Crop Protection 93 (2017) 52–59

Contents lists available at ScienceDirect

Crop Protection

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

Managing leaf diseases of carrots with traditional and alternative fungicides including baseline sensitivity studies

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ARTICLE INFO

Article history:
Received 17 June 2016
Received in revised form
31 October 2016
Accepted 17 November 2016

Keywords:
Carrots
Foliar diseases
Cercospora
Powdery mildew
Fungicides
Erysiphe heraclei
Baseline sensitivity

ABSTRACT

Field research was conducted to examine traditional and alternative fungicide options for controlling leaf diseases of carrots caused by powdery mildew and *Cercospora*. Wet conditions favoured leaf blights caused by *Cercospora* and dry favoured powdery mildew. Pyraclostrobin, azoxystrobin, and tebuconazole controlled both *Cercospora* leaf blight and powdery mildew whereas sulphur on its own controlled only powdery mildew compared to untreated plots. Spray oils did not improve powdery mildew control, but when combined with sulphur, improved *Cercospora* leaf blight control. A baseline sensitivity study indicated a powdery mildew isolate from South Australia, sourced from carrots sprayed with a fungicide containing azoxystrobin over several seasons, was less sensitive to azoxystrobin than an isolate from New South Wales which had not been exposed to the fungicide.

1. Introduction

Carrots are the fourth most valuable vegetable crop in Australia valued at $215 M per year (Australian Bureau of Statistics, 2011), being produced in all states for either the fresh or processing markets (including juice), or for seed production. Large scale carrot production in Australia relies on mechanical harvesting where carrots are pulled out of the ground by the tops (leaves).

Carrots can be grown all year round often in overlapping plantings. Carrots are irrigated by various means across different growing regions and soil types; they can be watered with overhead pivot irrigation, common in the majority of states, or with furrow irrigation, common in the Riverina region of New South Wales (NSW).

There are a number of diseases of carrots found in Australia including the leaf blight diseases (*Alternaria dauci* and *Cercospora carotae*), and powdery mildew (*Erysiphe heraclei*). *Alternaria radicina* is also present on carrots in Australia causing black rot of carrot roots but is also capable of causing foliage blight and damping off.

Alternaria dauci causes brown angular leaf spots on mainly older leaves which can coalesce and cause the whole leaf to collapse, and *Cercospora* causes tan spots found more on younger leaves which also can blight the whole leaf (Persley, 2010).

Various fungicides used for foliar diseases of carrot leaf blight include products that contain strobilurins, chlorothalonil, and copper based products. Strobilurins are a group of fungicides that were released for use in the late 1990's. The mode of action of strobilurins is through the inhibition of respiration in the fungus. They give excellent control of a wide range of diseases, however resistance to one in this group has been recorded (McGrath and Shishkoff, 2003). Instances of resistance have also been recorded for fungal diseases such as those caused by *Alternaria*, *Didymella*, *Mycosphaerella* spp. plus many others (Anonymous, 2012). In the case of foliar diseases caused by *Cercospora* and *Alternaria*, the use of disease prediction models may benefit timing of and reductions in spray applications (Dorman et al., 2009).

Powdery mildew was first reported on carrots in Australia in 2007 (Cunnington et al., 2008). Powdery mildew causes white powdery growth on all green plant tissue. Since it was first observed, powdery mildew incidence and levels have fluctuated in the carrot growing regions of NSW, South Australia (SA), and Tasmania (Tas). More recently it has been found in Queensland (Qld)

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http://dx.doi.org/10.1016/j.cropro.2016.11.017
0261-2194/

and Victoria (Vic). Foliar diseases reduce yield by reducing photosynthetic area and by the reduction of healthy leaf material for mechanical equipment to pull the carrots out of the ground (Davis and Raid, 2002).

Products such as the bicarbonates (Dik et al., 2003), oils (McGrath and Shishkoff, 2000), and even milk, provide some control of powdery mildews (Watson and Snudden, 2000). Biological control with other fungi such as *Ampelomyces* sp., *Tilletiopsis* sp., and the bacterium *Bacillus* sp. have been and continue to be investigated (Urquhart et al., 1994; Romero et al., 2007). These products, although having variable effects, do have a role in an integrated approach to controlling powdery mildews and other pathogens but are in need of more research.

Many growers were concerned with the difficulty in controlling foliar diseases, therefore a number of trials were conducted to examine the control of powdery mildew and *Cercospora* leaf blight using available fungicides and alternative products are reported.

2. Method

Tas trials were conducted within commercial carrot crops of the cultivar Ringo, sown on a Red Ferrosol soil at Wesley Vale. The trial designs were randomised complete blocks with five replicates. Plot size was 1.2 m × 5 m and sprayed with 306–400 L/ha of water and at 400 kpa using an air-pressurised knapsack precision sprayer with a 1.5 m boom and three TX12 hollow cone nozzles.

The NSW trial was conducted on a sandy loam site at Yanco Agricultural Institute in the semi-arid Riverina. Carrots of the cultivar Ricardo were sown with an "Earthway" precision seeder at an average seeding density of 48 carrots per metre on a 1.5 m bed; the rows were 30 cm apart with drip tape (Aqua traxx®-with emitters 100 mm apart) along both rows laying on the surface. Plots were 5 m long. Fungicide applications were carried out with a gas-powered backpack sprayer at a water application rate of 300 L/ha at 300 kPa with a 1.5 m boom and three TX12 hollow cone nozzles.

The trial design was a randomised complete block with four replications. Disease development was natural with no need to introduce sources of inoculum. Treatments to control leaf diseases consisted of traditional fungicides and alternative options.

Disease incidence and carrot yield were analysed using analysis of variance with either ARM 7 software or Genstat 11. When the analysis of variance indicated a significant treatment effect, Fisher's LSD tests (5% level) was used to compare means of the treatments.

A list of experiments is in Table 1 and a list of fungicides used in Table 2.

2.1. Field powdery mildew traditional fungicide trial-Tas

Treatments were applied in two foliar spray applications at eight day intervals commencing 176 days after sowing (DAS). The first spray was applied when the crop already had widespread and severe powdery mildew on the foliage. New foliage that developed after the first spray applications was assessed for powdery mildew 214 and 222 (DAS), close to harvest. Assessment was based on the amount of disease covering the plant and a disease severity rating (1 < 20%, 2 = 20–40%, 3 = 40–60%, 4 = 60–80% and 5 = 80–100% leaf coverage). Weights of carrots harvested from the middle of each plot (1 m × 1.6 m) were recorded and then adjusted to tonnes per hectare.

2.2. Field powdery mildew alternative fungicide trial-Tas

Treatments were applied in three foliar spray applications at eight day intervals commencing 176 DAS. The first spray was applied at the early onset of powdery mildew infection in the crop. Foliage was assessed for powdery mildew 214 and 222 DAS, the same as for Experiment 1. Weights of carrots harvested from the middle of each plot (1 m × 1.6 m) were recorded and then adjusted to tonnes per hectare.

2.3. Field Cercospora leaf blight traditional fungicide trial-Tas

Spray treatments were applied in three foliar applications at seven day intervals 111, 118 and 125 DAS. Leaf spots of *C. carotae* were first noted in some untreated control plots 120 DAS. Foliage was assessed for leaf and petiole blight due to *Cercospora* 158 and 167 DAS, close to harvest. Plants in each plot were assessed for *Cercospora* leaf blight coverage based on estimation of the percentage of leaves in the whole plot that were affected by leaf blight. Leaf petiole necrosis caused by *Cercospora* leaf blight were also examined and rated according to a rating scale, 1 = healthy and vigorous, 2 = few petiole lesions, no petiole necrosis, 3 = petiole lesions numerous, no petiole necrosis, 4 = 1–20% petiole necrosis, 5 = 21–40% petiole necrosis, 6 = 41–60% petiole necrosis, 7 = 61–80% petiole necrosis, 8 = 81–90% petiole necrosis, 9 = 91% petiole necrosis, 10 = 100% petiole necrosis. There was no powdery mildew in the crop. Fresh carrots and shoots were weighed over 2 m of row.

2.4. Field Cercospora leaf blight traditional fungicide frequency trial-Tas

Spray treatments were applied in two to four foliar spray applications at 7–8 day intervals (Table 3). Leaf spots of *C. carotae* were first noted in some untreated control plots 120 DAS. There was no powdery mildew in the crop, but there was widespread and severe *Cercospora* leaf blight due to relatively wet weather conditions. Foliage was assessed for leaf and petiole blight due to *C. carotae* 155 and 167 DAS, close to harvest, as described in Experiment 3.

2.5. Field Cercospora leaf blight alternative fungicide trial-Tas

Spray treatments were applied in three foliar spray applications 111, 118 and 125 DAS. Leaf spots of *C. carotae* were first noted in some untreated control plots 120 DAS. There was no powdery

Table 1
A list of trials undertaken.

Experiment No.	Description
2.1	Field powdery mildew traditional fungicide trial-Tas
2.2	Field powdery mildew alternatives fungicide trial-Tas
2.3	Field *Cercospora* leaf blight traditional fungicide trial-Tas
2.4	Field *Cercospora* leaf blight traditional fungicide frequency trial-Tas
2.5	Field *Cercospora* leaf blight alternatives fungicide trial-Tas
2.6	Field *Cercospora* leaf blight traditional fungicide trial-NSW
2.7	Azoxystrobin baseline sensitivity trials-SA