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Integrated Pest Management – can it contribute to sustainable food production in Europe with decreased reliance on conventional pesticides?

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Abstract: A suite of EU legislation under the Thematic Strategy on the Sustainable Use of Pesticides are the policy instruments supporting the wish of the European Parliament to see significant reductions in the use of conventional pesticides in EU agriculture. The adoption of integrated pest management (IPM) is the main pillar of the strategy to decrease pesticide use, while maintaining or expanding present levels of European food production. This paper supports this approach in principle but argues that the rapid pace of pesticide withdrawals will decrease farm output and/or the profitability of farming. Furthermore, there are insufficient IPM component technologies and systems available to farmers which offer practical and economically viable alternatives, to fill the gap in the crop protection toolbox which is widening with each additional pesticide removal.

Keywords*: integrated pest management, food security, agriculture, Europe*

Introduction

The European Parliament is the first legislative assembly to introduce a statutory requirement for the implementation of IPM on farms. This has been brought about through EC Directive 2009/128, i.e., the Sustainable Use Directive (SUD). The SUD is part of a suite of legislation on pesticide marketing and application which together constitute the 'Thematic Strategy on the Sustainable Use of Pesticides'. One of the requirements under this strategy is that by 2014, all pest control activity in agriculture in EU Member States should be conducted within an IPM framework. By the end of 2012, Member States are expected to have published National Action Plans towards decreasing pesticide use in agriculture.

For the purposes of this paper, we use the definition of IPM provided in EC Directive 91/414/EEC: "*The rational application of a combination of biological, biotechnical, chemical, cultural or plant-breeding measures, whereby the use of plant protection products is limited to the strict minimum necessary to maintain the pest population at levels below those causing economically unacceptable damage or loss*".

IPM as a concept was developed during the 1950s, yet there have been few examples of its widespread adoption as a complete and sustained system of management of the pests, diseases and weeds that threaten plant and animal health and crop productivity. Worldwide, IPM is perhaps most widely implemented on cotton, stimulated by reaction to heavy reliance on synthetic insecticides in crop production and the rsulting development of resistance in target pest populations. Decreasing efficacy of some key organophosphate and pyrethroid insecticides required increasing numbers of applications to achieve the required level of control.

The objective of the EC's Thematic Strategy is to decrease pesticide use, while enhancing biodiversity and protecting the farm environment. Farmers in the UK and in the rest of the EU, have already been forced to adapt to the legislative climate and the reduced availability of pesticides, following from the harmonised registration scheme that reduced significantly the number of available chemicals they could use. It is not currently clear how individual governments in the EU will interpret and promote IPM, in the context of the economic pressures being faced in Europe and the stated wish to reduce regulation and bureaucracy. Significantly, the EC does not expect the farmer to bear any additional costs associated with the implementation of IPM, compared to previous pest control practices. Furthermore, the Thematic Strategy defers to food security concerns within the EU and requires that food production must be maintained at current or increased levels in the years ahead. In practice, many in the farming industry believe that significant decreases in pesticide use may prove difficult to achieve, without adding to production costs and without decreasing crop yields (ADAS, 2008; Clarke et al., 2009). Questions arise therefore, concerning the technology available to deliver IPM systems which are practical, cost-effective and allow food production to be (at least) maintained at present levels.

Food Security in the UK and Europe

Rising populations, climate change, the competition between food and biofuels and the rising demand for animal protein in diets, are all driving an upward trend in food prices. Recent volatility in the prices of important commodities has brought food security higher up the agenda in the UK and European Union (Barling et al., 2010; Zahrnt, 2011). The UK is 60% self sufficient in food production overall, and 74% self sufficient in foods that can be produced in the UK (DEFRA, 2008) but these figures disguise large variations between individual commodities. Self sufficiency in fruits is only around 10%, whereas it approaches 100% for temperate cereals such as wheat. The 2008 DEFRA report goes on to say that one of the Department's strategic objectives is 'a thriving farming and food sector with an improving net environmental impact, that economic and environmental performances of farming are linked and that 'we need to make progress on both fronts to meet global challenges'. One such challenge is 'how to feed a growing population in a way that does not degrade the natural resources on which food production ultimately depends'.

Global population is expected to rise from 6 billion to 9 billion by 2050, requiring food production to increase by 70% compared to 2005-7 levels (FAO, 2010). Currently, large areas of fertile land in Africa are used to produce food for European consumption. The questionable economics and sustainability of continuing to do this, needs to be balanced against the income that households and developing country governments derive from international trade in agricultural commodities. Population levels are rising fastest in Africa and some other parts of the developing world, where local food security demands may increasingly conflict with the demand from international markets. At some stage, there may be political or economic resistance to continued exportation of food commodities into

Europe. Putting it another way, EU Member States may have to produce more of their own food in the foreseeable future. Friedhelm Schmider, Director General of the European Crop Protection Association (ECPA) was quoted in 2011 as saying '*We already see an area of Africa the size of Germany devoted to growing food for the European market. Growing our food outside of Europe is not the best option for our economy – and we are exporting a problem rather than applying the solutions that we are technologically equipped to deliver'*.

There are an increasing number of voices making the moral case for higher food production in Europe. Carel du Marchie Sarvaas, Director of Green Biotechnology Europe, (quoted on the EuropaBio website) said '*There is a certain hubris in the fact that the EU relies on other countries to supply it with food, feed, fibre and fuel. The EU has ignored its responsibility to produce more for far too long. Policymakers need to put policies in place that allow farmers to increase their productivity and competitiveness'*.

Climate change may create a further imperative for northern Europe to make a greater contribution to meeting the food deficit in the developing world, rather than their sending food to Europe to feed a comparatively well fed population. Fortunately, most climate models predict that cereal production in Europe will increase, as the benefit of rising CO_2 levels outweighs any negative impact of rising temperature (assuming that water availability does not become a limiting factor). This contrasts with forecasts of decreasing production in most African countries, caused by adverse changes in precipitation and temperature (Parry *et al*, 2004).

The reform process for the EC Common Agricultural Policy [CAP] has highlighted European food security. Those arguing in favour of continued food subsidies claim that the CAP helps to buffer EU farmers against shocks and protects the EU strategic food independence (Copa-Cojeca, 2008, quoted by Zahrnt, 2011) and indeed the view of the European Parliament expressed in a resolution passed in February 2011, is that to guarantee food security in the EU, a strong Common Agricultural Policy is needed.

The risk of declining farm incomes, caused by higher production costs to meet health, environmental and animal welfare standards, needs to be urgently addressed to ensure that farming is a profitable enterprise the EU. Zahrnt (2008) is sceptical of these arguments in favour of the CAP and argues instead that farm income and market support mechanisms are irrelevant to the high levels of food security enjoyed by the EU. The more appropriate concern, at least at present, may be for food quality rather than food quantity, as increasing numbers of European consumers seek to buy local fresh produce, often direct from the grower. A high incidence of diabetes, heart diseases and obesity in the European population and the resulting burden on the health services, further focuses attention on dietary quality. The value of nutritious, safe and affordable food should not be underestimated as a health promoter that increases life expectancy (European Food Information Council, 2006 and 5 a day campaign promoted by the National Health Service, Anon, 2011).

Public reaction to GM crops, if nothing else, has shown that special interest groups can exploit consumer concern for the quality of their food and this can have serious economic implications. A more relevant direction for CAP reform to take and one supported by the British Government, is to link farm payments to the adoption of farming practices that decrease agriculture's environmental impact and enhances biodiversity. In the UK the Environmental Stewardship Scheme supported by DEFRA and implemented by Natural England, is funded from the CAP. A reformed CAP might provide the mechanism to compensate farmers for the costs associated with decreased use of pesticides and implementation of IPM. The proviso that European food production per unit area should not decrease as a result of changes to farming systems through the implementation of IPM, will be a more difficult one to meet, as technically, there is some way to go before yields achieved with high input systems can be achieved with much decreased pesticide use. Webster et al. (1999) stated that 'considerable economic losses' would be suffered without pesticide use and quantified the yield increases, pointing to the 50% increase in gross margins that result from pesticide use in British wheat production. Webster and Bowles (1996) concluded that without pesticides, apple production would not be commercially viable in UK and farmers would have to use their land for other purposes. Production of carrots in the EU could become uneconomic due to the shortage of allowable pesticides (Bridge and Johnson, 2009).

IPM and the EU pesticide reduction strategy

EU policy is directed towards significant reductions in pesticide use in food production. Article 14 of the SUD states '*Member states shall take all necessary measures to promote low pesticide-input pest management, giving wherever possible, priority to non-chemical methods'***.** While IPM is central to the EU pesticide reduction strategy, there are still insufficient non-pesticide component technologies and too little adaptive research, to transform promising components into economically viable IPM systems. National Action Plans which were supposed to be published in EU Member States by end of 2011 (now expected in 2012), are unlikely to deliver significant decreases in pesticide use by the end of 2014. The commitment of the European Parliament and National governments to sustainable development, has to be matched by the delivery of resources to support research and development for 'resource-light', environmentally benign farming systems, capable of delivering the estimated 50% increase in production required to meet the global food requirement in 2030 (World Bank, 2008).

Without proven IPM systems for important crops it would be foolhardy to base future farming policy on the assumption that food production can be increased from a declining area of arable land, while at the same time, implementing sudden and drastic reductions in pesticide use. The Crop Protection Association has drawn attention to the contribution of pesticides to increased crop yields over the last 50 years and that organic systems deliver yields which are on average, 20 – 45% lower than those achieved in conventional farming (CPA, 2010).

Pesticide resistance

Resistance evolves in insect, pathogen and weed populations as a result of prolonged and intensive use of a particular active ingredient or, a number of products with similar active ingredients. As EC legislation decreases the number of pesticides available to farmers, reliance on the smaller number that remain will increase the pressure for resistance to develop in the target pests (Rotteveel et al., 2011). Already by 1994, 504 insect species were known to be resistant to at least one formulation of insecticide and at least 17 species of insect had become resistant to all major classes of insecticide (Cate and Hinkle, 1994). Resistance now occurs in thirteen orders of insects and arthropod species: Diptera (35 percent), Lepidoptera (15 percent), Coleoptera (14 percent), Hemiptera (in the broad sense, 14 percent), or mites (14 percent). (Tabashnik, undated).

One way to reduce the risk that pesticide resistance will develop, is to target a pest or pathogen with more than one product, each having active ingredients with different chemistries or modes of action. Following a conference in Slovenja in 2008 on pesticide resistance, the ‘Declaration of Ljubljana’ was signed by the organizing committee to highlight concerns that the rapid loss of pesticide registrations under the EU pesticide review process, was restricting the choice of chemistries available and making more likely, the development of pesticide resistance. They also expressed concern that the EC was moving from science-based risk assessment to hazard-based criteria, apparently weakening the need for scientific evidence for restrictions on pesticide registrations. There is no clear definition of terms such as ‘endochrine disruption’ which are being used to justify the refusal of registration of some important crop protection chemicals. Hazard is defined as the potential to do harm, whereas risk is the chance of harm occurring. Where two chemicals were registered which controlled the same insect, disease or weed, the one with the highest toxicity has been banned. At first glance this seems reasonable, but such a conclusion is fallacious and naive. Using such logic to transport would cause cars to be banned on the grounds that rail travel is safer. And many potent drugs would not be available because an overdose can kill. In fact we need to make sure that risks that relate to hazards are properly managed (reduced to an acceptable level) a concept that is difficult to grasp if you are not familiar with modern scientific principles. Of course we need to make sure that pesticides are used in a way that poses minimal risk to users, consumers and the environment, which is why the regulations relating to registration and use are so strict. Banning some of the ‘hazard’ pesticides has had serious consequences. One is that ‘minor use’ crops such as strawberries or salad vegetables now have a very limited list of products (in some cases none) to control diseases, insects and weeds. Another is that there is a tendency for the remaining pesticides to become over-used and to become less effective due to the development of resistance. The benefits of properly conducted pesticide use should not be forgotten. Conventional pesticides have made a significant contribution to the low food prices we enjoy in Europe and will remain an important IPM component (Cooper and Dobson, 207).

The position of the Insecticide Resistance Action Committee (IRAC) in the UK, is that a large-scale decrease in available pesticides will inevitably lead to more rapid development of resistance to the remaining products. Deregulation of organophosphate insecticides for the control of pollen beetle (*Meligethes aeneus*) in oilseed rape, has led to over-reliance on synthetic pyrethroids. As a consequence, resistance to some of the key pyrethroids has developed in several EU countries. There are similar concerns over resistance in aphid populations to the newer chemistries such as neonicotinoids and other insecticides. Diseases are a major factor in reducing yield and quality. Fungicide resistance began to appear in the 1970s with the increasing use of systemic fungicides with specific modes of action. Resistance to the benzimidazole fungicides became widespread on numerous crops and then to some of the phenylamide compounds. Later on resistance began to develop in a range of fungal pathogens to the dicarboximides, strobilurins and to some of the triazoles. Herbicides, which are the most used pesticides in Europe also suffer from resistance to key actives samong populations of commion weeds. Right now this is a particular problem for control of some of the grass weeds, especially blackgrass (*Alopecrus myosuroides*) which has become resistant to a range of actives. Wild oats (Avena spp.) have developed herbicide resistance on some farms in the UK and removal of tri-allate and difenzoquat has placed more dependence on a restricted range of products.

IPM implementation in the EU

The proposed period of less than 3 years between publication of the 'National Action Plans' and adoption of IPM on all farms in EU Member States is surely too short a lead time to allow development, validation and implementation of IPM systems across all farm and horticultural enterprises. However, success in achieving the 2014 targets, may depend on how IPM is interpreted and how compliance is to be measured. Some claim that most farms in the UK are already implementing IPM. By this they mean that rather than total reliance on pesticides, many farrmers combine pesticide use with some non-chemical measure or tactic to decrease pest damage. The same group believe that any farms which do not meet even those minimal IPM standards would easily be able to do so by 2014. If the EC decides to specify targets for the extent to which pesticide use is decreased through the implementation of IPM, then the 2014 target will be much more difficult to achieve.

Partly because the IPM concept has been around for so long, and because the term is interpreted loosely, EU policy makers intent on health and environmental protection, may not realise how far we are from having whole farm IPM systems that are attractive to farmers. This is particularly true for arable crops as the economics of IPM implantation become less attractive as crop value per unit area of cultivation increases. Adoption of biological control is most widespread in greenhouse systems and occurs to some extent in soft fruit and orchard crops. While there is mounting research evidence of non-chemical pest control methods that can decrease crop damage from pests and pathogens, the majority of these must be used in combinations that often include pesticides, in order to keep target pests below the level that causes economic damage. Non-chemical methods, even in combination, rarely provide a similar level of pest control to that which is achieved through the use of a single pesticide. Moreover implementation of any reduced pesticide 'integrated' package involves the farmer in more time and expense, and/or he must often accept a higher level of risk of crop damage, resulting in decreased yields and/or lower quality. The consumer may need to accept different quality standards for fresh produce, in order to access the perceived health and environmental benefits of decreased pesticide use.

The assumption that less pesticide necessarily equates with less profitable farming is not universally accepted. The French government has committed to a 50% decrease in pesticide use in agriculture between 2008 and 2018. A related study of 600 French farms over a 12year period concluded that in 80% of the case studies, significant cost reductions could be achieved by using less pesticide, without a decrease in production (Boussemart et al., 2011). This conclusion seems to support those of Koeijer et al. (2002) who estimated the technical efficiency of Dutch sugar beet farmers at only 50% and that improvements in sustainability could be achieved by better management, without creating a conflict between economic and environmental goals.

Another factor which is not often considered, is the extent to which pest damage may be 'iatrogenic', in other words, induced or exacerbated by pesticide spraying, caused for instance, by destroying natural enemy populations. When pesticide applications are reduced after a prolonged period of intensive use, pest damage may be much more severe at first, then beneficial insect and microbial population dynamics respond and redress the balance between pests and their natural control agents, resulting in fewer catastrophic occurrences of crop damage. However the so called 'fire brigade' use of pesticides will always be a necessary safeguard to prevent occasional total loss of a crop. Even organic farmers need such a recourse to offset the risk of such a calamity.

There have been numerous projects funded by the EC and UK Governments and producer organisations, to develop non-chemical control measures for some crop/pest systems. However, much more research is needed. Some previous work has been in response to pesticide withdrawals under the ECs Pesticide Review process or, where there are particular pressures to reduce pesticide residues on produce. Much work concludes that one or more non-chemical measures can decrease pest populations or decrease crop loss equivalent say, to 40 – 70% of that achieved by the current pesticide regime, but rarely has the practicality and economic viability of implementation been fully evaluated. Moreover this is far from integrating these measures into an IPM system that addresses pest control for the whole cropping system or a whole farm.

Farmers cannot be expected to implement a separate IPM package for each crop or pest in their farming enterprise. A step in the right direction was taken when the EC recently funded a large project, involving 10 countries, to develop IPM systems for a range of key crops in six farming systems. Over 12 million Euros have been made available over 4 years, from March 2011 for the project entitled 'Pesticide Use and Risk Reduction in European Farming Systems' (PURE). Nevertheless, this is still too little and too late, relative to 2014, to develop and validate IPM systems for the varied crop and agro-ecological matrix to be found across the EU. Not least of the obstacles is the widespread perception among the farming community that IPM is rarely practical to implement and the conviction that pesticide reduction strategies are an assault upon farming livelihoods. In addition, European farmers are expected to deliver amenity benefits and ecosystem services, that Governments and wider society expect from the rural landscape.

The emphasis varies between governments of different Member States towards statutory or voluntary approaches to encourage the implementation of measures to enhance environmental protection and food safety. In the UK the approach is to rely largely on voluntary measures, and this has met with some success through implementation of the Voluntary Initiative [VI]. Under the VI scheme about 30% (percentage is higher in England than rest of UK) of arable land in the UK is covered by farmers completing the annual Crop Protection Management Plan [CMP] or who subscribe to the 'Leaf' audit (VI, 2011). And around 80% of farms in England participate in the Environmental Stewardship [ES] scheme. Within ES some of the compliance indicators, such as wild flower bunds, are IPM component technologies because they encourage predators and parasitoids. However, the CMPs and ES schemes target mainly environmental protection and best practice in pesticide use. Put another way, their compliance criteria aim to decrease the adverse impact of pesticide use, rather than promote IPM or decreased reliance on pesticides within the context of ensuring the sustainability of farming livelihoods.

The role of genetically modified (GM) crops

Powerful lobby groups opposed to genetic modification have strongly influenced public attitudes towards acceptance of the technology in Europe. Advocacy against GM technology appears to have had more influence on policy than does the (lack of) any scientific evidence of public risk from growing GM crops (Tait and Barker, 2011). As a consequence, one of the most potentially important IPM and pesticide reduction component technologies remains little used in Europe. In contrast, GM crops carrying traits which confer resistance to certain insect pests are now grown on millions of hectares throughout the rest of the world. This is claimed to decrease pesticide use and improve environmental and health outcomes. After 15 years of expanding use of this technology, particularly outside Europe there is no evidence of increased human risk from the growing of GM crops. There is no other single technology presently available that can make such a major contribution to pesticide reduction with relatively little cost, in terms of additional labour input or changes required to the farming system (Brookes and Barfoot, 2010). Most insect resistant GM crops are modified to produce insecticidal toxins from the bacterium *Bacillus thuringiensis* and are known as Bt crops. A number of European countries, Spain in particular, have been growing Bt maize for more than a decade and there has been a significant decrease in the use of insecticides to control the Mediterranean corn borer (*Sesamia nonagrioides*) and European corn borer (*Ostrinia nubilalis*) (EC, 2008; Meissle et al., 2011).

Conclusions

- The future of European farming is one in which more food production will be required with fewer pesticides and IPM is seen as an important tool to achieve this.

- EU pesticide regulations have already achieved a significant decrease in the number of active ingredients available to European famers. There is no evidence that in the UK this has led to a significant decrease in the total amount of conventional pesticide used. However, the restricted choice of chemicals, has, increased the risk of pesticide resistance in key pest populations.

- Significant decreases in pesticide use and fewer choices available to farmers (while at the same time maintaining European food security and avoiding build up of pesticide resistance) will require that viable IPM systems be developed and adopted. We do not have enough such systems at the present time.

- There is a perception among many farmers that IPM, with minimal use of conventional pesticides, is too expensive and time-consuming to implement. To change perceptions and practices, realistic and economically viable systems need to be developed and demonstrated. Involvement of individual farmers and farmer organisations in research and development of non-chemical pesticides and IPM will be essential.

- ‘Off the shelf’ whole farm IPM systems which can be implemented without significant cost implications, are not yet available for most farming systems. This raises concern about the ability of farms to meet the EU’s 2014 target for IPM implementation and also, raises issues around compliance assessment.

- IPM is perceived too narrowly as a pest and disease control strategy, rather than in the wider context of ecosystem services, landscape management, social and health benefits and as part of a sustainable food and nutrition system.

- There is no data on how compliant European farms are at the present time, so how can compliance with the 2014 Directive be gauged.

- A decrease in the number of active ingredients available as chemical pesticides will mean more reliance on a narrow spectrum of treatments and higher risk of further losses of effective pesticides, due to the development of resistance in target pests.

- At the present stage of technology development, further withdrawal of pesticides from the market and wider use of non-chemical pest management methods is likely to decrease yields and incur additional production costs, resulting in increased food prices.

- Genetic engineering offers great opportunities to develop crops with in-built pest control systems and could be an important component of IPM systems in European farming.

- The outcomes of research on IPM component technologies need to be evaluated according to whether the research is intended to contribute to knowledge that may deliver new technologies in the future or, to deliver a technology with immediate application. No changes will happen if the cost-benefits are not proven, as it is crucial to the future of European food security that farming and the industries that support agriculture and horticulture, remain economically viable enterprises. Crop protection legislation and research should take account of the need for food production to be profitable and the potential negative impact of too rapid a withdrawal of key pesticides, on Europe's small and medium-sized enterprises engaged in food production and related input services.

- Environmental protection, climate change mitigation and enhancement of biodiversity, need to be 'joined-up', with IPM playing a key role as a foundation stone in building a sustainable food and nutrition system.

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