Applied methods for insect management in stored grain and oilseeds

Results of the storage insecticides survey carried out by COCERAL, EUROMAISIERS, EUROMALT and UNISTOCK

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Summary:

This report describes the techniques implemented by European grain and oilseeds storage operators for pest management in stored grain, with the aim to prevent the build-up of insect infestations while avoiding pest resistance.

Pest infestations in stored grains cause enormous economic losses through damage and contamination of food products. Under worldwide trading standards, the grain industry is committed to maintain the "zero tolerance" policy for live insects and other biological contamination. Therefore, harvested grain has to be stored in a manner which ensures that these standards are met. Currently, the available active substances are constrained to a limited number of fumigants and storage insecticides due to legislative restrictions.

In this context, COCERAL, EUROMAISIERS, EUROMALT and UNISTOCK are carrying out surveys to get better understanding of insect management as it is applied by the grain and oilseeds storekeepers. Results from the surveys showed that European storage operators face difficulties to combine the current available management methods and techniques.

Therefore, the four mentioned European associations emphasise the need for regulatory frameworks promoting the availability of storage insecticides and pest management solutions, as well as further research on new substances and alternative technologies in order to obtain more effective and less hazardous formulations.

Main findings

- In operator's own silos, the primary option to manage insect infestation is air circulation (59% of the respondents). Fumigation is the second alternative option (52% of the respondents), followed by storage insecticides (45% of the respondents). At port silos storage insecticides are the main option (24% of the respondents), followed by fumigation (17% of the respondents) and air circulation (10% of the respondents). At farm level, the principal option is fumigation (21% of the respondents), while the alternatives are equally air circulation and storage insecticides (14% of the respondents).

- The collected data show that the use of fumigation has increased at all levels of the grain and oilseeds supply chain, becoming the main insect management option at farm level.

- On the 2006/2007 crop, the most applied active substances were dichlorvos, malathion, pirimiphos methyl and deltamethrin. After the phasing out of dichlorvos and malathion in 2007, the use of deltamethrin, pirimiphos-methyl and chlorpyriphos-methyl significantly increased. This trend was also observed on the 2014/2015 and 2015/2016 crops, in which the use of deltamethrin considerably increased.

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Introduction

The European grain industry constantly works to ensure products of consistently high quality that are compliant with all food and feed safety requirements. Absence of insect infestation ('zero tolerance') and contamination have become an important consideration.

This report focuses particularly on insect management of stored grain at different level of the supply chain. Infestations can lead to extensive losses of stored grains resulting in:

- Deterioration and contamination from the presence of insects results in downgrading of grain and market value due to insect parts, odours, moulds and heat damage.
- Damaged grain is a favoured environment for the development of mould and mycotoxins. Therefore, food safety is also at stake.
- Deterioration of crop quality as a result of insect activity, such as loss of weight, nutritional value, germination and decrease of market value.

The ongoing review process of Active Substances (ASs) in the European legislative framework has consequences for grain storage at any operating level. Most of the active compounds used for knockdown[1] treatments (showing rapid effect on insect populations) were phased out in the review process under Regulation (EC) No 1107/2009, repealing Directive 91/414/EEC. Equivalent treatments applied as an alternative are scarce. Any further loss of ASs would reduce the ability of the operators to manage infestations. Therefore, our associations have carried out a survey to get an accurate understanding of insect management as it is applied by the grain storage operators.

The scope of this report is to present the main findings on the ongoing trends and current practices from the Insect Management Survey carried out by COCERAL, EUROMAISIERS, EUROMALT and UNISTOCK (Insect Management Survey, 2014; Segard, 2010).

A. Scientific review

1. Pest management

Once a cereal crop is harvested, it may be stored for a certain period of time before it is marketed or used as food, feed or as raw commodity. The length of time during which the cereals can be safely stored will depend on the harvest condition, the post-harvest treatment (such as drying and cleaning) and the type of storage facility being used. Grains stored at low temperatures and low moisture content can be kept in storage for longer periods of time before quality deterioration. The presence and build-up of insects, mites, moulds and fungi – all of them influenced by grain temperature and moisture content of the crop– will affect grain quality and duration of grain storage.

Rapid deterioration of the crop quality might occur with combined attacks by insects, acaroid and larvae. For cereals, a rise in temperature is expected due to respiration; it might also occur due to insect or fungal activity. Heating leads to moisture condensation within the grain mass in cool areas, which can increase insect infestation (Appert, 1987; Imura & Sinha, 1989).

[1] Knockdown in insects following application of an insecticide may be defined as the state of intoxication and partial paralysis which usually precedes death; see Wickham et al. (1974).

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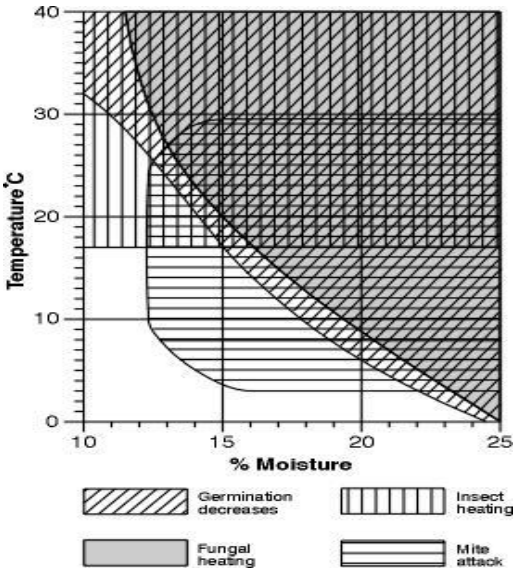

As insects cannot control their body temperature, they are inactive at low temperatures (below 8°C for insects and 3°C for mites). Grain moisture content below 13% stops the growth of most moulds and mites. Moisture content of the grains below 10% limits the development of most stored grain insects and pests. In addition to actual grain moisture, the volume of stored grain also affects the rate of cooling. Practical storage conditions are summarised in Figure 1.

Figure 1: *Practical storage conditions.* Adapted *from Appert (1987).*

2. Resistance to grain protectants and fumigants

Grain protectants (or storage insecticides) and fumigants are used extensively in the grain industry. A grain protectant is an insecticide that can be applied on stored grain. Fumigation is a method of using a lethal gas to exterminate pests, through suffocation or poisoning, within an enclosed space. The space is sealed to prevent the gas escaping to areas that are not being treated, for environmental and public safety, and to keep the gas at the required concentration for the appropriate time to be effective. The most used fumigant at storage level is phosphine (see Chapter 3. Fumigation).

Resistance to phosphine had been detected in China, India, the Dominican Republic and Australia (Collins, 1998). Heavy reliance on phosphine for insect control, however, means that there is enormous selection pressure for insects to evolve resistance. Besides, options for managing resistance to phosphine are limited because at present, the few other fumigants which are available, do not perform with a comparable level of effectiveness, without affecting the germination of the grain treated (Greig & Reeves, 1985).

Resistance to organophosphates insecticides (e.g., fenitrothion, pirimiphos-methyl and chlorpyrifos-methyl) is widespread. However, resistance to one or more of these insecticides has occurred in most major pest species. Since there is no single compound that will control all species attacking stored products, a combination of two insecticides must be applied (Talukder, 2009).

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B. Legislative background

Two legal texts have an impact on the pest management methods. Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of Plant Protection Products (PPPs) on the market and repealing Council Directives 79/117/EEC and 91/414/EEC has a direct effect on the availability of ASs on the market by regulating the authorisation process. Secondly, the Regulation (EC) No 396/2005 of the European Parliament and of the Council of 23 February 2005 on Maximum Residue Levels (MRLs) of pesticides in or on food and feed of plant and animal origin and amending Council Directive 91/414/EEC has also an influence on the way operators manage pest infestations because it establishes the maximum tolerances for the used ASs.

1. Regulation (EC) No 1107/2009 on placing PPPs on the market

Regulation (EC) 1107/2009 covers the general process of the placing on the market of PPPs. Its scope is limited to the process of approval of ASs at European level, and of authorisation of PPPs at Member State level. The Regulation lays down approval criteria for ASs. An AS shall be approved if it fulfils the criteria detailed in its Annex II. Therefore, chemical substances or micro-organisms in PPPs are only approved for use once they have undergone a scientific risk assessment, and safe use has been demonstrated through a peer-reviewed safety assessment. The Regulation came into force on 14 June 2011 and is directly applicable in all Member States, harmonising the rules applied in governing the authorisation of PPPs use.

Regulation (EC) No 1107/2009 repeals Council Directive 91/414/EEC of 15 July 1991 concerning the placing of PPPs on the market. The implementation of Directive 91/414 led to a rapid decline in the number of ASs available on the European market since 1993. The number of ASs available to the EU operators continues to decline under Regulation (EC) No 1107/2209, which includes hazard-based cut-off criteria.

Table I: *Current state of play of authorised active substances*[2]

No. ASs	Approved	Not approved	Pending
1367	494	826	27

2. Regulation (EC) 396/2005 on MRLs

A MRL must be established for every food crop on which residues of a pesticide may occur as a result of its authorised use. Regulation (EC) No 396/2005 of 23 February 2005 on MRLs of pesticides in or on food and feed of plant and animal origin seeks to provide a pan-EU range of MRLs in plant products, including grain and oilseeds. Harmonised MRLs eliminate barriers to trade and increase market transparency. The regulation applies to both EU and imported goods placed on the EU market. Fumigants fall under the scope of this regulation.

[2] http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=activesubstance.selection&language=EN, last visited 13 December 2017.

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Article 18 of Regulation (EC) No 396/2005 provides a derogation to MRLs compliance for Member States in case of post-harvest treatment with a fumigant on their own territory. Member States may authorise MRLs exceedance for substances listed in Annex VII (i.e., hydrogen phosphide, aluminium phosphide, magnesium phosphide and sulfuryl fluoride). The conditions are as follow:

- the products concerned are not intended for immediate consumption;
- controls are in place to ensure that these products are not made available to the consumer;
- the other Member States and the Commission are informed of the measures.

The aim of such an exemption is to prevent trade disruption of stored products that underwent post-harvest treatments with fumigants, considering that most phosphine is lost within few days from fumigations in ordinary, unsealed storages.

ASs have different MRLs on different crops. It is typical of storing sites throughout Europe to host different crops one after the other depending on the harvest season. Although good storing practices are in place, it is highly likely for pesticide residues to be transmitted to untreated crops, leading to cross-contamination between crops sharing the same handling and storage system.

C. Legislative developments for storage insecticides

Notwithstanding their legal status, effective storage insecticides are the following ones:

- Bifenthrin,
- Chlorpyriphos-methyl,
- Cypermethrin
- Deltamethrin,
- Dichlorvos,
- Endosulfan,
- Fenitrothion,
- Kieselgur,
- Malathion,
- Pirimiphos-methyl,
- Pyrethrins combined with Piperonil butoxide
- Spinosad

For each of these ASs, the Table II hereunder reports the EU and Codex MRLs for oilseeds and cereals.

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Table II: Legislative state of play for storage insecticides

Substance	Authorisation holder	Oilseeds		Cereals	
		EU MRL mg/kg	CODEX MRL mg/kg	EU MRL mg/kg	CODEX MRL mg/kg
Bifenthrin	FMC Chemical s.p.r.l	0.5 cotton seed 0.05 rapeseed 0.02* linseed, sunflower seeds, olives for oil production 0.3 soyabeans	0.05 rape seed 0.5 cotton seeds	0.5 wheat, barley, oats, 0.05 *other cereals	0.5 wheat 0.05 barley, maize 0,01* other cereals
Chlorpyrifos-methyl**	Dow AgroSciences Ltd	0.05 *	-	3	10 wheat 0.1 rice
Cypermethrin	FMC	0.2* linseed, sesame, poppy, sunflower seeds, cotton, rape seeds 0.05 soyabeans, olives for oil production	0.1	2 barley, oats, rice, rye, wheat. 0.03 maize, sorghum	0.3 2 barley, oats, rice rye and wheat
Zeta-Cypermethrin	FMC				
Deltamethrin cis-Deltamethrin	Bayer	0,07 rapeseed 0.05 sunflower seeds 0,02 soyabeans, linseed, cotton seeds 0,6 olives for oil production	0.05 Sunflower	1 Rice, Wheat 2 Other cereals	2
Dichlorvos – authorisation withdrawn in 2007	Denka International (NL)	0.01*	-	0.01*	7 rice, wheat
Endosulfan – authorisation withdrawn in 2006	Bayer	0.3 cotton seed 0.5 soyabeans 0,1* other oilseeds 0.05* olives for oil production	1 soybean dry 2 soybean crude oil	0.05*	-
Fenitrothion – authorisation withdrawn in 2007	Sumitomo Chemical Agro Europe initial applicant - Now generic	0.02*	-	0.05*	6
Kieselgur (diatomaceous earth, *TSS, diatomite, silica)*	Generic 5 applicants	No MRL required		No MRL required	
Malathion	Cheminova A/S (DK)	0.02*	20 cotton seeds	8	10 wheat 3 sorghum 0.05 maize

Piperonyl butoxide	Bayer	Not applicable	-	Not applicable	30 in cereal grains (accommodates post-harvest treatment)
Pirimiphos-methyl (F)	Syngenta	0.5 0,01* olives for oil production	-	0,5 maize, rice, rye 5 other cereals	7
Phosphane (phosphine PH3)	S & A Service-und Anwendungstechnik GmbH	0.05	-	0.05 barley, oat, rice, rye, wheat 0.7 sorghum, oat, maize	0.1 in cereal grains
Pyrethrins 1 and 2	generic 11 applicants	3 1 olives for oil production	-	3	0.3
Spinosad (F)	Dow AgroSciences Ltd	0.02*	0.01 cotton seeds	2	1
Sulfuryl fluoride	Dow AgroSciences Ltd	0.01*	-	0.05	0.05 barley, maize, wheat,

The pesticides EU – autorisation and MRLs database: http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=homepage&language=EN
Codex Alimentarius website: http://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/pesticides/en/

LEGEND
Storage insecticides approved
Storage insecticides not approved
Fumigants
Synergists
* Lower limit of analytical determination
** As of date of publication of this report, a draft Regulation amending MRLs for chlorpyrifos-methyl received a positive vote from Member States at Standing Committee meeting. The application of the new MRLs (0.05 mg/kg on wheat, maize and other cereals except rice, oat and barley) is expected by the end of 2018.

As opposed to dichlorvos and phosphine, insecticides like deltamethrin or bifenthrin have a long-term effect on insect populations. Data for ASs like permethrin or pyrethrin are not protected anymore by a patent. Therefore, knowing that data protection will not be ensured, there is no incentive for any company to carry out a submission file for renewal to the European Commission.

Both pyrethroids and pyrethrins are often formulated with oils or petroleum distillates and packaged in combination with synergists, such as piperonyl butoxide. Synergists are added to increase the effectiveness of the compound. Synergists do not have EU MRLs as Regulation (EC) No 396/2005 only covers ASs. However, Member States can set maximum limits for synergists such as piperonyl butoxide.

Pursuant to the approval of pirimiphos-methyl a revision of its MRLs was carried out. However, the revision process proved to be lengthy and difficult to carry on: studies demonstrating the residues cross-contamination were submitted to the Commission and were acknowledged by the European Food Safety Authority (EFSA). The review process ended in 2016, with the publication of the Regulation (EU) 2016/53 amending Annexes II and III to Regulation (EC) No 396/2005. As shown in Table II, the current MRLs applicable for pirimiphos-methyl are different for different crops, leading to a considerable risk of cross contamination.

D. Scope and method of investigation

1. A network of four European associations

Four European associations - Coceral, Euromalt, Euromaisiers and Unistock – have participated in this inquiry.

- **COCERAL** is the European association representing the trade in cereals, rice, feedstuffs, oilseeds, olive oil, oils and fats and agrosupply. Its Food and Feed Safety and Agrosupply sections gather specific expertise to meet a growing demand by the industry faced with continuous flow of legislation in these areas.
- **Unistock** is the European association of professional storekeepers for agri-bulk commodities.
- **Euromaisiers** is the representative organisation for the European dry maize milling sector. The industry mills about 1.5 million tonnes of maize each year to produce around 900.000 tonnes of "grits" and flour.
- **Euromalt** represents the European malting industry. Around 18 million tonnes of malt are produced annually around the world, of which around half is produced within the EU. Of the total malt production 94% is used for beer production, 4% for whisky production while the remaining 2% is destined for other food uses.

2. The inquiry and main characteristics of respondents

Three survey rounds were carried out, with the questionnaire being revised for the second round (2012-2013):

1. Round 1: March-June 2008 – crops monitored: 2006/2007 and 2007/2008;
2. Round 2: November 2012-April 2013 – crops monitored: 2009/2010 and 2010/2011;
3. Round 3: July-December 2017 – crops monitored: 2014/2015 and 2015/2016. The inquiry was designed in such a way that the respondents have to give short answers to precise questions (Annex 1). The file, initially drafted in English, was sent out to member companies.

In 2008 replies were obtained from operators from France, Germany, Hungary, Italy, the Netherlands, Poland, Spain and the United Kingdom. Operators from Austria, Belgium, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands, Poland, Spain, Sweden and the United Kingdom participated in the 2012-2013 survey. In 2017 replies were gathered from operators from Belgium, United Kingdom, Poland, Greece, Portugal, Germany, Lithuania, Spain, Italy, France and Ireland. All data were encoded. For reasons of confidentiality, the raw data are not published in this report.

The first series of questions cover the volume of marketed grain, oilseeds and pulses by the responding companies. In the first round (2008), operators were asked for the volumes of grain marketed. Overall, responding companies accounted for around 14 million tonnes of agri-products (see breakdown in Table III). In the second round (2012-2013), operators were given ranges of volumes to choose from, to facilitate their participation in the survey. The same approach was maintained for the 2017 survey. The majority of respondents market between 0-200 Kilotonnes (KT) of cereals, oilseeds and pulses (see Table IV and V). The amount of grain covered by the inquiry is a mix of grain stored in port silos, warehouses, silos and farm silos. This grain might be coming in or going out, it is only relevant to consider it as the "grain capacity managed by respondents".

Table III: *Volumes marketed by the respondents*

	Cereals	**Oilseeds**	**Pulses**
Total (metric tons)	11,115,936	2,256,629	131,526
			Data: 2008

Table IV: Volume of grain marketed by respondents

	0-200KT	200-500KT	500KT-1MT	>1MT
Cereals	42%	33%	12%	12%
Oilseeds	53%	5%	7%	0%
Pulses	30%	5%	0%	0%
			Data: 2012/2013	

Table V: Volume of grain marketed by respondents

	0-200KT	200-500KT	500KT-1MT	>1MT
Cereals	38%	17%	14%	21%
Oilseeds	14%	0%	7%	10%
Pulses	14%	0%	0%	3%
			Data: 2017	

Paragraph 2 of the survey (see Annexes 1, 2 and 3) refers, in a broad sense, to the management options applied by the operators. Furthermore, items 3, 4 and 5 of the Annexes cover much more detailed technical options. They deal respectively with ventilation techniques and chemical applications.

E. Findings

1. Applied methods to cool down cereals and oilseeds

Insect management consists of three main methods: cleaning, air circulation/ventilation and chemical treatments (insecticides and fumigation). Ventilation is the process of forcing the movement of ambient air (or air conditioned) of suitable quality (temperature and humidity). If cold air is available (during fall or winter seasons, on cold nights), introducing and moving this air throughout the grain mass gradually lower the temperature.

Although operators are equally likely to use one of the above described ventilation methods, the survey from 2012/2013 and 2017 show that the less used is air conditioning.

The data of the 2017 survey provides the following results (Figure 2):

- In operator's own silos, the primary applied method to prevent insect infestation is air circulation throughout the grain mass. At farm level the use of fumigation is the major alternative and storage insecticides is the major method applied in port silos. These results can be justified with the data presented in Figure 1 showing that, even at a grain temperature below 10°C and moisture content of the grain below 15%, infestation is still likely to occur.

- In operator's own silos both fumigation and insecticides are applied (~45-50%). Intensity of treatment is lower in the ports silos than in the silo because of higher turnover of grain mass in the bins.

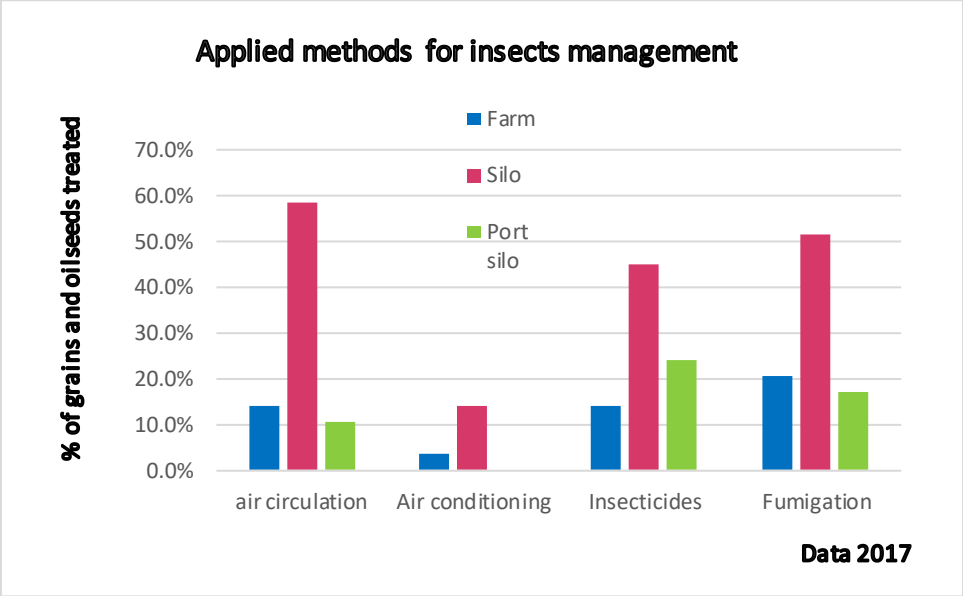

Figure 2: *Applied methods for insect management.* Source*: COCERAL, Unistock, Euromalt and Euromaisiers*

To implement these methods, operators need to have specific equipment on site (Figure 3, 4 and 5). According to the replies received, two general patterns are significant. First, a large majority of the surveyed companies are equipped with a system to monitor the

temperature in the premises. Second, ventilation system is also used together with the temperature monitoring system in the silos. It is also observed that all respondents have at least one of the three mentioned devices. These trends confirm also the 2007-2008 and 2012/2013 data (see Figure 4, 5).

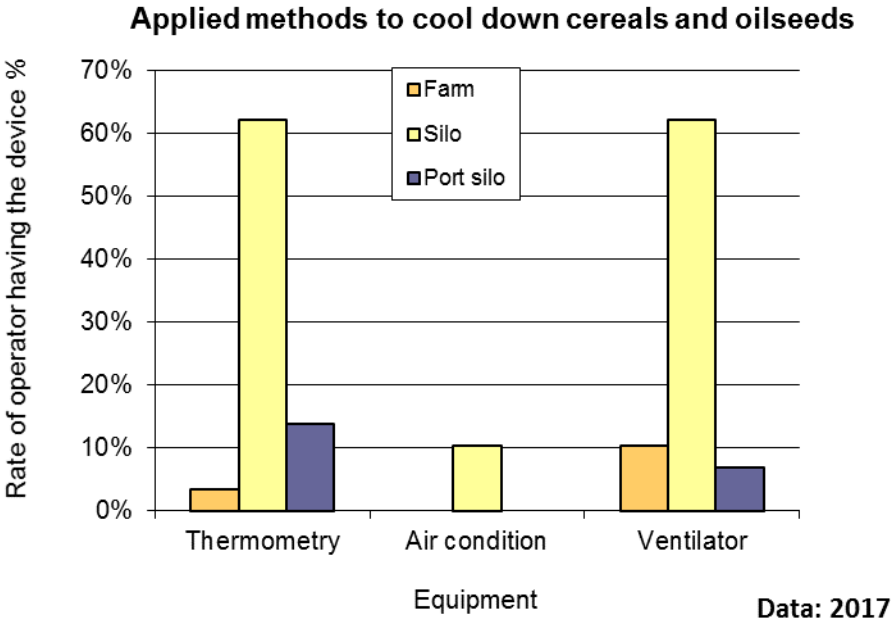

Figure 3 *Level of equipment of the respondents.*
Source*: COCERAL, Unistock, Euromalt and Euromaisiers. Data 2017*

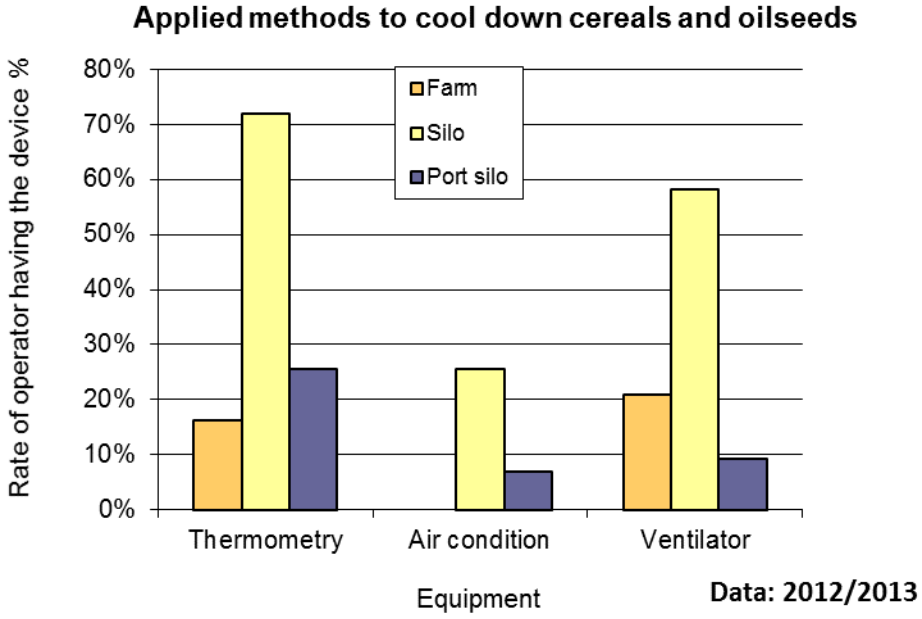

Figure 4 *Level of equipment of the respondents.*
Source*: COCERAL, Unistock, Euromalt and Euromaisiers. Data 2012/2013*

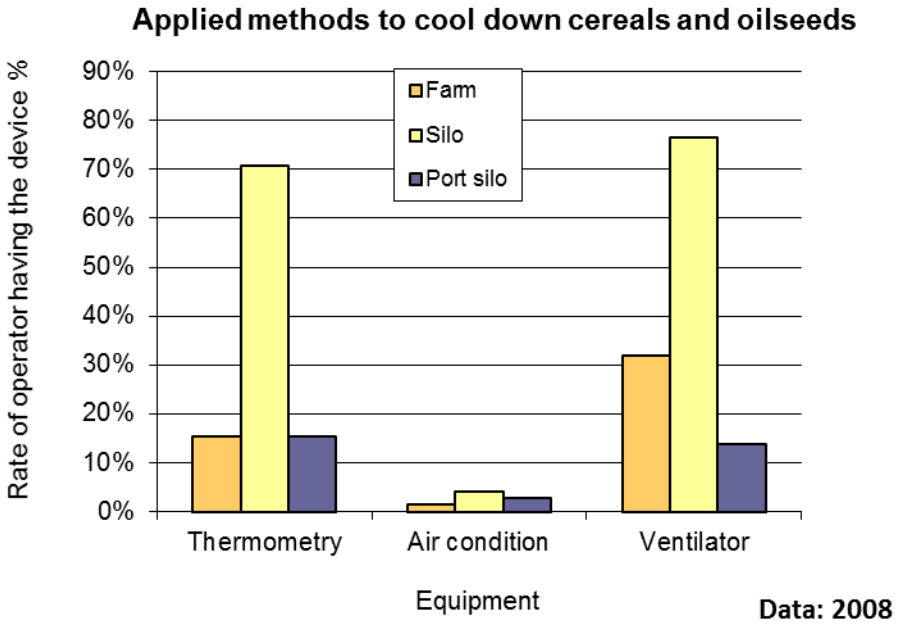

Figure 5: *Level of equipment of the respondents*
Source*: COCERAL, Unistock, Euromalt and Euromaisiers. Data: 2008*

At silo level, the most used methods to cool down the stored grain in case of emergency are either augering grain from one bin to another or piling up grain outdoor. It does imply that a free silo or a free ground floor is permanently available (Table V), and that there are some cold weather periods.

Table V: *Available devices to transfer the grain.*

	Free silo	Free area
Farm	6.9%	0.0%
Silo	37.9%	20.7%
Port silo	10.3%	3.4%

Data: 2017

2. Applied ASs

On the crop 2006/2007, the most applied ASs were dichlorvos, malathion, pirimiphos-methyl and deltamethrin (Figure 6, 7, and 8). At silo level (Figure 7), the use of pyrethrins combined with a synergist is an alternative. It is however demonstrated that there are no residual activities of the ASs. This implies that the operators further down the supply chain might have to treat the grain again. The publication of Commission Decision C(2007) 2338

of 6 June 2007[3] withdrawing the authorization of dichlorvos and the phasing out of malathion lead to changes in the use of ASs for the succeeding crops.

For the crop 2007/2008 (Figure 6, 7 and 8), increases in the use of deltamethrin, pirimiphos-methyl and chlorpyriphos-methyl were observed. These trends were maintained also for the 2009/2010 and 2010/2011 crops (Figure 6, 7 and 8).

The combination of piperonyl butoxyde with pyrethrins increased in the 2009/2010 and 2010/2011 crops for both uses in silos and port silos (Figures 7 and 8).

For the 2014/2015 crop the increase in the use of deltamethrin and pirimiphos-methyl are confirmed in farm, silos and port silos (Figure 6, 7 and 8). In farms, the use of chlorpyriphos-methyl was also significant but less used than previous years (Figure 6). In the last crops monitored (2014/2015 and 2015/2016) chlorpyriphos-methyl was not used anymore in both silos and port silos (Figure 7 and 8). This tendency was also seen for the use of "other pyrethroids" (Figure 7 and 8).

For the 2015/2016 crop deltamethrin showed to be the preferred substance, in all stages of storage (Figure 6, 7 and 8). The use of deltamethrin has undergone an important increase especially at silo level, where its use is almost doubled (from 38% in 2014/2015 crop to 78% in 2015/2016 crop, Figure 7). After deltamethrin, cypermethrin continues to be the major alternative at port silos (Figure 8), showing a constant use in the last two crops monitored (2014/2015 and 2015/2016). The use of pyrethrins combined with piperonyl butoxide was still relevant, as well as the use of pirimiphos-methyl (Figure 6, 7, and 8). However, due to the considerable risk of cross contamination, the use of this insecticide has decreased in the last crops monitored by the survey (2014/2015 and 2015/2016, Figure 6, 7 and 8).

The changes observed reflect the need for a sufficient range of PPPs to prevent the development of pest resistance.

[3] Commission Decision C(2007) 2338 of 6 June 2007[3] concerning the non-inclusion of dichlorvos in Annex I to Council Directive 91/414/EEC and the withdrawal of authorisations for plant protection products containing that substance

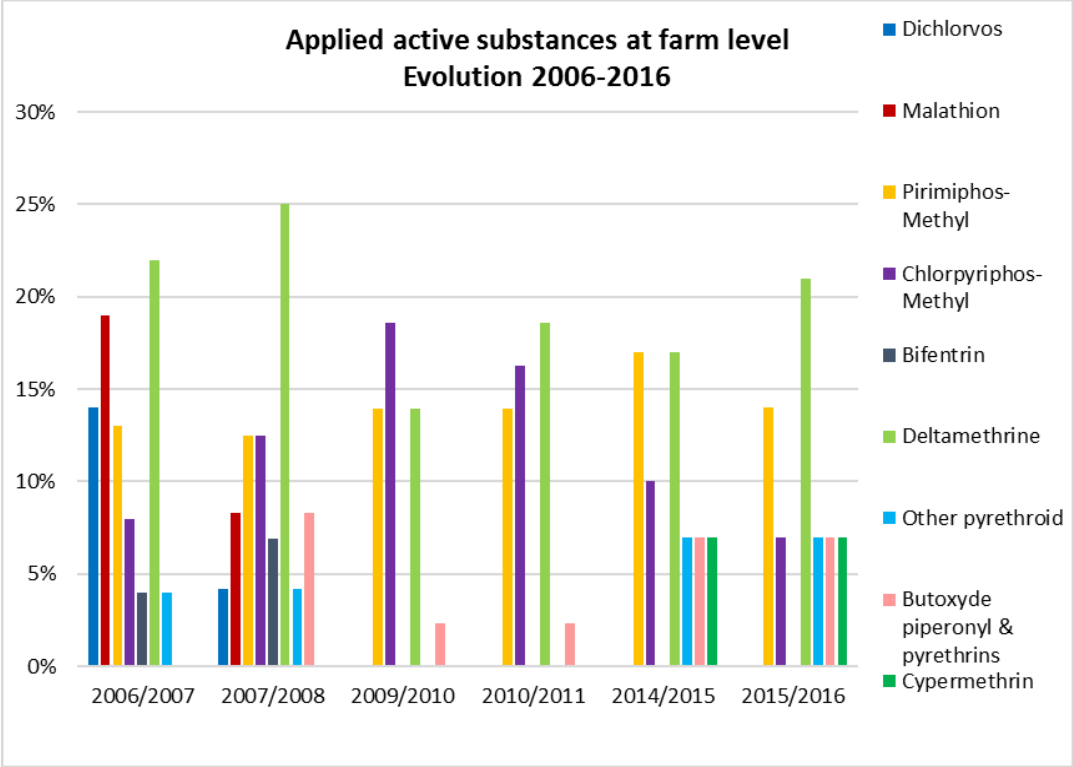

Figure 6: *Use of active substances at farm level as a % of total of respondents*

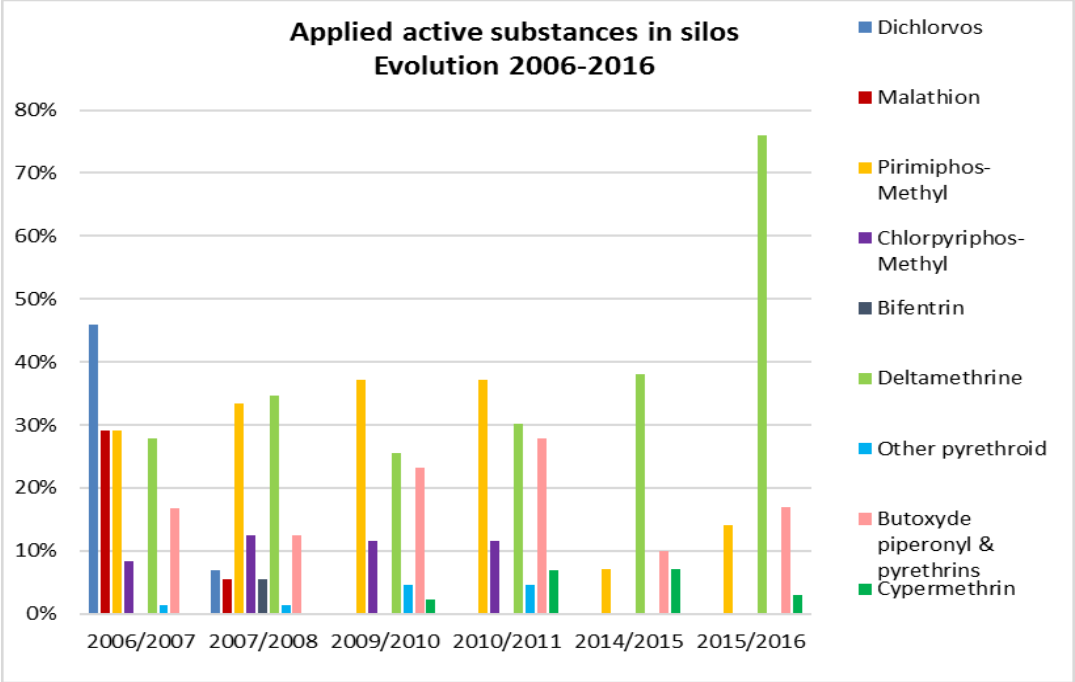

Figure 7: *Use of active substances in own silos as a % of total stored agri-product treated*

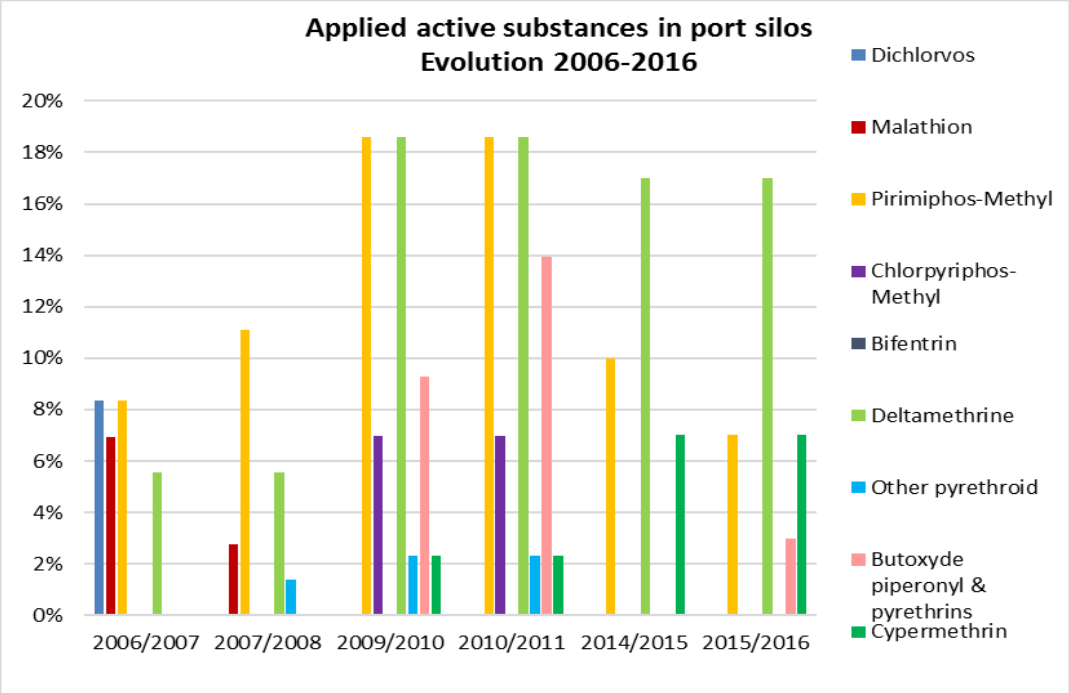

Figure 8: *Use of active substances in port silos as a % of total grain and oilseeds treated*

3. Fumigation

Hydrogen phosphide has become the predominant fumigant used for the treatment of bulk-stored oilseeds and grain throughout the world (Harein and Subramanyam, 1990). It is available in solid formulations of aluminium phosphide or magnesium phosphide. When exposed to high temperature and grain moisture the formulations release phosphine, a highly toxic gas to humans and other warm blood animals. The time required for the release of phosphine varies depending on temperature, grain moisture and formulation. Residues of the fumigants compound in the grain decline to below the MRL after overnight aeration. However, the grain should be left undisturbed for at least 72 hours (Bond, 1984). The usual practice is to leave the grain for a much longer period so that the fumigant vapours are gradually dissipated by leakage from the structure.

The inquiry shows that fumigation is used at all levels of the grain and oilseeds supply chain. The data collected show that the use of fumigation has increased in more recent years– see Table VI, VII and VIII.

Fumigation requires a cautious approach for its application and its technical implementation is often strictly legislated at national level. Consequently, only specially trained personnel or external operators are applying this treatment. The surveys show that outsourcing the treatment to specialised agencies is becoming more frequent in the recent years, with a constant increase in the last crops monitored by the surveys (see Tables VI, VII and VIII).

Table VI: *The use* of *fumigation technique and the choice of operators crops 2014/2015 and 2015/2016*

	Crop 2014/2015			Crop 2015/2016		
% of respondents	At farm	Own silos	Port silos	At farm	Own silos	Port silos
Hydrogen Phosphide (PH_3)	10%	45%	21%	10%	45%	24%
Sulfurylfluoride	0%	0%	0%	0%	0%	0%
Other*:*	0%	10%	0%	0%	10%	0%
Your skilled staff	3%	10%	3%	3%	10%	3%
External operators	21%	55%	31%	21%	59%	24%

Table VII*: The use of fumigation technique and the choice of operators crops 2009/2010 and 2010/2011*

	Crop 2009/2010			Crop 2010/2011		
% of respondents	At farm	Own silos	Port silos	At farm	Own silos	Port silos
Hydrogen Phosphide (PH_3)	14%	44%	23%	14%	44%	21%
Sulfurylfluoride	0%	5%	0%	0%	5%	0%
Other*:*	0%	2%	0%	0%	2%	0%
Your skilled staff	2%	19%	5%	2%	21%	7%
External operators	12%	49%	16%	12%	44%	19%

Table VIII*: The use of fumigation technique and the choice of operators crops 2006/2007 and 2007/2008*

	Crop 2006/2007			Crop 2007/2008		
% of respondents	At farm	Own silos	Port silos	At farm	Own silos	Port silos
Hydrogen Phosphide (PH_3)	1%	14%	11%	1%	14%	13%
Sulfurylfluoride	1%	7%	4%	1%	7%	4%
Other*:*	0%	3%	0%	0%	3%	0%
Your skilled staff	1%	13%	4%	1%	10%	3%
External operators	1%	10%	8%	1%	10%	11%

F. Conclusions

The distinction must be made between ASs used to knock-down adult insects and other ASs used as protectants or insecticides. Fumigating with phosphine is a good knock-down option but most eggs, larvae and pupae will survive and will begin breeding after phosphine gas concentration has dropped to low level (Bullen, 2007). The other ASs mentioned in Table II are storage insecticides that do not always kill adult insects present at the time of treatment (Bullen, 2007). These treatments are intended to control developing immature insect stages (i.e., larvae), rather than existing mature adult stages. It affects the population development rather than each adult insect. The development of pest resistance to widely used compounds could occur even faster than before.

Operators struggle to comply with the zero tolerance for live insect for the following reasons:

- The most effective ASs are being gradually withdrawn from the market;
- Fumigation, when safe and feasible, does not kill premature insect stages;
- Only two families of ASs for storage insecticides are left authorised in the EU (organophosphates and pyrethroids);
- Pyrethroids are highly soluble in fat (*e.g.*, deltamethrin). Therefore, the number of storage insecticides for oilseeds is even more limited;
- A further reduction in availability of storage insecticides will lead to increasing risk of pest infestation and resistances due to lack of alternatives.

Pest problems may not be uniformly distributed within the European countries as temperature and humidity play an important role in their development. In the case of Northern countries, efficient ventilation devices are usually enough to keep the grain temperature below 10°C. On the other hand, in many climatic zones, cool air is not sufficiently available after the harvest. And higher air flow may be required for timely aeration. However, this is often considered as economically unfeasible. In this case, insecticides or fumigation may have to be applied.

Under the current legislative constraints, the prospects for development and improvements are weak. The trend is towards increasing non-authorisation of ASs. It could have dire consequences on the ability of operators to ensure 11 months of storage that, on a yearly basis, start right after a short period of harvesting throughout Europe. Agricultural prices are market sensitive enough to be impacted by few percentages of grain loss that would be due to a poor insect management. We therefore stress the need for the legislation to take into account both the current volatility of the agri-product markets and the legislative constraints operators are faced with. In particular, both the review process of MRLs and existing substances should grasp the technical constraints of managing grain and oilseeds storage.

To conclude, this report shows that the tool box available for grain storage is not large enough. The trend from 2018 onwards is a major concern for operators as some of the remaining authorised existing substances are likely to be non-authorised due to hazard-based criteria (e.g., cypermethrin) or to see their MRLs on cereals lowered (e.g., chlorpyrifos-methyl). In addition, there are few chances that new storage insecticides are being developed. Even though producers continue research and development of new ASs, interest in research gets weaker and weaker due to legislative pressure. The grain sector encourages ASs and PPPs manufacturers to focus more research effort on storage insecticides and other solutions in order to obtain effective and less hazardous formulations.

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Annex 1: Questionnaire used for the 2008 enquiry

STORAGE INSECTICIDE ENQUIRY
- OPERATORS –

kindly reply by 7th March 2011

Member state:
.....

1. YOUR COMPANY

Volume of grain marketed by your company	
Products	Volume (thousand Tons)
Cereals	
Oilseeds	
Pulses	
Others (which ones)	

2. APPLIED METHODS FOR INSECTS CONTROL

	At farm (%)	In your own silos (%)	In port silos (%)
Cooling down silos			
Ambient air circulation			
Air conditioning			
Chemical treatment			
Insecticides (crop dusting, powdering, nebulisation)			
Fumigation			
Others techniques (which ones)			
.....			

3. COOLING DOWN THE SILOS: THE METHODS YOU APPLY

	Grain temperature (°C)	Ambient moisture level (%)
Trigger parameters for cooling down the silos		

Method for triggering the cooling down system:

☐ Manual

☐ Thermostat

IMPLEMENTED ACTIONS TO COOL DOWN THE SILO:

If YES X
If NO

A. Ventilation

Devices for temperature management	At farm	In your own silos	In port silos
Thermometry			
Air condition			
Ventilator			
Other			

B. Grain transfer

Devices for grain transfer	At farm	In your own silos	In port silos
Permanent free silo			
Permanent free unloading area			
Other			

4. CHEMICAL TREATMENTS: APPLIED ACTIVE SUBSTANCES & METHODS

*APPLIED ACTIVE SUBSTANCE**	Crop 2008/2009			Crop 2009/2010		
	At farm	Own silos	Port silos	At farm	Own silos	Port silos
Pyrimiphos-Methyl						
Chlorpyriphos-Methyl						
Deltamethrine						
Cypermethrin						
Other pyrethroid						
Pyrethrins + Butoxide piperonyl						
Other:						

** If the active substances are unknown please replace them with brand names in the table*

APPLIED METHODS OF TREATMENT	Crop 2008/2009			Crop 2009/2010		
	At farm	Own silos	Port silos	At farm	Own silos	Port silos
On grain						
On premises						
On both						

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5. FUMIGATION: APPLIED ACTIVE SUBSTANCES & OPERATORS

*APPLIED ACTIVE SUBSTANCE**	Crop 2008/2009			Crop 2009/2010		
	At farm	Own silos	Port silos	At farm	Own silos	Port silos
Hydrogen Phosphide (PH_3)						
Sulfurylfluoride (SO_2F_2)						
Other:						

** If the active substances are unknown please replace them with brand names in the table*

OPERATOR	Crop 2008/2009			Crop 2009/2010		
	At farm	Own silos	Port silos	At farm	Own silos	Port silos
Your skilled staff						
External operators						

6. CHEMICAL TREATMENT TRACEABILITY

	Crop 2008/2009	Crop 2009/2010
Treatment are registered		
Information are provided:		
- by your suppliers		
- to your buyers		

7. LEGISLATION AND SPOT-CHECK CONTROLS

	Yes	No
Have you ever been controlled by authorities in the framework of MRL? *		
Did you experienced problems or sanctions about MRL? *		
Did you face any misunderstanding of the regulation like: - Does the MRL applies the grain or to the processed grain (flour...)? - Other:		

* If yes, please specify:

.....

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STORAGE INSECTICIDE ENQUIRY

- ASSOCIATION –

kindly reply by 7th March 2011

Member state:
.....

Name of the association		
Number of members		
Quantity of marketed cereals in your country (thousand Tons)		
National storage capacity (thousand Tons)		
Average distribution of cereals oilseeds and pulse storage in the country (%)	At farm	
	Trader	
	Port silo	
Are there contradictions between then national authorizations and Annex 1 of the directive 91/414?		

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Annex 2: Questionnaire used for the 2012-2013 enquiry

STORAGE INSECTICIDE ENQUIRY

- OPERATORS –

Member state: .....

kindly reply by 7 December 2012

1. YOUR COMPANY

If YES X
If NO

The volumes of grain marketed by your company are marketed at:				
National level				
EU level				
Worldwide				
Products marketed	Volume in thousand Tons (KT)			
	Between 0 - 200 KT	Between 200-500 KT	Between 500KT-1MT	More than 1MT
Cereals				
Oilseeds				
Pulses				
Others (which ones)				

2. APPLIED METHODS FOR INSECTS CONTROL

	At farm (%)	In your own silos (%)	In port silos (%)	Barges or Ships (%)
Cooling down silos				
Ambient air circulation				
Air conditioning				
Chemical treatment				
Insecticides (crop dusting, powdering, nebulisation)				
Fumigation				
Others techniques (which ones)				
.....				

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3. COOLING DOWN THE SILOS: THE METHODS YOU APPLY

	Grain temperature (°C)	Ambient moisture level (%)
Trigger parameters for cooling down the silos		

Method for triggering the cooling down system:

☐ Manual
☐ Thermostat

IMPLEMENTED ACTIONS TO COOL DOWN THE SILO:

If YES X
If NO

A. **Ventilation**

Devices for temperature management	At farm	In your own silos	In port silos
Thermometry			
Air condition			
Ventilator			
Other			

B. **Grain transfer**

Devices for grain transfer	At farm	In your own silos	In port silos
Permanent free silo			
Permanent free unloading area			
Other			

4. CHEMICAL TREATMENTS: APPLIED ACTIVE SUBSTANCES & METHODS

*APPLIED ACTIVE SUBSTANCE**	Crop 2009/2010				Crop 2010/2011			
	At farm	Own silos	Port silos	On barges or ships	At farm	Own silos	Port silos	On barges or ships
Pyrimiphos-Methyl								
Chlorpyriphos-Methyl								
Deltamethrine								
Cypermethrin								
Other pyrethroid								
Pyrethrins + Butoxide piperonyl								
Other:								

** If the active substances are unknown please replace them with brand names in the table*

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APPLIED METHODS OF TREATMENT	Crop 2009/2010				Crop 2010/2011			
	At farm	Own silos	Port silos	On barges or ships	At farm	Own silos	Port silos	On barges or ships
On grain								
On premises								
On both								

WHY DO YOU APPLY THE TREATMENT?	
It is a standard treatment	
Because insects are present	
At client demand	
Other.....	

5. FUMIGATION: APPLIED ACTIVE SUBSTANCES & OPERATORS

*APPLIED ACTIVE SUBSTANCE**	Crop 2009/2010				Crop 2010/2011			
	At farm	Own silos	Port silos	On barges or ships	At farm	Own silos	Port silos	On barges or ships
Hydrogen Phosphide (PH_3)								
Sulfurylfluoride (SO_2F_2)								
Other:								

** If the active substances are unknown please replace them with brand names in the table*

OPERATOR	Crop 2009/2010				Crop 2010/2011			
	At farm	Own silos	Port silos	On barges or ships	At farm	Own silos	Port silos	On barges or ships
Your skilled staff								
External operators								

Does your national law require that operators and/or their staff have to be certified/trained for the application and use of plant protection products?

☐ Yes

☐ No

6. CHEMICAL TREATMENT TRACEABILITY

	Crop 2009/2010	Crop 2010/2011	Crop 2011/2012
Treatment are registered			
Information are provided:			
- by your suppliers			
- to your buyers			

7. LEGISLATION AND SPOT-CHECK CONTROLS

	Yes	No
Have you ever been controlled by authorities in the framework of MRL? *		
Did you experienced problems or sanctions about MRL? *		
When controlling processed products, how do your local authorities apply EC Regulation 396/2005? **- do they take into account processing factors?** or** **- do they keep only the whole grain MRLs?**		

* If yes, please specify:

.....

** If yes, who provides the information on the processing factors?

.....

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STORAGE INSECTICIDE ENQUIRY

- ASSOCIATION –

kindly reply by 7 December 2012

Member state:
.....

Name of the association		
Number of members		
Quantity of marketed cereals in your country (thousand Tons)		
National storage capacity (thousand Tons)		
Average distribution of cereals oilseeds and pulse storage in the country (%)	At farm	
	Countryside collector silos	
	Port silo	
Are there contradictions between then national authorizations and Annex 1 of the directive 91/414?		

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Annex 3: Questionnaire used for the 2017 enquiry

STORAGE INSECTICIDE ENQUIRY

- OPERATORS –

Member state: .....

kindly reply by 18 August 2017

1. YOUR COMPANY

If YES X
If NO

The volumes of grain marketed by your company are marketed at:				
National level				
EU level				
Worldwide				
Products marketed	Volume in thousand Tons (KT)			
	Between 0 - 200 KT	Between 200-500 KT	Between 500KT-1MT	More than 1MT
Cereals				
Oilseeds				
Pulses				
Others (which ones)				

2. APPLIED METHODS FOR INSECTS CONTROL

	At farm (%)	In your own silos (%)	In port silos (%)	Barges or Ships (%)
Cooling down silos				
Ambient air circulation				
Air conditioning				
Chemical treatment				
Insecticides (crop dusting, powdering, nebulisation)				
Fumigation				
Others techniques (which ones)				
.....				

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3. COOLING DOWN THE SILOS: THE METHODS YOU APPLY

	Grain temperature (°C)	Ambient moisture level (%)
Trigger parameters for cooling down the silos		

Method for triggering the cooling down system:

☐ Manual
☐ Thermostat

IMPLEMENTED ACTIONS TO COOL DOWN THE SILO:

If YES X
If NO

A. Ventilation

Devices for temperature management	At farm	In your own silos	In port silos
Thermometry			
Air condition			
Ventilator			
Other			

B. Grain transfer

Devices for grain transfer	At farm	In your own silos	In port silos
Permanent free silo			
Permanent free unloading area			
Other			

4. CHEMICAL TREATMENTS: APPLIED ACTIVE SUBSTANCES & METHODS

APPLIED ACTIVE SUBSTANCE*	Crop 2014/2015				Crop 2015/2016			
	At farm	Own silos	Port silos	On barges or ships	At farm	Own silos	Port silos	On barges or ships
Pirimiphos-Methyl								
Chlorpyriphos-Methyl								
Deltamethrine								
Cypermethrin								
Other pyrethroid								
Pyrethrins + Butoxide piperonyl								
Other:								

** If the active substances are unknown please replace them with brand names in the table*

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APPLIED METHODS OF TREATMENT	Crop 2014/2015				Crop 2015/2016			
	At farm	Own silos	Port silos	On barges or ships	At farm	Own silos	Port silos	On barges or ships
On grain								
On premises								
On both								

WHY DO YOU APPLY THE TREATMENT?	
It is a standard treatment	
Because insects are present	
At client demand	
Other…..	

5. FUMIGATION: APPLIED ACTIVE SUBSTANCES & OPERATORS

*APPLIED ACTIVE SUBSTANCE**	Crop 2014/2015				Crop 2015/2016			
	At farm	Own silos	Port silos	On barges or ships	At farm	Own silos	Port silos	On barges or ships
Hydrogen Phosphide (PH_3)								
Sulfurylfluoride (SO_2F_2)								
Other: ……								

** If the active substances are unknown please replace them with brand names in the table*

OPERATOR	Crop 2014/2015				Crop 2015/2016			
	At farm	Own silos	Port silos	On barges or ships	At farm	Own silos	Port silos	On barges or ships
Your skilled staff								
External operators								

Does your national law require that operators and/or their staff have to be certified/trained for the application and use of plant protection products?

☐ Yes

☐ No

6. CHEMICAL TREATMENT TRACEABILITY

	Crop 2014/2015	Crop 2015/2016	Crop 2016/2017
Treatments are registered			
Information are provided:			
- by your suppliers			
- to your buyers			

7. Legislation and spot-check controls

	Yes	No
Have you ever been controlled by authorities in the framework of MRL? *		
Did you experienced problems or sanctions about MRL? *		
When controlling processed products, how do your local authorities apply EC Regulation 396/2005? - **do they take into account processing factors?** or** - **do they keep only the whole grain MRLs?**		

* If yes, please specify:

……

** If yes, who provides the information on the processing factors?

……

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STORAGE INSECTICIDE ENQUIRY

- ASSOCIATION –

kindly reply by 18 August 2017

Member state:
.....

Name of the association		
Number of members		
Quantity of marketed cereals in your country (thousand Tons)		
National storage capacity (thousand Tons)		
Average distribution of cereals oilseeds and pulse storage in the country (%)	At farm	
	Countryside collector silos	
	Port silo	

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