Research

Improving Yields and Managing Dry Bean Bacterial Diseases in Nebraska with New Copper-Alternative Chemicals

Robert M. Harveson[†]

University of Nebraska, Panhandle Research and Extension Center, Scottsbluff

Accepted for publication 6 December 2018.

Abstract

Bacterial diseases, common blight, halo blight, brown spot, and wilt are major constraints to the production of dry edible beans in western Nebraska. Owing to a lack of effective control options, these diseases have been difficult to properly manage. Cultivars with partial disease resistance are available for some diseases, but not for all. Furthermore, few chemical products are accessible other than copper-based products, which have proven to be erratic in efficacy, depending on variables such as pathogen involved, disease pressure, and environmental conditions. Therefore, field studies were conducted in western Nebraska for 7 years (13 site years) evaluating newly emerging copper-alternative chemicals for

managing these diseases in dry beans. Over this time period, five different products were tested for at least 2 years each and were compared with two commercially available copper compounds (Kocide and MasterCop). The new alternatives included two growth-promoting chemicals (ecoAgra A300, WakeUP Summer), and three contact sanitizers (Goldshield 5, SaniDate, and OxiDate). Treatments with SaniDate and ecoAgra A300 more consistently produced higher yields than other treatments, while not reducing disease incidence. These improvements were achieved primarily under high levels of disease, providing promise for use in production systems in western Nebraska.

Dry Bean Diseases in Nebraska

Although dry beans in Nebraska may be affected by a number of fungal root rot and foliar diseases, this crop is particularly susceptible to bacterial diseases. There are four major bacterial diseases routinely found in bean production: common blight, halo blight, brown spot, and wilt, caused by *Xanthomonas axonopodis* pv. *phaseoli* (Smith 1897) Vautrin et al. 1995, *Pseudomonas syringae* pv. *phaseolicola* (Burkholder 1926) Young et al. 1978, *Pseudomonas syringae* pv. *syringae* (van Hall 1902), and *Curtobacterium flaccumfaciens* pv. *flaccumfaciens* (Hedges 1922) Collins and Jones 1984, respectively. They commonly occur within fields together as parts of a disease complex (Harveson and Schwartz 2007; Schwartz et al. 2005).

Disease Development and Management

Disease development and secondary spread throughout fields are similar for all dry bean bacterial diseases. Important factors promoting infection and spread include planting infected seed, planting beans in close proximity to infested fields in which disease occurred in the previous year, using reduced tillage methods of land preparation, or any event that can cause wounding in plants and movement of pathogens and infested residue between and within fields by cultivation equipment, irrigation water, or storms.

Each disease is favored by high levels of humidity and moisture; however, they differ in the respective temperatures favoring development for each disease: halo blight, less than 27°C; brown spot,

less than 29°C; common blight, greater than 27°C; and wilt, greater than 32°C (Schwartz et al. 2005; Steadman et al. 1996).

Historically, bacterial diseases have been difficult to manage owing to a scarcity of good alternative options. Partial resistance is available for some diseases in some cultivars, but complete disease resistance packages are lacking. Several popular cultivars have good levels of resistance to common and halo blights but are more prone to infection by other diseases such as rust or white mold (Steadman et al. 1996). Copper-based products are available for chemical management, but their efficacy has been inconsistent and variable, depending on pathogen, weather, and disease pressure. For example, increased economic returns from applying copper-based products have been achieved for halo blight and brown spot but not always for common blight (Garrett and Schwartz 1998; Gent et al. 2005; Legard and Schwartz 1987).

Owing to the lack of information on the efficacy of copper-based chemicals in controlling bacterial wilt, this study was initially conducted in 2010–2011 to evaluate the ability of copper to reduce this disease and increase yields in dry edible beans in western Nebraska (Table 1). In 2012, three additional new and unique, commercially available copper-alternative products were tested and compared with two copper chemicals (Table 2). Wilt was the primary focus for the first 3 years of this project because a recent disease survey identified it as the most commonly occurring disease in the Nebraska bean-growing regions (Harveson and Nielsen, unpublished).

The scope and objectives evolved and expanded in 2013–2016 to include additional copper-alternative products targeting all four bacterial pathogens simultaneously as a complex rather than focusing exclusively on wilt. Disease evaluations for this complex were based on general symptoms consistent with bacterial diseases, namely initial water-soaked lesions on foliage and pods that become necrotic with yellow borders or haloes (Fig. 1).

[†]Corresponding author: Robert M. Harveson; E-mail: rharveson2@unl.edu

Funding: Thanks to the Nebraska Dry Bean Commission for partial support of these studies.

Products Utilized over the Course of the Study

Seven different products were tested for at least 2 years each, including two copper-containing protectant chemicals (Kocide 3000, copper hydroxide, 46.1% active ingredient [a.i.], DuPont; and MasterCop, copper sulfate, 21.46% a.i., ADAMA USA) and two growth-promoting chemicals (ecoAgra A300 [ecoSolv] and WakeUP Summer [Renewable Farming]). These last two products were designed to improve crop health and vigor by promoting photosynthesis, root growth, and leaf absorption and translocation of nutrients into newly developing foliage. They consisted of plant-based fatty acids as the active ingredients. Three additional products were used as contact sanitizers that act directly on the pathogens on the leaf surface. These products were Goldshield 5 (ammonium chloride, 5% a.i., ABEK Marketing), SaniDate (hydrogen peroxide, 18.5% a.i., and peroxyacetic acid, 12.0% a.i., BioSafe Systems), and OxiDate (hydrogen dioxide, 27%, and peroxyacetic acid, 2.0% a.i., BioSafe Systems). The chemicals employed were all considered to be environmentally friendly, with four of them certified by the Organic Materials Review Institute (Kocide, MasterCop, SaniDate, and OxiDate). Thus, they could be used by organic farmers, a currently emerging practice within Nebraska that is growing substantially in breadth and popularity. All studies were initiated in mid-June by planting the great northern cultivar ‘Orion’ (Kelley Bean Co., Scottsbluff, NE), with a target population of 100,000 seeds/ha. This cultivar is highly susceptible to all four bacterial diseases.

TABLE 1 Results of 2010–2011 studies utilizing copper hydroxide (Kocide) for managing bacterial wilt in dry beans ^z						
Treatments ^{ns}	Disease incidence		100 seed weight (g)		Yield (kg/ha)	
	2010	2011	2010	2011	2010	2011
Control	22.2	18	31.1	33.3	2,116	2,784
1 application	22.5	19.3	30.5	32.7	1,968	2,908
2 applications	20.4	22.9	31.2	33.3	2,339	3,094
3 applications	24.3	16.5	30.5	32.8	2,232	3,168
LSD	14.2	15.3	1.8	2.0	536.1	790.6

^z Superscript ns = not significantly different, and LSD = least significant difference.

TABLE 2 Results of 2012 studies on copper-alternative chemicals for managing bacterial wilt in dry beans (rescue site) ^z			
Treatments	Disease incidence ^{ns}	100 seed weight (g)	Yield (kg/ha)
Control	36.7	26.7 b	946.2 b
Kocide	33.1	29.7 a	1,079.0 a
ecoAgra A300	34.7	29.9 a	1,231.8 a
WakeUP Summer	32.9	26.9 b	925.0 b
Goldshield 5	32.5	26.5 b	813.7 b
MasterCop	40.3	25.5 b	787.0 b
LSD	17.6	2.5	211.4

^z Means within columns followed by the same letter are not significantly different according to Fisher’s protected least significant difference (LSD) test ($P < 0.05$). Superscript ns = not significantly different.

Chemical Applications

Chemical applications were achieved with a Solo (Newport News, VA) diaphragm backpack sprayer fitted with a two-row boom and XR 80 02 VP nozzles (TeeJet Technologies). Sprays were applied in 55-cm bands over plants at a pressure of 20 psi. Applications occurred at midmorning and employed water as the carrier utilizing a total rate of 1,200 liters/h. Treatments were arranged in a randomized complete block design with at least five replications per treatment. Each plot consisted of four 7.6-m rows on 55-cm centers. Data were collected from the inner two rows, consisting of approximately 75 to 80 plants/row (150 to 160 plants/plot).

Field Experiments: Methodology

2010–2011. The 2010 and 2011 studies were conducted at the Mitchell Ag Lab, 5 miles north of Scottsbluff, NE, on a research field fitted with a subsurface drip irrigation system. This particular field was naturally infested with all four bacterial pathogens but was predominantly colonized by the wilt pathogen (*C. flaccumfaciens* pv. *flaccumfaciens*), mainly owing to a reduced tillage cropping system in a dry bean/corn rotation, resulting in consistently high levels of plant residues and resulting pathogen survival (Harveson et al. 2015).

There were four treatments in both years: the nontreated control and one, two, and three applications of copper hydroxide (Kocide) 7 to 10 days apart at a rate of 1.4 kg/ha beginning at flowering, which was approximately 40 days after emergence. Disease incidence (percentage of symptomatic plants) was assessed at least three times based on visual symptoms of bacterial wilt, consisting of wilting, interveinal chlorosis and necrosis, and death (Fig. 2). Yield parameters (seed yield and 100 seed weights) were measured at harvest.

2012. After 2 years, results from applications of Kocide (copper hydroxide) showed that the chemical was not effective in controlling bacterial wilt (Table 1). Therefore, in the 2012 season, the objectives of the study were expanded to include new products (ecoAgra A300, WakeUP Summer, and Goldshield 5), which were being promoted for managing another problematic bacterial disease of corn in Nebraska (Goss’s wilt and leaf blight), and to compare

FIGURE 1

Dry bean plants exhibiting symptoms characteristic of bacterial disease in general, with necrotic lesions of varying sizes with yellow borders and wilting and death of lower leaves. Common blight, halo blight, and wilt are present based on symptoms.

them to two commonly used copper products (Kocide and MasterCop). We also expanded the studies to include two sites, one at the drip field utilizing natural infection and a second study at the Panhandle Research and Extension Center in Scottsbluff (PHREC), established under sprinkler irrigation, inoculated with symptomatic, wilt-infected dry bean plants. Plants were inoculated in the greenhouse with a known, virulent wilt isolate originally obtained from the drip field at the Mitchell site in 2004, as previously described (Harveson et al. 2015; Urrea and Harveson 2014). These plants (two per plot) were transplanted randomly throughout each plot to serve as point sources of inoculum in an effort to simulate and monitor pathogen movement throughout a field after a storm event or water splashing from overhead irrigation (Fig. 3).

Both sites included six treatments: nontreated control, Kocide (1.4 kg/ha), MasterCop (1.2 liters/ha), ecoAgra A300 (dilute 1:300), WakeUP Summer (100 ml/ha), and Goldshield 5 (0.75%). All treatments were applied twice: the first at flowering (approximately 40 days after emergence) and a second application 7 to 10 days later. Owing to record-breaking hot and dry conditions that year, plant growth and disease development were poor at both sites; thus, no

FIGURE 2

Bacterial wilt-infected dry bean plants showing wilting, interveinal chlorosis, and death.

FIGURE 3

Wilt-infected bean plants (chlorotic plants) transplanted into PHREC study in 2012 as inoculum. The flags mark the boundaries of the plots.

data were collected at harvest from either site. However, in mid-July, a production field of great northern beans at the PHREC suddenly exhibited severe symptoms characteristic of bacterial wilt with an incidence estimated at 35 to 40% (Fig. 4). New plots were immediately established in this field with the same design and treated in the same manner with the six treatments listed above in the effort to serve as a last resort, rescue-oriented experiment.

2013–2014. Studies were conducted in both years at two separate locations similarly to the initial trials in 2012 described above with cultivar Orion at the subsurface drip field at Mitchell and the sprinkler-irrigated plots at the PHREC. The plots at Mitchell relied on natural infection, whereas the Scottsbluff site was inoculated. However, instead of transplanting infected plants within plots as in 2012, plants at PHREC were sprayed in the evening at flowering with a cocktail suspension consisting of equal quantities of one isolate from each of the four bacterial pathogens at a concentration of 1×10^6 CFU/ml. Applications utilized the same backpack sprayer methodology (approximately 250 ml of total liquid [water] per row). The same six treatments were employed as in 2012 with an additional product, SaniDate (dilute 1:1,000) for a total of seven treatments with six replications at each site, with the two treatment applications as in 2012: at flowering and 7 to 10 days later. The same harvest and disease incidence data were collected as previously described.

2015–2016. Studies were again conducted in both years at the naturally infested subsurface drip field at Mitchell and the sprinkler-irrigated plots at the PHREC utilizing the Orion great northern cultivar similarly as in the investigations from 2012–2014. These studies included two applications 7 to 10 days apart, with the same seven treatments (nontreated control, ecoAgra A300, Goldshield 5, Kocide, MasterCop, SaniDate, and WakeUP Summer), but with two additional treatments. These new treatments consisted of a new product similar to SaniDate called OxiDate (dilute 1:100) and a combination treatment of SaniDate and Kocide for first and second applications, respectively.

Data Analysis

Data were analyzed with the GLM procedure, and means of yield parameters and disease were separated by Fisher's protected least significant difference test ($P < 0.05$). Owing to differences in objectives, study design and methodologies, and treatments used

FIGURE 4

Severely diseased field utilized as a last resort rescue evaluation (2012). The flags mark the boundaries of the plots.

over the 7-year period, the results are presented in four separate groups: (i) 2010–2011, (ii) 2012, (iii) 2013–2014, and (iv) 2015–2016.

Results for all Studies (2010–2016)

2010–2011. In general, levels of disease from wilt were greater in 2010 than in 2011, and this is illustrated with the overall higher yields and lower disease incidence in 2011 (Table 1). No significant differences were seen among treatments for any collected yield or disease data for either year. Nevertheless, the 2011 study trended toward some positive results. Increases of 310 and 380 kg/ha were observed for two and three applications of the copper compound, respectively, compared with the untreated controls (Table 1). This suggested that it may be economically feasible for growers to use this method for managing this disease until new resistant cultivars are provided for their use. However, it is in most situations not practical to expect producers in Nebraska to apply up to three chemical applications on dry beans.

2012. From the third (rescue) site employed in 2012, we noted that adjacent fields planted to dry beans were not similarly diseased. The only differences among the fields were employed cultural practices. All were cropped to corn the previous year, but the unaffected fields contained dry bean variety trials and were disked and plowed before planting. The problem field utilized minimum tillage practices and was planted into heavy corn residues remaining on the soil surface from the previous season.

Two specific treatments (Kocide and ecoAgra A300) produced significantly higher yields after harvest (Table 2) than any other treatment during 2012. However, the use of these treatments did not affect disease incidence. The disease pressure was already very high when treatments were applied. This is illustrated by the poor yields observed for the controls and other treatments, and indicative of what would happen in similar situations in which no efforts for management were attempted (Table 2). None of these products are systemic in nature. They act only when in contact with the pathogens. Nevertheless, yields for ecoAgra A300 increased more than 400 ka/ha compared with the MasterCop treatment or almost 300 ka/ha compared with the nontreated control (Table 2).

2013–2014. Little disease (highest levels about 12%) was observed from the PHREC site despite intentionally inoculating plants with a bacterial suspension consisting of all four pathogens. Therefore, no differences were seen among treatments concerning yields, disease incidence, or 100 seed weight. The Mitchell site, however, had much higher levels of disease (30 to 40% incidence) than the PHREC site. Note the overall higher yields at PHREC compared with the Mitchell site (Tables 3 and 4). Two treatments (SaniDate and ecoAgra A300) emerged from both seasons consistently producing significantly better yields in kilograms per hectare compared with the copper treatments and controls. No other differences were found with 100 seed weight or disease incidence.

2015–2016. Although the PHREC site was again lower in disease incidence and severity overall than the Mitchell site and methodologies employed in these two seasons were identical, results of all measured parameters were very different between years, and from those of previous trials. The results from 2015 are not presented here from either site. The PHREC site was destroyed by a severe hailstorm, and the Mitchell site had such high levels of disease that no differences were observed among the treatments for any of the data collected. It is presumed that the disease levels were too severe to be sensitive to the chemical treatments.

Overall disease levels in 2016 were again very low at PHREC, as before (<3% incidence). Disease incidence was very high at Mitchell (70 to 80%), resulting in more differences among

treatments not seen at the PHREC site, as in previous years. Few differences were observed among treatments for yield or disease incidence at PHREC, similar to previous studies, with one exception. The SaniDate treatment produced significantly higher yields (more than 800 kg/ha) compared with the untreated control (Table 5). At the Mitchell site, the two treatments including SaniDate produced approximately 40% yield improvement over the nontreated control, but not 100 seed weight (not shown) or disease incidence (Table 5). The ecoAgra A300 treatment did not improve yields as well in 2016 as in the previous seasons but still produced significantly better yields (660 ka/ha) than the nontreated controls and several of the other treatments. Additionally, the WakeUP Summer treatment in 2016 produced yields more than 800 kg/ha higher than the nontreated control from the Mitchell site (Table 5).

Concluding Remarks

Losses in both yield and quality have been widely demonstrated for these important pathogens. In addition, they all now appear to be endemic in this region and capable of surviving as epiphytes on dry beans and weed species (Daub and Hagedorn 1981; Garrett and Schwartz 1998; Gent et al. 2005; Harveson et al. 2015; Legard and

TABLE 3
Results of 2013–2014 studies on copper-alternative chemicals for managing bacterial diseases in dry beans (PHREC site)^z

Treatments	Disease incidence ^{ns}		100 seed weight (g) ^{ns}		Yield (kg/ha) ^{ns}	
	2013	2014	2013	2014	2013	2014
Control	8.3	4.6	28.1	34.1	2,805.1	3,816.3
Kocide	11.2	5.6	28.9	35.5	2,846.3	4,145.3
ecoAgra A300	9.2	4.4	29.1	34.9	2,787.8	3,701.8
WakeUP Summer	10.1	4.7	28.5	35.6	2,314.1	3,905.1
Goldshield 5	9.3	4.4	28.8	35.6	2,908.8	4,045.8
MasterCop	10.5	5.3	28.7	35.8	2,886.5	3,955.5
SaniDate	7.0	5.0	28.1	35.5	2,760.4	4,103.4
LSD	6.9	7.0	1.8	1.9	610.2	644.0

^z Superscript ns = not significantly different, and LSD = least significant difference.

TABLE 4
Results of 2013–2014 studies on copper-alternative chemicals for managing bacterial diseases in dry beans (Mitchell site)^z

Treatments	Disease incidence ^{ns}		100 seed weight (g) ^{ns}		Yield (kg/ha)	
	2013	2014	2013	2014	2013	2014
Control	33.0	48.3	32.5	29.7	1,466.0 bc	1,747.0 b
Kocide	27.7	48.8	31.9	31.3	1,383.9 c	1,763.9 b
ecoAgra A300	34.4	46.9	32.1	31.0	1,856.2 a	2,025.2 a
WakeUP Summer	32.0	46.3	32.2	30.9	1,662.9 b	1,780.9 b
Goldshield 5	32.4	47.5	30.8	30.1	1,556.2 bc	1,765.2 b
MasterCop	32.2	45.3	31.1	30.5	1,641.0 b	1,736.9 b
SaniDate	28.2	41.0	32.7	30.5	2,014.0 a	2,095.3 a
LSD	8.5	8.8	2.8	2.1	169.7	360.4

^z Means within columns followed by the same letter are not statistically different according to Fisher's protected least significant difference (LSD) test ($P < 0.05$). Superscript ns = not significantly different.

TABLE 5
Results of 2016 study on copper-alternative chemicals for managing bacterial diseases in dry beans (PHREC and Mitchell sites)^z

Treatments	PHREC		Mitchell	
	Disease incidence ^{ns}	Yield (kg/ha)	Disease incidence ^{ns}	Yield (kg/ha)
Control	1.84	1,988.46 b	81.9	1,580.2 c
Kocide	1.40	2,377.1 ab	78.5	2,070.3 abc
ecoAgra A300	1.52	2,502.3 ab	79.7	2,240.5 ab
WakeUP Summer	2.80	2,175.7 ab	76.2	2,403 ab
Goldshield 5	1.74	2,462.8 ab	81.3	1,594.7 c
MasterCop	1.64	2,502.1 ab	76.9	1,789.2 bc
SaniDate	2.29	2,872.9 a	79.9	2,680.9 a
OxiDate	2.14	2,576.3 ab	81.6	2,580.9 ab
SaniDate/Kocide	2.70	2,492.8 ab	79.1	2,728.9 a
LSD	5.1	800.4	7.9	844.1

^z Means within columns followed by the same letter are not statistically different according to Fisher's protected least significant difference (LSD) test ($P < 0.05$). Superscript ns = not significantly different.

Schwartz 1987). Thus, we are going to have to adapt and learn to deal with them as a routine part of the production system in this region, just as is necessary for weed control or irrigation and fertility requirements.

We are currently working with a dry bean breeder on developing new disease-resistant cultivars to wilt and brown spot; however, it will still be several years until they have been developed and adapted for commercial use. This study was conducted to evaluate these copper-alternative products as a management tool for bacterial diseases in dry beans until resistant cultivars are available for producers.

To date there have been no published research articles concerning the utilization of copper-alternative products for bacterial disease management in dry edible beans. There have been several reports evaluating surface sanitizers in other plant pathosystems in vitro, including peroxyacetic acid for in vitro suppression of bacterial wilt (*Ralstonia pseudosolanacearum*) in tomato (Hong et al. 2018) and potato storage studies for managing *Phytophthora* and *Alternaria* diseases (Al-Mughrabi 2005, 2006). Another study assessed the lethal doses of surface disinfectants in the lab (including both hydrogen peroxide and hydrogen dioxide) required for killing *Botrytis cinerea* spores on the surface of various plant production substrates (Copes 2004). However, to my knowledge, this will be the first formal publication testing these types of chemicals on the management of any crop disease under field conditions.

Overall results since 2012 indicate that several of these new products show promise for managing these diseases in dry beans. They also appear to work well on a complex consisting of all four diseases and are considered to be environmentally friendly. However, their efficacy is still somewhat variable unless disease pressure is high. This is demonstrated from the overall poorer yields and higher disease levels from Mitchell for all years compared with those from PHREC (Tables 3, 4, and 5).

The consistently higher degree of disease from Mitchell is thought to be owing to the nature of the drip-irrigation field. The plots at this site were continually cropped with a dry bean/corn

rotation, but no tillage methods were ever employed, compared with the PHREC site, where cultivations occurred each year. As a result, crop residues at Mitchell remained on the soil surface, degrading more slowly than if any tillage operations had been used. These bacterial pathogens have been well documented to readily overwinter on infested plant tissues (Garrett and Schwartz 1998; Gent et al. 2005; Harveson et al. 2015), serving as a source of inoculum for the next susceptible host.

Although yields were not improved every year, two specific products (SaniDate and ecoAgra A300) more consistently produced higher yields than other treatments, despite not always reducing disease incidence. We seldom saw any improvement in 100 seed weight or disease incidence parameters. Although the two products possess different modes of action (contact sanitizer and plant growth promoter, respectively), both were effective for improving yields under high levels of disease pressure. SaniDate appears to act on bacterial diseases by slowing or prohibiting disease progress over time as a protectant, but not as a curative treatment for plants already infected. The ecoAgra A300 product apparently enhances vigor and plant growth, allowing improved total seed yields, despite plants still being infected.

The reason for the failure of SaniDate and ecoAgra A300 to significantly improve yields every year is uncertain. One explanation for this is environmental stresses such as extreme heat or hailstorms that may be imposed upon crops in some years but not others. This was particularly evident in both 2012 and 2015, when sites were abandoned. These factors are well known to enhance bacterial diseases and the accompanying damage they cause (Harveson and Schwartz 2007; Schwartz et al. 2005).

Unfortunately, SaniDate is a very caustic chemical, and some consultants and aerial applicators are reluctant to recommend or implement it owing to past issues observed with rapid degradation of spray equipment: nozzles, pumps, and hoses. This is assumed to be owing to the peroxyacetic acid (12% a.i.). However, OxiDate is another similar contact sanitizer available now with a lower concentration of peroxyacetic acid (2% a.i.) than SaniDate. It has gained in popularity for use because it is less harmful to spraying equipment and because these products are now commonly applied through irrigation systems.

Over the last 7 years, we have disseminated this information through field days, research reporting sessions, and preliminary newspaper and commodity magazine articles. As a result, the contact sanitizers (SaniDate and OxiDate) are now well-recognized, adopted, and routinely used in many grower production systems for managing bacterial diseases in dry beans in Nebraska and other areas of the central high plains (Colorado and Wyoming).

Acknowledgments

The author is grateful to Clay Carlson, Bob Hawley, Kathy Nielsen, and Tyler Patrick for technical support with the conduction of the studies, and the late Dean Yonts for use of the drip irrigation field.

Literature Cited

- Al-Mughrabi, K. I. 2005. Efficacy of OxiDate for control of early blight (*Alternaria solani*) in potato storages. *Plant Pathol. J.* 4:1-4.
- Al-Mughrabi, K. I. 2006. Sensitivity to hydrogen peroxide in vitro of North American isolates of *Phytophthora erythroseptica*, the cause of pink rot of potatoes. *Plant Pathol. J.* 5:7-10.
- Copes, W. E. 2004. Dose curves of disinfectants applied to plant production surfaces to control *Botrytis cinerea*. *Plant Dis.* 88:509-515.
- Daub, M. E., and Hagedorn, D. J. 1981. Epiphytic populations of *Pseudomonas syringae* on susceptible and resistant bean lines. *Phytopathology* 71: 547-550.

- Garrett, K. A., and Schwartz, H. F. 1998. Epiphytic *Pseudomonas syringae* on dry beans treated with copper-based bactericides. *Plant Dis.* 82:30-35.
- Gent, D. H., Lang, J. M., and Schwartz, H. F. 2005. Epiphytic survival of *Xanthomonas axonopodis* pv. *allii* and *X. axonopodis* pv. *phaseoli* on leguminous hosts and onion. *Plant Dis.* 89:558-564.
- Harveson, R. M., and Schwartz, H. F. 2007. Bacterial diseases of dry edible beans in the central high plains. Online publication. *Plant Health Prog.* 8. doi: 10.1094/PHP-2007-0125-01-DG
- Harveson, R. M., Schwartz, H. F., Urrea, C. A., and Yonts, C. D. 2015. Bacterial wilt of dry-edible beans in the central high plains of the U.S.: Past, present, and future. *Plant Dis.* 99:1665-1677.
- Hong, J. K., Jang, S. J., Lee, Y. H., Jo, Y. S., Yun, J. G., Jo, H., Park, C., and Kim, H. J. 2018. Reduced bacterial wilt in tomato plants by bactericidal peroxyacetic acid mixture treatment. *Plant Pathol. J.* 34:78-84.
- Legard, D. E., and Schwartz, H. F. 1987. Sources and management of *Pseudomonas syringae* pv. *phaseolicola* and *Pseudomonas syringae* pv. *syringae* epiphytes on dry beans in Colorado. *Phytopathology* 77:1503-1509.
- Schwartz, H. F., Franc, G. D., Hanson, L. E., and Harveson, R. M. 2005. Disease management. Pages 109-143 in: *Dry Bean Production and Pest Management*. H. F. Schwartz, M. A. Brick, R. M. Harveson, and G. D. Franc, eds. Bulletin 562A. Colorado State University, Fort Collins.
- Steadman, J. R., Schwartz, H. F., Kerr, E. D., Vidaver, A. K., and Coyne, D. P. 1996. Common bacterial blight and other bacterial diseases of bean on the central high plains of the USA. Pages 163-168 in: *First International Workshop on Common Bacterial Blight of Bean*. University of Puerto Rico, Feb 19-21, 1996. PROFRIJOL Doc. 96/2.
- Urrea, C. A., and Harveson, R. M. 2014. Identification of sources of bacterial wilt resistance in common beans (*Phaseolus vulgaris* L.). *Plant Dis.* 98:973-976.