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Comparative activity of agrochemical treatments on mycotoxin levels with regard to corn borers and *Fusarium* mycoflora in maize (*Zea mays* L.) fields

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ABSTRACT

Field trials were carried out in nine areas located in France during 2004, 2005 and 2006 to study the control of *Lepidoptera* caterpillars by agrochemical treatments and their consequences on *Fusarium* spp. mycoflora and mycotoxin levels. Treatments involved either an insecticide or an insecticide–fungicide association. Two species of maize borers: *Ostrinia nubilalis* Hübner [Lepidoptera: Crambidae] and *Sesamia nonagrioides* Lefebvre [Lepidoptera: Noctuidae], were monitored. Although the insect populations were controlled by agrochemicals, there was no reduction in *Fusarium* spp. mycoflora. Conversely a significant reduction of mycotoxin (trichothecenes, fumonisins and zearalenone) levels resulted from insecticide treatment. These experiments and results are discussed regarding the biology of maize borers and relationships with *Fusarium* spp.

1. Introduction

Among the major pests of maize (*Zea mays* L.) occurring currently in France, the European maize (corn) borer (ECB) *Ostrinia nubilalis* Hübner [Lepidoptera: Crambidae] is the most damaging insect (Agusti et al., 2005), followed by the maize (corn) stalk borer (CSB) *Sesamia nonagrioides* Lefebvre [Lepidoptera: Noctuidae] (Albajes et al., 2002), way ahead of the other borers *Heliothis armigera* Hübner [Lepidoptera: Noctuidae] and *Mythimna unipunctata* Haworth [Lepidoptera: Noctuidae]. *O. nubilalis* occurs throughout the country although *S. nonagrioides* is essentially observed in the South of France. *O. nubilalis* is a very cosmopolitan insect occurring on about 223 plants (Lewis, 1975), with five larval instars. According to the location, it has one generation per year (monovoltinism) in NorthEastern France, or two generations, exceptionally three (multivoltinism) in the South. *S. nonagrioides* is considered less damaging. It has seven larval instars, but is strictly multivoltine with two generations per year in SouthWestern France (Delos et al., 2007). These two borers are responsible for 5–27% loss in crops (up to 80% with high proliferation) (Krattiger, 1997). Moreover, these two pests are considered an aggravating factor for ear rot infection, because of the presence of mycotoxins at harvest. Maize crop quality was affected qualitatively and quantitatively (Dowd and Munkvold, 1999; Sobek and Munkvold, 1999).

Several studies have established that the control of *Lepidoptera* borers affected mycotoxin levels within harvested maize. This was demonstrated by methods such as prophylaxis (Almaa et al., 2005), biological control with parasitoïds (Dowd, 2000) and genetic control involving GMO *Bt* technology (Munkvold et al., 1999; Schaafsma et al., 2002; Dowd, 2003). Our work focussed on an

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evaluation in a comparative study of the efficiency of chemical pesticide treatments on insect populations, *Fusarium* spp. mycoflora at harvest and mycotoxin levels within maize kernels.

These experiments involved two kinds of treatments: an insecticide alone, and an insecticide with a fungicide. The aim of the treatments was to see if the chemical control of *Lepidoptera* by an insecticide decreased mycotoxin levels in the maize, and if the association of insecticide plus fungicide was synergistic. In a previous work on maize it was shown that the fungicide treatment alone was inefficient (Weissenberger, unpublished).

2. Materials and methods

2.1. Field trials

Experiments were carried out by the "Services Régionaux de la Protection des Végétaux (SRPV)" of the French Ministry of Agriculture and the "Fédérations Régionales de Défense contre les Organismes Nuisibles (FREDON)" in nine fields located all over France: Wiwersheim, Hurtigheim and Moyenvic (North East France), Courpiac, Thure and Castelnaudary (South West France), and Laloye, Saint Genes du Retz and Charmes (Middle and East France) (Fig. 1). These trials were located in monovoltine as well as multivoltine areas. According to the geographic localization and the climatic conditions, especially temperature average (Table 2), three areas could be distinguished: North East, Middle East and South-Western including three trial locations in each area (Fig. 1, Table 1). Experimental sites were characterized by an intensive maize production. The maize cultivars involved in these trials are representative of the cultivars cultivated within the areas chosen for the field trials (Table 1). The choice of these cultivars was guided by the duration of crop development (earliness factor) in such a way that the harvest occurred in all trials simultaneously. Regardless of the location of the trials, maize reached maturity in about 150 days.

Field trials were carried out under natural conditions during the summers of 2004, 2005 and 2006. Fields were seeded over a period of 20 days beginning April 15, 2004, 2005 and 2006. Temperatures and recorded rainfall during the bioassays were, respectively, between 16–20 °C, and 246–519 mm (Table 2). The schedule for treatments was determined according to insect monitoring in the field. Monitoring within a 30-day period between 15 April and 15 May with regard to trial's latitude, began by collecting maize borer larvae within the field. This was in order to rear them and to observe their growth to determine when they were going to change into imagos and fly. If the level of infestation in the trial field was not significant, the insects were collected in a neighboring field located in a circle of 2 km diameter, which represented the longest

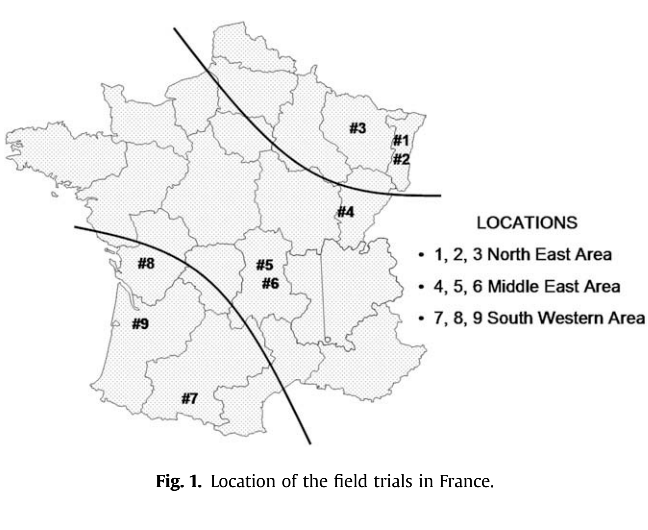

Fig. 1. Location of the field trials in France.

Table 1
Trials: geographical locations, maize cultivars and block number.

Area	Locality	Meteorological station	Zip Code	Cultivar	Company
North East	1. Wiwersheim	Wiwersheim	67370	Moncada	Syngenta Seeds
	2. Hurtigheim	Wiwersheim	67117	Magistral	KWS Saat AG
	3. Moyenvic	Château Salins	57630	DK312	Dekalb Company
Middle East	1. Laloye	Tavaux	39380	Pollen	MaïsAdour
	2. Charmes	Cintrat	03800	DK315	Dekalb Company
	3. Saint Genes du Retz	Cintrat	03380	DK315	Dekalb Company
South Western	1. Castelnaudary	Castelnaudary	11400	KWS1393	KWS Maïs France
	2. Thure	Marigny Brizay	86380	DK315	Dekalb Company
	3. Courpiac	Rauzan	33760	DK532	Dekalb Company

distance an ECB can fly. The insect rearing was supervised by a specialized network ("réseaux d'Alertes"®) under the control of French Ministry of Agriculture covering the entire French territory. They counted larvae, pupae and imagos in order to indicate to farmers the best period for treating the fields.

In monovoltine areas colonized by ECB only, the ECB caterpillars came out of winter diapause at the end of May–beginning of June, and pupation occurred 2 weeks later under the effect of the longer daylight and the increase in humidity level in the field (Eychenne, 1997). This step took 3 weeks. A temperature of 13 °C is regarded to be the thermal threshold for insect development (Guennelon, 1972). At the end of June and beginning of July, the male imagos hatched first and then the females (protandry) which attracted the males by sexual pheromones. After fertilization they laid synovogenic eggs (Stengel, 1982). The latter hatched into larvae which developed from the black head stage to L5 in 40–50 days. Caterpillars then prepared to enter winter diapause. In multivoltine areas colonized by both ECB and CSB, the ECB caterpillars came out of winter diapause in April–beginning of May and pupation occurred 2 weeks later (Eychenne, 1997). Over a period of 2 weeks, the imagos hatched at the end of May and beginning of June. The females oviposited and larvae developed until L5. A new pupation took place and a second generation of imagos emerged from the end of July until middle of August. From these imagos, eggs, then larvae, were formed in a second cycle of development until the caterpillar entered winter diapause (Stengel and Schubert, 1982). The rearing of these insects from the field made possible a precise monitoring of their reproductive cycle. It allowed the period when 50% of imagos emerged (emergence peak) to be determined. It was at this point that the insecticide should be applied on ECB for maximum efficiency. In the field infested by both ECB and CSB, the ECB emergence peak matches with CSB L3 which is the step more susceptible to insecticide (Eychenne, 1997).

Two kinds of pesticides were used. The insecticide deltamethrine (20 g ha^{-1}) was sprayed at the time of each emergence peak in the trials. The fungicide tebuconazole (250 g ha^{-1}) was sprayed in association with the insecticide at the time of maize female flowering. Deltamethrine ($C_{22}H_{19}Br_2NO_3$, CAS RN 52918-63-5) like all pyrethroids interfered with the sodium channels so that no transmission of nerve impulses could take place, whereas tebuconazole ($C_{16}H_{22}ClN_3O$, CAS RN 107534-96-3) is an inhibitor of the biosynthesis of sterols (ergosterol) focused on C14-demethylase (Tomlin, 2003).

Bioassays were arranged in a randomized block design. Each assay involved four blocks (Fig. 2) of surface area of 120 m^2 for each