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CONFERENCE REPORT

An ecosystem services approach to pesticide risk assessment and risk management of non-target terrestrial plants: recommendations from a SETAC Europe workshop

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Abstract The registration of plant protection products (PPPs) in the EU is under Regulation 1107/2009, which recommends a tiered approach to assessing the risk to non-target terrestrial plants (NTTPs). However, little information is provided on how to perform and implement higher tier studies or how to use them to refine the risk assessments. Therefore, a stakeholder workshop was organized to consolidate current knowledge and expertise to aid the further development of testing and assessment procedures for NTTPs. This brief communication highlights the agreed recommendations of the workshop, which relate to the three main themes, i.e. specific protection goals, risk assessment and mitigation. The participants of the workshop adopted the European Food Safety Authority (EFSA) approach of using an ecosystem services framework for identifying specific protection goals. First, delivery and protection of ecosystem services were discussed for in-crop, in-field and off-crop, and off-field areas. Second, lower and higher tier risk assessment methods, including modelling approaches, were evaluated. Third, options for risk mitigation of spray drift and run-off were discussed and evaluated. Several important knowledge gaps were identified, and specific data collation and literature-based tasks were actioned to begin to address them. A full workshop report is planned for the fall of 2014.

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Introduction

An essential requirement for effective risk assessment and risk management is a clear articulation of what is to be protected, where and when. General protection goals for use in regulating plant protection products (PPPs) are outlined in European legislation. However, these protection goals are only broadly defined, e.g. described in terms of "no adverse effects on…", and more specific protection goals are required to enable robust and effective ecological risk assessment and regulatory decision making (Nienstedt et al. 2012). In 2010, the European Food Safety Authority (EFSA) published an opinion outlining how an ecosystem services framework could be used to establish specific protection goals for plant protection products (EFSA 2010), an approach that has been endorsed at a recent EFSA Scientific Colloquium (EFSA 2014a). However, this colloquium also highlighted further work that was needed to make this approach operational, including translating protection goals into measureable assessment

endpoints. Here we report on the outcome of a recent workshop that begins to address this need for non-target terrestrial plants in agricultural landscapes.

Ecosystem services are the benefits people obtain from ecosystem structures and processes (Maltby 2013). The potential impact of toxicants on ecosystem services was recognized 25 years ago (Cairns and Niederlehner 1994), but the incorporation of ecosystem service effects in risk assessment has only been considered recently. EFSA (2010) was the first to apply the ecosystem services approach for the purpose of the derivation of protection goals underpinning the risk assessment for PPPs. However, the quantitative assessment of risks of chemicals to ecosystem service delivery is still in its infancy. To effectively incorporate ecosystem services into ecological risk assessment, it is necessary to have a good understanding of the key service-providing units. In ecosystems, plants represent such a key service-providing unit and EFSA (2010) identified non-target vascular plants as one of the key drivers of ecosystem services to be included in the risk assessment for PPPs.

Key ecosystem services terrestrial plants provide to humans vary from production of food, fibre, fuel, and medicines, through regulation of climate and water purification to aesthetic and recreational values (Table 1). Terrestrial plants are crucial to life on earth. In addition to their essential role in producing oxygen and removing carbon dioxide, they provide food and habitat for animals and resources for microorganisms. However, terrestrial plants can also reduce food production by competing with crop plants, and therefore, their abundance is controlled in agricultural systems, often through the use of PPPs. It has been estimated, for example, that black-grass infestations in the UK can result in losses of cereal production between 14 and 21 %, which equates to financial losses of £532 million (Clarke et al. 2011). Because PPPs are potentially harmful to non-target species, the challenge is to control target plants that adversely affect crop production (i.e., weeds), whilst minimizing the effects on the crop and other non-target terrestrial plants (NTTPs) that provide important ecosystem services. Identifying the ecosystem services of concern that are delivered by NTTPs in arable landscapes and understanding how PPPs influence their capacity to deliver those services are necessary for effective risk assessment and risk management of PPPs (Forbes and Calow 2013; Maltby 2013).

Table 1 Overview of main ecosystem services provided by terrestrial plants

Service groups	Ecosystem services
Provisioning	Food, fibre, fuel, genetic resources, natural medicines, biochemicals and pharmaceuticals, ornamental resources
Regulating	Regulation of pests and diseases, climate, air quality, erosion, water, pollination, resistance of invasion, purification of water and treatment of waste, phytoremediation and regulation of natural hazards such as landslips and flooding
Cultural	Educational values; knowledge systems for future generations; inspiration; aesthetic values, recreation and ecotourism; spiritual and religious values; cultural heritage values
Supporting	Soil formation and structuring, photosynthesis, primary production, nutrient cycling, decomposition and mineralization, sustainability of the food web, provision of habitat provision, cycling of water

After Millennium Ecosystem Assessment (2005)

The registration of PPPs in the EU is under Regulation 1107/2009. This regulation requires a prospective risk assessment for PPPs preceding their admission on the market. This admission might require additional mitigation measures for specific crops, e.g. required width of buffer strips. The mitigation measures are part of the risk management process. The prospective risk assessment follows a tiered approach to assessing the risks of PPPs. The tiered approach states that extended laboratory, semi-field, field studies and modelling may be conducted. However, little information is provided on how to perform and implement higher tier studies for NTTPs or how to use higher tier data for NTTPs to refine the risk assessments. EFSA are in the process of developing guidance to support Regulation 1107/2009, and NTTPs are one of the important topics that will be addressed in a new terrestrial guidance document, planned to start development in 2014 (EFSA 2014b). In the light of guidance development by EFSA and the absence of information on how to perform a tiered approach for NTTPs, a stakeholder workshop was organized to consolidate scientific, technical and regulatory expertise as input for the further development of robust, reliable and usable NTTP testing and assessment procedures and to discuss mitigation options as part of a risk management approach for decreasing risks in the application process of PPPs.

The workshop was held under the auspices of the Society of Environmental Toxicology and Chemistry (SETAC) Europe, with sponsorship from the European Crop Protection Association and participating stakeholder representatives, which were evenly distributed over the stakeholder groups of academia, business and government. The workshop objectives were as follows:

1. Consider the application of protection goals as defined in the EFSA opinion to NTTP risk assessment and testing
2. Evaluate methods for lower and higher tier
3. Define what approaches and information are needed to conduct higher-tier risk assessments for NTTPs
4. Consider how modelling of single and multiple NTTPs can be implemented in the risk assessment
5. Discuss approaches for mitigation of risk to NTTPs from different exposure routes

The workshop took place in the Netherlands between 1 and 3 April 2014 and included invited experts from academia, regulatory bodies and business. Here, we highlight the recommendations agreed upon by all workshop participants. These recommendations are organised around three main themes: specific protection goals, risk assessment and risk mitigation.

Specific protection goals

Terrestrial plants are classified into three groups based on their anatomy and mode of reproduction: non-vascular plants (bryophytes), vascular seedless plants (lycophytes, pteridophytes) and vascular seed plants (gymnosperms, angiosperms). Angiosperms have been traditionally divided into monocots (monocotyledons) and dicots (dicotyledons) based mainly on the number of cotyledons in the embryo. However, molecular data indicate that, whereas monocots form a distinct clade, dicots are polyphyletic, with the vast majority of species forming a large clade known as eudicots (Simpson 2010).

Discussions at the workshop focussed on vascular plants, of which there are more than 20,000 species in Europe (Bilz et al. 2011). In agro-ecosystems, vascular plants occur both within (in-field) and outside managed fields (off-field). In arable fields, vascular plants may occur within (in-crop) or outside (off-crop) the cropped area. The EFSA PPR Panel recommended that in-crop specific protection goals (SPGs) are applied to field margins (i.e. off-crop and in-field), whose primary purpose is PPP risk mitigation whereas off-crop SPGs are applied to off-crop and in-field areas whose primary purpose is enhancement of biodiversity (EFSA 2010). This view implies that protection goals in off-crop and in-field areas differ depending on their purpose. The workshop participants endorsed this recommendation.

NTTPs provide a wide range of provisioning, regulating, cultural and supporting ecosystem services within agro-ecosystems. However, the type and relative importance of ecosystem services will differ between different areas, i.e. in-crop, off-crop, in-field, and off-field (EFSA 2010), which is a consequence of the aim not to protect everything everywhere and of the view that ecosystem services might be negatively affected by PPPs. The potential role of in-crop NTTPs for support of the food web and provision of habitat was acknowledged, and there was agreement that the effect of PPPs on such supporting services could be compensated for in-field or off-field. The majority view was that this compensation was not part of pesticide risk assessment, but should be captured by other policy instruments (e.g. agri-environment schemes, greening policies, etc.), and incorporated into an integrated pest management approach.

The workshop agreed that the value of NTTPs to be protected is at the level of the population or higher and that important attributes for provision of ecosystem services are biomass, cover and abundance. Species composition (biodiversity) is important for some services, and reproduction is important for the sustainability of the population. The group agreed with the EFSA opinion that transient effects at a local scale are acceptable for some ecosystem services, but there should be negligible effects at either the landscape scale or in protected areas. This is in agreement with other regulatory frameworks operating at the landscape scale, i.e. the Water Framework Directive (WFD; EC 2000).

Risk assessment

Current first-tier risk assessment for non-target terrestrial plants in Regulation 1107/2009 is relatively simple. In the new data requirements, screening data with six plant species from six different families including monocots and dicots is required. In case of herbicidal or plant growth regulatory activity, a dose-response test on a selection of six to ten monocot (e.g. *Poaceae* and *Liliaceae*) and dicot (e.g. *Brassicaceae* and *Fabaceae*) plant species providing an ER_{50} value has to be conducted. Guidelines for non-target terrestrial plant testing (OECD 208; OECD 227) include procedures in which pots containing either seeds or two to four leaf plants are exposed to a chemical, normally as a spray application. Pots contain one or more seeds or plants of a single (crop) species and endpoints (no-observed-effect rate (NOER), x% effect rate (ERx), and % inhibition rate (IRx)) for emergence, survival and biomass are determined. The endpoints from these studies are then combined with exposure estimates (spray drift, volatilisation/deposition) to assess the risk to NTTPs.

For PPPs, extended laboratory studies following a more realistic exposure are requested if a risk has been identified. Semi-field and field tests on abundance of plants and production of biomass at different distances from the crop might be performed. As there are no standardized tests available, the type and conditions of these studies must be discussed with the national authorities.

A consequence of such assessments is that mitigation of risk (buffers and/or measures to reduce drift) is required in many cases, particularly for herbicides.

The assumption of the current terrestrial guidance document (EC 2002) is that the range of sensitivity of tested species is appropriate for the species we want to protect. Moreover, it defines non-target plants as "non-crop plants located outside the treated area". However, as test species used in laboratory and greenhouse tests are mainly crop plants, a concern was expressed during the workshop as to whether the tested species are protective of wild species. It was therefore recommended to conduct a literature review comparing the sensitivity of standard versus wild species (e.g. reviewing Boutin et al. 2012; Stephenson et al. 1997, 2000).

Another assumption in the current risk assessment procedure is that population-level effects can be adequately

estimated through measures of survival, growth and emergence. A concern was expressed over whether the current tested endpoints are protective of reproductive effects. It was agreed that reproduction via seeds might need to be considered as an endpoint for higher-tier. It was recommended that a literature review be conducted to assess if the current regulatory endpoints (i.e. assessment endpoints plus a safety factor) are protective of reproductive effects (e.g. reviewing Schmitz et al. 2014). This review should also address the specific modes of action of PPPs in order to identify whether these could be related to specific endpoints.

The concerns outlined above were part of a general concern expressed by some workshop participants about assessment factors and the need for validation of all uncertainties identified. Several proposals were made to reduce the uncertainties associated with single species tests. In the current risk assessment scheme, tests can be conducted under more realistic exposure conditions in, for example, greenhouse, semi-field or field trials. It is also possible to extend the number of species tested in order to generate a species sensitivity distribution (SSD). One proposal arising from the workshop was to prolong the test duration to demonstrate no unacceptable long-term effects.

In the current risk assessment, field studies (e.g. studies in field margins) or other multispecies studies (e.g. small plots to assess response of NTTPs to PPPs) may be used to answer specific questions. However, participants highlighted that there was limited experience with such studies, which may pose several challenges. There is therefore a need to clarify why such studies would be performed (i.e. for which regulatory question or outcome), what types of approaches may be available and how such studies may be conducted. It was recommended that understanding, knowledge and protocols for field and multispecies studies should be collated and exchanged.

It was agreed that mechanistic models of communities and populations could bring greater flexibility and/or possibilities to the risk assessment, may reduce the need for higher tier testing and could support the design of test protocols. Models can also help to link assessment endpoints to specific protection goals and may also help to define scenarios for risk assessment at the landscape level. It was agreed that, as EFSA was currently working on guidance for ecological modelling, reference should be made to the Scientific Opinions on good modelling practice and on the state of effect modelling approaches for regulatory risk assessment of pesticides in order to ensure a harmonized approach.

Mitigation

Mitigation of spray drift

Spray drift was considered to be one of the main routes of exposure of NTTP by PPPs. Risk from spray drift may be mitigated by reducing the amount of spray reaching NTTPs and/or by reducing the amount of drift produced. One common mitigation measure is to apply buffer zones (i.e. no-spray

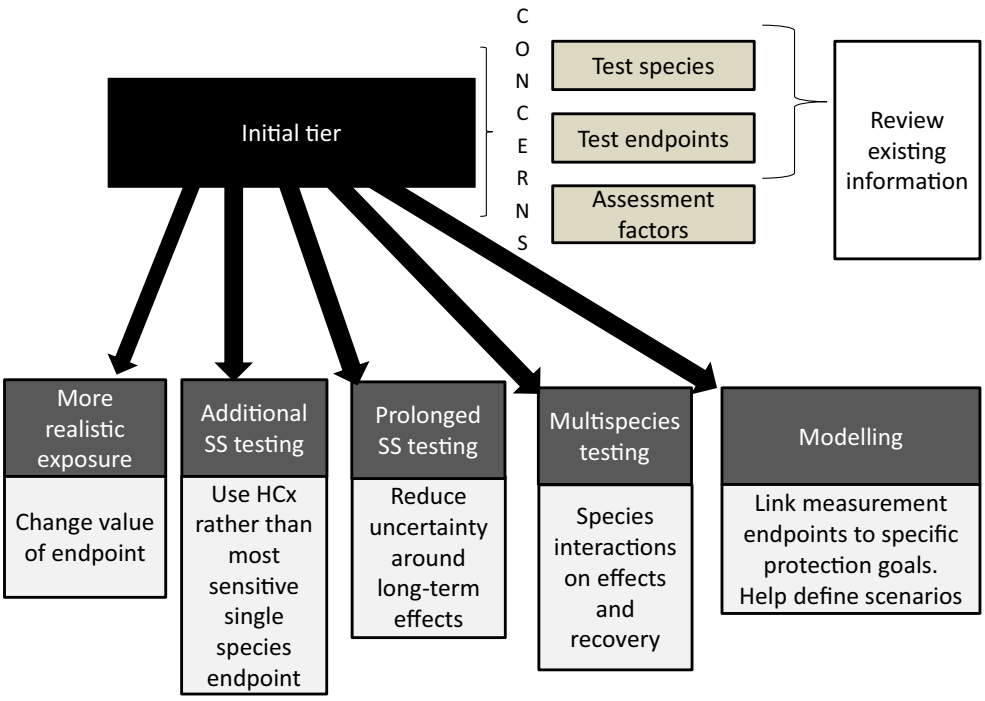

Fig. 1 Proposed higher tier options for NTTPs (*dark grey boxes*) and the associated benefits (*light grey box below each option*). *Mid-grey boxes* highlight key concerns relating to initial tier risk assessment, which will be addressed, in part, by reviewing existing information (*white box*)

zones) which are located either in-crop or off-crop/in-field to protect NTTPs growing off-field. In-field drift deposition can be intercepted with mesh-screens or tall vegetation (e.g. trees, shrubs or *Miscanthus* species). For example, in a field trial in Switzerland, windbreak hedges reduced spray drift by 75 %, a screen on the top of the orchard by 65 % and a coarse-mesh screen at the edge of the field showed an effect of about 20 % drift reduction (Schweizer et al. 2013).

Regarding drift reducing technology, modified nozzles have been developed that reduce drift between 25 and 95 %. Also, new formulations might reduce drift of droplets and volatiles (e.g. Enlist(R)). Drift-reducing nozzles produce larger and therefore heavier droplets. These droplets travel shorter distances than smaller, lighter droplets. However, in some cases, larger droplets might lead to a lower efficacy and therefore, a main prerequisite of drift reduction is that full efficacy is maintained. Trials in arable fields in Belgium with fungicides and herbicides have demonstrated that drift-reducing nozzles had a similar performance as conventional nozzles regarding biological efficacy (Nuyttens et al. 2009). In addition to using drift-reducing nozzles, the use of end-nozzles could reduce the quantity of overspray at the edge of field (0–2 m).

Precision farming technology offers the potential to reduce the area of herbicide application. With adequate information about the weed distribution patterns in the field and device control technology (e.g. GPS, GIS, on-board and spraying computer, application software, image analysis, and sensors), target areas can be localized and the usage of herbicides can be adjusted accordingly. However, for achieving an economic benefit of this expensive technology either sufficient utilization of the equipment, e.g. large-scale farms (600–900 ha) or contractors with a good annual usage of the technology is required (Schroers et al. 2010).

Table 2 Key workshop recommendations

1. The specific protection goals (SPGs) applied to in-field/off-crop areas is dependent on their primary purpose. In-crop SPGs are applied to areas whose primary purpose is mitigation of risks of PPPs (e.g. no-spray buffer zones). Off-crop SPGs are applied to areas whose primary purpose is enhancement of biodiversity.
2. The potential role of in-crop NTTPs for sustainability of the food web and provision of habitat was acknowledged, but the majority view was that compensation for these ecosystem services was not part of pesticide risk assessment.
3. The NTTP entity to be protected is the population or higher. Transient effects at a local scale are acceptable for some ecosystem services, but there should be negligible effects at either the landscape scale or in protected areas.
4. The extent to which the species currently tested are protective of wild species should be evaluated by comparing the sensitivity of standard and wild species.
5. The extent to which current regulatory endpoints are protective of population effects should be evaluated. Do reproductive endpoints need to be included?
6. There is little knowledge, guidance, and experience for conducting field studies or other multispecies studies with NTTPs. There is a need to collate available information and exchange understanding, knowledge and protocols.
7. Relative importance of different exposure pathways to NTTPs is unclear. There is a need to collate and review available information.

Mitigation of run-off

Mitigation measures for run-off include vegetative buffer strips, precision farming or adjusting the timing of application relative to weather conditions. The relative importance of run-off and other exposure pathways (e.g. volatilisation and airborne spray-drift) to NTTPs with different physical structures is not yet clear. Therefore, a recommendation was made at the workshop to collate information on the relative importance of different exposure pathways to NTTPs and to ensure to harmonize with other areas exposed to drift like non-target arthropods.

General conclusions, recommendations and outlook

NTTPs provide a wide range of provisioning, regulating, cultural and supporting ecosystem services (Fig. 1) and may occur in-crop, off-crop/in-field and off-field. The workshop participants agreed that the type and relative importance of ecosystem services provided by NTTPs differ between different areas both in-field and off-field. The key recommendations from the workshop are given in Table 2. The agreed outcome of the workshop is given in Fig. 1. The figure highlights the higher-tier options, the benefits from these options, the concerns raised around these options and the actions taken in order to reduce uncertainty. For the initial tiers, concern was especially raised around uncertainty related to test species (are standard test species protective for wild species?) and endpoints (are current regulatory endpoints protective of reproductive endpoints ?). At the level of field or other multispecies studies, participants concluded that these studies pose a challenge due to limited experience with this type of study and the absence of guidelines (what to measure and how ?). These questions were translated into specific actions including collating and reviewing data and literature (Fig. 1). The outcome of these specific actions will be included in the workshop report foreseen for the fall of 2014. This report will also discuss the results of the NTTP workshop in the light of the recommendations made by "Mitigating the Risk of Plant Protection Products in the Environment" (MAgPIE) workshop, the aim of which was to propose harmonized options for risk mitigation measures in Europe and the results of which are in progress (http://globe.setac.org/2013/may/setac-europe-workshop.html), and the "European Standard Characteristics

of Beneficials Regulatory Testing" ESCORT 3 workshop (Alix et al. (editors) 2012) linking non-target arthropod testing and risk assessment in soils with protection goals.

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