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Impact of fluopyram fungicide and preemergence herbicides on soybean injury, population, sudden death syndrome, and yield

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ABSTRACT

Field experiments were conducted in Indiana and Iowa in 2014 and 2015 to examine the effect of preemergence herbicides and fluopyram seed treatment on soybean (*Glycine max* (L.) Merr.) injury, plant population, sudden death syndrome (SDS; *Fusarium virguliforme* O'Donnell & T. Aoki), and yield. Sulfentrazone + cloransulam-methyl + S-metolachlor and flumioxazin + chlorimuron ethyl + S-metolachlor herbicides resulted in higher phytotoxicity at growth stage VC-V1 compared to a non-treated control. Phytotoxicity due to preemergence herbicide was rarely observed at V4. Seed treated with fluopyram resulted in higher phytotoxicity at VC-V1 than seed without fluopyram, regardless of preemergence herbicide treatment. The combination of preemergence herbicide and fluopyram did not increase the severity of soybean injury in any year or location compared to either applied alone. Preemergence herbicide treatment reduced plant population in Indiana in 2014 and Iowa in 2015 compared to the non-treated control, but did not affect yield. Fluopyram seed treatment reduced foliar symptoms of SDS by over 70% and increased yield up to 12% in Indiana, but had no effect on SDS or yield in Iowa. These results indicate that while injury can occur with both preemergence herbicides and fluopyram-treated seed, phytotoxicity is not more severe when both pesticides are used together, and yield is not reduced by their use. Farmers should continue to use preemergence herbicide programs if they treat their seed with fluopyram to manage SDS, and use production practices that minimize the risk of preemergence herbicide injury in soybean.

1. Introduction

Sudden death syndrome (SDS) of soybean (*Glycine max* (L.) Merr.) caused by the fungus *Fusarium virguliforme* O'Donnell & T. Aoki, is an annual threat in the Midwestern United States, and can cause yield loss of up to 80% in susceptible varieties (Roy et al., 1997). Symptoms of SDS include interveinal chlorosis and necrosis on the upper trifoliates, which usually appears during the reproductive growth stages of the soybean plant. Although symptoms are often first observed in the foliage, the fungus is soil-borne and infects shortly after seedlings germinate (Gongora-Canul and Leandro, 2011), producing a fungal toxin that is translocated to the foliar tissue, resulting in the characteristic symptoms of SDS (Pudake et al., 2013).

Sudden death syndrome is best managed using an integrated approach, since no single management tactic is 100% effective in years where environmental conditions favor disease. High soil moisture and low temperatures (15 °C) favor root rot, while high soil moisture (rainfall 12–15 cm/month) with moderate temperatures (approximately 25 °C) during reproductive stages favors the foliar symptoms of SDS (Kandel et al., 2016b; Scherm and Yang, 1996) Therefore, farmers are encouraged to manage SDS by using cultivars with genetic resistance, managing soybean cyst nematode (SCN), which has been shown to increase SDS severity (Westphal et al., 2014; Xing and Westphal, 2006), and through cultural practices such as crop rotation (Rupe et al., 1997) and tillage (Wrather et al., 1995). In addition to these cultural practices, the fungicide fluopyram (ILeVO®, Bayer CropScience, Research Triangle Park, NC) was registered in December 2014 on soybean, and has reduced SDS in several research trials across the Midwest and Ontario, Canada (Kandel et al., 2016a, b). Fluopyram is a succinate dehydrogenase inhibiting fungicide (SDHI; Fungicide Resistance Action Committee (FRAC) group 7) and moves systemically from the seed into the cotyledon and first true leaves of the soybean plant (J. Riggs, personal communication). This “pooling” of the fungicide can cause a phytotoxic response in the outer tissue of the cotyledon

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Fig. 1. Phytotoxicity of fluopyram seed treatment in soybean seedlings.

resulting in a brown to black discoloration on affected tissues. The phytotoxicity is sometimes referred to as the "halo effect," and is typically uniform across fluopyram-treated seed (Fig. 1). Shortly after the release of fluopyram, anecdotal observations by farmers and those in the agribusiness industry suggested that the phytotoxicity associated with fluopyram on soybean seedlings was more severe in fields where certain preemergence herbicides were applied to soybeans, and in some instances the combined injury was reported to have reduced plant population. This apparent synergism between the two chemicals is concerning to farmers, particularly due to the increase in preemergence herbicides for broadleaf weed control.

The prevalence of weed species resistant to postemergence soybean herbicide products such as glyphosate, acetolactate synthase inhibitors (Group 2 - ALS-inhibitors), and protoporphyrinogen oxidase inhibitors (Group 14 – PPO inhibitors) has increased across the primary soybean production areas of the United States (Heap, 2016). Currently, 16 weed species have evolved resistance to glyphosate in the United States (Heap, 2016). Control of herbicide resistant broadleaf weeds has become a major challenge in soybean production. In order to control herbicide resistant weeds, especially problematic species such as Palmer amaranth (*Amaranthus palmeri* S. Wats), waterhemp (*Amaranthus tuberculatus* (Moq.) J.D. Sauer), and marestail (*Conyza canadensis* (L.) Cronquist), farmers rely on preemergence herbicides. These herbicides reduce weed seedling populations and the need for multiple postemergence herbicide applications (Ellis and Griffin, 2002; Legleiter et al., 2009; Whitaker et al., 2010). For example, preemergence followed by postemergence herbicide applications resulted in greater control of glyphosate-resistant waterhemp through a growing season compared to postemergence applications alone (Sarangi et al., 2017).

Although preemergence herbicides are needed for weed control on soybeans, there are several application factors that increase the risk for these products to cause herbicide injury to soybean. Certain preemergence herbicide active ingredients can cause injury when they are applied in conditions when the soybean seedling is unable to rapidly metabolize the herbicide, such as in wet conditions (Taylor-Lovell et al., 2001). Injury can also occur if the application is delayed after planting and preemergence herbicides are applied close to soybean emergence. Other factors that can increase risk of injury include shallow planting, or inadequate soil to seed contact (row closure) as these factors increase the risk of contact between the herbicide and the germinating seed.

The soil conditions that favor risk of preemergence herbicide injury, such as cool, wet soil after planting and at emergence, are also the conditions that favor infection by *F. virguliforme*, meaning that farmers with fields at high-risk for SDS may choose to use fluopyram seed treatment, and need to understand the potential risk for soybean injury or loss from using preemergence herbicide applications along with fluopyram seed treatment. The objectives of this study were to examine the effect of common preemergence herbicide programs on soybean injury, stand, and final yield for seed treated with and without fluopyram, and determine if fluopyram + preemergence herbicides results in a synergistic phytotoxic effect on soybean seedlings.

2. Materials and methods

2.1. Field experiments in Indiana

Field experiments were established at the Pinney Purdue Ag Center (PPAC) in LaPorte County, Indiana (41.4431028, −86.9294834) in 2014 and 2015. Experiments were arranged as a randomized complete block design with four replications each year. Treatments consisted of a factorial arrangement of seed treatment by preemergence herbicide program. Each year, a cultivar moderately susceptible to SDS was selected for planting (Pioneer 92Y60 (SDS rating 4, 1 = worst, 9 = best) in 2014 and Beck's 278R4 (SDS rating 7, 1 = worst 9 = best) in 2015) and treated with either a commercial base seed treatment (CB) containing a combination of prothioconazole + penflufen + metalaxyl (EverGol® Energy, Bayer CropScience, 0.019 mg a.i./seed), metalaxyl (Allegiance®, Bayer CropScience, 0.02 mg a.i/seed), and clothianidin + *Bacillus firmus* (Poncho®/Votivo™, Bayer CropScience, 0.13 mg a.i/seed) or fluopyram standard rate (ILeVO®, Bayer CropScience, 0.15 mg a.i./seed) in addition to the CB. Preemergence herbicide treatments were applied to all experimental plots treated with both CB and fluopyram + CB seed each year. Preemergence herbicide treatments are listed in Table 1. The treatment of flumioxazin + chlorimuron ethyl + S-metolachlor is not a labeled application of these products, because of the known crop injury risk. This herbicide combination was intentionally included to attempt to injure soybeans and assess the effect of injury on the interaction between fluopyram and preemergence herbicide treatments.

Table 1
Preemergence herbicide active ingredients, common names, rate, and herbicide groups for treatments applied to experimental plots in 2014 and 2015 in Indiana and Iowa.

Active ingredient	Trade name	Rate (g/ha)	Herbicide group (s)	Test location and year
Flumioxazin + chlorimuron ethyl + S-metolachlor	Valor®XLT + Dual II Magnum	128 + 188	2, 14, 15	Indiana – 2014, 2015
Flumioxazin + pyroxasulfone	Fierce®	188 (Indiana) 224 (Iowa)	14, 15	Indiana – 2014, 2015 Iowa – 2014, 2015
Metribuzin	Sencor®	425	5	Iowa – 2014
Metribuzin + chlorimuron ethyl + metribuzin	Canopy + metribuzin	450 + 425	2, 5	Indiana – 2014, 2015
Saflufenacil + dimethenamid-P	Verdict®	256 (Indiana) 622 (Iowa)	14, 15	Indiana – 2014, 2015 Iowa – 2015
Sulfentrazone + chlorimuron- ethyl	Authority®XL	561	2, 14	Iowa – 2014
Sulfentrazone + cloransulam-methyl	Authority®First	196	2, 14	Iowa – 2015
Sulfentrazone + cloransulam-methyl + S-metolachlor	Authority®First + Dual II Magnum	159 + 188	2, 14, 15	Indiana – 2014, 2015