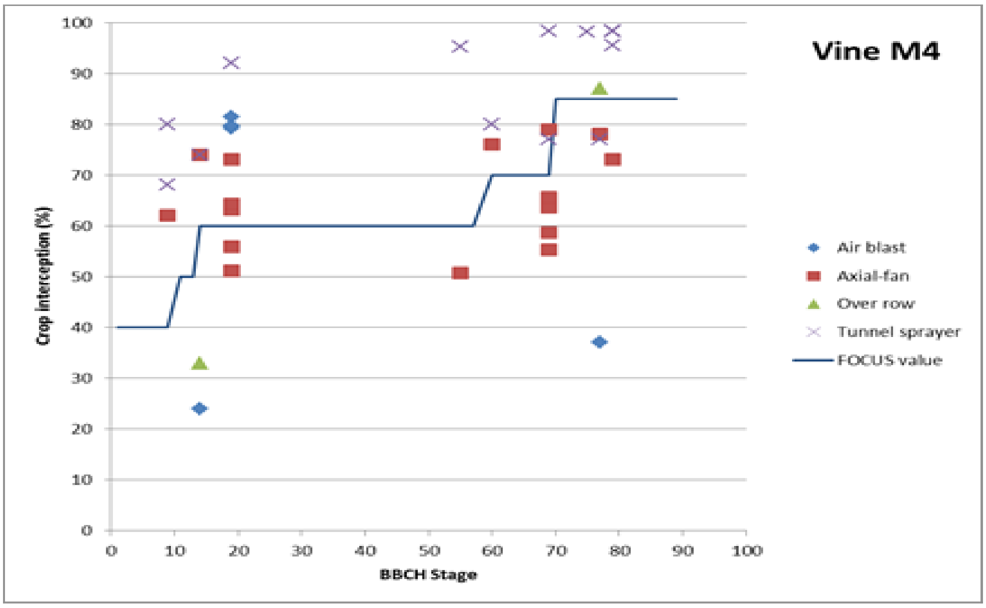

Figure 5: Crop interception values for vine calculated by M4 as a function of growth stage.

Table 13: Average of crop interception values derived from experiments in vine based on method M3/M6, and at different growth stages. The values in the last column are the CI values set by FOCUS, 2000.

Growth stage (BBCH)	Conventional sprayers	Tunnel sprayer	FOCUS
0-9	38	56	40
10-19	53	69	50
20-59			60
60-69	61	80	70
70-89	76	93	85

The comparison of the literature data presented here for vine crops and the FOCUS values was based on the crop interception data derived with method M3/M6 as required by EFSA. Despite some variation in the literature data, there is a good overall agreement with the existing FOCUS values if all data are taken into account. However, tunnel sprayers are not so common yet and leaving those data out, a revision of the FOCUS CI values will be considered in a more conservative approach. Based on the average of the measurements after spraying with conventional sprayers no revision of the FOCUS values is proposed in the early BBCH growth stages ranging from 0-20. At growth stage 20-59 the number of data is too limited to suggest a revision. At growth stage 60-69 a decrease of the FOCUS CI value from 70 to 60 per cent is suggested. Further, a revision of the existing FOCUS value from 85 to 75 per cent at BBCH 70-89 is suggested (see Figure 4 and Table 13).

5.2. Measurements of spray interception in potatoes

The review of studies in potato resulted in 3 references and 27 measurements (Table 14). The boom sprayer is the only technology employed in these studies, and here experiments were conducted evaluating ground deposits when spraying had been done at different growth stages. The study by van de Zande et al. (2005) was the only study where both ground and crop deposits were measured and hence interception could be derived by M1, M3, M4 and M6. In general Figure 6 illustrates that at the early growth stages (BBCH 20-39) some measurements are above and other measurements is below the FOCUS values. At growth stage BBCH 40-90 all the derived interception values are a little higher than the FOCUS values. When an average is calculated as shown in Table 15, it can be found that the CI values for growth stage 20-89 result in a higher CI value than recommended by FOCUS (2000) when all four methods are used. Thus, due to limited data on plant deposit, at growth stage 0-19 and 90-99 it is suggested to keep the FOCUS CI values at growth stage BBCH 0-19 and 90-99. The number of M3/M6 derived data is below five for each growth stage, therefore the proposals for BBCH stage 20-39 are based on the average of M3/M6, M4 and M1 (average is 63%). For BBCH stage 40-89 only data derived by method M4 are obtained and the proposals are based on the average of these data, which is 88%. Thus, it is suggested to increase the CI value in potato by 10% at BBCH 20-39 and 5% at BBCH 40-89. This results in CI values of 60% at BBCH 20-39 and 85% at BBCH 40-89.

Table 14: Relevant literature for crop interception in potatoes and methods used to derive CI.

ID	Reference	No.	Country	Variation	Methods
A-23	(Jensen and Spliid, 2003)	18	Denmark	Various growth stages	M4
A-158	(van de Zande, 2005)	7	NL	Various growth stages	M1, M3, M4, M6

A-312	(Leonard et al., 2000)	2	Ireland	Growth stage	M4
	Number of data in database	27			

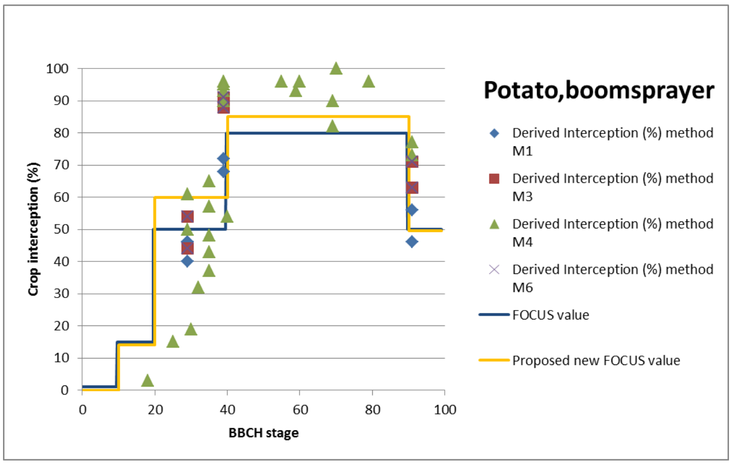

Figure 6: Crop interception values derived from potatoes, by the use of different methods as a function of growth stage. The proposed new FOCUS value is based on average of measurements conducted after spraying.

Table 15: Average of crop interception values derived from experiments in potato, by the use of different methods, (M1, M3, M4 and M6), at different growth stages. The values in the last column are the CI values set by FOCUS, 2000.

Growth stage (BBCH)	M1	M3	M4	M6	FOCUS
0-9					0
10-19			3		15
20-39	57	69	57	69	50
40-89			88		80
90-99	51	67	75	67	50

5.3. Measurements of spray interception in apples and pears (pome fruit)

All studies collected on apple resulted in 159 measurements (Table 16). Most studies measured only deposition on crops and hence crop interception values were derived by method M1. It is not common or recommended to use very high spray volumes so experimental data derived using higher volumes than 1000 l/ha were deleted before data in figures were plotted. There were no measurements in the crop stage named "leaf development". A few research groups have been measuring both crop and soil deposition, so crop interception could be derived by the use of methods M1, M3, M4 and M6. For

comparison of the calculation methods these data were plotted in Figure 8. Since M3 and M6 always result in the same crop interception value, only M3 is plotted in the figure.
The review of studies on pear resulted in four measurements (Table 17). Three of the measurements were compiled at the full leaf development stage and one at the bud and leaf development stage (Figure 7).
Comparison of data from the literature studies and the FOCUS values illustrates that the averages of the studies (where M1 was employed to derive CI values) result in lower CI values in all three growth stages (Figure 8). Most data were measured at "full leaves development" of which the FOCUS CI value is 80%. This is a very high value in comparison with the CI values obtained in the reviewed studies (Figure 7), in which only a few points give CI values of 80% or above.

Table 16: Relevant literature for interceptions data for apple and methods used to derive CI. (G*) is articles where data are in graphs.

ID	Reference	No.	Country	Variation	Methods
F-14	(Holownicki et al., 2000a)	8	Poland	Spray technology	M4
A-578	(Planas and Pons, 1991)	3	Spain	Spray volumes	M1, M3, M4, M6
A-755	(Herrington et al., 1981)	10	UK	Spray technology	M1
F-2	(Balsari et al., 2002)	4	Italy	Volume rate	M1, M3, M4, M6
A-213	(Jaeken et al., 2003)	5	Belgium	Spray nozzles	M1
F-16	(Holownicki et al., 2000b)	12	Poland	Air jet direction	M4
B-227	(Vercruysse et al., 1999)	2	Belgium	Growth stage	M4
A-397	(Doruchowski et al., 1996)	9	Sweden	Volume rate	M1
A-290	(Cross et al., 2001a)	27	UK	Spray flow rate	M1
A-282	(Cross et al., 2001b)	18	UK	Spray quality	M1
A-28	(Cross et al., 2003)	27	UK	Air flow rate	M1
A-356	(Cross et al., 1997)	4	UK	Forward and fan rotation	M1
B-488	(Cross, 1991)	6	UK	Spray technology	M1
B-404	(Huijsmans et al., 1993)	4	NL	Spray technology	M1, M3, M4, M6
B-589	(Heer et al., 1985a)	3	NL	Day variation	M1, M3, M4, M6
B-590	(Heer et al., 1985b)	10	NL	Spray volumes	M4 (G*)
F-028	(Triloff, 2011)	7	D	Spray volumes	M4 (G*)
	Number of data in database	159			

Table 17: Relevant literature for interceptions data for pear and methods used to derive CI.

ID	Reference	No.	Country	Variation	Methods
A-256 B227	(Vercruysse et al., 1999)	2	Belgium	Different spray technologies	M4
A-256	(Solanelles et al., 2002)	2	Spain	Different spray technologies	M4
	Number of data in database	4			

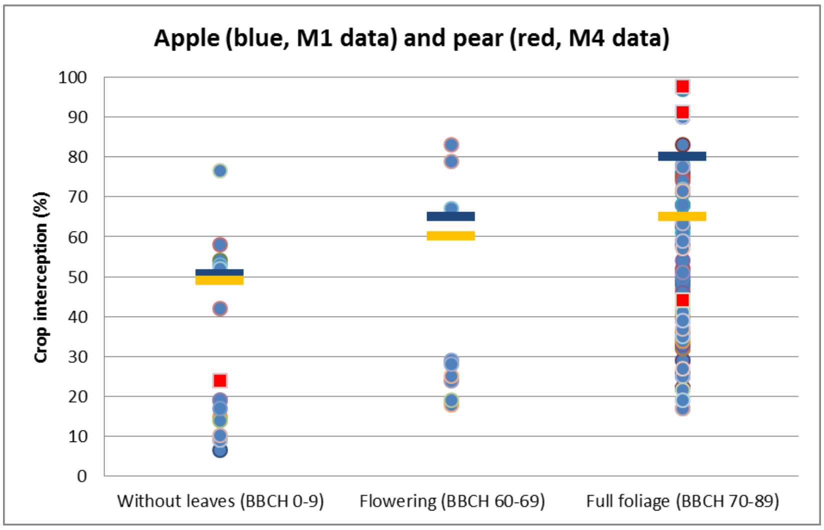

Figure 7: Crop interception data derived from crop deposits for apple (M1in blue) and ground deposits for pear (M4 in red). Measurements conducted at different growth stages. Blue line is the CI values mentioned in FOCUS report (2000) and yellow line is proposed new CI values.

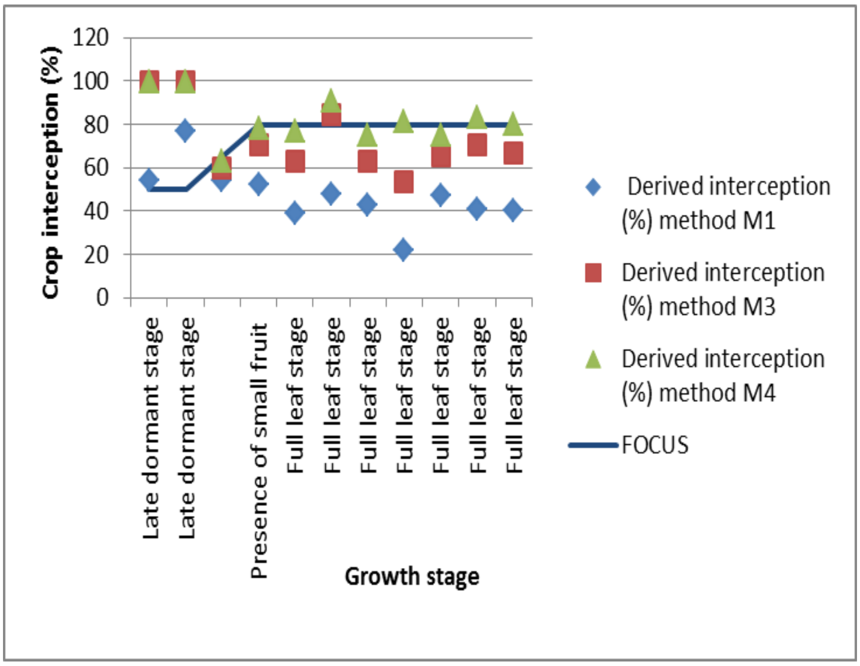

Figure 8: Data plotted where both crop and ground deposits were measured in apple trees. Crop interception factors were derived by calculation methods M1, M3/M6 and M4. Different researchers measured data at different growth stages. Planas and Pons (1991) sprayed at late dormant stage; Balsari et al. (2002) sprayed at reduced leaf development and when small fruits were present; Huijsmans et al. (1993) and de Heer et al. (1985a) both sprayed at full leaf stage.

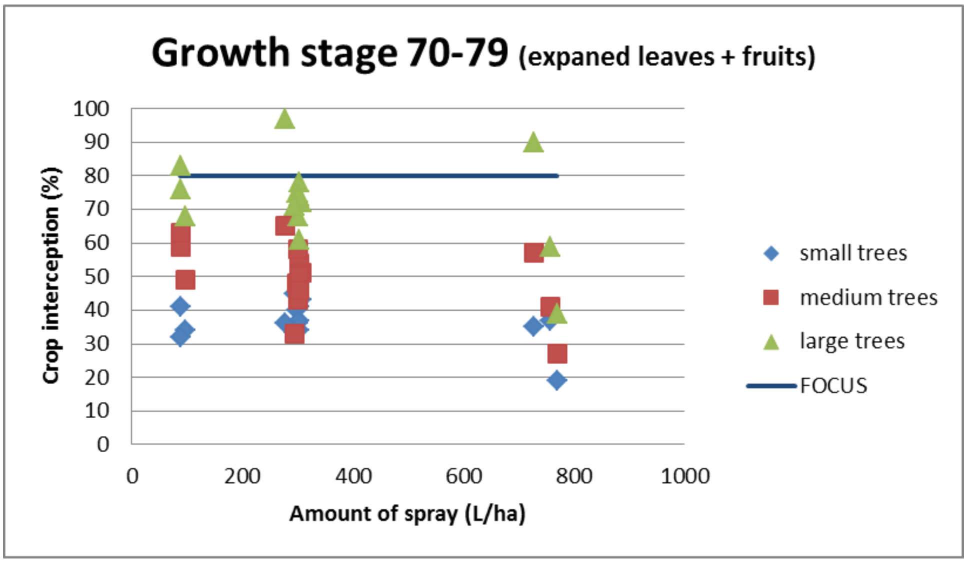

Figure 9: Crop interception data derived from crop deposits as a function of spray volume (M1). Measurements conducted at different tree sizes. From data published by Cross et al. 2001 (A-290 and A-282).

The most comprehensive study on CI in apples was carried out by a research group in the UK (Cross et al. 2001 and 2003). They evaluated the spray deposits, using an axial fan sprayer in a orchard with the Cox variety planted in 1980, 1989 and 1995. The studies resulted in collection of data from three different tree sizes and three different growth stages (in spring (April-May), during summer (June-July) and late summer (August-September). In the first two papers (A-290 and A-282) the effect of different spray volumes was tested at full foliage growth stage (Figure 9). In the third paper (A-28) different air volumes were evaluated at three different growth stages (Figure 10). When the plots are compared, it appears that the use of different air volumes results in similar crop interception values. The use of different amounts of spray volumes also results in similar crop interception values. One exception was in the case when high volumes (around 800 L/h) were applied, here there was a little decrease in CI value.

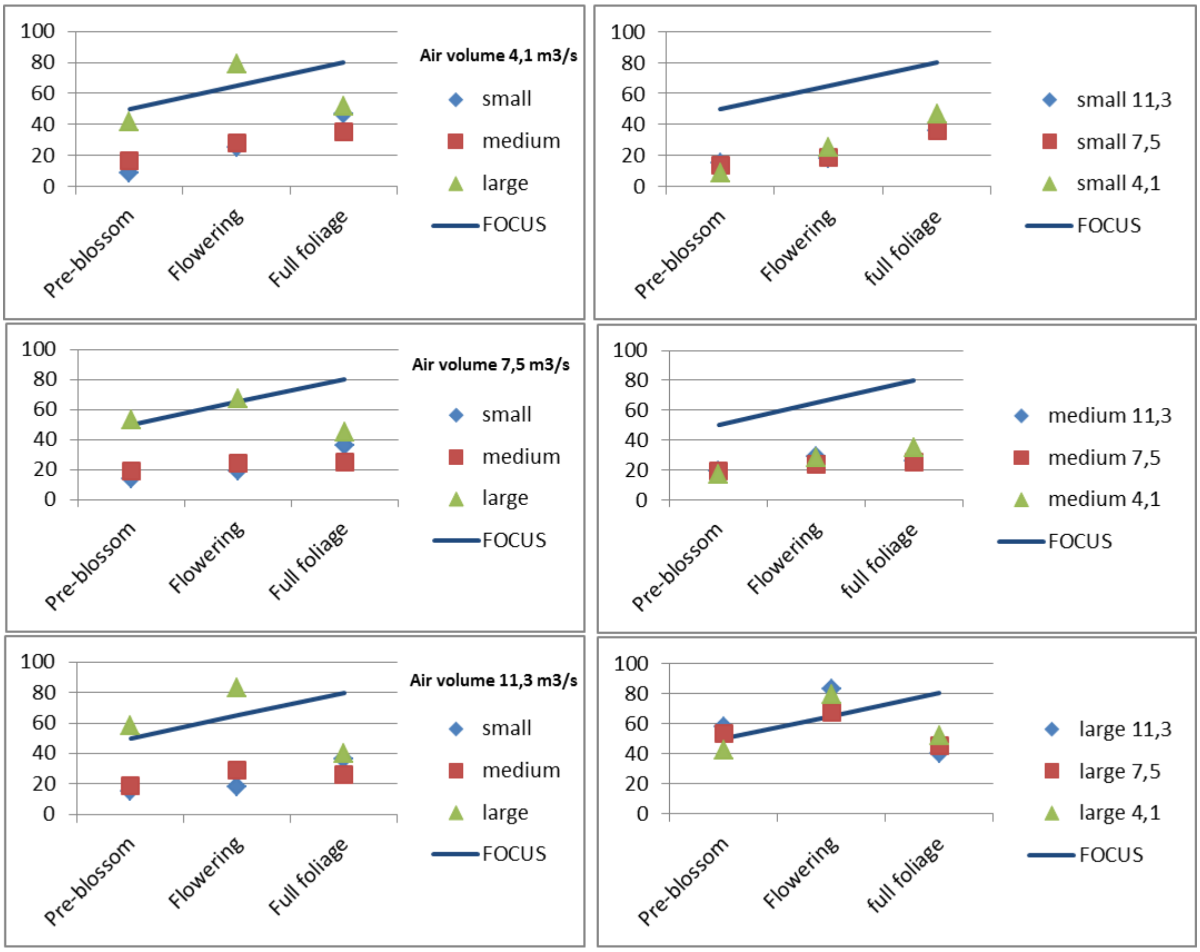

Figure 10: Crop interception data derived from crop deposits and spray volume (M1) and FOCUS values at the different growth stages. Measurements were captured after different spray treatments (use of different air volume) and in orchards with different tree sizes.

Table 18: Average of crop interception values derived from experiments in apple and pear by the use of different methods M1, M3, M4 and M6, at different growth stages. Calculations are based on data from all papers mentioned in Tables 15 and 16. The values in the last column are the CI values set by FOCUS, 2000.

Growth stage (BBCH)	M1	M3	M4	M6	FOCUS
Without leaves (0-9)	33				50
Flowering (60-69)	40				65
Full foliage (70-89)	48	67	83	67	80

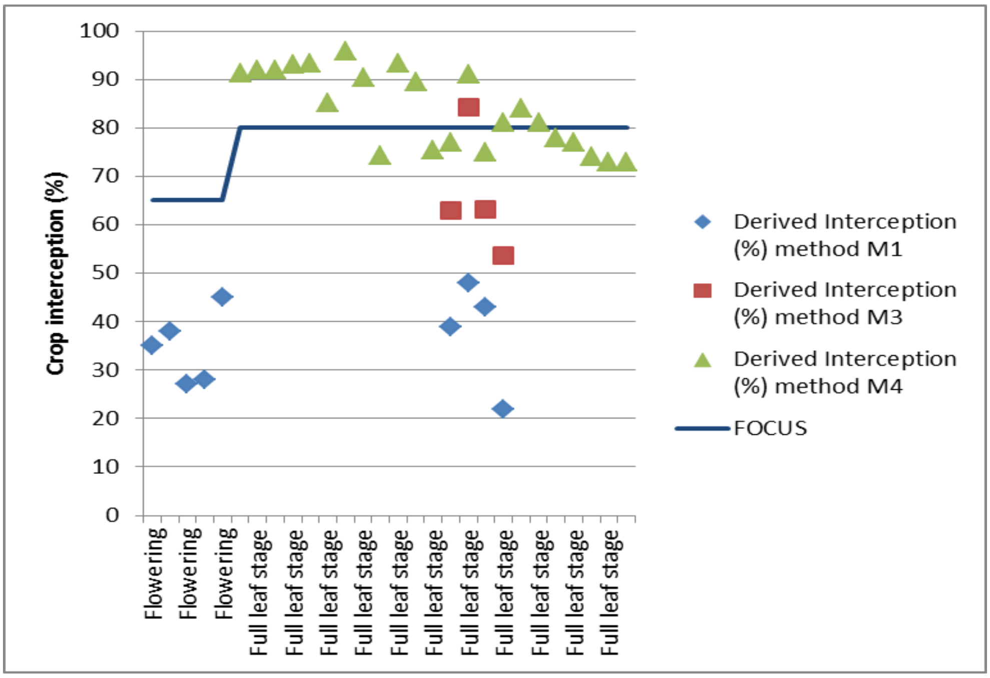

Figure 11: Crop interception data derived from four studies (Huijsmans et al., 1993; Holownicki et al., 2000b; Jaeken et al., 2003; Triloff, 2011). In those experiments, the measurements were conducted in apple orchards similar to the modern orchards grown today.

In general it is only the CI values measured on large trees and CI values in the first two growth stages, that reach the CI values used by FOCUS 2000. At full foliage and in the small and mediumsized trees crop interception was found to be below the FOCUS value. Thus, one possibility is to divide the FOCUS values in 3 groups based on age of the tree and then keep the FOCUS value for trees older than 17 years and lower the CI values for younger trees. However, since only one FOCUS value should be used independently of orchard size/age we recommend to use the information from experiments which are most similar to the way orchards are grown today, where the common growth system is 3.5 metre between rows and 1 metre or less between the trees (so that the growth of the trees almost covers the area like a wall) and the high is maximum 2.5 metre. In the study by Cross et al. (2001 and 2003) the distance between the trees was above 4 x 2 metre and therefore the space between the crown of the small trees was larger than in a common modern orchard grown today. Therefore, in this study it is more relevant to compare the FOCUS value with the medium-age or old trees. When we look into the description of the material and methods in the literature studies, there are four references (A213 by Jaeken et al., 2003, B404 by Huijsman et al.,1993, F16 by Holownicki et al., 200b and F28 by Triloff, 2011), in which the study was carried out in apple orchards with a distance between rows of 3-3.5 m and a distance between trees within the rows of 1.2-1.5 m. In those studies CI values were derived by M1, M3/M6 or M4 (Figure 11) and it is clear that the existing FOCUS value is in accordance with M4 data and above M1 data. Only four data points could be derived by method M3/M6 and the average of these is 13% below the existing FOCUS value. In addition it can be observed in Table 18 that M1 values are aproximately 20% lower than M3/M6 values (see also discussion of M1 in section 4.4). By adding 20% to the M1 average the following values are obtained: 50% at growth stage without leaves, 61% at flowering and 65% at full foliage.

Thus based on the M3/M6 data (only data points at full foliage) combined with M1 data our suggestion is to keep the CI FOCUS value at the first growth stage and decrease the CI value by 5% at flowering (from 65 to 60%) and further to decrease by 15% at full foliage (from 80 to 65%). This proposal is also in good agreement with the data shown in Figure 11, where the average of the four M3 data points at full leave stage is 66%.

5.4. Measurements of spray interception in citrus

The review study on citrus resulted in 3 references and 14 measurements (Table 19). In these studies there was no information on the growth stage. However, in the FOCUS 2000 report the crop interception value is 70% for all growth stages. Furthermore citrus is an evergreen species, so there will be fully developed leaves all year round. In general a higher spray volume is used in comparison with vine and apple. In comparison with the FOCUS values, M1-derived data are below the FOCUS value and M3/M6 and M4 derived crop interception is above the FOCUS value (Figure 12). In agreement with the objective crieteria (4.5.) the suggestion for revision of the CI value will be based on M3/M6. When the average of the M3/M6 data is calculated, it is 84%, so an increase of the value by 10% can be suggested.

In the study where spray interception is measured on orange trees with different crown densities, the high and medium density resulted in CI values above the FOCUS value, whereas applications on trees with low crown density resulted in CI values just below the FOCUS value (Figure 13).

Table 19: Relevant literature for interceptions data for citrus.

ID	Reference	No.	Country	Variation	Methods
A-334	(Cunningham and Harden, 1998b)	7	Australia	Different spray applications volumes	M1, M3, M4, M6
A-341	(Cunningham and Harden, 1998a)	4	Australia	Different spray applications volumes	M1, M3, M4, M6
A-18	(Meli et al., 2007)	3	Italy	Soil and surface water contamination	M1

Number of data in database	14

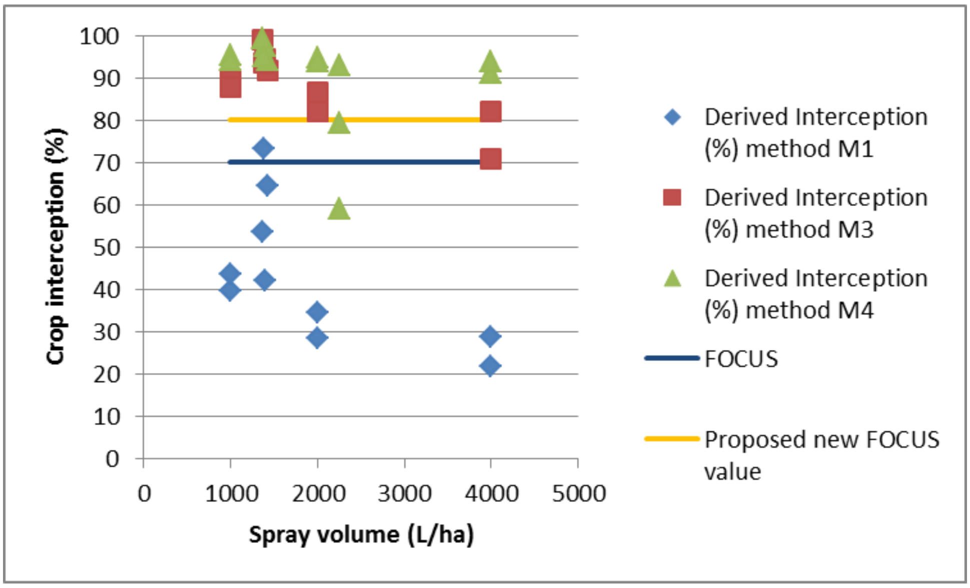

Figure 12: Crop interception values derived for citrus by the use of different methods as a function of spray volume.

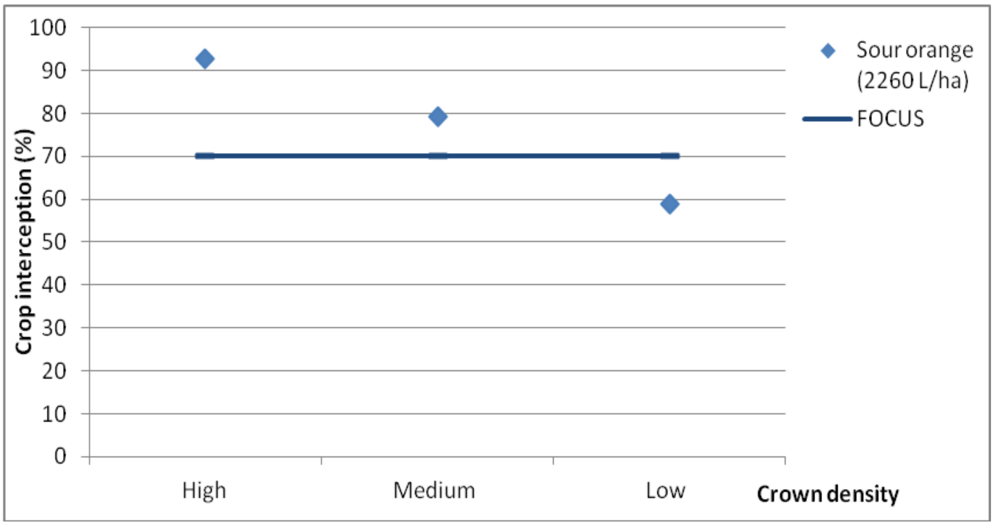

Figure 13: Crop interception values derived by M4 and measured after spraying of orange trees with different crown densities. Data from Meli et al. (2007).

5.5. Measurements of spray interception in cotton

The review of studies in cotton resulted in 3 references and 26 measurements (Table 20). All three references are from studies outside Europe, but as decribed in paragraph 2.1. page 10 it was decided to include those studies if the conditions was considered to be similar to European conditions. In A-702 by Willis et al. (1983) and A-826 by Wilis et al. (1985) it was possible to determine the BBCH growth stage due to the information of crop cover. In the BBCH tables (Meier, 2001) it is determined that at growth stage 34 the crop cover is 40%, at growth stage 35 crop cover is 50% and at growth stage 37 and 38 a coverage of 70 and 80% respectively is stated. In the third paper by Zeren and Moser (1988) (B-541) it was not possible to determine an exact growth stage, but due to the height of the plant, LAI and treatment time it could be compared with either the FOCUS values at growth stage 20-39 or the later one 40-89. Earlier in this report and in the report by van Beinum and Beulke (2010) a number of exclusion criteria were used to limit the number of references. But as an exception due to the limited number of publications on cotton it was decided to use this article in the review study (see also paragraph 4.5). Where the FOCUS values in Figure 14 are compared with the CI derived by M1, it seems as if most of the points are below 60%, so the FOCUS values are a little too high. However, it was shown in apple and discussed in section 4.4. that the M1 method often results in a lower CI value than using M3/M6. So based on those observations, it is not suggested to revise the FOCUS CI value.

Table 20: Relevant literature for interceptions data for cotton.

ID	Reference	No.	Country	Variation	Methods
A-702	(Willis et al., 1983)	3	USA	Volatile losses	M1
A-826	(Willis et al., 1985)	3	USA	Volatile losses	M1
B-541	(Zeren and Moser, 1988)	20	Turkey	Different spray nozzles	M1
	Number of data in database	26			

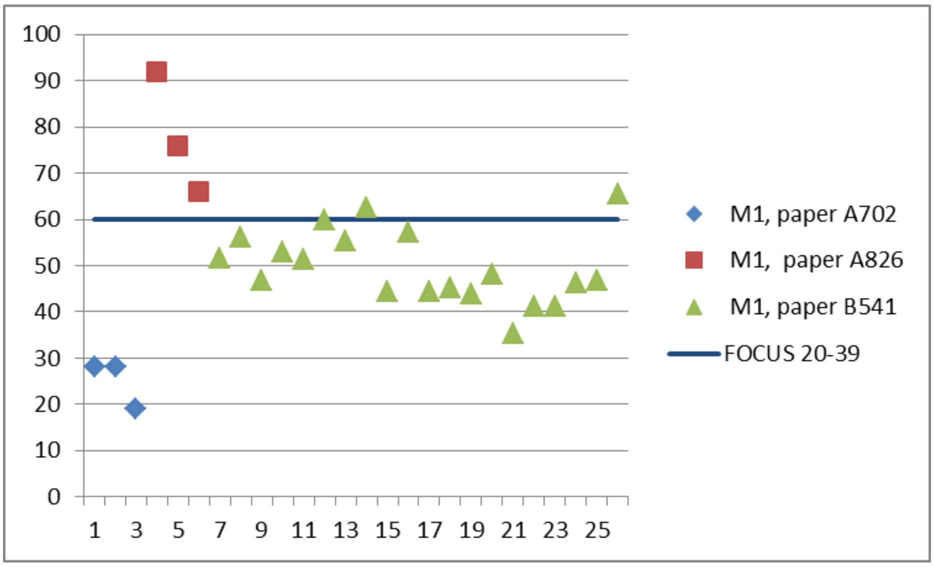

Figure 14: Crop interception values derived for cotton using method M1, based on 26 measurements from 3 different articles. No revised values were suggested.

5.6. Measurements of spray interception in sugar beet

In sugar beet there were two accepted references, one with nine measurements and one with 37 measurements (Table 21). The nine measurements conducted by May (1991) were captured at growth stage 33 after spraying with different spray technologies. In the other study by Jensen and Spliid (2003) only a standard spray technology (a boom sprayer) was used, but here the treatments were conducted at different stages during plant development (for three years). In Figure 15 it can be observed that from growth stage 20 and later the crop interception values for all measurements are above or close to the FOCUS values. At lower growth stages (below BBCH 20) there are a number of CI points on both sides of the FOCUS line. Figure 16 highlights the differences between those points, and it can be observed that the points below the FOCUS line are measurements from 2000 and 2001. The spray volumes were different in all three years, and still the CI were alike in year 2000 and 2001. The great difference between measurements conducted in 1999 and the two other years (2000 and 2001) was the way in which the paper strips for deposit collection were placed on the soil. The change of methods was only conducted at the early growth stage and the idea was to obtain a more realistic detection of ground deposit. The measurements were conducted at growth stages ranging from BBCH 10-19 to 20-39 and by taking the average result of the CI values result in 21% and 75% respectively. Upon comparison with the FOCUS CI values, which were set to 20% and 70%, no revision is recommended.

Table 21: Relevant literature for interception data for sugar beet.

ID	Reference	No.	Country	Variation	Methods
A-577	(May, 1991)	9	UK	Different spray technologies	M4
A-23	(Jensen and Spliid, 2003)	28	DK	Various growth stages	M4
	Number of data in database	37			

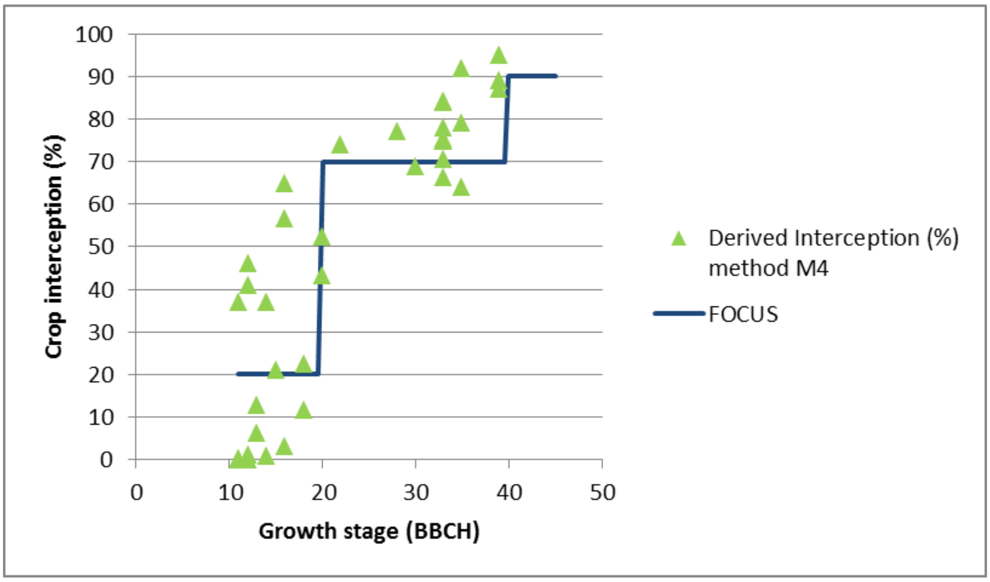

Figure 15: Crop interception values as a function of growth stage derived for sugar beet by the use of method M4.

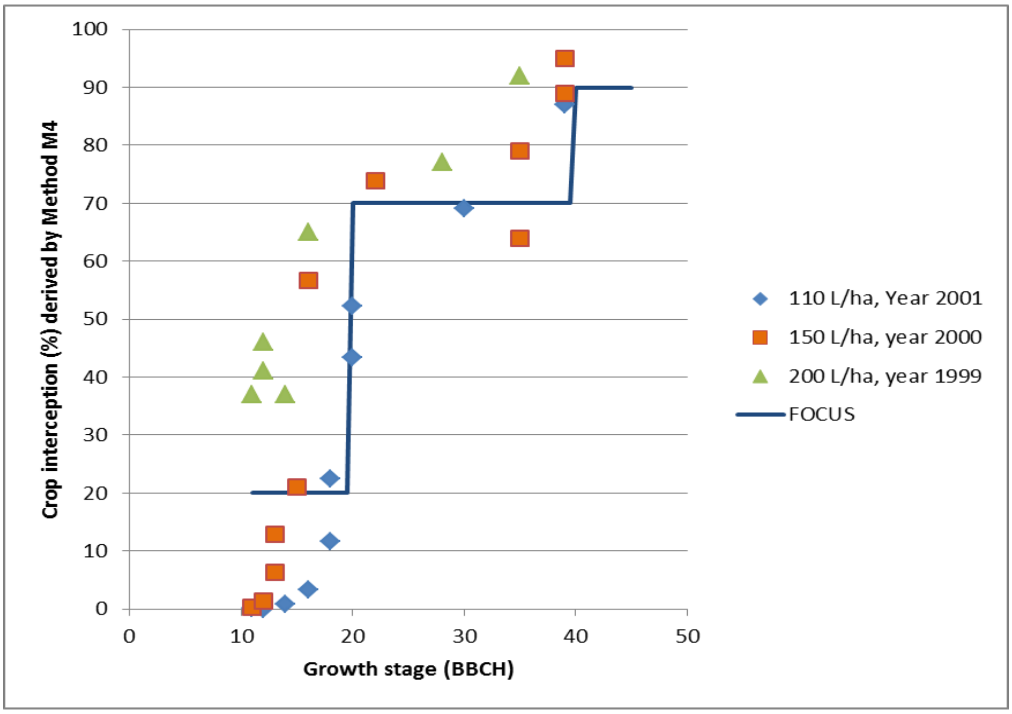

Figure 16: Crop interception values as a function of growth stage derived for sugar beet with the use of method M4, for three different spray volumes.

5.7. Measurements of spray interception in crops with limited or no data

For crop species in which less than 10 measurements were reported or in which the reported studies lacked some of the required information described in the exclusion criteria, no suggestions to change the FOCUS CI values are given. However, the data presented in Figures 18-25 still seem to be valuable information that can be used to discuss the present FOCUS values and the possible need for revision. For a number of crops, only measurements from one published paper were included in the database, and crop interception factors could be derived by method M4 (Table 22). Furthermore, the measurements were conducted at one single growth stage.

Bean and soybean

For bean, the 6 measurements were done during leaf development (no BBCH values were provided in the paper) and at that stage CI was above the FOCUS value. Measurements after spraying soybeans were conducted during flowering (no BBCH values were provided in the paper) and only one of the measurements reached the FOCUS value (Figure 18).

Tomato

For tomato no growth stage was reported in the article, but the height (25 cm) and width (14 cm) of the plants could be the indication of a young plant. Thus, from this description of the crop, it was correlated to BBCH growth stage 10-19 (leaf development) and data were compared with the FOCUS value for this growth stage. Three different spraying technologies were tested, and only the CI value derived from measurement of soil deposit after spraying with a Yawed band sprayer reached the FOCUS value (Figure 19).

Alfalfa

The study in alfalfa was conducted in July on an established field. Measurements were carried out 22 days after the crop had been mowed (cut down). Thus, the unmowed plants were considered as flowering plants and at that growth stage the FOCUS CI value is 90%. The mowed plants were considered being at growth stage stem elongation stage where the FOCUS CI value is 60%. The CI values were based on ground deposit (M4) and three of the measurements were above the FOCUS value, whereas the last one was just below the FOCUS value (Figure 20).

Maize

For maize there was one paper with 6 records. The only information regarding crop stage was the plant height of 2.5 metre and the LAI, which varied between the two locations where the crops used in the experiments were grown. When the plants are 2.5 metre and LAI is around 3, the crop development is supposed to be after stem elongation and around flowering or senescence. FOCUS values for these two growth stages are 75% and 90% respectively. The experimental CI value varied with two values below 65%, three close to 75% and the last measurement on 80% (Figure 21).

Olive

Olives is an evergreen tree and with a FOCUS value of 70% reported in the surface water scenarios. Only one paper reported an experiment in which CI values could be derived (based on ground deposit, M4). In this experiment a conventional sprayer was tested together with sprayers, where one and two sensors were mounted on the sprayer. In all three measurements the CI value reach above 85% (Figure 22).

Pea

In the paper about pea only one record could be reported and it is just below 70%, which is the FOCUS value reported in the surface water scenario. In the ground water scenario, the FOCUS value was set to 85% (Figure 23).

Strawberry
In the studies of strawberries only one reference was found. The deposit measurements were done in May 2007 and April 2008 below crops grown in Turkey, so the growth stage must be at flowering or the start of fruit development when the FOCUS CI value is 60%. Six records were collected based on three different spray technologies and repeated over two years. Five CI values derived by method M4 were above 60% indicating that this is the right CI value (Figure 24).

In general, for these crops it is difficult to draw a conclusion due to the limited data. However, for most of the crops the few data points indicate an acceptable agreement with the existing FOCUS values.

Bush berries
No articles on bush berries were found in the literature. However, in the extrapolation rules set by van der Linden and Resseler (2009) bush berries were compared with vines, using the same extrapolation rules. In the literature many published results can be used to determine CI values in vine at different growth stages. Therefore it is suggested to use for bush berries the same CI values as suggested for vine. So at growth stages without leaves (BBCH 0-9) it is proposed to reduce the CI value from 50 to 40%, and to decrease the CI value at the flower and full foliage state (BBCH 40-89) by 5%.

Leafy, root and bulb vegetable (cabbage, carrot and onion) and tobacco
No data were found on these crops and in the earlier work published by FOCUS (2000) it was proposed to use the extrapolation rule, where max soil cover is multiplied by 0.9. We suggest that this is still the best one until new studies on CI in these crops are compiled. Therefore no revision is suggested for those crops.

Sunflower
No articles on sunflower were found in the literature study. In the extrapolation rules set by van der Linden and Resseler (2009) sunflower were compared with maize, but in our literature study on maize the published results were too limited to revise the focus CI value. Therefore no revision is suggested for sunflower.

Oil seed rape, linseed and hops
No data from literature or extrapolation rules are found on these crops, so no suggestion for revision of Focus CI values was made.

Peach (stone fruit)
The review of studies in stone fruit showed two papers on peach (Table 22). The first paper includes one measurement of ground deposit, and the other paper four measurements of ground deposit and four measurements of crop deposit. Thus, the studies of peach are used as guidelines for revising the interception factors for stone fruit and the CI value can be derived by method M3/M6. No CI values for peach were proposed by the FOCUS Groundwater Group (FOCUS 2000). Therefore, the interception values of FOCUS surface water scenarios (Anonymous, 2011a) were considered for a comparison with the calculated CI from the relevant literature (see appendix E). At full development

stage the FOCUS value were set to 40% at BBCH 20-39 and 70% at BBCH 40-89. In Figure 25 the CI data derived by M3/M6 show values around 70% at full leaf development.Therefore it is suggested to keep the FOCUS CI value.

Table 22: Relevant literature for interceptions data of crops with limited data.

ID	Reference	No.	Country	Variation	Crop	Methods
E-67	(Rodrigues-Costa et al., 2011)	6	Brazil	Different spray applications volumes	Bean	M4
E-35	(Christovam et al., 2010)	4	Brazil	Different air speed	Soybean	M4
A-376	(Giles and Slaughter, 1997)	3	USA	Different spray technologies	Tomato	M4
A-427	(Schauber et al., 1995)	4	USA	Mowed and unmowed	Alfalfa	M4
A-146	(Michielsen et al., 2006)	6	NL	Different spray technologies	Maize	M4 (G*)
A-256	(Solanelles et al., 2002)	3	Spain	Different spray technologies	Olive	M4
D-001	(Arnold et al., 1984)	1	UK		Pea	M4
E-73	(Yarpuz-Bozdogan et al., 2011)	6	Turkey	Different spray technologies	Strawberries	M4
A-155	(Balsari et al., 2005)	1	Italy		Peach	M4
E-024	(Gaynor and Layne, 1979)	4	Canada	Different spraying technologies	Peach	M1, M3, M4, M6
	Number of data in database	38				

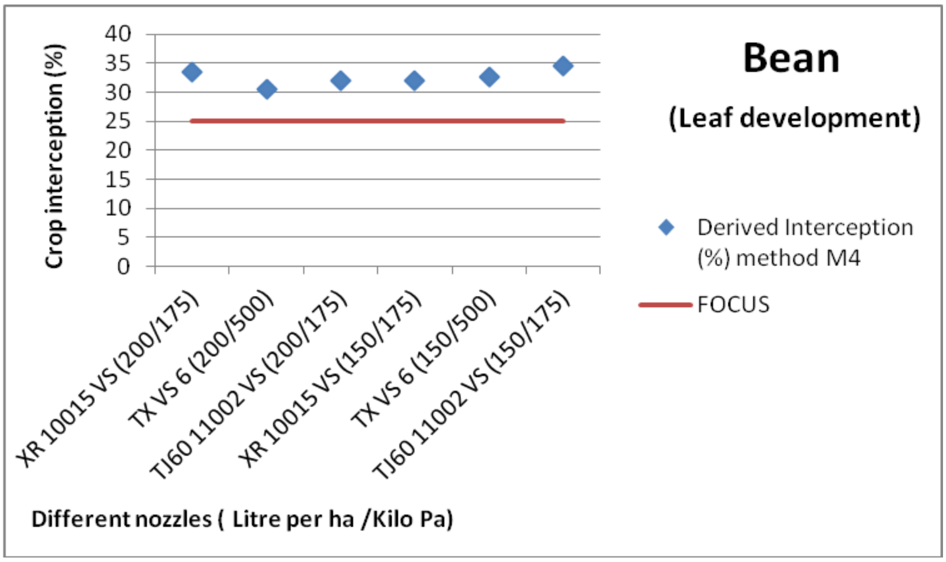

Figure 17: Crop interception values derived by method M4 and measured after spraying of beans by the use of different spray volumes and pressure. No BBCH values were provided in the paper.

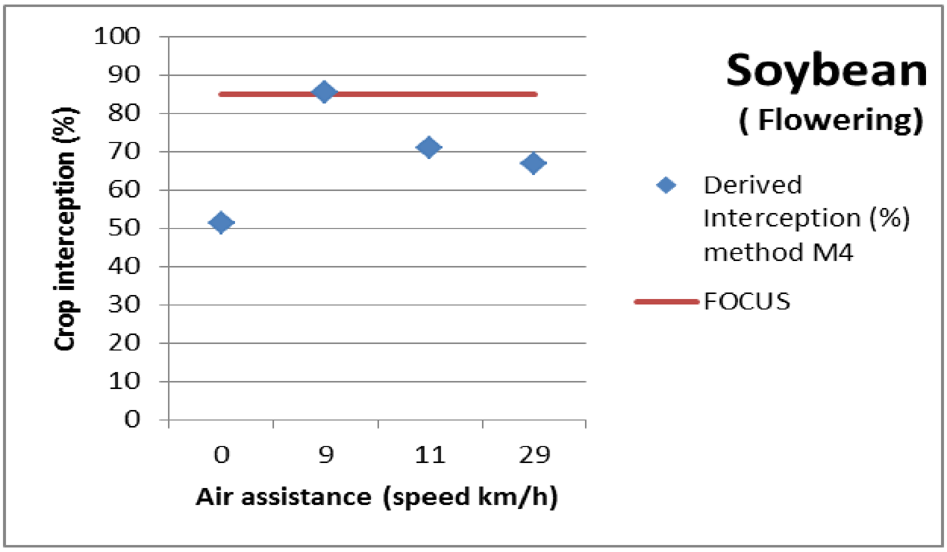

Figure 18: Crop interception values derived by method M4 and measured after spraying of soybeans with the use of different levels of airassistance. No BBCH values were provided in the paper.

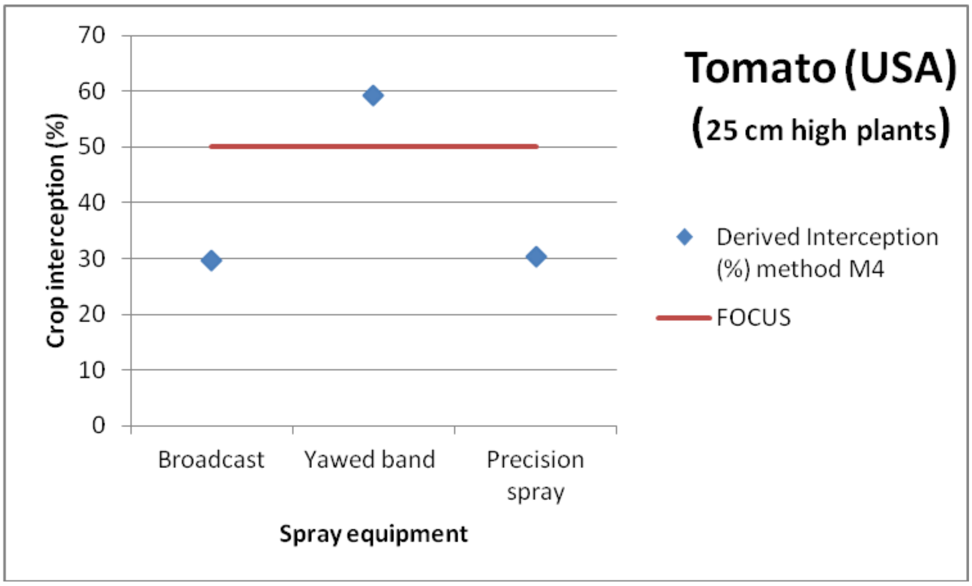

Figure 19: Crop interception values derived by method M4 and measured after spraying of tomatoes with the use of different spray equipment. No BBCH values were provided in the paper.

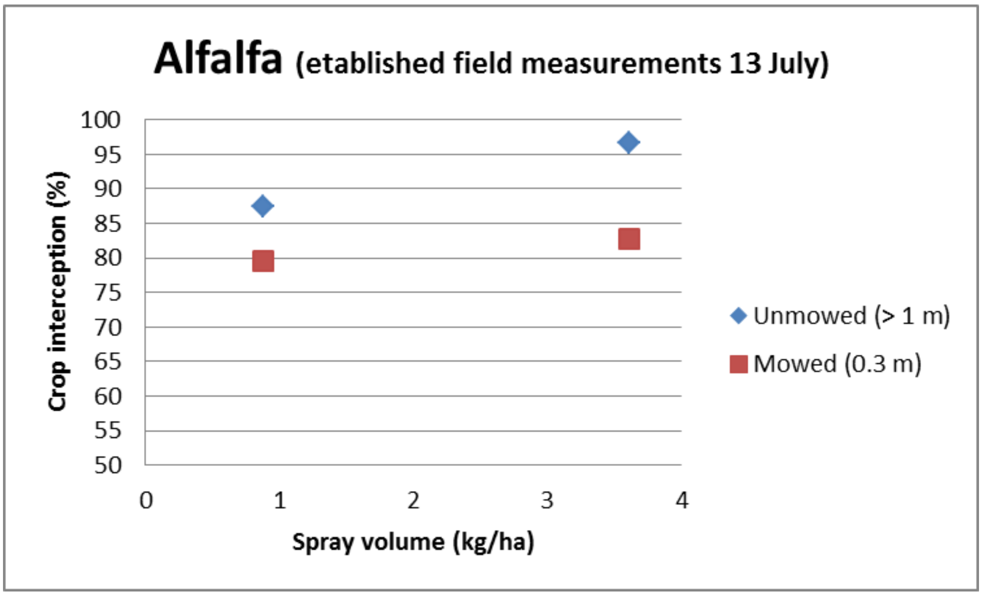

Figure 20: Crop interception values derived by method M4 and measured after spraying and 22 days after part of the alfalfa field was mowed. No BBCH values were provided in the paper, but after plants are mowed stem elongation will start and those plants that are not mowed may start flowering. FOCUS values are 60% at stem elongation and 90% at flowering and senescence.

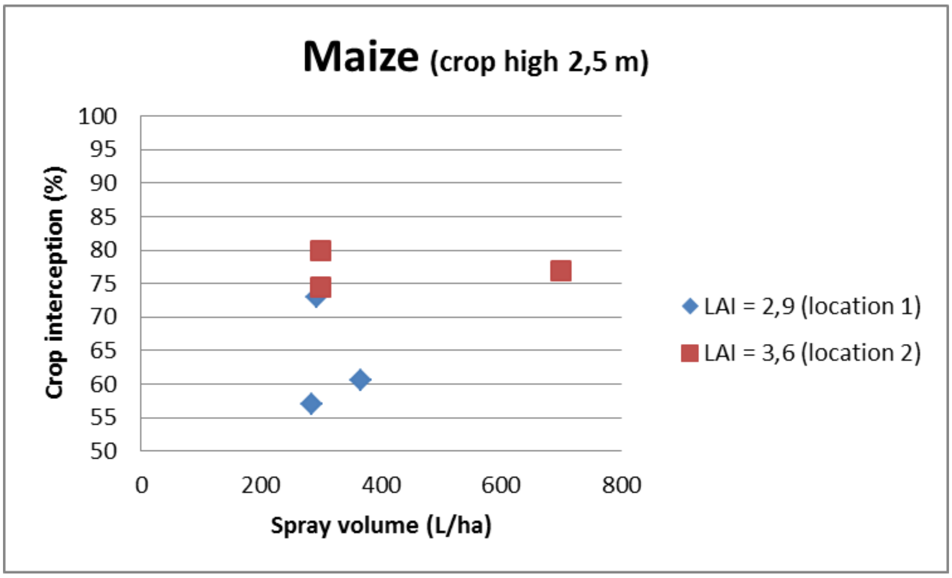

Figure 21: Crop interception values derived by method M4 and measured after spraying of the maize field. No BBCH values were provided in the paper, but it is suggested to be around flowering or senescence. FOCUS values are 75% at flowering and 90 % at senescence.

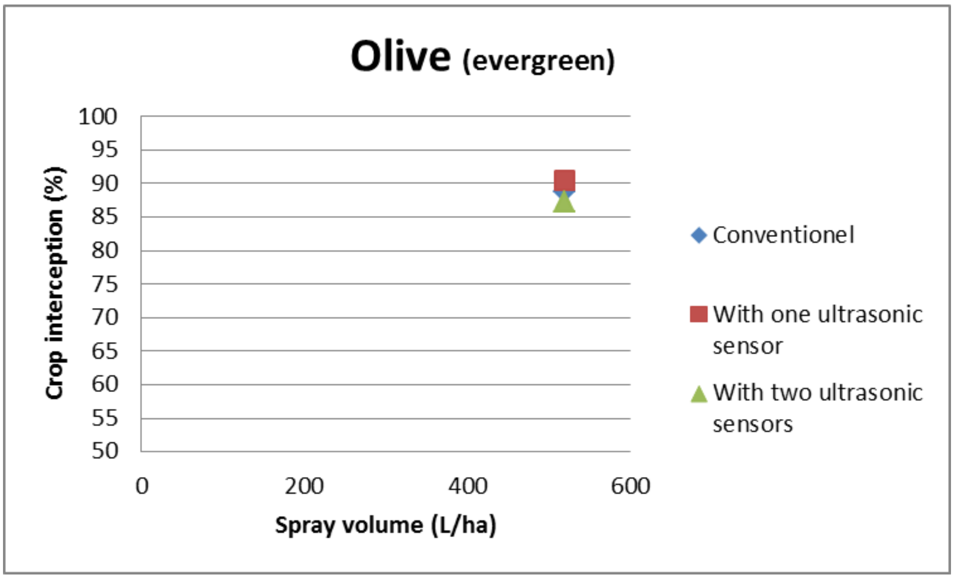

Figure 22: Crop interception values derived by method M4 and measured after spraying the olive trees. No BBCH values were provided in the paper, but olive is an evergreen plant and the FOCUS CI value is 70% for all growth stages.

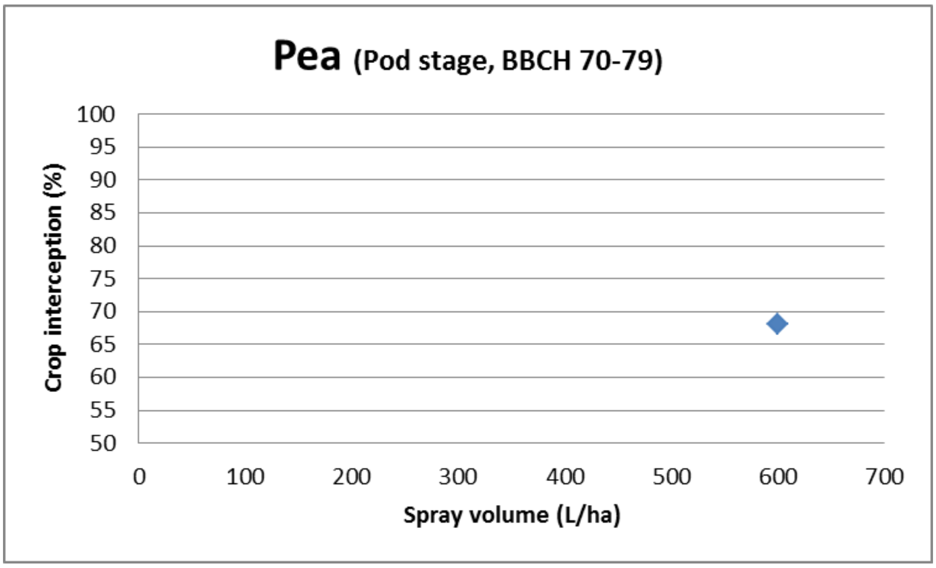

Figure 23: Crop interception values derived by method M4 and measured after spraying pea plants at pod stage (BBCH 70-79). FOCUS value for pea at BBCH growth stage 40-89 is 85%.

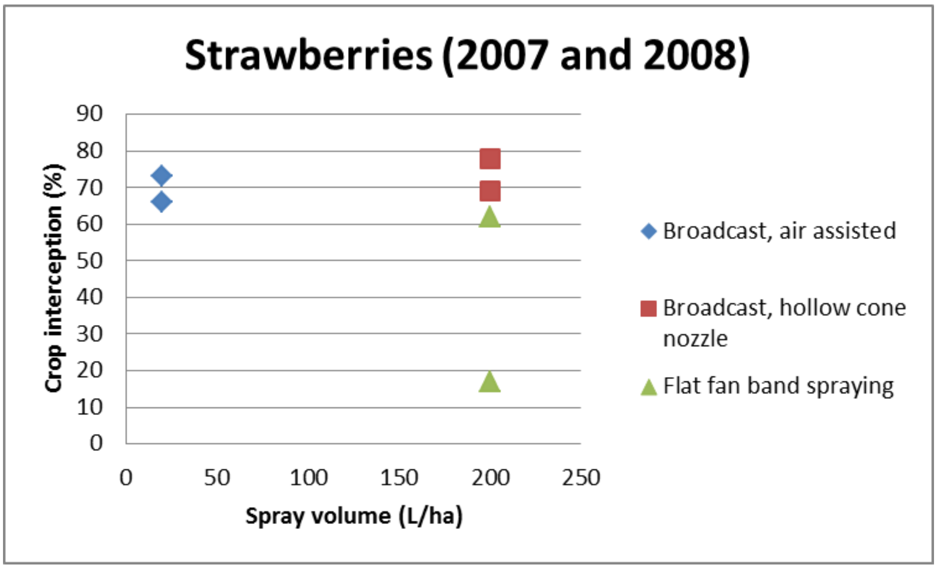

Figure 24: Crop interception values derived by method M4 and measured after spraying. No BBCH stage. FOCUS values are 30% at leaf development, 50% at stem elongation and 60% at flowering and senescence.

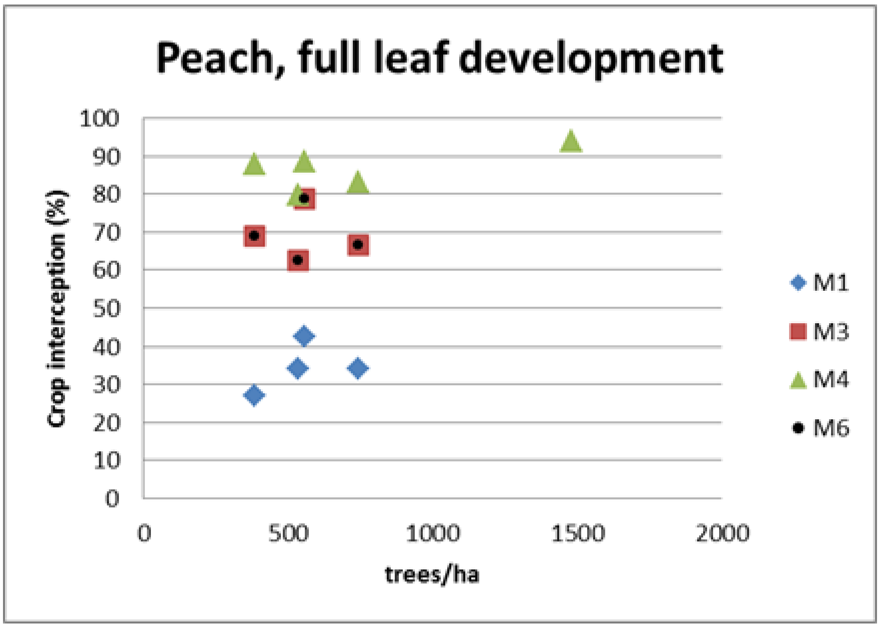

Figure 25.: Crop interception values for peach derived by method M1, M3, M4 and M6 measured after spraying at full leaf development. FOCUS values in the surface water scenarios were set to 70% at full leaf development stage (Anonymous, 2011a).

6. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

This literature survey collected studies on crop interception of pesticides in all other FOCUS values than cereals. The collected studies are very heterogeneous as the studies typically had another purpose than investigating crop interception of pesticides. In many studies the purpose was to compare spray equipment, and information of spray deposit was reported as µg or µl tracer per cm^2 leaves without any information of leaf area index or no information on the growth stage of the crop. In other studies the purpose was to study the reduction of drift without measuring deposit on the crop or on the ground underneath the crop. Different methods of assessing crop intereption were applied, and also other methodological differences were found. Therefore a set of rules was defined in order to require certain minimal criteria before a proposal to revise the existing FOCUS is given.

The number of published data was large enough for vine, potato, cotton, sugar beet, citrus and stone and pome fruit at different growth stages to reconsider the existing FOCUS CI values and make proposals for new CI values. For bean, soybean and tomato data were only obtained at one growth stage and for most of the crop there were not sufficient data for revision of the FOCUS CI values.

New CI values for revision are proposed for vine at BBCH growth stage 60-89 and for pome fruit at flowering and full foliage growth stage (BBCH 60-89). Further a revision is proposed of the FOCUS values for citrus generally and for potato at BBCH growth stage 20-39 and 40-89. At the moment, CI values for bush berries (and vine) are based on an extrapolation rule. In future it is suggested to revise CI values for bush berries so they are similar to the proposed values for vine (Table 23) based on published studies.

A general problem is the limited number of data or no data in many combinations of crop and growth stage that do not justify revision of the existing FOCUS values.

Table 23: Proposal for revision of the FOCUS CI values for each crop.

Crop	Revision	Explanation
Vine	Yes, decrease by 10% at BBCH 60-89	By use of conventional sprayers the average M3/M6- derived CI values fit the FOCUS values at the early growth stages, but are lower at the late growth stages.
Apple and pear /pome fruit	Yes, decrease by 5% at flowering (BBCH 60-69) and 15% at full foliage (BBCH 70-89).	Average based on M1 is always 20% below M3/M6. However, adding 20% to the average value results still in a lower value than the FOCUS CI value.
Citrus	Increase by 10 %	M3/M6 is above 70%.
Bush berries	Yes, decrease by10% at BBCH 0-9, by 5% at BBCH 40-89	Revision is based on extrapolation rules for which bush berries are compared with vines.
Stone fruit	No revision	Limited number of data (less than 10 measurements)
Olives	No revision	Limited number of data (less than 10 measurements)
Beans	No revision	Limited number of data (less than 10 measurements)
Cabbage/ vegetables, leafy	No revision	No data
Carrots/ vegetables, root	No revision	No data
Cotton	No revision	M1 data are lower than FOCUS, but by adding 20% they reach the level
Grass/alfalfa	No revision	Limited number of data (less than 10 measurements)
Linseed	No revision	No data
Maize	No revision	Limited number of data (less than 10 measurements)
Oil seed rape	No revision	No data
Onions/ vegetable, bulb	No revision	No data
Peas/legumes	No revision	Limited number of data (less than 10 measurements)
Potatoes	Yes, increase by 10% at BBCH 20-39 and 5% at 40-89	The average CI value is more than 10% higher when all four methods are applied at growth stage 20-39 and more than 5% higher for growth stage 40-89, where M4 is the applied method.
Soybean	No revision	Limited number of data (less than 10 measurements)
Strawberries	No revision	Limited number of data (less than 10 measurements)
Sugar beets	No revision	Experimental data is close to FOCUS CI values
Sunflower	No revision	No data
Tobacco	No revision	No data
Tomatoes/ vegetable fruiting	No revision	Limited number of data (less than 10 measurements)
Hops	No revision	No data

RECOMMENDATIONS

It is recommended that in future studies in which the aim is to collect data to establish crop interception values the following measurements and information should be recorded in the studies:

- Total spray amount
- Plant deposition
- Soil deposition
- Leaf area index
- Spray volume per hectare
- Growth stage (description or BBCH)

Deposition measurements should be carried out with validated methods and at least 5 independent measurements for each growth stage. With independent means that they should be carried out in different fields/years/regions in order to have at least 5 different situations that represent the typical crop development of that crop at the selected growth stage. The measurements should cover the whole growth period with an interval between measurements adapted to the crop in question. Measurements should be carried out in crops representative of European conditions with regard to cultivation practice in order to cover the variation in crop interception expected.

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APPENDICES

A. LIST OF ALL FOCUS CROPS

FOCUS groundwater scenarios (Anonymous, 2011b)	**FOCUS surface water scenarios (Anonymous, 2011a)**
Potatoes	Potatoes
Sugar beet	Sugar beet
Beans (field and vegetable)	Beans (Fritz et al.)
Soybean	Soybean
Maize	Maize
Oil seed rape (summer and winter)	Oil seed rape (summer and winter)
Sunflower	Sunflower
Tobacco	Tobacco
Cotton	Cotton
Vines	Vines
Citrus	Citrus
Grass (alfalfa)	Grass (alfalfa)
Peas	Legumes
Carrots	Vegetables, root
Onions	Vegetable, bulb
Cabbage	Vegetable, leafy
Tomatoes	Vegetable, fruit
Linseed	Hops
Apples	Pome/stone fruit
Strawberries	Olives
Winter cereals	Winter cereals
Spring cereals	Spring cereals
Bush berries	

B. DATABASES INCLUDED IN THE SEARCH

Previous study from 1980- OCT2010 (Fera report)	New search (AU)
CAB Abstracts	CAB Abstracts
AGRICOLA	AGRICOLA
AGRIS	AGRIS
Aquatic Science & Fisheries Abstracts	Aquatic Science & Fisheries Abstracts
Environmental Engineering Abstracts	Environmental Engineering Abstracts
Water Resources Abstracts	Water Resources Abstracts
Derwent Biotech Res	Derwent Biotech Res
Enviroline	Enviroline
Pollution Abstracts	Pollution Abstracts
Environmental Science	Environmental Science
Geobase	Geobase
SciSearch	SciSearch
Dissertation Abs Online	Dissertation Abs Online
FEDRIP	
Inside Conferences	
Pesticide Fact File	
GeoArchive	

C. Search logic

Search History

Set	Results	Save History / Open Saved History
# 22	75	#7 AND #2 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 21	34	#7 AND #1 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 20	2	#6 AND #1 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 19	381	#5 AND #3 AND #1 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 18	87	#4 AND #3 AND #1 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 17	101	#5 AND #4 AND #2 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 16	44	#5 AND #4 AND #1 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 15	Approximately 5,120	#3 AND #2 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 14	2,134	#5 AND #2 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 13	253	#4 AND #2 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 12	5	#6 AND #2 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 11	1,671	#3 AND #1 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 10	24	#2 AND #1 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 9	1,348	#5 AND #1 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 8	121	#4 AND #1 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 7	Approximately 11,569	Topic=(through fall) *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 6	374	Topic=(spray retention) *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 5	Approximately 1,198,333	Topic=(spray? or droplet? or application? or apply? or applied or nozzle?) *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 4	Approximately 119,795	Topic=(pesticide? or plant protection product? or crop protection product? or active substance? or insecticide? or fungicide? or herbicide? or tracer?) *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 3	Approximately 1,213,898	Topic=(crop or crops or plants or foliar or foliage or leaf or leaves or canop? or tree? or bush? or shrub? or row? width? or soil or soils or ground?) *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 2	Approximately 24,907	Topic=(deposit?) *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 1	Approximately 11,028	Topic=(Interception or intercepted) *Timespan=2010-2012* *Search language=English Lemmatization=On*

Search on topic from 2010-2012

Search History

Set	Results	Save History / Open Saved History
# 17	0	#4 AND #3 AND #2 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 16	1	#5 AND #3 AND #2 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 15	0	#4 AND #3 AND #1 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 14	3	#5 AND #3 AND #1 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 13	0	#5 AND #4 AND #1 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 12	31	#5 AND #2 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 11	1	#4 AND #2 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 10	68	#3 AND #2 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 9	23	#5 AND #1 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 8	101	#3 AND #1 *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 7	454	Title=(through fall) *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 6	33	Title=(spray retention) *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 5	Approximately 126,503	Title=(spray? or droplet? or application? or apply? or applied or nozzle?) *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 4	Approximately 11,583	Title=(pesticide? or plant protection product? or crop protection product? or active substance? or insecticide? or fungicide? or herbicide? or tracer?) *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 3	Approximately 305,808	Title=(crop or crops or plants or foliar or foliage or leaf or leaves or canop? or tree? or bush? or shrub? or row? width? or soil or soils or ground?) *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 2	2,485	Title=(deposit?) *Timespan=2010-2012* *Search language=English Lemmatization=On*
# 1	1,518	Title=(Interception or intercepted) *Timespan=2010-2012* *Search language=English Lemmatization=On*

Search on title from 2010-2012

Search History

Set	Results	Save History / Open Saved History
# 22	57	#7 AND #2 *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 21	38	#7 AND #1 *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 20	6	#6 AND #1 *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 19	191	#5 AND #3 AND #1 *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 18	64	#4 AND #3 AND #1 *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 17	240	#5 AND #4 AND #2 *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 16	25	#5 AND #4 AND #1 *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 15	Approximately 5,206	#3 AND #2 *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 14	1,759	#5 AND #2 *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 13	538	#4 AND #2 *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 12	9	#6 AND #2 *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 11	1,396	#3 AND #1 *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 10	17	#2 AND #1 *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 9	653	#5 AND #1 *Timespan=1928-1980*
# 8	72	#4 AND #1 *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 7	Approximately 10,644	Topic=(through fall) *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 6	437	Topic=(spray retention) *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 5	Approximately 815,463	Topic=(spray? or droplet? or application? or apply? or applied or nozzle?) *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 4	Approximately 207,826	Topic=(pesticide? or plant protection product? or crop protection product? or active substance? or insecticide? or fungicide? or herbicide? or tracer?) *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 3	Approximately 1,734,340	Topic=(crop or crops or plants or foliar or foliage or leaf or leaves or canop? or tree? or bush? or shrub? or row? width? or soil or soils or ground?) *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 2	Approximately 28,386	Topic=(deposit?) *Timespan=1928-1980* *Search language=English Lemmatization=On*
# 1	Approximately 5,752	Topic=(Interception or intercepted) *Timespan=1928-1980* *Search language=English Lemmatization=On*

Search on topic from 1899-1980

Search History

Set	Results	Save History / Open Saved History
# 17	2	#4 AND #3 AND #2 *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 16	3	#5 AND #3 AND #2 *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 15	0	#4 AND #3 AND #1 *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 14	3	#5 AND #3 AND #1 *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 13	0	#5 AND #4 AND #1 *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 12	80	#5 AND #2 *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 11	32	#4 AND #2 *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 10	310	#3 AND #2 *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 9	12	#5 AND #1 *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 8	134	#3 AND #1 *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 7	253	Title=(through fall) *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 6	44	Title=(spray retention) *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 5	Approximately 126,644	Title=(spray? or droplet? or application? or apply? or applied or nozzle?) *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 4	Approximately 52,466	Title=(pesticide? or plant protection product? or crop protection product? or active substance? or insecticide? or fungicide? or herbicide? or tracer?) *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 3	Approximately 465,699	Title=(crop or crops or plants or foliar or foliage or leaf or leaves or canop? or tree? or bush? or shrub? or row? width? or soil or soils or ground?) *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 2	Approximately 13,550	Title=(deposit?) *Timespan=1899-1980* *Search language=English Lemmatization=On*
# 1	993	Title=(Interception or intercepted) *Timespan=1899-1980* *Search language=English Lemmatization=On*

Search on title from 1899-1980

D. Content of data base

Raw data and descriptive information from literature

A	Record ID	Sequential numbering of records in the database
B	Reference ID	Reference numbering used during literature search
C	Reference	Reference (authors, year)
D	Treatment	Description of treatment differences between measurements of same reference
E	Type of measurement for deposition on the crop	Type of values listed in the reference (i.e. plant deposition or soil deposition) with its units
F	Measured values on crop	Values for interception or deposition listed in the publication
G	SD	Standard deviation listed in the publication
H	n	Number of measurements from which value and standard deviation were derived
I	Type of measurement for deposition on the soil	Type of values listed in the reference (i.e. plant deposition or soil deposition) with its units
J	Measured values on soil	Values for interception or deposition listed in the publication
K	SD	Standard deviation listed in the publication
L	n	Number of measurements from which value and standard deviation were derived
M	Sedimentation drift	Deposition measured on ground outside crop row, listed in the publication
N	SD	Standard deviation listed in the publication
O	Airborne drift and evaporation	
P	SD	Standard deviation listed in the publication
Q	Measuring recycling	
R	SD	Standard deviation listed in the publication
S	Applied substance	Whether tracer, pesticide, formulant, surfactant or combination
T	Tracer name	Name of tracer if applicable
U	Pesticide active ingredient	Chemical name of active ingredient (pesticide or metal) if applicable
V	Pesticide application rate	Application rate of the active ingredient
W	Pesticide application rate units	Units for application rate
X	Pesticide product name	Commercial name of product (formulated pesticide)
Y	Pesticide formulation type	e.g. WP = wettable powder, EC = emulsifiable concentrate
Z	Surfactant name	Name of surfactant (product name or chemical name)
AA	Product concentration in spraying liquid	Concentration of formulant or surfactant in the spraying liquid
AB	units	Units for product concentration
AC	Crop type	Crop type (e.g. rye, carrots, pears)
AD	BBCH growth stage used	Adressed in accordance to description or other scales

	in figures (in repport)	
AE	Crop growth stage	Crop growth stage at the time of spraying
AF	Crop growth stage classification	Type of classification used for crop growth stage (e.g. BBCH)
AG	Crop growth stage observed or estimated	Whether the crop growth stage was observed and reported or if estimated from date or description (e.g. emerging/flowering)
AH	Crop height (m)	Height of the crop (m)
AI	Soil cover (%)	Percentage soil cover at the time of spraying (only if reported in the publication)
AJ	Leaf area index	Leaf area index at the time of spraying (only if reported in the publication)
AK	Definition (0 = not stated; 1 = leaf area per unit area field; 2 = leaf area per unit projected area)	Definition used by authors for leaf area index(0 = not stated; 1 = leaf area per unit area field; 2 = leaf area per unit projected area)
AL	Row spacing or crop density	Row spacing (m) or crop density (plants/m2) at the time of spraying
AM	Units	Units for row spacing / crop density
AN	Comments	Any comments related to crop (e.g. crop beds, pruning)
AO	Agricultural practice	Any comments related to agricultural practice (e.g. manure, weeds)
AP	Country	Geographical location where the study took place
AQ	Town	Geographical location where the study took place
AR	Application date	When spray application took place
AS	Year	When spray application took place
AT	Temperature (°C)	Weather conditions during spray application
AU	Wind speed (m/s)	Weather conditions during spray application
AV	Comments (e.g. sunshine or cloud)	Weather conditions during spray application
AW	Type of study (field or indoor)	Field study or indoor study
AX	comments	
AY	Time after application	Time between the spray application and the sampling (minutes or hours)
AZ	Technique for plant deposition measurements	e.g. sampling whole plants or sampling of leaves
BA	Description method 1	Method details from publication
BB	Description method 2	Method details from publication continued
BC	Technique for soil deposition measurements	e.g. filter paper, petri dishes or soil sampling
BD	Description method 1	Method details copied from publication
BE	Description method 2	Method details copied from publication continued
BF	Sprayer category	Sprayer category from drop down list
BG	Sprayer description	Sprayer name/description from publication

BH	Nozzle type	Name/make of nozzle
BI	Spray volume	Volume of liquid sprayed per unit field area
BJ	Unit	Units of volume sprayed
BK	Pressure	Hydraulic pressure applied to nozzle during spraying
BL	Unit	Units of hydraulic pressure
BM	Driving speed	Driving speed of the sprayers across the crops during spray application
BN	Unit	Units of driving speed
BO	Comments	Comments related to sprayer equipment

Intermediate calculations

BR	Deposition on plant (% of applied)	Amount of deposition on the plants as a percentage of the applied dose
BS	Deposition on plant (% of above canopy)	Amount of deposition on the plants as a percentage of the deposition measured above canopy or on bare soil
BT	Deposition on plant (% of total deposition on plant and soil)	Amount of deposition on the plants as a percentage of the total deposition measured on the soil and the plants
BU	Calculation method	Equation used to calculate % deposition by the plants
BW	Deposition on soil (% of applied)	Amount of deposition on the soil as a percentage of the applied dose
BX	Deposition on soil (% of above canopy)	Amount of deposition on the plants as a percentage of the deposition measured above canopy or on bare soil
BY	Deposition on soil (% of total deposition on plant and soil)	Amount of deposition on the soil as a percentage of the total deposition measured on the soil and the plants
BZ	Calculation method	Equation used to calculate % deposition by the soil
CA	Total deposition on plant and soil (% of applied)	Sum of deposition measured on the soil and on the plants expressed as a percentage of the applied dose
CB	Calculation method	Equation used to calculate total deposition on plant and soil

Calculated interception values

CD	Derived Interception (%) method M1	Interception calculated from plant deposition as a percentage of the applied dose
CE	Calculation method M1	Equation used to calculate % interception
CF	Derived Interception (%) method M2	Interception calculated from plant deposition as a percentage of the deposition measured above canopy or on bare soil
CG	Calculation method M2	Equation used to calculate % interception
CH	Derived Interception (%) method M3	Interception calculated from plant deposition as a percentage of the total deposition measured on the soil and the plants
CI	Calculation method M3	Equation used to calculate % interception

CJ	Derived Interception (%) method M4	Interception calculated from soil deposition as a percentage of the applied dose
CK	Calculation method M4	Equation used to calculate % interception
CL	Derived Interception (%) method M5	Interception calculated from soil deposition as a percentage of the deposition measured above canopy or on bare soil
CM	Calculation method M5	Equation used to calculate % interception
CL	Derived Interception (%) method M6	Interception calculated from soil deposition as a percentage of the total deposition measured on the soil and the plants
CO	Calculation method M6	Equation used to calculate % interception

E. CROP INTERCEPTION DATA

Data are obtained from lists in the FOCUS groundwater (A), the surface water scenarios (B) (Anonymous, 2002,2011a) and proposals of new CI values (C), Table 23 in this report.

Vines	Without leaves	First leaves	Leaf development	Flowering	Ripening
CI (A)	40	50	60	70	85
BBCH	0-9	10-19	20-39	40-89	-
CI (B)	0	40	50	70	-
CI (C)				**60**	**75**
Apple (Pome)	Without leaves	Foliage development	Flowering	Full foliage	
CI (A)	50	70	65	80	
CI (C)			**60**	**65**	
BBCH	0-9	10-19	20-39	40-89	-
CI (B)	0	20	40	70	-
Citrus			All stages		
CI (A)	70	70	70	70	70
CI (B)	70	70	70	70	-
CI (C)	**80**	**80**	**80**	**80**	**80**
Bush berries	Without leaves	Flowering	Full foliage		
CI (A)	50	65	80	-	-
CI (C)	**40**	**60**	**75**		
Stone fruit BBCH	0-9	10-19	20-39	40-89	-
CI (B)	0	20	40	70	-
Olives BBCH	0-9	10-19	20-39	40-89	-
CI (B)	0	70	70	70	-

Crop	Bare emergence		Leaf development		Stem elongation			Flowering			Senescence/ ripening	
					BBCH							
	0-9		10-19		20-39			40-89			90-99	
	A	B	A	B	A	B	C	A	B	C	A	B
Beans	0	0	25	25	40	40		70	70		80	-
Cabbage/ vegetables, leafy	0	0	25	25	40	40		70	70		90	-
Carrots/ vegetables, root	0	0	25	25	60	50		80	70		80	-
Cotton	0	0	30	30	60	60		75	75		90	-
Grass/alfalfa	0	0	40	40	60	60		90	75		90	-
Linseed	0		30		60			70			90	-
Maize	0	0	25	25	50	50		75	75		90	-
Oil seed rape	0	0	40	40	80	70		80	75		90	-
Onions/ vegetable, bulb	0	0	10	10	25	25		40	40		60	-
Peas/legumes	0	0	35	25	55	50		85	70		85	-
Potatoes	0	0	15	15	50	50	**60**	80	70	**85**	50	-
Soybean	0	0	35	20	55	50		85	75		65	-
Strawberries	0		30		50			60			60	-
Sugar beets	0		20		70 rosette			90			90	-
Sunflower	0	0	20	20	50	50		75	75		90	-
Tobacco	0	0	50	20	70	70		90	75		90	-
Tomatoes/ vegetable fruiting	0	0	50	25	70	50		80	70		50	-
Hops		0		20		50			70			-

F. Personal contacts

Organisation	Contact person	Response
Wageningen University (NL)	Jan van de Zande	On book chapter
Silsoe Spray Application Unit (UK)	Paul Miller	Send a list of papers
East Malling Research (UK)	Jerry Cross/ Peter Walklate	Three papers on apple
University of Turin (I)	Paolo Balsari	Two papers on vine
Julius Kühn Institute (D)	Andreas Herbst or Heinz Ganzelmeier	No papers
Cornell University (USA)	Andrew Landers	No papers
Institute for Agricultural and Fisheries Research (ILVO) (B)	David Nyuttens	Send a list of papers
Norwegian University of Life Sciences (N)	Nils Bjugstad	One paper on strawberries
University of California (USA)	Ken Giles	No response
Universitat Politecnica de Catalunya (E)	Emilio Gil	Three papers on vine
Research Institute of Pomology and Floriculture (PL)	Greg Doruchowski	Four papers on apple
Marktgemeinschaft Bodenseeobst (Germany)	Peter Triloff	Will send something later on
Universitat de Lleida (Spain)	Santiago Planas	Three papers on vine, orchards and olive

GLOSSARY /ABBREVIATIONS

BBCH	Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie, and is a scale that describes the growth of the different plants species
CI	Crop interception
Deposition	Deposition/deposit is defined as the volume of spray or the mass of tracer that remains on the plant or soil immediately after spraying. This can be expressed as volume or mass per plant, per area collector or as a percentage of the applied dose
FOCUS	Forum for co-ordination of pesticide fate models and their use
GB	Growth stage
GLEAMS	Ground water loading effects of agricultural management system
Interception	Interception is defined as the percentage of spray intercepted by the crops in the field. In this context, the field is defined as the whole cropped area, including the areas between crop rows or beds or between individual trees in an orchard
Leaf area index	Leaf area index (or LAI) is defined as the measure of one-sided leaf area per unit area of land. A LAI value of 2 indicates that there are 2 hectares of leaf surface on a hectare of crop
Training	Vine training systems utilize the practice of trellising and pruning in order to dictate and control the canopy of a grape vine, which will influence not only the potential yield of that year's crop but also the quality of the grapes due to the access of air and sunlight needed for the grapes to ripen fully and for preventing various grape diseases.