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Effects of agrochemical treatments on the occurrence of Fusarium ear rot and fumonisin contamination of maize in Southern Italy

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ABSTRACT

The efficacy of agrochemical treatments, based on three different fungicides combined with an insecticide, was tested in southern Italy for two years on three maize hybrids to control Fusarium ear rot of maize and the accumulation in the maize kernels of the carcinogenic mycotoxins fumonisins. Insect damage incidence and severity, disease incidence and severity, identification of *Fusarium* species and levels of fumonisin contamination in kernels were determined. Field trials showed in both years that natural colonization of maize kernels by the fumonisin producing species *Fusarium proliferatum* and *F. verticillioides* (up to 81.5 and 26.5%, respectively) and total fumonisin contamination (up to 68.2 $\mu g\,g^{-1}$) were highly severe. For all hybrids and in both years, the treatment with the insecticide applied alone reduced the insect damage severity consistently and the content of fumonisins in the kernel only in half of the cases, whereas fungicide treatments applied in combination with the insecticide showed a further significant reduction of fumonisin contamination in the three hybrids and in both years.

1. Introduction

Fusarium ear rot is a severe and worldwide disease of maize (*Zea mays* L.) that causes significant yield and economic losses. Among the *Fusarium* species involved in the disease, *F. proliferatum* (teleomorph *Gibberella intermedia*) and *F. verticillioides* (teleomorph *G. moniliformis*), two species belonging to the *G. fujikuroi* complex (Leslie and Summerel, 2006), are frequently isolated (Logrieco et al., 1995; Munkvold et al., 1998). Both species produce the carcinogenic mycotoxins fumonisins (IARC, 2002), in particular fumonisin B_1 (FB_1), B_2 (FB_2) and B_3 (FB_3) that can accumulate in maize kernels, generally, at a level higher for FB_1 compared to FB_2 and/or FB_3 (Pascale et al., 2002; Desjardins, 2006). Fumonisins are related to a wide range of animal and human health problems, being epidemiologically associated with human esophageal cancer and neural tube defect, and causing leukoencephalomalacia in equine, pulmonary edema in swine, nephrotoxicity and hepatotoxicity in several animals (Desjardins, 2006).

Although the occurrence of fumonisins in maize in Italy has been mainly documented in the northern regions (Ritieni et al., 1997; Battilani et al., 2008), little information is available on the maize cultivated in central-southern Italy. This area is characterized by warm, dry weather and drought stress during the grain-filling period, conditions that represent key factors for both Fusarium ear rot and fumonisin contamination (Miller, 2001; Rossi et al., 2009). Besides climate parameters, several factors may affect Fusarium ear rot of maize and fumonisin contamination and must be considered, such as host genotype, insect injuries to kernels, cultural practices and pest management strategy (Miller, 2001; Munkvold, 2003; Folcher et al., 2009).

Both *F. proliferatum* and *F. verticillioides* can infect all parts of the maize plant (root, stalk, silks, cob, kernels) during the whole cropping season and can survive on maize crop residues for several years as a primary inoculum source for the infections on the subsequent maize crop (Cotten and Munkvold, 1998; Munkvold, 2003; Naef and Défago, 2006; Rossi et al., 2009).

These pathogens can infect maize ears mainly through three different ways: seeds, silks and wounds caused by insects and birds (Munkvold et al., 1997). Furthermore, although the role and importance of the pathways of pathogen penetration in maize kernels is not yet clear, recent research has further elucidated the mechanism of penetration of the pathogen through the silks (Duncan and Howard, 2010) and has also shown a significant production of airborne conidia of *F. verticillioides* from maize stalks during the silk emission in open field (Rossi et al., 2009). Therefore, inappropriate management of maize crop residues, especially in areas where maize is grown in short rotation or as continuous crop, can cause a high production of airborne spores as potential inoculum for silk

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infection (Rossi et al., 2009; Duncan and Howard, 2010). In addition, however, a high correlation has also been found between the level of insect damage and Fusarium ear rot severity (Munkvold, 2003). In this regard, significant mycotoxin reductions were obtained by a suitable agrochemical insect control strategy combined with other field practices such as early sowing date, appropriate hybrid selection for each specific area, proper fertilization, and long crop rotation (Munkvold, 2003; Folcher et al., 2009). On the other hand, our recent investigations carried out in southern Italy on different maize hybrids and under natural infection, recorded variable and, in some cases, high Fusarium ear rot severity and fumonisin kernel contamination also in fields treated with insecticide (De Curtis et al., 2008). The aim of this study was to evaluate the efficacy of three fungicides combined with an insecticide in reducing Fusarium ear rot severity and fumonisin kernel contamination under natural conditions.

Fig. 1. Symptoms of Fusarium ear root on maize kernels without any evident insect damage.

2. Materials and methods

2.1. Field trials

Field experiments were carried out under natural conditions, during two consecutive growing seasons 2005 and 2006, at the Experimental Farm of the Agricultural Educational Institute “San Pardo” of Larino, CB, Italy (159 m, altitude; 41°50′N, 14°57′E). The experiments were conducted on the same field in both years, where, in the previous two years, 2003 and 2004, winter wheat and maize have been cultivated, respectively. Three hybrids typically cultivated in this area were selected: two belong to the FAO maturity class 300 [NK Surtep (105 days) and NK Cisko (110 days)] and one to the maturity class 400 [NK Stella (115 days)] – Syngenta seeds (Cremona, Italy).

The chemical applications were performed in four treatments and based on commercial synthetic fungicides combined with an insecticide treatment as follows:

(1) fungicide Folicur WG® [active ingredient (a.i.): 25% tebuconazole] manufactured by Bayer CropScience (Milan, Italy), at the rate of 1.0 kg ha^{-1}, combined to the insecticide Karate® (a.i.: 2.5% lambda-cyhalothrin) manufactured by Syngenta Crop Protection (Milan, Italy);
(2) fungicide Eminent 40 EW® (a.i.: 3.85% tetraconazole) manufactured by Isagro Italia (Milan, Italy), at the rate of 3.0 L ha^{-1} and combined to the insecticide Karate®;
(3) fungicide Tiptor S® (a.i.: 32.3 and 4.3% prochloraz + cyproconazole, respectively) manufactured by Syngenta Crop Protection, at the rate of 1.25 L ha^{-1}, combined to the insecticide Karate®.
(4) insecticide Karate®, at the rate of 0.5 kg ha^{-1}.

The four treatments were compared to the untreated control. The experimental design was a completely randomized block with three replicates (plots) for each treatment and each maize hybrid. Each experimental plot was 20 m × 6 m, with a total of approximately 800 plants for each plot. Two rows of maize plants were used as a border, along the whole plot. All the soil and plant management practices, as well as weed control and irrigation, were conducted according to the Good Agricultural Practices applied in Italy.

Fungicides were applied both to soil and foliage two times: 3 days after complete silk emission (stage 65 of the BBCH scale) and at early dough (stage 83 of the BBCH scale) growth stages; the growth stages were monitored daily according to the BBCH scale (Weber and Bleiholder, 1990). Fungicides were distributed to the soil by means of the drip irrigation system as reported by De Curtis et al. (2010). Treatments to the foliage were carried out by spraying 600 L ha^{-1} of the fungicide suspension using a self-propelled sprayer (mod. IRIS, BARGAM® S.P.A., Imola, Italy) equipped with 24 fan nozzles (model, Turbo TwinJet® AITTJ60) at a pressure of 300 kPa and an operation speed of 5 km h^{-1}. The insecticide was applied only to the foliage and aimed against the corn stalk borer (CSB) *Sesamia nonagrioides* Lefèbvre (Lepidoptera, Noctuidae), the main maize insect pest in the experimental area; timing of applications was chosen by monitoring insect flight activity by means of oil traps (Germinara et al., 2007) baited with rubber septum dispensers each containing 1 mg of sex attractants: (Z)-11-hexadecenyl-acetate, (Z)-hexacedenol, (Z)-11-hexadecenal and dodecanyl-acetate in the ratio of 9:1:1:1 (Novapher, San Donato Milanese, Milan, Italy) (Germinara et al., 2005). The dispensers were replaced every 30 days. Adults captured were collected and counted every 3 days. The insecticide applications were carried out after 5 days of the CSB flight peak spraying 600 L ha^{-1} of the insecticide suspension by means of a self-propelled sprayer equipped as mentioned above.

2.2. Disease ratings

The Fusarium ear rot incidence and severity was evaluated on all the ears of fifty maize plants randomly collected by handpicking at the centre of each plot, at the harvest phenological stage (99 of the BBCH scale). The Fusarium ear rot incidence was calculated as the percentage of ears with clear symptoms of the disease, while the Fusarium ear rot severity was calculated as the percentage of kernels per ear with symptoms of the disease. To this end, the ears were visually evaluated for Fusarium ear rot by using a seven-class disease severity rating scale, proposed by Reid et al. (1999), based on the estimation of ear rot as the percentage of kernels visibly damaged as follows: 1 = 0%, 2 = 1–3%, 3 = 4–10%, 4 = 11–25%, 5 = 26–50%, 6 = 51–75%, and 7 > 75% of kernels with visible symptoms of infection such as rot, discolored kernels and mycelia growth (Fig. 1), as reported by Reid et al. (1999). The Fusarium ear rot severity was calculated according to the McKinney formula (19): Fusarium ear rot severity = $\Sigma[(n \times c)/N \times C] \times 100$, where n is the number of ears per class, c the number of classes, N is the total number of ears assessed per plot and C is the number of highest class (=7). The Fusarium ear rot incidence was calculated by evaluating the percentage of the ears visibly showing the symptoms of Fusarium ear rot (discolored kernels, mycelia growth, etc.) on the total number of ears sampled.