SOIL PH IN RELATION TO BROWN STEM ROT AND SOYBEAN CYST NEMATODE

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The soybean cyst nematode (SCN; *Heterodera glycines*) and brown stem rot (BSR) fungus (*Phialophora gregata*) are serious pests of soybean, occurring over a range of soil types and soil pH. Often found in the same field, management strategies implemented to control one pathogen may in fact exacerbate damage caused by the other. As soybean acreage has increased, the duration between soybean crops has decreased in crop rotation schemes, thus also increasing the frequency of detecting dually infected fields. Control of each pathogen is directed at variety selection and crop rotation, and is refined further by matching variety selection with choice of herbicides and tillage practices.

Diagnosis and Impact of SCN and BSR

Soil sampling and inspection of soybean roots in midsummer are methods to detect the presence of SCN in a field. Factors indicative of a SCN infestation include a gradual erosion of yield over years and late outbreaks of weeds in areas of fields with stunted plants and sparse crop canopies. Yield loss due to SCN is related directly to the ability of SCN to reproduce on roots. However, the agronomic effect of SCN is greatest if low soil moisture and possibly other pathogens inflict a stress on soybean plants. SCN is found in fields regardless of soil type, but as soil sand content increases, the action threshold is lowered. Unless managed, yield loss occurs in varying degrees each year once the SCN population reaches a threshold density. Yield loss due to BSR, on the other hand, appears to vary more each year because of the apparent influence of weather, tillage practices, soil moisture and variety planted. Yield loss due to BSR is generally greatest when foliar symptoms are present. Foliar symptoms are more likely to develop when air and soil temperatures are normal to below normal during late pod development and soil type and moisture status are conducive for high yield potential.

Research Project

With funding from the Soybean Research and Development Council and the Wisconsin Soybean Marketing Board, a research project was implemented to study the relationship of soil factors to the biology and pathogenic activity of SCN and BSR. Soil pH was the focus of the study, but organic matter, phosphorus, potassium and cation exchange capacity also were studied because of their close association with soil pH. Soil pH has long been recognized as an important factor that regulates availability of nutrients to the soybean plant and ultimately affects soybean yield. However, the effect of soil pH on soybean pathogens is not well understood. One field site for this study has both SCN and BSR, as well

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as a large range in soil pH. An important element of the study was the use of soybean varieties that differed in reaction to BSR and SCN. A second field location was selected because of high BSR pressure and the absence of SCN at the Arlington Agricultural Research Station.

Results of SCN-Soil pH Study

Most data supports the conclusion that soybean yield increases as soil pH increases. Exceptions occur when soil pH exceeds 8.0 and iron chlorosis develops because of low availability of soil iron. However, in the presence of SCN, the positive effect of pH neutral (pH 7.0) soil on soybean yield was negated, with highest yield associated with soil pH levels of 6.0-6.5 in all years of the study. This result was explained by the discovery that SCN population density increased as soil pH increased, although the strength of this relationship varied by year (1997, r=0.84; 1998, r=0.76; 1999, r=0.31; 2000, r=0.48; 2001, r=0.47). The relationship of SCN population density and soil pH was lowest in 1999 possibly due to lower SCN populations resulting from the use of SCN resistant varieties in 1997. Results from five years of field studies indicates that high population density of SCN at planting can be expected in areas of fields with soil pH levels of 7.0 to 8.0 compared to areas of soil pH 5.9 to 6.5. Soil pH over 7.0 was consistently associated with high initial SCN egg density (Table 1).

The SCN is frequently found in an aggregated distribution of varying population density. Soil type, tillage patterns and movement of soil within fields are possible explanations of the usual mosaic pattern of the 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 its introduction.

Table 1. Relationship between soil pH and population density of the soybean cyst nematode at planting.

	Initial SCN Eggs/100 cc of Soil Soil pH Range		
Year	5.8-6.4	6.5-7.0	7.1-8.0
1997	450	2400	4300
1998	160	760	3200
1999	50	670	1220
2000	463	636	1994
2001	1973	1203	5123

As expected, the yield difference between resistant and susceptible varieties increased as SCN population density increased. Furthermore the relationship between soil pH and SCN activity was substantiated further by the findings that differences in yield between resistant and susceptible varieties varied as soil pH varied in the experimental site. The status of soil pH in a field may become important to a grower interested in managing SCN. For example, once SCN is discovered on a farm, growers must decide whether to use or not to modify current crop management practices of the field or farm. The use of SCN resistant varieties is considered a first option in management of SCN. These data suggest that soil pH can be used in conjunction with SCN population density and field distribution data to determine if SCN resistant varieties are needed. SCN resistant varieties are not an automatic solution to management of SCN. Some SCN resistant varieties are lacking the yield potential of elite SCN susceptible varieties. Thus, a significant yield penalty may be realized if an SCN resistant variety is planted in a field with SCN populations that are below damage thresholds. There is no question of the value of SCN resistant when SCN populations exceed damage thresholds. The yield of SCN resistant varieties exceeded the yield of susceptible ones on average 5-17 bushels per acre, and reaches as much as 30 bushels per acre in individual plots location in areas of the filed at soil pH 7.0-8.0 (Table 2). However, data from the current study supports a conclusion that the yield advantage of SCN resistant varieties over susceptible varieties may not be realized in fields with soil pH approaching 6.0.

Table 2. Difference in yield between SCN resistant and susceptible varieties in soil with different soil pH.

	Yield difference - bu/A Soil pH range		
Year	5.8-6.4	6.5-7.0	7.1-8.0
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
2001	5.6	6.9	8.7

Monitoring SCN reproduction is important to implementing a soybean management plan in the presence of SCN. Although final population densities varied by year, data supported a strong conclusion that SCN populations increased more 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 compared to SCN population densities in soils with pH levels of 5.8-6.4 for the five-year study (Table 3). There is not strong evidence to explain why lower initial populations of SCN are observed in low pH soils compared to soils at pH 7.0-8.0. Current data suggest populations of SCN, in the absence of soybean, appeared to decline faster in low pH compared to high pH regions of the field plot (Table 4). SCN population density in the lowest pH portions of the field declined 79-fold from the final population in 1997 to the initial population detected in the spring of

1999. In contrast, SCN population density in the high pH portions of the field declined 8-10-fold during the same time period.

Table 3. Relationship between soil pH and final population density of the soybean cyst nematode at harvest.

	Final SCN Eggs/100 cc of Soil Soil pH Range		
Year	5.8-6.4	6.5-7.0	7.1-8.0
1997	3950	6950	9750
1998	500	1500	2550
1999	2000	6800	7500
2000	786	766	1574
2001	6390	6200	9458

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

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

Corn was planted in plot in 1998.

The value of SCN resistance to protect yield potential is important, but the ability to support less SCN reproduction may be of equal importance for the long term. In this current study, SCN resistant varieties were associated with lower SCN population densities at harvest, while SCN susceptible varieties were associated with higher SCN population densities, regardless of soil pH levels or initial SCN population densities. Although damage thresholds of SCN may vary with soil type and seasonal climatic conditions, harvest populations densities of 2,000 eggs per 100 cc of soil are yield limiting in many cases. In this current study, SCN associated with SCN resistant varieties were above 2000 eggs per 100 cc of soil only in plots with soil pH greater than 7.0. Data support a conclusion that SCN populations may be managed more effectively with variety selection at soil pH levels below 7.0 (Table 5). 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 SCN resistant and SCN susceptible varieties for final SCN population densities at varying soil pH.

		Final SCN Eggs/100 cc of Soil Soil pH Range		
Year	SCN Reaction	5.8-6.4	6.5-7.0	7.1-8.0
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
2001	Resistant	2422	2108	4694
	Susceptible	11806	6750	14036

Results of Studies- Brown Stem Rot

Results from several years of small plot and large-scale on-farm trials suggest that brown stem rot severity is greatest as soil pH approached 6.0. These frequent observations prompted studies at a non-SCN site. Results from seven years of experiments indicate a yield difference between BSR resistant and BSR susceptible varieties decline as soil pH increases from 5.7-6.7 (Table 6.) A strong correlation between soil pH and symptom severity appears in BSR susceptible varieties, but not in BSR resistant varieties. At an SCN site, BSR severity was low in 1997 and 1998; however the BSR pathogen was detected in the roots and stems of the soybeans. Populations of the BSR pathogen decreased as soil pH increased for both years as well. In 1999 and 2000, foliar symptoms of BSR were observed, and as soil pH increased, symptom severity decreased. The greatest levels of BSR foliar and stem symptoms were observed in 2001.

Table 6. Yield difference of BSR resistant and susceptible varieties across a range of soil pH in a silt loam for seven years at Arlington, Wisconsin.

Year	Soil pH	Yield difference- bu/a
1992	6.0	19
1993	6.7	8
1994	5.7	16
1995	6.3	5
1996	6.5	1
1998	6.7	1
1999	6.7	5

Reaction of SCN Resistant Varieties to Brown Stem Rot

Varieties used in these studies were not only selected for SCN resistance, but also on the source of SCN resistance. Most varieties have the PI 88788 source, but varieties derived from the Peking source also were planted. Substantial data is now available to support the conclusion that most SCN resistant varieties with the PI88788 source of resistance also express no symptoms or mild BSR symptoms in the field. In contrast, SCN resistant varieties derived from Peking are extremely susceptible to BSR. The use of SCN resistant varieties with the PI 88788 source will greatly lower the risk of BSR especially in fields with soil pH 7.0.

Population of Brown Stem Rot Pathogen Detected in Roots and Stems

While foliar and stem symptoms of BSR decreased at high soil pH, it was not known if the levels of the BSR pathogen in stems and roots also decreased. Using ground stem and root tissue dilution plated onto selective media, colony forming units (CFU) of the BSR pathogen was quantified in 2000 and 2001. CFU values are an estimate of pathogen activity in plant tissues. In 2000, lowest levels of the BSR pathogen were found at the highest soil pH (Table 7).

Table 7. Levels of the BSR pathogen at different soil pH levels, 2000.

	CFU/per gram of tissue	
Soil pH	Stem	Root
6.1	457	700
6.2	335	9080
6.8	322	547
7.8	23	718
7.9	0	2
8.0	2	42

To further refine these findings, a study was initiated in 2001 to study all possible BSR resistant/SCN resistant combinations over the range of soil pH. BSR foliar and stem symptom development was greatest at low pH, however the BSR pathogen was detected at all soil pH levels. As soil pH increased, levels of the BSR pathogen decreased in stem and root tissue. (Figure 1). For BSR resistant varieties, as soil pH increased, the number of BSR pathogen CFU decreased. This relationship was not observed in BSR susceptible varieties, where levels of the pathogen were elevated, regardless of soil pH. For SCN resistant varieties with the PI 88788 source of SCN resistance, significantly less cfu of the BSR pathogen were detected. The Peking source of SCN resistance supported the highest levels of BSR pathogen cfu in both root and stem tissues. (Table 8)

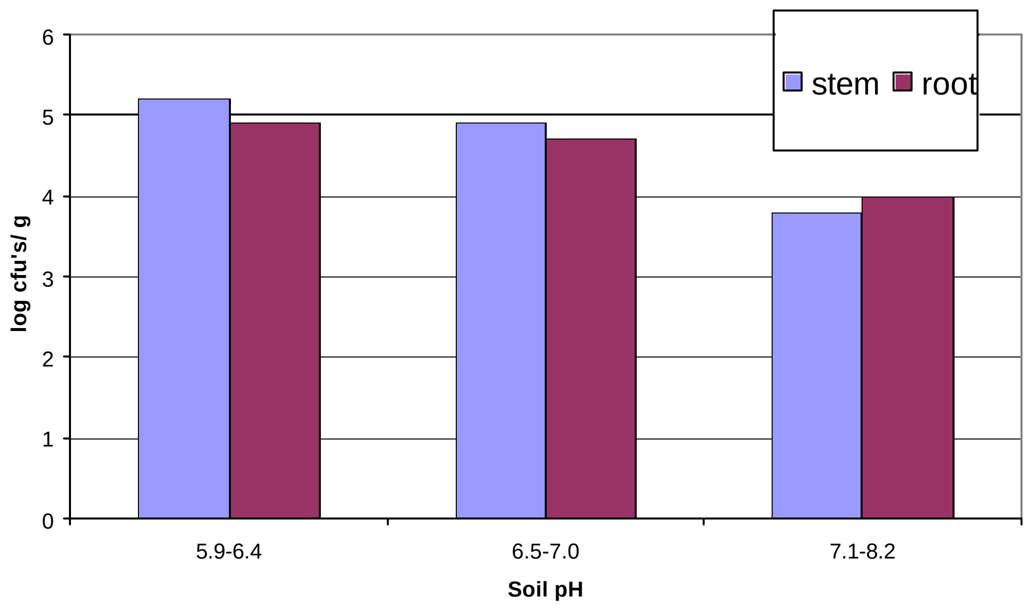

Figure 1. Levels of the BSR pathogen decrease as soil pH increases. A log change of 4.6 to 4.7 represents approximately 20,000 CFU increase.

Table 8. Levels of BSR pathogen CFU based on disease reaction.

	CFU/ gram of tissue	
	Stem	Root
BSR Resistant	77834	42953
BSR Susceptible	320313	245291
SCN Resistant (PI 88788)	133071	68450
SCN Resistant (Peking)	591750	316625
SCN Susceptible	150406	154452

Summary

Yield loss caused by BSR is greatest if soil pH is low and SCN causes greater yield loss if soil pH is high. Management of soybean diseases not only encompasses pathogen detection, resistant varieties and crop rotation, but also knowledge of the soil pH of a particular field. Results from current studies indicate that soil pH may be used to predict the presence of SCN and BSR, as well as changes in pathogen population and assess the risk of yield loss caused by each pathogen. BSR severity increases as soil pH decreases, while SCN population density 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. Growers also have the option to decide whether it is cost effective to modify soil pH to manage specific soybean diseases.

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