Crop Protection xxx (2016) 1–8

Contents lists available at ScienceDirect

Crop Protection

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

# Risk assessment of soil-pest damage to grain maize in Europe within the framework of Integrated Pest Management

Lorenzo Furlan [a,*], Vasileios P. Vasileiadis [b], Francesca Chiarini [a], Hilfred Huiting [c], Robert Leskovšek [d], Jaka Razinger [d], Imre J. Holb [e,f], Erica Sartori [b], Gregor Urek [d], Arnd Verschwele [g], Isadora Benvegnù [a], Maurizio Sattin [b]

[a] Veneto Agricoltura, 35020 Legnaro (PD), Italy
[b] National Research Council (CNR), Institute of Agro-Environmental and Forest Biology, 35020 Legnaro (PD), Italy
[c] Applied Plant Research, Wageningen University, Lelystad, The Netherlands
[d] Agricultural Institute of Slovenia, Ljubljana, Slovenia
[e] University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management, Debrecen, Hungary
[f] Plant Protection Institute, Centre for Agricultural Research, Hungarian Academy of Sciences, Budapest, Hungary
[g] Julius Kühn-Institut, Federal Research Centre for Cultivated Plants, Braunschweig, Germany

A R T I C L E I N F O

*Article history:*
Received 5 August 2016
Received in revised form
20 November 2016
Accepted 21 November 2016
Available online xxx

*Keywords:*
Wireworms
Soil-pests
IPM
Maize
Soil insecticides
Damage risk factors
*Agriotes*

A B S T R A C T

The management of soil-pests relies largely on conventional insecticides. Within the framework of the EU's PURE project, data were collected to assess the risk of soil-pest damage to grain maize in Europe in order to implement Integrated Pest Management (IPM) of soil-pests in a more practical and sustainable manner, thus optimizing the use of soil insecticides (in-furrow or as seed-dressing) at sowing. Plant density and soil-pest damage to maize seeds and/or plants during the growing season were determined in fields with no or some risk factors. Risk assessment on a sample of sixteen experimental sites (a total of 109.95 ha of maize) located in five European countries (Germany, Hungary, Italy, Slovenia and the Netherlands) from 2011 to 2014 showed a low risk of soil-pest damage to maize. In all fields, wireworms (*Agriotes* spp. larvae) caused 99.5%–100% of the plant damage, meaning that damage by other soil-pests was negligible. The fields studied were divided into two groups: those with no risk and those with risk factors. According to previous research, the risk factors were *Agriotes brevis* Candeze and *Agriotes sordidus* Illiger as prevalent damaging species, soil Organic Matter content over 5%, rotation including meadows and/or double crops, as well as surrounding landscape being mainly meadows, uncultivated grass and double crops, cover crops, and poor drainage. In the fields with no risk factors, wireworm plant damage (mainly holes in the collar causing central leaf wilting) never exceeded 15%, a threshold value for potential yield reduction. Furthermore, plant damage was much lower or even negligible in the vast majority of the fields (i.e. over 90% of fields had less than 5% wireworm damage to maize plants). Risk factors, such as rotation including meadows and/or double crops, led to the percentage of cultivated land with significant wireworm plant damage being even lower than predicted (8.7% instead of 14.7%) and almost 50% of that predicted for the whole sample (2.7% instead of 4.9%). In the few cases where plant damage was higher than 15%, yield was not affected when untreated strips were compared with strips treated with soil insecticides. In all trials, the soil insecticide Tefluthrin did not significantly increase the density of healthy maize plants or grain yield. In more than 99% of cases, no economic damage to maize by soil-pests was recorded. These results demonstrate that the occurrence of risk factors may increase the risk of wireworm damage to maize crops, while the probability of damage to a field with no risk factors is always very low (less than 1%). This highlights the importance of integrating risk assessment of soil-pest damage to maize into IPM strategies, which would include: i) an “area-wide” risk assessment evaluating the possible presence of risk factors, including click beetle population monitoring with pheromone traps, and ii) “complementary field monitoring” with bait traps where risk assessment has identified the presence of risk factors. In fields with no risk factors, treating maize with soil insecticides

* Corresponding author.
*E-mail address:* lorenzo.furlan@venetoagricoltura.org (L. Furlan).

http://dx.doi.org/10.1016/j.cropro.2016.11.029

was found to be pointless. Therefore, IPM strategies in maize that include risk assessment of soil-pest damage may lead to a significant reduction in soil insecticides use and, consequently, to a reduction in environmental impact.



## 1. Introduction

European Directive 128/2009/EC on the sustainable use of pesticides made it mandatory to apply the principles of Integrated Pest Management (IPM) in the European Union from 1st January 2014 (Barzman et al., 2015). The first IPM principle recommends the prevention and suppression of harmful organisms by the adoption of crop rotation and other preventive agronomic strategies that may reduce the risk of pest outbreaks and the need for a plant protection measure. In order to comply with Directive 128/2009/EC, farmers should apply the following principles before deciding whether to treat their crops with chemicals: i) chemical treatment may be carried out only when and where adequate methods and tools, including field observations and scientifically sound warning, forecasting and early diagnosis systems, have established that levels of harmful organisms are above pre-determined economic thresholds for crop protection; ii) when economic thresholds are exceeded, agronomic solutions, biological control, physical treatment, or any other non-chemical pest-control method should be considered as a replacement for chemical treatment whenever available and feasible; and iii) when economic thresholds are exceeded and no agronomic solutions, biological control, physical treatment or any other non-chemical pest control methods are available, chemical treatment should be selected from options that pose the lowest risk to the environment and human health, and its use should be limited over space and time so that the risk of pest resistance is minimized (Barzman et al., 2015).

Although IPM strategies are commonly used in many European cropping systems, such as orchards and vineyards, they have not been widely adopted in annual cropping systems, including maize (Furlan et al., 2013; Furlan and Kreutzweiser, 2015). As a consequence, current soil-pest control is mainly pesticide-based and soil insecticides, such as neonicotinoids, are still widely used in maize, causing a negative impact on the environment (van der Sluijs et al., 2015). As arable farming often has limited resources in terms of income, labour and technology, special effort is needed to ensure that the objectives of Directive 128/2009/EC are met from the outset. Therefore, to encourage the development and adoption of IPM in arable crops, there is a need for: i) low-cost strategies; ii) time-efficiency; and iii) financially and environmentally sustainable pesticides or other pest management methods. Until recently, the adoption of IPM strategies against soil-pests has been extremely difficult due to a lack of reliable information on the key aspects of the pest species concerned, such as distribution and life cycles (Furlan, 2005). In order to implement IPM at a low cost, it is important to establish the risk factors that cause an increase in wireworm population levels and the consequent damage, given that wireworms are the most harmful soil-pest at European level (Furlan, 2005). The main species of wireworms belong to the genus *Agriotes* and include *A. brevis* Candeze, *A. lineatus* L., *A. litigiosus* Rossi, *A. obscurus* L., *A. sordidus* Illiger, *A. sputator* L. and *A. ustulatus* Schäller (Furlan, 2005). Information about the distribution of some species is already available, with *A. obscurus*, *A. lineatus* and *A. sputator* known to be the most serious threats in central northern Europe, and *A. litigiosus* the most serious in south-eastern Europe (Furlan et al., 2001a; Furlan and Tóth, 2007). Detailed information about life cycles is currently available for the following species: *A. litigiosus* (Kosmacevskij, 1955), *A. obscurus* (Sufyan et al., 2014), *A. sordidus* (Furlan, 2004), and *A. ustulatus* (Furlan, 1998).

In order to exploit available information and enable the adoption of IPM in European grain-maize-based cropping systems, a working group was formed within the European Union's PURE project. Various "on-station" surveys were conducted in five European countries from 2011 to 2014 to investigate two IPM levels in maize compared with conventional management. "On-farm" surveys were also conducted to investigate individual IPM tools in maize against major pests (Vasileiadis et al., 2015, 2016; Razinger et al., 2016). Only some of these surveys studied the effect of soil insecticide use on maize, whereas the majority of surveys conducted by this working group contributed the data needed to perform a risk assessment of soil-pest damage to maize, as per the procedures devised by Furlan et al. (2016).

The main aims of the present study were to: i) provide an initial estimate of soil-pest risk damage to maize at European level; ii) set up an effective, practical, environmentally and economically sustainable IPM strategy that includes risk assessment of soil-pests; and iii) assess the efficacy of a commonly used soil insecticide on maize crops.

## 2. Materials and methods

### 2.1. Experimental sites, design and crop management

In order to evaluate the risk of soil-pest damage to maize, assessments of plant damage, soil-pest presence and agronomic characteristics were conducted on sixteen experimental sites from 2011 to 2014 as part of the EU's PURE project in three of Europe's major grain-maize growing regions: southern Europe (Italy), eastern Europe (Hungary and Slovenia) and central Europe (Germany). An "on-station" experiment was also conducted in the Netherlands, which is more suited to silage maize. Thirteen experimental sites in the five countries included three large "on-farm" fields of ca. 1 ha. Each field was designated with a different management method: i) CON = currently used conventional approach; ii) WEED = IPM approach for weed management; and iii) ECB = IPM of the European Corn Borer (*Ostrinia nubilalis* Hübner, Razinger et al., 2016; Vasileiadis et al., 2015). Three additional sites hosted "on-station" trials with 300 $m^2$ plots and included three treatments (two without soil insecticides) repeated three times in a randomized block layout. The experimental sites and their distribution are reported in Table 1 and Fig. 1. The three main grain-maize producing regions selected for these surveys represent the wide range of climatic and soil conditions in Europe (Vasileiadis et al., 2015, 2016; Razinger et al., 2016). Northern Italy (five "on-farm" surveys and one "on-station") represented southern European conditions, where the average characteristics are medium-heavy soils, relatively cold winters and warm-hot summers, medium-high rainfall or irrigation, and high grain-yield potential. Southern Germany (two "on-farm" surveys) represented central European conditions with cold winters and mild-warm summers, medium-high rainfall, and medium-high grain-yield potential. Central Slovenia (two "on-farm" surveys) represented eastern European conditions with cold winters and warm summers, medium-high rainfall during the maize-growing season, generally no irrigation

Please cite this article in press as: Furlan, L., et al., Risk assessment of soil-pest damage to grain maize in Europe within the framework of Integrated Pest Management, Crop Protection (2016), http://dx.doi.org/10.1016/j.cropro.2016.11.029