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Efficacy and timing of application of fungicides for plum rust control in Turkey

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ABSTRACT

Little information is available regarding the efficacy and timing of modern fungicides for the control of plum rust. In this study, modern fungicides, including triazoles, strobilurins, and benzimidazoles, and a classic fungicide (chlorothalonil) were tested under both greenhouse and field experiments. Excellent disease control was obtained by the pre-inoculation application of all fungicides in the greenhouse experiments. However, only triazoles (tebuconazole, difenoconazole, flusilazole and hexaconazole) were effective when applied up to 6 or 7 days after inoculation. Unexpectedly, strobilurins (azoxystrobin and trifloxystrobin) and benzimidazoles (thiophanate-methyl and carbendazim) were not effective when applied at any time after inoculation. In field experiments, early-season fungicide applications effectively inhibited primary infections; however, these applications provided no apparent benefit in preventing secondary infections and premature leaf fall later in the season. All fungicides provided better control over the season and significantly reduced premature leaf fall when applied immediately after rust pustules (uredinia) were first observed. It is suggested that all fungicides tested in this study can be used for plum rust control. Disease monitoring data indicated that disease severity remained low throughout May but dramatically increased in early June. Mid-May is evidently the best time to initiate fungicide sprays against rust on plums; the spray should be applied before or when rust pustules are first observed and when rust is present at low severity.

1. Introduction

Plum rust, which is caused by *Tranzschelia discolor* f.sp. *domesticae* (Fckl.) Tranz. & Litv., is a common disease in many plum-producing countries (Laundon and Rainbow, 1998). In Western Turkey, the severity of plum rust has increased dramatically over the last decade (Erincik and Döken, 2010). The presence of highly susceptible plum varieties, as well as the widespread existence of the alternate host, *Anemone coronaria*, are considered the main factors affecting the high incidence of the disease in the region (Erincik and Döken, 2010; Özkul and Erincik, 2010).

The fungus attacks and invades mainly leaf tissue and causes angular yellow-orange spots on the upper surface and light brown to black pustules on the lower surface (Bertrand, 1995). When the pustule forms, the pathogen breaks epidermal cells and the cuticle layer on the leaves, causing uncontrolled and excessive water loss. Heavily infected trees can lose their leaves prematurely, even in the middle of the growing season (Özkul and Erincik, 2010). The defoliated trees usually develop new leaves, shoots and even flowers, thereby reducing fruit set and tree vigor for the following year (Bertrand, 1995).

Management options for plum rust are quite limited in Turkey for several reasons. Eradication of the alternate host, *A. coronaria*, is not feasible because it is widely distributed, especially in grasslands, and scrubs in hilly regions (Erincik and Döken, 2010). Growers reject the idea of growing rust-tolerant plum varieties instead of the susceptible varieties 'Papaz' and 'Bekiroğlu' because of the high market value of these two varieties. Chemical control is also limited because currently few fungicides have been registered for the disease.

In most countries, chemical control appears to be one of the most practical measures for managing plum rust (Kable et al., 1987a; Menniti and Pratella, 1992; Michailides and Ogawa, 1986; Reuveni, 2000; Sharma and Bhardwaj, 2001). In early reports, mancozeb, zineb, chlorothalonil, bitertanol, ziram and sulfur, which are the common classic protectant fungicides, have been reported

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as effectively controlling *T. discolor* (Kable et al., 1987a; Menniti and Pratella, 1992; Michailides and Ogawa, 1986). However, few reports have described the efficacy of modern fungicides against this disease (Kable et al., 1987b; Reuveni, 2000; Sharma and Bhardwaj, 2001).

In Turkey, the chemical control of plum rust has not been studied. Little information is available about the disease progression from which logical conclusions could be drawn regarding fungicide timing. The objectives of this study were: 1) to evaluate fungicides for their pre- and post-infection activity against plum rust under controlled conditions, 2) to determine the efficacy and timing of fungicide application for controlling plum rust in the field, and 3) to monitor the seasonal changes of plum rust severity in Western Turkey.

2. Materials and methods

2.1. Studies under controlled environment conditions

2.1.1. Pre-inoculation fungicide applications

The fungicides were selected to represent triazoles, strobilurins, benzimidazoles and a classic protectant fungicide class. The fungicides and the two experimental rates (the half- and full-rate) that were evaluated in the experiments were as follows (concentrations are expressed as the amount of active ingredient in 100 L of water): tebuconazole (Folicur 25 WP, Bayer Crop Science) at the rates of 5 and 10 g a.i.; hexaconazole (Bestwill 0.5 SC, Bioagro) at the rates of 1.25 and 2.5 ml a.i.; azoxystrobin (Quadris 0.25 SC, Syngenta) at the rates of 7.5 and 15 ml a.i.; thiophanate-methyl (Sumitop 70 WP, Sumitomo) at the rates of 24.5 and 49 g a.i.; and chlorothalonil (Casaro 50 SC, Agrobest) at the rates of 25 and 50 ml a.i. The fungicides were tested against two inoculum types (aeciospore and urediniospore) of *T. discolor* f.sp. *domesticae* that infect plums.

As experimental plants, one- or two-year-old grafted plum plants of the cultivar 'Papaz' were grown in plastic pots (10 L capacity). For the plant to gain homogeneous tissue, each plant was trained to at least four young shoots and allowed to grow until each shoot had at least 10 fully developed leaves. Aeciospore inoculum was collected from naturally infected *A. coronaria* leaves. Fungicide solutions were applied at the rates mentioned above to the plants using a hand sprayer until run-off. The plants were left to dry for 6 h before inoculation. Control plants were treated with water at the same amount as that used in the fungicide treatments. Except for the negative control, all plants were inoculated with the aeciospore suspension, which was adjusted to 1×10^5 spores/ml (Erincik and Döken, 2010). The plants were completely covered with moistened plastic bags and incubated in a growth chamber for 24 h at 24 °C under fluorescent lights with a 14 h photoperiod. At the end of the incubation period, the plants were moved to the greenhouse. On day 30 after inoculation, four shoots on each plant and 10 leaves on each shoot were evaluated visually for the presence of rust symptoms. The experimental design was completely randomized using four replications; each replication comprised one plant.

Another greenhouse trial was conducted to test the fungicides against an urediniospore inoculum. The test plants were maintained and grown as described above. Urediniospore inoculum was harvested from naturally infected plum leaves. Urediniospore suspension was prepared as described above for the aeciospore suspension. The further steps of the trial were performed using the same procedures as those described above.

2.1.2. Post-inoculation application studies

To evaluate the post-infection activity of the fungicides, spray treatments were conducted at 24, 48, 72, 96, 120, 144 and 168 h after inoculation. In the first experiment, tebuconazole, hexaconazole, azoxystrobin, and thiophanate-methyl (fungicides known as having either systemic or translaminar properties) were tested at the full rates. In addition to these fungicides, trifloxystrobin (Flint WG 50, Bayer Crop Science) was also tested at the rate of 15 g a.i./100 L^{-1}. In the second experiment, in addition to the fungicides tested in the first experiment (with the exception of hexaconazole), difenoconazole (Score 250 EC, Syngenta), flusilazole (Puch 40 EC, Du Pont) and carbendazim (Carbendazim 50 WPIMPA) were also tested at the rates of 2.5 ml, 2.0 ml, and 37.5 g a.i/100 L^{-1}, respectively. Inoculum preparation, inoculation, incubation and disease assessment were performed in the same way, as described above for the pre-inoculation studies.

2.2. Field studies

Field trials were conducted in a commercial plum orchard in Aydin Province in two successive years, 2009 and 2010. The experimental trees were 4- or 5-year-old trees of the variety 'Papaz', which is known to be very susceptible to plum rust (Erincik and Döken, 2010; Özkul and Erincik, 2010). Plant spacing was 10 × 10 m. In 2009, hexaconazole, azoxystrobin, thiophanate-methyl and chlorothalonil were used at the same rates as those described for the greenhouse studies. In the experiments conducted in 2010, hexaconazole was replaced with tebuconazole because hexaconazole had been banned for agricultural use by the Ministry of Agriculture of Turkey. Two different spray-timings, denoted PI and SI, were established based on the infection stages of *T. discolor* f.sp. *domesticae*. PI sprays were applied against primary infections and were applied twice, at leaf emergence and 10 days later. PI sprays were applied on April 6 and April 16 in 2009 and on March 26 and April 6 in 2010. SI sprays were arranged against secondary infections and were first applied when uredium structures became visible and then once again after 10 days. SI sprays were applied on June 5 and June 15 in 2009 and on May 14 and May 24 in 2010. Fungicides were applied using a 12-L hand-pressurized knapsack sprayer (Model:Osatu Star 16 Green, Goizper S. Coop. Antzuola, Spain), which had been calibrated to deliver the spray at 289 kPa through a conical nozzle until run-off. The experiments were conducted using a randomized complete block design with four blocks. Disease assessments were conducted 30 days after the last spraying. Ten shoots representing different sides of the tree were randomly selected, and 7 leaves on each selected shoot were evaluated for the disease. To determine the effect of the fungicide treatments on premature leaf fall later in the season, leaf fall was assessed by counting leaf scars on ten randomly selected shoots per tree in each plot in mid-season (July 15) of both years.

2.3. Monitoring of seasonal changes of plum rust severity

To evaluate seasonal changes in plum rust severity, naturally infected plum trees were monitored throughout the growing season in two successive years, 2009 and 2010. Four plum trees were selected at random in the orchard, and ten shoots per tree were marked for serial disease severity assessments. The trees were not treated with fungicide throughout the growing season. Starting from the first appearance of rust pustules, the number of rust pustules on each leaf was assessed weekly. In addition, the cumulative numbers of fallen leaves on each shoot were also recorded during the assessments. Monitoring was terminated when the percentage of fallen leaves reached over 95%.

2.4. Disease assessments and data analysis

In the disease assessments, a disease diagram having a scale with 8 levels (0 = no pustules; 1 = 1–10; 2 = 11–25; 3 = 26–50;