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Interaction between seed treatments, surfactants and foliar fungicides on controlling dry bean anthracnose (*Colletotrichum lindemuthianum*)

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ABSTRACT

Anthracnose, caused by fungal pathogen *Colletotrichum lindemuthianum* (Sacc. & Magnus) Briosi Cav. is one of the main production constraints of the dry bean (*Phaseolus vulgaris* L.) industry in Ontario. A field study was carried out in 2007 and 2008 to investigate the effect of two seed treatments (DCT (diazinon + captan + thiophanate-methyl) and MFA (metalaxyl-M + fludioxonil + azoxystrobin)) and two foliar fungicides (pyraclostrobin and azoxystrobin) applied with and without a surfactant under low and high disease pressure conditions at Exeter ON. Eighteen treatment combinations were tested in a randomized complete block design with four replicates. The treatment effects were examined by measuring disease development on leaf and pod tissue, pod destruction index, pick (discolored and misshaped seed), yield and return on investment (ROI). The seed treatment MFA performed similarly to DCT, and should be considered a suitable replacement to DCT for dry bean growers. However, utilizing a strobilurin fungicide in both seed and foliar treatments raises concern, as this practice increases the risk of disease resistance. The addition of a surfactant to azoxystrobin increased seed yield and ROI under high disease pressure, but had no effect when added to pyraclostrobin. Pyraclostrobin outperformed azoxystrobin for some disease indices as well as for yield under high disease pressure and for ROI under low and high disease pressure conditions.

1. Introduction

Anthracnose (*Colletotrichum lindemuthianum*) (Sacc. & Magnus) Briosi & Cav. is a major disease of dry bean (*Phaseolus vulgaris* L.) in Ontario, which results in substantial economic losses for growers. The disease is transferred to uninfested fields primarily through contaminated seed and then it is distributed within a field under favorable precipitation conditions (Tu, 1988). Rain droplets dislodge disease spores and mycelia, and can spread them up to 1.5 m (Tu, 1981). Gusting winds during a precipitation event can result in long distance disease spread of 3.0–4.6 m from the source (Tu, 1981). The main disease symptoms are discolored leaf veins and sunken brown lesions on stems, petioles and pods. Immature pods shrivel and dry under severe infection conditions (Pastor-Corrales, 2005). When seeds are infected, the seed coat often becomes discolored as lesions develop (Tu, 1988). This drastically reduces seed quality and its' marketable value, especially in white bean cultivars. As the seed infection rate rises, there is a linear increase in canopy disease ratings, and a linear decrease in seed yield (Conner et al., 2009).

Pyraclostrobin and azoxystrobin are strobilurin fungicides, which have been recommended for commercial use against plant pathogenic fungal diseases on a wide range of crops (Bartlett et al., 2002). Separate studies carried out in Brazil using azoxystrobin (Picinini and Fernandes, 2000) and pyraclostrobin (Rava, 2002) showed they reduce anthracnose severity in dry bean. In Manitoba, a sequential application of pyraclostrobin gave better anthracnose control than a single application at early or late flowering stages (Conner et al., 2004). Pyraclostrobin was superior to azoxystrobin in controlling dry bean anthracnose under favorable conditions for disease development in Ontario (Gillard et al., 2012a). Combining a seed treatment and a foliar application of azoxystrobin gave superior anthracnose control, compared to either one alone (Gillard et al., 2012b; Pynenburg et al., 2011).

Surfactants are widely used to enhance the efficacy of various pesticides, but a significant improvement in disease control can only be achieved when a suitable surfactant is selected for a specific fungicide–pathogen–crop interaction. Substantial evidence exists in the scientific literature documenting the benefits of adding a surfactant to azoxystrobin. The control of a root inhibiting fungus

Abbreviations: DAP, days after planting; WAP, weeks after planting; ROI, return on investment.

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Olpidium bornovanus (Sahtijanci) Karling in melons (*Cucumis melo* L.) was improved when Agral 90 (non-ionic surfactant 90% ai, Norac Concepts Inc., Guelph, ON) was added to a hydroponic solution of azoxystrobin (Stanghellini et al., 2010). The addition of Agral 90 enhanced the efficacy of azoxystrobin at a rate as low as 0.075 ai ha^{-1}, in controlling citrus black spot disease in orange (*Citrus sinensis* (L.) Osbeck) caused by *Guignardia citricarpa* Kelly (Schutte et al., 2003). There is a lack of published work on the use of Kornoil Concentrate for foliar fungicides, but evidence exists for similar products. A seed oil based adjuvant improved azoxystrobin absorption in onion (*Allium cepa* L.) and potato (*Solanum tuberosum* L.) by 30 and 21%, respectively (Gent et al., 2003). Transcuticular penetration of Amistar (azoxystrobin) increased to 92.8% when applied with Ekol (winter rape oil), whereas it was only 37.6% in the control (Zelená and Veverka, 2007). The use of surfactants may result in phytotoxicity and significant yield reductions with certain pesticides in sensitive crops (Gent et al., 2003). This was reported for azoxystrobin (Cole et al., 2005) in the control of *Colletotrichum gloeosporioides* on wintercreeper (*Euonymus fortunei* (Turcz.) Hand.-Maz.) and pyraclostrobin (Khan et al., 2007) in the control of cercospora leaf spot (*Cercospora beticola* Sacc.) on sugar beet (*Beta vulgaris* L.).

The seed treatment DCT (diazinon + captan + thiophanate-methyl) was first recommended to the Ontario dry bean industry almost 35 years ago (Edgington and MacNeill, 1978). For the next 25 years, it was the predominant seed treatment to control seed-borne infection of anthracnose. Thiophanate-methyl was identified as the key ingredient in DCT for anthracnose control (Tu, 1996). Industry concerns with DCT's formulation led to research for a replacement product. The first studies (Gillard et al., 2012b) compared DCT to Apron Maxx (metalaxyl-M + fludioxonil, Syngenta Crop Protection Inc., Guelph, ON). DCT consistently provided superior disease control on leaf and pod tissue under both low and high disease pressure. In another study, the seed treatment MFA (metalaxyl-M + fludioxonil + azoxystrobin) improved plant emergence, early season plant vigor and reduced anthracnose severity in dry bean seed (Pynenburg et al., 2011). However, MFA was not compared to DCT in that study. After 2007, MFA became the dominant seed treatment for dry bean seed in Ontario (P. Cornwell, Hensall District Co-operative, Hensall ON, pers. comm. to C. Gillard), based on the product's efficacy and ease of use. The accumulated evidence to date and an industry preference for a seed treatment with MFA led to the primary objective of this study – to compare MFA and DCT for the control of seed borne anthracnose of dry bean.

The value of new fungicides for the management of dry bean anthracnose needs to be continuously updated. A number of disease management studies have been published evaluating fungicides and surfactants on various crops, but there is a lack of knowledge of the combined effect of seed treatments, commercial fungicides and surfactants on dry bean anthracnose. Therefore, a series of field experiments were carried out to compare two seed treatments for the management of dry bean anthracnose under low and high disease pressure conditions in Ontario Canada, and to investigate the interaction of these seed treatments with two foliar fungicides applied with and without a surfactant.

2. Material and methods

Two field experiments were carried out at Exeter ON in 2007 and repeated in 2008, using the anthracnose susceptible navy bean cultivar OAC Rex. Weather data was collected using a WatchDog 2900ET weather station (Spectrum Technologies Inc., Plansfield IL, USA) placed next to the field site. A manual rain gauge was used to confirm the precipitation totals from the weather station.

A mixture of seed with and without visible anthracnose lesions, obtained from previous studies, was sorted using a Sortex electric eye (model 425BF, Gunson Sortex Ltd., London, UK) that separated the seed into unblemished and blemished lots. Different ratios of the two seed lots were used to plant two separate experiments in order to create low and high disease pressure, as visible anthracnose lesions on the seed coat has been found to increase disease pressure (Conner et al., 2006; Tu, 1983). The low disease pressure experiments (E1 in 2007 and E3 in 2008) used only presumedly infected seed without visible lesions, while the high disease pressure experiments (E2 in 2007 and E4 in 2008) used a mixture of presumedly infected seeds with and without visible lesions (30:70).

Eighteen treatments (Table 1) were arranged in a randomized complete block design with four replicates for each experiment. The experimental units consisted of 5 rows spaced 43 cm apart and planted 6 m long. After plant emergence, the rows were trimmed to

Table 1
Treatment list (Seed treatments, foliar fungicides and surfactants) and the application timing for the foliar fungicides at Exeter, Ontario.

Treatment		Application timing (Crop growth stage)[a]			
		A	B	C[b]	D
1	Untreated Control				
2	Fungicide Control (azoxystrobin) – Maximum application	*	*	*	*
3	Pyraclostrobin + Agral 90		*	*	
4	Azoxystrobin – Minimum application		*	*	
5	Azoxystrobin + Kornoil Concentrate (COC)		*	*	
6	Pyraclostrobin – Minimum application		*	*	
7	Pyraclostrobin + COC		*	*	
8	MFA				
9	MFA + Azoxystrobin		*	*	
10	MFA + Azoxystrobin + COC		*	*	
11	MFA + Pyraclostrobin		*	*	
12	MFA + Pyraclostrobin + COC		*	*	
13	DCT				
14	DCT + Azoxystrobin		*	*	
15	DCT + Azoxystrobin + COC		*	*	
16	DCT + Pyraclostrobin		*	*	
17	DCT + Pyraclostrobin + COC		*	*	
18	COC		*	*	

* Indicates the application of a foliar fungicide.
COC – Crop Oil Concentrate surfactant.
[a] Timing A = 5th trifoliolate leaf stage (33 DAP), Timing B = Mid flower (47 DAP), Timing C = Full flower (58 DAP), Timing D = 10 days after full flower (68 DAP).
[b] Applied in 2008 only.