Minnesota Soybean Research and Promotion Council

Annual Research Progress Report

Site-specific Soybean Cyst Nematodes Detection Using EC Mapping

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Soil sampling is an efficient way to determine if Soybean Cyst Nematodes (SCN) are present in a field to mitigate millions of dollars in yield losses. From a practical standpoint, nematode detection and characterization based on the physical collection of soil samples is labor-intensive and time-consuming. The population of cyst nematodes in the infected area depends on soil and climate conditions and the existence of the host plant. Therefore, accurate detection and quantifying spatially aggregated nematodes, especially in a large production field, is challenging. In addition, early detection is important to manage SCN and minimize yield loss. Plant-parasitic nematodes pose a significant agricultural threat, leading to substantial yield losses in economically important crops like cotton and soybeans (Figures 1-2) worldwide (Blair et al., 1999; Koenning et al., 1996).

They exhibit diverse host interactions, with some entering and feeding within host cells, while others migrate through the soil to feed on roots (Chen et al., 2021). Different nematode types are greatly affected by soil abiotic characteristics (Blair et al., 1999; Overstreet et al., 2014), which include soil pH, organic matter, texture, chemicals, and microbial activity. The southern root-knot, spiral, and lesion nematodes tend to thrive in sandy or coarse-textured soils (Monfort et al., 2007; Herring et al., 2010). On the other hand, reniform nematodes are more prevalent in silt-rich soils (Jones et al., 2013). The existence of some nematodes and their population is typically associated with soils containing higher percent sand content (Benjlil et al., 2020). A significant correlation exists between soil nematode distribution and various soil characteristics, including pH, compaction, clay content, and organic matter (Robinson et al.), in line with patterns seen in previous studies (Monfort et al., 2008). It's important to note that this assessment, due to field variations and diverse project objectives, isn't definitive and may yield different results in other locations (Avendaño et al., 2018). High soil strength limits nematode breeding, while less compacted soil promotes nematode growth, similar to the effect of clay content. Organic matter can either help or harm nematodes (Avendaño et al., 2004). The relationship with soil organic matter is less clear in areas where high organic matter is present, nematode counts increase. This increase pattern may be due to the absence of other nematode-feeding soil microorganisms, potentially suppressing nematode populations. Further data collection will provide more clarity (Blair et al., 1999). Despite weak correlations, likely

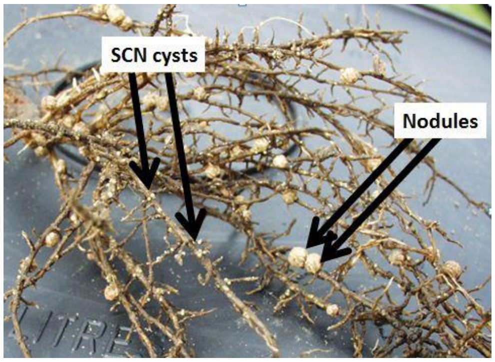


Fig 1. Soybean cyst nematodes feeding on roots
(https://fieldcropnews.com/2020/09/omafra-field-crop-report-september-17-2020/)

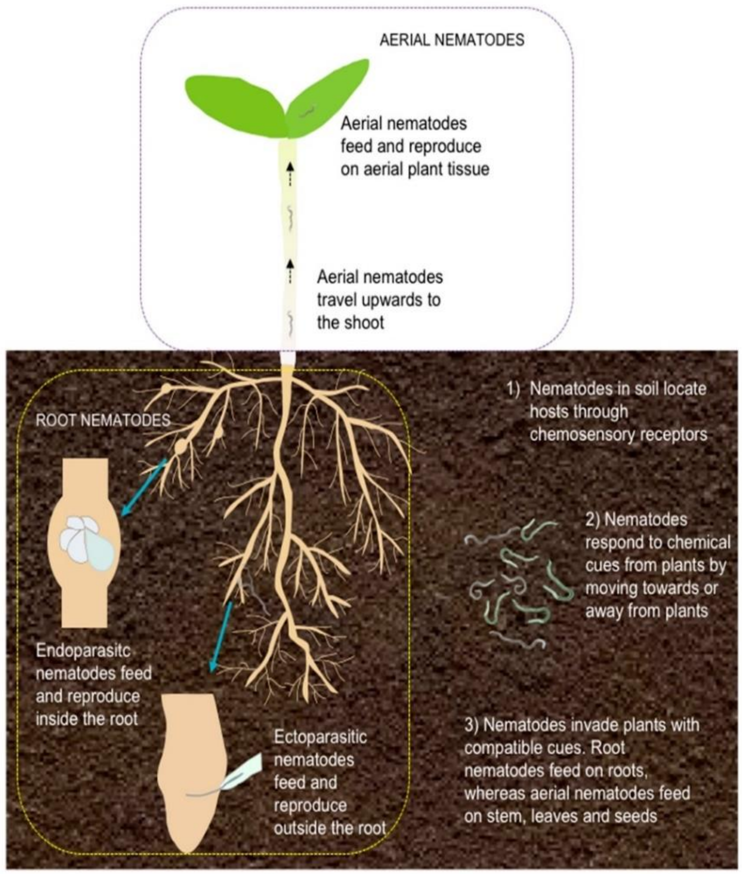


Fig 2. Different type of plant parasitic nematodes

influenced by a small sample size and various errors (Patzold et al., 2008), pH and soil texture play significant roles in determining SCN egg distribution. Determining nematode distribution is challenging due to soil texture variations. For example, clay soil, classified as per USDA, can contain up to 45% sand, creating different-sized pores for nematodes (Williams & Hoey, 1987). Researchers struggle to characterize nematode distribution due to varying soil factors (Acharya et al., 2017), and conventional methods treat the entire field as a unit, ignoring variability can be ineffective and costly (Khalilian et al., 2003). Zone mapping offers an alternative, dividing fields based on soil EC due to close relationship with soil texture (Evans et al., 2002). EC reading could be considered a site-specific nematode management method (Fig 3-5).

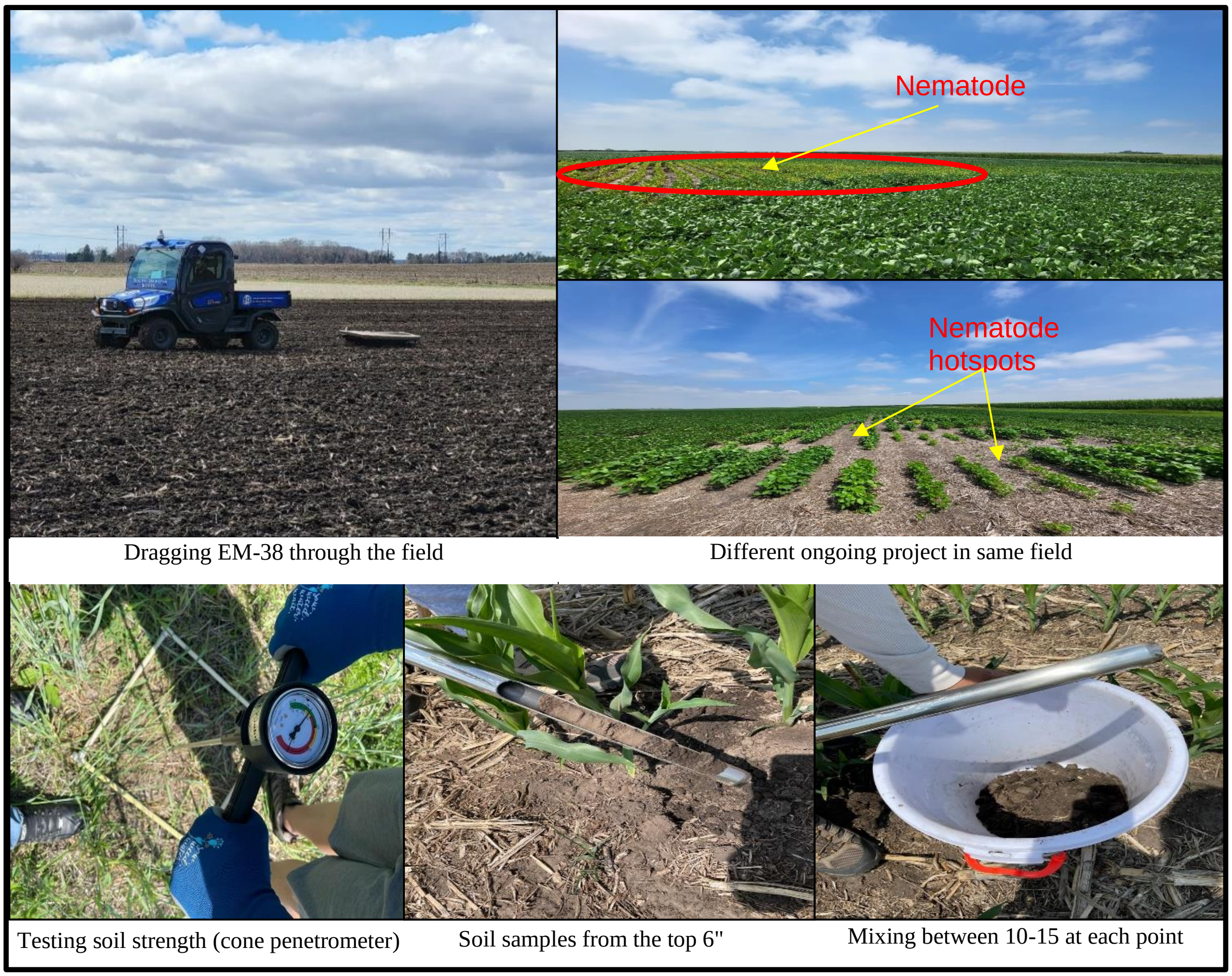


Fig 3. Nematodes population is strongly correlated with soil texture.

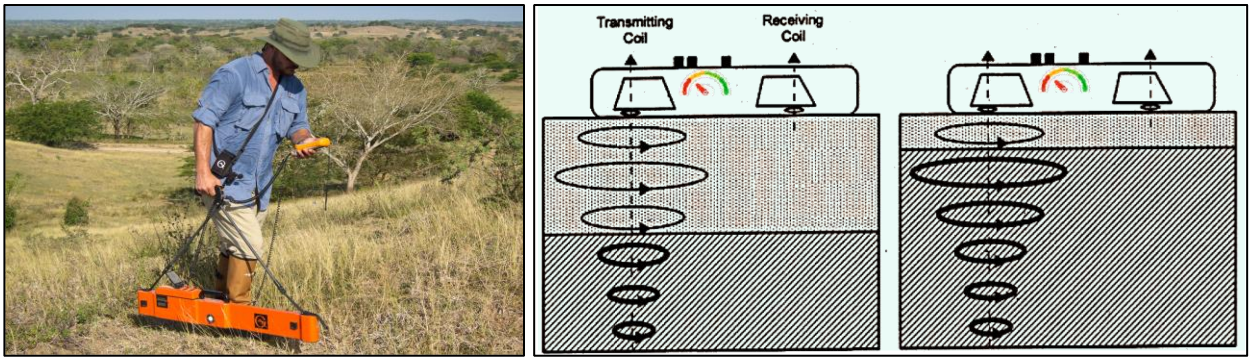


Fig 4. Using EM38 to collect EC information from the field.

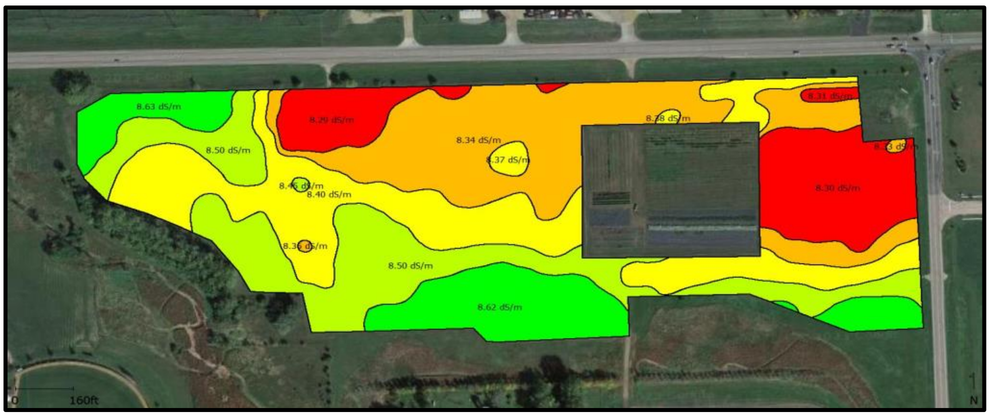


Fig 5. Making management zone based on the soil texture.

Effect of PCCS on population reduction of SCN

Host resistance and crop rotation are commonly used to manage nematodes due to their eco-friendly and cost-effective nature (Doolittle et al., 1994). Previous research has proposed integrating cover crops into these strategies to reduce nematode (Schmitt & Riggs, 1991), densities in infested fields (Fig 6). Cover crops, like oilseed radish, act as trap crops, reducing cyst nematode populations (Chen et al., 2021). The dense roots of red clover and alfalfa hinder SCN juveniles from penetrating and reproducing (Riga et al., 2001). Annual ryegrass and white clover exudates increase SCN egg hatching and

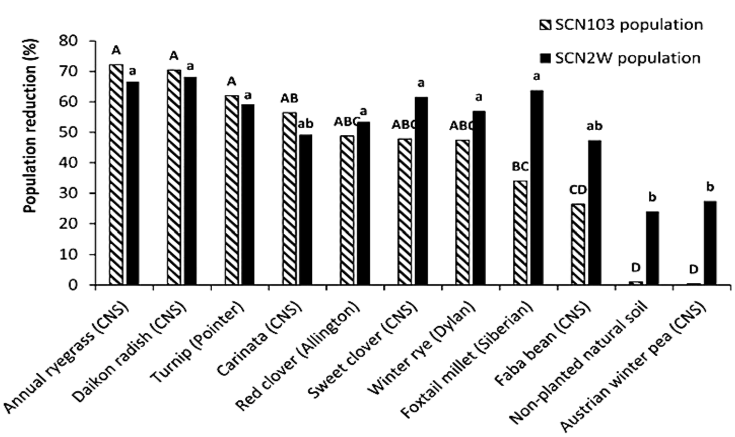


Fig 6. Effect of different type of cover crops on population reduction of SCN (https://doi.org/10.1094/PDIS-08-20-1778-RE)

deplete juveniles' reserves in the absence of host plants (Chen et al., 2021). Although SCN eggs can hatch and penetrate sun hemp roots, they fail to develop into mature SCN females, thus disrupting their life cycle (Chen et al., 2021).

Testing soil strength

Soil compaction, which affects crop performance and yield, varies among fields due to factors such as soil texture and organic matter. Understanding and mitigating its effects is crucial. In this study, we used a cone penetrometer on May 25th to assess soil strength alongside plant sampling. The average compaction reading from subsamples served as the indicator for soil strength in specific sampling areas.

Soil physical characteristic

For each zone, three points were selected based on the absolute value of the EC reading. After collecting samples, all of them were analyzed for pH, K+, Mg, Ca, OM, Solid Salts, CEC, and Texture. Subsequently, these results were imported into the SMS program to create contour maps based on different variations. Our findings revealed a strong relationship between EC readings and pH, solid salts, and texture. Generally, low EC readings indicated larger particle sizes, low nutrient content, acidity, and good moisture drainage, whereas high EC readings indicated smaller particle sizes, nutrient richness, alkalinity, and poor moisture drainage. It is essential to note that while EC readings provide valuable insights into soil characteristics, they do not provide exact estimations. Nonetheless, since it is impractical to take samples from every point in the field, the zones created based on EC readings serve as reliable indicators of areas with similar soil conditions. While taking soil samples is necessary for a more comprehensive understanding, creating zones based on EC readings is preferable to blind and random sampling. Having an overview of the entire field allows for more precise soil sampling, enabling targeted identification of susceptible areas for SCN infestations.

SCN mitigation

A positive SCN detection requires adopting an integrated management approach, including planting resistant cultivars, non-SCN hosts or poor SCN host crop rotation, or the use of nematicide seed treatments (Niblack, 2005). A periodic SCN soil test is also needed to monitor the SCN population changes in the field. An increase in SCN populations would call for tactics or management methods (Strunk and Byamukama,https://extension.sdstate.edu/cover-crop-considerations-when-dealing-soybean-cyst-nematode). The cysts can remain viable for more than ten years and continue to reproduce and accumulate in the soil if an SCN host is included in the crop rotation. The cover crop significantly reduced population densities of nematodes without nematicides application (Marshall et al., 2016). According to a study (2016-2017) at South Dakota State University (SDSU), several weed species are hosts for SCN in South Dakota (Basnet et al., 2020). Similarly, some cover crops can be hosts for SCN (Acharya et al. 2020); therefore, selecting cover crops is very important for soybean producers dealing with SCN in their fields. The effects of non-host cover crops on reducing the soybean cyst nematode population compared to the initial population density reported being from 44 to 67%. At the same time, the natural reductions in fallow were from 4 to 24% (Acharya et al. 2021). This study suggested that cover crops can reduce the SCN populations. Consequently, it is recommended to select non-SCN hosts or poor SCN hosts in cover cropping systems in crop rotation, especially for the suspected area or a positive SCN detected area. The collected soil samples from each point were divided into two equal portions, each labeled differently for soil testing and SCN egg count analysis. These samples were shipped to AGVISE Laboratories in Benson, Minnesota. For a more comprehensive understanding of the field, contour maps of soil variations and SCN egg count distribution were created using the kriging method within the SMS software.

Results and discussion

Site specific management zones: After mapping field with EM-38 prior the planting EC reading was ranged from 8.53-9.33 from the lowest to highest. Field was divided to five different zones based on the EC Shallow reading (Table 1).

Management zones	EC dS/m
Red	8.52-8.60
Orange	8.60-8.71
Yellow	8.71-8.84
Light green	8.84-8.96
Dark green	8.96-9.33

Table 1. Shallow EC range for different management zones.

Soil characteristics

For each zone, three points were selected based on the absolute value of the EC reading. After collecting samples, all of them were analyzed for pH, K+, Mg, Ca, OM, Solid Salts, CEC, and Texture. Subsequently, these results were imported into the SMS program to create contour maps based on different variations. Our findings revealed a strong relationship between EC readings and pH, solid salts, and texture. Generally, low EC readings indicated larger particle sizes, low nutrient content, acidity, and good moisture drainage, whereas high EC readings indicated smaller particle sizes, nutrient richness, alkalinity, and poor moisture drainage (Table 2).

It is essential to note that while EC readings provide valuable insights into soil characteristics, they do not provide exact estimations. Nonetheless, since it is impractical to take samples from every point in the field, the zones created based on EC readings serve as reliable indicators of areas with similar soil conditions. While taking soil samples is necessary for a more comprehensive understanding, creating zones based on EC readings is preferable to blind and random sampling. Having an overview of the entire field allows for more precise soil sampling, enabling targeted identification of susceptible areas for SCN infestations.

	pH Prior to planting season	pH After harvesting	OM % Prior to planting season	OM % After harvesting	CEC (meq/g) Prior to planting season	CEC After harvesting	Salts mmho/cm Prior to planting season	Salts mmho/cm After harvesting	Clay % content Prior to planting season	Clay % content After harvesting	k ppm Prior to planting season	k ppm After harvesting
Dark green	7.70	7.97	4.63	5.03	32.23	32.57	1.00	0.75	25.00	27.33	313.33	430.67
Red	6.13	6.17	4.27	4.30	23.60	21.97	0.44	0.11	27.67	29.33	253.00	350.00
Orange	6.83	6.83	4.60	4.97	25.20	23.93	0.43	0.15	29.00	29.33	308.67	380.67
Yellow	7.30	7.37	5.07	5.27	31.77	28.77	0.84	0.20	27.33	31.67	276.00	319.00
Light green	7.03	7.30	5.33	5.50	28.97	29.93	0.53	0.19	34.33	36.67	355.00	474.00

Table 2. Soil properties in different management zones

SCN Egg counts

Our results indicate a notable increase in SCN populations in almost all tested points post-harvest compared to pre-planting levels. Remarkably, only two samples from the northern corner of the field showed a significant decrease in egg counts. This reduction might be attributed to the use of high-resistance soybean varieties or specific agronomic practices applied to that area (Fig 7).

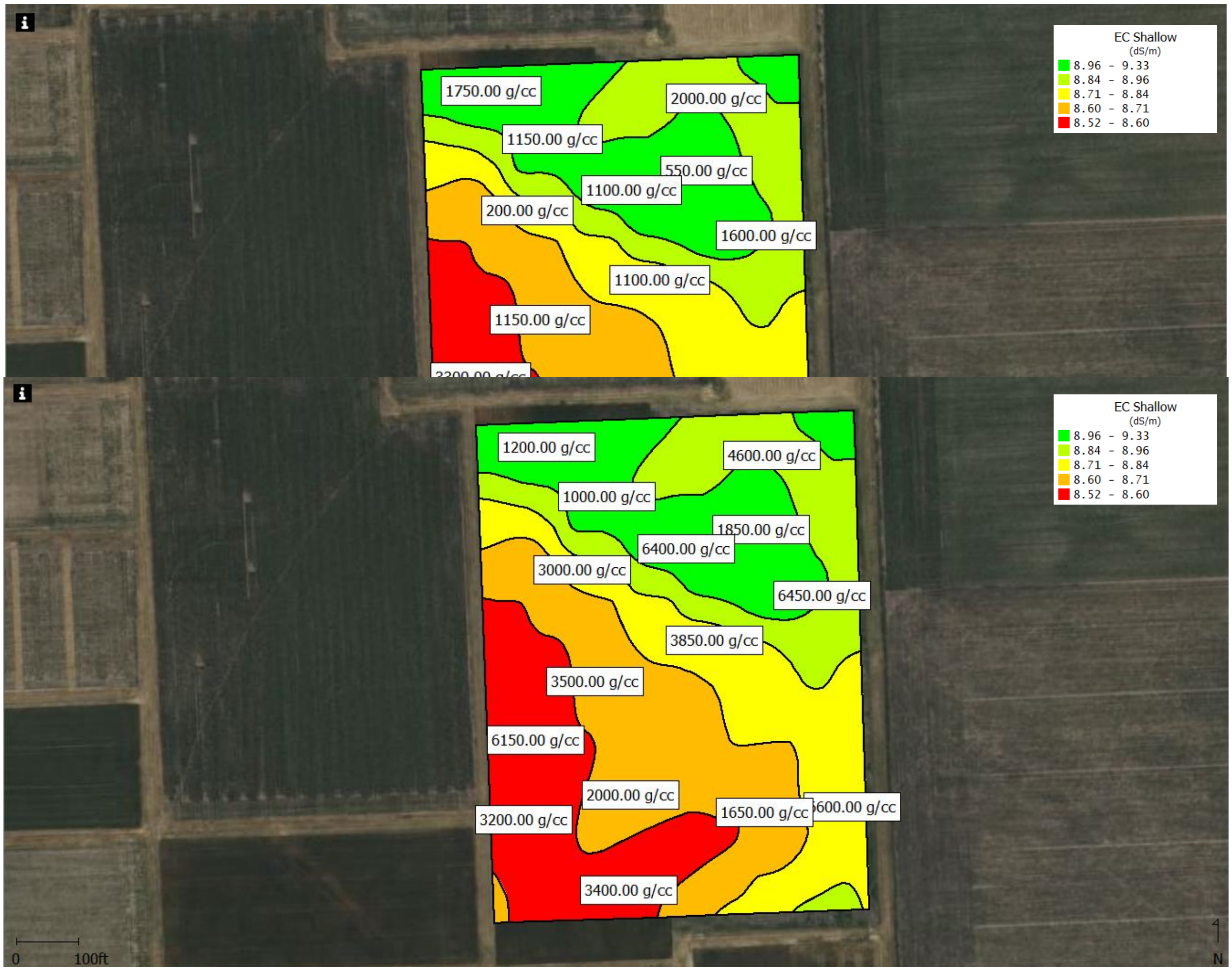
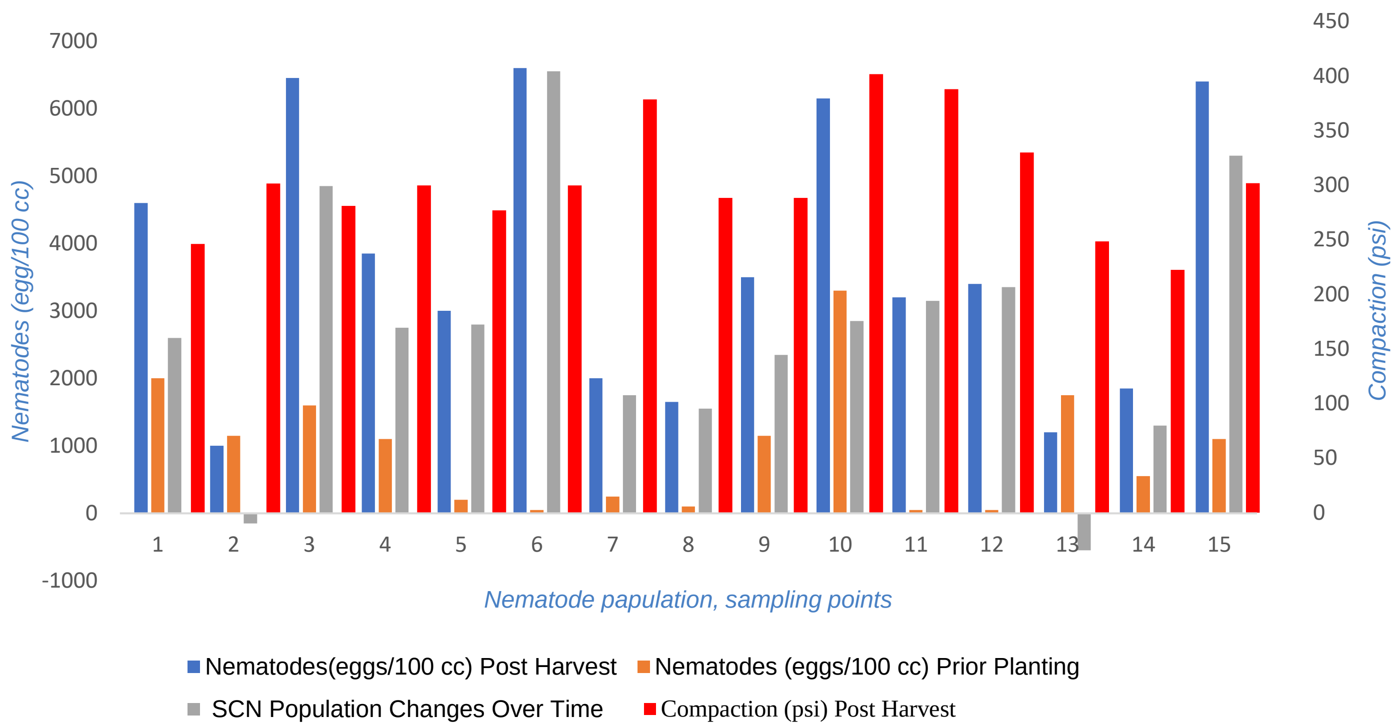


Fig 7. Nematode counts post- harvest (Base map is EC Shallow)



Nematode count vs Soil properties

A notable correlation between soil nematode distribution and various soil characteristics, including pH, compaction, clay content, and organic matter, has been revealed by the research findings, which align with consistent patterns observed in previous studies. However, it is essential to acknowledge that due to many variations in the field and ongoing projects with diverse objectives, the current assessment is not definitive and may result in different outcomes in other locations.Based on observations, it has been noticed that areas with high soil strength restrict nematode breeding, while nematodes thrive more in less compacted soil. A similar trend is also observed for clay content. However, the relationship with soil organic matter is not as straightforward. In areas where organic matter is high, an increase in nematode counts has been observed, which contrasts with findings from some previous studies. This pattern might be attributed to the potential absence of other soil microorganisms that could feed on nematodes or compete with them, possibly suppressing nematode populations below a threshold that limits their life cycles. Further observations and data collection are expected to clarify this correlation. Despite the presence of weak correlations between the results, which could be influenced by the small number of observations and various errors, such as differences in treatments and conditions, it is evident that pH and soil texture play significant roles in determining the distribution of SCN eggs (Fig. 9). Generally, areas with low pH and a high percentage of silt tend to exhibit higher nematode counts compared to other areas.

Fig 8. Soil compaction map

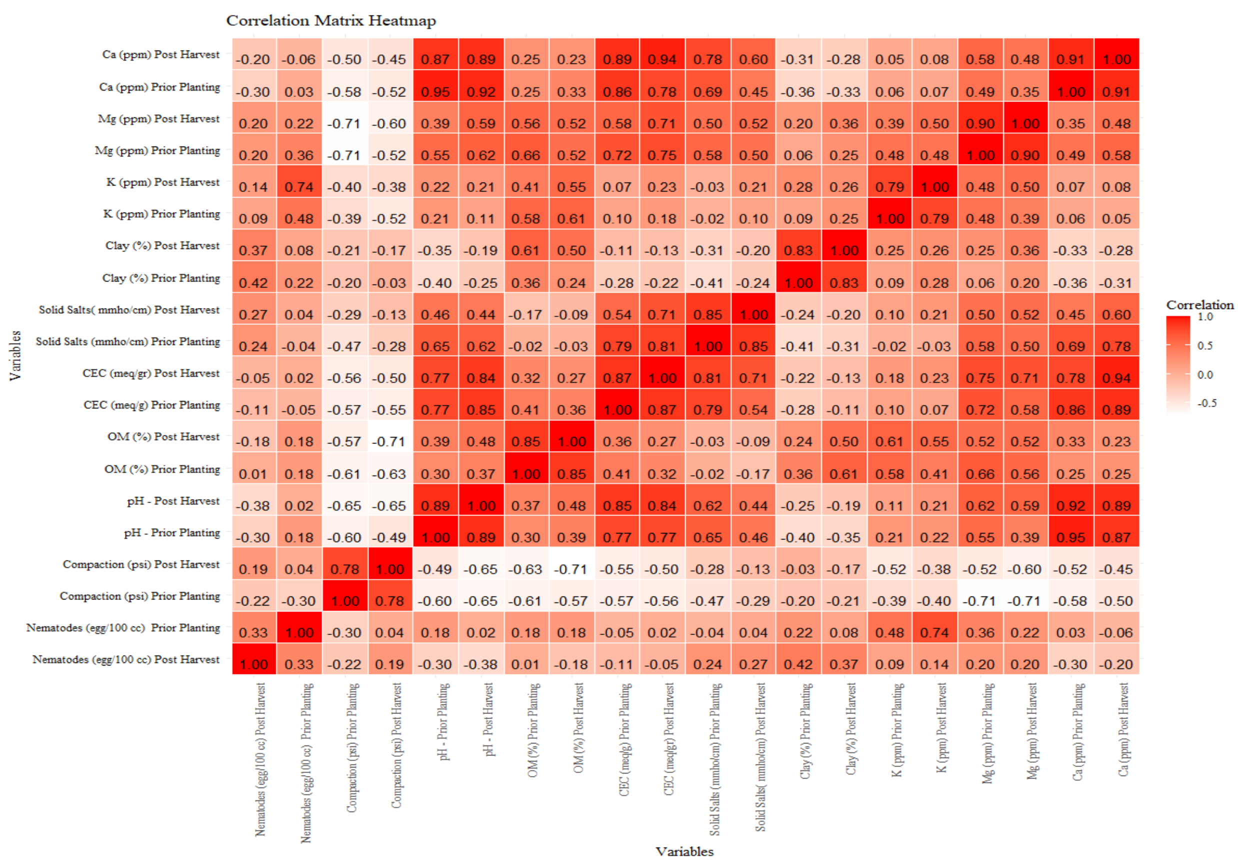


Fig 9. Nematode correlation matrix heat-map

Progress

The soybean harvest has been successfully completed, and while the sampling and initial data collection phase is finished, we are currently awaiting the receipt of detailed harvest data. For a thorough analysis, it's crucial to obtain more specific information about the agricultural practices employed in the field, particularly regarding fertilizer and herbicide applications. This additional data will be instrumental in enriching our understanding and facilitating a comprehensive evaluation of the field conditions and their impact on the crop yield and health.

Outcome

In conclusion, our research provides valuable insights into the relationship between nematode counts and soil properties, but it is crucial to consider the complexity of field conditions and the need for further investigations to establish more robust correlations. Understanding these interactions will enhance our ability to implement targeted management strategies for nematode control, contributing to improved soybean crop health and productivity.

Challenges & future works

One of the biggest challenges faced during the study was the lack of cultivation uniformity in the field, resulting from the presence of three different ongoing projects. Mapping only a single field limited the ability to fully understand and accurately identify the most crucial soil factors influencing SCN breeding under various biotic and abiotic conditions. To obtain more precise insights, it becomes imperative to gather additional data from different fields. The goal is to publish these test results to encourage more farmers to participate in monitoring SCN in their infested fields, paving the way for a clearer path towards comprehensive understanding and effective management strategies. We are currently seeking collaborative partners for the future phase of this project. We need to work and collaborate with growers in their fields to get more precise insights and gather additional data from different fields and disseminate and share the results of this study with them.

Soybean Cyst Nematodes Spatial Detection Using EC Mapping

Cyst Nematode (*Heterodera glycines Ichinolie)* is the most damaging soybean pest. Therefore, it needs to be managed to minimize yield loss. Sampling is an efficient way to determine if Soybean Cyst Nematodes (SCN) are present in a field. A positive SCN detected field requires adopting an integrated management approach, including planting resistant cultivars, non-SCN hosts, poor SCN host crop rotation, or using nematicide seed treatments (Niblack, 2005). The cysts can remain viable for more than ten years and continue to reproduce and accumulate in the soil if an SCN host is included in the crop rotation. A periodic SCN soil test is also needed to monitor the SCN population changes in the field. An increase in SCN populations would call for tactics or management methods (Strunk and Byamukama, https://extension.sdstate.edu-cyst-nematode). From a practical standpoint, nematode detection and characterization based on the physical collection of soil samples is labor-intensive and time-consuming.

The population of cyst nematodes in the infected area depends on soil and climate conditions and the host plant's existence. Based on previous research, the nematode population density is consistently higher in sandy soil than in clay or loam (Wyse-Pester et al., 2002; Avendaño et al., 2004; Monfort et al., 2007; Cheng et al., 2018). Similarly, sand, clay, and silt in the soil are spatially structured and strongly correlated with SCN population density (Avendano et al., 2004).

According to research studies, the percentage of clay or sand in the soil is strongly correlated with EC data and has a significant correlation with SCN populations (Overstreet et al., 2014). On the other hand, cover crops significantly reduced the population densities of nematodes without nematicides application (Marshall et al., 2016). This study also suggest that cover crops can reduce SCN populations. However, selecting non-SCN hosts or poor SCN hosts in cover cropping systems in crop rotation is recommended, especially for the suspected area or a positive SCN detected area.
We propose to evaluate and demonstrate soil property map value as an indicator of where SCN can be expected in an infested field. This study provides the basics for how site-specific soil texture data can improve the spatial prediction of SCN. We will collect soil samples in a geostatistical sampling design based on soil properties variation.

The EM-38 equipment is now available at SDSU and measures equivalent soil electrical conductivity across a field to rapidly determine various soil physical properties. The implement can be operated at 5-20 mph speeds and can measure a 40-60 ft swath in most fields. This equipment would allow a 100-acre field to be mapped for the soil type in a few hours rather than the several days required for manual grid sampling and standard laboratory texture analyses. Soil texture maps allow producers to selectively focus nematode sampling efforts only in the parts of the field with a high probability of having a nematode problem.

This is a **three-year** project with **the overarching goal** of assisting soybean producers in adopting advanced technologies, including site-specific detection strategies in improving SCN management in infested fields. We are seeking to collaborate with soybean growers to work with us on this project.

For more information or/and if you are interested in working with us, don't hesitate to contact Dr. Nafchi at Ali.Nafchi@sdstate.edu.

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Appendix