Journal für Kulturpflanzen, 68 (2). S. 38–44, 2016, ISSN 1867-0911, DOI: 10.5073/JfK.2016.02.02 Verlag Eugen Ulmer KG, Stuttgart

Garnet Marlen Kroos, Dagmar W. Klementz

Chemical control of pest insects in stored-product protection in Germany – Present Situation and Challenges –*

Chemische Pflanzenschutzmaßnahmen gegen Vorratsschädlinge in Deutschland – Situationsbeschreibung und Herausforderungen –

Abstract

During the last 15 years the number of approved active substances and the assortment of authorized Plant Protection Products used in stored-product protection has decreased. An overview of these authorized Plant Protection Products in Germany and the uses are presented.

To avoid resistance and maintain a wide variety of approved chemical methods, uses of chemical Plant Protection Products have to follow best technology and standards available. Above all, efforts have to be made to develop new active substances and Plant Protection Products for the pest control in stored products which consider aspects of substainable production and food safety.

Key words: Authorized plant protection products (Germany), chemical control, contact insecticides, fumigation, stored-product protection

Zusammenfassung

In den letzten 15 Jahren haben sich die Anzahl der im Vorratsschutz zugelassenen Pflanzenschutzmittel und die Palette der darin verwendeten Wirkstoffe in Deutschland deutlich verringert. Eine Übersicht über die aktuell zugelassenen Pflanzenschutzmittel und Anwendungen werden für das sogenannte Einsatzgebiet ‚Vorratsschutz' gegeben.

Um Resistenzen vorzubeugen und eine möglichst große Auswahl an zugelassenen chemischen Verfahren zu erhalten, ist es in der Praxis erforderlich, beste verfügbare Technolgien und Standards bei der Anwendung von Pflanzenschutzmitteln zu berücksichtigen. Vor diesem Hintergrund müssen auch Anstrengungen unternommen werden, um neue Wirkstoffe und Pflanzenschutzmittel für die Schädlingsbekämpfung in gelagerten Erzeugnissen pflanzlicher Herkunft zu entwickeln, die insbesondere den gestiegenen Ansprüchen der nachhaltigen Produktion und der Lebensmittelsicherheit genügen.

Stichwörter: Chemische Maßnahmen im Vorratsschutz, zugelassene Pflanzenschutzmittel (Deutschland), Kontaktinsektizide, Begasungsmittel, Vorratsschutz

Introduction

The major part of the harvested plant products is used for food and feed – e.g. in Germany about 25% of the grain is provided for food and about 60% for feed (Statistisches Jahrbuch, 2014).

In the context of the European approach to food safety 'From Farm to Fork' this is one of the reasons why the protection of unprocessed stored plant products assigned to be food is part of the food and feed production chain and consumer protection. Food and feed safety and hygienic requirements are applied at each stage of production, processing and distribution. In this context, these stan-

*According to a Poster Presentation: 11th International Working Conference on Stored Product Protection, 24–28. November 2014, Chiang Mai, Thailand (Corresponding author: Garnet Marlen Kroos, poster presenting author: Dagmar Klementz)

Institute
Julius Kühn-Institut – Federal Research Centre for Cultivated Plants, Institute for Ecological Chemistry, Plant Analysis and Stored-Product Protection, Berlin, Germany

Correspondence
Dr. Garnet Marlen Kroos, Julius Kühn-Institut (JKI), Federal Research Centre for Cultivated Plants, Institute for Ecological Chemistry, Plant Analysis and Stored-Product Protection, Königin-Luise-Straße 19, 14195 Berlin, Germany, E-Mail: garnet-marlen.kroos@jki.bund.de

Accepted
18 December 2015

dards are also related to stored products of plant origin. Specific hygiene rules for primary production should be considered where necessary. It is essential to ensure food safety throughout the food chain, starting with preventive consumer protection at primary production and stored-product protection.

The European Regulations (178/2002/EC and 852/2004/EC) and corresponding sector-specific national laws or rules (Lebensmittelhygiene-Verordnung-LMHV, 2010) aim to ensure that food is safe and harmless and shall not be placed on the market if it is injurious to health or unfit for human consumption implying also deteriorated, nauseous or unfavorable impacts and contaminated food (e.g. by foreign bodies or extraneous matter, pest animals/insects, heavy metals, mycotoxins, unacceptable taste or odour, decomposition, mould).

Furthermore, worldwide trading standards maintain the 'zero tolerance' for living insects. A presence of living pest organisms in stored plant products would jeopardize the stock itself and the supply chain for food and feed (COCERAL, 2010). Therefore, the absence of living insects, other extraneous matter and contaminants is an important aspect in stock-keeping, trade, and in preservation of crops. Harvested crops therefore have to be stored in a way that ensures high quality and is considering all mentioned requirements, storage standards (FAO, 2003) and the state of technology (e.g. cooling, air circulation).

According to Regulation (EC) No. 1107/2009 and national plant protection law, pests in simply processed or unprocessed plant products can be controlled by Plant Protection Products unless the main purpose is considered to be for reasons of hygiene (Fig. 1).

In addition to an insect management of plant products by cleaning, ventilation/cooling and other effective and economically viable alternatives, treatments with Plant Protection Products are main methods to disinfest stored commodities providing that the use of chemical products in integrated pest management situations is necessary (EPPO, 2003), and consequently combined with a low pesticide-input management. Contact insecticides play an important role in the stored-product protection because fumigants are not applicable under all practical conditions, due to lack of gas tightness or other constraints. Nevertheless, fumigation with phosphine remains one of the key methods for the disinfestation of e.g. bulk grain and oilseeds (COCERAL, 2014). For insect

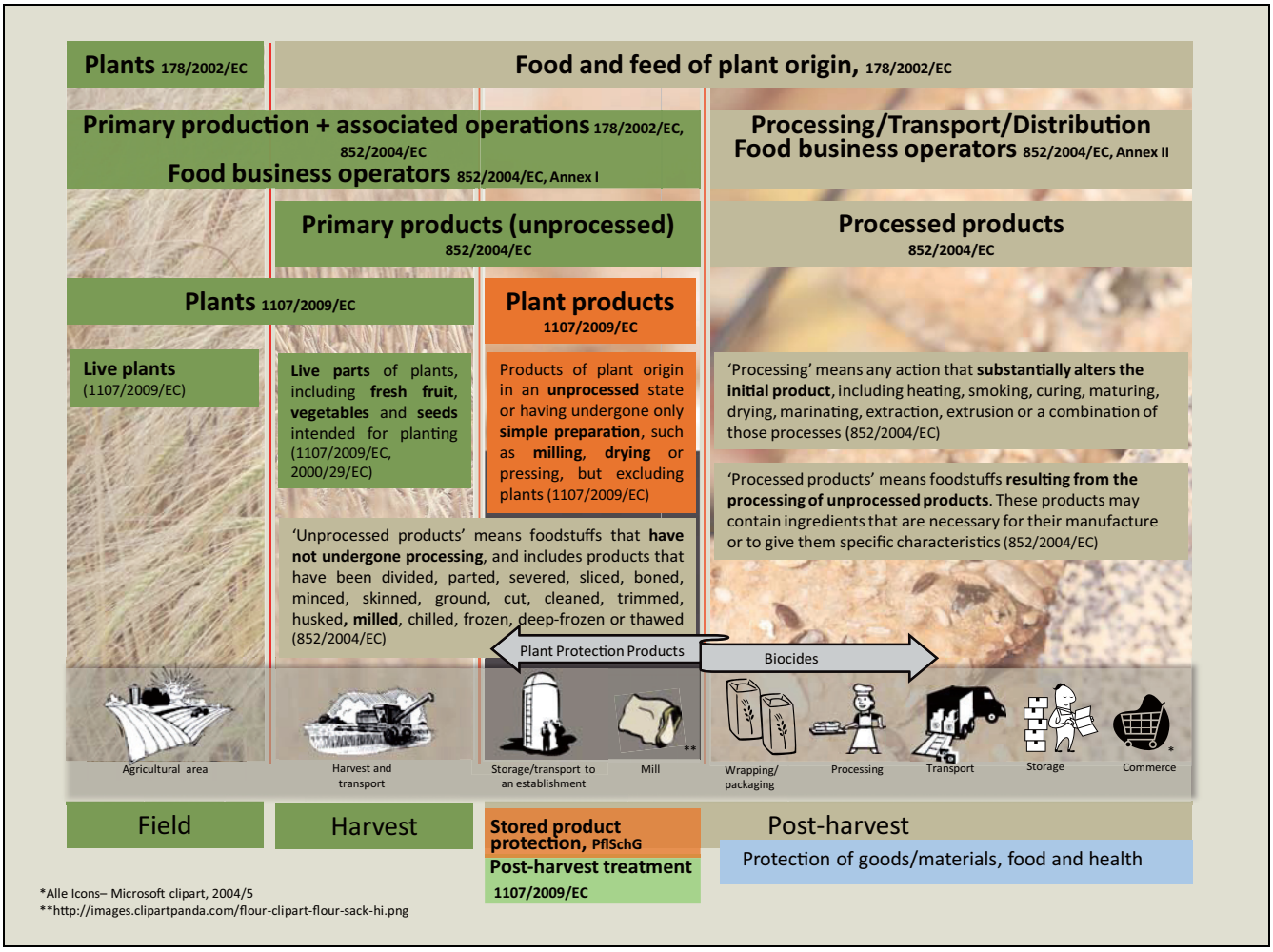

Fig. 1. Definitions of plant products and food.

control in infested empty structures, e.g. on farms, in ports and at retailers, phosphine, sulfuryl fluoride and carbon dioxide has taken the place of the phased out methyl bromide. Applications of carbon dioxide under high pressure conditions also serve the purpose in special uses and applications in valuable goods (e.g. herbs, spices).

Plant Protection Products in storage – present situation in Germany

In Germany, currently a total of 20 Plant Protection Products (PPP) is available for the chemical control measures in the field of stored-product protection (BVL, 2015b). Therefrom currently 18 are insecticides, with a downward trend having dearly stopped in the recent years. Two of the insecticides have an acaricidal effect and are additionally approved for this indication (Fig. 2 and 3, Tab. 2).

In the recent years the number of active substances has been stabilized: nine insecticides, two acaricides and one rodenticide are authorized for applications in stored-product protection in 2015 (Fig. 2 and 3). Nevertheless, there have been cuts in the last ten years such as the non-inclusion of active ingredients in Europe, e.g. methyl bromide, dichlorvos, nitrogen and hydrogen cyanide used in stored-product protection.

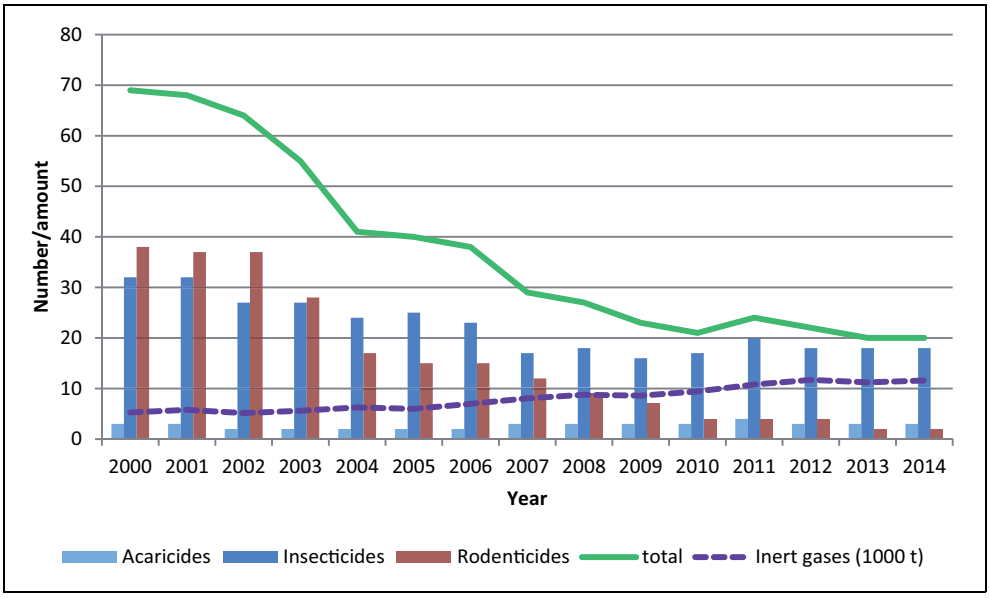

Fig. 2. Plant Protection Products authorized for uses in stored-product protection.

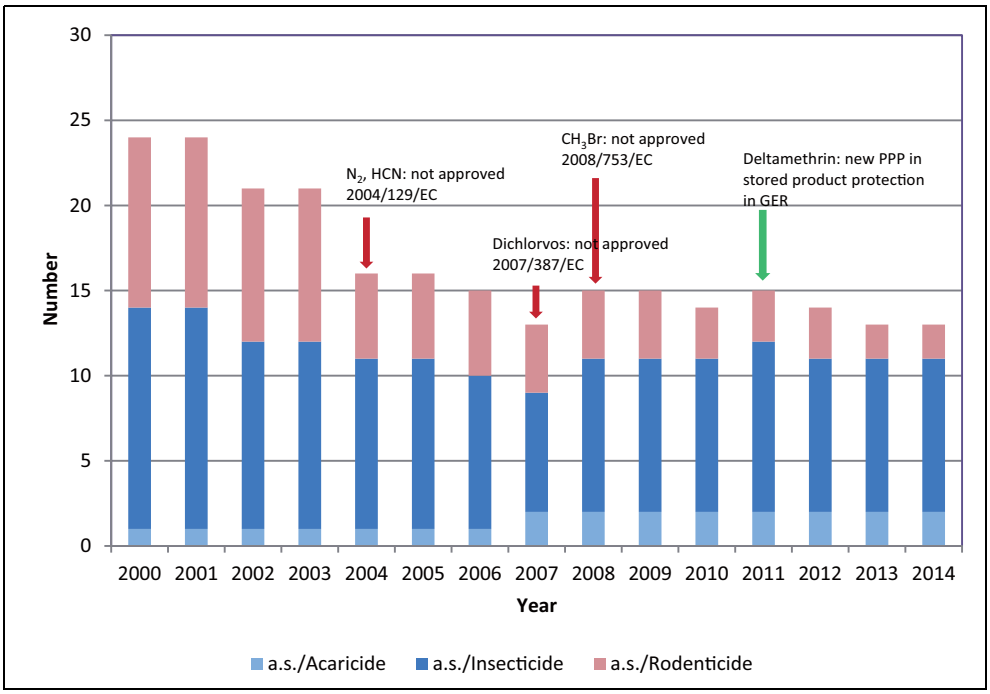

Fig. 3. Active substances in authorized PPP for uses in stored-product protection in Germany.

Tab. 1. Sales quantity of active substances (inland, professional) in Germany (from BVL, 2015a)

Active Substance in Plant Protection Products – stored plant products	Acaricide (A) Insecticide (I) Rodenticide (R)	Uses – solely referred to stored plant protection	Sales quantity [t]					
			2014	2013	2012	2011	2010	2009
Aluminium phosphide	I/R	/	25–100	25–100	25–100	25–100	25–100	25–100
Magnesium phosphide	I	x	1,0–2,5	2,5–10	1,5–2,5	1,0–2,5	1,0–25	10–25
Phosphane	I	x	1,0–2,5	1,0–2,5	< 1	< 1	< 1	< 1
Sulfuryl fluoride	I	x	25–100	25–100	25–100	10–25	25–100	25–100
Carbon dioxide	I/A	x	> 10000	> 10000	> 10000	> 10000	> 10000	> 10000
Deltamethrin	I	/	2,5–10	2,5–10	2,5–10	2,5–10	1,0–2,5	2,5–10
Pyrethrins	I	/	< 1	< 1	< 1	< 1	< 1	< 1
Pirimiphos-methyl	I	x	2,5–10	2,5–10	2,5–10	2,5–10	10–25	10–25
Kieselgur (diatomaceous earth)	I/A	x	2,5–10	2,5–10	2,5–10	10–25	10–25	10–25

Tab. 2. Insecticides/Acaricides in stored-product protection and authorized uses

Active Substance	PPP function	summary of approved uses:'crop/object'
Aluminium phosphide	Insecticide	Empty rooms, sacks, stored cereals, dried fruits, dried vegetables, coffee, cocoa, tea, cereal products (flour, flakes), starch, expeller, spices, pulses
Deltamethrin	Insecticide	Empty rooms (before taking dried pulses and cereals into storage), cereals on the conveyor (during stock transfer and filling)
Diatomaceous earth	Insecticide/Acaricide	Rooms, stored cereals (during filling)
Carbon dioxide	Insecticide/Acaricide	Stored cereals, oily seeds, medicinal plants, tobacco, cereal products, dried fruits, tea, spices, stored goods
Magnesium phosphide	Insecticide	Empty rooms, sacks, stored cereals, dried fruits, dried vegetables, coffee, cocoa, tea, cereal products (flour, flakes), starch, expeller, spices, pulses, oilseeds, medicinal plants, tobacco, hay, nuts
Phosphane	Insecticide/Acaricide	Stored cereals, dried fruits, coffee, cocoa, oily seeds
Pirimiphos-methyl	Insecticide	Stored cereals (excluded corn, rye, rice, buckwheat) direct application on the conveyor during filling
Pyrethrine	Insecticide	Empty rooms (pyrethrum also used in organic farming)
Sulfuryl fluoride	Insecticide	Empty rooms (no co-treatment of cereal or cereal products), dried fruits, nuts, walnuts, hardwood + pinewood (round timber and package/dunnage in containers, for shipment)

Any further loss of active substances with an effective knockdown effect and a high efficacy will make it difficult to manage infestations especially in the context with the 'zero tolerance'. For this reason, the risk of pest resistances against contact insecticides and other widely used compounds (e.g. phosphide degassing hydrogen phosphine) could occur even faster than before. According to the marginal options of chemical methods, pest control has to strengthen the role of prevention and monitoring methods. Pest control itself has to be efficient and combined with the Good Agricultural Practice (GAP) defined for all authorized uses and Good Hygiene Practice (GHP) for primary production (852/2004/EC; Annex).

Five of the insecticidal active substances used in the products for stored-product protection, authorized in Germany, are gases and more than half of these products work on the base of hydrogen phosphine: Fumigation with phosphine remains still one of the key methods for disinfestation of stored products (Tab. 1 and 2) like bulk grain and bagged cocoa beans.

Sulfuryl fluoride is one of the two non-phosphine-releasing fumigants, in addition to carbon dioxide as an inert gas in stored-product protection. For insect control in food and feed factories and other infested empty structures, sulfuryl fluoride has taken the place of methyl bromide. Fumigation often is the last option after other alternatives of the pest control have failed or do not present feasible options. When using the authorized ProFume (containing sulfuryl fluoride) it has to be mentioned that most of the uses only imply the control of post-embryonic stages that are larvae and imago. In Germany, eggs are excluded of the authorized use because the total mor-

tality during applications could not always be ensured under practical conditions. Especially at temperatures below 20°C re-infestation by hatching can occur (Flingelli et al., 2014). Therefore, under practical conditions and when used in accordance with the proposed label ProFume can be an effective fumigant for the control of stored product pests. Though, the results also reflect that the mortality of pests in all stages depends on the sensitivity of the organisms and development stages as well as on the conditions of the particular fumigation (e.g. structure of the facility, leaking rate, temperature) and cannot be easily extrapolated to other situations.

In Germany carbon dioxide is approved as an insecticide and acaricide, but only for uses in stored-product protection. The merchandized domestic amount of this inert gas has increased in stored-product protection over the last ten years. The actual volume of 11588 t carbon dioxide represents about 25% of all active substances in Plant Protection Products and 10% of all Plant Protection Products delivered in 2014 in Germany (BVL, 2015).

The uses of four contact insecticides remain on the German market. They contain diatomaceous earth, deltamethrin, pirimiphos methyl and pyrethrines as active substances. Beside this, this small number of represented substances and contact insecticides play an important role in stored-product protection, especially uses in empty facilities (Tab. 3), because in many practical situations fumigants are not applicable due to lack of gas tightness or other circumstances.

Tab. 3. Authorized uses to disinfest storage facilities in Germany

Plant Protection Product*	Area of use: ‚room'	Notes on the use/situation/restriction
DETIA-GAS-EX B Aluminium phosphide	empty silo cells/compartments empty rooms	–
K-Obiol EC25 Deltamethrin	empty rooms	before taking dried pulses and cereals into storage
SILICO-SEC Kieselgur (diatomaceous earth) * mites	empty rooms mills and storage rooms/granaries rooms	– in the presence of stored goods –
DEGESCH-PLATE Magnesium phosphide	empty rooms	–
INSEKTENIL-Naturpyrethrum-Spray Pyrethrine * plus moths	rooms in mills and storages/granaries	in the presence of cereals, cereal products, products of oilseeds (expeller), nuts, dried fruits, tobacco
INSEKTENIL-Raumnebel-fuerte Pyrethrine * only beetles, moths	rooms in mills and storages/granaries	in the presence of cereals, cereal products, products of oilseeds, nuts, dried fruits, tobacco
	horizontal grain storage facilities	in the presence of bulk grain
INSEKTENIL-Raumnebel-Spray Pyrethrine * Only beetles, moths	rooms in mills and storage rooms/granaries	in the presence of cereals, cereal products, products of oilseeds, nuts, dried fruits, tobacco
	mills: rooms in food processing businesses where plant products were stored and simply processed storages/granaries: incl. storages of food processing businesses and agricultural storages	
ProFume Sulfuryl fluoride * Larvae – adults, except eggs	rooms in mills and storages/granaries empty rooms, storages and silo cells rooms in mills	– – During fumigation: keep cereals that are stored inside the mill safe under gastight coverage/conditions; keep away milled or husked cereal products

* special other target organisms

The European Directive 2011/31/EU restricts Plant Protection Products containing the approved active substance 'pirimiphos-methyl' (2007/52/EC) to applications with automated systems; hand–held application shall not be authorized. Therefore, the use is limited to the direct treatment of grain, excluding maize, on conveyors during putting into stock. At the end of 2013 further variations have excluded applications on rice, rye and buckwheat.

In 2011 two Plant Protection Products containing the active ingredient deltamethrin were approved; these authorized spray applications could partially compensate the limitations for pirimiphos-methyl containing Plant Protection Products, especially considering agricultural storages and smallholders.

In accordance with Regulation (EC) No 834/2007 only indoor applications using Plant Protection Products containing pyrethrines against beetles and moths are available for organic farming.

The approval of difenacoum (against brown rat, house mouse, house rat) has expired at the end of 2014 because only uses as a rodenticide in the form of pre-prepared baits placed in specially constructed, tamper resistant and secured bait boxes can be authorized according to Regulation (EU) No 540/2011. Besides this, it has to be noted that in some regions of Germany genetic resistance against difenacoum has already occured.

For the control of rodents in the agricultural area of plant-product protection only a single rodenticide remains on the market: zinc phosphide (against house mouse). However, this authorization of uses with zinc phosphide will end in April 2016. Without replacement or renewal, no rodenticide for applications in stored-product protection would be available to protect stored products of plant origin.

Since most of the commensal rodents are classified as vectors for pathogens, one of the main purposes of using pesticides in this field is the control of organisms that are harmful to human health. To meet these hygienic uses there is a great number of biocides on the German market that could cover the mentioned gap of Plant Protection Products if it is **not** intended to reduce direct damage to natural plant products.

Challenges and future prospects

Since only a few active substance classes and a small number of Plant Protection Products are available for protecting stored plant products in Germany, efforts in research and development of efficient, sustainable, less hazardous and more ecological formulations are recommended. Those products could be alternatives in the process of comparable assessment, even if it takes about 10 years from finding and first research tests of a new active substance and the authorization of the product. At the same time the global challenges like climate change and consumption of resources need plant protection solutions to establish sustainable intensification of production and save yields for about 9.5 billion people in 2050 (FAO, 2000) worldwide.

Besides efficient prevention and monitoring methods and other non-chemical controlling methods (e.g. heat, cooling, biological antagonists), chemical compounds keep their important part within stored-product protection when the quality of already infested stored products has to be preserved or storage facilities should get disinfested before filling. In this context, Plant Protection Products are a tool in integrated pest management (IPM) to protect harvested plant products from common and quarantine/invasive pest species in global trade and for recovery of otherwise lost food/feed for feeding rather than for repurposing it for other uses (e.g. biogas) (G20, 2015). To support this intention, Plant Protetection Products are evaluated according to the state of science and have undergone a risk-based authorization process due to the precautionary principle (COM, 2000). Furthermore, regulatory science has to enhance translation of basic science into regulatory applications (e.g. guidelines, standards) to support optimized uses of Plant Protection Products according to integrated pest management, the best available technology and good agricultural practice (Fig. 3 and 4).

Acknowledgements

The authors gratefully acknowledge in particular the contributions of Dr. G. Joermann, scientist of the Federal Office of Consumer Protection and Food Safety, who provided the statistical records on registered Plant Protection Products in Germany.

References

Bundesamt für Verbraucherschutz und Lebensmittelsicherheit (BVL), 2015a: Absatz an Pflanzenschutzmitteln in der Bundesrepublik Deutschland, Ergebnisse der Meldungen gemäß § 64

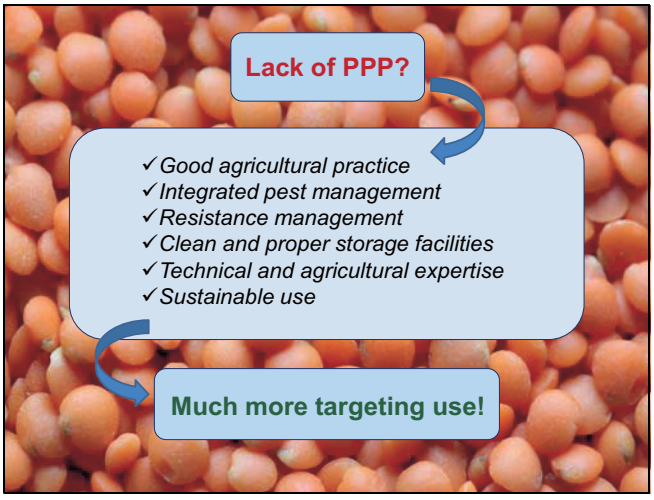

Fig. 4. Much more targeting use of pesticides.

Pflanzenschutzgesetz für das Jahr 2000-2014. http://www.bvl.bund.de/psmstatistiken.

Bundesamt für Verbraucherschutz und Lebensmittelsicherheit (BVL), 2015b: (Online-Datenbank Pflanzenschutzmittel. http://www.bvl.bund.de/DE/04_Pflanzenschutzmittel/01_Aufgaben/02_ZulassungPSM/01_ZugelPSM/01_OnlineDatenbank/psm_onlineDB_node.html.

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, Bundesministerium für Gesundheit, 2007: Verordnung über Anforderungen an die Hygiene beim Herstellen, Behandeln und Inverkehrbringen von Lebensmitteln (Lebensmittelhygiene-Verordnung-LMHV). Ausfertigungsdatum: 08.08.2007, BGBl. I S. 1816, 1817, zuletzt durch Artikel 1 der Verordnung vom 14. Juli 2010 (BGBl. I S. 929) geändert.

COCERAL – EUROMALT – EUROMAISIERS – UNISTOCK, 2010: European Good Hygiene Practices Guide for the collection, storage, trading and transport of cereals, oilseeds and protein crops. COCERAL/COGECA, Version: 20 July 2010.

COCERAL – EUROMALT – EUROMAISIERS – UNISTOCK, 2014b: Applied methods for insect management in stored grain and oilseeds, 2014 b. Results of the storage insecticides survey carried out by COCERAL, EUROMAISIERS, EUROMALT and UNISTOCK. January 2014, www.coceral.com.

Council of the European Union, 2007: Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91. OJ L 189, 2007, p. 1-23.

EPPO, 2003: Good plant protection practice. EPPO Standards PP 2/1(2) 2003, Bulletin OEPP/EPPO Bulletin **33**, 87-89.

European Commission, 2007: COMMISSION DIRECTIVE 2007/52/EC of 16 August 2007 amending Council Directive 91/414/EEC to include ethoprophos, pirimiphos-methyl and fipronil as active substances.

European Commission, 2000a: Communication from the Commission on the precautionary principle. COM/2000/0001 final, http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52000DC0001.

European Commission, 2011: Commission Directive 2011/31/EU of 7 March 2011 amending Council Directive 91/414/EEC as regards a restriction of the use of the active substance pirimiphos-methyl Text with EEA relevance. OJ L 61, 2011, p. 18-20.

European Commisssion, 2015: EU-Pesticides Database. http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=homepage&language=EN.

European Parliament and Council of the European Union, 2004: Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 2004, p. 1-54.

European Parliament and Council of the European Union, 2009: Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC. OJ L 309, 2009, p. 1-50.

European Parliament and of the Council, 2002: Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. OJ L 031, 01/02/2002 P. 0001 – 0024.

European Parliament and of the Council, 2011: Commission Implementation Regulation (EU) No 540/2011 of 25 May 2011 implementing Regulation (EC) No 1107/2009 of the European Parliament and of the Council as regards the list of approved active substances. OJ No L 153/1, 11.6.2011.

FAO Committee on Agriculture (COAG), 2003: Development of a Framework for Good Agricultural Practices. Seventeenth Session, Rome, 13 March-4 April 2003, GAP paper.

FAO, 2000b: Expert Meeting on 'How to Feed the World' in 2050. Food and Agriculture Organization of the United Nations, Economic and Social Development Department. Report of the FAO expert meeting on how to feed the world in 2050. Rome, 24-26 June 2009.

Flingelli, G., M. Schöller, D.W. Klemnetz, C. Reichmuth, 2014: Influence of temperature and exposure time on the mortality of Tribolium castaneum eggs at fumigation with sulfuryl fluoride with regard to the progressive egg development. Journal für Kulturpflanzen – Journal of Cultivated Plants **66** (1), 7-14.

G20, 2015: G20 Agriculture Ministers Meeting. Istanbul, 7-8 May 2015, Final Communiqué.

Statistisches Bundesamt, 2014: Statistisches Jahrbuch, Deutschland und Internationales, www.destatis.de. ISBN 978-3-8246-1029-7.