The Yields II Project: Research-Based Management Information

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Soil pH Influences Soybean Disease Potential

Research shows that soil pH may be used to predict the yield-robbing potential of soybean cyst nematode (SCN) and brown stem rot (BSR) and to guide soybean growers in management decisions to minimize yield loss caused by both pathogens.

Soybean growers understand the importance of soil pH to soybean nutrition and related effects on soybean yield. Likewise, soybean growers are aware of the yield-robbing potential of the soybean cyst nematode (SCN) and brown stem rot (BSR), a vascular disease of soybean. SCN and the BSR fungus are commonly found together throughout the North Central states. Our research shows that soil pH has a profound effect on the degree of yield loss caused by SCN and the BSR fungus and provides insight into how soil pH interacts with soybean pathogens. This knowledge can be applied to the design of soybean disease management systems.

SCN and BSR reduce soybean yield

The importance of SCN and BSR has grown steadily since the introduction of soybean into the North Central states. In recent years, the time interval between soybean crops has decreased, resulting in greater disease potential. Despite shortened intervals between soybean planting, many fields do not have problems caused by SCN or BSR. Normally, the population density of SCN and disease potential of BSR steadily rise in an alternating rotation of corn and susceptible soybean varieties. The effect of soil pH on both SCN and BSR is a partial explanation for why some fields maintain minimal problems despite susceptible varieties and cultural practices that would normally favor a high risk of infection by each pathogen.

Soil factors and soybean disease

The effect of many soil properties, including pH, on soybean pathogens and diseases has not received extensive attention by researchers. The Yields II Project provided a unique opportunity for a multiyear study of the effect of soil pH on soybean pathogens. A commercial field was found with a range of soil pH conditions and SCN and the BSR pathogen were both present, which provided an additional and unique study opportunity. Although there were some previous indications of soil pH affecting SCN, this investigation was designed to make critical comparisons of treatment variables. Most data support the conclusion that soybean yield increases as soil pH increases. Exceptions occur when soil pH exceeds 7.4 and iron chlorosis develops because of low availability of soil iron. Results of this study indicate expected soil pH and yield relationships are modified by SCN and BSR. Soil fertility information must be combined with knowledge of potential disease pressure to implement profitable soybean management systems.

Soil pH and spring populations of SCN

The highest spring population densities of SCN were observed in soils of pH 7.0 or greater for all years of the study (Table 1). Results also indicate that high population density of SCN at planting can be expected in field areas with soil pH 7.0–8.0 compared with areas of soil pH 5.9–6.5. Soil pH greater than 7.0 was consistently associated with high initial SCN egg density (Table 1).

SCN is frequently found in an aggregated distribution of varying population density. Point of introduction, soil type, tillage patterns, and movement of soil within fields are possible explanations of the usual mosaic distribution pattern of SCN in infested fields. The findings of this research suggest that soil pH is another factor that governs the distribution of SCN in fields. The findings also suggest that soil pH may govern the degree that SCN populations increase in a field after introduction.

Table 1. Relationship between soil pH and population density of SCN at planting in a field with an alternating corn–soybean rotation.

	Soil pH Range		
	5.8–6.4	6.5–7.0	7.1–8.0
Year	**Initial SCN Eggs/100 cc of Soil**		
1	450	2400	4300
2	160	760	3200
3	50	670	1220
4	463	636	1994

Soil pH and SCN-resistant soybean varieties

The yield advantage of SCN-resistant varieties over susceptible varieties generally increases with rising SCN population density. This generalization was validated in our study. The yield advantage of SCN-resistant varieties was greatest in high pH soils and lowest in low pH soils (Table 2). Yield, regardless of variety-SCN reaction, was generally greatest at soil pH 6.0 compared with higher pH soils. This result is contrary to expected results related to soil pH and yield. The yield of SCN-resistant varieties exceeded the yield of susceptible varieties on average by 4–17 bushels per acre, and reached as much as 30 bushels per acre in individual plots located in areas of the field at soil pH 7.1–8.0 (Table 2). The yield advantage of SCN-resistant varieties over susceptible varieties may not be realized in SCN-infested fields with soil pH in the range of 6.4 or lower.

Table 2. Yield differences between SCN-resistant and SCN-susceptible varieties grown across a range of soil pH.

	Soil pH Range		
	5.8–6.4	6.5–7.0	7.1–8.0
Year	**Yield Difference (bu/acre)**		
1997	4.3	14.3	16.8
1998	0	1.7	4.5
1999	0.7	10.1	12.7
2000	0.5	–3.5	4.3
Average	1.4	5.6	9.6

The status of soil pH in a field may become important to growers interested in managing SCN. For example, once SCN is discovered on a farm, growers must decide whether to modify current crop management practices. The use of SCN-resistant varieties is considered a primary option in management of SCN. These data suggest that soil pH could possibly be used in conjunction with SCN population density and field distribution data to determine whether SCN-resistant varieties are needed.

Soil pH and monitoring fields for SCN

Monitoring SCN reproduction is important to implementing a soybean management plan for fields infested with this pathogen. Although final population densities varied by year, SCN populations were highest in the areas of the field with the highest soil pH (Table 3). SCN populations at soil pH 7.1–8.0 averaged 3.8-fold higher than those at soil pH 5.8–6.4 for the 4-year study (Table 3). Population density of SCN, in the absence of soybean in 1998, declined 79-fold in areas of the field with low pH soils compared to an eight-fold decrease in high pH soils

(Table 4). Although SCN population densities increased during the growing season in all soils regardless of pH, populations in areas of high soil pH consistently and dramatically exceeded populations in low soil pH areas (Table 4).

Table 3. Relationship between soil pH and final population density of SCN at harvest.

	Soil pH Range		
	5.8–6.4	6.5–7.0	7.1–8.0
Year	Final SCN Eggs/100 cc of Soil		
1997	3950	6950	9750
1998	500	1500	2550
1999	2000	6800	7500
2000	786	766	1574

Table 4. Relationship among soil pH and initial and final SCN population densities in a soybean–corn rotation (1997–1999).

	Soil pH Range		
	5.8–6.4	6.5–7.0	7.1–8.0
Year	SCN Eggs/100 cc of Soil		
1997 Initial SCN	450	2400	4300
1997 Final SCN	3950	6950	9750
1998 Corn	—	—	—
1999 Initial SCN	50	670	1220
1999 Final SCN	2000	6800	7500

The value of SCN resistance to protect yield potential on an annual basis is important, but the ability to support less SCN reproduction may be equally important in the long term. SCN-resistant varieties were associated with lower SCN population densities at harvest, whereas SCN-susceptible varieties were associated with higher SCN population densities, regardless of soil pH levels or initial SCN population densities (Table 5). In the current study, final season SCN populations associated with SCN-resistant varieties exceeded 2000 eggs per 100 cc of soil only in plots with soil pH greater than 7.0. Soybean growers must be aware that soybean varieties vary in degree of resistance to SCN and many are not capable of reducing SCN population densities. Soil pH may be used to predict future changes in SCN populations based on whether susceptible or resistant varieties are grown.

Table 5. Comparison of final SCN population densities on SCN-resistant and SCN-susceptible varieties at varying soil pH.

		Soil pH Range		
		5.8–6.4	6.5–7.0	7.1–8.0
Year	SCN Reaction	Final SCN Eggs/100 cc of Soil		
1997	Resistant	883	825	2517
	Susceptible	6867	15875	17150
1998	Resistant	100	275	1175
	Susceptible	675	2800	3950
1999	Resistant	481	825	2813
	Susceptible	3125	10283	12012
2000	Resistant	446	527	577
	Susceptible	1126	1291	2473

Soil pH and BSR severity

The severity of BSR generally increases with time in an annual alternating rotation of soybean and corn (Figure 1). However, the rise in BSR potential is strongly modified by soil pH (Figure 1). The severity of BSR is greatest when soil pH is near 6.0 and is less severe when soil pH is 7.0 or greater (Figure 1). These conclusions are drawn from results of multiple years of small-plot and large-scale on-farm trials. Although severity of foliar symptoms varied by year, the greatest levels of BSR foliar and stem symptoms were observed in the low pH areas of the field (Figure 2).

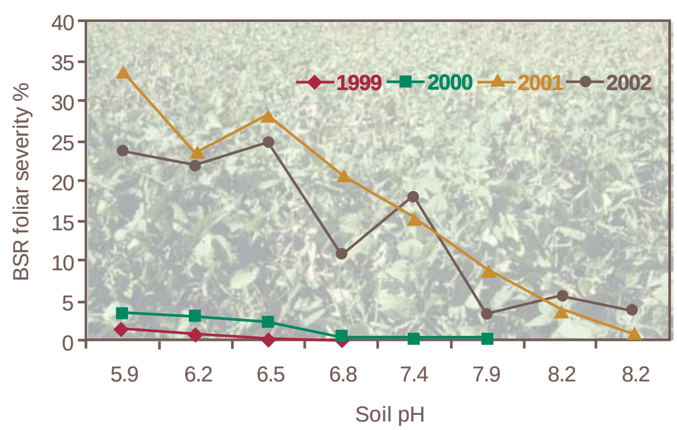

Figure 1. Increase in BSR severity (1999–2002) in a field planted to corn 4 years prior to 1999.

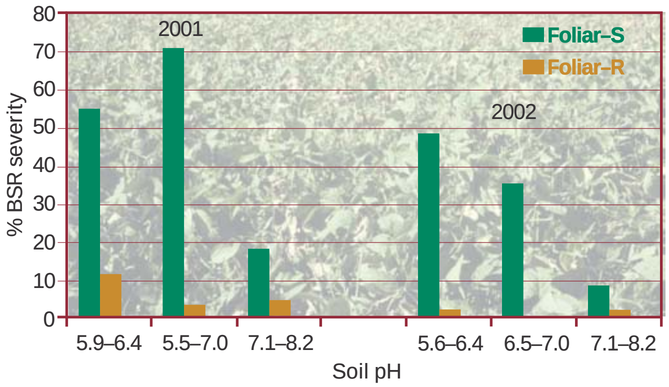

Figure 2. Foliar symptom severity of BSR is greatest at low soil pH for both resistant (R) and susceptible (S) soybean varieties. Data are for 2001 and 2002.

Comparison of susceptible (left) vs. resistant (right) soybean varieties.

Foliar symptoms of BSR are characterized by tissues between major veins becoming yellow followed by death.

Populations of BSR pathogen detected in roots and stems

Comparison of normal internal stem tissues (left) to brown discoloration of internal stem tissues caused by the BSR pathogen.

Symptom severity of BSR is controlled by soybean variety, population density of the pathogen, pathogen strain, and climatic and soil factors. Although foliar and stem symptoms of BSR decreased at high soil pH, the mechanism of this response is not known. Stems and roots were assayed for the presence and population density of the BSR pathogen (Figure 3). The BSR pathogen was detected in plants regardless of soil pH. Density of the BSR pathogen was lowest in both root and stem tissues of plants grown in higher soil pHs and highest in plants grown at lower soil pHs. Thus, populations of the pathogen were correlated with the range in symptom severity associated with differing soil pH. Density of the BSR pathogen was lowest in tissues of BSR-resistant varieties and highest in tissues of susceptible varieties. As soil pH increased, the density of the BSR pathogen in tissues of resistant varieties decreased, but remained high in susceptible varieties regardless of soil pH (Figure 3).

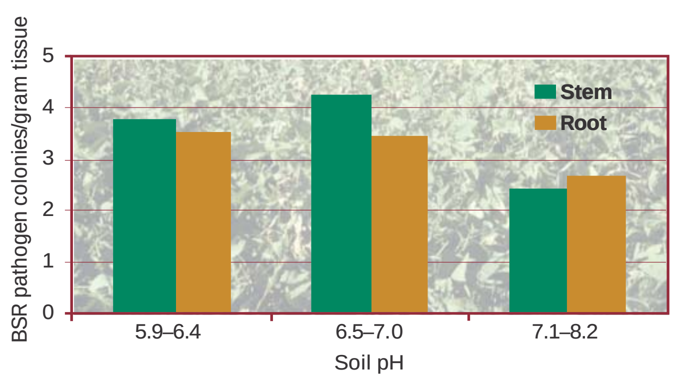

Figure 3. Levels of BSR pathogen in roots and stems decrease as soil pH increases. Using the presented scale, a difference in 0.1 units represents an approximately 20,000 colony-forming unit increase/gram of tissue (summary data 2001–2002).

Yield advantage of BSR-resistant varieties is greatest at low soil pH

The trend of BSR symptom severity with soil pH correlates well with soybean yield. The yield advantage of BSR-resistant varieties over BSR-susceptible varieties is greatest when soil pH is lower than or near 6.0 and declines as soil pH increases to the range of 7.0–8.0 (Figure 4). BSR-susceptible varieties express high symptom severity when grown in soils low in pH, but not when grown in soils with elevated pH (Figure 2). In contrast, BSR-resistant varieties express mild symptom severity regardless of soil pH. The contrasting levels of symptom severity for brown stem rot-resistant and -susceptible varieties are related to differences in pathogen reproduction in plant tissues (Figure 5).

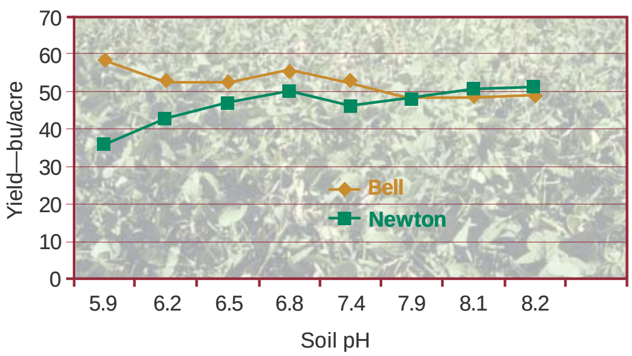

Figure 4. Yield of variety Bell, resistant to both SCN and BSR, compared with yield of variety Newton, resistant to SCN but susceptible to BSR, grown in soils of differing pH and infested with both SCN and the BSR pathogen (average of 2001–2002 data).

Appearance of soybean canopy of a BSR-susceptible variety at growth stage R5–6.

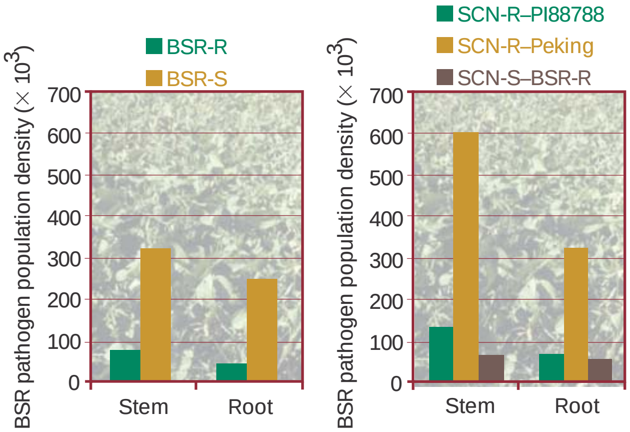

Figure 5. BSR-resistant varieties support lower reproduction of the BSR pathogen compared with susceptible varieties. Soybean varieties with SCN resistance derived from PI88788 are resistant to BSR and support less reproduction of the pathogen. Soybean varieties with SCN resistance derived from Peking are susceptible to BSR and support significantly higher reproduction of the BSR pathogen.

SCN-resistant varieties and BSR

Soybean varieties have improved greatly in the past 15 years for resistance to both the BSR pathogen and SCN. Resistance to both BSR and SCN comes from several different and independent sources. The number of varieties with BSR resistance has grown in recent years. Starting in the early 1990s, results from field trials suggested that some SCN-resistant varieties also expressed resistance to BSR. Further investigation revealed that most SCN-resistant varieties with resistance derived from PI88788 were resistant to BSR, but varieties with resistance derived from Peking were susceptible to BSR. Fortunately, most SCN-resistant varieties are derived from parents that trace to PI88788. The use of SCN-resistant varieties with the PI88788 source will greatly lower the risk of BSR. For SCN-resistant varieties with the PI88788 source of SCN resistance, significantly fewer propagules of the BSR pathogen are detected; and at levels similar to varieties rated as resistant to BSR, but BSR resistance is derived from other sources. High BSR pathogen populations are detected in SCN-resistant varieties derived from Peking (Figure 5). Soon SCN-resistent varieties will be available that are derived from the variety Hartwig. This source of resistance is considered superior to other sources of SCN resistance such as PI88788 and Peking. However, Hartwig and some experimental lines derived from this source of SCN resistance are susceptible to BSR.

Management of SCN and BSR

Management of soybean diseases not only encompasses pathogen detection and use of resistant varieties and crop rotation but also knowledge of soil pH of a particular field. Our data indicate that BSR severity increases as soil pH decreases, whereas SCN increases as soil pH increases. Once a field is characterized for soil pH, the appropriate rotation sequence and soybean variety selection may be used to formulate a comprehensive soybean plant health management program (Figure 6). Growers also have the option to decide whether it is cost-effective to modify soil pH to manage specific soybean diseases.

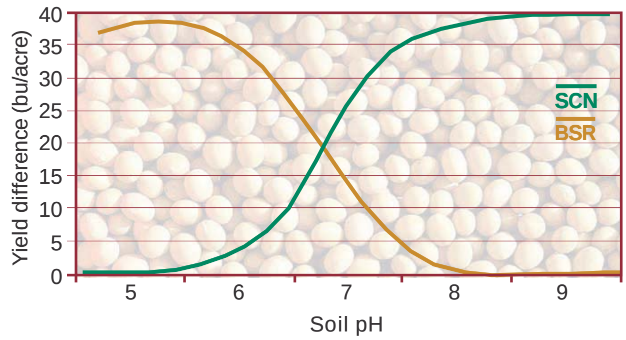

Figure 6. Theoretical yield difference between resistant and susceptible varieties differs by pathogen. BSR yield loss is greatest at low soil pH and SCN yield loss is greatest at high soil pH.

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Prepared by

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