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Title: How contradictory EU policies led to the development of a pest: the story of oilseed rape and the cabbage stem flea beetle

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Abstract

Oilseed rape can be used to produce biodiesel which can substitute non-renewable fuels for transport. In the early 2000s, the EU introduced a series of policies and market-based incentives to encourage the production of biofuels in order to meet their obligations to reduce greenhouse gas emissions. This led to a large increase in the area of oilseed rape grown across Europe with a simultaneous rise in insect pests which were largely controlled by synthetic insecticides. However, the withdrawal of neonicotinoid seed treatments in 2013 and the development of insecticide resistance in key insect pests led to crop failures and significant yield losses. Integrated Pest Management approaches could have prevented this pest problem, however the lack of support and clear financial mechanisms for the enforcement of the 2009 Sustainable Use of Pesticides Directive meant that the cabbage stem flea beetle (CSFB; *Psylliodes chrysocephala*) has become a serious pest and the area of oilseed rape grown is now falling sharply leading to the need for imports. We suggest that it is imperative for Integrated Pest Management approaches to now become written into new EU and UK policies and to incentivise the development of tools required for implementation and use by farmers.

Introduction

Society currently faces a whole raft of global challenges to future, sustainable development (United Nations 2021). Three key challenges include mitigating and reversing climate change, halting declines in biodiversity, and producing healthy and nutritious food for the growing world population. These challenges are interlinked and the ways in which society must respond are complex and wide-ranging (Liu et al. 2015; EEA 2020). As the drivers of these global problems are better understood, the EU has designed a range of policies to try to address them:

1. In response to the problems of climate change and global warming, there is a need to reduce Greenhouse Gas emissions (Hansen et al. 2013; Peters et al. 2013). Therefore, policies to drive change towards the use of greener fuels have been introduced.
2. In response to the need for healthy and residue-free food, there was a need to introduce policies for the sustainable use of pesticides in crop production.
3. In response to the problems associated with the loss of insect biodiversity (Sánchez-Bayo and Wyckhuy 2019; Wagner 2020), there was a need for the reduction (ban) in the use of neonicotinoid insecticides which have been linked to declines in insect, and more specifically, pollinator diversity.

These policies all impacted on the production methods for oilseed rape (OSR) (*Brassica napus* L.) and the way in which the insect pests of this crop can be managed within the European Union area. This perspectives paper aims to (i) show how contradictory EU policies led to the development of a serious pest in OSR and the resulting implications for the sustainability of OSR cropping; and (ii) position Integrated Pest Management (IPM) as the most suitable management strategy. Furthermore, we highlight the need for incorporating IPM into the eco-environmental policies and wish to stimulate debate about how to do this, so that IPM becomes a successful and realistic alternative to insecticide use.

EU biofuels policy

The transport sector is a major source of greenhouse gas (GHG) emissions, responsible for nearly a quarter of Europe's GHG emissions (European Commission 2016). To reduce these emissions in Europe, the EU introduced the Directive 2003/30/EC (2003) to promote the use of biofuels or other renewable fuels for transport. Biofuels are "*a renewable energy source produced from natural (biobased) material, which can be used as substitute for petroleum fuels*" (Demirbas 2009). Much of the biofuel produced and used in the EU is biodiesel, which represents the 85% of the total transport biofuels market (USDA 2020). The major feedstock for EU biodiesel is OSR (USDA 2020), a food crop already widely grown across EU for vegetable oil, animal feed and with value as break crop in cereal rotations in arable agriculture. Currently, the production of biofuel from crops still requires the use of fossil fuels during crop production (Dalgaard et al. 2001), and other factors including various social, economic, environmental and technical issues need to be overcome to make the production process more sustainable (Oumer et al. 2018). However, biofuel production from OSR has been calculated to have a positive net energy balance (Kusek et al. 2016) and can also contribute towards circular, self-sufficient systems in terms of energy requirements (Markussen et al. 2015).

The EU Biofuels policy (2003/30/EC) was designed to meet obligations agreed in the Kyoto Protocol to reduce GHG emissions. It set a non-binding target of 2% fuel used in the transport sector to be derived from biofuels by 2005 and 5.75% by 2010. To help Member States achieve these targets, the European Commission introduced Directive EC 2003/96 on Energy Taxation, which allowed countries to exempt biofuels from excise taxes on fuels, compensating for the higher cost of production. In addition, as part of the 2003 reform of the Common Agricultural Policy (CAP), support payments for farmers were decoupled to the crops produced so they could respond freely to the increasing demand for energy crops. This reform also introduced a special aid for energy crops (45€ per hectare) allowing them to be grown on set-aside land while still receiving the set-aside area payment (European Parliament and the Council 2005). The reform paved the way for farmers to grow more energy crops, including OSR. Furthermore in 2005, the European Commission published a Biomass Action Plan to set out measures to reduce Europe's dependency on fossil fuels and reduce GHG emissions by increasing the development of biomass energy from wood, wastes and agricultural crops (European Parliament and the Council 2005). The Biomass Action Plan created market-based incentives to further promote biofuels in the EU and developing countries, removing barriers to the development of the market and supporting research and development (European Parliament and the Council 2005). The Commission also highlighted the importance of national targets, imposing obligatory measures and ensuring the sustainable production of biofuels. Later, the EU produced two legislative proposals: the Renewable Energy Directive and the Fuel Quality Directive (2009/30/EC). These directives set out two goals: (1) The delivery of a minimum of 20% of total energy to be derived from renewable sources by 2020 in every Member State; and more specifically (2) 10% of all transport fuels to be derived from renewable sources by 2020 across every Member State. The Fuel Quality Directive played an important role in increasing the inclusion of biofuels in the market as it enabled higher blends of biofuels in petrol and diesel, thus promoting the use of biofuels by suppliers and increasing the demand (Londo 2009).

Consequences of the EU biofuels policy

Since the EU Biofuels policy and the CAP reform came into action in 2003 there has been a large increase in the area of OSR grown and production across the EU (FAOSTAT, 2021; Figure 1). The OSR harvested area increased by 78% between 2003 - 2010, achieving a record harvested area of 6.4 million hectares in 2010 (FAOSTAT, 2021). Also, the shares of biodiesel made from vegetable oils blended with petrol and diesel increased; with an annual growth rate of 44% for biodiesel production between 2005 and 2007 (Banse et al. 2008). In 2004, 27% of oilseed produced in EU was processed into biodiesel (Demirbas, 2009). Four Member States produced more than two-thirds of the EU's oilseed production: Germany (24% of the total), France (20%), Poland (10%) and the United Kingdom (9%) (USDA 2008). The OSR grown area in the EU relatively remained stable from 2010 until 2018, when it sharply decreased to levels similar to those recorded in 2006 (Figure 1).

[Figure 1]

Sustainability issues

It is already widely accepted that EU policies have led to an increased use of food crops for the production of conventional biofuels, which may not be the most resource efficient approach (Wesseler and Drabik 2016); increasing biofuel production has impacted food prices (Mueller et al. 2008; Herwartz and Saucedo 2020) and caused indirect land use changes (Bowyer 2010; Wicke et al. 2012). Another, perhaps less cited issue, related to the increased demand for biofuels is that the increase in the OSR area grown has led to an increased simplicity of the agricultural landscape and reduction in non-crop area (Strijker 2005; Ericsson et al. 2009), providing higher availability of resources for insect pests and altering pest control ecosystem services. It has been shown that diversified landscapes with higher proportions of semi-natural areas exhibit lower pest abundance and/or higher biocontrol services in fields than simple large-scale landscapes with low proportions of non-crop areas (Bianchi et al. 2006; Landis et al. 2008; Veres et al. 2013; Gagic et al. 2021). Although there have been some studies that showed CSFB population increases over the period that the area of the crop has expanded (Nilsson 2002; Collins 2017; Lundin 2021), none have yet clearly related these with increases in OSR area grown. However, it has been shown how pollen beetle (*Brassicogethes aeneus*) became a troublesome pest after 3–4 years of intensive OSR cultivation and remains so (Hokkanen 2000); indeed, reproductive success of pollen beetles has increased by 200-300% during the first 16 years of OSR cultivation compared to those beetles living on cruciferous weeds (their natural host plants) (Hokkanen 2000). Also, structural simplicity in agricultural landscapes and reduced percentage of non-crop area has been correlated with large amounts of pollen beetle damage and reduced larval parasitism rates (Thies and Tscharntke 1999).

This rise in pest populations has led to increased need for the use of control products such as synthetic insecticides (FAOSTAT 2021); mainly pyrethroid sprays and neonicotinoid seed treatment, which have their own negative impacts on public health and the environment (Blacquière et al. 2012; Koureas et al. 2012). The (over) dependence on synthetic insecticides raised concerns about the 'sustainability' of biofuel production in the EU. Calls for technology to support reaching the target of 5.75% fuel used in the transport sector to be derived from biofuels by 2010 and the need for sustainable methods of pest control started to play an important role in the biofuels debate. In this respect, genetically modified (GM) plants have been recommended as a new option for biofuel production (Gressel 2008; Moser et al. 2013). A range of genetically modified OSR varieties, that are either herbicide-tolerant or insect-resistant, have been developed some of which are now being grown in many parts of the world (especially in Canada, USA, Australia, Chile) (ISAAA 2017). For example, genetically modified lines of spring OSR (canola) with high trichome density tested in Canada have been reported to deter feeding by related *Phylotretta* flea beetles (Soroka et al. 2011; Alahakoon et al. 2016). A similar approach could have been tested in Europe against CSFB, however, due to EU regulations, development of genetically modified OSR varieties attracted little support by Industry and funders, which potentially hindered the development of resistant lines.

The EU Sustainable Use Directive

In 2009, in response to the concerns about the over-use of synthetic insecticides, the EU approved a legislative package that was passed into law which increased restrictions on the range of available pesticides and, for the first time, also placed constraints on their use ('the pesticides package': Regulation (EC) No 1107/2009; Regulation (EC) No 1185/2009, Directive 2009/127/EC and Directive 2009/128/EC on the Sustainable Use of pesticides). The Sustainable Use Directive states that IPM offers ‘an approach to reduce the development of harmful organisms where plant protection products and methods are appropriately considered and kept to levels that are economically and ecologically justified and minimise risks to human health and the environment’. This directive had two main aims: (1) establish a framework for the sustainable use of pesticides ensuring they are safe for humans, animals and environment while effective for plant protection; (2) promote the use of IPM including the use of non-(synthetic) toxicant chemical alternatives for pest control. Member States were required to develop National Action Plans, a set of quantitative objectives, timetables and indicators to reduce risks and impacts of pesticide use and encourage the introduction of IPM to reduce dependency on pesticides.

Impacts of contradictory policies

Despite the moderating efforts of the EU, these directives led to a continued demand for biofuel production in the EU (Figure 1), elevating the demand for OSR further, and increasing the reliance on insecticides for pest control. Also, the vagueness of the guidance for implementation of the 2009 Sustainable Use Directive decreased its impact and led to large variations between the regulations and measures implemented in the Member States' National Action Plans. This turned into a dramatic situation when, in 2013, the EU restricted the use of three neonicotinoid insecticides: clothianidin, imidacloprid and thiametoxam, on crops attractive to bees, including OSR (European Commission 2013 (EU) No 485/2013), due to concerns over potential detrimental effects of insecticides on birds and bees (Blacquière et al. 2012; Gill et al. 2012; Henry et al. 2012; Whitehorn et al. 2012). Until this time synthetic insecticides had remained the main method of insect pest control in OSR. Farmers used neonicotinoid treated seeds (Maienfisch et al. 2001) to protect OSR from CSFB feeding damage through its establishment phase and for ensuring healthy crops capable of surviving the winter. This seed treatment was combined with applications of several pyrethroid insecticide sprays during the rest of the growing season to control CSFB larvae, which mine the stems and weaken the plant, and pollen beetle pests (which feed on buds causing abscission). The neonicotinoid ban removed the main method of control for CSFB and consequently, pyrethroids became the only permitted control. However, the prolonged used of pyrethroids on OSR contributed to high selection pressure for insecticide resistance. Even before the ban, populations of CSFB resistant to pyrethroids were discovered across the EU (Heimbach and Müller 2012; Zimmer et al. 2014). Furthermore, the neonicotinoid ban, the reduced efficacy of pyrethroids and lack of effective alternative controls, were coupled with warm winters (Copernicus Climate Change Service, 2021), which are conducive to CSFB reproduction (Mathiasen et al. 2015; Conrad et al. 2021) during the years immediately before and after the ban. This led to the 'perfect storm', and populations of beetles exploded, particularly in countries such as the UK and northern France with maritime climates that favor extended oviposition and larval development (Mathiasen et al. 2015).

The inability to control CSFB led to high crop losses and complete failure of the crop in some countries (Zheng et al. 2020; Nicholls, 2016). In the UK in 2014, 76% of the national area of OSR crop was affected by adult feeding damage causing c.5% crop loss nationally (Nicholls 2016). Of this loss, 62% occurred in eastern regions, causing an estimated loss of £13M in this area alone (Nicholls 2016). Several farmers opted to replant (Alves et al. 2015) sustaining losses that would not be accounted for in final yield totals. The pest continues to be a major problem; resistance is now widespread across Europe (Bothorel et al. 2018; Stará and Kocourek 2019) with resistance levels increasing each year (Willis et al. 2020). In 2020, 39% of OSR in UK did not make it to harvest with 14% being redrilled due to severe CSFB damage (Bayer 2020); yields fell to their lowest level in over a decade (Defra 2020) and OSR imports were necessary – ironically from countries outside the EU that still permit use of neonicotinoid seed treatments (Collier 2019). Loss of control of CSFB has made OSR cultivation in certain countries such as UK, Germany and France very risky and has been attributed as the major cause of the decline of OSR area grown (Andert et al. 2021). Possibly as a direct result of this decline in the area of OSR grown, and in order to meet the EU transport targets for 2020, imports of palm oil used for biodiesel reached an all-time high in 2020 (Rangaraju 2021). These imports are strongly liked with Indirect Land Use Changes and deforestations in third (non-EU) countries (Cazzolla Gatti et al. 2019; Cisneros et al. 2020).

In the absence of an adequate accompanying sustainability framework and risk assessment of the impacts of the increasing demand for OSR in Europe, it is clear that the contradictory (even if well-intentioned) policy initiatives led to the development of a serious pest. Perhaps, if the National Action Plans had been implemented (and put into law) at the same time as the drive for OSR expansion to meet the biofuel target, then the biofuel target would have been reached without relying on imports, and insecticide resistant CSFB populations might not be so widespread. However, there was a lag in implementation and slow behavioral change in the use of insecticides over that timeframe which allowed CSFB to 'escape' control.

The way forward

The European Commission's 2018 review of the sustainable use of pesticides directive concluded that although all Member States had to implement National Action Plans to reduce the risk and environmental impact of pesticides, these were not always sufficient. The Sustainable Use Directive did not specify the contents of the National Action Plans in detail and often lacked clear criteria on how to implement and monitor these plans. The vagueness of these provisions did not lead to the required rate of adoption of alternative pest control techniques and resulted in great diversity between Member States in terms of the National Action Plans' coverage and completeness (European Commission 2019). This review also emphasized farmers' lack of knowledge and understanding about the IPM principles and application, which also limits the impact of this directive and the extent to which it can help to reduce insecticide dependency. For the policy to be successful and widely adopted, farmers' needs, and problem awareness should be better considered; this could be achieved by involving farmers in the co-design of these policies (Busse et al. 2021; Hurley et al. 2020).

Going forwards, our reliance on insecticides for crop protection is clearly unsustainable and a broad range of management options are required for farmers to be able to combat CSFB, and other insect pests, in a sustainable and efficient way. In this context, IPM is recognised as a key element to reduce dependency on insecticides and to achieve a more sustainable agriculture (Birch et al. 2011; Barzman et al. 2015), and is highly encouraged by European legislations (Defra 2019; European Commission 2019). It offers a set of tools that can help suppress pest damage and discern when -and what- control methods are required, reducing unnecessary insecticide inputs and minimising environmental damage. IPM has the potential to play a central role in preventing OSR disappearing from rotations. IPM methods for CSFB have been recently reviewed (Ortega-Ramos et al. in press); thresholds and monitoring methods for CSFB are widely available (Ortega-Ramos et al. in press) and although there are currently few alternatives to insecticide control, it has been shown that some cultural prevention methods like reduced tillage (Ulber and Schierbaum-Schickler 2003; Valantin-Morison et al. 2007; Lundin et al. 2020) and companion planting

(Barari et al. 2005; Verret et al. 2017; Breitenmoser et al. 2020; White et al. 2020) can help suppress CSFB infestations and damage. Also, natural enemies, especially hymenopteran parasitoids, have been shown to have significant potential to reduce CSFB populations (Barari et al. 2005; Ferguson et al. 2006; Jordan et al. 2020); biocontrol potential could be increased if farmers adopt appropriate habitat management measures to promote natural enemy populations. However, there is a need for further research to produce the scientific advances necessary for the development and commercialization of tools and techniques needed to make IPM a reality. Also, to facilitate the successful adoption of IPM techniques, farmers need to be incentivized to adopt IPM (Zhang et al. 2018; Creissen et al. 2021).

Even though some EU countries have local initiatives to reduce insecticide use and encourage use of 'greener' alternatives, there is no formal process for ranking these and little information available to help farms make choices (Lefebvre et al. 2015). Therefore, there is a need to update and disseminate practical guidelines that are customized to each Member State that set out the existing technologies and non-synthetic control methods available to control pests and diseases on specific crops. These guidelines should be made easily available to growers and supported by independent advisory services.

Conclusion

Both Europe and the UK now have opportunities to design new policies through the 'Farm to Fork Strategy' (as part of the European Green Deal) and the Environmental Land Management (ELM) scheme, respectively, that will genuinely help meet the challenges of food production, climate change mitigation and environmental sustainability. Immediate improvements could be made by including IPM strategies in the new EU Eco-schemes that incentivize environment-friendly farming practices as part of the 2023 CAP reforms. In the UK, Defra have just concluded a consultation on a revised draft of the National Action Plans, and it seems likely that IPM will play an increasingly prominent role in the 25 Year Environment Plan and the evolving ELM scheme. To make these new policies successful, farmers need to be included in the design of these schemes and provided with adequate training to make IPM in OSR a real alternative to insecticides and prevent the mistakes of the past.

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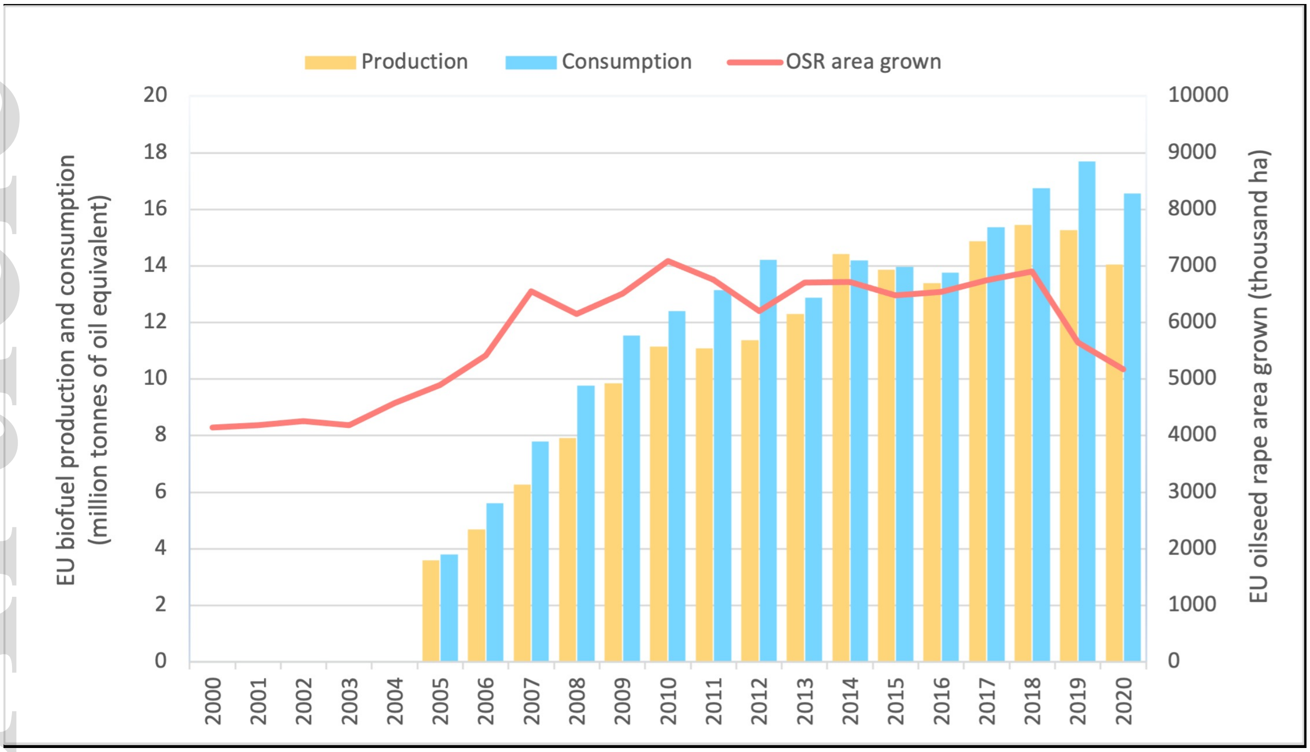

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