Agriculture, Ecosystems and Environment 233 (2016) 318–324

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Historical change and drivers of insect pest abundances in red clover seed production

Ola Lundin[a,b,*], Maj Rundlöf[c,d], Henrik G. Smith[c,e], Riccardo Bommarco[a]

[a] Swedish University of Agricultural Sciences, Department of Ecology, SE-750 07 Uppsala, Sweden
[b] University of California, Department of Entomology and Nematology, Davis, CA 95616, USA
[c] Lund University, Department of Biology, SE-223 62 Lund, Sweden
[d] University of Minnesota, Department of Ecology, Evolution, and Behavior, Saint Paul, MN 55108, USA
[e] Lund University, Centre for Environmental and Climate Research, SE-223 62 Lund, Sweden

ARTICLE INFO

Article history:
Received 7 March 2016
Received in revised form 29 August 2016
Accepted 21 September 2016
Available online xxx

Keywords:
Protapion spp
Pest control
Spintherus dubius
Triaspis spp
Trifolium pratense

ABSTRACT

Plant-feeding insects reduce yields substantially in all major crops despite considerable crop protection efforts. A lack of long-term monitoring data and insufficient ecological knowledge of pest insects limit our possibilities to characterize drivers of change in their abundances. We demonstrate how a suite of complementary methods and data sources can be used to analyse historical shifts in pest abundance and species composition when continuous monitoring data for pest insects and their natural enemies are lacking. We compared historic and current abundances of seed weevils (*Protapion* spp.) in red clover fields grown for seed in southernmost Sweden using data from 60 fields 1935–1937 and 53 fields 2008–2011 respectively. We found higher pest abundances in the current data, and parasitism rates provided by wasps appeared to be lower in recent times compared with the 1930s. A separate analysis of 1504 observations of the insect pest species made 1936–2012 and reported into a public database showed that a formerly subdominant seed weevil species, *Protapion trifolii* L. has now become the dominating pest species, whereas *Protapion apricans* Hbst. became relatively less common over time. This shift correlated with increased spring temperatures in the study area. Finally, we analysed if the proportion farmland in the surrounding landscape, temperature, precipitation and distance to nearest clover field in the previous year could explain pest abundances 2008–2011. We found that fields with less precipitation that were embedded in landscapes with a high proportion of farmland at the 5 km radius had higher pest abundances. Our results combined suggest that landscape scale changes in agricultural land use and increased spring temperatures both have contributed to the increased pest abundances observed 2008–2011 compared to 1935–1937. This study illustrates that a combination of approaches can compensate for the common situation when continuous long-term monitoring data is lacking, and improve our understanding of historic versus current insect pest abundances and the potential drivers of change.

1. Introduction

Despite extensive crop protection efforts, primarily in the form of chemical control, proportional crop yield losses to pests, pathogens and weeds have remained constant or even increased in the last century (Oerke et al., 1994; Pimentel et al., 1991). Animal pests, primarily insects, typically reduce yields in all major crops by 5–15% (Oerke and Dehne, 2004). Historical changes in crop pest damage might be driven by a multitude of factors including changes in field scale agricultural management (crop breeding, fertilization, pesticide use etc.), land use at the landscape scale and climate (Chaplin-Kramer et al., 2011; Dávila-Flores et al., 2013; Porter et al., 1991). The relative importance among these factors remains, however, largely unclear.

One important reason why so little is known about the drivers of crop losses to pests in the long term is lack of continuous monitoring data and ecological knowledge on pest insects. Standardized monitoring data, with which long term temporal trends in crop pest and natural enemy abundances can be analysed (e.g., Alyokhin et al., 2005; Lu et al., 2012), is only rarely available. In the absence of such data, an alternative is to resort to several

* Corresponding author at: University of California, Department of Entomology and Nematology, Davis, CA 95616, USA.
E-mail addresses: ola.lundin@slu.se, olalundin@ucdavis.edu (O. Lundin).

http://dx.doi.org/10.1016/j.agee.2016.09.025
0167-8809/

complementary data sources and approaches. For instance, the national annals of applied entomological research often contain useful but scattered data for functionally important insects (e.g., Bommarco et al., 2012). Furthermore, insects, including pest species, are often reported by citizens into publicly available databases, e.g., those connected to the Global Biodiversity Information Facility (GBIF, www.gbif.org). Although it is often difficult to infer shifts in absolute species abundances from such records, where information about sampling intensity and other methodological details are often not reported, these sources are nevertheless valuable for detecting trends in relative abundance of species over time (e.g., Jeppsson et al., 2010). Another way to compensate for lack of continuous time series data on pests is to analyse drivers of recent spatial variation in pest abundances, and identify which of the drivers found that may be responsible for driving differences across time periods. By combining these approaches we can confirm shifts in occurrence and composition of pest species and their natural enemies over extended time periods, and potentially also identify drivers of change.

Red clover crops grown for seed suffer considerable losses to insect pests, in Europe mainly to *Protapion* spp. seed weevils (Coleoptera: Apionidae) (Markkula et al., 1964; Lundin et al., 2012). In southernmost Sweden, *P. trifolii* is currently the most common pest species in red clover fields (Lundin et al., 2012). This species has historically been thought to be restricted in its distribution and abundance in Scandinavia by low spring temperatures which delay its reproduction (Markkula and Myllymäki, 1962), or by high autumn precipitation which promotes fungal infections of overwintering weevils (Notini, 1938). Parasitic hymenopteran wasps are important natural enemies of clover seed weevils (Kruess and Tscharntke 1994). Intensification of agriculture and landscape simplification have been shown to negatively affect parasitoids and other natural enemies, but whether this also contributed to increased pest pressures is less studied and remains unclear for many crops (Chaplin-Kramer et al., 2011). As a final potentially important driver of pest abundance to consider in our study system, there is some support for the idea that increased distance between clover fields from one season to the next negatively affects seed weevil abundances in clover (Langer and Rohde 2005).

We studied historical changes and the potential drivers of pest abundances and parasitism rates provided by natural enemies in Swedish red clover grown for seed using three complementary approaches. First, we compared *Protapion* pest abundance and parasitism provided by natural enemies in data sets from two distinct time periods: 1934–1937 (historic period) with 2008–2011 (present period). Second, we explored shifts in relative species abundances in the *Protapion* pest community 1936–2012 with data from public database records and related them to changes in climate over the same period. Finally, we analysed if the proportion farmland in the surrounding landscape, temperature, precipitation and distance to nearest clover field in the previous year could explain pest abundances and parasitism rates provided by natural enemies 2008–2011.

2. Material and methods

2.1. Study species and region

Our study was conducted in Skåne in southernmost Sweden (Fig. 1), where land use is dominated by agriculture and main crops grown are wheat, barley, oilseed rape and ley (fertilized grassland).

Protapion spp. weevils, in particular the clover seed weevils *P. trifolii* L. and *P. apricans* Hbst. are the major pest insects in the study area (Lundin et al., 2012). Clover seed weevils hibernate as adults, mainly outside the fields in dry and protected habitats (Ohlsson, 1968). They infest clover fields in the spring and oviposit in clover

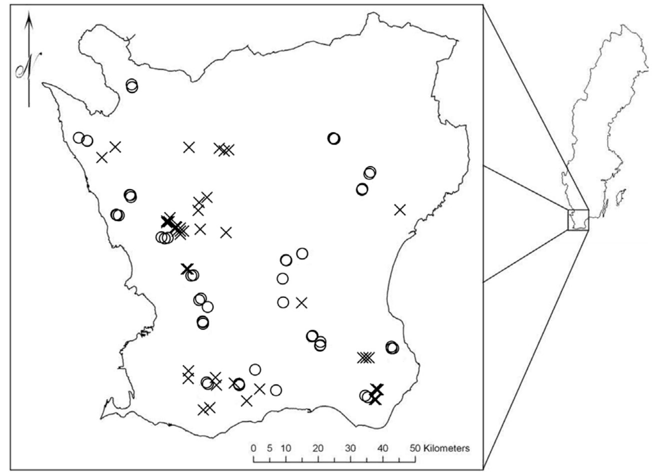

Fig. 1. The study region Skåne in southernmost Sweden with 1935–1937 field sites (crosses) and 2008–2011 field sites (circles) indicated.

buds (Jones, 1950). The larva develops inside the inflorescence, where it consumes 6–10 ovules and developing seeds (Jones, 1950). The hatched juveniles make an autumn migration back to overwintering habitats (Schnell, 1955).

Parasitic hymenopteran wasps attack larval instars of clover seed weevils (Gønget, 1997; Notini, 1935). *Spintherus dubius* Nees is the most common parasitoid species (Kruess and Tscharntke, 1994; Kruess, 1996; Lundin et al., 2012). The parasitoids lay their eggs under the cuticle of medium-to-late instars of weevil larvae (Kruess, 1996; Notini, 1935). Several species probably overwinter as adults in dry locations (Graham, 1969). The ecology of the parasitoids is otherwise poorly known, but there are indications that they are poorer dispersers than their hosts (Kruess and Tscharntke, 1994).

2.2. Historic versus present pest abundances and parasitism rates

Our first aim was to compare historic and present *Protapion* pest abundances and parasitism rates provided by natural enemies. Notini (1935, 1938) initiated a comprehensive sampling of seed weevils in red clover in Sweden. Pest abundance was measured on 605 fields distributed throughout the country between 1933 and 1937. The historic data used here consists of spatially explicit raw data on pest abundance from 60 fields in the study region collected over three consecutive seasons: 1935 ($n = 20$), 1936 ($n = 22$), and 1937 ($n = 18$) (Notini, 1938). 200–400 inflorescences were collected from each field in July and August in each year at a crop stage when "weevil larva survival was not jeopardised by cutting the flower stem" and inflorescences were sampled at "a safe" distance from field edges (Notini, 1938). Sampled inflorescences were put in paper boxes with connected glass tubes. *Protapion* weevils that emerged were determined to species. Sampling in the historic time period was conducted before the introduction of any chemical pesticides. Parasitism rates in the historic period were only reported as county means from a single year in 1934 (Notini, 1935). Two parasitoid morphospecies were found and counted in the hatching samples, "*Pteromalus* sp." and "*Sigalphus caudatus*". The parasitism rate for the study region was based on information from 21 fields in the two former counties Malmöhus (12 fields, 40.4% parasitism) and Kristianstad (9 fields, 33.9% parasitism). We calculated a study region mean parasitism rate by averaging these two county means weighted by the number of fields in each county.

We sampled pest abundances from 53 fields in the study region over four consecutive seasons: 2008 ($n = 14$), 2009 ($n = 17$), 2010