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EVALUATION OF FUNGICIDE SEED TREATMENTS FOR SWEET CORN

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ABSTRACT

Eighteen seed treatments and a non-treated control were evaluated at 16 locations in 2012 using the sweet corn hybrid, Super Sweet Jubilee (*sh2*). The seed treatments included registered and experimental fungicides, and one organic fungicide. Some treatments included seed enhancements, including one organic product, and insecticides. Treatments were evaluated for their effect on seedling stand and vigor. The two organic treatments resulted in significantly smaller stand counts and lower vigor ratings compared to conventional seed treatments at most locations. The organic fungicide, Champ Formula 2, slightly improved stands compared to the non-treated control at many locations, especially when tested in colder environments. The results from the other organic treatment were comparable to the non-treated control. All of the conventional treatments had stand counts and vigor ratings that were similar to the two industry standard seed treatment mixtures in the trial. Several products were shown to be equivalent substitutes for components of seed treatment mixtures for sweet corn.

INTRODUCTION

Fungicide seed treatments can be an effective tool to minimize stand losses due to seed rot and seedling diseases. They have proven to be especially useful for sweet corn production, which is why most commercial sweet corn seed is sold to growers with a seed treatment already applied. Sweet corn is susceptible to seed rot and seedling diseases caused by a number of fungal and fungus-like pathogens. Seed-borne fungi, like *Fusarium moniliforme* and *Penicillium oxalicum*, are often found on sweet corn seed and have been shown to cause seed rot, seedling blight, and reduced seedling vigor (Anderegg & Guthrie, 1981; Caldwell, Tuite, & Carlton, 1981). Some *Rhizopus* species can also be seed-borne and have been associated with diseased seedlings (Wilson & Mohan, 1991). Soil-borne pathogens such as *Pythium ultimum*, *Rhizoctonia solani*, and some *Fusarium* species are also known to cause seedling diseases in many areas where sweet corn is grown (Berger & Wolf, 1974; Sumner & Bell, 1982; Wilson & Mohan, 1991). Several different fungicide products are used as seed treatments, but not all products are equally effective against all pathogens. So, choosing the right combination of products to apply as a seed treatment is important.

The International Sweet Corn Development Association (ISCDA) formed a Seed Treatment Committee in the early 1990's to help the sweet corn industry identify the best performing seed treatments for sweet corn production across diverse planting environments. The committee has been organizing an annual seed treatment trial for more than 20 years now. The committee selects seed treatments for testing and then provides them to researchers across the country to plant and evaluate for their effect on seedling stand and vigor. Results of the entire trial are compiled and summarized to provide information to the sweet corn industry. The results are used mainly by seed treatment companies to evaluate and market their products, and by sweet corn seed companies to help them decide which products to apply to the seeds they distribute to growers across the country. Most of the sweet corn seed companies that supply seed for commercial production have representatives that participate on the ISDCA Seed Treatment Committee, so this trial has a major impact on commercial sweet corn production nationwide.

This paper reports the results of the 2012 ISCDA Multi-location Seed Treatment Trial. The seed treatments included many conventional fungicides currently registered for use on sweet corn and also some experimental fungicides and an organic fungicide. One treatment was an organic seed enhancement product without fungicides. A few insecticides were also tested. The seed treatments ranged from single component treatments to mixtures of up to seven different products. Many of the treatments were designed to evaluate products within seed treatment mixtures; some product substitutions, additions, or rate modifications were assessed. Non-treated seed and two standard seed treatments that are used widely by the sweet corn industry were included for comparison.

MATERIALS AND METHODS

Eighteen seed treatments and a non-treated control were evaluated at 16 locations using one seed lot of the sweet corn variety, Super Sweet Jubilee (*sh2*). This variety was selected because, like most "supersweet" hybrids, it is highly susceptible to seed rot and seedling diseases. The warm germination rate of the seed lot was 84% and the cold germination rate was 70% in a laboratory test performed by Syngenta Seeds, Inc. in December, 2011. Seed treatments were sponsored by five seed treatment companies (BASF Corporation; Nufarm Americas, Inc.; Syngenta Crop Protection, LLC; T.J. Technologies, Inc.; and Valent USA Corporation). Additionally, two standard seed treatment mixtures and an organic seed treatment were selected by the ISCDA Seed Treatment Committee. The seed treatments with active ingredients and rates are listed in Table 1. For each treatment, the ingredients were applied as pre-mixed slurries. Sixteen sets of treated seed were sent to researchers in seven states (FL, ID, IL, MN, NY, WA, and WI). Locations, planting dates, and cooperating researchers are shown in Table 2. Each set of seed was planted using a randomized complete block design with four replications. One-hundred seeds were planted per plot. Planting methods varied from hand-planting to mechanical planters, and planting dates ranged from February to September. Some sites had two plantings on different dates (FL-2/FL-3, ID-1/ID-4, and MN-1/MN-2). Stand counts and vigor ratings were recorded in each plot at the 5-6 leaf stage. Some locations did not record vigor (MN-2, NY-2). Vigor ratings were on a qualitative visual scale of 1-5 (1=extremely weak, 2=weak, 3=fair, 4=vigorous, and 5=very vigorous). Data from each planting were subjected to analysis of variance (ANOVA) and a pairwise comparison of treatment means using Fisher's protected least significant difference method, LSD (0.05). Data from each of the plantings were then combined in a summary across trial locations, and analyzed with ANOVA and a comparison of the combined treatment means. Data were analyzed using ARM 9 and ARM ST 8 software from Gylling Data Management, Inc.

TABLE 1. 2012 ISCDA Seed Treatments.

Treatment	Product (active ingredient) and Rate
1 - Control	No Treatment
2 - Standard	Dividend Extreme (difenconazole + mefenoxam) 15.0[z] + Apron XL LS (mefenoxam) 8.9[z] + Maxim 4 FS (fludioxonil) 2.5[z] + Vitavax-34 (carboxin) 91.3[z]
3 - Standard	Captan 4 Flowable (captan) 78.0[z] + Thiram 42-S (thiram) 78.0[z] + Dividend Extreme (difenconazole + mefenoxam) 37.5[z] + Apron XL LS (mefenoxam) 7.5[z] +Vitavax-34 (carboxin) 100.0[z]
4 - BASF	Stamina F3 HL (pyraclostrobin + tritconazole + metalaxyl) 27.0[z] + Cruiser 5FS[x] (thiamethoxam) 0.3[y]
5 - BASF	Dividend Extreme (difenconazole + mefenoxam) 15.0[z] + Apron XL LS (mefenoxam) 8.9[z] + Maxim 4 FS (fludioxonil) 2.5[z] + Vitavax-34 (carboxin) 91.3[z] + Stamina (pyraclostrobin) 10.4[z]
6 - Nufarm	Signet 480 FS (thiram) 78[z] + Sativa 309 FS (tebuconazole) 15.0[z] + Sebring 381 FS (metalaxl) 15.5[z] + Senator 600 FS[x] (imidacloprid) 233.0[y]
7 - Nufarm	Spirato 480 FS (fludioxonil) 2.5[z] + Sativa 380 FS (tebuconazole) 15.0[z] + Sebring 318 FS (metalaxyl) 15.5[z] + Senator 600 FS[x] (imidacloprid) 233[y]
8 - Syngenta	Dividend Extreme (difenconazole + mefenoxam) 15.0[z] + Apron XL LS (mefenoxam) 4.5[z] + Maxim 4 FS (fludioxonil) 2.5[z] + Cruiser 5FS[x] (thiamethoxam) 0.3[y]
9 - Syngenta	Maxim Quattro (fludioxonil + mefenoxam + azoxystrobin + thiabendazole) 0.06[y] + Apron XL LS (mefenoxam) 2.0[z] + Cruiser 5FS[x] (thiamethoxam) 0.3[y]
10 - Syngenta	Maxim Quattro (fludioxonil + mefenoxam + azoxystrobin + thiabendazole) 0.06[y] + Apron XL LS (mefenoxam) 2.0[z] + Avicta Duo[x] (abamectin + thiamethoxam) 0.45[y]
11 - TJ Technolgies	Dividend Extreme (difenconazole + mefenoxam) 15.0[z] + Apron XL LS (mefenoxam) 8.9[z] + Maxim 4 FS (fludioxonil) 2.5[z] + Vitavax-34 (carboxin) 91.3[z] + Quick Roots (proprietary a.i.)
12 - TJ Technologies	Organic Quick Roots (proprietary a.i.)
13 - TJ Technologies	Dividend Extreme (difenconazole + mefenoxam) 15.0[z] + Apron XL LS (mefenoxam) 8.9[z] + Maxim 4 FS (fludioxonil) 2.5[z] + Vitavax-34 (carboxin) 91.3[z] + Quick Roots + TJ EXP A3AP + TJ EXP HB2T
14 - Valent	Metlock 3.7 FS (metconazole) 2.5[z] + Sebring 318 FS (metalaxyl) 15.5[z] + Rizolex (tolclofos-methyl) 10.0[z] + Nipsit Inside[x] 5FS (clothianidin) 0.25[y]
15 - Valent	Metlock 3.7 FS (metconazole) 2.5[z] + Sebring 318 FS (metalaxyl) 15.5[z] + Rizolex (tolclofos-methyl) 10.0[z] + Signet 480 FS (thiram) 78.8[z] + Nipsit Inside 5FS[x] (clothianidin) 0.25[y]
16 - Valent	Metlock 3.7 FS (metconazole) 2.5[z] + Sebring 318 FS (metalaxyl) 15.5[z] + Rizolex (tolclofos-methyl) 10.0[z] + Signet 480 FS (thiram) 78.8[z] + Captan 4 Flowable (captan) 78.0[z] + Nipsit Inside 5FS[x] (clothianidin) 0.25[y]
17 - Valent	Metlock 3.7 FS (metconazole) 2.5[z] + Sebring 318 FS (metalaxyl) 15.5[z] + V10208 (ethaboxam) + Rizolex (tolclofos-methyl) 10.0[z] + Signet 480 FS (thiram) 78.8[z] + Captan 4 Flowable 78.0[z] + Nipsit Inside 5FS[x] (clothianidin) 0.25[y]
18 - Valent	Metlock 3.7 FS (metconazole) 2.5[z] + Sebring 318 FS (metalaxyl) 15.5[z] + Rizolex (tolclofos-methyl) 10.0[z] + Signet 480 FS (thiram) 78.0[z] + Captan 4 Flowable (captan) 78.0[z] + V10355[x] + Nipsit Inside 5FS[x] (clothianidin) 0.25[y]
19 - Organic	Champ Formula 2 Flowable (copper hydroxide) 70.0[z]

Treatment	Product (active ingredient) and Rate
z Rate applied in g a.i./100 kg seed. y Rate applied in mg a.i./seed. x Insecticide	

TABLE 2. Locations, planting dates, and participating researchers.

FL-1	Naples, FL	Feb. 24, 2012	Justin Minor, Syngenta Seeds, Inc.
FL-2	Belle Glade, FL	Feb. 29, 2012	Robert Bieriger, University of Florida
FL-3	Belle Glade, FL	Sep. 25, 2012	Robert Bieriger, University of Florida
ID-1	Nampa, ID	Apr. 11, 2012	Justin Minor, Syngenta Seeds, Inc.
ID-2	Huston, ID	Apr. 13, 2012	Don Ogawa, Crookham Company
ID-3	Nampa, ID	May 22, 2012	Ron Baker, Harris Moran Seed
ID-4	Nampa, ID	Jun. 12, 2012	Justin Minor, Syngenta Seeds, Inc.
IL-1	Mendodta, IL	May 11, 2012	Steve Otto, Del Monte Foods
MN-1	Stanton, MN	Apr. 24, 2012	Justin Minor, Syngenta Seeds, Inc.
MN-2	Stanton, MN	Jun. 1, 2012	Justin Minor Syngenta Seeds, Inc.
NY-1	Geneva, NY	May 24, 2012	James Ballerstein, Cornell University
NY-2	Aurora, NY	Jun. 8, 2012	Margaret Smith, Cornell University
WA-1	George, WA	Apr. 9, 2012	Carrie Wohleb, Washington State University
WA-2	Ephrata, WA	Jul. 2, 2012	Carrie Wohleb, Washington State University
WI-1	Plainfield, WI	May 1, 2012	Justin Minor, Syngenta Seeds, Inc.
WI-2	DeForest, WI	May 15, 2012	Tim Gustafson, Monsanto Vegetable Seeds

RESULTS AND DISCUSSION

The ANOVA for the entire data set indicated a significant treatment x location interaction for % stand results ($P<0.0001$), so the data could not simply be averaged across all 16 locations. While it is important to examine each location individually, it is difficult to draw conclusions from such a large set of data. Therefore, locations that appeared to have similar treatment x location effects were grouped and analyzed again. ID-4 was not included in the group analysis because there were no significant treatment effects at this location. Two additional locations – NY-1 and WA-1 – were removed because they had highly variable % stand results as indicated by high coefficient of variation values (CV = 15 and 31, respectively). The WA-1 location had several plots damaged by gophers. The NY-1 location experienced unusually dry and cool environmental conditions. Two main groupings were identified based on mean % stand results for the non-treated control. Group 1 includes locations with the smallest mean % stand results for the non-treated control, ranging from 22% to 45% (FL-2, ID-1, ID-2, ID-3, MN-1, and NY-2). Four of these locations were planted in April (ID-1, ID-2, ID-3, and MN-1) when soils were cold and not conducive to rapid germination and seedling development. The ANOVA for Group 1 showed no treatment x location interactions for % stand ($P=0.1942$) or vigor ($P=0.2209$). Group 2 includes locations with larger mean % stand results for the non-treated control, ranging from 51% to 66% (FL-1, FL-3, IL-1, MN-2, WA-1, WI-1, and WI-2). Normal growing conditions were noted for these plantings. The ANOVA for Group 2 indicated no treatment x location interactions for % stand ($P=0.4700$) or vigor ($P=0.5489$). This paper will focus on the results of the Group 1 and Group 2 summaries across locations.

The treatment means for % stand and vigor at grouped locations are shown in Table 3. The non-treated control and Treatments 12 resulted in some of the smallest stand counts and lowest vigor ratings in the trial for both groups. Treatment 12 was an organic seed enhancement product that did not include fungicides or any other products; therefore it was not expected to control seed rot or seedling diseases. However, the manufacturer of this product expected to see some improvement in vigor compared to non-treated seed. This trial ended at the 5-6 leaf stage, so any impacts that the seed enhancement may have had on later growth were not assessed. The other organic seed treatment (Treatment 19) also resulted in significantly smaller stand counts compared to the conventional seed treatments in the trial, and there was no significant difference between % stand results for Treatment 19 and the non-treated control in the Group 2 summary. However, Treatment 19 had a small, but significantly larger stand count compared to the non-treated control in the Group 1 summary, and a small, but significantly larger stand count compared to Treatment 12 in the Group 2 summary. In some previous years of the ISCDA Multi-location Seed Treatment Trial, a few biological organic seed treatments have been tested. Unfortunately, they have all resulted in stands that were not significantly different from the non-treated control (Wohleb, 2010; Wohleb, 2011; Wohleb, 2012a; Wohleb, 2012b). Since many of the locations for this trial are planted during cold soil temperatures (< 50° F), the biological component of these seed treatments may not be active. The ISCDA Seed Treatment Committee decided to include Champ Formula 2, which is a copper hydroxide formulation, in the 2012 trial to test an organic seed treatment that would probably be less affected by soil temperature. Champ Formula 2 did not compare favorably to the conventional seed treatments in this study, but it resulted in stand counts that were slightly better than those of the non-treated control plots for many locations, particularly in the cooler environments. It should also be noted that none of the planting locations were located in organic fields or managed under organic conditions.

TABLE 3. Results of the 2012 ISCDA Seed Treatment Trial. Means of % STAND and VIGOR for two grouped summaries across locations. Group 1 includes averaged results across six locations (FL-2, ID-1, ID-2, ID-3, MN-1, and NY-1). Group 2 includes averaged results across seven locations (FL-1, FL-3, IL-1, MN-2, WA-2, WI-1, and WI-2).

	GROUP 1		**GROUP 2**	
TREATMENT	Stand (%)	Vigor (1-5)	Stand (%)	Vigor (1-5)
1 - Control	34.2 c	2.53 b	57.9 ef	2.95 ef
2 - Standard	71.1 a	3.64 a	69.0 d	3.53 a-d
3 - Standard	73.7 a	3.55 a	74.1 abc	3.77 abc
4 - BASF	68.8 a	3.60 a	74.0 abc	3.80 ab
5 - BASF	72.3 a	3.57 a	70.0 cd	3.48 a-d
6 - Nufarm	69.5 a	3.59 a	70.0 cd	3.35 cde
7 - Nufarm	70.0 a	3.55 a	71.7 a-d	3.59 abc
8 - Syngenta	70.2 a	3.44 a	72.4 a-d	3.40 bcd
9 - Syngenta	69.8 a	3.49 a	74.4 abc	3.88 a
10 - Syngenta	69.9 a	3.51 a	73.8 abc	3.77 abc
11 - TJ Technologies	68.9 a	3.51 a	72.1 a-d	3.46 a-d
12 - TJ Technologies	38.6 bc	2.61 b	56.0 f	2.90 f
13 - TJ Technologies	69.4 a	3.59 a	69.0 d	3.51 a-d
14 - Valent	68.0 a	3.44 a	71.0 bcd	3.69 abc
15 - Valent	68.1 a	3.56 a	75.4 ab	3.85 a
16 - Valent	70.7 a	3.48 a	72.4 a-d	3.85 a
17 - Valent	73.3 a	3.65 a	75.8 a	3.64 abc
18 - Valent	70.4 a	3.52 a	72.1 a-d	3.81 ab
19 - Organic	44.0 b	2.65 b	60.9 e	3.15 def
Grand Mean	**65.3**	**3.39**	**70.1**	**3.55**
LSD (P=0.05)	*5.8*	*0.5*	*6.3*	*0.6*

Figure 1. Sweet corn plots showing a range in seedling vigor. Plots planted with organic seed treatments (Treatment 12 and Treatment 19) are shown left and right, and a plot planted with a standard treatment (Treatment 3) is shown in the middle. WA-2 location, 25 days after planting.

The stand counts and vigor ratings for all other seed treatments in the trial were comparable to those of the two standard seed treatments (Treatments 2 and 3). There were no significant differences between the two standards in the Group 1 summary. However, Treatment 2 had a smaller stand count compared to Treatment 3 in the Group 2 summary. More differences among treatments were detected in the Group 2 summary than in the Group 1 summary. The highest ranking seed treatment for % stand in Group 2 was Treatment 17, which had a significantly larger stand count compared to Treatments 2, 5, 6, 12, 13, 14, and 19, and was comparable to the top performing standard treatment. Treatment 17 was a combination of seven products, including broad-spectrum protectant fungicides (captan and thiram), a product specifically aimed at control of *Rhizoctonia solani* (tolclofos-methyl), a systemic fungicide with activity against seed-borne *Fusarium* (metconazole), products to control soil-borne *Pythium* (metalaxyl and ethaboxam), and a systemic insecticide (clothianidin). Treatments 4, 7, 8, 9, 10, 11, 15, 16, and 18 resulted in stands that were also comparable to the top performing standard in the Group 2 summary.

Figure 2. Sweet corn plots showing a range in seedling vigor. Plots planted using non-treated seed (Treatment 1), and standard treatments (Treatment 2 and Treatment 3) are shown from left to right. WA-2 location, 25 days after planting.

The trial included several seed treatments that added products, substituted products, and/or increased rates of fungicides in the mixtures. Treatment 5 added Stamina (pyraclostrobin) to Treatment 2. Stand counts and vigor ratings for both the Group 1 and Group 2 summaries were not significantly different for these two treatments, so the addition of Stamina, a broad-sprectrum fungicide, did not improve performance of the mixture. Treatment 2 already included a broad-sprectrum fungicide, Maxim. This study did not examine Stamina as a 1:1 substitute for other broad-spectrum fungicides. Treatments 11 and 13 added seed enhancements to Treatment 2. All three treatments performed similarly at both the Group 1 and Group 2 locations, so there was no evidence that the seed enhancements improved stand or vigor in this trial. Any effects the seed enhancements may have had on growth beyond the 5-6 leaf stage were not assessed. Treatments 6 and 7 substituted fungicides, Signet (thiram) and Spirato (fludioxonil). These treatments performed similarly in the Group 1 and Group 2 summaries, suggesting that thiram and fludioxonil are acceptable substitutes; both are broad-spectrum and non-systemic protectant fungicides. Treatments 9 and 10 substituted insecticides, Cruiser (thiamethoxam) and Avicta Duo (thiamethoxam + abamectin). These two treatments performed similarly in the Group 1 and Group 2 summaries, however no insect pressure was noted for any of the locations of the trial.

Valent USA, Inc. is a relatively new company to the seed treatment business, and has only recently been developing seed treatment mixtures to market for use on sweet corn. Their products were compared in five seed treatment entries in the 2012 trial. All five treatments resulted in stand counts that were similar to the top performing standard in the Group 2 summary. When compared to each other, the five Valent treatments gave similar results, except that Treatment 17 had a significantly larger stand count compared to Treatment 14 in the Group 2 summary of locations. Treatment 17 added V10208, an experimental oomycete fungicide (active ingredient, ethaboxam), and two broad-spectrum fungicides (captan and thiram) to the products in Treatment 14. Ethaboxam is a new oomycete fungicide with a unique mode of action. This fungicide is interesting because alternatives to metalaxyl and mefenoxam are needed. Nearly all sweet corn seed is treated with metalaxyl or mefenoxam to control damping-off caused by *Pythium* spp. This increases the risk for pathogen resistance, and in fact, metalaxyl-resistant isolates of *Pythium ultimum* have been identified in some potato producing areas of the Pacific Northwest (Porter et. al, 2009). This is concerning to sweet corn producers in the region, because sweet corn is frequently rotated with potatoes. Ethaboxam may prove to be a useful tool for fungicide resistance management and for controlling damping-off caused by metalaxyl-resistant *Pythium ultimum*. A treatment comparing ethaboxam to metalaxyl would have been interesting, but was not included in this trial. Representatives from Valent USA, Inc. have indicated that they only plan to offer a seed treatment product that includes both ethaboxam and metalaxyl (personal communication, 2012).

A closer inspection of the results at each of the 16 locations can provide more information about seed treatments and the individual components of each mixture, but further analysis is not attempted in this paper. Individual results for each of the 16 locations, including treatment mean comparisons for % stand and vigor ratings, can be obtained by contacting the research coordinator for the ISCDA Seed Treatment Committee, Carrie Wohleb at cwohleb@wsu.edu.

SUMMARY

The two organic treatments examined in this trial resulted in smaller stand counts and lower vigor ratings compared to the conventional seed treatments at most locations. However, the organic treatment with Champ Formula 2 resulted in a small, but significantly larger stand count compared to the non-treated control at many of the locations, especially those that were planted into cooler soils. The performance of most of the conventional seed treatments in this trial was comparable to that of the two industry standard seed treatments. Many of the results of this trial demonstrate products that could be equivalent substitutes in seed treatment mixtures for sweet corn. More than 20 years of the multi-location trials have demonstrated that seed treatments including three components generally provide the most reliable control of seed rot and seedling diseases: (1) broad-spectrum fungicides; (2) systemic fungicides with activity against seed-borne *Penicillium* and *Fusarium*; and (3) an oomycete fungicide to control *Pythium* (Wilson and Mohan, 1991; Wilson et. al, 1993). In fields that have had problems with soil insects, it may also be beneficial to include a systemic insecticide seed treatment. Since insects were not noted to be a problem at any of the locations where this trial was planted, it is not surprising that insecticides added to the fungicide mixtures did not appear to improve stands or vigor in this trial. Seed enhancements are often added to seed treatment mixtures to boost plant health, but in this trial they did not result in any stand or vigor improvements at the 5-6 leaf stage.

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