On the implementation of the eight principles of IPM

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Table of contents

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A guidance document produced by ENDURE[1]

Note: This is the 2011 version of this guidance document. It was originally initiated in 2008 by a request from the European Commission's DG Environment to contribute to a guidance document and has been evolving since. ENDURE will issue future versions covering all eight IPM principles in more detail and updated to reflect current advancement in IPM implementation.

Why this paper?

ENDURE supports the efforts of the European Commission to assist Member States in the development of low pesticide-input pest management and in particular the establishment of necessary conditions for the implementation of Integrated Pest Management (IPM) (Art. 14 of Directive 2009/128/EC). By January 1, 2014, the National Action Plans of each Member State must show how the principles of IPM as set out by the Framework Directive are implemented by all professional users.

IPM has many different meanings and crop protection—which draws on many disciplines and involves several sectors of economic activity—is a particularly difficult field when it comes to producing clear and widely applicable recommendations. This complexity must nevertheless be tackled in order to formalise the link between policy on IPM and its implementation—something that until now has been a scattered collection of experiences. Rather than simplify IPM for the sake of simpler implementation, ENDURE wishes to highlight its dynamic, systemic and knowledge-intensive aspects and how these relate to the implementation of its eight principles. This paper aims to contribute to a reflection on these complex aspects of IPM at a time when Member States are engaging in the development of policies to favour it.

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I. On the overall implementation of IPM principles

Systemic nature of IPM

IPM creates synergies by integrating complementary methods drawing from a diverse array of approaches that make use of biological control agents, landscape features, plant genetics, cultural and mechanical methods, biotechnologies, and information technologies, together with some pesticides still needed when addressing particularly problematic pests or facing critical situations. Such a diversity of solutions is also needed to ensure long-term sustainability of control measures: the continuous use of a single method to control a given pest, be it the most favourable solution initially, will rapidly induce pest populations to evolve and overcome this method, whether a chemical one or not.

This means that the definition of IPM principles and their application require a broad perspective on current farming practices, one that considers production through a systems approach for example referring to cropping systems rather than to individual crops. Effective monitoring as well as guidelines would be facilitated if they were developed by cropping system rather than by crop. In fact, many of the levers that can be manipulated to achieve more robust agro-ecosystems are to be found at the cropping systems level.

If IPM is understood within a systems-based approach, it becomes difficult, if not impossible, to extract the effect of a single measure out of the system context. Indeed, systems theory tells us that systems have behaviour of their own and that the simple sum of the effects of their components does not correspond to the systems effect. That is why it is more advisable to talk about effects or success of IPM strategies rather than tactics. Strategies are understood as combinations and integration of tactics across an extended spatial and temporal domain while tactics are individual measures chosen for a given crop and pest in a given year.

The systems approach therefore applies to the temporal scale, where in many cases, multi-year effects need to be taken into consideration. This has consequences, for example, on how success of the applied plant protection measures should be assessed (Principle 8). To evaluate success based on record keeping, it is important to be aware that the application of IPM, which by nature involves strategies deployed across more than one growing season, needs evaluating records across more than just one season to be able to judge effectiveness. This is particularly true for weeds, soil-borne diseases, and unpredictable insect outbreaks.

The systemic nature of IPM implies that, in accordance with Principle 1 on prevention and/or suppression of harmful organisms, the emphasis should be on creating the conditions that reduce the frequency and intensity of pest outbreaks. It also means that crop protection measures should as much as possible be addressed collectively rather than in isolation.

The dynamic nature of IPM

IPM is a continuously improving process in which innovative solutions are integrated and locally adapted as they emerge and contribute to reducing reliance on pesticides in agricultural systems. IPM can be considered as a continuum, ranging from optimisation of pesticide use within the 'current' crop protection system to substitution via the adoption of non-chemical strategies and to more radical redesign of production systems by acting on crop rotations, landscape and varieties. ENDURE's sociological studies showed that farmer transitions along the IPM continuum is very gradual and comes at different speeds. Among arable crop producers, practices involving reduced dosages, modification of sowing dates and stand density based on careful consideration of several trade-offs, reduced fertiliser use, foregoing growth regulators and planning longer more diversified rotations are adopted in a piecemeal fashion over time. One change often leading to another resulting in the end in system-level changes.

Different levels of IPM are conceivable

The continuous nature of IPM makes it more difficult to deal with. When evaluating success, for example, a dichotomous "yes/no" or "adopt/don't adopt" logic may be easier from the point of view of assessing compliance but is not appropriate relative to the nature of IPM. It would be more productive for example to distinguish between 'entry level' requirements and 'higher level' requirements. In a cropping system based on potato production, for example, an 'entry level' requirement could be to adopt a 3-year rotation without other Solanaceae crops and a 'higher level' requirement could be to additionally include implementation of a specified minimum distance between potato fields in the same farm. The UK system put in place for the application of agri-environmental schemes may serve as examples of how to structure cropping-system specific guidelines: the UK 'entry level stewardship' system could correspond to IPM compulsory cropping system guidelines while the 'higher level environmental stewardship' system could correspond to IPM optional cropping system guidelines. See Natural England and DEFRA websites for details.

With respect to policy, the essential issue is to enable the process of moving along the IPM continuum to occur over the long term. Lasting support in terms of more permanent types of funding and institutions dedicated to IPM have a greater chance of success than short- term incentives or educational initiatives. It also means that evaluating the progress of IPM R&D efforts requires a certain lag time.

Transition toward IPM involves a learning process and collective dynamics

At field level, adopting IPM is not merely a matter of adopting new techniques; it is also the product of individual farmer histories and the social relationships they establish over time within their professional environment and with society.

Collective dynamics are key to supporting farmer transitions towards substitution and redesign strategies. A social sciences study conducted by ENDURE showed the value of membership to an IPM farmer group. In these groups, farmers learn from one another and from advisers and, when they are present, researchers. They jointly construct technical solutions adapted to their specific situation. The interviews showed that farmers gain confidence because their individual decisions are taken within a group, or at least challenged with the opinions of other farmers and of the adviser.

The study showed the importance of collective dynamics in supporting farmer adoption of IPM as borne out by the observation that nearly all farmers who had clearly entered into the IPM continuum were also active members of professional organisations. In contrast, isolated farmers were less likely to engage in IPM.

IPM requires an enabling food supply chain

Consumer demand can evolve in favour of IPM. Educational campaigns in favour of relaxed visual standards and acceptance of varietal diversity on the shelf would create favourable conditions for the marketing of IPM-produced food.

Supermarket procurement strategies can contribute to reducing risks. They could go a long way towards achieving reduced reliance on pesticides and advanced forms of IPM if they were to include relaxed visual standards and acceptance of resistant varieties.

Genuine partnerships between farmers, buyers and suppliers based on a common interest in reducing dependence on pesticides are needed. Such partnerships would result in broad and sustained support for IPM from farmers, but would entail rewarding farmers for their efforts and ensuring their access to the advisory and monitoring support which is required for IPM.

Knowledge resources

There are a few cases where solutions seem available at least from the point of view of researchers and need "only" to be implemented. For the majority of pest problems in cropping systems however, much applied research is still needed. It should be emphasised that much information which is not yet in a 'ready-to-use' format needs to be provided to widely implement IPM in practice. To face this need and new demand, ENDURE is advocating very significant efforts to increase the range of effective and affordable IPM solutions. This requires a coordinated plan to:

- encourage public and private research on new crop protection technologies and facilitate the regulatory conditions for their availability on the market,
- support multidisciplinary research on whole systems–an emerging field—as a way to design truly innovative IPM strategies,
- develop information, education and recognition of these integrated strategies for the benefit of farmers, advisers and other actors of the food chain, including the general public,
- maintain a momentum at the European level to create synergies from national efforts.

The fact that the general principles of IPM become mandatory and crop or sector specific IPM guidelines are voluntary might become an obstacle. If farmers shall adopt true IPM principles, there is no better way than providing them with a series of cropping system-specific guidelines on how to reach this goal. Otherwise the concrete risk is that principles remain principles and are never turned into actions. However, when it comes to bridging the gap between general IPM principles and crop specific guidelines, it should not be assumed that 'integrated production (IP)' guidelines, when they exist, automatically provide the desired crop specific IPM guidelines. IPM is site-specific and dynamic. In Italy, most crop-specific IP schemes included as guidelines for the regional application of EU Reg. 2078/92 and subsequent ones could be a starting point for the production of improved guidelines but are not useful for the implementation of IPM in their current state. In addition, existing IP schemes mainly pertain to fruit and vegetables, not arable crops.

Advisory services

Communication to professional users needs further development and should be recognised as the main vehicle by which MSs ensure IPM implementation. But efficient advisory services are present only in a limited number of EU countries: this should be one of the points in which the EU and MSs need to massively invest in the years to come to ensure IPM implementation. MSs could engage in special efforts to educate specifically authorised IPM advisors to guarantee that the basic principles are taught and disseminated. Advisors can work as multiplicators with groups of farmers or technicians. ENDURE partners have good experience with systems where advisors train groups of farmers in workshops for example in Hungary after the arrival of the western corn rootworm, or in Denmark with "experience groups".

Although many tools and methods specific to minor crops may not be available, the same reference systems (web, advisory systems, etc.) for delivering such information could be used. There should be no particular need to separate the organisation of delivery systems according to major and minor crops. In fact, the advisory system should be organised not by crop but by cropping system type such as arable crops, vegetable crops, forage crops, fruit trees, vineyards, olive groves, and small fruits. Effective monitoring systems run by regional agencies organised according to a cropping system by pest typology matrix can provide invaluable advisory support.

Policies dealing with agricultural research and extension can take into consideration the importance of collective dynamics. They can build on existing farmer groups or create new ones involving farmers, advisers, researchers and other relevant stakeholders. Training to develop new types of competencies associated with collective learning processes may be needed.

ENDURE offers a large menu of training modules that advisory organisations can draw on to support their IPM training activities, in terms of both approach and content. These modules are compiled with the ENDURE IPM training guide available at http://www.endure-network.eu/endure_publications/endure_ipm_training_guide .

II. On the implementation of individual principles

Principle 1 – Achieving prevention and / or suppression of harmful organisms

The prevention and/or suppression of harmful organisms should be achieved or supported among other options especially by:

— crop rotation,

— use of adequate cultivation techniques (e.g. stale seedbed technique, sowing dates and densities, under-sowing, conservation tillage, pruning and direct sowing),

— use, where appropriate, of resistant/tolerant cultivars and standard/certified seed and planting material,

— use of balanced fertilisation, liming and irrigation/drainage practices,

— preventing the spreading of harmful organisms by hygiene measures (e.g. by regular cleansing of machinery and equipment),

— protection and enhancement of important beneficial organisms, e.g. by adequate plant protection measures or the utilisation of ecological infrastructures inside and outside production sites.

IPM implies a move away from pest 'control' in favour of pest 'management'. This distinction in favour of 'management' is more in line with the concept and principles of IPM which entail a broader context, and a focus shifted on prevention rather than on the wise use of direct methods for in-crop pest control. That is why prevention should be given priority whenever feasible. Principle 1 should indeed come first.

The manipulation of crop sequences in non-perennial crops is a major lever to achieve effective prevention. Provisions that favour rotations and discourage continuous cropping are key to favouring IPM and should be promoted. As a general guideline wherever feasible, alternating winter and spring-summer crops in arable rotations should be suggested as this will break the life cycle of many pests more efficiently than a rotation of the same duration with just winter or summer crops. Similar guidelines should also be developed for vegetable cropping systems with the promotion of rotations between leaf and root crops, and discouraging crops of the same botanical family to occur frequently. Naturally, these sorts of guidelines whose underlying rationale is based on knowledge of ecological processes should also consider the economic viability of introducing new crops into a system.

Maize-based cropping systems offer an illustration of the importance of crop sequence/rotation. Maize monoculture is widespread especially in central and southern EU and where maize silage for fodder and energy production is common. Provisions to encourage rotation will have to take this into consideration.

Standardisation in space and time leads to the selection of the best-adapted pests. Therefore, rotation is a key element to stabilize trophic and competitive relations in cropping systems, including maize based cropping systems, in all EU regions. Rotation is a key element for managing some pests like Diabrotica virginifera and several noxious weeds while avoiding the dependence on high input of pesticides and the diffusion of intractable pests.

Crop rotation is also the main agronomic tool to prevent or delay the selection of biotypes resistant to specific pesticides. This issue is becoming increasingly important given paucity of new pesticide (especially herbicide) modes of action.

Proper rotation is rare, and crop sequences where the crop choice is market driven are commonly implemented. Expert interviews highlighted that only the EU northern region evaluated an overall positive effect of the composition and sequence of the crop rotation. The need for European, national and regional policies to encourage sustainable systems based on crop rotation was also stressed by the experts. Certain aspects of prevention dealing with healthy planting material and detection of pathogens in substrates deserve more attention, particularly in light of new technologies. Many pathogens associated with seed become the source of disease in the subsequent year. Also weed seed as contamination with harvest can become a major problem in the subsequent year. Certification of disease-free seed, seed potatoes, bulbs, cuttings, and new sorting technologies are very helpful in avoiding problems. Soil substrates, manure and other amendments can be screened with modern molecular multiplex technologies to qualitatively and quantitatively assess the disease situation. Based upon such diagnosis, better decisions can be made regarding what to grow in the subsequent growing season.

Conservation tillage is often mentioned as an example of adequate cultivation techniques but the relevance of conservation tillage and no-till practices to the development of IPM systems is not obvious. While it is true that reduced tillage does favour the conservation of soil organic matter and can help to reduce CO_2 emissions and reduce the risk of soil erosion, its supposed benefits for crop protection cannot be generalised. For example, Fusarium blight, one of the main causes of mycotoxins, is greatly favoured by no-till systems where maize and wheat residues remain on the soil surface all-year long. Also, no-till systems are usually associated with greater herbicide dependency and with creating conditions more favourable to the evolution of herbicide resistance. The benefits of conservation tillage need to be assessed relative to multiple sustainability criteria generating trade-offs. As is often the case with IPM, no simple and general rule can be advanced.

Principle 2 – Monitoring

Harmful organisms must be monitored by adequate methods and tools, where available. Such adequate tools should include observations in the field as well as scientifically sound warning, forecasting and early diagnosis systems, where feasible, as well as the use of advice from professionally qualified advisors.

Early warning or forecasting systems may not be available in many MS or for many crops. In Denmark, an extensive monitoring system linked to the advisory system is credited with being a major asset allowing Denmark to be among the lowest pesticide user in arable crops. In any case, there is little doubt that moving away from a pesticide-base strategy implies monitoring activities at regular intervals.

Principle 3 – Decision based on monitoring and thresholds

Based on the results of the monitoring the professional user has to decide whether and when to apply plant protection measures. Robust and scientifically sound threshold values are essential components for decision making. For harmful organisms threshold levels defined for the region, specific areas, crops and particular climatic conditions must be taken into account before treatments, where feasible.

While it is true that "*robust and scientifically sound threshold values are essential components for decision-making*" and that sound intervention thresholds have an important role to play in IPM, it should be realised that thresholds may not always apply, may not always be available, and may not be sufficient. There have been situations where IPM programmes have exclusively centred on the use threshold-based decisions. This can be counter-productive when the decision systems are not in place or are not appropriate, giving users a reason to completely forego the idea of decisions based on observation and explicit decision rules. It may be better to stress the general importance of observation and the need for sound decision rules.

In addition, intervention thresholds are not always pertinent. Historically, IPM emerged in the area of insect pest control where the use of intervention thresholds has generated very good results. However, the practicability of threshold-based decisions against diseases and weeds has yet to be shown. In fact, for organisms such as weeds that usually appear as a community (i.e., a set of multiple species) and not as a population, there is no scientific consensus regarding the pertinence of thresholds. In the case of polycyclic diseases, it is established that control is often much more efficient when targeted to the primary cycle, before disease symptoms are apparent and while the inoculum level is very low, than on the subsequent secondary cycles, which is contradictory with the threshold principle.

Realistically, we cannot assume that robust and scientifically sound Economic Injury Levels will be available for all major pests in all major crops; this is an ideal situation that we can strive towards but that cannot be achieved. Complexity, regional and site specificities, emerging and invading pests, differing crop management practices, and – ideally – the integration of externalities make that impossible. That is why Principle 1 is in number one position; we should do our best to create the conditions that reduce the frequency and intensity of outbreaks. Prevention and the creation of robust cropping systems are indeed the cornerstones of IPM.

Although Principle 3 (monitoring and threshold-based decisions) is true and important, it does not by itself ensure IPM. It should be noted that the idea of basing the entire decision-making process on a single criterion – the threshold – reflects an "older" view of IPM which does not necessarily satisfy Principle 1 and the need to integrate all possible measures.

Principle 4 – Non-chemical methods

Sustainable biological, physical and other non-chemical methods must be preferred to chemical methods if they provide satisfactory pest control.

The availability of non-chemical alternative measures certainly varies in the different production areas. But it should be mentioned that for arable crops, many effective physical weed control methods are available.

With regards to weeds for example, Integrated weed management (IWM) is an IPM approach covering many methods that can be combined and applied in various ways in a cropping system to reduce damage from weeds in the long-term. Ideally, an IWM strategy should be composed of preventive, cultural and direct (chemical or non-chemical) tactics. Several non-chemical direct methods (e.g. suppressive winter cover crops, stale seedbed technique, pre-emergence cultivation, increased crop stands, inter-row precision hoes equipped with tools for intra-row weed control) can be successfully applied in maize-based cropping systems without jeopardising cob or grain yield. As usual, the best strategy must be adapted to local pedo-climatic and socio-economic conditions.

Principle 5 – Pesticide selection

The pesticides applied shall be as specific as possible for the target and shall have the least side effects on human health, non-target organisms and the environment.

Sound selection of pesticide to minimise unwanted effects is of course helpful. Observing this principle in Italy's Emilia-Romagna region contributed to significant improvements during the last 25 years in that region. IPM regulation and implementation in that region tackled both pesticide quantity and quality with the aim of promoting a plant protection with reduced impact on human health and the environment while allowing for economically acceptable production. The quantity of pesticides used was reduced by 20-35%. Only pesticides with a lower impact on human health and the environment were allowed in the "IPM system". Between 70 and 90% of the pesticides with high acute toxicity and between 40 and 95% of those with a high chronic toxicity have been excluded from the "IPM system". The limitation or ban of the use of certain pesticides has been dictated by: toxicological aspects (comparative assessment between chronic risk phrases: carcinogenic, mutagenic and teratogenic effects), environmental aspects (negative effects on non-targeted organisms, water and land and persistence in the environment), carry-over effect and residues in the final products, selectivity as regards beneficial organisms, risk of selecting resistant populations.

Principle 6 – Reduced use

The professional user should keep the use of pesticides and other forms of intervention to levels that are necessary, e.g. by reduced doses, reduced application frequency or partial applications, considering that the level of risk in vegetation is acceptable and they do not increase the risk for development of resistance in populations of harmful organisms.

It needs to mentioned that the view that the use of lower dosages is associated with a higher risk of resistance development is true mainly in simplified intensive systems (e.g. continuous cropping). Such risk is checked if farmers make full use of preventive measures (crop rotation, use of cultivars genetically resistant to pests, etc.). Therefore, if the conditions for the implementation of 'true' IPM are met, diversification of the system will itself reduce the risk of occurrence of pesticide resistance. Reducing pesticide doses need not be associated with increased rates of resistance to pesticide.

In fact, there is no consistent evidence that reduced dosage is related to resistance development.

A useful distinction should be made between the concept of "necessary minimum" and the "registered (=authorized) dose" rate. The registered label dose is actually a maximum dose justified by many trials conducted as part of the authorisation process. Often, appropriate and lower doses can be recommended specifically as long as information on pest level, weed size, and canopy is included in decision-making. In any case, the criterion to achieve true IPM and assess environmental effects should certainly go beyond the reduction of dose rates.

The new vision of sustainable pesticide use should focus on a desirable control level which is then related to the selection pressure due to the biological activity and persistence of active ingredients rather than focus on dose volume and reduction. A striking example is that of sulfonylurea herbicides (ALS inhibitors): their doses are 100 - to 400-fold lower than older post-emergence herbicides but – due to their high biological activity and persistence – they are claimed responsible for the vast majority of occurrence of herbicide-resistant weed biotypes in the latest 15 years or so (also for anti-resistance strategies).

Regarding the management of pesticide resistance, it should also be noted that the strategy of spraying at a low pest infestation levels in order to minimize selection pressure can at times conflict with threshold-based decision rules. This dilemma may need to be addressed.

Principle 7 – Anti-resistance strategies

> Where the risk of resistance against a plant protection measure is known and where the level of harmful organisms requires repeated application of pesticides to the crops, available anti-resistance strategies should be applied to maintain the effectiveness of the products. This may include the use of multiple pesticides with different modes of action.

Resistance to pesticides has been constantly increasing and jeopardising the efficacy of many pesticides, thereby threatening the sustainability of several conventional cropping systems. A more effective implementation of IPM should lower *per se* the risk of resistance evolution. However, resistance management requires access to a diversity of chemistries, with different modes of action. The reduction of the number of modes of action due to the implementation of the Directive 91/414 and the decline of new modes of action made available by the agro-chemical industry will exacerbate the problem. In this context, it is important to preserve the efficacy of the few pesticides left on the market. Resistance management based on effective integration of chemical and non-chemical methods in an IPM context, where crop rotation plays a key role in arable situations and pest monitoring is regularly implemented, has to be adopted. The cropping systems where the diversity in space and time is particularly low (e.g. perennials, winter cereals, rice) will face a challenge.

Principle 8 – Evaluation

Based on the records on the use of pesticides and on the monitoring of harmful organisms the professional user should check the success of the applied plant protection measures.

To measure progress or simply efficacy, we need performance criteria and a standard as references. The need to define how to evaluate success is apparent when there is a reference to "providing satisfactory control" as in Principle 4. Does 'satisfactory control' refer to the control attained by chemical measures only or that attained by the best IPM strategy including wise use of chemical and non-chemical methods? Here a process of re-thinking and reassessment of methods needs to be initiated. We need to accept that over the last 50 years, chemical pesticides have been very successful at replacing all other means of management due to their capacity to quickly kill large numbers of target organisms at a relatively low apparent cost. That means that all alternative methods will probably have lower and slower control power and should therefore be combined as much as possible to achieve satisfactory management or regulation of pest populations. It also means that alternative methods may also require extra labour or are probably more expensive for professional users. It is important that the best possible level of control attained by chemical use is not considered as the standard for the definition of 'satisfactory' control. Otherwise, we would just stick to those methods that have 100% efficacy such as methyl bromide but create a biological void.

Naturally, evaluating performance according to margins rather than yields is more directly related to farmer objectives. This is true with IPM. But IPM, which is associated with changes in risk management, also calls for changes in the criteria used to measure performance, particularly those related to the presence of pests and weeds.

Because IPM and conventional growers don't face the same types of risks, they have different conceptions of what constitutes good practice. It is important that such changes in the way performance is evaluated be shared among the farming community so that they replace older standards.