Parliamentary Office of Science and Technology

postnote

June 2009 Number 336

CROP PROTECTION

The pesticide approvals process in Europe is changing. Consequently, a number of compounds used to protect European crops from weeds, pests and disease may no longer be available. Proponents believe this will benefit health and the environment; others fear significant decreases in crop yield and quality. This POSTnote explores the potential implications for UK agriculture and horticulture and examines other crop protection strategies available that complement or compensate for pesticides.

Pesticides and Crop Protection

Since the 1960s, agricultural production has outpaced population growth. Dramatic increases in pesticide and fertiliser use, as well as improved farming practices and plant breeding, have all contributed.

The term pesticide covers a broad range of products that kill or control unwanted organisms. Most agricultural and horticultural crops in the UK are treated with insecticides, fungicides and herbicides to control a wide range of insects, fungal diseases and weeds respectively (Box 1). The majority are made, patented and marketed by agrochemical companies. Each pesticide contains an essential component known as the 'active ingredient' that disrupts biochemical and physiological processes in pest organisms.

Many farmers and growers consider pesticides an effective and versatile means of improving yield and safeguarding quality. Consumer demand for 'blemish-free' fruit and vegetables encourages pesticide use. Overuse can lead to pest resistance, which can be overcome by using pesticides with different modes of action. Pesticides that have activity against a wide range of pests are important for controlling emerging pest problems. However, some of these, such as the organochlorines, have been linked to adverse health and environment effects, and are widely prohibited today.[1]

In general, pesticides are now more specific and less persistent in the environment but concerns over safety remain. Non-government organisations (NGOs) such as Pesticide Action Network UK (PAN UK) press for less pesticide use while some European governments have pesticide use reduction programmes. Large supermarket chains have adopted their own pesticide policies. For example, the Co-operative Group (Co-op), has lists of banned pesticides for all their farms.[2] The Co-op recently restricted the use of a group of insecticides after perceived links to declining honeybee populations.

Box 1. Major UK Crops and Chemical Pest Control

Cereals dominate UK agriculture with outputs at market prices of over £3bn. Wheat represents nearly two-thirds of all land used for cereal production with barley and oats making up the majority of the rest. Nearly 2m tonnes of oilseed rape worth over £600m is produced to make vegetable oil and biofuels. UK horticultural production of fresh vegetables and fruit is worth approximately £1bn and £500m respectively.[3]

UK sales of herbicides and fungicides in 2007 were £194.1m and £160.2m respectively, vastly outselling insecticides at £29.5m. This generally reflects the composition of pest species in the UK though insects are more important in horticulture than agriculture.

- Herbicides control weeds that cause significant problems in wheat and oilseed rape such as blackgrass.
- Fungicides, such as the triazoles, tackle key diseases of wheat while others are widely used against potato blight. They also prevent scab and mildew diseases common in fruit and control rot in strawberries.
- Insecticides play a major role in controlling aphids that damage various crops by feeding or transmitting plant viruses. Oilseed rape is widely treated with insecticides to reduce pollen beetle populations.
- Pesticides have also been developed to kill other economically damaging organisms such as potato cyst nematodes and slugs.

European Directive 91/414/EEC

The Chemicals Regulation Directorate (CRD) of the Health and Safety Executive (formerly the Pesticide Safety Directorate, an executive agency of the Department of the Environment, Food and Rural Affairs (Defra)), regulates pesticides in agriculture, horticulture, forestry, food storage and recreational parks as well as domestic gardens on behalf of the EU. The approval of pesticides in the UK falls under a dual-system of national and European legislation (Box 2). Under Directive

91/414/EEC, around 75% of some 1000 active ingredients used in pesticide products have been removed from the market since 1993.

> **Box 2. The European Pesticide Approvals Process**
> Any company seeking approval of a substance under Directive 91/414/EEC must file a comprehensive dossier, documenting all risk and safety issues. This is evaluated by a 'rapporteur' Member State and then considered by all Member States, the European Food Safety Authority and the European Commission (EC). If the active ingredient meets the specific standards, it is approved and listed in Annex I of the Directive. Plant protection products containing an active ingredient listed in Annex I are then authorised at a national level as long as acceptable use is proven, taking into consideration formulation, climatic and agronomic factors.

Changes to Directive 91/414/EEC

Risk versus Hazard

The *hazard* associated with using any chemical, such as a pesticide, is its inherent ability to cause adverse health or environmental effects. However, the *risk* that such a chemical will cause these effects is dependent on the way it is used in practice. Risk assessment takes into account both the hazards of the chemical and exposure to it. Under Directive 91/414/EEC, pesticides have been approved on the basis of risk assessment alone.

European Parliament Vote and Issues

In January 2009, the European Parliament voted for a Regulation to replace Directive 91/414/EEC. Among the changes, new hazard based 'cut-off' criteria will be introduced and as a result active ingredients will lose approval if they have any of the following properties:

- cause DNA mutations (mutagenic);
- cause cancers (carcinogenic);
- disrupt endocrines or are toxic for reproduction;
- are a persistent organic pollutant;
- are persistent, bioaccumulating and toxic or;
- are 'very persistent and very bioaccumulating'.

A number of pesticides currently used in Europe that do not meet the criteria will be withdrawn. In addition, pesticides affecting the delivery of the Water Framework Directive (2000/60/EC) (WFD) (POSTnote 320) may be reviewed and approvals withdrawn. The full implications remain unknown with some issues unresolved or unclear:

- A scientific definition of an endocrine disruptor has yet to be adopted (POSTnote 108). This will affect for example, the triazole fungicides (Box 1).
- The EC has not explained its approach to non-EU imported food produce containing residues of pesticides withdrawn from use in the EU.

Motivation for Proposals and Response

Supporters of the regulation believe that the changes will:

- reduce risks to human health (consumers, workers, residents and bystanders);
- reduce risks to the environment (particularly with regard to water quality);
- offer incentives for the industry to manufacture safer products.

There is a *derogation* allowing substances that fail certain 'cut-off' criteria, but for which no other pest control measures are available, to be approved for up to 5 years. The industry is unconvinced this derogation will be effective in practice. The UK Crop Protection Association states that a new compound costs approximately £175M and takes 10 years to research and develop, so there will be no 'quick fix' for any loss.

The proposals have sparked fierce debate in the media. Many farmers and scientists, along with the agrochemical industry, are alarmed that no EU-wide impact assessment on agriculture based on the hazard criteria was conducted. The National Farmers Union (NFU) condemns the changes, citing potential threats to food production and difficult futures for members. The UK government has also been concerned about the lack of impact assessment. However, the majority of EU Member States support the proposals.

Impact on UK Agriculture

CRD have identified the active ingredients that are most likely to fail the hazard criteria although this is not a definitive list.[4] Evaluations on some important crops in England and Wales have been conducted by various agricultural bodies (Box 3). No formal assessment has been conducted on horticultural crops due to uncertainties regarding the final definition of endocrine disruptor. However, experts predict:

- many minor crops, for example carrots, onions, peas, lettuce and beans, will experience severe if not total yield failures due to losses of herbicides;
- a greater reliance on non-EU imports;
- fruit and vegetables will become more expensive or unavailable, affecting the UK government campaign for a healthy diet.

Leading scientists fear pesticide resistance will increase due to the loss of a sufficient diversity of chemicals.

> **Box 3. Possible UK Impact and Response**
> CRD have identified some 50 active substances that may lose approval. Most of these are approved in the UK.[4] From these estimates, ADAS, an environmental and rural consultancy group, made an agronomic assessment on cereals and oilseeds[5], concluding that:
>
> - grass weed resistance will rise due to herbicide loss;
> - the loss of triazole fungicides will lead to significant increases of wheat diseases;
> - the loss of herbicides through the Water Framework Directive could potentially cost cereal and oilseed growers £500M annually.
>
> Positions of individual organisations include:
>
> - The Potato Council believes the loss of key fungicides will increase control costs of potato blight;
> - The British Beet Research Organisation fears increased growing costs and yield reductions in sugar beet;
> - The British Crop Production Council feels that as the probability of registering new compounds decreases so will R&D investment.
> - PAN UK welcomes the proposals and are satisfied that the issue of pesticides and food safety has been raised in the public eye.

Alternative Crop Protection Solutions

The Growing Problem

Farmers and scientists maintain that pesticides will continue to play a crucial role in protecting crops from pests, weeds and disease. The UK government's chief scientific adviser, Professor John Beddington, says that demand for food will increase 50% by 2030 as the global population reaches 8.3bn. Furthermore, the UN Food and Agricultural Organisation (FAO) estimates that food production must double by 2050. Over 70% of UK land is already devoted to food and biofuel production, leaving little available to increase productivity.[6] To achieve these goals, agricultural systems should be made more environmentally sustainable[7] and incorporate crop protection strategies that are economically viable, long lasting, improve yields and minimise damage to the environment. The Environment, Food and Rural Affairs (EFRA) Committee is conducting an inquiry, ‘Securing Food Supplies up to 2050: the challenges for the UK’, to address these issues.[8]

A range of other crop protection measures is available to farmers and growers, although their accessibility varies. These are based on either physical or cultural practices as well as biological and genetic processes. Often they are used alongside pesticides although further options for controlling weeds are limited. Existing and future approaches to crop protection are currently being explored in an inquiry by the Royal Society: the conclusions will be released in late 2009.

Physical and Cultural Practices

Physical methods destroy or disrupt the life-cycle of the pest through non-chemical approaches, such as fly control on vegetable crops using netting. The manipulation of the environment to disrupt pests is the basis of cultural control including, crop rotation, timing of harvest and irrigation. These methods are traditional and are already associated with good farming and growing practices. The withdrawal or restriction of herbicides will increase the adoption of these practices for weed control despite having many additional economic or environmental costs.

Biological Processes

Natural Compounds and Semiochemicals

Chemicals from natural sources with limited modification, for example pyrethrins from chrysanthemum flowers, have been used in pest control for centuries. However, their often lower effectiveness compared with synthetic pesticides means that few are currently registered and marketed by companies.

Semiochemicals are substances that pass messages between insects such as pheromones. These have been successfully exploited to manipulate the behaviour and development of pests and their natural enemies (Box 4). Although seen as a non-toxic and benign method of crop protection compared with agrochemicals, extensive research and funding is required for wider use.

Natural Enemies and Biological Control

Pest populations can be reduced by exploiting their natural enemies in the environment. This is the basis of biological control (BC) and is principally practised in enclosed environments, such as glasshouses. Natural enemies or biological control agents (BCAs) (Box 5) are mass produced by commercial companies and include:

- predatory insects and mites.
- insect parasites that kill the host organism (parasitoids).
- microbial pathogens and parasites such as nematodes, fungi, bacteria, viruses and protozoa (Box 5).

Box 4. Semiochemicals and Insect Control

Semiochemicals have been exploited to protect crops and improve yields. For example, in a ‘push-pull’ system, farmers plant crops that repel (push) damaging insects away between the valuable crop. Simultaneously trap crops are planted nearby that produce attractant semiochemicals to ‘pull’ in predators and parasites of the pests. This technique, developed at Rothamsted Research in the UK, has been effective in African subsistence farms to target pests of maize and sorghum. However, due to the high pest specificity of the technique, there are relatively few examples where this is used commercially throughout the world.

BC can be self-perpetuating, help to combat pesticide resistance and development costs are comparable with chemical spraying. However, lengthy implementation, an incomplete understanding of pest and natural enemy ecology, together with a lack of performance and reliability outside controlled environments have prevented widespread use.

Box 5. Biological Control Agents

BCAs require strict regulation to prevent ecological damage. Large scale trials are required to demonstrate efficacy and safety. Testing can account for up to 50% of registration costs compared with 10% for agrochemicals. Furthermore, the low market value of BCAs compared with agrochemicals is hindering the development of biological control. Consequently, CRD has initiated a scheme to reduce regulatory and financial hurdles.[9]

BCAs are highly specific to their target pests and to be economically successful must be:

- easy and relatively cheap to rear;
- host specific to a major valuable crop;
- be at least as effective than pesticides.

Several native or exotic natural enemies have been employed to reduce insect pests. Until recently, no BCAs, although widely used elsewhere, had been released in the EU against weeds. However, the Advisory Committee on Releases to the Environment has now given approval to Defra for field testing of psyllid bugs to control Japanese knotweed. Fungal products have had limited commercial success. Some viruses have been developed to control insects such as caterpillars and moths. Nematodes work well against soil pests and can, for example, be used against slugs where economical.

Genetic Control

Plant Breeding and Disease Resistance

Plants have been bred for over 100 years to resist pest and disease and significant advances have been made in controlling many important parasites. Cereal, potato and oilseed crops have benefited from improved yields with reduced pesticide applications. Resistant varieties thus form the mainstay of food production which is economically and environmentally sound. Research institutes in the UK, such as the John Innes Centre, collaborate closely with breeding companies to establish resistant crops. The National Institute of Agricultural Botany (NIAB), an independent plant research organisation, investigates genetic and breeding techniques and also advises farmers when disease resistance sources in a crop are likely to become ineffective.

Marker-assisted Selection

The efficiency and precision of plant breeding can be improved using marker-assisted selection (MAS). Conventional breeding can take 5-10 years to create required plant varieties. In MAS, plant DNA is screened to detect any genetic variation that may underlie a desired trait such as disease resistance. Several traits and hundreds of plant varieties can be simultaneously analysed. MAS has had a significant impact on maize and sugar beet. Despite its potential, the cost of the technology has limited its impact on the UK's major cereal crops.

Genetically Modified (GM) Crops

There are currently two types of GM crops commercially grown with improved resistance to pests;

- incorporation of pest resistance genes into crops to produce chemicals with insecticidal effect (such as bacterial toxin genes in cotton, maize and potato);
- herbicide tolerance allowing the use of herbicides that target a broad range of weeds.

No suitable GM crop is yet registered for cultivation in the UK, despite being grown in 25 countries on 125m hectares worldwide. Examples of GM crops currently being researched for the benefit of developing countries include disease resistant bananas in East Africa, moth resistant green crops in India and nematode resistant rice, banana and potato. Since the GM Farm Scale Evaluations (POSTnote 211), the first UK GM trial was approved by Defra in 2007 (Box 6). The EU evaluates applications for a GM crop on a case-by-case basis. The biotechnology industry and leading scientists in the UK believe the European regulatory system is inhibiting uptake of the technology.[10]

Box 6. Potato Disease and Genetic Control

Currently, the UK produces nearly 6m tonnes of potatoes at a value of over £750m. Significant diseases include:

- **Potato Blight** – control requires several fungicide sprays and breeding resistant varieties is a constant challenge as the disease evolves rapidly;
- **Potato Cyst Nematodes (PCN)** – cause over £50m damage a year in the UK. There are a restricted number of available genes resistant to PCNs.

The Scottish Crop Research Institute (SCRI) screens collections of potato varieties for genes associated with resistance to these diseases. The Sainsbury Laboratory is producing blight-resistant varieties with added nutritional content. GM solutions to both problems have been recently field-trialled in the UK.

Integrated Crop Protection

Applying a diverse range of crop protection methods, while using the minimum amount of pesticide necessary, is the preferred approach to pest, weed and disease management. This is the concept of integrated pest management (IPM). IPM adopts a range of technologies and techniques, such as agronomic practices, monitoring of pest populations, biological control and resistant varieties, to combat pests and diseases of various crops. On the whole, yields are maintained or improved while providing ecological benefits and preventing the development of pesticide resistance.[11] IPM is more widely practised in protected environments such as glasshouses, with costs competitive with chemical control. As part of a new Directive on the safe and sustainable use of pesticides, all EU member states must actively promote low-input pesticide pest management programmes such as IPM.

Overview

- The new hazard based approvals process is expected to remove a number of pesticides currently used in UK agriculture and horticulture from the market, though the exact number is still unknown.
- The potential loss of specific active substances, such as the triazoles, has led to estimates that UK cereal, oilseed and horticultural crop production will suffer.
- Current agricultural systems that are dependent on intensive pesticide use are not viable; this has resulted in integrated approaches to crop protection being developed and adopted by many farmers and growers.
- Biological control, plant breeding and GM crops offer alternative solutions although each has benefits and disadvantages.

Endnotes

1 Kishi, M. (2005) in Pretty, J. (ed) *The Pesticide Detox*, p23-38 Earthscan, London
2 http://www.co-operative.coop/food/ethics/Environmental-impact/Guide-to-pesticides/
3 http://statistics.defra.gov.uk/esg/quick/agri.asp
4 http://www.pesticides.gov.uk/environment.asp?id=1980
5 The Home Grown Cereals Authority, *Research Review 70*, http://www.hgca.com/publink.aspx?id=5850
6 Chandler, D. *et al*. Policy note for European Parliament's Committee on Agriculture and Rural Development. http://www.europarl.europa.eu/activities/committees/studies/download.do?language=en&file=24635
7 English Nature, 1994. Planning for environmental sustainability. In: Sustainability in Practice, Issue 1, June, English Nature.
8 HoC EFRA Committee. *Securing Food Supplies up to 2050: the challenges for the UK*
9 http://www.pesticides.gov.uk/biopesticides_home.asp
10 Sense About Science: *Making Sense of GM* (2009) http://www.senseaboutscience.org.uk/index.php/site/project/16/
11 Pretty *et al*. (2006) *Environmental Science & Technology* **3**, 24-43

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of public policy issues that have a basis in science and technology.

POST is grateful to Chris Jones for researching this briefing, to the BBSRC for funding his parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author Dr Jonathan Wentworth, at POST.

The Parliamentary Office of Science and Technology, 7 Millbank, London, SW1P 3JA; Tel: 020 7219 2840; email: post@parliament.uk

www.parliament.uk/parliamentary_offices/post/pubs2009.cfm