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A review of economic thresholds for invertebrate pests in UK arable crops

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ABSTRACT

The economic threshold for an invertebrate pest of an arable crop is the population density at which control measures should be implemented to prevent economic damage. It is a valuable method of determining whether or not control measures are necessary against an individual pest or group of pests. For thresholds to be effective, farmers and agronomists need to be confident that they accurately reflect the risk of economic loss in relation to the current cropping systems, as well as being practical to use. A lack of confidence can lead to the use of insurance sprays (insecticides applied irrespective of actual pest abundance), which are environmentally damaging, increase the risk of pest resistance, and decrease gross margins. We found that most current economic thresholds for pests of arable crops are not based on published evidence, and almost none account for the ability of crops to tolerate pest damage, or the amount, or type of crop damage that pests can cause. Furthermore, many of the methods of pest assessment are impractical, do not guarantee sufficiently accurate estimates of pest abundance, and are not described with sufficient detail to ensure consistency of pest assessment. Following a critique of current economic thresholds, this paper describes the relationship between invertebrate pest damage to crops, yield formation, and crop tolerance to pest damage, and describes what crop information is required to account for the capacity of crops to tolerate damage. This understanding is used to identify the key elements of economic threshold schemes for arable invertebrate pests, and describe a process by which thresholds can be applied. Finally we discuss the impact revised thresholds would have on crop production, and the further work needed to develop accurate, reliable, practical economic threshold schemes within integrated pest management strategies. We conclude that effective management of invertebrate pests in arable crops is reliant on: (1) Quantifying the crop damage a pest can cause; (2) Understanding the degree of tolerance a crop has to pest damage, and (3) Accurate and practical methods for assessing pest abundance.

Contents

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1. Introduction

Invertebrate pests can cause substantial yield losses in arable crops (Oerke, 2006; Culliney, 2014). Reductions in pesticide availability is of concern, because current pest management relies on these products to protect crops from extensive damage (Hillocks, 2012). Insecticides are an important component in the management of invertebrate pests, improving crop production when applied correctly (Oerke and Dehne, 2004). The low cost of frequently used insecticides (e.g. synthetic pyrethroids) relative to potential economic losses associated with invertebrate pests encourages prophylactic applications (e.g. calendar or insurance sprays) even though these are not always the most economic option (Johnson et al., 2009; De Freitas Bueno et al., 2011; Reisig et al., 2012). Prophylactic insecticide application can also have long term impacts, resulting in economic losses, compromised pest management and increased risk of damage to the surrounding environment (Pimentel, 2005).

Resistance is a constant threat to pesticide efficacy, and inappropriate or excessive use increases the likelihood of resistance developing (Bass et al., 2014). Resistance to pyrethroids for example has already been identified in several important pests, including pollen beetle *Meligethes aeneus* F. (Coleoptera: Nitidulidae, Slater et al., 2011), cabbage stem flea beetle *Psylliodes chrysocephala* L. (Coleoptera: Chrysomelidae, Hojland et al., 2015), grain aphids *Sitobion avenae* F. (Hemiptera: Aphididae, Foster et al., 2014), and the peach potato aphid *Myzus persicae* (Sulzer) (Hemiptera: Aphididae, Bass et al., 2014). Resistance drives the market for new chemicals, the development and registration of which cost substantial amounts over many years (Sparks, 2013). These costs are ultimately reflected in pesticide prices to the farmer. Aside from these direct costs, inappropriate application of insecticides may reduce the abundance of beneficial organisms such as naturally occurring predators of pests, leading to reductions in yield (Landis et al., 2000; Relyea, 2005; Desneux et al., 2007; Geiger et al., 2010; Brittain and Potts, 2011).

Concerns over the long term impacts of pesticide applications have led to increased restrictions on use, removal of products from the market, and more rigorous procedures for registration of new active ingredients (Hillocks, 2012; Köhler and Triebskorn, 2013; van der Sluijs et al., 2014). The European Commission has proposed more changes to the assessment of active ingredients, with the potential to reduce further the number of products available in arable farming (Skevas et al., 2013). The EU Sustainable Use Directive (SUD), SUD 2009/128/EC, provides guidelines on the use of pesticides, promoting low input regimes, including Integrated Pest Management (IPM) (Clarke et al., 2009). To comply with the SUD and to cope with the ongoing reductions in the availability of crop protection chemicals, farmers and agronomists need to give much greater consideration to decisions concerning whether or not to apply insecticides. This will require improved risk assessment, fundamental to which is the use of robust, user friendly economic thresholds for invertebrate arable pests (Rose et al., 2016).

Economic thresholds are a valuable method of assessing whether or not control measures, such as insecticides, are necessary to reduce the risk of economic losses. They are usually defined in terms of the number of a pest per unit area, per plant, or per part of plant, above which action should be taken. The following terms are used to define key aspects of threshold applications, developed from definitions in Painter (1951), Stern et al. (1959) and Pedigo et al. (1986);

- Crop damage – Crop injury which leads to measurable loss of yield or reduction in quality.
- Crop injury - The effect of pest feeding, or other activities, on the growth or appearance of crop plants.
- Economic damage – The extent of crop damage that justifies the cost of control.
- Economic injury level (EIL) – The lowest pest population density that will cause economic damage.
- Economic threshold– The pest population density at which control measures should be implemented to prevent pest populations reaching the EIL.
- Host-plant resistance – The relative amount of heritable qualities possessed by the plant which influence the ultimate degree of damage done by invertebrate pests.
- Host-plant tolerance – The capacity for a crop to be injured without any discernible impact on yield.

Thresholds exist for most pests in the UK, however limited data have been collected on their implementation, and few account for variability in crop value or input costs over time. The Food and Environment Research Agency (FERA) oilseed rape (*Brassica napus* L.) survey and Insecticide Usage Survey show that, between 2004 and 2014, the amount of insecticide applications on oilseed rape steadily increased, reflecting both an increase in total weight of active ingredients applied, and an increase in average number of applications per year (PUS statistics 2004–2014). There is little evidence that farmers regularly use economic thresholds to support insecticide application decisions (Cohen et al., 1998), highlighted for example, by the disparity between the proportion of oilseed rape fields in which insecticides targeting pollen beetle were applied and the proportion of those sites in which the economic threshold for the pest was exceeded (Fig. 1).

The availability of cheap pyrethroids, which offer a low cost and effective way of rapidly reducing pest numbers, is likely to encourage farmers to apply insecticides as an insurance spray and probably accounts for a significant proportion of unnecessary applications (Pannell, 1991; Pedersen et al., 2012; Dewar, 2016). However, there are also a number of other reasons why insecticides are applied without reference to economic thresholds. Firstly, the thresholds may be based on outdated or unsubstantiated research, and so are considered unreliable by farmers and agronomists (Ellis et al., 2012). Secondly, thresholds may fail to account for variation in the crop's ability to resist and/or tolerate pest damage (Gu et al., 2008). Thirdly, it may be too time consuming to undertake the assessment methods required to determine if a threshold has been reached, making them impractical in comparison to the time and cost efficiency of applying pesticides (Sharma et al., 2011; Ellis et al., 2012). Given these concerns, and in the context of fluctuations in the value of crops and the cost of plant protection products, farmers understandably err on the side of caution.

Several authors have previously considered the main components that comprise a comprehensive economic threshold scheme (Bardner and Fletcher, 1974; Poston et al., 1983; Pedigo et al., 1986; Litsinger, 2009). In this review, we summarise current economic