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Agronomic and economic assessment of intensive pest management of dry bean (*Phaseolus vulgaris*)

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A B S T R A C T

Two common production constraints of dry bean (*Phaseolus vulgaris*) in Ontario are annual weeds and anthracnose (caused by *Colletotrichum lindemuthianum*). Dry bean is not considered a competitive crop and weed interference can result in substantial yield losses, while anthracnose is considered one of the most devastating diseases in dry bean production. A study conducted in Ontario Canada, examined the effect of two herbicide programs on weed management, thiamethoxam insecticide treatment on plant enhancement and three fungicide programs on anthracnose development in a navy bean cv. 'OAC Rex'. The premium herbicide program (s-metolachlor + imazethapyr) reduced percent weed ground cover relative to the economic herbicide program (trifluralin) in five of six locations. Thiamethoxam increased emergence and vigour at only one location, which contradicts reported benefits of thiamethoxam on plant health. The herbicide or thiamethoxam treatments did not affect anthracnose disease severity, visible seed quality, net yield or economic return. The fungicide seed treatment was often superior to the untreated control, for a number of the parameters measured. The application date of the foliar fungicide, relative to the onset of disease, varied between site-years. This dramatically influenced the fungicide's effectiveness. Foliar fungicides increased seed quality and net economic return compared to the control when applied prior to disease development. The combination of fungicide seed treatment followed by a foliar fungicide provided the largest reduction in anthracnose severity.

1. Introduction

Dry bean (*Phaseolus vulgaris* L.) is susceptible to a number of unrelated stresses and requires a high level of management (Graham and Ranalli, 1997). Dry beans compete poorly with weeds, and weed interference in dry beans can result in substantial yield losses (Chikoye et al., 1995; Malik et al., 1993; Sikkema et al., 2008). Early season weed control in dry bean in Ontario is generally achieved through the use of three soil applied herbicides; trifluralin, S-metolachlor and imazethapyr. Trifluralin is part of the dinitroaniline (Group 3) herbicide family, S-metolachlor is part of the chloroacetamide (Group 15) herbicide family and imazethapyr is part of the imidazolinone (Group 2) herbicide family. Imazethapyr, in combination with trifluralin or S-metolachlor, is able to provide a high level of weed control in dry beans (Arnold et al., 1993). In several dry bean market classes, imazethapyr can cause injury (Arnold et al., 1993; Bauer et al., 1995; Blackshaw and Saindon, 1996; Renner and Powell, 1992; Sikkema et al., 2004; Soltani et al., 2004a, 2006; Vencill, 2002; Wilson and Miller, 1991) including reduced plant height, shoot and root dry weight and yield (Sikkema et al., 2006; Soltani et al., 2007b), under certain environmental conditions. Dry bean tolerance to imazethapyr and S-metolachlor depends on the application rate, application timing, market class, cultivar and environmental conditions (Blackshaw and Saindon, 1996; Renner and Powell, 1992; Soltani et al., 2007b; VanGessel et al., 2000; Vencill et al., 1990; Ward and Weaver, 1996). Therefore, imazethapyr, trifluralin and s-metolachlor can provide a high level of weed control in dry beans, but imazethapyr has the potential to cause crop injury under certain conditions.

Thiamethoxam is a neonicotinoid insecticide and is marketed and sold as a seed treatment on many crops in Canada. Thiamethoxam controls dry bean pests such as soybean aphid *Aphis glycines* (Matsumura), bean leaf beetle *Cerotoma trifurcate* (Forster), potato leaf hopper *Empoasca fabae* (Harris) and cucumber beetle *Diabrotica undecimpunctata* (Howardi) (Calafiori and Barbieri, 2001; Nault et al., 2004; OMAFRA, 2007). Aside from its insecticidal properties, thiamethoxam is thought to promote plant health. The perceived benefits include improved early stand establishment and vigour, uniform seedling stand, increased growth, taller plants,

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increased plant density and ability to handle environmental stress (such as drought) better than untreated plants. These effects are often seen visually, but are hard to measure quantitatively. In one study, thiamethoxam increased seed germination and the number of viable nodules in dry bean (Calafiori and Barbieri, 2001) while in another study (Lourencao et al., 2003), no yield advantage was reported. Usually, thiamethoxam promotes early plant development due to efficient control of the pests (Hofer et al., 2000). No other reports were found in the published literature on the effect of thiamethoxam on plant vigour. Lebun (2008) reported anecdotal observations that indicated the plant vigour benefit of thiamethoxam occurs more frequently in dicot compared to monocot crops, and occurs when crops are seeded under stressed conditions.

Anthracnose is caused by *Colletotrichum lindemuthianum* (Sacc. & Magn.) Briosi & Cav. (teleomorph: *Glomerella cingulata* (Stonem.) Spauld and Shrenk). It is considered as one of the most widespread and economically important diseases in dry bean production areas of the world (Habtu et al., 1996; Tu, 1983), because it reduces yield by up to 95% (Melotto et al., 2000; Mordue, 1971; Pastor-Corrales and Tu, 1989; Shao and Teri, 1985; Tu, 1988) and has a detrimental effect on seed quality (Conner et al., 2004). The environmental conditions in southern Ontario are highly conducive to anthracnose disease development (Tu, 1981, 1982). Initial anthracnose symptoms consist of reddish-brown lesions on the stems and veins on the lower leaves. The symptoms begin at the bottom of the plant and progress up the plant resulting in sunken lesions on the pods (Schwartz et al., 2005). Pod lesions result in a high incidence of lesions on the seed (Pastor-Corrales and Tu, 1989; Tu, 1981), which results in reduced marketability and yield. In a recent study conducted in Manitoba Canada, researchers reported that a 7% seed-borne anthracnose infection level resulted in yield losses ranging from 15 to 32% (Conner et al., 2004). Row spacing and plant growth habit did not influence anthracnose disease severity (Conner et al., 2006).

Anthracnose is commonly spread through the use of infected seed in a new field (Tu, 1992) and, therefore primary controls include disease free seed, seed treatments and foliar fungicides. Compared to infected symptomless seed, planting infected seed with visible lesions has been reported to increase the transmission of anthracnose (Tu, 1983), and decrease emergence (Tu, 1992, 1996). Seed treatments containing thiophanate-methyl prevents the transmission of anthracnose seed lesions to seedlings, but does not completely prevent disease transmission from heavily infected seed (Tu, 1996). Research conducted in 2007 and 2008 concluded that DCT versus azoxystrobin plus fludioxonil and metalaxyl-M provided equivalent early season control of anthracnose (Gillard, 2009). Foliar application of strobilurin fungicides is an important component of an integrated strategy to minimize dry bean losses due to anthracnose (Conner et al., 2004; Rava, 2002), resulting in yield increases up to 60% (Oliveira, 2003). A sequential application of pyraclostrobin at 40 and 80% bloom provided the best control of seed-borne anthracnose (Conner et al., 2004), compared to a single application. Azoxystrobin and pyraclostrobin both effectively reduced anthracnose disease severity and increased yield compared to an untreated control (Gillard, 2009; Kuo et al., 1999; Oliveira, 2003). Azoxystrobin was found to be superior to thiophanate-methyl when applied as a foliar fungicide (Picinini and Fernandes, 2000).

Several factors influence the economic returns for a chemical pest management system for dry bean. The use of herbicides generally provides higher net returns in dry beans (Sikkema et al., 2007; Soltani et al., 2007a; Tharp et al., 2004). Factors that influence the economic returns of herbicides include the knowledge of weed species composition, weed density and crop tolerance. The proper implementation of a weed management strategy can influence the return on investment of either reduced rate or economic threshold approaches, compared to recommendations that are based on inadequate knowledge of field or pest conditions or applying a blanket herbicide program (Forcella et al., 1996; O'Donovan et al., 2004; Renner et al., 1999; Tharp et al., 2004). The same logic could be applied to insecticide and fungicide products.

The objective of this study was to investigate the agronomic and economic benefits of a chemical pest management system for dry beans. This study focused on three crop inputs; insecticide seed treatment, herbicide and fungicide programs (seed treatment and foliar fungicide) to control anthracnose. Evaluations included crop emergence, vigour, seed quality and yield, pesticide efficacy, crop tolerance and the net economic return from pesticide use.

2. Materials and methods

Six field studies were conducted over a two-year period (2007 and 2008) at three locations in the main dry bean production region of Ontario, Canada. Experiments were conducted at the Huron Research Station near Exeter, Honeywood Research Farm near Plattsville, and the University of Guelph, Ridgetown Campus near Ridgetown. The soil type was a Brookston clay loam soil (pH 7.8, organic matter (O.M.) 4.4%, sand 30%, silt 44% and clay 26%) at Exeter, a Honeywood silt loam soil (pH 6.2. O.M. 3.2%, sand 37%, silt 52 and clay 12%) at Plattsville, and a Brookston loam soil (pH 7.3, O.M. 4.5%, sand 45%, silt 29% and clay 26%) at Ridgetown. Seedbed preparation at Exeter consisted of autumn mouldboard plowing followed by two passes with a field cultivator in the spring, and at Plattsville and Ridgetown consisted of autumn chisel plowing followed by two passes with a field cultivator in the spring.

The experiment was established as a three-way factorial arrangement in a randomized complete block design with four replications, at three locations in each one of the two years of the study. Factor one was an insecticide seed treatment, factor two was the herbicide program and factor three was the foliar fungicide program. Each plot was 2.15 m wide (five rows spaced 43 cm apart) and 6 m long. The first and fifth rows were planted with soybean (*Glycine max* (L.) Merr.) to minimize anthracnose disease movement between plots. The middle three rows were planted to a navy bean (cv. 'OAC Rex'), using seed harvested from anthracnose studies from the previous year. It was observed that ten percent of the seed had lesions on the seed coat that were consistent with typical anthracnose disease lesions. This cultivar is resistant to common bacterial blight *Xanthamonas axonopodis pv. phaseoli* Smith (Dye). Insecticide treatments included thiamethoxam applied at 50 g ai 100 kg^{-1} seed and an untreated control. The insecticide was applied 30–40 days prior to planting with a Hege 11 seed treater (Wintersteiger Inc. 4705 Amelia Earhart Drive Salt Lake City, UT). Two herbicide programs were compared; an economic program consisting of trifluralin applied PPI at 0.6 kg ai ha^{-1}, and a premium program consisting of a tank mix of *s*-metolachlor plus imazethapyr applied PPI at $1.14 + 0.045$ kg ai ha^{-1}, respectively. The two herbicide programs were expected to provide significant differences in weed control. A zero herbicide control treatment was not included in this study, as this is not a suitable production practice for most dry bean growers. The herbicides were applied to the soil surface one day prior to seeding and incorporated with two passes of a field cultivator set approximately 10 cm deep. All herbicide, foliar fungicide and insecticide applications were made with a CO_2-pressurized backpack sprayer calibrated to deliver 200 l ha^{-1} of spray solution at a pressure of 200 kPa using Teejet 8002 flat-fan nozzles (Spraying Systems Co., P.O. Box 7900, Wheaton, IL). The spray boom was 1.5 m long with four nozzles spaced 0.5 m apart. The fungicide treatments included a seed treatment (ST) of azoxystrobin at 1 g ai 100 kg^{-1} seed plus fludioxonil & metalaxyl-M at