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Careful choice of insecticides in integrated pest management strategies against *Ostrinia nubilalis* (Hübner) in maize conserves *Orius* spp. in the field

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A B S T R A C T

A long-term field experiment was set up in April 2011 at Legnaro, Italy, within the European Project PURE, to evaluate two Integrated Pest Management (IPM) tools against conventional pest management in maize-based cropping systems (MBCS) that involved different crops every year. Three foliar insecticide treatments were applied against *Ostrinia nubilalis* (Hübner) in 2011 and 2014 when maize was present in the rotation. Lambda-cyhalothrin was applied as the conventional management (CON), while chlorantraniliprole and a biological insecticide containing *Bacillus thuringiensis* var. *kurstaki* were tested for IPM1 and IPM2, respectively. The minute pirate bug (*Orius* spp.) was the most abundant among the beneficial organisms and was considered as the indicator species to evaluate the impact of the insecticide treatments tested. Statistical analysis showed no significant difference in *Orius* nymphs (N), adults (A) and total population (N + A) before treatments, whereas after treatments *Orius* was significantly lower in the CON than in IPM in all cases. No differences in *Orius* population were determined between IPM1 and IPM2. The percentage reduction calculated in total *Orius* (N + A) after the three insecticide treatments ranged from 91% for CON, 18% for IPM1 to 4% for IPM2. The latter had a significantly higher number of plants broken below the ear, total number of broken plants and damaged ears by *O. nubilalis* compared to CON and IPM1, but no significant difference was determined between treatments in percentage ear surface damaged, being below 1% in all cases. Treatment with chlorantraniliprole did not affect *Orius* population confirming its selectivity towards this species, conserved *Orius* at the same level as *B. thuringiensis* var. *kurstaki* and had similar efficacy to the CON against *O. nubilalis*.

1. Introduction

Maize (*Zea mays* L.) is one of the most important crops in Europe, covering an area of approximately 16 million hectares (for grain and silage maize production) within the European Union (EU) member states in 2014 (EUROSTAT, 2015). It is grown either as monoculture or in rotation with other crops and the crop protection practiced is mainly pesticide-based with different levels of IPM adoption (Vasileiadis et al., 2011). A common set of arthropod pests, weeds and fungal diseases are the major biotic stresses in most European maize growing regions (Meissle et al., 2010).

The European corn borer (*Ostrinia nubilalis* Hübner) is the most important maize pest in many parts of Europe, while the Mediterranean corn borer (*Sesamia nonagrioides* Lef.; MCB) is predominant in warmer areas of southern Europe (Meissle et al., 2010). Yield is affected by *O. nubilalis* damage to the ear and larvae tunnelling in the stalk resulting in breakage (Butrón et al., 2009; Razinger et al., 2016). In addition, *O. nubilalis* damage can affect crop health by vectoring *Fusarium moniliforme*, facilitating fungal infections and favouring high levels of fumonisins in maize kernels (Sobek and Munkvold, 1999; Butrón et al., 2009).

Foliar broad-spectrum insecticides are conventionally applied on maize in many European countries (e.g. Spain, Hungary, Poland, Germany, Italy and France) to control mainly corn borers but also

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western corn rootworm (*Diabrotica virgifera virgifera* LeConte) adults and corn earworm (*Helicoverpa armigera* Hübner) larvae (Meissle et al., 2010). However, the intensive and repeated use of insecticides, e.g. pyrethroids, may lead to the development of pest resistance (Pereira et al., 2015), secondary pest populations outbreaks, environmental contamination and effects on non-target organisms (Gill and Garg, 2014). Naturally occurring predators and parasitoids, which contribute considerably to biological control in the field, are often harmed by the deleterious effects of such broad spectrum insecticide applications (Biondi et al., 2012). Loss of beneficial populations over such a large cultivated area might have an impact on conservative biological control at landscape scale also influencing crops other than maize (Veres et al., 2012).

The reduction in pesticide dependence, as well as the health risks and adverse impacts on the environment deriving from their use, is an integral part of the European Union's (EU) agenda for agriculture (European Parliament, 2009). The adoption of the eight IPM principles, as stated in the EU Directive on Sustainable Use of Pesticides (2009/128/EC), is mandatory for all professional users of pesticides throughout the European member states from 1 January 2014 (Barzman et al., 2015). However, the development and adoption of crop-specific IPM guidelines remains voluntary in Europe (Lamichhane et al., 2016). Several alternatives to insecticides for *O. nubilalis* control in maize production have been suggested and/or are being used worldwide, such as maize hybrids with increased tolerance to insects (Velasco et al., 2002), the use of pheromone-mating disruption (Fadamiro et al., 1999), the use of *Bt*–maize expressing the insecticidal protein Cry1Ab from *Bacillus thuringiensis* (Devos et al., 2008) and biological control with mass releases of *Trichogramma brassicae* (Razinger et al., 2016). Conservative biological control in maize-based cropping systems (MBCS) (i.e. by provision of resources or refugia in the field, habitat manipulation within field and at landscape scale, choosing selective insecticides) was recently recommended as a means for balancing, and eventually reducing in the long term, pest populations and high infestation levels, resulting in insecticide use reduction (Vasileiadis et al., 2011; Veres et al., 2013). In addition to semi-natural areas, arable fields can also enhance conservative biological control at landscape scale if they are managed extensively (Veres et al., 2012). The adoption of such IPM alternatives by European farmers can significantly contribute to meeting the commitment of EU member states to a sustainable use of pesticides and a reduction of the risks and adverse impacts on human health and the environment. However, to achieve this and promote IPM implementation, robust evidence on the sustainability of these alternatives is needed to motivate their adoption by stakeholders. This can only be done through assessing and validating them at field scale under real climatic conditions and using existing farm equipment. Indeed, the effect that IPM alternatives, e.g. selective insecticides, have on beneficial organisms has not been widely investigated in field studies but mostly in laboratory or semi-field studies (e.g. Dinter et al., 2008; Biondi et al., 2012).

Building from this information, a working group was formed within the European Project PURE with the general objective of testing and validating innovative IPM solutions that reduce dependence on pesticides in European MBCS. This study aims to evaluate, under real field conditions, the impact that different types of pest management applied against *O. nubilalis* in maize have on beneficial organisms, ranging from the conventional approach to IPM-based solutions that potentially conserve natural enemies in the field and promote conservative biological control in MBCS.

2. Materials and methods

2.1. Experimental site, design and crop management

A long-term on-station experiment was set up in 2011, at Legnaro, Italy, to evaluate the effect that three MBCS with different levels of crop protection (conventional; CON, IPM1 and IPM2) have on major pests, weeds and diseases in maize. The candidate IPM levels to be tested were selected based on the outcomes of various working groups in the EU project ENDURE (European Network for Durable Exploitation of Crop Protection Strategies; http://www.endure-network.eu) for maize systems in this region (Meissle et al., 2010; Vasileiadis et al., 2011, 2013) and after consultation with various local stakeholders (e.g. extension services, agrochemical companies, farmers, academic and research institutions). The experimental design was a completely randomised approach with three replicates for each system investigated (9 m × 40 m plot size). The MBCS being tested involve different crops in their rotation each year, thus not all crops per system are present each year resulting in no climatic replication. Thus, in 2011 maize was present in all systems, in 2012 and 2013 different crops were involved in the rotation of each system and maize was present again in all systems in 2014 when the second rotation cycle began. The maize hybrid Korimbos was sown in both years across all treatments and fertiliser rates were the same.

Using these 2-year maize data, this study aims to evaluate the effect of the three different crop protection practices used in the respective CON, IPM1 and IPM2 systems against the major maize pest *O. nubilalis*, as well as the impact of the insecticide products applied on the beneficial organisms present in the field. More specifically, in terms of pest management, three different foliar insecticide treatments were applied against the second generation larvae, as these are the most damaging to the crop, based on the monitoring of *O. nubilalis* flight dynamics by light traps and when the threshold range of 25–30% pupation was reached. The recommended dose of lambda-cyhalothrin (19.5 g a.i./ha) plus an oil adjuvant was applied as the CON management, while chlorantraniliprole (30 g a.i./ha), an insecticide considered selective to beneficial arthropods and two applications of a biological insecticide containing *Bacillus thuringiensis* var. *kurstaki* (1000 g/ha) were applied as the two IPM tools. All insecticides were applied using a 9 m wide boom portable field sprayer equipped with 19 flat-fan nozzles (110°), a spray volume of 500 L/ha and a spray pressure of 350 kPa. Adequate space between plots (4 m) was used as a buffer zone to avoid any effects between the different treatments applied.

2.2. Sampling methods

Beneficial organisms present in the plots were assessed during the silk flowering period by randomly choosing 25 plants from the centre of each plot and sampling the maize ear zone 1 day before and 1 week after the insecticide treatments, to record the number and taxa of insects present. Sampling of maize ears was reported to be a suitable method for detecting changes in arthropod abundance (Eckert et al., 2006; Veres et al., 2010).

O. nubilalis damage was assessed before harvest by forming two sub-plots of 20 m x 2 maize rows in the centre of each plot where the total maize plants and number of plants broken above and below the ear were recorded. The percentage of damaged ears was also assessed by randomly choosing 10 plants from each sub-plot and visually assessing their ears for percentage surface damage using a scale of 1–7 that corresponds to: 1 = 0%, 2 = 1–3%, 3 = 4–10%, 4 = 11–25%, 5 = 26–50%, 6 = 51–75%, 7 > 75% (Razinger et al., 2016).