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# Profitability and efficacy of soybean seed treatment in Michigan

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ABSTRACT

Soybean (*Glycine max* Merr.) is a globally important oilseed crop. Use of seed treatments to avert yield loss by managing seedling pathogens, early-season insects, and nematodes has become more common. Seed treatments may effectively protect plant stand and plant health in the presence of pathogens and pests, but the profitability of prophylactic seed treatment use across diverse environments remains in question, particularly when pests and pathogen populations are low or absent. Seed treatments, including a non-treated control (NTC), fungicide (F), fungicide-insecticide (FI), and fungicide-insecticide-biological nematode protectant (FIN), were evaluated on four soybean varieties at seven field sites in 2013, 2014, and 2015. In 2013, yield data was collected, and in subsequent years additional parameters were measured. FIN significantly improved plant stand at two sites in 2014 and three sites in 2015. Scant soybean aphid (*Aphis glycines* Matsumura) numbers were found at four sites across 2014 and 2015. Soybean aphid populations in FI plots were lower relative to the NTC at two of the four sites. Soybean cyst nematode (*Heterodera glycines* Ichinohe) (SCN) was present in one field in 2015, but FIN treatment did not significantly reduce SCN reproduction or population relative to the NTC. Yield across soybean varieties was significantly improved by FIN at the Allegan county sites in 2013 and 2015. Across sites in 2013, no seed treatment significantly improved net returns relative to the NTC. Across sites in 2014 and 2015, FIN significantly reduced net returns relative to the NTC. The probability that a seed treatment would result in economically neutral or positive outcomes was estimated by using Maximum Likelihood Estimation. Results from these planting dates and seeding rates indicate that seed treatments may not benefit all soybean growers. Seed treatment benefits may be affected by soybean variety, soil, environmental conditions, planting population, and planting date. Early planting dates and reduced seeding rates may see an increase in seed treatment profitability.

## 1. Introduction

Seed treatment use in soybean is recommended for low-quality seed (Edje and Burris, 1971; Lueschen et al., 1991; Sinclair, 1993; TeKrony et al., 1974; Wall et al., 1983), for soybean varieties that are susceptible or partially resistant to seedling diseases (Dorrance and McClure, 2001), or for seed planted under suboptimal conditions that favor seedling disease (Guy et al., 1989; Lueschen et al., 1991; Sinclair, 1993). However, recent studies have proposed that fungicide and fungicide-insecticide seed treatments can be prophylactically used to increase yield across diverse environments, thus increasing profitability (Bradley, 2008; Gaspar et al., 2015; Poag et al., 2005). From 1996 to 2013, use of seed treatment rose from 8% to > 75% of soybeans planted in the United States (Munkvold, 2009; Munkvold et al., 2014). This trend may be due to changes in seed treatment recommendations, marketing, and adoption of earlier planting and reduced tillage practices that increase risk for plant stand loss (Esker and Conley, 2012; Dorrance et al., 2009).

Soybean plant stand and yield can be reduced by several pests and pathogens. Damping-off and root rot can be caused by true fungi, such as *Rhizoctonia solani* J. G. Kühn and *Fusarium* species, and oomycetes, such as *Phytophthora sojae* Kaufm. and Gerd. and *Pythium* species (Arias et al., 2013; Farias and Griffin, 1990; Rizvi and Yang, 1996; Schlub and Lockwood, 1981; Tachibana et al., 1971; Schmitthenner, 1985). Insects, such as seedcorn maggot (*Delia platura* Meigen), can also reduce soybean plant stand (Miller and McClanahan, 1960). Soybean aphid (*Aphis glycines* Matsumara) can reduce yield at populations above 675 aphids/plant at growth stages R3-R5 (Ragsdale et al., 2007). Soybean cyst nematode (*Heterodera glycines* Ichinohe) (SCN), along with root rots and seedling diseases, are cited as principal causes of yield loss throughout the soybean-producing regions of the United States (Wrather et al., 2001; Wrather and Koenning, 2006; Koenning and Wrather, 2010; Mueller et al., 2016) and the rest of the world (Wrather et al., 2010). Seed treatments are intended to manage these pests and pathogens, but the efficacy and profitability of these treatments remains uncertain under Michigan conditions.

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Commercial seed treatment options often include multiple fungicides that target different soilborne organisms. Metalaxyl and other phenylamide fungicides are used to manage oomycete diseases caused by *Phytophthora* and *Pythium* spp. (Dorrance and McClure, 2001; Dorrance et al., 2009). Other fungicides, including fludioxonil and strobilurins, are used to manage fungi such as *Fusarium* spp. and *Rhizoctonia solani* (Broders et al., 2007b; Dorrance et al., 2003; Ellis et al., 2010; Guy et al., 1989). Seed treatment formulations may also include a neonicotinoid insecticide, such as clothianidin, to manage corn seed maggot, bean leaf beetle, and soybean aphid (Cox and Cherney, 2011; Gaspar et al., 2015). Seed treatments may also include a nematicide or biological nematode protectant to mitigate SCN damage (Gaspar et al., 2014).

Seed treatments that minimize plant stand loss may allow growers to improve profitability by reducing their seeding rates. However, studies have shown variable effects of fungicide seed treatment on plant stand. Though plant stands of fungicide-treated seed were significantly higher (31%) than non-treated seed across field sites in one year of a two-year study in North Dakota (Bradley, 2008), several other studies have seen no significant plant stand benefit from the use of fungicidal seed treatments (Bradley et al., 2001; Gaspar et al., 2014, 2015; Schulz and Thelen, 2008). Combined fungicide-insecticide treatments relative to non-treated seed have been shown to improve plant stand by 3%–17% across field sites, even in years where fungicide seed treatments caused no significant plant stand improvement (Cox and Cherney, 2014; Esker and Conley, 2012; Gaspar et al., 2014). Seed treatments containing a fungicide, insecticide, and biological nematode protectant have been documented to increase plant stand by as much as 19% across field sites (Gaspar et al., 2014).

Though significant yield improvements due to seed-applied fungicides have been as high as 19% across field sites (Bradley, 2008), a study in Wisconsin indicated that the probability of breaking even may be equivalent between seeds with fungicide and those without (Gaspar et al., 2015). A multiple-state study showed that use of neonicotinoid insecticide seed treatments alone improved yield relative to the non-treated control during soybean aphid outbreaks, but had no yield benefit in the absence of aphids and had less than a 50% chance of recouping treatment cost at soybean prices $12.00/kg (Johnson et al., 2009). However, use of fungicide-insecticide seed treatments resulted in significant yield improvements of 1%–4% across environments in Wisconsin at currently recommended planting populations in spite of there being no reported insect pressure (Esker and Conley, 2012; Gaspar et al., 2014, 2015). Soybeans treated with fungicide, insecticide, and biological nematode protectant also significantly improved yield by 1%–4% compared to non-treated seed across sites with and without SCN (Gaspar et al., 2014, 2017). For studies that have reported significant benefits in mean yield from seed treatment, yield benefits were observed at fewer than 30% of field sites (Bradley et al., 2001; Bradley, 2008; Cox et al., 2008; Cox and Cherney, 2011; Esker and Conley, 2012; Gaspar et al., 2014; Schulz and Thelen, 2008). Identifying factors that impact the profitability of seed treatment use could assist soybean growers to make decisions that are economical for their production systems.

The objectives of this study were to 1) assess the efficacy of commercial seed treatments in improving plant stand and managing pests such as soybean aphid and SCN, 2) to determine the effects of seed treatment on soybean yield and profitability when used prophylactically across diverse field conditions, and 3) to identify factors that may impact the economic benefits of seed treatments.

## 2. Materials and methods

Four soybean varieties with varying SCN susceptibilities were planted in 2013, 2014, and 2015. Soybean varieties were supplied by Asgrow and Pioneer. Varieties differed slightly by site and year (Table 1). Variety names are not specified due to the data being proprietary. Seed treatments were categorized across seed companies into the following groups: non-treated control (NTC), fungicide (F), fungicide-insecticide (FI), and fungicide-insecticide-biological nematode protectant (FIN). Though seed treatment formulations varied by company (Table 2), treatments contained chemistries that targeted the same pests and pathogens and were assumed to behave similarly. Seed treatments were the same over the three-year study. Asgrow seed was treated by agitating seeds and treatment chemistries in a 5-gallon container until seed was uniformly coated. Pioneer seed was commercially treated in a custom octagonal drum applicator.

**Table 1**
**Soybean varieties used to evaluate seed treatments,** with information regarding resistance to Soybean Cyst Nemtode (SCN) and Phytophthora root rot and "X" denoting their use in a given year of the field trial, respectively. Variety names are not specifically mentioned due to the information being proprietary.

| Variety Name | SCN Resistance[a] | *Phytopthora* field tolerance[b] | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|
| Asgrow-1 | None | 5 | X | X | X |
| Asgrow-2 | PI 88788 | 4 | X | X | X |
| Pioneer-1 | None | 3 | X | | |
| Pioneer-2 | PI 88788 | * | X | | |
| Pioneer-3 | Peking | 4 | | X | X |
| Pioneer-4 | PI 88788 | 4 | | X | X |

*Denotes data that is missions.

[a] Soybean varieties either had no SCN resistance or SCN resistance conferred by the soybean line PI 88788 (Epps and Hartwigg, 1972) or Peking (Ross and Brim, 1957).

[b] Phytophthora root rot tolerance is rated on a scale from 1 to 9. For Asgrow varieties, 9 is the lowest score, and one is the highest score. For Pioneer varieties, 1 is lowest, and 9 is highest.

Across study years, planting dates ranged from 7 May to 9 June at seven field sites that were part of the Michigan Soybean Performance Trials (Table 3). Climate data for each site were collected using the PRISM Climate Group database (Prism Climate Group, Oregon State University, 2016). Plots were arranged in a randomized complete block design, with four replications in 2013 and six replications in 2014 and 2015. In 2013, seeds were planted with a custom-built, six-row planter with seed units (John Deere, Moline, IL). In 2014, 2015, seeds were planted using a custom-built, six-row Almaco precision vacuum planter with a Seed Pro 360 controller (Almaco, Nevada, IA) and John Deere seed units. Seeds were planted 3.8 cm deep in 38 cm rows with a seeding rate of 395,000 seeds/ha. Each plot was 6.1 m long and was trimmed to 4.3 m long prior to harvest.

In 2013, yield was the only parameter measured. In 2014, 2015, seed treatment efficacy was also evaluated by quantifying plant stand, plant height, root dry weight, aphid populations, and SCN populations. Plant stand was determined at growth stages VC-V1 (Fehr et al., 1971) by counting all of the living, emerged plants in two of the four center rows. Plant height and root dry weight were taken as a measure of seedling health in 2014 and 2015, respectively. In 2014, the height of 10 randomly selected seedlings from the four center rows of each plot was determined by measuring the distance from the soil surface to the apical tips of each seedling. Seedlings were measured at growth stages V2/V3 at all sites except Hillsdale, where they were measured at growth stage V1. In 2015, root dry weight was measured for 10 consecutive emerged seedlings from an outside row of each plot by washing the roots, separating roots and shoots, and drying the roots at 49 °C ± 11 °C until dry weights stabilized. First instances of scouting for soybean aphids ranged from June 2 to July 10, depending on site and year. Given especially low incidences of soybean aphid in 2014 and 2015, the apical tip and nearest trifoliate leaf of fifty soybean plants from the NTC plots at each site were scouted for soybean aphids to determine which sites had adequate aphid incidences to compare effects of treated and non-treated soybeans. For any site that had aphids present in ≥25% of NTC plots, aphid populations were determined on