Predictive Modeling of Sudden Death Syndrome of Soybean in Kansas

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Introduction

- *Fusarium virguliforme*, a soilborne pathogen that infects and colonizes the roots of soybeans, is the primary causal agent of soybean sudden death syndrome (SDS).
- Optimal conditions for SDS infection are 15°C-17.2°C with high soil moisture during the VE to V3 growth stage, followed by temperatures around 25°C with rain/irrigation during the R1 to R7 growth stage.
- Symptoms appear at or shortly after flowering and include root necrosis, interveinal leaf chlorosis and necrosis, flower abortion, reduced number of pods and seed size, and premature defoliation.
- Yield losses typically range from 5-15%, with highly infested fields reporting losses up to 100%.
- Growers currently rely on pre-planting management strategies, including resistant cultivars and seed treatments, with no control options after planting for SDS.
- **Previous research has primarily examined the impact of in-season weather on disease progression, leaving growers with limited in-season opportunities to adapt their management strategies[1,2,3].**

Figure 1: Progression of SDS leaf chlorosis and necrosis

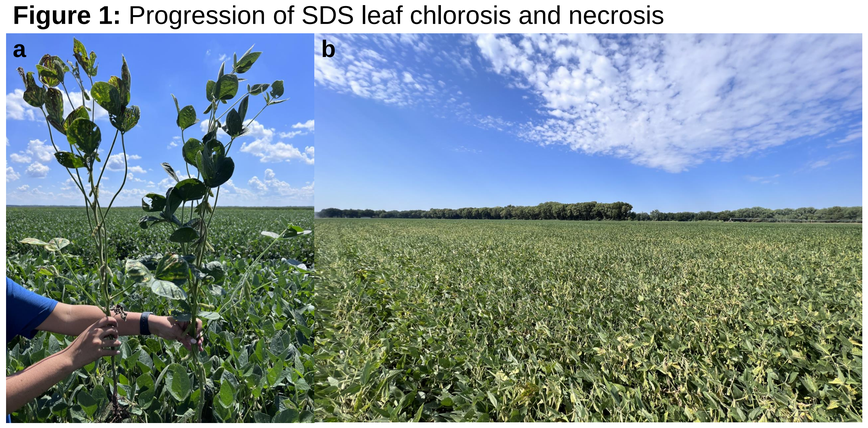

Figure 2a: Symptomatic SDS soybean plant (left) compared to healthy soybean plant (right)
Figure 2b: Visual SDS symptoms in a Shawnee County field from 2022

Objectives

- Identify weather variables that are associated with SDS development.
- Develop predictive models that could help soybean growers evaluate the risk of severe SDS based on weather observed prior to planting.

Materials and Methods

- Organize historical records of SDS from Rossville and Topeka Kansas (USA) gathered between 2013 and 2022.
- Percent SDS severity was visually evaluated at R6 growth stage.
- Observations of disease were paired with hourly observations of rainfall, soil temperature, and soil moisture (Kansas Mesonet stations and OpenMeteo (https://open-meteo.com/)).
- Weather variables were summarized to represent environments favorable for SDS 7, 14, 21, and 28 days before and after planting.

Results

Summaries of environment:

- *Rainfall:* duration of rainfall (hours), number of days with rain, and total rainfall.
- *Soil temperature:* average, minimum, maximum, and the duration that soil temperatures were between 15°C-17.2°C (hours).
- *Soil Moisture:* average, minimum, and maximum soil moisture levels.

Analysis:

- SDS was coded as a binary variable with SDS severity > 5% = 1, and < 5% = 0.
- Variables were evaluated for potential association with severe SDS with a combination of Boosted Classification Trees, and Logistic Regression selection procedures including Elastic Net and Adaptive Lasso.
- Candidate models were developed with Logistic regression and relationships between environment and disease were evaluated with scatter plots.
- Candidate models represented both pre- and post-planting environments.
- All data analysis was conducted using R and JMP Pro software.

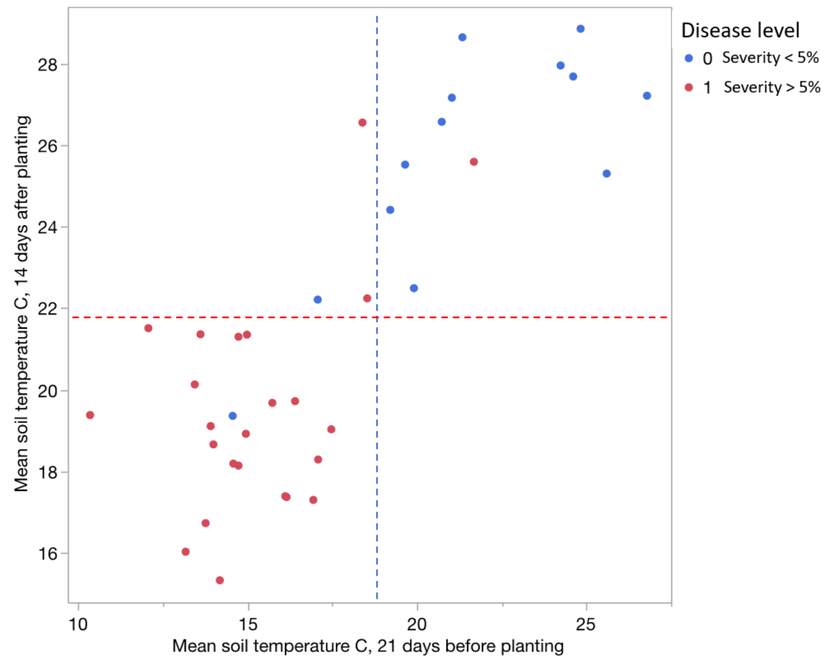

Figure 3: Preliminary models describing the probability of severe SDS based on soil temperature 21 days before planting and 14 days after planting.

Table 1. Logistic regression models estimating the risk of severe SDS on soybean in Northeastern Kansas, USA. Models are based on field trials conducted between 2013-2023.

Time Period	Variable	AIC	ROC	P*	Sensitivity	Specificity	Accuracy
Before Planting	Mean soil temperature 21 days before planting	27.8	0.92	0.5	0.96	0.85	0.92
	Mean soil temperature 7 days before planting	32.2	0.88	0.5	0.92	0.77	0.86
	Duration that soil temperature is between 15.0 - 17.2 C 7 days before planting (hours)	33.7	0.88	0.5	0.88	0.77	0.84
After Planting	Mean soil temperature 14 days after planting	28.5	0.93	0.75	0.88	0.92	0.89
	Duration that soil temperature is between 15.0 - 17.2 C 7 days after planting (hours)	33.2	0.88	0.5	0.88	0.85	0.86
	Number of days with rain 21 days after planting	41.6	0.79	0.5	0.88	0.46	0.73

AIC = Akaike Information Criterion
ROC = Receiver Operator Characteristic
P* = Probability threshold within the logistic regression model for evaluating accuracy metrics
Sensitivity = Proportion of correctly classified location-years with > 5.0% SDS severity
Specificity = Proportion of correctly classified location-years with < 5.0% SDS severity
Accuracy = Proportion of correctly classified location-years

Conclusions

- Soil temperature 21 days before planting and 14 days after planting were strongly associated with SDS severity.
- Soil moisture and rain within the first 21 days after planting were also associated with disease risk, but soil temperature appeared to be a more consistent indicator of disease.
- Models based on summaries of soil temperature prior to planting predicted years with severe SDS with more than 80% accuracy.
- Future research will seek to provide estimates of disease risk that provide soybean growers with more time to adjust disease management strategies. Management options might include adjusting the planting date to avoid periods of the greatest disease risk, switching soybean varieties, or adding fungicide seed treatments to seed prior to planting.

References

1. Bi, L., Hu G., Raza, M.M., Kandel, Y., Leandro, L., Mueller, D. 2020. A Gated Recurrent Units (GRU)-Based Model for Early Detection of Soybean Sudden Death Syndrome through Time-Series Satellite Imagery. *Remote Sensing* 12(21):3621.
2. Roth, M.G., Noel Z.A., Wang, J., Warner, F., Byrne, A.M., and Chilvers, M.I. 2019. Predicting Soybean Yield and Sudden Death Syndrome Development Using At-Planting Risk Factors. *Phytopathology* 109:10, 1710-1719.
3. Scherm, H., and Yang, X. B. 1996. Development of sudden death syndrome of soybean in relation to soil temperature and soil water matric potential. *Phytopathology* 86:642-649.