# Identification and Diagnosis of Long-Term Problem Areas in Fields of Agronomic Crops

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## Abstract

Since farming began, those who tilled the soil and planted and harvested crops have noticed areas within boundaries of their fields that do not produce as well as other areas. Centuries ago, nomadic farmers attributed these events to the wrath of unhappy gods or witches' curses. However, with today's technologies farmers can do better. Farmers today must also produce more to meet the food demands of a growing world population. To maintain their competitive advantage, American farmers need to be producing crops more efficiently than other producers in the world's agricultural commodity markets. The objective of this paper is to educate producers to recognize what they need to test for and how to evaluating test results when dealing with problem areas in fields. Two different problem areas within two different soybean (*Glycine max*) fields were observed, analyzed, and tested in Caroline County during the 2017 growing season. Farmers verified that problem areas existed for years, and so in both fields, both problem areas as well as adjacent non-problem areas were tested for soil fertility, soybean nutrient content, and nematodes. Comparative tests confirmed that the problematic areas in both fields had inadequate fertility and low pH, and detrimental population levels of nematodes, which were exacerbated by low pH and inadequate fertility. Nematode species varied by site but included root knot (*Meloidogyne* spp.), dagger (*Xiphinema* spp.), and sting (*Belonolaimus* spp.) nematodes. The comparative tests also confirmed that of the two problem spots, the problem spots in both fields were the same soil series as the remainder of the field.

Site A's problem area had a low pH, low potassium, and 1660 root knot nematodes per 500 mg of soil. A root knot population over 170 is detrimental to a soybean. Other diseases

found included charcoal rot (*Macrophomina phaseolina*) and fusarium root rot and wilt (*Fusarium* spp). Soybeans in the problem area in Site A were 50% shorter than the rest of the field and contained few pods at the R6 growth stage. Site B's problem area soybean stand was 50% shorter than the rest of the field and also had considerably fewer pods. Site A's problem area also suffered from a low pH, and phosphorus was yield limiting from both low pH and low soil levels. Site B also had detrimental levels of nematodes, with 160 sting nematodes and 440 dagger nematodes, in addition to fall panicum (*Panicum dichotomiflorum*) and large crabgrass (*Digitaria sanguinalis*). In conclusion, problem spots in fields present a problem for farmers in Virginia that need evaluating, and when evaluating, all factors such as soil fertility, environmental aspects, pests, and genetic potential should be considered.

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## Introduction

According to Virginia Department of Agriculture and Consumer Services, Virginia is nationally ranked twenty fifth in total farmland acres in the United States (VDACS, 2017), and is nationally ranked 29$^{th}$ in grains and oilseeds (USDA, 2012). Virginia has 44,800 farms that cover over 8.1 million acres, or 32 percent of Virginia's total land area of 25.3 million acres (VDACS, 2017). Agriculture is Virginia's leading industry, with sales exceeding $3.8 billion annually and providing work and income for more than 69,000 workers (VDACS, 2017). With this information we can state agriculture is not only an important industry for producers in Virginia, but for all citizens in Virginia. By themselves, agronomic crop fields are an overwhelming part of Virginia agriculture. According to the National Agricultural Statistics Service (NASS, 2016), soybeans are grown on 7.5% of Virginia farmland, and total 610,000 acres. Corn is grown on 6% of Virginia's arable farmland, which equals 490,000 acres (NASS, 2016). Winter wheat is produced on 2.6% of Virginia's farmland, and it totals 210,000 acres (NASS, 2016). Among all farm commodities produced in Virginia, soybeans rank statewide at #6, corn grain is ranked #7, hay at #9, and winter wheat at #12, with these four crops producing well over $709 million annually (Table 1) (VDACS, 2017).

With the importance of Virginia agronomic field crops, it is safe to assume that yield and directly associated returns per acre are tremendously important. Returns per acre depend on market price and yield (Griliches, 1958) of which yield is the variable farmers can change. Yield has four different components: genetic crop yield potential, environment, management practices, and crop pests (Chastain, 2017). Long term problem spots within fields are common, and can be attributed to one or more aforementioned components that regulate yield.

Four major yield components that are important for Virginia crop production systems include:

1. Genetic potential. Yield refers to product mass at final harvest, for which dry matter content should be specified (Evans et al, 1999). Genetic hybrid traits or variety and seed vigor directly result in yield. Older hybrids or varieties with a known history of poor yields will not yield as well as hybrids or varieties with a higher yield history. Likewise, farmers that plant old, or poorly stored seed with poor germination will suffer lower yields than those who plant good vigorous seed at the same seeding rate.
2. Environment. Environment is defined as the surroundings or conditions in which a person, animal, or plant lives or operates (Miriam Webster, 2017). Environment can highly alter yield development. Plant or crop environment would be soil, water, sunlight, soil pH level, and soil nutrient levels that when in short supply or excess, can severely alter yields (Robbins et al, 1965). Although Virginia can provide model growing seasons for most agronomic crops, it can also produce years of statewide summer drought and precipitous springs, as well as areas of localized drought or excess rainfalls (DCR, 2006).
3. Management practices. Management practices such as timely planting of seed with accurate depth and spacing, timely pest control, soil management practices, and timely harvests can increase yields, while poor management will reduce yields (Hobbs, 2007). Furthermore, producers that do not manage or maintain equipment correctly will directly affect yield, due to breakdowns, blowing seed out of machine, cracking seed, planting too deep or shallow, and other mismanagement practices.

4. Crop pests. Crop pests account for highest yield loss in United States agriculture. In 1961 U.S. farmers spent an estimated $310 million dollars, exclusive of application costs, to control pests (Headley, 1968). Three years later, in 1964, that figure increased to $514 million dollars (Headley, 1968). Thirty years later, approximately 500 million kg of more than 600 different pesticide types are applied annually in the United States at a cost of $10 billion (Pimentel and Greiner, 1997). Despite widespread application of pesticides in the United States at recommended dosages, pests (insects, plant pathogens, and weeds) destroy 37% of all potential crops (Pimentel, 1997). Of the 37% of pest damage to crops, insects destroy 13%, plant pathogens 12%, and weeds 12%. In general, each dollar invested in pesticide control returns about $4 in protected crops (Pimentel, 1997).

From the aforementioned figures on crop pests, one may assume the probability of problem areas in fields may be more pest related than not pest related. However, this paper addresses problem areas in fields as areas with a historically lower or reduced yield. We can often eliminate many factors such as highly mobile insects due to the fact that these spots are small areas and not the entire field. Many insects, such as corn earworm (*Helicoverpa zea*), are highly mobile and will generally affect the entire field as opposed to small spots (Herbert et al, 2009). According to Herbert et al (2009), female moths will be attracted to flowering soybeans and invade the entire field. Many other highly mobile insects will follow this pattern (Kennedy and Rabb, 1979). Being highly mobile is also a characteristic for many fungal diseases, where symptoms of disease will be throughout a field versus small spots. Fungi and Oomycetes produce sexually and asexually by spores, which can be spread long distances by wind, soil, or water (Agrios, 1972). A crop's genetic potential can also be eliminated as a possible cause for differences between problem and non-problem areas, since if that is planted in poor performing and good performing spots are the same. Environmental factors such as lack of plant available nutrients, low or high pH due to spreader malfunctions, and lack of rainfall can also affect a small area.

The objective of this project is to educate the reader on realizing and diagnosing problem areas in fields. The importance of the problem area, how to recognize a continuous problem spot in a grain crop field, how to rationally determine what factors may or may not be affecting the crop, how to test for pests, and once getting test results, being able to interpret the results to determine the reason for the problem area will be discussed.

## Materials and Methods

Two different fields with problem areas were inspected in Caroline County, Virginia during the early August 2017 growing season. Both fields were non-irrigated and contained recently released varieties of R5/R6 yield stage soybeans (*Glycine max*). Both problem areas of both fields contained similar looking soybeans that appeared undernourished and shorter than the adjacent soybeans growing next to them (Figures 1 and 2). The first field is located approximately three miles outside of the county seat with a latitude and longitude of 38$^{o}$0’56”N 77$^{o}$21’36”W that henceforth will be called “Site A” (Figure 1). Site A’s soybean was Channel 4916 R2X/5R bean, a RoundupReady 2 Xtend soybean that claims to offer good southern root knot nematode (SRKN), sudden death syndrome (SDS), Stem Canker (SC), and frog eye leaf spot (FELS) resistance. The other area is located ten miles southeast of Site A with a latitude and longitude of 37$^{o}$59’6”N 77$^{o}$17’5”W that henceforth will be called “Site B” (Figure 2). Site B was planted in Asgrow 4831 RR2Y soybean, whose variety traits are RoundupReady 2 and sulfonylurea tolerance (STS). Geological and environmental information about each site is listed in Table 2.

Site A and B's problem spots were inspected on September 7, 2017. Site A had a 0% slope, while Site B had a rolling terrain. Utilizing the "ribboning technique" (Brady and Neil, 2012), Site A's soil was determined to be sandy loam; site B's soil was determined to be clay loam. Field examination dismisses the possibility of a non-surveyed soil inclusion that may not be shown in the Soil Survey. Root zone soil samples were taken from the top six inches of the soil profile for testing of soil nutrients and pH, which are paramount for healthy, growing crops (Tisdale, et al, 1985). Soil and root samples were also taken to test nematode concentrations. Soybean disease, often impossible to see, can be very detrimental to yields, so several problem area plant samples and non-problem area plant samples from Site A (Figure 3) and Site B (Figure 4) were gathered and sent to the Disease Lab at the Tidewater Agricultural Research and Extension Center in Suffolk to test for disease. At the lab, plants were visually inspected for signs and symptoms of disease. If foliar disease symptoms were observed, the disease was identified and noted. Roots were examined under a dissecting microscope at 10X magnification. Necrosis, root rot, and the presence of nematodes were noted. Stems were split with a razor blade to determine if any discoloration or fungal growth was present within the vascular system or cortical tissues. All disease and nematodes were identified based on symptomology and morphological descriptions in the Compendium of Soybean Diseases and Pests (Hartman et al. 2015). A dozen problem area and non-problem area trifoliate leaves from the upper part of several plants were sampled for nitrogen, sulfur, phosphorus, potassium, magnesium, calcium, sodium, boron, zinc, manganese, iron, copper, and aluminum content. These trifoliate leaves were tested for total nitrogen via dry combustion (AOAC Method 993.13); phosphorus, potassium, calcium, magnesium and sulfur via AOAC Method 993.31, and metals via AOAC Method SW-846 (AOAC International, 2000). Results from the plant tissue analysis are crucial in reaffirming other tests for crop problems or failures. During a field inspection, the presence (or absence) of any visible weeds, insects, or other pests in the problem areas versus the non-problem areas were noted.

## Results and Discussion

### Site A

*Field Inspection.* Soybeans in the problem area were 25% of the height of soybean in the non-problem area. There were no visual soil or topographic differences in problem areas compared to non-problem areas (Figure 1). Noting problem area shape is important in conjunction with all tests, in determining the reason for the problem area. For example, an oval-shaped problem area that is longer in the travel direction of equipment can indicate dragged soil from tillage. If indicated, tillage may be slowly spreading a soil borne disease, soil fertility issue, or soil dependent insect around. The shape of Site A's problem spot was oval in shape and longer in the direction of travel, so it was not ruled out that a pest, soil pH or nutrient issue, or environmental issue may be the source of the problem spot. Lastly, pods of problem area soybeans were counted and with Casteel's formula for estimating soybean yield (Casteel, 2012) the problem area yield was estimated at 7 bu./A.

*Soil.* USDA Caroline County Soil Survey indicated Site A's problem spot soil and non-problem spot soil were the same, which was a Tomotley/Roanoke Complex, classified as a fine-loamy, mixed, semi active, thermic Typic Endoaquults (Bricker, 2009). However, soil inclusions can be missed in this survey. Field examination from hand texturing via "ribboning technique"

(Brady and Neil, 2012) indicated that the soil was a sandy loam, and problem area and non-problem area had similar physical and textural properties, which dismissed the possibility of a soil inclusion. However, it is important to note that differences in clay content, water holding capability, and cation exchange capacity can affect biomass and yield (Brady and Neil, 2012). Differences in soil can influence yield due to cation exchange capacity water holding content.

_Soil Fertility_. The soil reports for Site A's problem area and non-problem area (Table 3) both indicated possible deficiencies. Adequate soil nutrient levels are paramount for producing biomass to produce yield, to absorb pest attacks with less damage, and to utilize sunlight (Tisdale et al, 1985). Macro-nutrients, although not high in quantity, were assessed by VA Tech Soil Test Lab as more than sufficient for the projected 7 bu./A for the problem area. Micro-nutrients in both the problem area and the non-problem area were measured as sufficient for soybean production (Table 3), indicating micro-nutrients were not the cause of the problem area.

_Soil pH._ Site A's problem area soil pH was 5.2, which was different than the non-problem area, which had a soil pH of 6.0 (Table 3). Verification from the farmer indicated that this area supposedly received the same rate of lime as did the non-problem areas of the field, although Site A's problem area and the non-problem area soil test proved that the pH was very different. One explanation may be a lime application "skip". Skips can happen when spreading damp lime because at times, especially in flat, sandy fields, the spreader truck is riding smoothly enough not to shake down damp lime. Due to the flat and sandy soil of Site A, this may be a cause of low pH at Site A's problem area. Another possible explanation can be that a heavier textured, clay soil in the problem area would have a higher buffering capacity. Due to a higher buffering capacity, the soil holds more hydrogen ions, which makes the soil more acidic. In this instance it would take more lime to raise the pH in this problem area. Regardless of the cause, low pH can limit nutrient availability (Figure 6). While nutrients were detected in the soil, as described above, if availability to the plant is limited, soybeans may experience stress, which was observed in the tissue analysis described below.

Insect and Weed Pests. No weeds, visible disease, visible insects, or indications of common vertebrate pests of the area such as groundhog (*Marmota monax*) or eastern white-tailed deer (*Odocoileus virginianus*) were noted during visual inspections.

Nematodes. Site A's problem area nematode assay (Table 4) revealed that a population of 1660 root knot nematode per 500 cubic centimeters of soil were found in the sample sent to the Virginia Tech Nematode Assay Lab. According to Virginia Cooperative Extension, a population over 170 root knot (*Meloidogyne* spp.) nematode per 500 cubic centimeters of soil will cause crop damage to soybean (Holshouser et al, 2011). Other nematode species were found but none at yield reducing levels. Site A's non-problem area nematode assay (Table 4) revealed 60 soybean cyst juvenile (*Heterodera* sp.) nematodes per 500 cubic centimeters of soil are a problem, as indicated on Virginia Tech's Nematode Threshold Density (Figure 5). Other nematodes found via assay included 420 stunt (*Tylenchorhynchus* sp.), 1020 spiral (*Helicotylenchus* sp.), 140 root knot (*Meloidogyne* spp.), 460 lance (*Hoplolaimus* sp.), and 40 ring (*Mesocriconema* sp.) per 500 cubic centimeters of soil, and all may cause crop damage if conditions are unfavorable (Table 4). Site A's problem area soybeans also showed possible nematode symptoms, such as reduced size, few pods, and galls on roots. These high populations of nematodes contrast what the populations could be if Site A had a neutral pH. Site A's problem area soil pH was 5.2, not far above a pH of 5.0, an acidic environment where many nematode species do not survive well (Burns, 1971). Overall, the data indicates that while nematodes were present in both problem and non-problem areas, only the problem area contained nematodes at detrimental levels to soybean.

_Pathogens_. Site A's non-problem area was disease free (Table 5). Conversely, Site A's problem area was diagnosed with charcoal rot (*Macrophomina phaseolina*) and fusarium root rot and wilt (*Fusarium* spp.) (Table 5). Charcoal rot is a fungal disease that is severe and damaging during times of external stress such as hot, dry weather or heavy nematode presence (Iowa State University, 2017). Symptoms of fusarium root rot and wilt, like charcoal rot, are also more noticeable under stress from lack of moisture or hot conditions (Iowa State University, 2017). In this problem area, charcoal rot and fusarium root rot were not the main cause of the problem area, but were secondary problems and due largely to lack of plant vigor.

_Weather_. Although no reliable weather data is available, the summer of 2017 was reported to be hot and dry in eastern Caroline County during July 2017, which are not favorable for soybean growth. Since both problem and non-problem areas were subject to the same weather, this is not a causing factor of the problem area.

_Tissue Nutrient Analysis_. Trifoliate leaf tissue tests (Table 6) from Site A's problem area concluded that phosphorus, potassium, and sulfur were deficient, which is consistent with low pH, low potassium soil availability, and root knot nematode damage. With low amounts of nutrients available due to low pH, nematode damaged roots further stress the plant because damaged roots are less able to absorb nutrients. Nematode damaged roots also inhibit the ability of the plant to absorb soil water. Comparatively, Site A's non-problem area trifoliate leaves tested higher in nutrients, especially potassium (Table 6).

_Site A summary_. It was determined that the 5.2 pH of the problem spot resulted in limited availability of phosphorus, potassium, calcium, sulfur, and magnesium, which further resulted in a small, nutrient deficient plant (Figure 6) (Nutrient Technologies, 2017). Detrimental population levels of root knot (*Meloidogyne* spp.) nematode were a factor that also contributed to Site A's problem area stunted soybeans. Charcoal rot and fusarium root rot and wilt, secondary pathogens, also were very visible and damaging to the problem areas stunted plants. All of these factors are summarized in Table 7.

### Site B

*Field Inspection*. Soybeans in site B's problem spot were half as tall and pod numbers were less than 50% of the non-problem spot (Figure 2). Damage was confined to a small area so vertebrate pests such as groundhog and deer could be dismissed as a causing factor. Groundhogs will have open burrows with large dirt mounds near feeding spots, and eastern whitetail deer will pick and graze over a widespread area (MSU, 2017). Unlike Site A, where soil and topography were similar, Site B problem areas were confined to small hills where the soil had a more orange tinge than the grayish to dark grayish brown color of a Kempsville-Emporia complex.

*Soil*. Hand texturing via "ribboning technique" (Brady and Neil, 2012) indicated that the soil was a clay loam, and problem area and non-problem area had similar physical and textural properties. Referring to the Caroline County Soil Survey would indicate the field a Kempsville/Emporia complex, which is classified as a fine-loamy siliceous subactive thermic Typic Hapludults complex (Bricker, 2009).

*Soil Fertility*. The fertility of Site B's problem area was not adequate for growing healthy soybean. Site B's problem area and non-problem area soil nutrient analysis report (Table 3) indicated soil phosphorus was 19 lb./A, which restrict yield. Potassium in both Site B's problem and non-problem area was similar, therefore potassium availability did not contribute to the Site

B's problem area.  Micro-nutrients also could be dismissed as a cause for Site B's problem area as both tested sufficient for soybean production by VA Tech Soil Test Lab (Table 3).

*<u>Soil pH.</u>* Site B's non-problem area pH was 6.5, whereas Site B's problem area's pH was 5.8. Low pH can limit availability of many macro-nutrients to the plant (Figure 6), which was evident in the reduced soybean height and pod count as well as in tissue tests (Table 6).According to the soil test report, one half ton of lime was recommended to address a 5.8 pH. In speaking with the farmer, he sampled the problem area the prior fall and due to a lower pH, asked his commercial spreader to spread an additional ton of lime per acre on the problem area. Regardless of application or not, had one ton of lime been applied 8 months earlier, the pH change throughout the root zone would have been small, due to not being tilled in and to the fact that not all lime will react in 12 months (Mullins et al, 2009). According to Mullins et al, lime should be mixed to tillage depth to give best results (Mullins et al, 2009).  In this problem area, lime would have not have had sufficient time to take effect. With Site B's problem area pH being lower than the non-problem area (5.8 versus 6.5), and with potassium values of Site B's problem area being very low we attribute some difference in soybean performance between the problem and non-problem area to low pH and lack of nutrients.

*<u>Insect and Weed Pests</u>*. There were no visible insect pests or damage from visible insect pests. The problem area and had a higher population of large crabgrass (*Digitaria sanguinalis*) and fall panicum (*Panicum dichotomiflorum*) than the non-problem area (Figure 2).  Fall panicum and large crabgrass was not indicative of herbicide skip, as herbicide skips happen in an entire field or in a linear fashion in the field. Weed infestation is likely due to the stunted soybean, which reduced competition for fall panicum and large crabgrass (Sandell, 1998). Therefore, the weeds exacerbated the problem but were not the source of the problem.

*Nematodes*. Site B's problem area nematode assay (Table 4) revealed it contained 440 dagger *(Xiphinema* sp.), 1060 spiral (*Helicotylenchus* sp.), 60 lance (*Hoplolaimus* sp.), and 160 sting (*Belonolaimus* sp.) nematode per 500 cubic centimeters of soil. Of these populations, the dagger nematodes were in excess of the 300 per 500 cubic centimeters of soil that cause crop damage, and the sting nematodes were also in excess of the 20 per 500 cubic centimeters that cause crop damage (Figure 5). The Site B non-problem area nematode assay summary (Table 4) revealed the field also contained lesion (*Pratylenchus* spp.), stunt (*Tylenchorhynchus* sp.), spiral (*Helicotylenchus* sp.), lance (*Hoplolaimus* sp.), and ring (*Mesocriconema* sp.) nematodes, none of which were in populations detrimental to soybeans.  All thresholds are listed in Figure 5.

*Pathogens*. One similarity at Site B's problem area versus its non-problem area was crop disease. Samples from both areas were sent to Tidewater Agricultural Research and Extension Center Disease Lab in Suffolk, Virginia, and resulting reports (Table 5) show both areas tested positive for stem canker (*Diaporthe phaseolorum*), so this was not the reason for Site B's problem area. Notably, stem canker is favored by early season prolonged wet weather and by continuous conservation tillage (Malvick, 2002); both of which were characteristic for Site B.

*Tissue Test*. Site B problem area and non-problem tissue tests (Table 6) confirmed that sulfur, phosphorus and potassium were low in the problem area. The non-problem area tissue tests confirmed the plant in that area could gather the nutrients sufficient for plant growth.

*Site B summary*.  As summarized in Table 10, a 5.8 soil pH, with a low level of soil phosphorus, and high numbers of dagger *(Xiphinema* sp.) and sting (*Belonolaimus* sp.) nematode per 500 cubic centimeters of soil were the reason for the lack of growth of soybeans in the problem area. Site B's tissue test confirms this as a low pH, low available phosphorus, and damaging numbers of nematode will damage roots to the point where uptake of sulfur, phosphorus and potassium will be low. Site B's problem area soybean's lack of growth resulted in slow ground cover in 30 inch rows, which encouraged germination and growth of fall panicum and large crabgrass.

## Conclusions

When evaluating problem spots, always consider all aspects of soil, environment, pests and pest management systems, and the production system being used. In problem areas of both sites, low pH contributed to low availability of many nutrients for the plant. Soil fertility reports of low potassium and phosphorus levels would not allow for high yields. Nematode damaged soybean roots further compromised nutrient and water uptake. Site B's problem spot also had grassy weed issues, which reduces yield and is attributed to the low soil pH and its nutrient uptake constraints. Problem spots of both sites had disease in them, but in Site B the same disease was present in the non-problem spot as was in the problem spot. Farmers need to be cognizant of problem spots, and consider testing problem spots in all aspects for good plant growth. To address problem spots and increase crop yields, producers must test problem areas for soil texture and physical properties, soil nutrient availability, soil pH, and pests, and then thoroughly analyze test results, past weather patterns, and management practices of problem areas compared to non-problem areas.

Table 1. Virginia's Top 10 Farm Commodities 2016.

| RANK | COMMODITY | CASH RECEIPTS ($) |
|---|---|---|
| 1 | Broilers | 918,000,000 |
| 2 | Cattle/Calves | 714,000,000 |
| 3 | Milk | 478,000,000 |
| 4 | Turkeys | 326,000,000 |
| 5 | Greenhouse/Nursery (Misc. Crops*) | 298,000,000 |
| 6 | Soybeans | 259,000,000 |
| 7 | Corn, Grain | 219,000,000 |
| 8 | All Other Animals+ | 216,000,000 |
| 9 | Hay | 119,000,000 |
| 10 | Tobacco | 117,000,000 |

Source: 2016 USDA NASS and ERS data figures rounded to the nearest million dollars

Table 2. Geological and environmental information on the fields and problem areas of Site A and Site B.

| | Site A | Site B |
|---|---|---|
| Longitude/Latitude | 38$^{o}$0’56”N 77$^{o}$21’36”W | 37$^{o}$59’6”N 77$^{o}$17’5”W |
| Crop | Soybean<br>Channel 4916 R2X/5R | Soybean<br>Asgrow 4831 RR2Y |
| Total acres | 27 | 7.2 |
| Acres in problem spot(s) | 3 (approx.) | <1 (approx.) |
| Soil in problem spots(s)<br>(Bricker, 2009) | 26A Tomotley/Roanoke Complex, 0-2% slopes (fine-loamy, mixed, semi active, thermic Typic Endoaquults) | 11B Kempsville/Emporia Complex, 2-6% slopes (fine-loamy, siliceous, subactive, thermic Typic Hapludults) |
| Soil in field<br>(Bricker, 2009) | 26A Tomotley/Roanoke Complex, 0-2% slopes | 11B Kempsville/Emporia Complex, 2-6% slopes |
| Tillage in last 5 years | Shallow vertical tillage/no-till<br>Subsoiling every 3$^{rd}$ year | No-till |

Table 3. Site A and Site B problem area and non-problem area soil nutrient reports -- soybean field in Caroline County, VA September, 2017.

| | Site A | | Site B | |
|---|---|---|---|---|
| | problem area | non-problem area | problem area | non-problem area |
| soil pH | 5.2 | 6.0 | 5.8 | 6.5 |
| buffer pH | 6.16 | 6.35 | 6.26 | 6.34 |
| phosphorus (lb./A) | 105 (H+) | 71 (H) | 19 (M-) | 40 (H-) |
| potassium (lb./A) | 65 (L+) | 69 (L+) | 125 (M) | 59 (L+) |
| calcium (lb./A) | 742 (M-) | 956 (M-) | 935 (M-) | 1474 (H-) |
| magnesium (lb./A) | 75 (M-) | 153 (H-) | 303 (VH) | 248 (VH) |
| zinc (ppm) | 9.4 (SUFF) | 4.2 (SUFF) | 0.4 (SUFF) | 4.3 (SUFF) |
| Manganese (ppm) | 4.3 (SUFF) | 4.0 (DEF) | 2.4 (SUFF) | 4.2 (SUFF) |
| copper (ppm) | 2.2 (SUFF) | 1.1 (SUFF) | 0.5 (SUFF) | 1.0 (SUFF) |
| iron (ppm) | 66.9 (SUFF) | 19.6 (SUFF) | 6.6 (SUFF) | 10.2 (SUFF) |
| boron (ppm) | 0.1 (SUFF) | 0.1 (SUFF) | 0.2 (SUFF) | 0.2 (SUFF) |

Table 4. Site A and Site B problem area and non-problem area Nematode Diagnostic Assay Reports -- soybean field in Caroline County, VA September 2017.

| | Site A | | Site B | |
|---|---|---|---|---|
| | problem area | non-problem area | problem area | non-problem area |
| *Pratylenchus* spp. (lesion) | | | | 40 |
| Meloidogyne spp. (root knot) | 1660 | 140 | | |
| *Heterodera* sp. (SCN Juveniles) (cysts) | | 60 | | |
| *Trichoderous* sp. (stubby root) | 80 | | | |
| *Xiphinema* sp. (dagger) | 60 | | 440 | |
| *Tylenchorhynchus* sp. (stunt) | | 420 | | 600 |
| *Helicotylenchus* sp. (spiral) | 100 | 1020 | 1060 | 80 |
| *Hoplolaimus* sp. (lance) | 160 | 460 | 60 | 80 |
| *Mesocriconema* sp. (ring) | | 40 | | 20 |
| *Belonolaimus* sp. (sting) | | | 160 | |

Nematodes will not affect crop yield

Nematodes may cause crop damage if growing conditions are unfavorable

Nematodes will cause crop damage

Table 5. Site A and Site B problem area and non-problem area disease reports -- soybean field in Caroline County, VA September 2017.

| Site A | | Site B | |
|---|---|---|---|
| problem area | non-problem area | problem area | non-problem area |
| charcoal rot (*Macrophomina phaseolina*) | no disease found | stem canker *(Diaporthe phaseolorum)* | stem canker *(Diaporthe phaseolorum)* |
| fusarium root rot and wilt (*Fusarium* spp.) | | | |

Table 6. Site A and Site B problem area and non-problem area plant tissue analysis -- soybean field in Caroline County, VA September 2017.

| | Site A | | Site B | |
|---|---|---|---|---|
| | problem area | non-problem area | problem area | non-problem area |
| nitrogen (%) | 3.66 | 3.78 | 2.28 | 2.84 |
| sulfur (%) | 0.2 | 0.25 | 0.15 | 0.21 |
| phosphorus (%) | 0.22 | 0.29 | 0.17 | 0.23 |
| potassium (%) | 1.56 | 0.85 | 0.44 | 1.14 |
| magnesium (%) | 0.27 | 0.51 | 0.76 | 0.38 |
| calcium (%) | 0.83 | 1.98 | 3.00 | 1.90 |
| sodium (%) | 0.01 | 0.01 | 0.01 | 0.01 |
| boron (PPM) | 35 | 30 | 34 | 29 |
| zinc (PPM) | 22 | 49 | 54 | 69 |
| manganese(PPM) | 30 | 66 | 118 | 89 |
| iron (PPM) | 57 | 79 | 62 | 58 |
| copper (PPM) | 7 | 11 | 8 | 9 |
| aluminum (PPM) | 26 | 24 | 38 | 27 |

Chart nomenclature:

Very high and high level – dark green

Sufficient level – light green

Low level - yellow

Deficient level – red

Table 7. Site A summary data for soil fertility, disease, nematode counts, and plant tissue analysis from soybean field in Caroline County, VA September, 2017.

| | Problem area | Non-problem area |
|---|---|---|
| Soil pH | 5.2 | 6.0 |
| Soil phosphorus (lb./A) | 105 (H+) | 71 (H) |
| Soil potassium (lb./A) | 65 (L+) | 69 (L+) |
| Soil calcium (lb./A) | 742 (M-) | 956 (M-) |
| Soil magnesium (lb./A) | 75 (M-) | 153 (H-) |
| Soil micro-nutrients (Table 3) | sufficient | sufficient in all but Mn |
| Disease (Table 6) | charcoal rot<br>fusarium root rot | none observed |
| Nematode in detrimental populations (Table 5) | 1660 root knot (*Meloidogyne* spp.) (over 170 detrimental) | none observed |
| Plant analysis deficiencies (Table 7) | N, S, P, and K | N and K |

Table 8. Site B summary data for soil fertility, disease, nematode counts, and plant tissue analysis from soybean field in Caroline County, VA September, 2017.

| | Problem area | Non-problem area |
|---|---|---|
| Soil pH | 5.8 | 6.5 |
| Soil phosphorus (lb./A) | 19 (M-) | 40 (H-) |
| Soil potassium (lb./A) | 125 (M | 59 (L+) |
| Soil calcium (lb./A) | 935 (M-) | 1474 (H-) |
| Soil magnesium (lb./A) | 303 (VH) | 248 (VH) |
| Soil micro-nutrients (Table 3) | sufficient | sufficient |
| Disease (Table 6) | stem canker | stem canker |
| Nematode (in detrimental populations) (Table 5) | 160 sting (*Belonalaimus* sp.) (over 20 detrimental) 440 dagger (*Xiphinema* sp.) (over 300 detrimental) | none observed |
| Plant analysis deficiencies (Table 7) | S, P, and K | K |

Figure 1. Site A picture of soybean field with problem area soybeans versus non-problem area soybean field in Caroline County, VA September 2017.

Figure 2. Site B picture of soybean field with problem area soybeans versus non-problem area soybean field in Caroline County, VA September 2017.

Figure 3. Site A picture of uprooted problem area soybeans versus uprooted non-problem area soybean field in Caroline County, VA September 2017.

Figure 4. Site B picture of uprooted problem area soybeans versus uprooted non-problem area soybean field in Caroline County, VA September 2017.

Figure 5. Nematode Threshold Densities – Virginia Tech Nematode Diagnostic Laboratory.

**Virginia Tech Nematode Diagnostic Assay Laboratory**

**Nematode Threshold Densities**

# Soybeans

| Nematode | Recommendation Codes | | |
|---|---|---|---|
| | A | B | C |
| *Belonolaimus* sp. (Sting) | 0 | 10 | 20+ |
| *Helicotylenchus* sp. (Spiral) | 0-990 | 1000+ | - |
| *Heterodera* sp. (Cyst) juveniles | 0-10 | 20-50 | 60+ |
| cysts | 0 | 0 | 1+ |
| *Hoplolaimus* sp. (Lance) | 0-290 | 300-490 | 500+ |
| *Mesocriconema* sp. (Ring) | 0-190 | 200-690 | 700+ |
| *Meloidogyne* spp. (Root-knotl) | 0-40 | 50-160 | 170+ |
| *Xiphinema* sp. (Dagger) | 0-90 | 100-290 | 300+ |
| *Paratrichodorus* sp. (Stubby root) | 0-80 | 90+ | - |
| *Tylenchorhynchus* sp. (Stunt) | 0-290 | 300-990 | 1000+ |
| *Pratylenchus* spp. (Lesion) | 0-90 | 100-290 | 300+ |

Based on 500 $cm^3$ of soil.

**Recommendation Codes:**

A. Production of the crop to be grown should not be affected by nematodes.

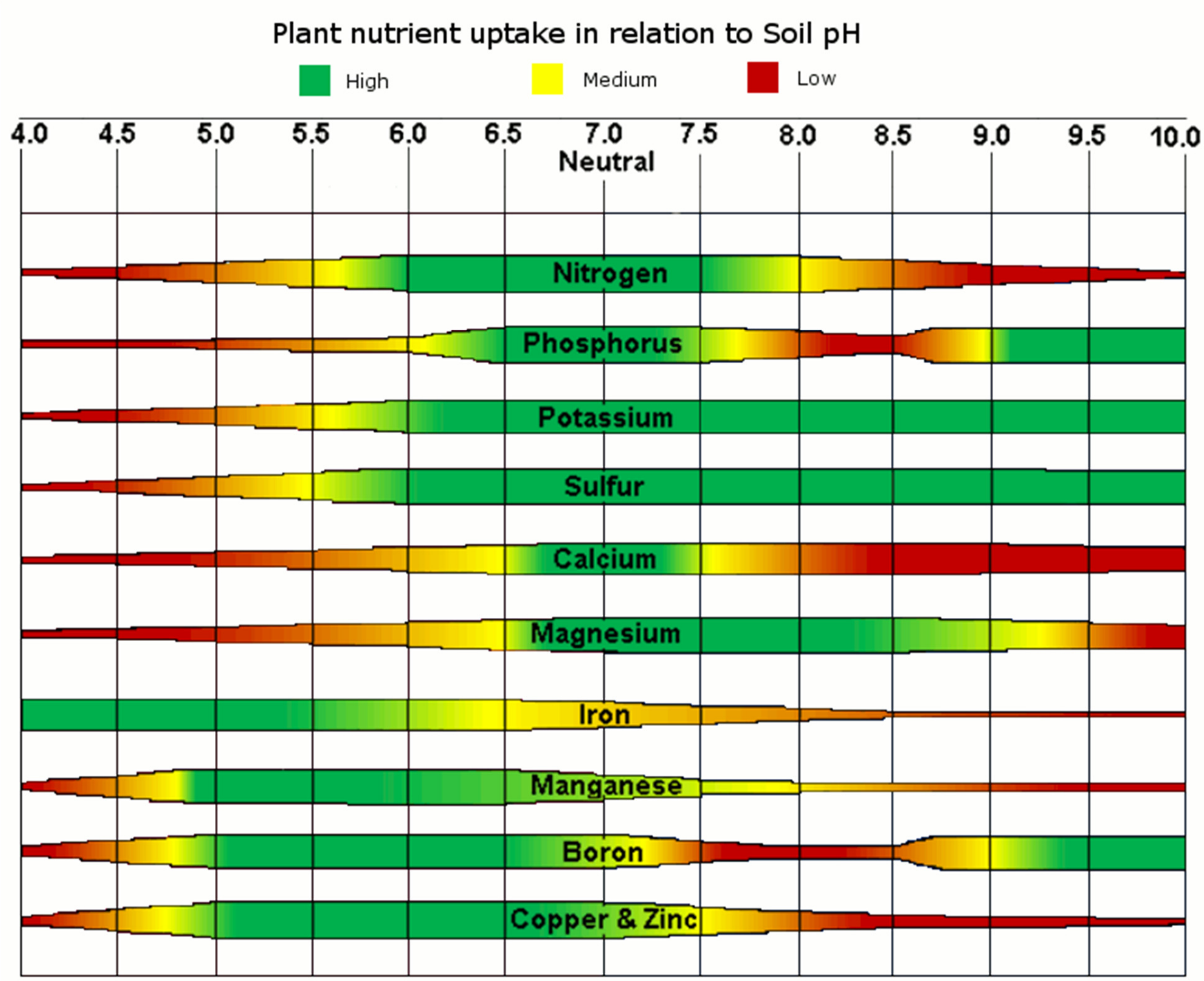
B. Nematodes may cause crop damage if growing conditions are unfavorable. A nematicide may be profitable.

C. Nematodes will probably cause crop damage and a nematicide should be profitable.

D. Use a nematode resistant variety.

E. Rotate with a nonhost crop.

Figure 6. Nutrient availability in relation to soil pH.




Source: Nutrient Technologies, 2017

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