Crop Protection 93 (2017) 9–18

Contents lists available at ScienceDirect

Crop Protection

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

Efficacy and timing of application of oxathiapiprolin against black shank of flue-cured tobacco

R.J. Bittner*, A.L. Mila

Department of Plant Pathology, North Carolina State University, Campus Box 7616, Raleigh, NC 27612, United States

ARTICLE INFO

Article history:
Received 24 July 2016
Received in revised form
25 October 2016
Accepted 29 October 2016

Keywords:
Oxathiapiprolin
Black shank
Tobacco

ABSTRACT

Phytophthora nicotianae, the causal agent of black shank, is one of the most important soilborne pathogens of tobacco (*Nicotiana tabacum* L.). The use of soil applied fungicides has been a significant component of effective black shank management for tobacco growers. Oxathiapiprolin is a new fungicide with a novel mode of action that has shown efficacy against many oomycetes, including *P. nicotianae*. Studies were conducted in 2012 in fields naturally infested with *P. nicotianae* to determine the efficacy of different rates, methods, and timing of applications of oxathiapiprolin against black shank. Field trials were conducted in 2013 and 2014 to examine the efficacy of alternating applications of oxathiapiprolin and mefenoxam against black shank. Fungicide treatments were applied to the soil on the day of transplanting tobacco to the field, on the day of first cultivation (14–25 days after transplant), and during last cultivation (46–65 days after transplant). A single application of oxathiapiprolin in the transplant water at 0.07, 0.14, or 0.28 kg a.i./ha significantly decreased area under the disease progress curve (AUDPC) compared to the non-treated control in the 2012 field trials. In addition, treatments with three applications of oxathiapiprolin at all tested rates significantly reduced AUDPC compared to non-treated control. In field trials from 2013 and 2014, alternating applications of oxathiapiprolin at transplant, mefenoxam at first cultivation, and oxathiapiprolin at last cultivation significantly lowered AUDPC compared to the non-treated control. In contrast, the AUDPC after three applications of mefenoxam at transplant, first cultivation, and last cultivation did not differ significantly from the non-treated control. Overall, our results indicate that soil-directed applications of oxathiapiprolin, alone or in alternation with mefenoxam are efficacious for the reduction of black shank of tobacco.

1. Introduction

Black shank of tobacco, caused by the soilborne oomycete pathogen *Phytophthora nicotianae* van Breda de Haan (=*P. nicotianae* var. *nicotianae*), is one of the most destructive diseases on flue-cured and burley tobacco (*Nicotiana tabacum* L.) in North Carolina and throughout the world (Lucas, 1975; Shew and Lucas, 1991; Shoemaker and Shew, 1999). *Phytophthora nicotianae* was first introduced into North Carolina tobacco in 1931 and then quickly spread across the tobacco growing regions of the state (Lucas, 1975). North Carolina is the largest flue-cured tobacco producing state in the USA, representing over 75% of the market (Brown and Snell, 2015). In North Carolina, annual tobacco yield losses due to black shank may range between 1 and 3%, resulting in the loss of 7–21 million dollars for tobacco growers (Mila and Radcliff, 2014).

Phytophthora nicotianae directly infects the roots and lower stems of tobacco plants, and can occasionally infect the leaves through splash dispersal (Shew and Lucas, 1991; Shoemaker and Shew, 1999). Infections happen at any growth stage when environmental conditions are favorable. Wet and humid environmental conditions, which are prevalent during the growing season, favor the pathogen and make the disease one of the most difficult to manage in tobacco (Lucas, 1975; Mila and Radcliff, 2014; Shew and Lucas, 1991). Black shank symptoms include a black lesion on the base of the stem, wilting and chlorosis of the plant leaves (especially under dry conditions), necrosis of the roots, and separation of the pith into necrotic disks (Lucas, 1975; Mila and Radcliff, 2014; Shew and Lucas, 1991). Effective management of this disease requires an integrated strategy involving several measures such as: two or more years of rotation with non-host crops, destruction of plant material at the end of a growing season, use of resistant

* Corresponding author.
E-mail address: rjbittne@ncsu.edu (R.J. Bittner).

http://dx.doi.org/10.1016/j.cropro.2016.10.019
0261-2194/

cultivars, and application of fungicides (Lucas, 1975; Mila and Radcliff, 2014; Shew and Lucas, 1991).

Cultural practices such as crop rotation can be difficult to implement because of insufficient available land, reducing the length of the rotation and thus improving the long-term survival of chlamydospores formed by the pathogen, which are known to persist in the soil for several years (Shew and Lucas, 1991). The use of resistant cultivars is one of the most effective management practices; however, because of risk for development of new pathogen races, resistant cultivars should not be the only control method implemented. There are currently three physiological races (0, 1, and 3) of *P. nicotianae* on tobacco in North Carolina (Apple, 1962; Gallup and Shew, 2010; Lucas, 1975). Race 0 was the most predominant race of *P. nicotianae* in tobacco growing areas until the 1990's, when tobacco cultivars expressing the *Ph* gene, a qualitative resistance gene, were introduced (Sullivan et al., 2005). Race 0 is controlled by the *Ph* gene, whereas race 1 overcomes this type of resistance. After the introduction of the *Ph* gene, the pathogen population changed rapidly due to the emergence and dominance of race 1 because of the extensive use of cultivars containing this gene (Gallup and Shew, 2010).

Fungicide use is one of the most common methods to manage black shank. Fluopicolide and mefenoxam (Presidio® and Ridomil Gold SL®) are currently registered for black shank control in the USA. Fluopicolide is a systemic fungicide in the benzamides group, and was previously registered in other crops for oomycete control. Fluopicolide was not registered for tobacco until the 2015 growing season. Mefenoxam, also known as metalaxyl-m, was registered in 1996 and is the more active isomer of the original fungicide metalaxyl that was introduced in 1977. Metalaxyl and mefenoxam belong to a systemic class of fungicides known as the phenylamides, and have shown efficacy against black shank in numerous studies (Antonopoulos et al., 2010; Cohen and Coffey, 1986; Csinos et al., 1986; Csinos and Minton, 1983; Ferrin and Kabashima, 1991; Shew, 1984; Staub and Young, 1980). Kannwischer and Mitchell (1978) were the first to demonstrate efficacy of metalaxyl in the field, showing that it increased tobacco yield especially when resistant cultivars were also used. Mefenoxam and metalaxyl are most efficacious against black shank when applied early in the growing season, specifically at transplant and first cultivation (Antonopoulos et al., 2010; Mila and Radcliff, 2014; Reilly, 1980). Mefenoxam has remained efficacious for use since its introduction in 1996, with no true fungicide resistance observed in the field. Nevertheless, continuous field use of mefenoxam can cause a decrease in the mycelial sensitivity of *P. nicotianae* isolates over time (Shew, 1985; Parkunan et al., 2010).

Oxathiapiprolin (Orondis®), of the new fungicide class piperdinyl-thiazole-isoxazoline, is efficacious against oomycetes, and became available for the 2016 tobacco growing season. Three applications of oxathiapiprolin applied to the soil at transplant, first (2–3 weeks after transplant), and last cultivation (8–9 weeks after transplant) were as efficacious against black shank as mefenoxam in field studies in Georgia and North Carolina (Ji et al., 2014; Bittner and Mila, 2016). The two fungicides were applied in the transplant water, while at first and last cultivation fungicides were applied to the raised tobacco bed and incorporated into the soil through immediate cultivation. In general, black shank incidence was significantly reduced and crop yield increased with oxathiapiprolin when compared to the non-treated control (Ji et al., 2014). Disease incidence after three applications of oxathiapiprolin also was significantly lower than or equal to the standard treatment of three applications of mefenoxam (Ji et al., 2014; Bittner and Mila, 2016). The Fungicide Resistance Action Committee (FRAC) lists oxathiapiprolin as at medium-to-high risk for pathogen resistance development (Anonymous, 2016). One potential strategy to combat the risk of fungicide resistance is the use of alternate applications of oxathiapiprolin with fungicides of different modes of action.

In this field study we investigated the efficacy of: (i) different rates, number, and methods of oxathiapiprolin applications and (ii) alternation of oxathiapiprolin and mefenoxam applications for management of black shank caused by *P. nicotianae* in North Carolina tobacco fields.

2. Materials and methods

2.1. Field locations

Field trials were conducted at the Upper Coastal Plain Research Station (UCPRS), in Edgecombe County, North Carolina, in 2012, 2013 and 2014, and at an on-farm site in Yadkin County, North Carolina, in 2012 (for a total of four different field environments). The soil types were a Goldsboro Fine Sandy Loam at the UCPRS and a Poplar Forest Fine Sandy Loam at the Yadkin County field site. The field location in Yadkin County had a history of severe black shank incidence on tobacco the year before the establishment of the field trial. The field in UCPRS had a continuous history of severe black shank on tobacco in previous years. Race 1 of *P. nicotianae* was the predominant race present at both locations. Fertilizers and pesticides for insect and nematode control were applied before and after transplanting according to North Carolina State University Cooperative Extension recommendations. At the Yadkin location, fertilization and insect control was conducted as in the rest of the grower's operation.

2.2. Experimental design

Flue-cured tobacco cultivar NC71, which has the *Ph* gene that is effective against race 0 of *P. nicotianae*, was used in all field studies. Plants were grown from seed in 288-cell styrofoam trays with 2.5 × 2.5 cm cells containing potting mix (Carolinas Choice, Carolina Soil Company, Kinston, North Carolina). Tobacco seedlings were maintained in a greenhouse until the transplant date. Seedlings were transplanted on 17 April in 2012, 23 April in 2013, 24 April in 2014 at UCPRS; and on 5 May 2012 at the on-farm location in Yadkin County. Seedlings were transplanted 56 cm apart in each row. Field plots were arranged in a randomized complete block design, with four replicate one-row plots that were 1.17 m wide and 15.24 m long. A non-treated, control was also included in each trial. A non-treated row was planted in-between two rows that contained treated plots to prevent interplot interference. Plots were separated from each other with a 3 m alley. The number of plants per plot was obtained approximately three weeks after transplanting at each location in each year.

2.3. Application of fungicides

Treatments at both 2012 locations were identical (Table 1). Applications of fungicides were made to seedlings in the tray immediately prior to transplanting and at transplant (17 April at UCPRS and 5 May in Yadkin County), at first cultivation (7 May at UCPRS and 30 May in Yadkin County), and at last cultivation (18 June at UCPRS and 21 June in Yadkin County). Tray applications were conducted at the greenhouse the same day tobacco seedlings were transplanted to the field. Seedlings in the 288-cell tray were sprayed with oxathiapiprolin (Experimental Material, DPX-QGU42) at a rate of 0.035 kg a.i./ha with a CO_2-powered sprayer operated at 207 kPa, immediately followed by lightly sprinkling with 1 L of water to rinse the product from the foliage and into the root ball. At-transplant applications involved pouring 88.7 ml of a fungicide solution into the furrow around each plant in each plot in order to