Achieving sustainable pest control – hard lessons from the pyrethroid story and implications for an IPM future

A report of the recent meeting on insecticide usage and its impact on IPM held at Rothamsted Research, Harpenden, UK on 29 January 2017.

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Following the successful inaugural Annual Review held in 2016, the BCPC Pests and Beneficials Working Group organised the second Annual Review which took place at Rothamsted Research in January 2017. The meeting discussed the current heavy use of insecticides, and in particular pyrethroids, in arable and horticultural crops, and the impact of this usage on implementation of Integrated Pest Management (IPM) techniques. Representatives of the pesticide manufacturing, research, regulatory, education, agronomist and grower sectors, gathered to hear and debate whether IPM had been compromised by over-use of pyrethroids in the UK, and what might be done about it in the future. The programme, compiled by **Caroline Nicholls** of the AHDB and **Dr Tom Pope** of Harper Adams University, brought together expert speakers to this controversial subject. The Chairmanship of **Professor John Pickett** (National Academy of Sciences and former head of the Biological Chemistry Department at Rothamsted Research) ensured a full and open discussion, during which a wide range of views was presented.

Historical usage of pesticides in the UK

Who better to present a historical perspective on pesticide usage in the UK than **David Garthwaite**, who has been the Fera lead conducting the Pesticide Usage Surveys (PUS) since 1997. He explained that the surveys were first conducted over 50 years ago in 1965, funded by MAFF, and subsequently by its successor, Defra, to provide government and other interested parties (the agro-chemical industry, academia, the public and pressure groups) with independently collected accurate data on agricultural practices, especially pesticide usage. Growers who participated in the surveys were chosen by stratified selection based on Government Office Region and farm size, with 90% participating voluntarily.

Many of the first surveys were conducted on horticultural crops, and it was not until 1974 that the first arable survey was done. Surveys have also been carried out on grain, fruit, vegetable and potato stores. Since 1987, survey results stored on the PUS relational databases have included full field level data; summary data

from these are now available on-line (https://secure.fera.defra.gov.uk/pusstats/surveys/9099surveys.cfm).

Examination of the data since the inception of the surveys has shown some very interesting patterns of use, affected by evolution of active ingredients, but also in some years by the incidence of specific pest problems. For example, the most prominent pesticides used in wheat from 1974–mid 1980s were organophosphate (OP) products or the carbamate, pirimicarb, mostly applied to control aphids in summer. These were replaced by pyrethroids, particularly cypermethrin and latterly lambda-cyhalothrin, as they came on stream in the late 1980s, and their usage increased substantially from 1988–1990 (Fig. 1), often applied in the autumn to control aphid vectors of BYDV, probably encouraged by their relatively low cost. There was, however, a peculiar dip in usage of pyrethroids in 1994, which on examination, was attributed to a cold wet autumn in 1993 that prevented application of autumn sprays, and an epidemic of orange wheat blossom midge (OWBM) in summer 1994, against which growers used the OP chlorpyrifos.

Further examples of changes in pesticide usage in such diverse crops as hops, orchards, and strawberries were described. Usage of insecticides in hops has declined considerably in recent years due partly to a reduction in area grown, but also to changes in application from overall sprays to use of neonicotinoids as drenches, which has removed the need for further sprays. Heavy usage of pyrethroids in orchards prior to 1987 was followed by an increase in the use of OPs, including chlorpyrifos, as natural enemies of spider mites were seriously affected by the pyrethroids. Since the withdrawal of chlorpyrifos in 2016, it will be interesting to see what the response of growers will be to this scenario when the 2016 survey is published in 2017.

Pesticide usage in strawberries has changed considerably since the introduction of French & Spanish Tunnels, and the introduction of 'everbearer' varieties in order to provide continuity of supply to customers. In particular, the number of insecticide applications has increased significantly from 2006 onwards, in response to a longer growing season and an environment more conducive for pest species to multiply. Resistance to insecticides in many of the pests, and a desire to preserve both natural enemies and commercial and naturally occurring pollinators has seen the introduction of biopesticides and biocontrol on a larger scale.

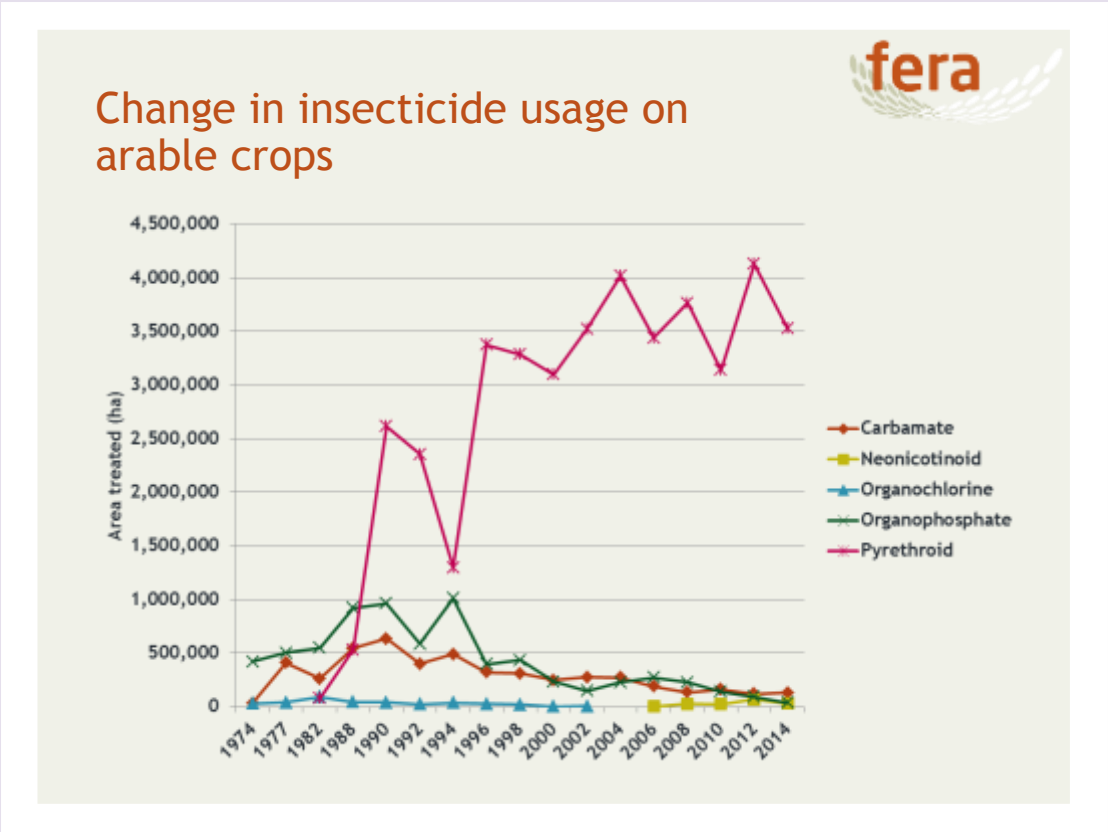

Fig. 1. Changes in insecticide usage on arable crops 1974-2014.

Managing insecticide resistance in UK pests

The development of resistance was the subject of the second talk by **Dr Stephen Foster** of Rothamsted Research. Not surprisingly, given the huge increase in area treated with pyrethroids as shown in Fig. 1, the number of pests that have evolved resistance to pyrethroids has increased considerably in the last decade or so. Dr Foster described the most serious problems that have developed in recent years, and which are now causing growers concern, especially following the withdrawal of some insecticides with alternative modes of action, such as pirimicarb and chlorpyrifos in 2016.

Insecticide resistance in aphids, especially the peach–potato aphid, *Myzus persicae*, has given greatest cause for concern. *Myzus persicae* has evolved resistance mechanisms to several classes of insecticides, including elevated levels of carboxylesterases which confer resistance to OPs, Modified Acetyl Choline Esterase (MACE) which confers resistance to pirimicarb, and knockdown resistance (kdr) and super kdr conferring resistance to to pyrethroids. The latter two of these in the UK are now present in 86-95% of wild aphids in non-protected crops (Fig. 2). Resistance to the neonicotinoids is also a concern, but perhaps less so following the restriction on neonicotinoid seed treatments in 2013. Nevertheless, resistance to this class of chemicals has been detected in southern Europe in orchards where spraying is frequent. So far these highly-resistant biotypes have not been found in the UK; only biotypes with relatively low levels of resistance to neonicotinoids have been identified.

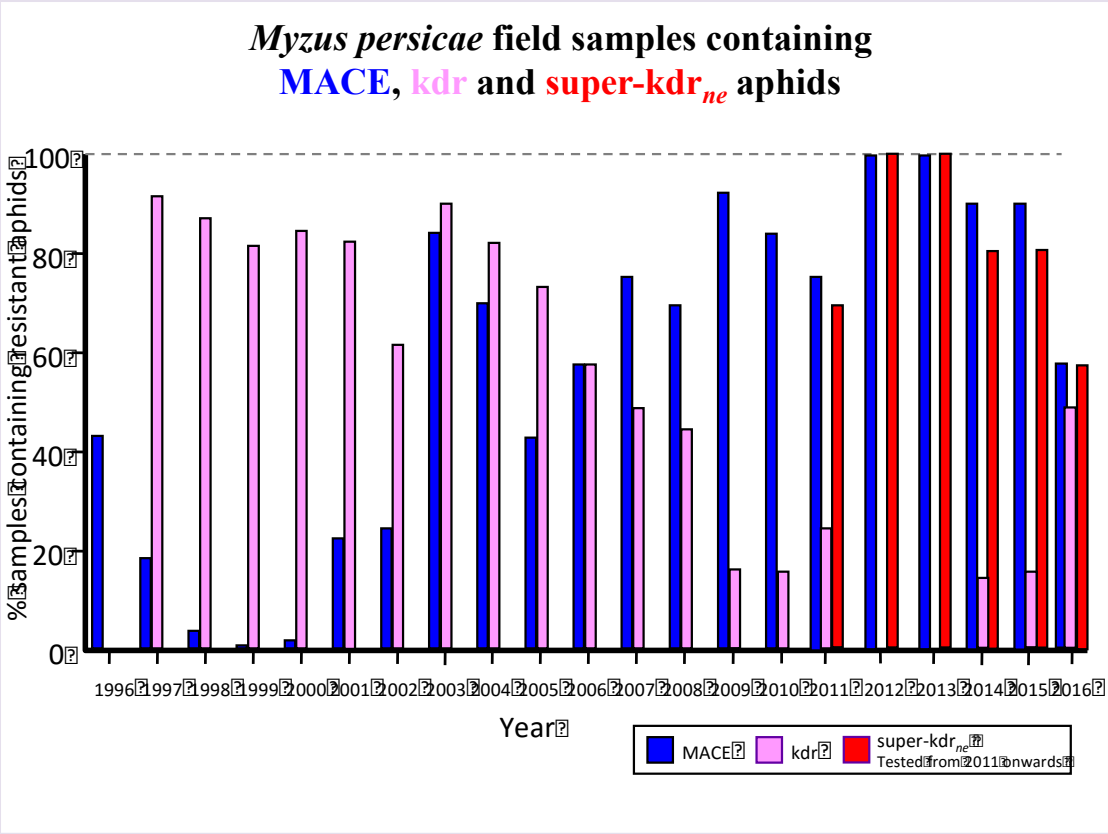

Fig. 2 Changes in the resistance characteristics of *Myzus persicae* from 1996-2016

The grain aphid, *Sitobion avenae*, has also developed insecticide resistance in recent years. Since 2011, when control failures were first reported in wheat crops in the summer, up to 50% of this species in some areas (e.g. East Anglia) have been found to contain a kdr mutation similar to that in *M. persicae.* Modern detection methods have allowed stored samples of this species to be tested, and it has been shown that the first cases of kdr in *S. avenae* were found in Rothamsted Insect Survey suction trap catches in 2009 at Kirton in Lincolnshire. Surveys of live aphids in 2015 and 2016 have shown widespread distribution of resistance, but with the highest levels occurring in the eastern region, where presumably selection pressure is greatest.

In other insect groups, resistance to pyrethroids is most apparent in pests of oilseed rape and brassica crops, including the cabbage stem flea beetle, *Psylliodes chrysocephala*, and the pollen beetle, *Meligethes aeneaus.* The former species is now almost uncontrollable in the eastern region following the restriction on neonicotinoid seed treatments in 2013, and the lack of effective alternatives. Instances of resistance to pyrethroids in pea and bean weevils, *Sitona lineatus*, and the recent epidemic of diamond back moth, *Plutella xylostella*, were also described. All these examples have one thing in common – exposure (some would say over-exposure) to pyrethroids on a regular basis.

These two presentations set the scene for a panel debate on the use of IPM techniques, and how they might have been compromised by the frequent

insurance use of pyrethroid insecticides. Short presentations were given by five speakers from different sectors of the agri-industry. First up was ex-ADAS agronomist **Dr Dave Ellerton**, who now holds the position of Technical Development Director at Hutchinsons. With long experience of the industry, he recalled resistance to insecticides being uncommon in the past, but now examples of poor control caused by the evolution of resistant strains were widespread, which he attributed to a switch from OPs to pyrethroids over the years. He stressed that IPM techniques, such as attention to drilling dates and use of resistant varieties when available, were often adopted by growers. But the value of monitoring and forecasting schemes, and adherence to thresholds was now less, often because of the need for frequent visits; there simply were not enough hours in the day. He called for more remote monitoring methods, and greater farmer involvement to counteract the tendency of farmers to apply insurance treatments in tank mixes to save application costs. The risk-averse attitude of many growers was so strong that it was often very difficult to persuade growers NOT to spray, and it was this approach to pest control that had driven the use of insecticides to such high levels.

The next speaker was **Dr David Cooper**, formerly Manager/Scientific Advisor of the Crops and Horticulture Policy Delivery Team R&D Programme in Defra, who has extensive experience of the regulatory legislation underpinning pesticide use in the UK. Dr Cooper asked if societal, food supply chain, pesticide resistance and regulatory pressures meant that IPM had 'come of age'. He described how the EU had had significant impact on current rules around the use of pesticides. In terms of what an IPM programme should look like, Dr Cooper commented that it was important that a systems approach was taken rather than simply seeing IPM as an alternate technology to a reliance on pesticides.

The ag-chem industry was represented by **David Holah,** Regulatory Affairs specialist from Bayer Crop Science. Mr Holah cited the substantial reduction in the number of active ingredients in recent years, following pressure from environmental groups within the EU, as contributory to the increase in resistance problems. This process resulted in more concentrated use of fewer and fewer products, increasing selection pressure. The significant cost of registering new products had slowed to a trickle the production of new active ingredients with different modes of action. Ecotoxicological studies were some of the more expensive studies now required to underpin registration, and few companies could afford the outlay with no guarantee of reasonable market share, especially when competing with cheap pyrethroids. He commented that guidance documents from the European Food Safety Authority (EFSA) were no longer fit for purpose, and would make most products unregisterable, especially if the proposed increase in the size of buffer zones from 6m to 30-50 m is implemented. He said the plant protection toolbox was now half full, and it could potentially be empty if/when current proposals were adopted.

The next Dave to talk was **Dr Dave Chandler**, Principal Research Fellow at Warwick Crop Centre at Wellesbourne, who focused on the use of biopesticides and IPM. The numbers of such products had increased to circa 40 in the UK, with 120 in Europe as a whole, and looked set to overtake conventional pesticides in

the next 20 years. Biopesticides have lots of attributes, such as low risk, no residues, short re-entry and harvest intervals. They also have low development costs, about 10-20 percent of conventional pesticides, which allowed them to be developed for niche markets. They did, however, also have significant challenges. Their performance was often weak, or sub-optimal, they were expensive, especially compared to pyrethroids, had variable efficacy, and were less robust. Risk-averse growers were very wary of adopting such products at the moment, but they may become more amenable in the future when yet more conventional products are removed.

The breeders' point of view was expressed by **Tracey Creasy**, Conventional Cereal Asset Manager, for North Europe at Syngenta. Although she conceded that there were few examples of varietal resistance in current arable crops in Europe, she cited the success of orange wheat blossom midge (OWBM) resistance in current wheat varieties. These were not always selected by growers for their insect-resistance properties, as growers tended to choose on the basis of yields and disease resistance first, but at least the choice was there. Other examples of resistance including to the Russian wheat aphid, *Diuraphis noxia,* hessian fly *Mayetiola destructor*, and sawflies (Cephidae) were available elsewhere in Europe, where these pests were more prevalent. Varietal resistance to cereal aphids was being investigated at Rothamsted Research, based on natural resistance identified in *Triticum monococcum*, but so far had not been successfully introgressed into conventional varieties. It is likely to take up to 15 years before useful genes have been introduced, so meanwhile the industry will still need to rely on chemistry and other means.

A lively debate followed these presentations, as the audience sought to take messages from the ensuing discussions.

After lunch, the use of IPM in the horticultural industry was presented by **Dr Rosemary Collier**, Director of Warwick Crop Centre. The challenges facing the horticultural industry derive from the diversity of crops, and low thresholds to pest attack. Their high value is dependent on high quality, with low tolerance of even slight contamination, which, with demand for uniformity and targeted maturation dates, carries higher importance than yield. For example, larvae of hoverflies (Syrphidae) might be considered to be a useful natural predator by crop protection experts, but are regarded by consumers in an even worse light than the pest aphids they consume – it is a maggot after all. Pest control in horticulture is compromised by a limited armoury, caused partially by the small market, which deters ag-chem companies from registering new products. Extensions of Authorisations for Minor Use (EAMUs) and applications for emergency authorisation have saved the day for many producers, but there needs to be a concerted effort to maintain the choice of active ingredients. Insecticide-resistance in the horticultural industry is a major problem, with many examples represented on the Insecticide Resistance Action Group (IRAG) web site. Most examples of resistance are to pyrethroids and pirimicarb, both of which have been widely used (Fig. 3) until they have been, in many cases, rendered ineffective. Now the focus of attention is on IPM programmes, which

take account of cultural control, host plant resistance, rotations, spatial separation, use of fleeces, cover crops and diversity. There is also more interest now in biopesticides, especially where there is a need to preserve pollinators e.g. with greenhouse tomatoes, and a greater use of decision support systems. The management of pests is becoming a higher priority, and requires a greater investment in time and adoption of existing and novel technologies.

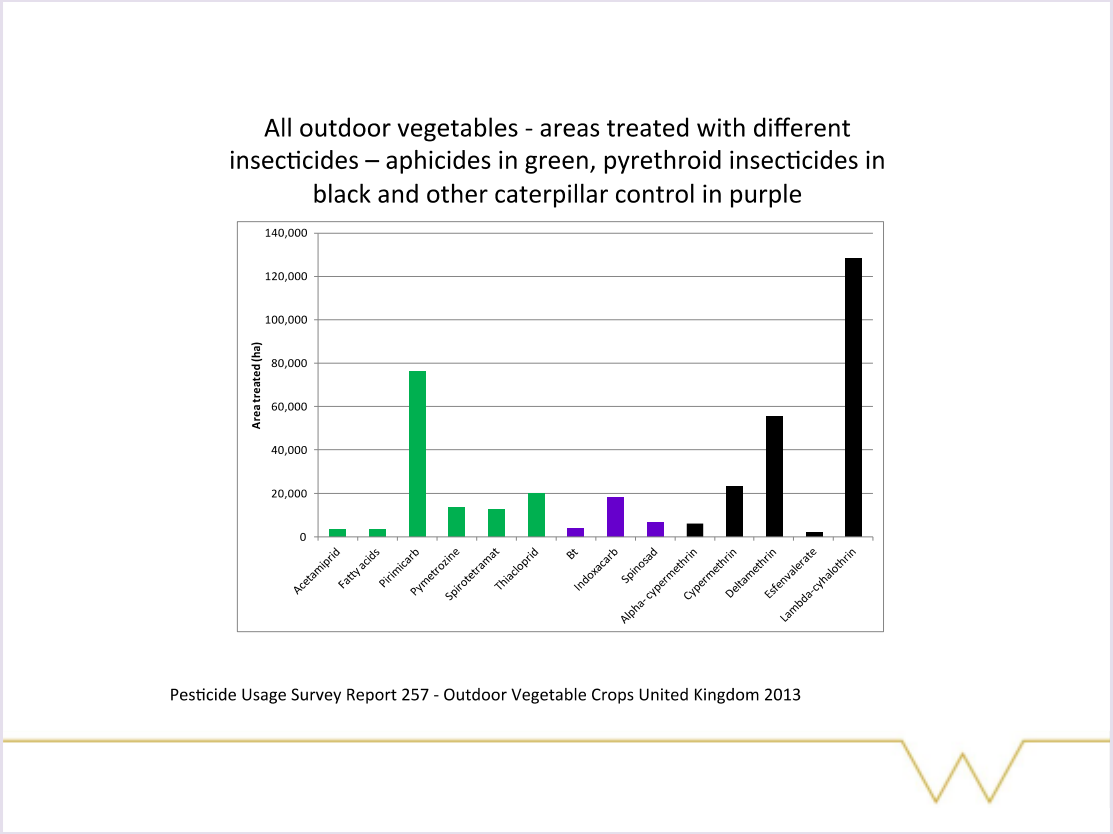

Fig. 3. Pesticide use in outdoor vegetables in 2013.

The final speaker of the day was **Dr Roma Gwynn**, a biopesticide specialist with Biorationale. She highlighted the increasing market share that biopesticides now enjoy (Fig. 4), with a trebling of EU-registered products in the last 15 years, including products as diverse as bacteria, fungi, pheromones and botanicals. New formulations are being developed constantly, focusing on new targets and improved delivery to the crop. The best use of these products is as part of IPM to manage pest populations to below damage thresholds. Such novel control methods have lower development costs than conventional insecticides, but require intensive knowledge by growers to get the best value from their use. In the future, there are likely to be new species of microbes, with improved application systems. Dr Gwynn suggested that the rising importance of biopesticides within the crop protection industry would be best served by smaller companies (SMEs) rather than giant multi-nationals, whose targets are on a different scale.

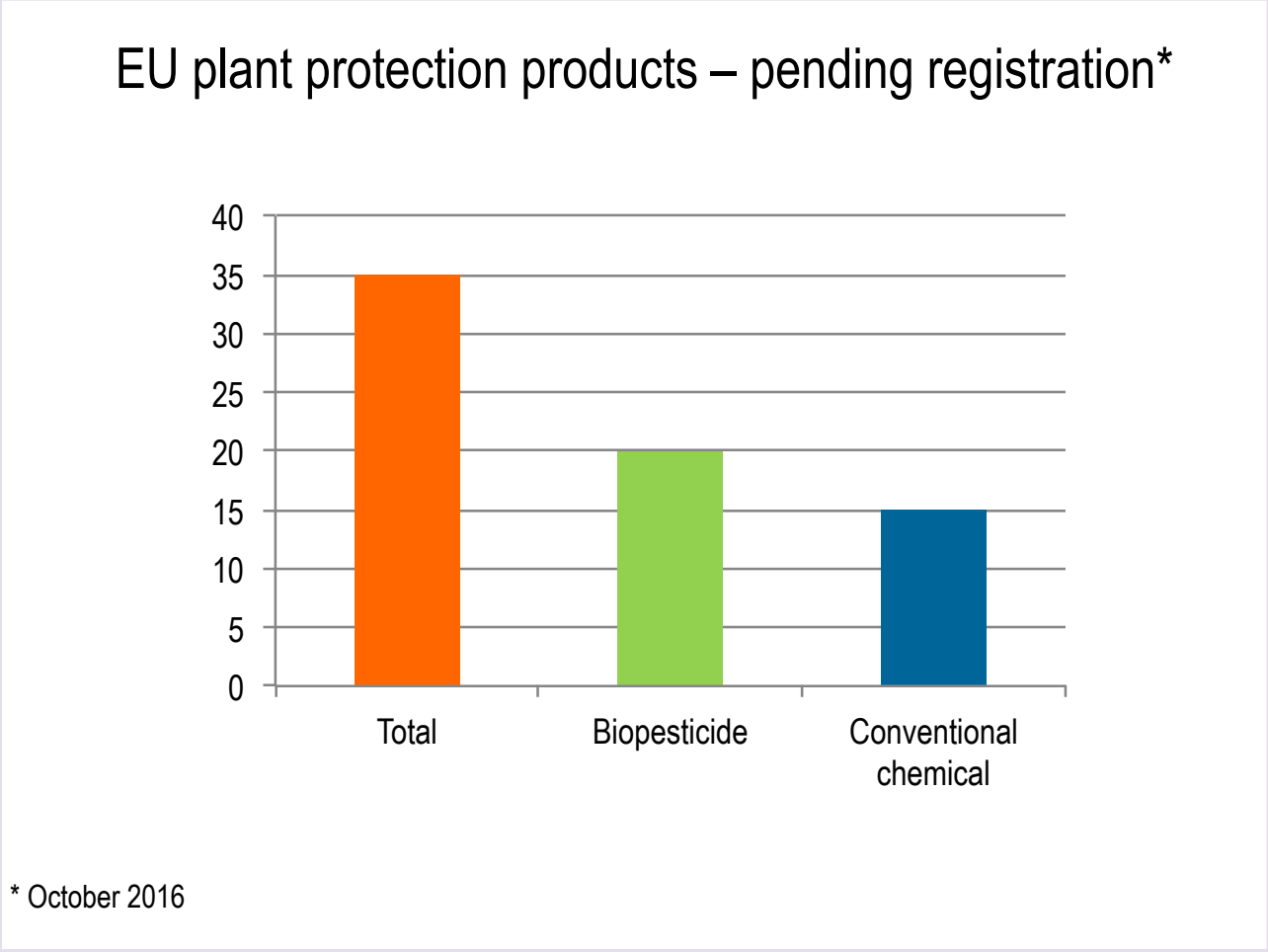

Fig. 4 The number of biopesticides pending registration in the EU compared to conventional in 2016

Chairman **Prof. John Pickett**, summarised the meeting, highlighting the need for sustainable pest control by protecting the remaining chemical tools to allow for fire-fighting in epidemic situations, but in the meantime by developing new tools, new chemistry, new genes and new systems, all of which require new funding. At the end of the day, all of these efforts need to be made to alleviate world poverty.