Reducing pesticide use and risks - What action is needed?

Briefing paper

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In Part I of this briefing paper we largely draw on information and published studies compiled in the following publications:

- FAO (2011). *Save and Grow. A policy maker's guide to the sustainable intensification of smallholder crop production.* Rome: FAO.
- IAASTD (2009). *International assessment of agricultural knowledge, science and technology for development: global report.* Washington DC: Island Press.
- Pretty, J. (2005). *The Pesticide Detox - Towards a more sustainable agriculture .* London : Earthscan.
- Pretty, J. and Bharucha, Z. P. (2015). Integrated Pest Management for Sustainable Intensification of Agriculture in Asia and Africa. *Insects*, Insects 2015, 6, 152-182;.
- Greenpeace (2015). *Pesticides and our Health. A growing concern.* Greenpeace UK.
- Leu, A. (2014). *The Myths of Safe Pesticides.* Austin, Texas: Acres USA.

Part II builds on the results of a Symposium on pesticide reduction held on 3rd September 2015 at ETH Zurich, Switzerland. It compiles the conclusions of panel discussions and workshops involving 130 participants including consumers and their organisations, farmers and their organisations, scientists from various disciplines (agriculture, plant breeding, food safety, health, economy, ecosystems science, ecotoxicology, aquatic science, food systems, corporate social responsibility etc.), food brands, processors, retailers, public health organisations, water suppliers, investors, government offices (agriculture, economy, environment, veterinary and food safety), beekeepers, biocontrol suppliers, environmental and social advocacy NGOs, development cooperation organisations, and UN organisations. Their contributions are gratefully acknowledged.

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Executive Summary

Pesticides play a sensitive role in food systems: they are applied in order to protect crops, but they can have negative impacts on environment and human health. While global pesticide use has grown to 3.5 billion kg active ingredients per year, a significant portion of the chemicals applied has proved to be excessive, uneconomic or unnecessary both in industrialized and developing countries. For society as a whole it would be desirable to gradually reduce pesticide use to a level where negative impacts – externalities like health hazards, biodiversity loss or water pollution – at least do not outweigh the value added in terms of yields or cost savings in production. Today there is a consensus among a wide range of stakeholders that pesticide use needs to be gradually reduced to a level that is effectively required to ensure crop production, and that risks of pesticide application need to be reduced as far as possible. Experience across the world shows that pesticide use can be reduced considerably without unduly reducing yields or increasing costs of production. A step-wise reduction of pesticide use is feasible already within the current production systems and with the knowledge, technologies and alternatives available today.

There is a large body of scientific evidence that the current use of pesticides has unwanted side effects on human health and environment. These externalities are particularly grave in some developing countries and emerging economies because of the widespread use of highly hazardous pesticides, the low level of awareness on risks and the lack of protective equipment. Phasing out of highly hazardous pesticides is therefore absolutely necessary also in these countries. But even in countries where strict registration processes are in place and farmers apply pesticides as prescribed, multiple pesticide residues are found in food and water bodies. Various studies concluded that pesticide exposure is a significant additional risk factor in many chronic diseases such as several types of cancer, Parkinson's disease and Alzheimer's disease. There is circumstantial evidence that exposure to pesticides is associated with disruption in the immune system and hormone imbalances which may increase the risk for obesity, diabetes, autoimmune diseases, reproductive problems and food allergies. Unborn and young children are in particular vulnerable to pesticide exposure. Numerous studies reported for children exposed to high levels of pesticides a delay in their cognitive development, behavioural effects and birth defects. Other studies indicate that even pesticide exposure from diet can be associated with poorer intellectual development or attention deficit/hyperactivity disorder (ADHD).

Pesticides are now found in every habitat on earth and are routinely detected in both marine and terrestrial animals. Pesticides in freshwater supplies have become a serious and increasingly costly concern, with detected levels often exceeding the set limits. There is substantial published literature on the effects of pesticides on wildlife and biodiversity. Studies have shown that systemic insecticides affect the viability of bee colonies. Widespread pesticide application negatively affects beneficial insects, spiders and birds, thus aggravating subsequent incidence of pest outbreak. More independent and robust basic research is needed on the impacts of pesticides particularly with regards to the long-term effect of pesticide formulations and their metabolites, and on synergistic effects of multiple residues on human health and on ecosystems. In the absence of full information the pre-cautionary principle requires that pesticides are not permitted to be used if scientifically robust studies indicate unacceptable risks, and that action is taken to reduce overall pesticide exposure.

Farmers do not apply pesticides without reason but in order to ensure productivity, to manage entrepreneurial risks and to compete in the market in terms of quality and price. Pesticide use is often cheaper than using alternatives like biocontrol or mechanical pest and weed management. Traders, retailers and consumers expect cheap and visually perfect products. The amount of pesticides needed to protect crops depends on the robustness of the farming system. Over the past decades diversity in farming systems has been greatly reduced in terms of crops and varieties grown as well as in natural habitats. In order to succeed with pesticide

reduction it is therefore essential to bring diversity back into agriculture. Farming systems need to be redesigned or adjusted based on the available knowledge on agro-ecology. Suitable agronomic practices like crop rotation and the use of resistant varieties are key preventive measures. Breeding strategies are needed to create robust varieties that facilitate the introduction of agro-ecological farming systems at large scale. In addition, farmers need to avail of various means to effectively manage pests, diseases and weeds. Biocontrol, the use of botanical extracts and other organic farming methods offer promising options and need to be strengthened. More public research is needed in order to advance the design of better farming systems and the development of alternatives to synthetic pesticides.

Agro-ecology, integrated pest management and the use of alternatives need to be integrated in vocational education, training and technical advice to farmers. Best practice from different approaches need to be identified in order to design more resilient farming systems and better management practices. As farmers mainly learn from practical experience it is important to demonstrate alternatives in plot trials and pilot farms and to facilitate the exchange of know-how. In addition it is important that farmers are made aware of the risks associated with pesticide use and get equipped with feasible measures to reduce these risks.

Pesticide reduction is a shared responsibility of the overall society, including scientists, farmers, consumers, governments and the private sector. Food brands, processors and retailers take a crucial role in increasing the demand for low- or no-pesticide products which is an essential driver for pesticide reduction. They can demand that their suppliers do not use hazardous pesticides and that measures are taken to gradually reduce pesticide use. They are well placed to promote resistant varieties and to raise awareness among consumers. An increase in demand for organic products and for products from integrated production significantly contributes to reduce pesticide use. Increasing the product range and the sales of organic products is therefore an important contribution to pesticide reduction. In addition, brands and retailers can convert entire products to compliance with minimum sustainability standards that address pesticide use to some extent. There is a need for more awareness raising among consumers with regard to what is “good food” - a product that is safe, healthy, tasty, good for the environment and good for those who produce it, but not necessarily visually perfect. Fact-based information on pesticide issues and on ways to reduce pesticide use and risks also needs to be conveyed to scientists, government offices, public health and consumer organisations, the management of relevant companies, investors etc. so that all stakeholder pull in the same direction.

Governments have a range of policy instruments to find a responsible balance between enabling judicious pesticide use where needed, and reducing the adverse health, environmental and agronomic risks. When health and environmental costs are factored in, pesticide application is only economical at a much lower threshold than what is commonly practiced. A pesticide tax is therefore a worthwhile tool to internalize and minimize externalities of pesticide use. However, to be effective, the tax needs to differentiate between levels of toxicity or hazard. The income generated through the tax should be used to support alternatives. Pesticide use is already highly regulated by national legislation and international conventions and policies. The long-term effects of using multiple pesticides, however, need to be better understood, and transparency in registration processes needs to be improved in order to allow informed weighing of risks against benefits of pesticides. By revisiting regulations and policies governments can set a conducive environment for pesticide reduction. The development of national action plans to reduce pesticide risks is an important opportunity for reducing externalities and for promoting alternatives. They can enhance enforcement of existing legislation and boost efforts and innovations. It is important, however, that action plans include binding and measurable reduction goals as well as milestones to get there.

Introduction

In recent months pesticides received increased attention in the media: New research results indicate that pesticides increase the risk of severe health problems like cancer, Parkinson, dementia, diabetes and other diseases. The International Agency for Research on Cancer (IARC) of the World Health Organization classified the most commonly used herbicide glyphosate as “probably carcinogenic”, which initiated a heated discussion. Multiple pesticide residues are found in food, drinking water, surface water, breast milk and urine. Systemic pesticides (neonicotinoids) could be responsible for the collapse of bee colonies. Pesticides contribute to loss of biodiversity etc.

Debates around pesticides are usually highly polarized, with opponents demanding an immediate ban of pesticides because they are not safe, and proponents arguing that we cannot maintain food production without pesticides. As a consequence of this deadlock progress to address pesticide issues is slow and fragmented.

What pesticide use would be desirable for society?

For society as a whole, the ultimate goal should be to manage pests in a way that allows sustainable crop production, without negative impacts on environment and human health. It would be desirable that pesticides were only used when inevitable and with the least level of side effects. In economic terms, the negative externalities (i.e. the impact on health and environment and the costs to avoid them) should at least not be higher than the value generated by using pesticides (i.e. yield increase and net cost reduction). Current pesticide use is often far higher than what this equation suggests. It is therefore reasonable to combine all available know-how and forces in order to identify pathways for gradual reduction of pesticide use.

Purpose of this paper

This paper shall provide orientation and guidance to a broad range of stakeholders including policy makers on how pesticide use can be reduced at a global level. Part I of this paper provides a brief overview on current facts and issues related to pesticides and on available strategies and policy instruments to reduce and regulate their use. It largely builds on recent publications that elaborate on this topic in much detail based on comprehensive literature reviews (see References). Part II of this paper will summarize the conclusions of a symposium on pesticide reduction held on 3 September 2015 in Zurich, Switzerland. In this symposium a broad range of stakeholders from science, civil society, private sector and government discuss the need and feasibility of pesticide reduction and concrete action to get there.

PART I: OVERVIEW ON ISSUES, APPROACHES AND POLICIES RELATED TO PESTICIDE REDUCTION

1. Pesticide use in agriculture – What are the issues?

1.1. Current use of pesticides in agriculture

Pesticides are used to protect crops and livestock from various pests, diseases, competition from weeds and parasites, thus contributing to increased agricultural production. They help farmers to reduce production costs and risks, and to survive in a highly competitive market. Global pesticide use has grown over the past 20 years to 3.5 billion kg active ingredients per year, amounting to a global market worth $45 billion (1). A significant portion of the chemicals applied has proved to be excessive, uneconomic or unnecessary both in industrialized and developing countries (2). While some countries reduced pesticide use over the past two decades (particularly UK, France, Denmark and Japan), in most regions it considerably increased (1). In Switzerland, pesticide sales are more or less stable at 2'120 tons of active ingredients in 2013 (3). The volume alone, however, does not necessarily reflect the impact of pesticides used, as older products are often replaced by substances that have more effect at lower doses.

What type of pesticides are used

Herbicides account for 42%, insecticides 27%, fungicides 22% and disinfectants and other agrochemicals 9% of global pesticide sales. In Switzerland, fungicides have the highest share (47%), followed by herbicides (35%) and insecticides (17%) (3). Herbicides dominate the North American and European domestic markets where they are also used to synchronize ripening of crops, but insecticides are more commonly used elsewhere in the world (1). Pesticide use intensity is highest in vegetable, fruit and cotton production.

Today's most used herbicide glyphosate was introduced in combination with genetically modified herbicide-tolerant (HT) crops in the late 1990s. Presently, glyphosate formulations (e.g. *Roundup)* account for more than 50% of total herbicide use (4) and are applied on more than 80% of the genetically modified crops (5). The use of herbicides allows for methods like low- and zero-tillage that reduce soil erosion. However, serious concerns are increasingly raised due to the development of herbicide-resistant weeds.

1.2. Pesticides and health

Pesticides can have adverse effects to human health - acute but also chronic. While there are no accurate data available on acute pesticide poisoning due to occupational and accidental exposure most estimates are in the range of several million cases per year (6). Acute pesticide poisoning is a serious problem in developing countries and emerging economies, where many farmers use highly hazardous products, often without adequate protective measures. The harms in actual conditions of use are experienced disproportionately by the poor and disadvantaged (2). Replacing highly hazardous pesticides such as endosulfan and paraquat with less toxic ones, and training farmers on proper handling of pesticides are expected to reduce acute poisoning. However, despite official adoption of the FAO/WHO International Code of Conduct on the Distribution & Use of Pesticides in 1985, there is evidence from the field that, especially in developing countries, pesticides still pose a serious threat to human

health and the environment. Sadly enough, pesticide poisoning also plays today an important role as a mean of suicide (7).

Exposure to pesticides

In Europe and North America the focus of concern has generally shifted to chronic effects due to low-level exposures (8). Farmers and pesticide applicators are particularly prone to adverse effects due to their direct exposure to pesticides at work. In addition, in agricultural areas where pesticides are heavily used, the population nearby is also at risk. Pesticides drift in the air, pollute soil and water resources and can thus contaminate large areas. The widest exposure to pesticides, however, is through residues in food. Exposure is presented as multiple mixtures of chemicals, the toxic effect of which are unknown, particularly over longer time scales (9). In some cases these substances can interact such that mixtures may have unpredictable and higher toxicities than the individual components themselves (10). Most research on pesticides is done on the active ingredient. So-called inert ingredients in pesticide formulations that enhance the effect of the active ingredient, however, can also cause substantial health effects (11). In addition, metabolites of active and inert ingredients can be of even higher toxicity than the original substances (10).

Fruits and vegetables frequently have the highest levels of pesticide residues – food items that are generally eaten because they are deemed healthy. But also animal products contain pesticide residues that accumulate from feed or from treatment against parasites, or, in the case of fish and seafood, through bioaccumulation in the aquatic food web systems (12). Studies have shown that people consuming an organic diet may be expected to have consistently lower pesticide intakes than those who consume a conventional diet (13).

Health hazards due to low-level, long-term exposure to pesticides

The literature on health effects of pesticides at general exposure levels is inconclusive, and more research is definitely needed (14) (15). While most industry-financed research suggests that pesticides imply few health risks if they are properly used, there are hundreds of scientific studies published in renowned journals that point out serious health hazards (10) (16). Though there are inherent problems in conducting large-scale experiments and directly assessing causation of these human health problems, the statistical associations between exposure to certain pesticides and the incidence of some diseases are compelling and cannot be ignored (12). Moreover, some persons have an inherent genetic susceptibility to the health effects of pesticide exposure and are therefore likely to be more at risk than others.

Increased risk for cancer and damage to the nervous system

There is widespread evidence that exposure to certain pesticides is a significant additional risk factor in many chronic diseases, including different forms of cancer, neurodegenerative diseases and disruptions of the digestive system (10), (12). Various studies among farmers, farm workers and their families showed increased incidences of several types of cancer, such as lymphatic and blood system, lip, stomach, prostate, brain, testes, skin cancers and soft tissue sarcoma (17), (18), (14). The International Agency for Research on Cancer recently classified the widely used herbicide glyphosate as probably carcinogenic to humans (19). Several studies found that exposure to pesticides is statistically associated with an increased risk of developing Parkinson’s disease (20) (21) and Alzheimer’s disease (22). Whilst aging almost certainly represents the greatest risk factor, low-dose/long-term exposures to pesticides have been implicated as a further factor. Other studies found that chronic low-level exposure to certain pesticides may be related to adverse effects on brain functioning, including changes in attention, speech, sight, memory and emotional aspects (23), (24).

Effects on immune and hormone system

There is circumstantial evidence that pesticide exposure is associated with disruption in the immune system (25), and hormone imbalances (26), (27). These effects may increase the risk for diseases such as obesity and diabetes, autoimmune diseases or reproductive problems. Exposure to certain insecticides may also contribute to the increasing incidence of food allergies in westernized societies (28). Some studies showed that impacts may be extremely long-term as pesticides can disrupt gene expression and impact the following generations not directly exposed to pesticides (12).

Effects of prenatal and infant exposure

Unborn and young children are in particular vulnerable to pesticide exposure due to the high rate of growth and complex development processes, the higher dose per body weight and the lower level of detoxifying enzymes compared to adults. Children themselves employed in agricultural work, as often the case particularly in developing countries, are particularly vulnerable to the toxic effects of pesticides. Numerous studies reported for children exposed to high levels of pesticides a delay in their cognitive development, behavioural effects and birth defects (12), (10). A study in California, US, found that high levels of organophosphorus pesticides in mother's urine were statistically associated with poorer intellectual development and deficits in working memory in the children when they reached 7 years of age (29). These cognitive effects occurred in children whose mother's urine had levels of organophosphate pesticides that were near the upper end of the range typically found across the general US population. Another study reported that children with higher urinary pesticide levels, mainly from diet, were more likely to be diagnosed with attention deficit/hyperactivity disorder (ADHD) (30).

1.3. Pesticides and the environment

A large part of the pesticides applied to crops are either taken up by the plants and animals or are degraded by microbial or chemical pathways. A considerable fraction of the amount applied, however, is dispersed into the environment, by air drift, leaching and run-off so that they are found in soils, surface and ground water (31). Pesticides in freshwater supplies have become a serious and increasingly costly concern, with detected levels often exceeding the set limits (in the EU: 0.1 µg l^{-1} for any individual active ingredient, or 0.5 µg l^{-1} for total pesticides). In Switzerland, 70% of surface waters had pesticide levels above the official limit (32). Pesticides are now found in every habitat on earth and are routinely detected in both marine and terrestrial animals (33).

Reduced biodiversity and ecosystem services

There is substantial published literature on the effects of pesticides on wildlife and biodiversity. Pesticide use has particularly contributed to the declines in the populations of birds, insects, amphibians and aquatic communities (34), (35), (36) (37). The effect is either direct through exposure, or indirect through a reduction in food availability. The widespread use of systemic pesticides that are absorbed by the crops is predicted to result in substantial impacts on biodiversity and ecosystem functioning (38). Studies have shown that systemic insecticides from the group of neonicotinoids can trigger the collapse of bee colonies, thus reducing their function as pollinators (39). Widespread and continued herbicide application eliminates plant species in fields and bordering areas that provide food and shelter to beneficial insects, spiders and birds. The effects of pesticides are enhanced by loss of habitat due to industrial farming methods.

Aggravated pest problems

Pesticide use reduces populations of insects, spiders and birds that naturally control pests. As pests usually recover faster than their predators, pesticide use can aggravate subsequent incidence of pest outbreak. In some cases reduced populations of beneficial insects due to overuse of pesticides contributed to the rise of pests that previously were of minor importance. Cotton and rice are two historical examples of induced pest problems by mismanagement and overuse of insecticides. Another growing concern is that pests and weeds increasingly develop resistance to pesticides. New pesticides are developed or combinations of pesticides are used in order to control them, resulting in additional costs and new side effects.

1.4. Economics of pesticide use

Pesticide application in agriculture has obvious short-term economic benefits – otherwise farmers would not use them. They may reduce the costs of production (e.g. by using herbicides instead of mechanical weeding) or reduce crop loss due to pest or disease infestation. However, pesticides also cause costs to society in terms of health and environmental costs. These external costs are not (yet) reflected in the market price of pesticides. They include health costs to humans (acute and long-term effects), costs of adverse effects on biodiversity (loss of beneficial insects, pollinators and wildlife), drinking water treatment costs, losses in aquaculture and fisheries, and costs of greenhouse gas emissions during pesticide manufacturing. Due to methodological difficulties and lack of data it is extremely difficult to quantify external costs of pesticide use. Estimates are in the range of US$4-19 per kg active ingredient, or $19-106 per ha cropland (1). With some 3.5 billion kg applied worldwide, this would suggest annual costs of $10-60 billion, for a market size of $45 billion.

However, these estimates do not account for the health effects of chronic exposure to pesticides described in chapter 1.2. If only a small fraction of the occurrence of certain diseases like cancer, dementia, diabetes and behavioural disorders can be attributed to pesticides, their external costs would be far higher. In addition, stockpiles of obsolete pesticides exist in many of the least developed countries and are a particularly high risk in situations of political instability. The root causes of the accumulation of these wastes are poor pesticide regulation and management; and over-reliance on chemical pesticides as a first option for pest control. Disposal of obsolete stocks is an extremely expensive undertaking which poses an economic burden on the governments and societies.

Factoring-in health and environmental costs

The question at hand is not to weigh the total benefits of pesticides against their total external costs in order to decide on whether or not to ban them completely – a rather theoretical scenario. More important is to assess to what extent pesticides can be reduced so that the costs of that change (in terms of lower yields or higher production costs) is compensated by an equal reduction in external costs. When health and environmental costs are factored in, pesticide application is only economical at a much lower threshold than what is commonly practiced. In addition, evidence from introducing Integrated Pest Management (IPM) suggests that in a majority of cases pesticides can be reduced through better management practices without substantially reducing yields or increasing costs. The concept of economic thresholds balances the value of crops lost to pests or diseases with the costs of pesticide treatments.

2. Strategies available for pesticide reduction

Ideally, agricultural systems should be designed in a way that pests, diseases and weeds do not build up to a level that they cause significant damage to the crop. Suitable agronomic practices, the use of resistant varieties, and Integrated Pest Management are key preventive measures. Bio control and the use of natural substances can complement these efforts. The safe application of minimal toxic synthetic pesticides should be used as a last resort. The following chapters provide an overview of applied approaches. In practice, they are overlapping and are often combined.

2.1. Agronomic practices

Suitable agronomic practices are essential to achieve healthy crops and to prevent build-up of pest, disease and weed pressure (40). The following practices are of particular importance:

- Appropriate plant nutrition and soil fertility management based on organic matter forms the basis for healthy crops that are less susceptible to pests, diseases and weeds;
- Crop rotation prevents the carryover of pest, pathogen and weed populations to the following season;
- Intercropping and the use of variety mixtures limits the spread of pests and diseases and provides food and shelter for natural enemies of pests;
- Timely shallow tillage reduces weed populations and at the same time improves nutrient supply to the crop;
- Appropriate irrigation management avoids water stress (too little or too much water) that makes crops susceptible to pests and diseases and reduces proliferation of weeds;
- Appropriate timing of sowing or planting and of intercultural operations reduce pest pressure.
- Precision farming like spraying of hot-spots and weeding with optical detectors.

2.2. Resistant crops

Crops and crop varieties differ in their susceptibility to pests and diseases and in their ability to compete with weeds. Growing crops suitable for local conditions and selecting appropriate crop varieties is therefore fundamental to a preventive pest management system. The use of resistant varieties together with rotations of non-susceptible crops can substantially limit pest build-up within a field (8). While breeding for insect, disease and nematode pest resistance is well known, much less effort has been focused on breeding crops for greater weed suppressiveness. Resistance in crop varieties can be achieved by traditional breeding methods like crossing and selection as well as through genetic engineering. In both cases an identified resistance is incorporated into a plant with high yield potential and other favourable agronomic characteristics. Collections of traditional varieties and wild relatives are often a good source of useful resistance genes. Traditional plant breeding, however, takes time and results are only visible after years. Resistance may not be lasting as pests and diseases can adapt to the new crop. The wider the genetic base of resistance, the more likely is it to last.

Gene technology to breed resistant varieties

Marker assisted breeding and genetic engineering can speed up this process (41). Gene editing based on the CRISPR system (clustered regularly interspaced short palindromic repeats) allows with high precision to introduce specific genes into varieties. The most important insect resistant crops produced by genetic engineering carry genes of the soil bacterium *Bacillus thuringiensis* (Bt). These genes induce the crop to produce a protein (Bt-toxin) that is toxic to specific insects that feed on the crop. However, the most widely used genetically engineered crops today are those resistant to herbicides like glyphosate (42). The

herbicide is harmless to the modified crop and thus 'non-selective' herbicides can be used to remove all other plants in a field. It is currently not evident whether the use of genetically modified organisms (GMO) so far has reduced pesticide application (43). Critics point out unwanted side effects on beneficial insects and other non-target organisms and to a narrowing of genetic crop diversity (44).

2.3. Bio-control and natural pesticides

Bio-control makes use of pathogens (bacteria, fungi, viruses), insect predators or parasitoids, pheromones and insect traps to keep pest populations low (2). The total eradication of a pest, which results from the use of synthetic pesticides, would reduce the food supply of the pest's natural enemies, undermining a key element in system resilience. The aim, therefore, should be to manage insect pest populations to the point where natural predation operates in a balanced way and crop losses to pests are kept to an acceptable minimum (40). The most widely used bio-control methods are:

- Conservation and augmentation of natural enemies of pests through flower strips, hedge rows and other natural habitats;
- Release of predators and parasitoids of pests such as *Trichogramma*, lady bird beetles, lacewings and predatory mites;
- Sprays with pathogens of pests such as *Bacillus thuringiensis*, *Beauvaria*, *Trichoderma* and nematode species;
- Pheromone dispensers to disrupt mating of pests;
- Traps like sticky coloured boards, pheromone traps and light traps to catch insect pests.

Natural pesticides

Various plant extracts and other natural materials are used that repel pests, reduce their feeding or reproductive activities, reduce proliferation of diseases or act as biopesticides. Some of them, however, also have unwanted side effects. Most commonly used natural pesticides are:

- Neem, the extract of the seeds of a tree common in tropical and sub-tropical areas, reduces proliferation of insect pests while having little impact on beneficial insects;
- Pyrethrum, the extract of a chrysanthemum species, decomposes rapidly in the environment, but affects beneficial insects and is toxic to aquatic life;
- Copper is widely used to control for fungal diseases, but it accumulates in the soil;
- Sulphur, soap and paraffinic oil preparations are used to control mites, aphids and other pests, but they also affect beneficial insects.

2.4. Integrated Pest Management

The FAO defines Integrated Pest Management (IPM) as the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment (45). IPM is an ecosystem approach that does not seek to eradicate pests - but rather to manage them. It is founded on the idea that the first and most fundamental line of defence against pests and diseases in agriculture is a healthy agro-ecosystem, in which the biological processes that underpin production are protected, encouraged and enhanced (40).

The approach is knowledge-intensives and requires a broad understanding of the specific crop, its pests (including weeds) and their natural enemies. Strong focus is on pest prevention by applying good agronomic practices and using resistant varieties, pest identification and monitoring and biological pest control. As soon as the economic threshold is achieved - the point at which the cost of pesticide use pays off (cost of expected loss in harvest exceeds the

cost of treatment) - chemical pest control becomes profitable. The last step includes learning and adapting from IPM for the next crop season.

Pesticide reduction without yield loss

In the global South IPM techniques are often promoted through Farmer Field Schools (FFS) in which a group of farmers frequently meets to share field observations and exchange experience. Through IPM-FFS rice farmers in the Philippines reduced pesticide application frequency and applications per hectare by 70%, increased yields by 12% and increased the inter-year stability of yields (1). Many examples across the world demonstrate that IPM can reduce pesticides while increasing the profitability for farmers. Integrated Production (IP), such as the label IP-Suisse, builds on IPM in their production guidelines.

2.5. Agroecology

Agroecology is a discipline that defines, classifies and studies agricultural systems from an ecological and socio-economic perspective, and applies ecological concepts and principles to the design and management of sustainable agroecosystems (46). It is an integrative way of farming that focuses on working with and understanding the interactions between plants, animals, humans and the environment. In Agroecology pest control seeks to reinforce interactions of pests and natural enemies with the aim to maintain a natural balance in the ecosystem (47). While there is no consent on what techniques and inputs are compatible with agroecology the common denominator is to make use of biodiversity-based ecological processes to optimize agricultural production systems.

Agroecology is gaining momentum

The increasingly high profile of agroecology is reflected in the growing body of evidence on high- performing agroecological management practices (48). A study examined 40 initiatives employing agroecological production methods in 20 countries, involving 10.4 million farmers (49). Analysis of project outcomes demonstrated not only an average crop yield increase of 113% compared to conventional systems, but also numerous environmental benefits, including carbon sequestration and reductions in pesticide use and soil erosion. Agroecological strategies like crop diversification, animal integration, soil organic management and water conservation are also expected to reduce vulnerabilities of farming systems and rural communities to climate change (50).

A particularly useful application of agroecology is the Push-Pull method introduced in Eastern Africa to control stem borer and striga weed in maize production (51). Farmers use Napier grass and desmodium legume as intercrops in their maize fields. Desmodium produces a smell that repels the maize stemborer - the push component, whereas Napier grass planted around the maize field acts as a trap plant for the stemborer - the pull component – and is also used as animal fodder. In addition, desmodium suppresses Striga weeds while fixing valuable nitrogen to the soil.

2.6. Organic agriculture

Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects (52). Organic standards strictly prohibit any use of synthetic pesticides. Crop protection in organic agriculture builds on good agronomic practices such as crop rotation and intercropping, the use of organic manures, resistant varieties and bio-control to prevent that pest, diseases and weeds cause significant damage. Organic farming makes use of techniques similar to Integrated Pest Management and agroecology, with the only difference that synthetic chemicals cannot be used as a last resort.

Instead, organic farmers can use specific natural substances permitted by organic standards to control pests and diseases if preventive methods are not sufficient. Some of them, however, also have unwanted side effects on non-target organisms. Particularly the use of copper to control fungal diseases is problematic due to its accumulation in soils.

Limited yield reduction

Diversified organic systems can be more productive than monocropping, particularly in tropical regions where they often contribute to improved food security and livelihoods (53). At global level, however, yields in organic crops and systems tend to be 10-18% lower than in conventional agriculture (54). As the main reason for lower yields is probably related to nutrient management, the yield reduction effect of not using synthetic pesticides is likely to be in the range of maximum 5-8% on average. In specific crops like vegetables and fruits and for specific pests and diseases, however, organic farmers still face considerable challenges. More research is needed to identify suitable organic solutions for these cases.

2.7. Use of less hazardous pesticides

There are various systems to classify pesticides as per their toxicity for humans and the environment. Phasing out the use of highly hazardous pesticides and replacing them with less hazardous ones is therefore the most obvious way to reduce the negative side-effects of pesticides (55). This approach needs to be combined with safe handling of pesticides so that their impact on people and the environment is minimized. The use of protective gear and the observation of waiting periods before harvest are the most important measures in this regard. However, in many countries the lack of information, unavailability of protective equipment and its impracticality in hot and humid climates result in low adoption rates (8).

3. Policies to reduce pesticide use and risks

3.1. International policies and instruments

International codes, treaties, conventions, commissions and advisory bodies play an important role in for plant protection and pesticide management. Through the ratification of international conventions, governments accept obligations to incorporate them into national policies. The following international policies and instruments are most relevant with regard to reducing the risk associated with pesticide use.

The Rotterdam Convention covers international trade in hazardous chemicals (most of them being pesticides) with the aim of protecting human health and the environment. If all parties agree that a specific pesticide constitutes severe health or environmental hazards it can be listed for prior informed consent procedures. They require exporting countries of these chemicals to notify importing authorities on data of known hazards. As any party can veto the listing of a pesticide the process is rather slow. Currently the convention lists 33 pesticides.

The Stockholm Convention aims to eliminate or restrict the production and use of persistent organic pollutants (POPs), some of which are pesticides. Based on a specified review process pesticides that fulfil the criteria for POPs can be listed for elimination or restriction.

The International Code of Conduct on Pesticide Management is a voluntary framework that has been endorsed by the FAO Members, and supported by key

pesticide industry associations and civil society organizations (55). It became a role model to the development of pesticide legislation, and the major pesticide companies have agreed to abide by the Code of Conduct.

The Strategic Approach to International Chemicals Management (SAICM) is a voluntary policy framework and strategy facilitated by UNEP to promote chemical safety around the world. It brings together stakeholders and sectors that include agriculture, environment, health, industry, labour, economics, science and academia to catalyse achievement of the goal by 2020 "that chemicals are used and produced in ways that minimize adverse effects on human health and the environment."

The Joint Meeting on Pesticide Residues (JMPR) is an expert ad hoc body administered jointly by FAO and WHO with the purpose of harmonizing the requirement and the risk assessment on the pesticide residues. It recommends maximum residue levels in food and feed commodities and provides guidance on pesticide product quality parameters for regulatory and trade purposes.

3.2. National legislation and policies

The role of governments is to find a responsible balance between enabling judicious pesticide use where such use is necessary to achieve desirable crop production levels, and reducing the adverse health, environmental and agronomic risks (8). Governments have a range of policy instruments to influence this balance. Pesticide legislation and registration offers possibilities for regulating the availability and use of pesticides. The use of dangerous products can be banned or restricted to certain crops, users or circumstances. Governments have the opportunity and power to make budget allocations on the enforcement of pesticide legislation, for monitoring of pesticides residues in food and drinking water, and for research into the side-effects of pesticides use.

Various instruments are available

Public health policies may address pesticide residues in food and drinking water, and risks associated with the storage, transport and disposal of pesticides. Environmental policies on water quality, nature conservation and biodiversity can also influence the availability and use of pesticides. In addition there are financial instruments to provide incentives or disincentives for certain practices in crop production. This could be pesticide taxes or import tariffs, but also financial incentives for the development and use of alternative pest management approaches and products, and support for the local manufacture of such products. Pesticide-use fees or pesticide taxes may be used to finance the development of alternative pest management practices and subsidize their adoption. Equally important is to address factors that foster unnecessary pesticide use, such as pesticide subsidies, pesticide application recommendations by agricultural extension services or possible conflicts of interest affecting regulatory authorities, research and extension (56)**.**

Phasing out, phasing in

More and more countries, both industrialized and developing, are phasing out highly hazardous pesticides, while encouraging less hazardous pest management approaches and products (8). Integrated Pest Management (IPM) and biological control programmes are increasingly recognized and promoted as viable alternatives. Several countries have set IPM targets or declared IPM as the preferred approach to pest management. However, many developing countries are still facing various constraints to the effective enforcement of their

regulatory systems. Available financing and human resources for the control of pesticides are very small.

3.3. Pesticide action plans

In 2009 the European Union Commission passed a directive that requires all member countries to adopt National Action Plans (NAPs) to set up their quantitative objectives, targets, measures and timetables to reduce risks and impacts of pesticide use on human health and the environment and to encourage the development and introduction of Integrated Pest Management and of alternative approaches or techniques in order to reduce dependency on the use of pesticides (57). In 2013, the Pesticide Action Network (PAN) Europe has undertaken an analysis of all the NAPs that Member States have developed to comply with the EU Directive (58). They concluded that Member States' ambition to reduce pesticides use is extremely low due to:

- Lacking quantitative objectives, targets, and clear timetables for pesticide use reductions;
- Recycling what is already mandatory from other EU policies, without proposing new actions;
- Indicators for pesticide use reductions or conversion towards more use of non-chemical techniques are replaced by 'soft' targets (number of training hours, number of guidelines developed, number of certificates issued) unable to measure the effective change.

Two countries stand out as progressive examples with regard to pesticide reduction policies: Denmark and Sweden (58).

Denmark introduced its first pesticide reduction plan in 1986 to protect the ground water that is consumed directly without any purification treatment. Since that time, Denmark has banned specific pesticides when it was proved that they reached ground water. In 1999, an expert committee prepared a report on reduction of pesticide use. It recommended a reduction goal implemented through a three-pronged strategy: covering spraying-free zones, organic farming, and general use reduction through new technology and better farming practises. The recommendations, however, have only partly been implemented, and the goal has still not been reached. Nevertheless, the early introduction of a pesticide policy has led to the result that Danish products (especially fruit and vegetables) have residue levels of pesticides below the EU average today. In July 2013, Denmark introduced a pesticide tax on insecticides linked to environmental and health hazards.

Sweden has the overall objective of becoming a non-toxic environment. The Swedish National Action Plan contributes to this objective by further expanding on this goal through the following objectives:

▷ Concentrations of pesticides in surface and ground water should be close to zero;

▷ Pesticide residues in vegetables grown in Sweden should be low and not pose risks to the consumer;

▷ Development of sustainable farming systems, which includes alternative methods and techniques, will be developed and applied to a greater extent in order to reduce the dependence on chemical pesticides, as well as a specific target for organic agriculture.

The Swedish NAP defines detailed objectives, monitoring procedures and actions in a broad range of areas.

Swiss National Action Plan under development

The Swiss Federal Council mandated its administration to develop a National Action Plan on Pesticides by end of 2016. The Federal Office for Agriculture (BLW) initiated expert groups to formulate objectives and measures for pesticide risk reduction and organized workshops with interested stakeholder groups. A group of Swiss environmental organisations (WWF, Greenpeace, Pro Natura and BirdLife) demand that the government formulates concrete pesticide reduction targets in its National Action Plan. They elaborated a guidance document with nine demands addressed to the Swiss government (59).

3.4. Private sector and civil society initiatives

The growing consumer desire for safe and wholesome food and a similar demand from investors' side, motivated the food sector to proactively respond with more critical attention being paid to the crop production practices of their suppliers (8). Some of the largest players in the market now actively pursue internal policies to reduce safety risks through supply chain management. They often demand from their suppliers that certain production protocols are followed, including more sustainable pest management and more responsible pesticide management. The GLOBALGAP initiative of supermarket chains and their suppliers is an example of this approach (http://www.globalgap.org). A similar initiative is the Sustainable Agriculture Initiative (SAI) of a group of food processing companies, which promotes the sustainable use of production resources to safeguard their long-term economic availability (http://www.saiplatform.org). Another response to consumer demand for safe and sustainable products is the broad range and increasing market shares of products carrying sustainability labels (see http://www.isealalliance.org). Most of them address pesticide use to some extent, ranging from a total ban of synthetic pesticides in organic labels to rather vague formulations of objectives that are difficult to monitor or enforce.

Civil society initiatives

There are several civil society organisations and initiatives dedicated to the reduction of pesticide hazards. The most important one among them is the Pesticide Action Network (PAN) that involves over 600 participating nongovernmental organizations, institutions and individuals in over 90 countries working to replace the use of hazardous pesticides with ecologically sound and socially just alternatives. PAN was founded in 1982 and has five independent, collaborating Regional Centers that implement its projects and campaigns. Various environmental organisations worldwide lobby for using less pesticides and raise awareness among the public.

In Switzerland, the Berne Declaration (EvB) advocates for a global phasing-out of highly hazardous pesticides, with focus on paraquat. The four main environmental NGOs joined forces to lobby for concrete pesticide reduction targets in the Swiss National Action Plan. Consumer organisations and public health organisations also increasingly address the topic. In May 2015 the Swiss consumer organisation (SKS), Doctors for the environment (AEFU) and Greenpeace jointly launched a petition to ban the use of glyphosate.

PART II: CONCLUSIONS AND RECOMMENDED ACTION

The second part of this briefing paper summarizes the results of a Symposium on pest reduction held on 3rd September in Zurich, Switzerland. 130 representatives of a broad range of stakeholders from Switzerland and neighbouring countries discussed the necessity and feasibility of pesticide reduction and developed a set of proposed action to move towards this objective. Although the participants came from a wide range of backgrounds and sometimes conflicting positions the discussions were non-polarized and focussed on shared objectives and common ground. All statements and proposals included in the following chapters were made in plenum and were not disputed.

4. Consensus on objectives and strategies

4.1. Broad consensus on objectives

Today there is a consensus among a wide range of stakeholders that pesticide use needs to be gradually reduced to a level that is effectively required to ensure crop production, and that risks of pesticide application need to be reduced as far as possible. Stakeholders include consumers and their organisations, farmers and their organisations, scientists from various disciplines (agriculture, plant breeding, food safety, health, economy, ecosystems science, ecotoxicology, aquatic science, food systems, corporate social responsibility etc.), food brands, processors, retailers, public health organisations, water suppliers, investors, government offices (agriculture, economy, environment, veterinary and food safety), beekeepers, biocontrol suppliers, environmental and social advocacy NGOs, development cooperation organisations, and UN organisations. This provides a strong mandate to policy makers, value chain actors and to civil society to take appropriate measures.

Reducing the reliance on pesticides

It is widely accepted that we need to reduce reliance on pesticides for agricultural production in order to reduce unwanted side effects (see chapter 4.2). At the same time it is clear that pesticide use cannot be phased out entirely in the near future. Most of our current agricultural systems depend on pesticides for their productivity, for various reasons (see chapter 4.3). In order to reduce this dependency the design of farming systems needs to be revised to some extent. However, a step-wise reduction of pesticide use is feasible already within the current production systems and with the knowledge, technologies and alternatives available today. Experience across the world shows that pesticide use can be reduced considerably without unduly reducing yields or increasing costs of production.

Reducing the risks of pesticides used

Given that reducing the reliance on pesticides is the most crucial step, the remaining pesticide use needs to happen in a way that risks are maintained as low as possible. This requires that hazardous pesticides are replaced with less hazardous ones. It also requires that pesticides are used in a way that the risks of negative impact on health and environment are minimized. Adherence to user instructions, use of protective equipment and observation of buffer zones and waiting periods need to be ensured.

Phasing out of highly hazardous pesticides

Developing countries and emerging economies are often not able to ensure safe handling of hazardous pesticides, with severe impacts on human health and environment. A majority of farmers and farm workers does not use adequate protective gear and is not likely to do so in future. Phasing out of highly hazardous pesticides (HHPs) is therefore absolutely necessary also in these countries. The international conventions (Rotterdam and Stockholm conventions) provide a useful framework for this, but are not sufficiently effective due to the veto option by individual countries. Even if pesticides have been identified to fulfil all criteria for HHP, they therefore not always get listed under the conventions. Understandably, manufacturers of HHPs often protect their business interests by taking significant influence on decision makers. It is therefore important to ensure that decisions are taken in the best interest of society.

4.2. Why is it necessary to reduce pesticides and their risks?

Reducing externalities

There is a large body of scientific evidence that the current use of pesticides has unwanted side effects on human health and environment. These externalities are particularly grave in some developing countries and emerging economies because of the widespread use of highly hazardous pesticides, the low level of awareness on risks and the lack of protective equipment. But even in countries where strict registration processes are in place and farmers apply pesticides as prescribed, multiple pesticide residues are found in food and water bodies. The effects of pesticide residues are difficult to accurately assess due to the large number of active ingredients and commercially available pesticide formulations, the even larger number of metabolites that are sometimes more toxic than the original ingredient, and the synergistic effects of multiple residues. Ecosystems as well as human beings are highly complex and we struggle to understand all the effects of pesticides, in particular the long-term effects of multiple residues.

Applying the precautionary principle

In practice it is very difficult to duly assess the risk of pesticides submitted for registration. The long-term risk of pesticides tend to be underestimated as the knowledge and awareness for negative effects usually lags behind. When e.g. DDT was introduced it was considered a major improvement until unwanted side effects became evident. Once hazards are proven the phasing-out of registered pesticides still may take several years. More research is therefore needed particularly on the long-term and synergistic effects of pesticides on health and environment. In the absence of full information the precautionary principle requires that pesticides are not permitted to be used if scientifically robust studies indicate unacceptable risks, and that action is taken to reduce overall pesticide exposure. The risk associated with specific pesticides also needs to be re-assessed if they are widely used, thus exposing a large number of people and a wide range of ecosystems.

Reducing external costs

The unwanted side effects of pesticide use causes substantial costs to society. These costs include health costs (of both acute and chronic effects), costs of adverse effects on ecosystems and their services (e.g. loss of beneficial insects, pollinators and wildlife), and drinking water treatment costs. Although it is difficult for methodological reasons to accurately assess external costs of pesticide use, conservative estimates show that these costs are substantial. At the same time, the benefits of pesticide use in terms of increased yields are often overestimated.

Consumer expectations concerning residues

Last but not least pesticide reduction is a necessity because most consumers expect that their food and environments are free from pesticide residues. Surveys show that a majority of consumers are concerned about pesticide residues. In this sense there is currently a disconnection between market offer and consumer demand. Consumer demand should be a key determinant for producers, retailers and policy makers.

4.3. Understanding the root causes of the pesticide problem

Understanding why pesticides are used

Farmers do not apply pesticides without reason but in order to ensure productivity, to manage entrepreneurial risks and to compete in the market in terms of quality and price. Even if farmers apply good agronomic practices like crop rotation they are confronted with the challenge to control pests, diseases and weeds in sensitive crops and under difficult weather conditions. Pesticide use is often cheaper and more effective than using alternatives like biocontrol or mechanical pest and weed management. Traders, retailers and consumers expect cheap and visually perfect products. These requirements, however, are disconnected from the expectation that products shall be safe for health and environment.

Loss of diversity in farming systems

The amount of pesticides needed to protect crops depends on the robustness of the farming system. If crops are cultivated in locations that are not suitable to their requirements, they are more susceptible to pests and diseases. Over the past decades diversity in farming systems has been greatly reduced in terms of crops and varieties grown as well as in natural habitats. The result is a loss of eco-system services like natural pest control through predators and a loss of soil fertility, both affecting the robustness of the farming system. In order to succeed with pesticide reduction it is therefore essential to bring diversity back into agriculture. This involves moving away from monocultures of single varieties, increasing diversity of crops and natural habitats, but also increasing the genetic diversity of cultivated varieties.

The legacy of established crop varieties

Over the past decades crop breeding has focused on yields and other output-oriented factors, but has mostly neglected selection for resistance. Robust traditional varieties have often been replaced by high-yielding ones that respond well to chemical inputs but are susceptible to pests and diseases. As most seed companies are now owned by agrochemical companies, seed providers have limited interest in developing robust varieties. Moreover, consumers are used to and prefer the established varieties and are reluctant to accept new, more robust ones. Robust varieties, however, are an essential element in the design of farming systems that rely less on pesticides.

Role of agro-input providers

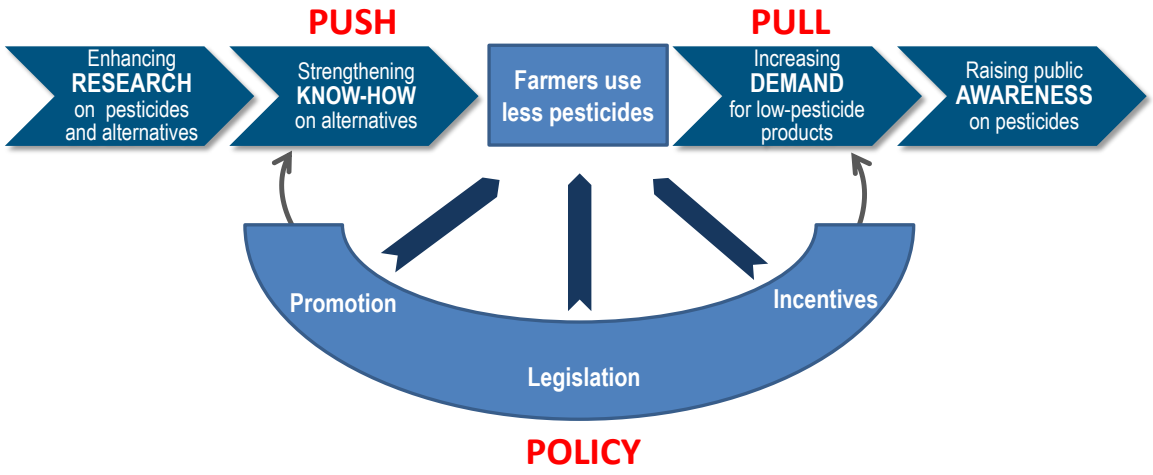
The current business model of the agro-input industry is still based on selling pesticides. As the development and registration of pesticides requires large investments it is currently difficult to reach consensus on the objective to reduce pesticides or to phase out HHPs. Due to their marketing power and their role in extension, agro-input manufacturers and traders have substantial influence on farming practices. Most of them have ventured into developing and offering biocontrol and other alternative pest control methods. With their control over a large part of the seed market they also have a unique position in the development of robust varieties. They could therefore become an important driver in the development of more robust varieties, alternative pest control inputs and modern technology for precision farming.

Lack of information and awareness

There is a general lack of information and awareness on pesticide issues that needs to be addressed. Many farmers are not fully aware of the negative effects of pesticide use and on the availability of alternatives. The same is true for consumers, retailers, policy makers and even for scientists. It is therefore important that fact-based information is compiled and disseminated.

4.4. How to approach pesticide reduction

It is obvious that there is no single or quick solution to reduce pesticide use and the associated risks. There is a consensus that pesticide reduction requires a set of changes in current production systems, value chains and in the policy environment. Three factors are required to work together (see figure below): availability of and know-how on alternatives, increasing demand for low-/no-pesticide products and conducive legislation and policies.



Joint responsibility

Pesticide reduction is a joint responsibility that cannot be burdened on the farmer alone. Pesticide reduction positively affects public goods and reduces costs currently borne by society. Therefore, the investment of public funds for pesticide reduction is justified. It also is in the interest of the private sector as it can result in competitive advantage or offer new business opportunities. Investments of the private sector in the development and promotion of alternatives is crucial. Pesticide reduction will only succeed if there is collaboration among different kinds of stakeholders, particularly of stakeholders along the value chain from producers to consumers.

Addressing trade-offs

When pursuing pesticide reduction it is important to openly address possible trade-offs. It is most critical to de-couple pesticide use and long term yields. Pesticide reduction is not a reasonable option for a country if it coincides with substantial reduction of yields and increased import from places where pesticides are used indiscriminately. Pesticide reduction also needs to be compatible with the need to secure farm incomes and to keep production risks low. There are also possible trade-offs between pesticide reduction and other objectives like soil conservation (no-till farming may require herbicide use) and reducing greenhouse gas emissions (mechanical weeding may require more energy) that need to be openly discussed.

5. Recommended action

5.1. Enhancing knowledge through research

Understanding the impacts of pesticide use

More independent robust basic research is needed on the impacts of pesticides particularly with regards to the long-term effect of pesticide formulations and their metabolites and on synergistic effects of multiple residues on human health and on ecosystems. Ecosystems as well as human beings are highly complex and we struggle to understand all the effects of pesticides, in particular the long-term effects of multiple residues. Data on pesticide use and relevant studies from private companies that are used for registration need to be made accessible so that they can contribute to the body of knowledge.

Assessing the external costs of pesticide use

The full external costs of pesticide use need to be calculated or estimated in order to set them in relation with the benefits of pesticide use. This will also help in determining what level of pesticide use is acceptable for society, and in monitoring progress towards. The introduction of mechanisms to internalize these costs into the price of pesticides in the form of taxes need to be evaluated, taking into consideration the specific risks associated with different pesticides.

Re-designing farming systems based on agro-ecology

In order to reduce reliance on pesticides it is crucial to get diversity back into crops, farming systems and landscapes. Farming systems need to be redesigned or adjusted based on the available knowledge on agro-ecology. Additional research is required to increase the understanding of how diversity can be used to protect crops. Farmers need to avail of various preventive and curative means to effectively manage pests, diseases and weeds (including management of resistance). Agricultural diversity is enhanced when diverse farming systems are co-existing in a region (i.e. integrated and organic systems).

Breeding robust varieties

Breeding strategies are needed to create genetic resources that facilitate the introduction of agro-ecological farming systems at large scale. Considerable progress has been made in some crops (e.g. scab resistant apple varieties) while the introduction of resistant potato varieties in the market hasn't succeeded yet. The use of modern gene-technology-based breeding techniques can speed up and enhance the development of robust or resistant varieties.

Advancing alternative crop protection methods

There is a broad consensus that more alternatives are needed that are scalable. Biocontrol options through augmentation of predators, release of beneficial organisms or application of microbes still offer an important potential that needs to be used. Botanical extracts and microorganisms show many beneficial impacts and present a huge opportunity to develop "safer" active ingredients. However, their potential hazards need to be thoroughly tested in order to avoid unintended consequences. In order to develop, register and commercialize these new products considerable investments are needed. New ways of funding the development of alternative crop protection methods and new business models for crop protection services are needed.

Funding research and development

Public research is very important to assess impacts of pesticides and to identify and test alternatives. Unfortunately it is difficult to get funding for research on ecotoxicology, in particular because results are uncertain. There is already considerable research happening of which the findings need to be made more visible. In order to make progress in research it is important to identify priority areas and to join forces of government, private sector (input manufacturers as well as food brands and retailers) and civil society (e.g. philanthropists).

5.2. Strengthening know-how on alternatives and on safe use

Applying agro-ecology for designing resilient farming systems

Farms that grow locally adopted crops in suitable rotations and with methods enhancing soil fertility and biodiversity face less pest, disease and weed problems. In order to transfer the available knowledge to practitioners it is important that agro-ecology is integrated in vocational education and training curricula. It is worth analysing the experience of France where agro-ecology is currently being mainstreamed in agriculture. Best practice from the different systems should be identified in order to design more resilient farming systems and better management practices. Conventional farmers can learn a lot from organic ones (e.g. the use of biocontrol or botanical sprays), and vice versa (e.g. precision farming techniques like selective spraying).

Education, training and information for better pest management

Agro-ecology, integrated pest management and the use of alternatives also needs to be integrated in the work of extension or rural advisory services. They need to become part of the recommendations on good agricultural practices. In some countries this may require a change in the business model of extension services in order to make them independent from the sales of pesticides. As farmers mainly learn from practical experience it is important to demonstrate alternatives in plot trials and pilot farms and to facilitate the exchange of know-how among practitioners. In many countries the farmer field school approach has proven quite effective in this regard. Information and communication technology is available for improving timely access to know-how and for optimizing crop management (e.g. forecasts of pest and disease pressure allows better timing of management practices).

Capacity building on safe use

In many developing countries and emerging economies farmers are very far from “safe use” of pesticides, making the phase out of HHPs an absolute priority. Nevertheless it is important that farmers are made aware of the risks associated with pesticide use and get equipped with realistic and feasible measures to reduce these risks. One option could be that farmers need to undergo a compulsory training on the risks of pesticides, their avoidance, and on safe use to acquire a permit required to purchase pesticides. This could also become a requirement for home gardeners also in industrialized countries who usually have less knowledge on these aspects compared to professional farmers.

5.3. Increasing the demand for low-/no-pesticide products

Food brands, traders, processors and retailers take a crucial role in increasing the demand for low- or no-pesticide products which is an essential driver for pesticide reduction. The same is true for the natural textile sector, particularly for cotton. Retailers are well positioned to translate the demand of consumers to producers, but can also raise awareness among consumers for how food is produced. Openness for collaboration with the food and fibre industry and with retailers is therefore crucial to achieve change. Consumer expectations that

food is free of pesticide residues and responsibility for health and environment are important reasons for processors and retailers to engage in pesticide reduction.

Applying restrictions on hazardous pesticides

Food processors and retailers can enforce that suppliers comply with existing laws and codes. In addition, they can go a step further by imposing additional restrictions, e.g. prohibiting pesticides included on the list of highly hazardous pesticides of the Pesticide Action Network (PAN). They can and should conduct regular residue tests in order to ensure compliance with their set requirements, and inform their suppliers on the results of these tests.

Introducing resistant varieties in the market

The introduction of more robust or resistant crop varieties strongly depends on whether they are accepted in the market. Processors and retailers are well placed to promote these varieties, as the successful introduction of scab resistant apple varieties in Switzerland has shown. They can also contribute to pesticide reduction by revising their quality requirements e.g. by tolerating small cosmetic defects. These important measures require pro-active awareness raising and information of consumers with suitable marketing activities.

Promoting sustainability labelled products

Increasing the product range and the sales of organic products is an important contribution to pesticide reduction. Organic consumption is steadily growing so that promotion of organic products offers an interesting business opportunity. In addition, brands and retailers can convert entire products to compliance with minimum sustainability standards such as UTZ certified, Fairtrade, Rainforest Alliance, 4C, Round Table on Responsible Soy (RTRS), Round table on Sustainable Palm Oil (RSPO) and the Better Cotton Initiative (BCI). These standards address pesticide use to some extent, mostly by excluding certain hazardous pesticides, demanding for safety measures (training and safety equipment) and even for IPM. Gradually strengthening these standards with regard to pesticide reduction and safe use of pesticides along the measures indicated earlier offers scope for continuous improvement in a significant segment of consumption. For wider outreach pesticide use and risk reduction should also be integrated in widely used industry standards such as GlobalGAP and BRC.

Supporting research, capacity building and conversion

Brands and retailers can also play an important role in supporting the development of knowledge and in capacity building of farmers. Some of them fund research on alternatives, support IPM training for producers or encourage conversion to more sustainable systems. The focus is usually on crops and value chains that are known to use a lot of pesticides. Some of the know-how and technologies can also be transferred to other crops and farming systems. The food industry can also play an important role in lobbying for better policy frameworks.

5.4. Raising awareness for pesticide issues

Raising awareness among consumers

Consumers may be aware of the risks of pesticides, but not always of the consequences of their choices. Consumers are rarely aware that the impact of pesticide use on producers in the South is far worse than the impact on consumers in the North. They should be made more aware of the health risks associated with unsustainably produced food for the involved farmers and farm workers. There is a need for more awareness raising among consumers with regard to what is “good food” - a product that is safe, healthy, tasty, good for the environment and good for those who produce it, but not necessarily visually perfect. This information needs to be brought to a wider public in order to induce change. New alliances are needed to achieve

this raise in awareness. Governments, science, the health sector, the food industry, the water sector, environmental groups and media should join forces for this task. One should not scare people, but inform them, show alternatives, and motivate them to ask and pay for good food. At the same time one should abstain from calming down consumer fears with regard to pesticide risks.

Raising awareness among decision makers

Awareness also needs to be raised among decision makers in different fields and sectors. As indicated earlier pesticide reduction is a joint responsibility and requires that all stakeholder pull in the same direction. Fact-based information on pesticide issues and on ways to reduce pesticide use and risks needs to be conveyed to scientists, government offices, public health and consumer organisations, the management of relevant companies, investors etc. This will help scientists to integrate pesticide related issues and the search for alternatives into their research agendas, that governments design and implement conducive policies, that companies address pesticide issues in their supply chain policies and use opportunities for alternative business models, and that investors include pesticide issues in their investment decisions. It also helps to strengthen the link between farmers, consumers, private sector, civil society and governments. Fortunately everybody is a food consumer and therefore directly concerned also as an individual.

5.5. Revisiting legislation and policies

There is a consensus that policy making needs to be science-based. Experience shows that if scientists point out risks that have so far been underestimated, they are usually right, but it often takes years until policy sufficiently reacts. It is therefore important to make information on pesticide externalities, on the availability of alternatives and on options to reduce pesticides and their risks available to relevant government authorities. By revisiting regulations and policies governments can set a conducive environment for pesticide reduction. Policies can boost efforts and innovations in the private sector also in the field of agricultural production. Imposed or self-imposed restrictions on pesticide use or sending out the signal to farmers that certain pesticides will no longer be available in future will foster the search for alternatives.

Pesticide action plans

The development of national action plans to reduce pesticide risks is an important opportunity for reducing externalities and for promoting alternatives. They can enhance enforcement of existing legislation and define additional measures. It is important, however, that action plans include binding and measurable reduction targets as well as milestones to get there. Targets need to be acceptable to stakeholders and reachable (e.g. tolerable residues instead of zero residues). If the emphasis is on incentives for alternatives and improved practices rather than on economic disincentives for current practices the action plan is more likely to meet with broad acceptance. Voluntary restrictions by the private sector may enble faster results than only trying to impose restrictions. The main aim should be to advance alternatives through a combination of regulations and incentives.

Revising the regulatory practice

Current practices for pesticide registration are complex and already cover acute toxicity of single active ingredients fairly well. Commercially available pesticide formulations may contain substances that increase the toxicity of the active ingredient. In Switzerland and the EU the whole formulation is tested for acute toxicity. Additional risk assessment studies are performed on additives so that those of toxicological concern can be classified. However, metabolites of ingredients and synergistic or additive effects with other pesticides or with substances naturally occurring in food items may increase the impact of pesticide exposure. While many studies

are performed for the registration of a new pesticide more research is needed to close certain gaps particularly in order to better assess the long-term health and environmental risks related to pesticide exposure. Regulatory practices need to be based on the latest findings, also taking into consideration the results of independent published research. International codes and conventions and regional collaboration on legislation and regulation processes provide valuable guidelines for continuous improvement.

Improving transparency

The toxicity of active ingredients is currently assessed based on studies provided by the manufacturer. These studies are kept confidential for reason of competition. Weighing risks against benefits, however, are not only technical but also political decisions involving values. The underlying information therefore needs to be transparent. Transparency is also needed with regard to who is involved in decision making so that conflicts of interest can be ruled out. At EU level data related to the toxicity of active ingredients are now being published in an online database, but regulatory authorities agree that there is still scope for improvement.

Internalizing external costs

If external costs of pesticide use are integrated in their sales price they become less economical compared to alternatives. Their use therefore will decrease to some extent, as experience in Denmark has shown. A pesticide tax is therefore a worthwhile tool to internalize and minimize externalities of pesticide use. However, to be effective, the tax needs to differentiate between levels of toxicity or hazard. The income generated through the tax should be used to support alternatives and to cover the costs related to monitoring activities. Where pesticides still receive subsidies or beneficial treatment like lower value added tax rates their removal are a necessary first step. As pesticide use is relatively inelastic to price increase, taxes would need to be substantial in order to have an effect. This may affect political acceptability of introducing a pesticide tax. Rewarding the non-use of pesticides with a subsidy or introducing payments for environmental services may be politically easier to introduce.

Supporting the development of alternatives

There is a consensus that more public research is needed in order to advance the design of better farming systems and the development of alternatives to synthetic pesticides. This requires that research programs are focused on areas where pesticide reduction is crucial, and that sufficient funds are made available. As we have seen earlier breeding of resistant varieties is of high importance for pesticide reduction and should therefore receive sufficient attention. The registration and market introduction of improved varieties requires substantial efforts that are worth supporting. Governments could also provide funds for the required testing and registration of alternative means such as biocontrol and the use of botanical preparations.

Enhancing education, training and advice

As elaborated earlier it is important that vocational education and training integrate the transmission of knowledge on agro-ecology and on alternative pest management options. In most countries governments play a crucial role in agricultural education and training and therefore should ensure that this happens. It is equally important to strengthen advisory services to farmers that are independent from the agro-chemical industry. Advisory systems should avail of modern information and communication technology to transmit knowledge and information to farmers. Early pest and disease prognosis systems, for example, are an important element in effective advisory systems.

Promoting sustainable farming systems

In organic farming systems the amount of active ingredients applied is greatly reduced compared to conventional systems. An increase in areas under organic farming would

therefore significantly contribute to the objective of pesticide reduction. It is therefore desirable for society as a whole that the demand for organic products increases. Similarly, an increase in market share of products from integrated production or of products meeting sustainability standards would contribute to reduce pesticide use. Governments can provide incentives to convert to organic farming or integrated production or can demand that products meet certain minimum standards. Public procurement of organic, integrated or sustainability labelled produce can also contribute to raising demand for low- and no-pesticide products, and set important signals.

Providing information and raising awareness

Broader public awareness on the impact of pesticides is an important factor to increase demand for low- or no-pesticide products. Governments should therefore support fact-based consumer information through public media and other suitable means. Information and awareness raising should already start at school level.

Assessing the risks of pesticides and monitoring progress

More research is needed to better assess and monitor the impact of pesticides on human health and on ecosystems. Monitoring is also required in order to assess whether the measures taken in order to reduce pesticide use and risks are effective or need to be adapted.

6. Conclusions

Pesticides play a sensitive role in food systems. On the one side they contribute to ensuring sufficient food production and on the other side they pose risks to food safety, health and environment. For society as a whole it would be desirable to gradually reduce pesticide use to a level where negative impacts – externalities like health hazards, biodiversity loss or water pollution – at least do not outweigh the value added in terms of yields or cost savings in production. Today there is a consensus among a wide range of stakeholders that pesticide use needs to be gradually reduced to a level that is effectively required to ensure crop production, and that risks of pesticide application need to be reduced as far as possible.

Experience from across the world shows that current pesticide use can be substantially reduced without jeopardizing production. However, there is no single quick solution available but a combination of measures is required in order to gradually reduce pesticides and their associated risks. The amount of pesticides used depends on the resilience of crops and farming systems. Pesticide reduction therefore requires that farming systems re-integrate diversity and that available knowledge and alternative technologies are applied. Further efforts are required to enhance the understanding of farming systems and to develop robust varieties and alternative means to manage pests, diseases and weeds.

Moving into this direction is a shared responsibility not only of farmers, but also of researchers, companies, consumers, civil society organisations and governments. Consumer demand and the engagement of food processors and retailers play important roles in increasing the market share of products produced with less or without pesticides. There is a need for more collaboration along the value chain, from consumers to producers. Retailers are positioned at a crucial interface as they translate the demand of consumers to producers, but are also able to raise awareness among consumers on how food is produced.

Governments need to adapt or introduce regulations and policies that ensure that pesticide risks are minimized, that pesticide use is reduced and that alternative systems and methods are promoted. Regulations and policies need to be based on the latest available knowledge and decision making processes need to be transparent. Introducing restrictions on pesticide use and taxes that internalize external costs into the price of pesticides can foster innovation and the development of alternatives. Research and investments are needed in order to assess and monitor impacts of pesticide use and to develop alternatives. Governments need to define roadmaps with clear reduction targets and monitor progress.

Annex: Overview of actions proposed

Overview of actions proposed for pesticide reduction (summary result of the symposium on pesticide reduction of 3rd September 2015 at ETH Zurich).

Know-how and advice (PUSH)

- Investment in research on alternatives / diversity / breeds -> Government / Private Sector
- Research in risks of pesticidies (also of alternatives) and on better risk management
- Improve information, training and advice to farmers
- Promote GAP, IPM, agroecology, diversity, biocontrol, locally adapted crops; make use of ICT
- Demonstrate alternatives, exchange know-how
- Business models for alternative plant protection
- Collaboration among stakeholders along value chain

Processing, retail, consumers (PULL)

- Informing and motivating consumers on "good food" (media, schools, home gardeners)
- Alliance between research, health, water sector etc.
- Introduce resistant varieties in shops
- Retailers engage in organic farming and (improved) labels addressing pesticides
- Promotion of "safe" food offers competitive advantage
- Strengthen the link between consumers - private sector - farmers to reduce pesticide use
- CSR policies on pesticide risk management / Rating?

Legislation, promotion, incentives (POLICY)

- Enforce implementation of existing regulation
- Revise pesticide regulation / policies based on latest scientific know-how
- Registration: Implement pre-cautionary principle, phase out hazardous pesticides
- Incentives (drop subsidies, raise taxes, payments for environmental services, support for conversion, independent extension, crop risk insurance)
- Pesticide tax specific on toxicity, use income for alternatives (see DK model) -> internalize external costs
- Inform governments on pesticide reduction / alternatives
- International conventions and regional collaboration on legislation/regulation
- Food industry jointly lobbying for better policy frameworks
- Public procurement of labelled / "better" produce

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