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Suppression of Soybean Yield Potential in the Continental United States by Plant Diseases from 2006 to 2009

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Abstract

Research must focus on management of diseases that cause extensive losses, especially when funds for research are limited. Knowledge of the losses caused by various soybean diseases is essential when prioritizing research budgets. The objective of this project was to compile estimates of soybean yield potential losses caused by diseases for each soybean producing state in the United States from 2006 to 2009. This data is of special interest since the 4-year period summarized in this report, permits an examination of the impact of soybean rust that was first reported in the United States in 2004. Thus, in addition to the goal of providing this information to aid funding agencies and scientists in prioritizing research objectives and budgets, an examination of the impact of soybean rust on soybean yield losses relative to other diseases is warranted. Yield losses caused by individual diseases varied among states and years. Soybean cyst nematode caused more yield losses than any other disease during 2006 to 2009. Seedling diseases, Phytophthora root and stem rot, sudden death syndrome, Sclerotinia stem rot, and charcoal rot ranked in the top six of diseases that caused yield loss during these years. Soybean yield losses due to soybean rust and Sclerotinia stem rot varied greatly over years, especially when compared to other diseases.

Introduction

High yields are critical to maintaining acceptable profit margins when producing soybean in the United States. Income derived from this crop can be improved if appropriate disease management tactics are employed (12). Plant diseases may result in lower farm income for rural economies as well as the profitability of allied industries in urban areas such as farm equipment manufacturers. Research priorities must focus on management of diseases that cause extensive losses, especially when funds for research are limited. Knowledge of the magnitude of yield losses caused by various soybean diseases is essential when establishing research budgets.

The Southern Soybean Disease Workers (SSDW) has estimated soybean losses due to diseases in the southern United States each year since 1974. Estimates have been published annually in the proceedings of this organization with the most recent estimates being published in 2009 and 2010 (4,5). Estimates of soybean yield losses due to diseases were published for each Southern state from 1974 to 1994, the United States from 1996 to 1998, the United States and Ontario from 1999 to 2002, and the United States from 2003 to 2007 (9,10,11,12). Most recently, estimates of yield losses to individual diseases for the United States during 1996 to 2007 were summarized in 2009 (13). Estimates of disease impacts on soybean yields have been extensively used, quoted, and cited in the literature.

This research was prepared through a joint effort of North Central Regional Committee on soybean pathology (NCERA-212) and the SSDW. A common goal of these two groups has been to monitor and publicize the development of new or recurring diseases of soybean in North America. The current work is of

special importance due to the discovery of soybean rust in North America in 2004 (1,8). The USDA Economic Research Service estimated that soybean rust could result in annual losses from soybean rust of $240 million to $2.0 billion (6). Crop protection specialists and scientists made extensive preparations for the potential introduction of soybean rust, including a concerted effort by state specialists to apply for and receive Section 18 Emergency registrations for additional fungicides on soybean (3). This paper reports a summary of disease impacts on collective yield and does not deal with impact in each soybean producing state. The objective was to compile estimates of soybean yield losses due to diseases for the United States from 2006 to 2009. The primary goal was to provide an assessment of the major diseases impacting soybean production in order to aid funding agencies and scientists in prioritizing research objectives and budgets.

Information Collection

Plant pathologists from each soybean-producing state in the United States were asked to estimate the percent each soybean disease suppressed yield in their state during 2006 to 2009 on an annual basis. Their estimates were developed from field surveys, research plot data, plant disease diagnostic laboratory records, and questionnaires to field faculty. Most used several of these methods and consulted with their colleagues to develop an estimate of percent loss. Annual soybean production figures were obtained from the National Agricultural Statistics Service website (www.nass.usda.gov/Data_and_Statistics/Quick_Stats) in February of the following year. Production losses were based on estimates of yield in the absence of disease (4).

Soybean Production and the Impact of Soybean Diseases

Production in the United States was 3.19 billion bu from 74.6 million acres in 2006, 2.59 billion bu from 64.1 million acres in 2007, 2.96 billion bu from 74.7 million acres in 2008, and 3.36 billion bu from 76.4 million acres in 2009.

Plant diseases suppressed soybean production in the United States in 2006 to 2009, and yield losses to individual diseases varied among years (Table 1). Soybean cyst nematode (*Heterodera glycines* Ichinohe) caused more yield potential losses from 2006 to 2009 than any other single disease (Table 1, Fig. 1). Perceived yield losses to soybean cyst nematode declined in the United States from 213.9 million bu in 1996 to 93.9 million bu in 2007 (13). However, yield suppression due to this pathogen was greater in 2008 and 2009 than 2007 (Table 1). The reasons for these changes in yield losses are not known.

Seedling diseases and Phytophthora root and stem rot [*Phytophthora sojae* (Kaufman & Gerdemann)] were the second and third most damaging when ranked over the 4-year period. Seedling diseases caused yield losses in both the northern and southern regions of the United States during 2006 to 2009 (Table 1). The greatest yield losses due to seedling diseases occurred in Illinois, Kansas, Minnesota, North Dakota, and Ohio (4,5,13). Seedling diseases had a greater influence on production in 2008 and 2009 than in 2006 and 2007, and the relative importance of seedling diseases in soybean production is very obvious when data is summarized over years (Table 1, Fig. 1).

Phytophthora root and stem rot continued to cause yield losses in most states from 2006 to 2009 and estimates varied from 53.8 million bu in 2006 to 25.1 million bu in 2007 (Table 1). This variation was probably due to variation in weather between years, but may be due to changes in the pathogen and increased soybean production with shorter rotations.

Table 1. Estimated yield losses in bushels of soybeans due to diseases in 28 U.S. states* during 2006, 2007, 2008, and 2009.

Diseases	2006	2007	2008	2009
Anthracnose	18,113,000	10,008,000	11,086,000	17,866,000
Bacterial diseases	3,731,000	6,159,000	6,319,000	4,348,000
Brown spot	19,720,000	11,454,000	22,152,000	23,576,000
Brown stem rot	18,284,000	11,788,000	12,200,000	19,942,000
Charcoal rot	25,637,000	30,133,000	22,414,000	9,417,000
Downy mildew	5,418,000	1,337,000	11,904,000	5,955,000
Frogeye leaf spot	12,682,000	9,446,000	6,756,000	7,565,000
Fusarium root rot	6,215,000	5,804,000	10,604,000	8,276,000
Other diseases	2,045,000	150,000	828,000	640,000
Phomopsis seed rot	4,485,000	1,985,000	5,846,000	23,246,000
Phytophthora rot	53,808,000	25,085,000	48,638,000	44,679,000
Pod and stem blight	7,655,000	5,510,000	8,198,000	16,466,000
Purple seed stain	3,132,000	2,706,000	7,172,000	12,869,000
Rhizoctonia aerial blight	460,000	320,000	410,000	70,000
Root-knot & other nematodes	7,919,000	6,250,000	9,677,000	6,959,000
Soybean rust	901,000	550,000	220,000	2,890,000
Sclerotinia stem rot	13,305,000	5,114,000	11,608,000	59,275,000
Seedling diseases	39,885,000	33,905,000	54,811,000	55,492,000
Southern blight	190,000	180,000	250,000	260,000
Soybean cyst nematode	123,778,000	93,981,000	171,997,000	120,048,000
Stem canker	7,779,000	5,055,000	5,661,000	5,562,000
Sudden death syndrome	27,320,000	22,078,000	20,412,000	34,473,000
Virus	7,451,000	6,676,000	5,957,000	4,577,000
Total	410,593,000	296,845,000	458,478,000	484,451,000

* States represented include AL, AR, DE, FL, GA, IA, IL, IN, KS, KY, LA, MD, MI, MN, MO, NC, ND, NE, OH, OK, PA, SC, SD, TN, TX, VA, and WI.

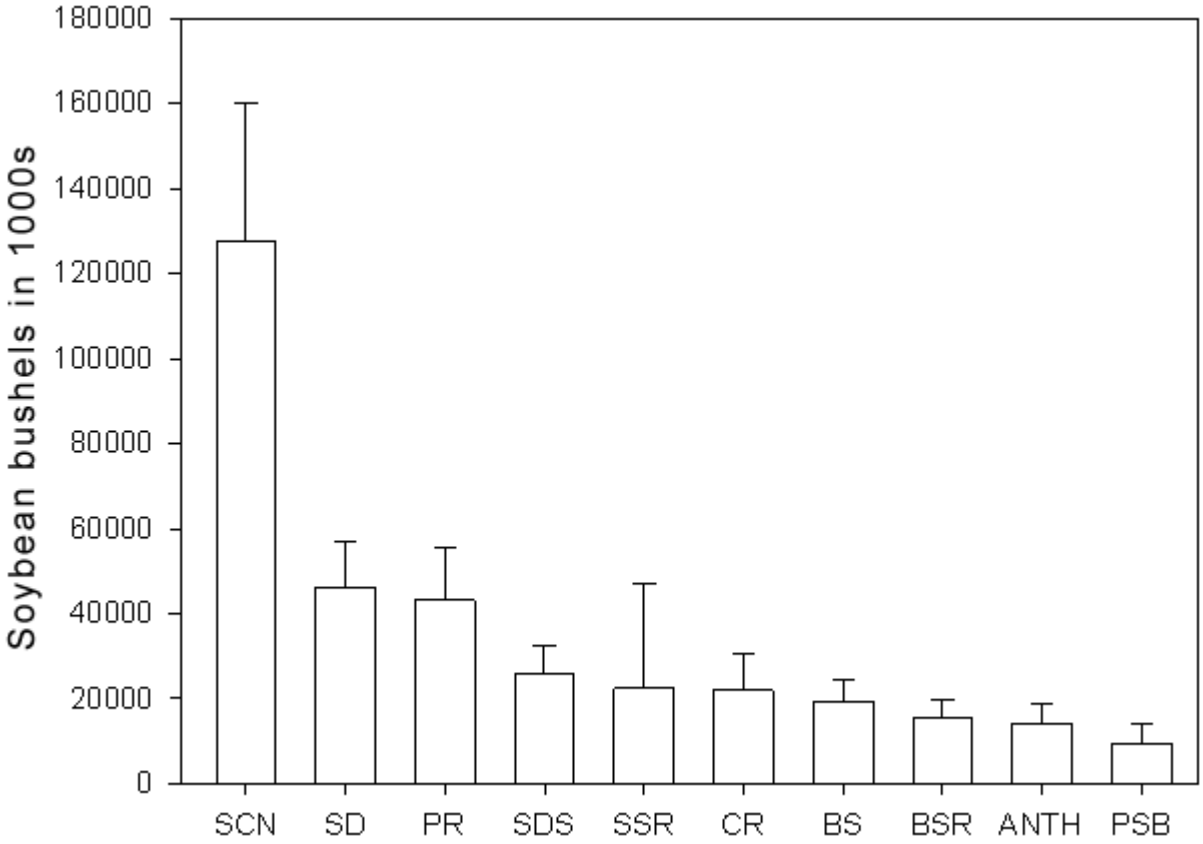

Fig. 1. Mean and standard deviation of soybean seed yield (bushels) suppression by the ten most damaging diseases from 2006 to 2009 in the United States. SCN = soybean cyst nematode, SD = seedling disease, PR = Phythopthora root and stem rot, SDS = sudden death syndrome, SSR = Sclerotinia stem rot, CR = charcoal rot, BS = brown spot, BSR = brown stem rot, ANTH = anthracnose, and PSB = pod and stem blight.

Sudden death syndrome [*Fusarium solani* f. sp. *glycines* (Roy)] was the fourth most important disease when averaged over 2006 to 2009, but was the fifth most important disease from 2007 to 2009. Sudden death syndrome caused appreciable yield losses in Arkansas, Iowa, Illinois, Indiana, Minnesota, and Tennessee during 2006 to 2009 compared to other states (4,5,13). Scherm and Yang (7) determined that weather patterns were more conducive for this disease in the central United States than any other area of the country, and these data confirm their observation.

Losses due to Sclerotinia stem rot [*Sclerotinia sclerotiorum* (Lib.) deBary] increased dramatically in 2009 when it was the second most damaging disease following soybean cyst nematode (Table 1). The high losses incurred as a result of Sclerotinia stem rot in 2009 resulted in this disease being the second most important in 2009 even though it was the fifth most important disease over the 4-year period (Fig. 1). The yield losses to this disease were lowest during 2001 and 2003, at about 2.2 million bushels, and greatest in 2004 and 2009, about 60.0 million bushels (11,12,13). The differences in seed yield suppression from this disease among years may be related to differing weather patterns or regional changes in cultivars. Since Sclerotinia stem rot was not among the top eight diseases from 2006 to 2008, yet increased so dramatically in 2009, greater research and extension efforts on this disease seem warranted. Sclerotinia stem rot of soybean is typically a problem in Northern states with the largest soybean acreage in the United States, but is rarely detected in Southern States (*data not included*).

Charcoal root rot [*Macrophomina phaseolina* (Tassi) Goid] caused more yield losses during 2006 to 2008 than 2009 (Table 1), but these yield losses are greatest in the Southern United States (3,4). Charcoal rot resistant cultivars are not available for planting so these differences are probably due to yearly variation in weather patterns.

Soybean cyst nematode, seedling diseases, and Phytophthora root and stem rot are the three greatest causes of losses in soybean yield potential (Fig. 1). These three diseases are followed in importance by sudden death syndrome, Sclerotinia stem rot and charcoal rot which are also soilborne diseases. Thus, soilborne diseases, account for the greatest impacts of disease on potential production losses when averaged over the period of this study. Foliar diseases, as a group (Cercospora blight, brown spot, anthracnose, pod and stem blight, frogeye leaf spot, downy mildew, Rhizoctonia aerial blight, and soybean rust) represent a relatively small portion of total losses in yield potential. An obvious conclusion is that more emphasis in management of soilborne diseases, including nematode plant-parasites, is needed. Fungicides are available for management of most foliar diseases, but predictability of a positive yield response from fungicides remains fairly low for many production areas (S. R. Koenning, *personal observation*). Soybean producers now have a greater number of fungicides for foliar application with the addition of a number of triazole fungicides that have been registered because of soybean rust. The triazole fungicides are typically excellent products for rusts and powdery mildew, but there efficacy for other soybean diseases may differ considerably from that of the fungicides that were previously available for control of other diseases.

Soybean rust [*Phakopsora pachyrhizi* (Syd & P. Syd.)] was first confirmed on soybean in nine states in the Continental United States during November and December, 2004; Alabama, Arkansas, Florida, Georgia, Louisiana, Missouri, Mississippi, Tennessee, and South Carolina (1,7). Seed yield loss due to soybean rust was greater in 2009 compared to 2006, 2007, and 2008 (Table 1). Soybean rust was detected in 14, 18, 14, and 17 states in the continental United States in 2006, 2007, 2008, and 2009, respectively, according to incidence reported on the USDA Public Soybean Rust Website (sbr.ipmpipe.org/cgi-bin/sbr/public.cgi). The ranking for soybean rust in respect to the other 23 diseases included in this report was never higher than nineteenth during the period covered. The need to manage soybean rust, which has received considerable support for research and extension efforts, should perhaps be deemphasized in spending priorities. Nevertheless, Southern states still need to continue research and extension efforts on soybean rust, and the monitoring network in the Southern United States to minimize unnecessary fungicide applications for management of rust.

Reliable estimates of crop losses to diseases based on precise methodology using crop surveys and crop loss models have been very useful for defining the severity of various plant diseases (2). Although the methodology used in this research can and will be improved, estimates in this paper were by knowledgeable extension pathologists with input from consultants and other soybean agronomists who are covering large geographical regions, and are believed to provide reasonably accurate assessment of losses in yield potential.

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