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IS IT POSSIBLE TO DETECT NEMATODES IN SOYBEAN (*Glycine max* L.) USING REMOTE SENSING?

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TÍTULO DA DISSERTAÇÃO: "IS IT POSSIBLE TO DETECT NEMATODES IN SOYBEAN (*Glycine max* L.) USING REMOTE SENSING?"

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Jaboticabal, 10 de agosto de 2020

CURRICULUM

LETÍCIA BERNABÉ SANTOS – Born in Franca, São Paulo, on February 18, 1995, André Neves Santos' and Andréia Bernabé's daughter, both also born in Franca, São Paulo. She was raised since the age of 5 in Rondonópolis, Mato Grosso where she attended Elementary School at Cenecista School "13 de Junho" and, High School at Pestalozzi School, in the city of Franca - SP, finished in 2012. Joined in Higher Education in 2013 in the Agronomic Engineering course at Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), Campus de Jaboticabal, obtaining the title of Agronomist, in February 2018. During her graduation she received a scholarship from the Tutorial Education (PET Agro) for three years, in research, teaching and extension. In addition, she participated in three scientific initiation projects, all aimed at the study of nematode control. To conclude the course, she did a curricular internship at the Bayer Company, in Sorriso - MT. In August 2018, she started her Masters course in Agronomy (Crop Production), in the Precision Agriculture area, at the São Paulo State University "Júlio de Mesquita Filho" - Campus de Jaboticabal, São Paulo, at the Agricultural Machinery and Mechanization Laboratory (LAMMA), where she conducted research using remote sensing to identify the occurrence of nematodes in soybean. In January 2020, she held a sandwich internship for 6 months at Kansas State University (KSU), Manhattan - KS, where she developed skills focused on statistics and writing.

EPIGRAPH

“Don’t speak too quickly. Say only that the horse is not in the barn.

That is all we know; the rest is judgment.

If I’ve been cursed or not, how can you know? How can you judge?”

The Old Man and the White Horse

Max Lucado’s Version (In the Eye of the Storm)

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SUMMARY

É POSSÍVEL DETECTAR SINTOMAS DE NEMATOIDES EM SOJA (*Glycine max* L.) UTILIZANDO SENSORIAMENTO REMOTO?

RESUMO

A utilização de técnicas de sensoriamento remoto teve expressivo aumento na agricultura nos últimos anos para avaliar diferentes estresses em culturas. Contudo, ainda são poucos trabalhos que avaliaram a viabilidade na identificação de nematoides. A atual amostragem de nematoides é intensiva em tempo e trabalho e não representa a variabilidade da infestação em todo o campo, dificultando a previsão precisa e o manejo. Portanto, foram desenvolvidos trabalhos visando verificar o potencial uso do sensoriamento aéreo na identificação de sintomas da ocorrência de nematoides na cultura da soja. No primeiro capítulo desta dissertação encontra-se a revisão de literatura contendo tópicos específicos relacionados ao tema central. No segundo, foi avaliada a variabilidade da ocorrência de nematoides em dois campos de produção da cultura da soja e o efeito da área de infestação em relação ao centro da reboleira (dentro, extremidade ou fora), assim como o comportamento multiespectral desses locais. Observou-se que as bandas do vermelho e NIR tiveram comportamento similar nas duas áreas avaliadas e foram capazes de se diferenciar em relação à localização na reboleira. No terceiro capítulo, o objetivo foi determinar a relação bivariada entre bandas espectrais individuais e índices de vegetação (IVs), todos relativos à condição da soja (plantas infectadas versus não infectadas). Utilizamos três algoritmos (Logistic Regression - LR, Random Forest – RF, Conditional Inference Tree – CIT) com três opções para entrada de dados: apenas bandas (modelo reduzido), apenas IVs e bandas mais IVs (modelo completo) para classificar as plantas. Os resultados demonstram a capacidade de se utilizar dados multiespectrais para distinguir plantas de soja infectadas por nematoides e não infectadas, utilizando sensoriamento aéreo combinado com aprendizado de máquina. No quarto capítulo, tem-se as considerações finais com os principais resultados, fatores limitantes, recomendações e os próximos passos da pesquisa.

PALAVRAS-CHAVE: imagens multiespectrais, detecção de doenças, nematoides, soja, aprendizado de máquina, agricultura digital.

IS IT POSSIBLE TO DETECT NEMATODES SYMPTOMS IN SOYBEAN (*Glycine max* L.) USING REMOTE SENSING?

Abstract

Remote sensing techniques have increased significantly in agriculture in recent years to assess different crop stresses. However, there are still few studies that have evaluated the viability to identify nematodes symptoms. The current nematode sampling approach is time and labor intensive and does not represent the variability of the infestation across the field, complicating its accurate prediction and management. Therefore, this work was carried out to verify the potential use of aerial sensing to identify nematodes symptoms occurring in soybean. The first chapter of this dissertation is a literature review containing specific topics. The second chapter is a variability analysis of nematode occurrence in soybean fields and the effect of the infestation area in relation to the center of the hotspot (inside, border or outside) were evaluated, as well as the multispectral behavior of these locations. It was observed that the red and near-infrared bands had similar behavior in the two areas and were able to differentiate different infestation areas in relation to location in the hotspot. In the third chapter, the objective was to determine the bivariate relationship between individual spectral bands and vegetation indices (VIs), all related to the condition of the soybean (infected versus non-infected plants). We used three algorithms (logistic regression, random forest, and conditional inference tree) with three options for data entry: only bands (reduced model), only VIs and bands plus VIs (complete model) to classify the plants. The results demonstrate the ability of multispectral data to distinguish nematode-infected and non-infected soybean plants, using aerial sensing combined with machine learning. In the fourth chapter, there are the final considerations with the main results, limiting factors, recommendations and the next steps of the research.

Keywords: multispectral imaging, disease detection, nematodes, soybean, machine learning, digital agriculture.

Chapter 1 – General Considerations

1. Introduction

This thesis is structured in four chapters with topics related to digital agriculture (DA), with focus on remote sensing at aerial level of data collection using an unmanned aerial vehicle (UAV) coupled with a multispectral sensor to detect nematode occurrence in soybean plants. Crop protection proved to be relevant as nematode attack can cause severe damage and advances in remote sensing equipment like UAV, development of small sensors, software, algorithms and digital imaging methodology enables the scalable assessment of field damage conditions.

Several plant pathogens can cause losses in soybean yield, but parasitic plant nematodes (PPN) are especially important given that the tropical conditions in Brazil are very favorable to their propagation. Due to nematodes ability to adapt to several agro-climatic zones, they can occur in any cropping system, being considered diverse and omnipresent (Nasu et al., 2018). Nematodes are round worms that can cause significant damage to crop plants affecting specially root growth development (inducing gall or feeding on the cortisol tissues), stunted growth due to the reduced nutrient uptake from soil and predisposition of roots to secondary pathogens invasion (Jones et al., 2013).

As the majority of its occurrence is in the soil, nematode damage is difficult to diagnose and manage. Currently, farmers around the world assess plant health through ground-based soil sampling to indicate the nematode occurrence. The method is destructive, highly subjective and does not represent the variability of the infestation throughout the field. Despite being widely used to detect different crop stresses, multispectral reflectance sensors for assessing nematode damage in soybeans has

not been thoroughly evaluated. Therefore, in order to improve the nematode damage identification in the field, it is believed that remote sensing can be a potential tool capable of improving nematode management.

The first chapter presents the theorical framework to support the hypothesis that is possible to investigate nematode occurrence in soybean plants using remote sensing as a more efficient and non-destructive tool. The second- and third-chapters present results from application of remote sensing techniques in soybean plants infected with nematodes analyzed using analysis of variance (ANOVA) and machine learning algorithms which proved to be reasonable options for monitoring nematode infection. At last, the fourth chapter presents the final considerations of the presented master's thesis, demonstrating the best results obtained in a cohesive manner, as well as some limitations and future next steps.

5. Conclusion

This research provided a useful nematode identification workflow for distinguishing soybean plants infected with nematodes using high spatial resolution aerial sensing data combined with machine learning. The findings can support further development of more precise soil-borne parasites identification models.

Statistical non-parametric techniques were able to identify spectral wavelengths differentiating between soybean plants infected or not with nematodes. Green and NIR

spectral bands presented greater values of accuracy for model detection to separate infected versus non-infected plants, even when compared with different tested VIs. Spectral bands as an input applied to CIT were able to identify nematode-infected plants with reasonable classification accuracy and better performance than RF and LR methods.

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