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Efficacy of strobilurins and mixtures with DMI fungicides in controlling powdery mildew in field-grown sugar beet

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Abstract

Powdery mildew, caused by *Erysiphe betae*, is a major foliar disease of sugar beet in areas with dry and relatively warm weather, worldwide. Four fungicides—azoxystrobin, kresoxim-methyl, pyraclostrobin and trifloxystrobin—were evaluated, at three application doses (100, 150 and 200 g a.i. ha^{-1}), for control of the disease. Trifloxystrobin and kresoxim-methyl were the most effective with control efficacy values higher than 94% compared to the control treatment even when applied at the lowest application dose of 100 g a.i. ha^{-1}. Azoxystrobin and pyraclostrobin had poor to modest activity against the disease even at the highest application dose. Disease severity, in terms of area under the disease progress curve values, was significantly correlated with decreased root yield, while no significant correlation existed between disease severity and sugar content of the roots or sucrose yield. In addition, the efficacy of tank mixtures of each of the strobilurin fungicides applied at 100 g a.i. ha^{-1} with either of two sterol demethylation-inhibiting fungicides, difenoconazole and cyproconazole applied at 62.5 and 25 g a.i. ha^{-1}, respectively, was evaluated. The mixtures of azoxystrobin and pyraclostrobin with either difenoconazole or cyproconazole provided better control efficacy compared to single applications of each mixture partner, while the tank mixtures of trifloxystrobin and kresoxim-methyl with either difenoconazole or cyproconazole provided better control efficacy compared to single applications of difenoconazole or cyproconazole and similar control efficacy compared to that obtained by single applications of the strobilurin fungicides.

Keywords: Azoxystrobin; Difenoconazole; *Erysiphe betae*; Kresoxim-methyl; Pyraclostrobin; Trifloxystrobin

1. Introduction

Sugar beet powdery mildew, caused by *Erysiphe betae*, is among the most important foliar diseases of sugar beet, worldwide. Severe attacks of powdery mildew occur in southern Europe, in northwestern Europe and in North America (Asher and Williams, 1991; Byford, 1996; Ruppel et al., 1975). Under conditions of high disease pressure and in the absence of control measures, reduction of root yield may exceed 22% and that of root sucrose content may exceed 13% (Forster, 1979; Hills et al., 1975). Dry conditions and relatively high temperatures favor disease development. In Greece, powdery mildew epidemics usually start during early June in areas of Thessaly and Central Macedonia, while in Western Macedonia and Thrace disease epidemics start in late July.

Control of the disease is mainly achieved by applications of broad spectrum systemic fungicides, mainly belonging to the ergosterol biosynthesis inhibitors (EBIs), also active against Cercospora leaf-spot caused by *Cercospora beticola* or by applications of the protective fungicide, sulfur, which is powdery mildew specific (Asher and Williams 1996; Byford, 1996; Hills et al., 1985). In Greece, where the most important foliar disease of sugar beet is Cercospora leaf-spot, sugar beet fields are treated 3–6 times a year with fungicides to control the two main foliar diseases. To control powdery mildew, during the early fungicide spray applications, sulfur is added to a tank mixture of maneb and chlorothalonil. After July, control of the disease is based on applications of the morpholine fungicide fenpropimorph and sterol demethylation-inhibiting fungicides

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(DMIs), such as difenoconazole, flutriafol, cyproconazole and tetraconazole, which are active against both pathogens. However, development of resistance to DMIs by *C. beticola* (Karaoglanidis et al., 2002, 2003) requires the implementation of fungicide spray application programs that delay the evolution of resistance to DMIs by minimizing the selection pressure on the fungal population. Consequently, the need for introduction into the spray program of new compounds that possess modes of action different from that of DMIs and are equally effective against both *C. beticola* and *E. betae*, is obvious.

Strobilurin fungicides constitute a relatively new fungicide class, developed from natural fungicidal derivatives, such as strobilurin A, oudemansin A and myxothiazol A (Bartlett et al., 2002). The mechanism of action of strobilurins is inhibition of mitochondrial respiration by binding at the Q_0 site of cytochrome *b*, thus blocking the electron transport between cytochrome *b* and cytochrome c_1, leading to a disruption of the energy cycle (Anke, 1995; Bartlett et al., 2002; Gisi et al., 2000). Compounds belonging to the strobilurins include kresoxim-methyl (Ammermann et al., 1992), azoxystrobin (Godwin et al., 1992), metaminostrobin (Hayase et al., 1995), trifloxystrobin (Margot et al., 1998), fenamidone (Mercer et al., 1998), picoxystrobin (Godwin et al., 2000), pyraclostrobin (Ammermann et al., 2000), famoxadone (Sternberg et al., 2001) and fluoxastrobin (Haeuser-Hahn et al., 2002). Strobilurins possesses an extremely broad spectrum of activity including *Ascomycetes*, *Deuteromycetes*, *Basidiomycetes* and *Oomycetes* (Ammermann et al., 1992; Margot et al., 1998; Ypema and Gold, 1999; Wong and Wilcox, 2001). However, despite the importance of *E. betae* as foliar pathogen of sugar beet and the long tradition of its control with fungicides, there is only one report regarding the modest efficacy of azoxystrobin against the pathogen under controlled environmental conditions (Anesiadis et al., 2003).

The current study was conducted in order to: (a) test the efficacy of four strobilurin fungicides, azoxystrobin, trifloxystrobin, pyraclostrobin and kresoxim-methyl, against the pathogen under field conditions and (b) test the efficacy of mixtures of these fungicides with DMIs under field conditions.

2. Materials and methods

2.1. Plant material

The experiments were conducted during 2003 and 2004, in the Amyndeon area, Western Macedonia, Greece. Two adjacent fields were selected for the experiments of each year. In this area, powdery mildew is the most important foliar disease of sugar beet due to the relatively warm and dry summers prevailing in the region. Usually, 3–4 fungicide spray applications per growing season are required for satisfactory disease control. The selected fields were previously cropped to corn and received a pre-planting fertilization of 700 kg ha^{-1} 20N–8P–10K, during both years of the study.

2.2. Experimental design

The sugar beet cultivar selected for the experiment was "Rival", a cultivar sensitive to powdery mildew. Field plots consisted of six 11-m rows spaced 45 cm apart and arranged in a randomized block design with four replicates per treatment. In order to minimize, as much as possible, the risk of interplot-interference, the plots were separated from each other by a 4 m buffer zone which remained free of sugar beet plants. Plants were seeded, with a commercial planter, on 27 March 2003 and on 20 March 2004. Field plots were treated with recommended herbicides and insecticides as needed. During the cultivation period, plants were irrigated five times in 2003 and six times in 2004, receiving on average 30–40 mm of water per irrigation.

2.3. Fungicides

Fungicides used in the study were commercial formulations of trifloxystrobin (Flint 50 WG, Bayer Cropscience Hellas), pyraclostrobin (F-500 25 EC, BASF Hellas), kresoxim-methyl (Strobby 50 WG, BASF Hellas), azoxystrobin (Ortiva 25 SC, Syngenta Hellas), difenoconazole (Score 25 EC, Syngenta Hellas), cyproconazole (Caddy 10 SL, Bayer Cropscience Hellas) and sulfur (Thiovit 80 WG, Syngenta Hellas). The fungicides were applied either alone or in mixtures at several doses listed in the results tables.

2.4. Field trials

Spray applications were initiated before the appearance of any disease symptom on the plants, just after the "closing" of the rows and repeated at intervals of 15–20 days. In total, four spray applications per treatment were carried out. In 2003, the first application took place on 9 July, the second on 24 July, the third on 12 August and the fourth on 31 August. In 2004, the first spray application took place on 6 July, the second on 27 July, the third on 14 August and the fourth on 1 September. Fungicide solutions were applied using an AZO precision sprayer, at a volume of 0.41 per plot and a pressure of 400 kPa.

2.5. Disease assessment

For the assessment of powdery mildew severity, a six-category scale disease index suggested by Hills et al. (1980) was used. Scale categories indicated leaf area covered by fungus mycelium ($R_0 = 0\%$, $R_1 = 10\%$, $R_2 = 35\%$, $R_3 = 65\%$, $R_4 = 90\%$, $R_5 = 100\%$). This rating system has the advantage of more comfortable visual discrimination resulting in less error in estimating percent disease than when disease percentages are used directly (Hills et al., 1980). Area under the disease progress curve (AUDPC)