Is Biology Winning the Battle Against Phytophthora Root Rot of Soybean?

Dean Malvick, University of Minnesota

Wade Webster, North Dakota State University

Advanced Crop Advisors Workshop…Fargo….January 2024

opics for this session

- hat is *Phytophthora root rot and what causes it*
- sease development, symptoms, and diagnosis
- stablished and new methods to detect and identify fferent pathotypes of *P. sojae*
- anagement of Phytophthora root rot

Phytophthora root rot of soybean

- *tophthora sojae* & *P. sansomeana*-``'oomycetes (water molds
- soybean plants at all growth stages.
- hogens survives in the soil for years
- tophthora rot is associated with warm and saturated soils
- *tophthora sojae* exists as different pathotypes




Phytophthora sansomeana

- Appears not as common as *P. sojae?* (*as far as we kn*
  - Infects soybean and corn
  - Occurs across the Midwest

Figure 3. Soybean seedlings killed by hypocotyl-slit inoculation with the unknown isolate and abundant rosette-patterned growth of the unknown isolate on PDA vs. *P.*

ytophthora is related to the Oomycete *Pythium*

hium rot on Soybean. Typically favored by wet, cool soil



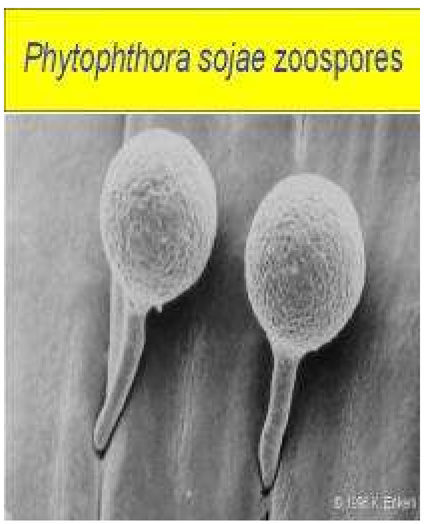
Sources of photos: top two – UIUC, and bottom- MS State)

The Pathogen

Oomycetes, such as *Phytophthora sojae*, are organisms which were once classified in the Kingdom of Fungi, but which are now considered to be more closely related to the Protista.

Oospores of P.sojae

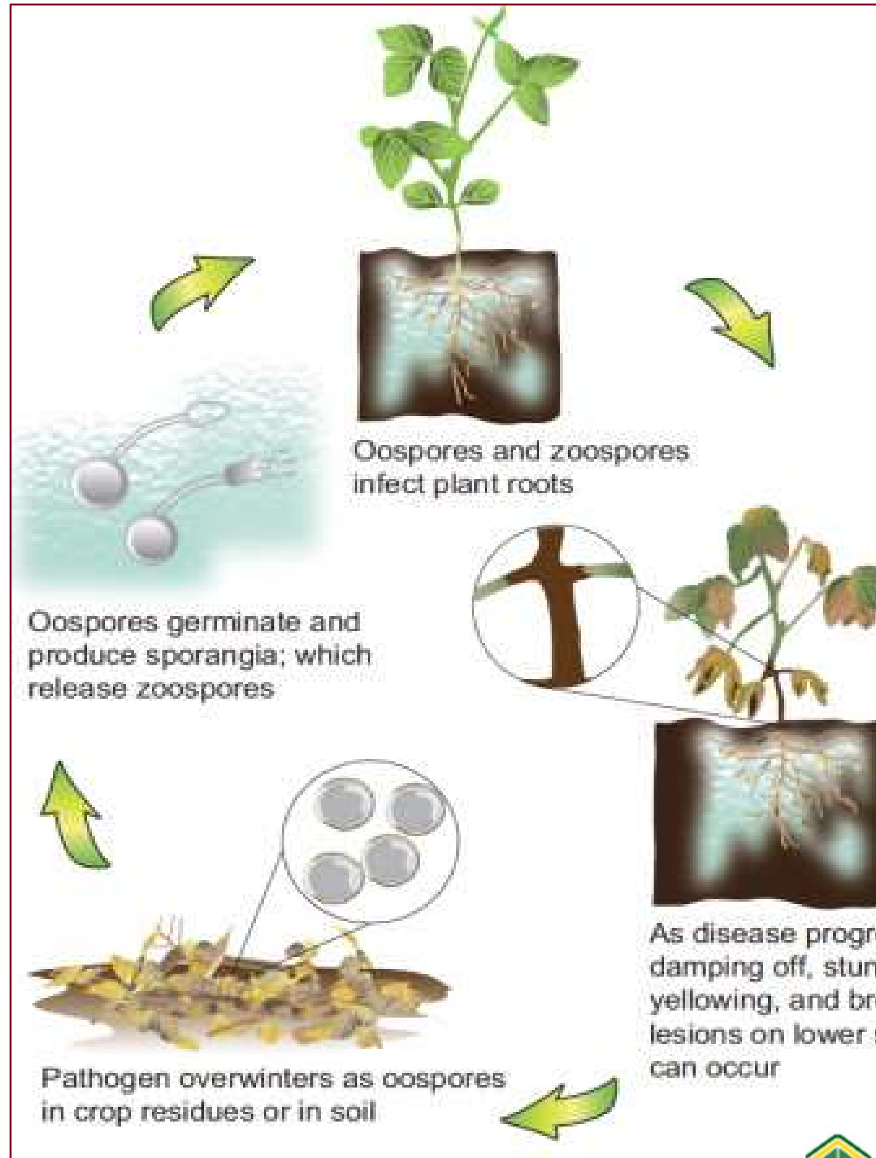
Schmitthenner, OSU



Enkerli, Univ. of GA

Zoosporangia of *P. sojae*

Schmitthenner, OSU



Phytophthora root and stem rot disease cycle.

Phytophthora rot of soybean

ase Cycle

rsists as oospores in soil

ospores germinate in spring (60 F)

orangia release zoospores when soil is flooded

ospores are attracted to roots and swim to them

ospores attach to root surface and penetrate

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D. Malvick
UIUC- Crop Sciences

ytophthora sojae exists as different pathotypes
Pathotypes (vs races) of *P. sojae*

hat is a pathotype?

- Defined based on which Rps genes are overcome in differential soybe varieties with different Rps genes (1a, 1b, 1c, 1d, 1k, 3a, 6 and 7)

- For pathotype, the Rps genes that are overcome are reported.

- Especially valuable in areas (most) where mixed types occur.

<u>kamples:</u>

ace 25	Pathotype: 1a,1b,1c,1k,7
ix of races 3, 25, 41	Pathotype: 1a,1b,1c,1d,1k,7

hytophthora sojae: Races and Pathotypes

What is a race vs. pathotype

- **Defined based on which Rps genes are overcome in differential soybean varieties with 8 different Rps genes (1a, 1b, 1c, 1d, 1k, 3a, 6 and 7)**

- **Examples of races**

Race 3: overcomes Rps 1b and 7

Race 25: overcomes Rps 1a, 1b, 1c, 1k and 7

Race 30: overcomes Rps 1a, 1b, 1k, 3a, 6, 7

Race 41: overcomes Rps 1a, 1b, 1d, 1k and 7

Race 54: overcomes Rps 1d and 7

Phytophthora Survey Projects

Objectives: determine races/pathotypes of *Phytophthora sojae* in a region and evaluate different sources of resistance

Approach: collect soil and plant samples; isolate *P. sojae*, and test race/pathotype via greenhouse or lab. tests

Outcomes
- Race/pathtype distribution
- Resistance efficacy – include Rps8
- New Phytoph. sp.
- Partial resistance/tolerance evaluations

esistance to Phytophthora: Rps Resistance

ablished method to determine resistance and pathotypes

- solate pathogen from plants or soil, then grow in lab
- Seedlings (5-7 days old) are inoculated through wound in stem
- Seedlings kept in moist conditions for 12-18 hr
- Seedlings rated susceptible or resistant 7-10 d later

New method(s) to test for pathotype: extract pathogen DNA (fr nfected plant or soil) and test with DNA method (e.g., AYOS)

A recently-developed molecular method designed to efficiently and accurately identify *P. sojae* variants

97% accuracy rate when compared to a modified plant inoculation method

Discriminant haplotypes of avirulence genes of *Phytophthora sojae* lead to a molecular assay to predict phenotypes

Chloé Dussault-Benoit[1] | Geneviève Arsenault-Labrecque[1] | Humira Sonah[1,2] | François Belzile[1] | Richard R. Bélanger[1]

Molecular Assessment of Pathotype Diversity of *Phytophthora sojae* in Canada Highlights Declining Sources of Resistance in Soybean

Vanessa Tremblay,[1] Debra L. McLaren,[2] Yong Min Kim,[2] Stephen E. Strelkov,[3] Robert L. Conner,[4] Owen Wally,[5] and Richard R. Bélanger[1,*]

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[2] Agriculture and Agri-Food Canada, Brandon Research and Development Centre, Brandon, Manitoba, R7A 5Y3 Canada
[3] Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, Alberta, T6G 2P5 Canada
[4] Agriculture and Agri-Food Canada, Morden Research and Development Centre, Morden, Manitoba, R6M 1Y5 Canada
[5] Harrow Research and Development Centre, Agriculture and Agri-Food Canada, Harrow, Ontario, N0R 1G0 Canada

RESEARCH ARTICLE Open Access

Stable predictive markers for *Phytophthora sojae* avirulence genes that impair infection of soybean uncovered by whole genome sequencing of 31 isolates

Geneviève Arsenault-Labrecque[1], Humira Sonah[1], Amandine Lebreton[1], Caroline Labbé[1], Geneviève Marchand[2], Allen Xue[3], François Belzile[1], Brian J. Kraus[4], Niklaus J. Grünwald[4] and Richard R. Bélanger[1*]

Mutations in the Promoter and Coding Regions of *Avr3a* Cause Gain of Virulence of *Phytophthora sojae* to *Rps3a* in Soybean

*Yanhong Hu, Zhihua He, Yebin Kang and Linkai Cui**

[illegible]

Phytophthora Root Rot Symptoms and Identification

- Seedling death
- Stunting
- Premature wilting
- Development of dark brown lesion creeping up from soil

Disease Symptoms and Identification

- Seedling death
- Stunting
- Premature wilting
- Development of dark brown lesion creeping up from soil line

Phytophthora Root Rot risk factors

- Varieties without major resistance genes: Rps1K, Rps1c, Rps6, or Rps3
- Varieties with low tolerance (partial resistance)
- Poor soil drainage
- Frequent rainfall in the first month after planting
- Warm wet soil for extended periods
- History of disease in field

ytophthora rot of soybean: <u>Management</u>

- deally: plant in well-drained locations
- Choose varieties with Rps genes that are effective against specific pathotypes
- Treat seed with specific 'fungicides' ('oomyticides')

- n the long run, the best varieties may have partial resist tolerance) combined with specific Rps resistance

Soil Drainage to Reduce Phytoph RR

Figure 6. Saturat
fields can signific
chances of Phyto
incidence.

- ve soil drainage & reduce compaction to eliminate/reduce floodi
- ph zoospores are produced only when soil is saturated
- s are not saturated early in the season, they may escape disease

Ohioline
Ohio State University Extension

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Phytophthora Damping-off and Root Rot of Soybean

Dana Martin, Research Associate, Department of Plant Pathology, The Ohio State University
Dr. Anne E. Dorrance, Professor, Department of Plant Pathology, The Ohio State University

eed treatments for Managing Phytopthora Root Rot

CROP PROTECTION NETWORK
A Product of Land Grant Universities

Fungicide Efficacy for Control of Soybean Seedling Diseases (05/2023)

Efficacy categories:
P=Poor; F=Fair; G=Good; VG=Very Good; E=Excellent;
NL=Not Labeled for use against this disease; NR=Not Recommended;
U=Unknown efficacy or insufficient data to rank product

Fungicide active ingredient	*Pythium* spp.[1]	Phytophthora	*Rhizoctonia* spp.	*Fusarium* spp.[1,3]	Sudden death syndrome (SDS) *Fusarium virguliforme*	*Diaporthe* spp.
Azoxystrobin	P-G	NS	VG	F-G	NR	P
Carboxin	U	U	G	U	NR	U
Ethaboxam	E	E	NR	NR	NR	NR
Fludioxonil	NR	NR	G	F-VG	NR	G
Fluopyram	NR	NR	NR	NR	VG	NR
Fluxapyroxad	U	U	E	G	NR	G
Ipconazole	P	NR	F-G	F-E	NR	G
Mefenoxam	E[2]	E	NR	NR	NR	NR
Metalaxyl	E[2]	E	NR	NR	NR	NR
Oxathiapiprolin	P-G	E	NR	NR	NR	NR
PCNB	NR	NR	G	U	NR	G
Penflufen	NR	NR	G	G	NR	G
Prothioconazole	NR	NR	G	G	NR	G
Pydiflumetofen	NS	NS	NS	NS	VG	NS
Pyraclostrobin	P-G	NR	F-G	F	NR	G
Sedaxane	NR	NR	E	NS	NR	G
Thiabendazole	NR	NR	NS	NS	P	G
Trifloxystrobin	P	P	F-E	F-G	NR	P-F

[1] Products may vary in efficacy against different *Fusarium* and *Pythium* species.
[2] Areas with mefenoxam or metalaxyl insensitive populations may see less efficacy with these products.
[3] Listed seed treatments do not have efficacy against *Fusarium virguliforme*, causal agent of sudden death syndrome.

https://cropprotectionnetwork.s3.amazonaws.com/cpn1
cideefficacysoybeanseedling_2023.pdf

Rps Genes and Field Tolerance

ps Genes

- Single genes
- Effective against specific races
- Correct combinations prevent disease
- Resistance can easily break down

Field Tolerance

- Multiple genes
- Does not depend on *P. soja* races
- Allows for reduced disease development, but not complete
- Durable resistance

eployment of Resistance

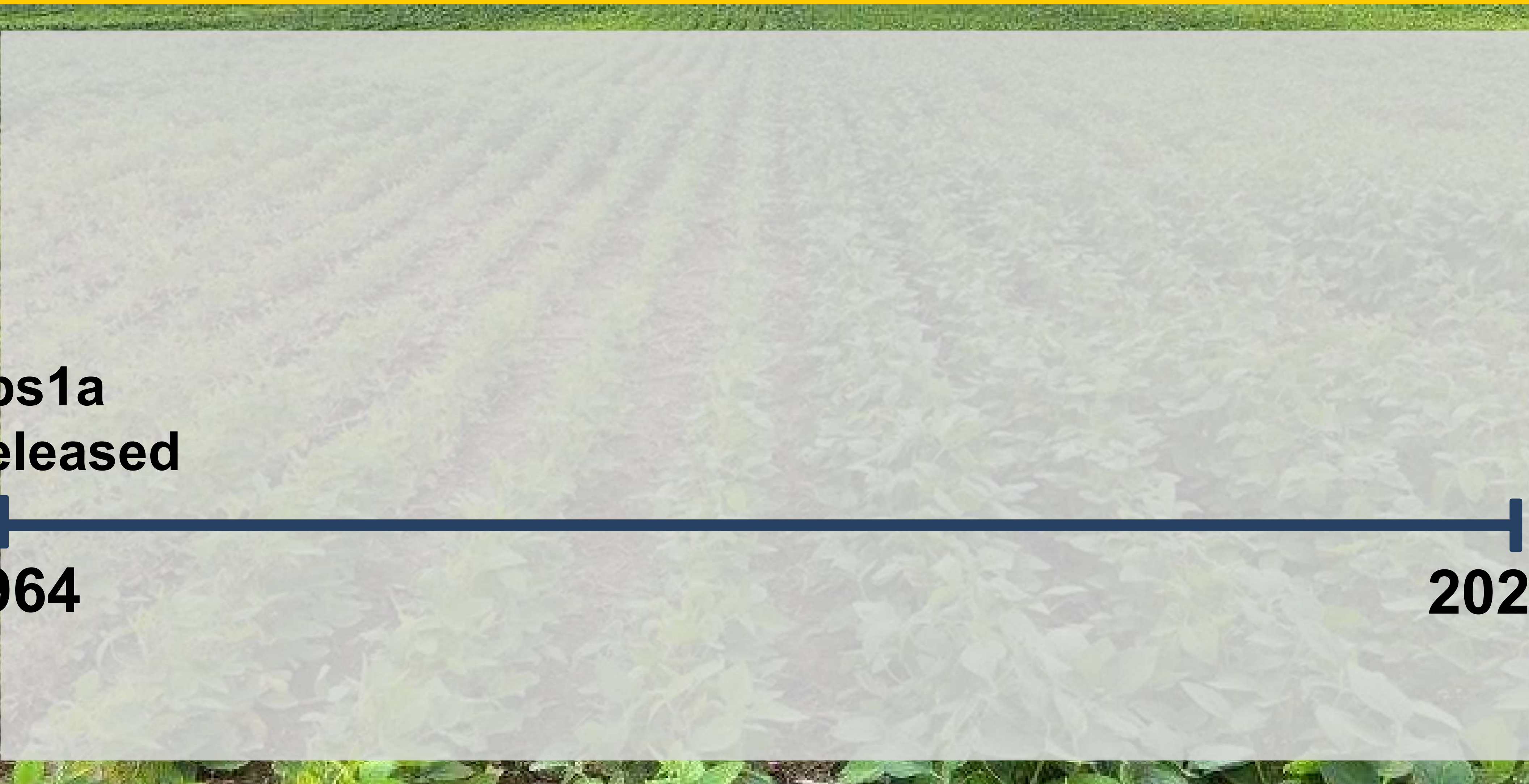

Photo: Marty Ch

eployment of Resistance

Rps1a No
Longer
Effective

ps1a
eleased

964

1972

202

Photo: Marty Ch

eployment of Resistance

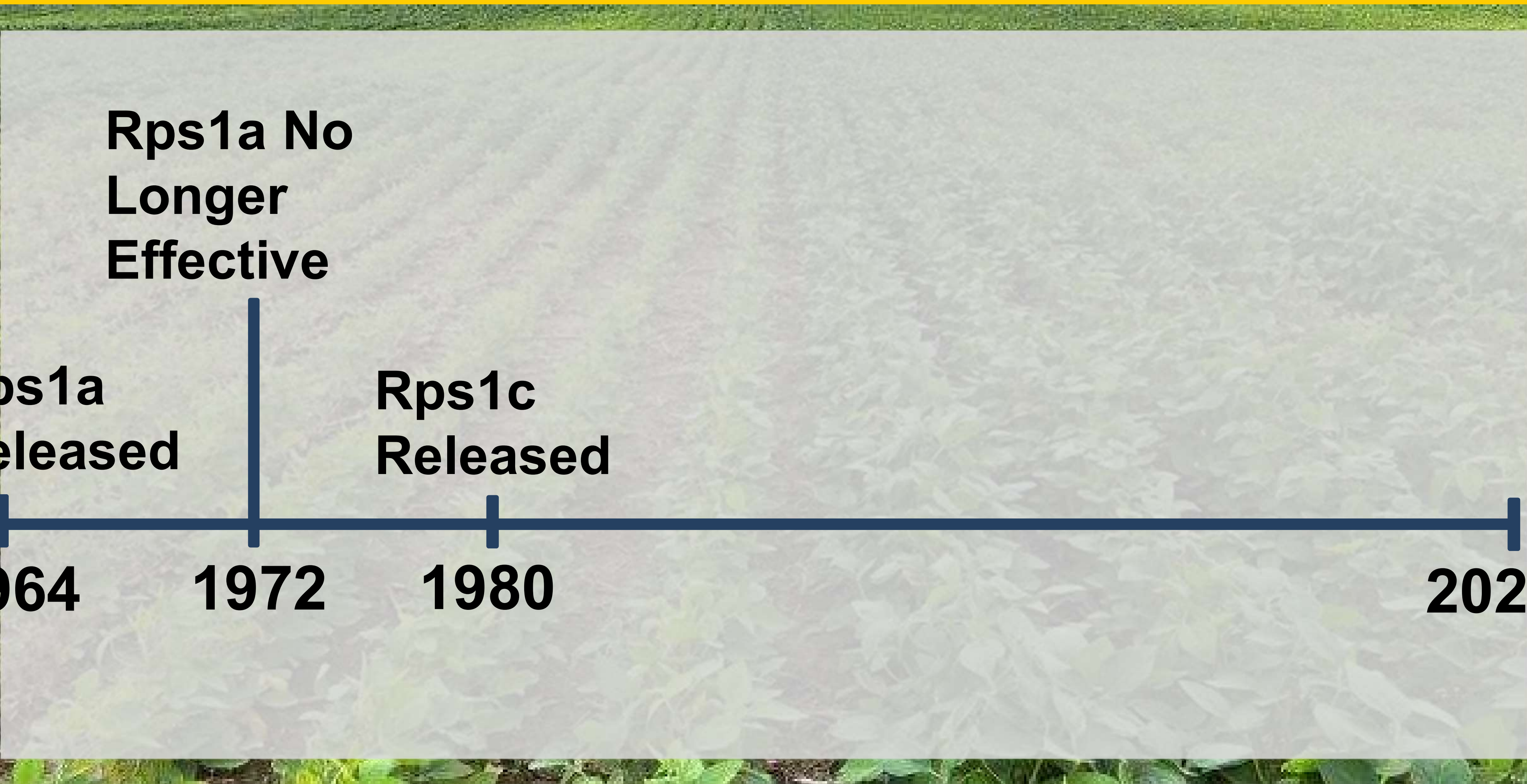

Photo: Marty Ch

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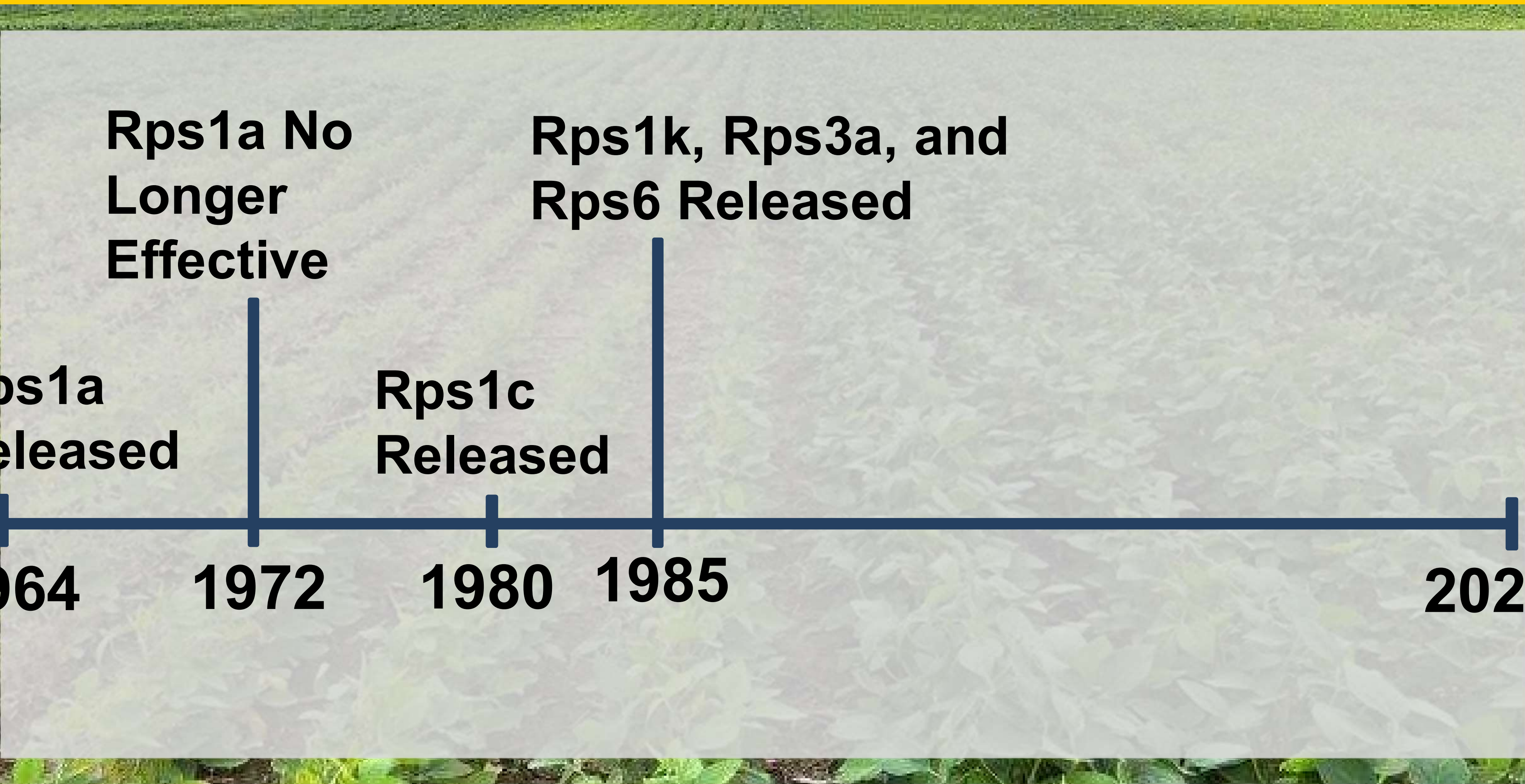
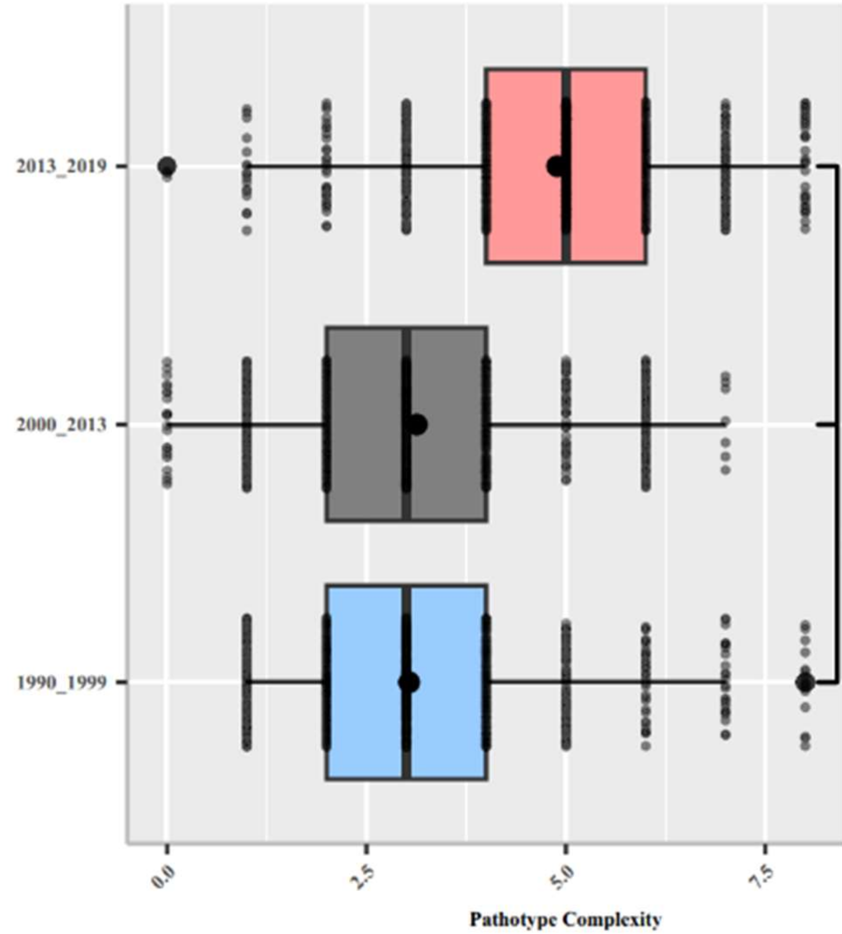


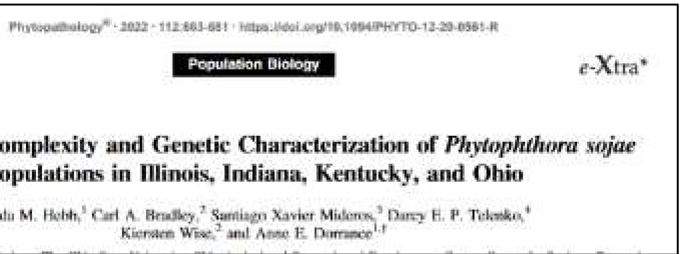
Photo: Marty Ch

ffectiveness of Rps Genes Across the US

- *ojae* has adapted to Rps genes
- ater diversity of pathotypes currently developing
- s is a result of overreliance on same Rps genes



Efficacy of Rps Genes against *P. sojae* in Illinois, Indiana, Ohio, and Kentucky. 2016-2018

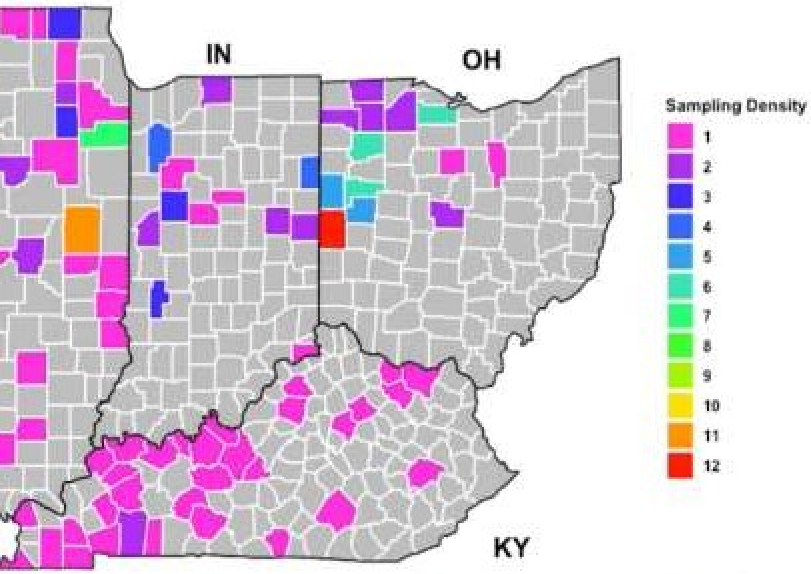

Phytopathology® · 2022 · 112:663-681 · https://doi.org/10.1094/PHYTO-12-20-0561-R

Population Biology

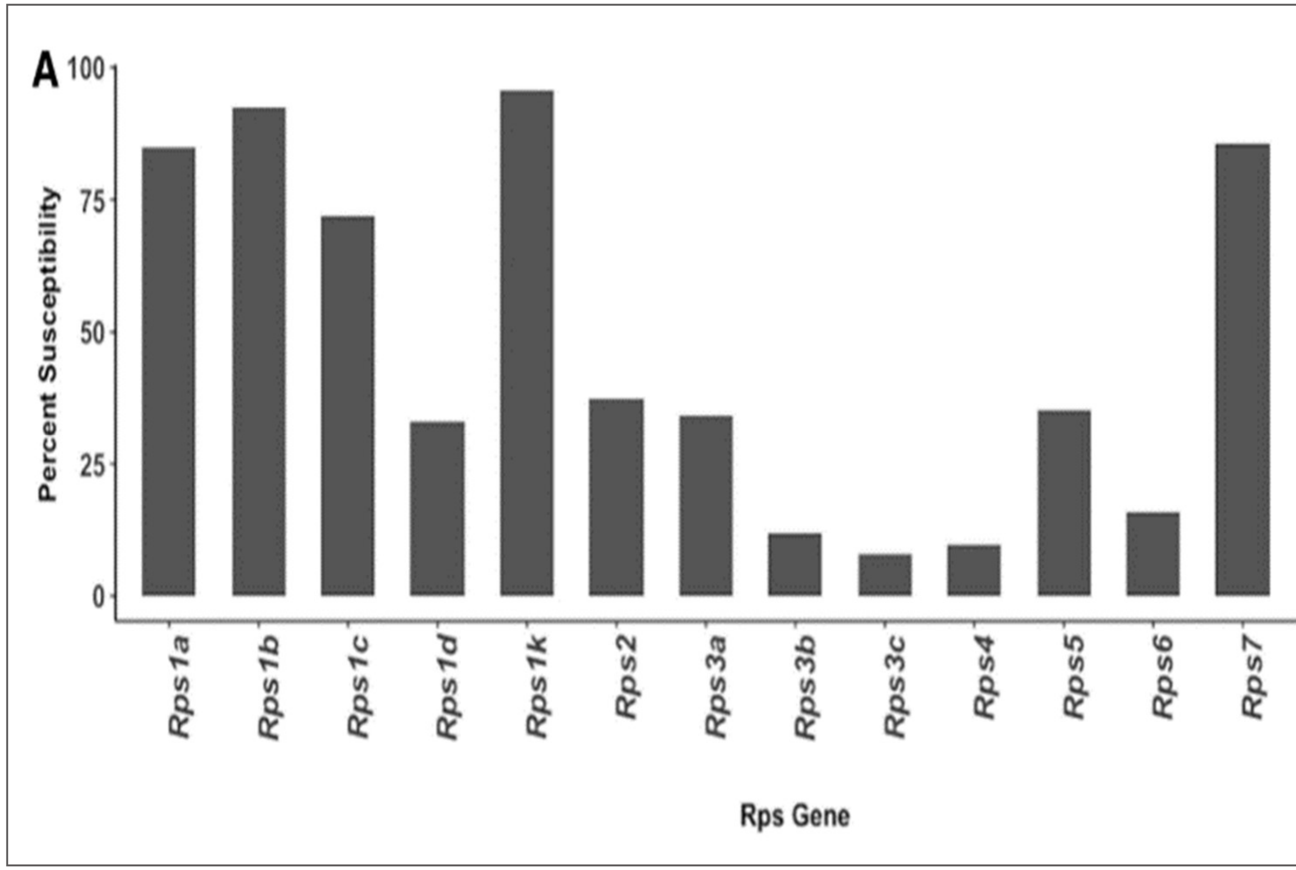
e-Xtra*

omplexity and Genetic Characterization of *Phytophthora sojae* opulations in Illinois, Indiana, Kentucky, and Ohio

alu M. Hebb,[1] Carl A. Bradley,[2] Santiago Xavier Mideros,[3] Darcy E. P. Telenko,[4] Kiersten Wise,[2] and Anne E. Dorrance[1,†]



for collection of soil samples with *Phytophthora sojae* by county in Illinois, Indiana, Kentucky, and Ohio. The number of fields sam- d from one to 12. Soil samples were collected between 2016 and 2018.



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nmunications

https://doi.org/10.1038/s41467-023-41321-7

al-temporal analysis on *Phytophthora* resistance-gene efficacy

uary 2023
gust 2023
September 2023

Austin G. McCoy[1], Richard R. Belanger[2], Carl A. Bradley[3], Daniel G. Cerritos-Garcia[4], Vinicius C. Garnica[5], Loren J. Giesler[6], Pablo E. Grijalba[7], Eduardo Guillin[8], Maria A. Henriquez[9], Yong Min Kim[10], Dean K. Malvick[11], Rashelle L. Matthiesen[12], Santiago X. Mideros[13], Zachary A. Noel[14], Alison E. Robertson[17], Mitchell G. Roth[16], Clarice L. Schmidt[12], Damon L. Smith[16], Adam H. Sparks[17,18], Darcy E. P. Telenko[19], Vanessa Tremblay[2], Owen Wally[20] & Martin I. Chilvers[1]

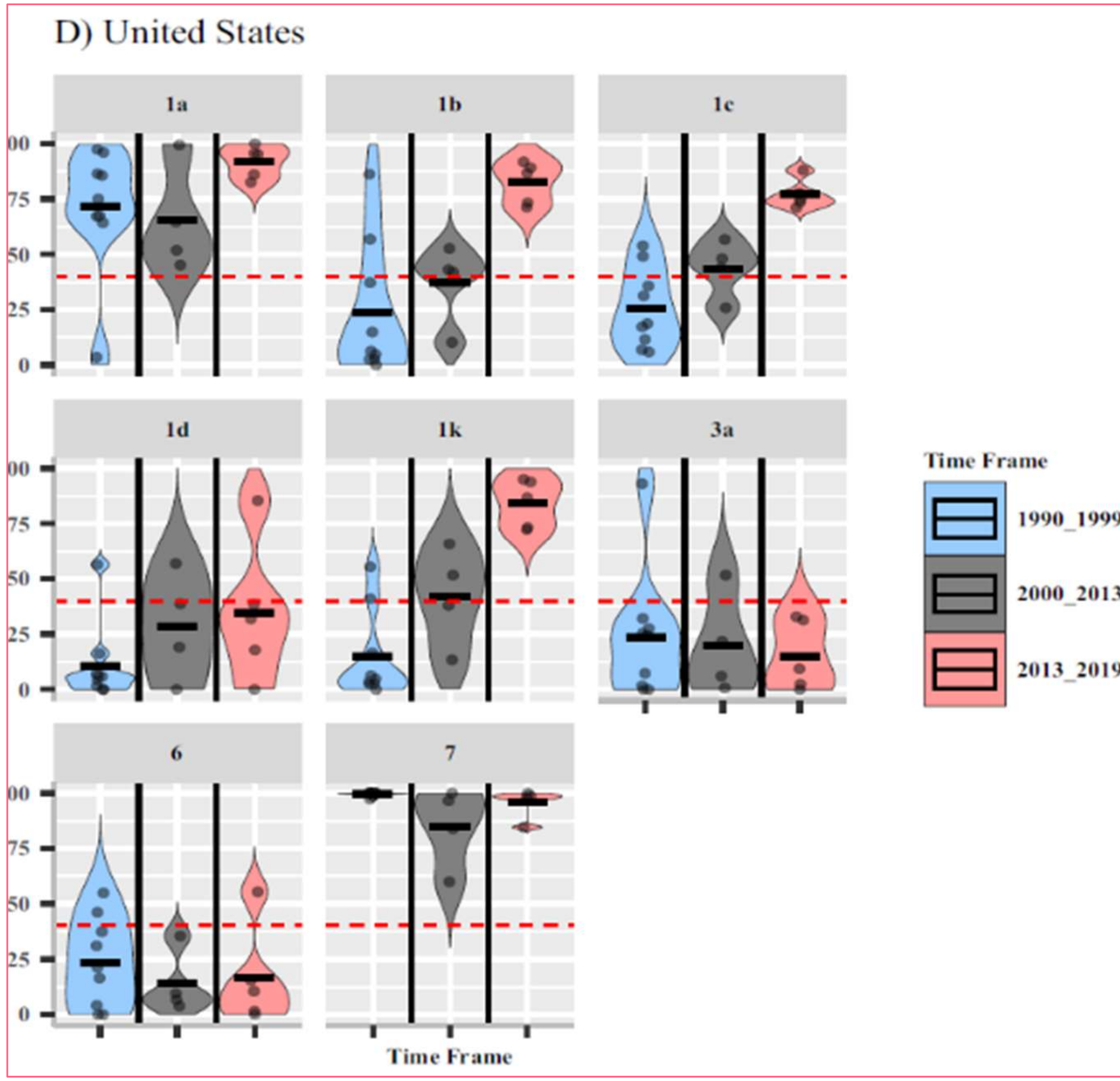


Fig. 2 | Resistance gene efficacy for each *Rps* gene and timepoint interaction by country. Facets denote the *Rps* genes tested; the *Y*-axis is the percent of isolates that are pathogenic on a given gene at a specific time frame from each study. Panel

Efficacy of Rps Genes against *P. sojae* in 11 Midwestern States. 2012-2013

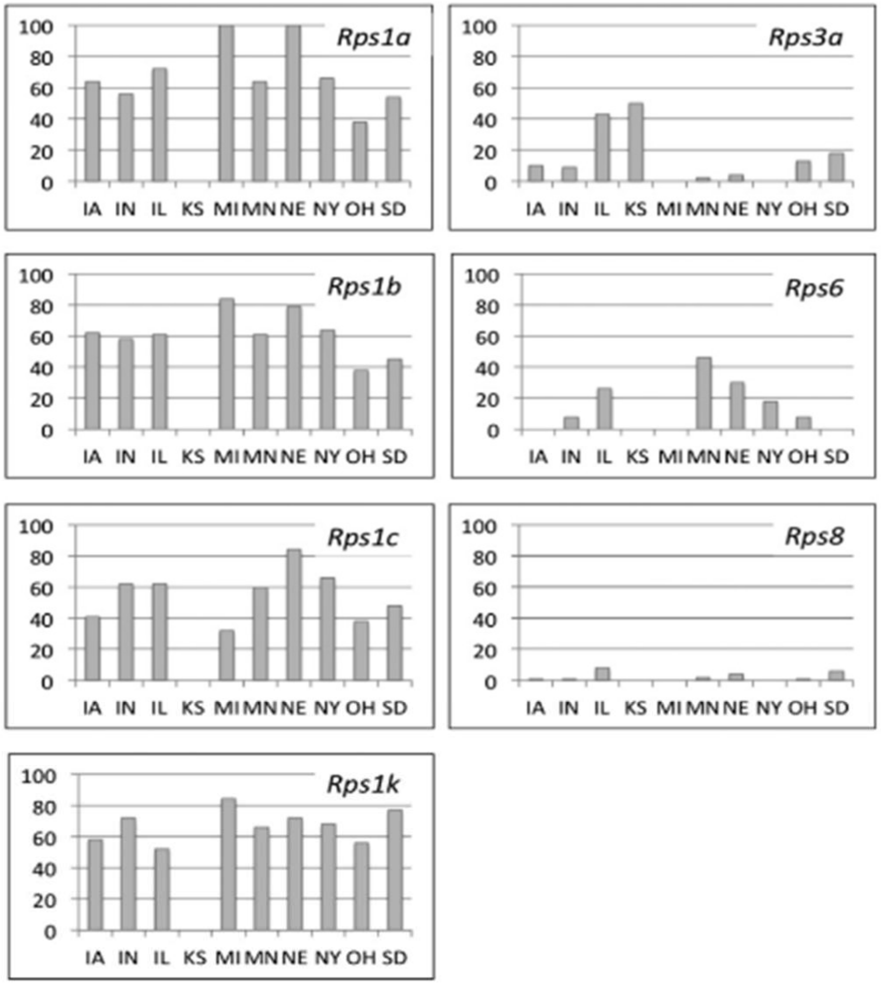
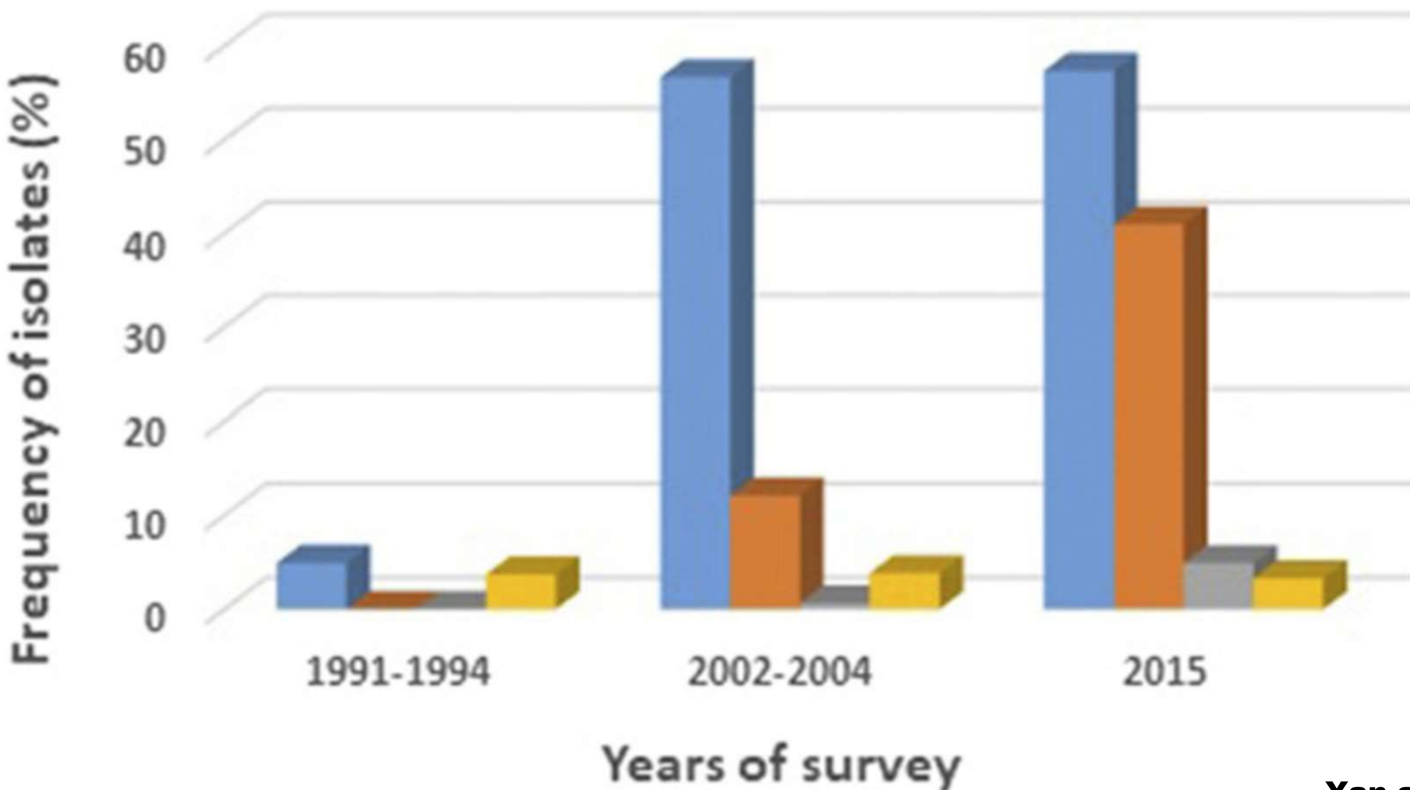


Fig. 3. Proportion of isolates of *Phytophthora sojae* collected in each state that are virulent on soybean *Rps* genes *1a, 1b, 1c, 1k, 3a, 6*, and *8*. Abbreviations: IA = Iowa, IN = Indiana, IL = Illinois, KS = Kansas, MI = Michigan, MN = Minnesota, NE = Nebraska, NY = New York, OH = Ohio, and SD = South Dakota.

Dorrance, A. E., Kurle, J., Robertson, A. E., Bradley, C. A., Giesler, L., Wise, K. and Concibido, V. C. 2016. Pathotype diversity of *Phytophthora sojae* in eleven states in the United States. Plant Dis. 100:1429-1437.

ffectiveness of Rps Genes in North Dakota

- s of 2015, Rps1c and Rps1k re relatively neffective
- Rps3a and Rps6 re still effective



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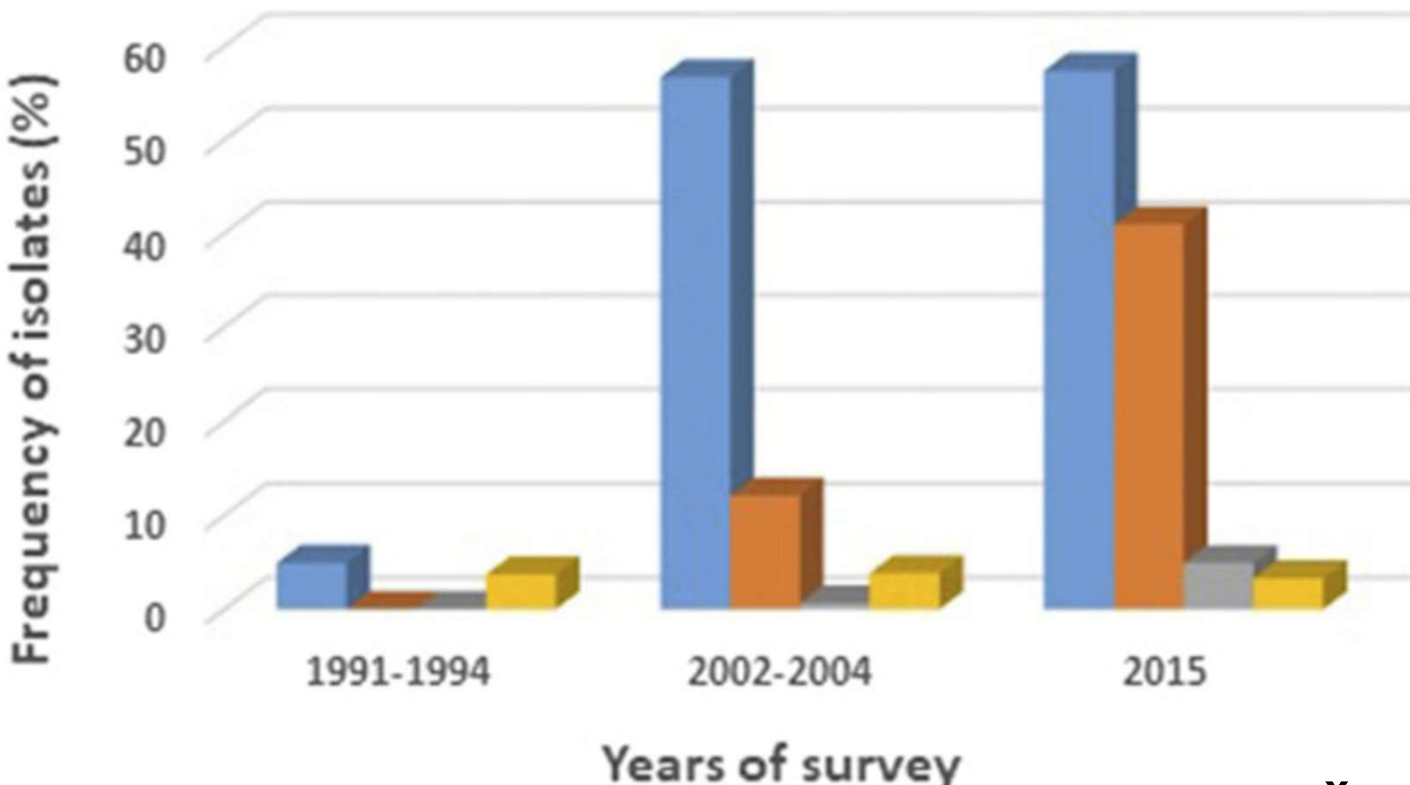

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orth Dakota Phytophthora Survey – Updat

Last ND Phytophthora survey was performed in 2015 (only in Red River Valley)

orth Dakota Phytophthora Survey – Updat

- Last ND Phytophthora survey was performed in 2015 (only in Red River Valley)
- In 2023, collected from 142 fields across ND
- Will continue to collect samples and screen for Rps gene effectiveness through 2025

ending Samples to NDSU

seeing suspected Phytophthora issues in 2024, send amples to Wade Webster - NDSU Soybean Pathologis nd Extension Specialist

chard.webster@ndsu.edu

01-231-8363

402 Albrecht Blvd.
alster Hall 306
argo, ND 58108

MN Phytophthora Survey

We are collecting soil and plant amples from Minnesota fields and o identify *P. sojae* pathotypes and variants

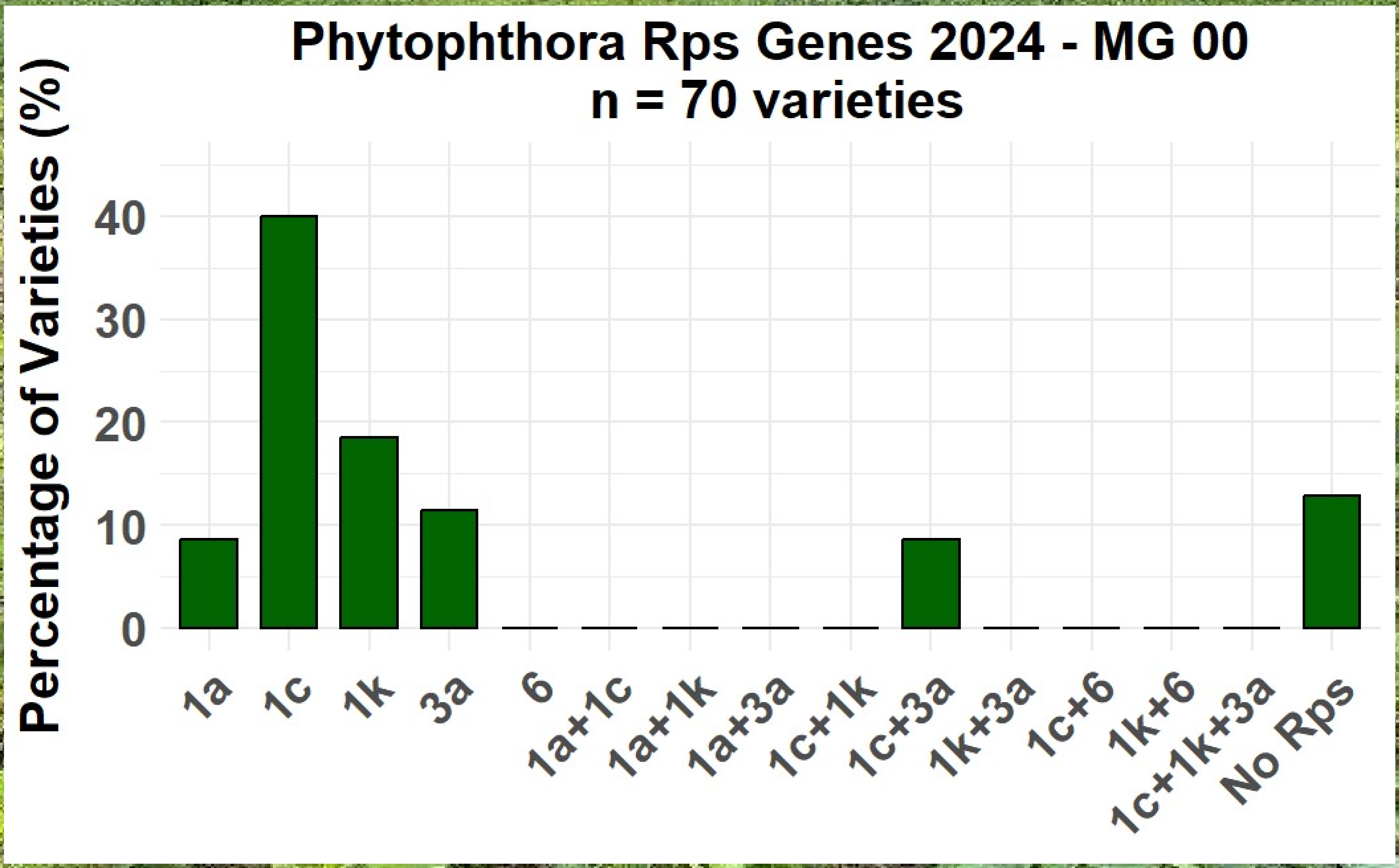
If you would like to send soil or tissue samples, please contact:

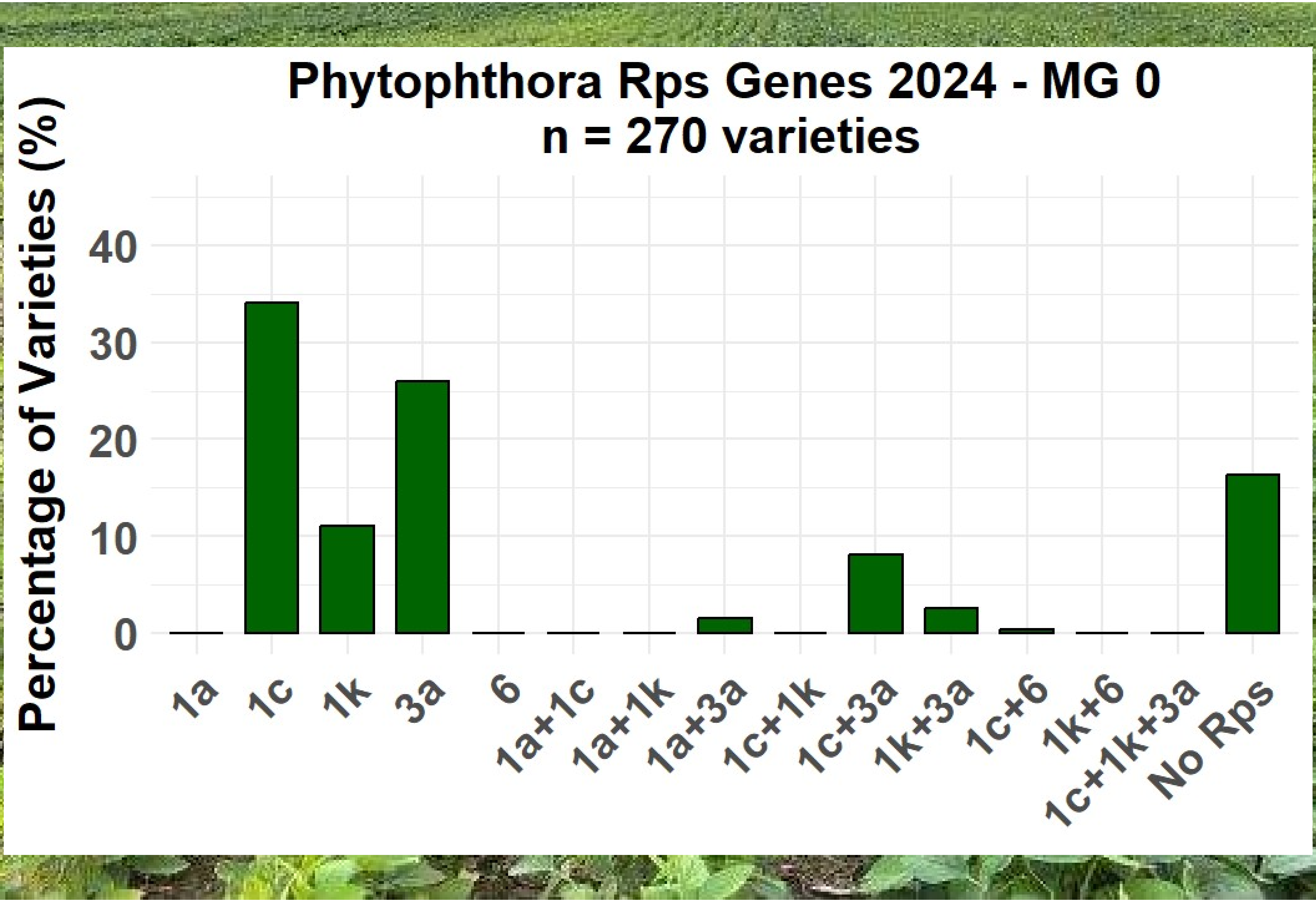
Kat Markham
markat@umn.edu

Megan McCaghey
mmccaghe@umn.edu

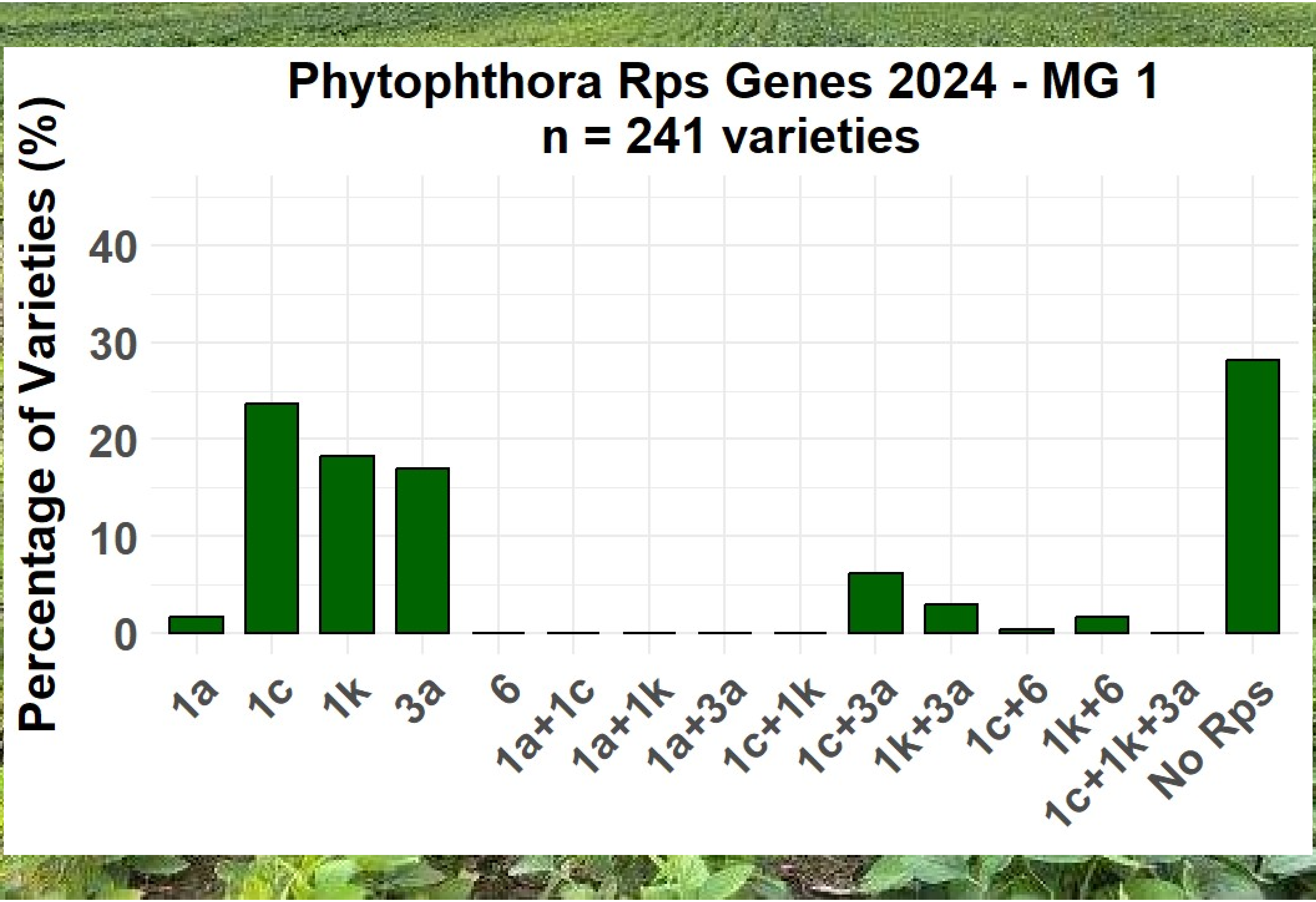
What Options Do We Have?

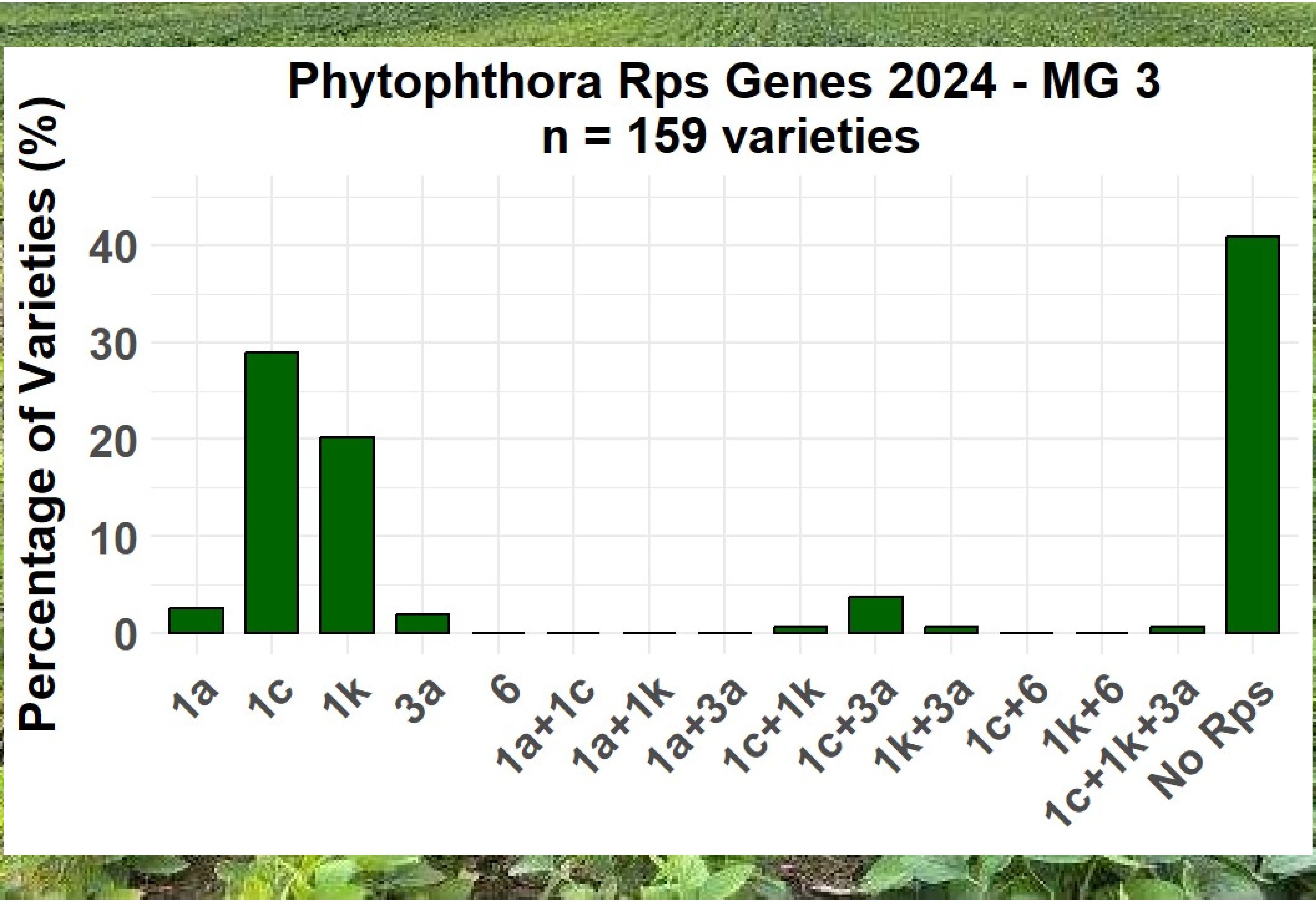
Photo: Soybean Research Informatio


Phytophthora Rps Genes 2024 - MG 00
n = 70 varieties
Percentage of Varieties (%)
0
10
20
30
40
1a
1c
1k
3a
6
1a+1c
1a+1k
1a+3a
1c+1k
1c+3a
1k+3a
1c+6
1k+6
1c+1k+3a
No Rps



Phytophthora Rps Genes 2024 - MG 0
n = 270 varieties
Percentage of Varieties (%)
0
10
20
30
40
1a
1c
1k
3a
6
1a+1c
1a+1k
1a+3a
1c+1k
1c+3a
1k+3a
1c+6
1k+6
1c+1k+3a
No Rps


Phytophthora Rps Genes 2024 - MG 1
n = 241 varieties
Percentage of Varieties (%)
0
10
20
30
40
1a
1c
1k
3a
6
1a+1c
1a+1k
1a+3a
1c+1k
1c+3a
1k+3a
1c+6
1k+6
1c+1k+3a
No Rps



Phytophthora Rps Genes 2024 - MG 3
n = 159 varieties
Percentage of Varieties (%)
40
30
20
10
0
1a
1c
1k
3a
6
1a+1c
1a+1k
1a+3a
1c+1k
1c+3a
1k+3a
1c+6
1k+6
1c+1k+3a
No Rps

Phytophthora rot of soybean
anagement with partial resistance ("tolerance")

- At least partially effective against all pathotypes of *P. sojae*
- Partially resistant (tolerance) varieties may be necessary where pathotypes (races) defeat available Rps genes
- Limited root rot develops
- Restricts fungal colonization of plant.

ield Tolerance

- **Slows the development of lesions**
- **Reduces the number of oospores produced**

Photo: Marty Ch

opics covered in this session

- hat is *Phytophthora root rot and what causes it*
- sease development, symptoms, and diagnosis
- stablished and new methods to detect and identify fferent pathotypes of *P. sojae*
- anagement of Phytophthora root rot

Questions or Comments

Dean Malvick, University of Minnesota
Wade Webster, North Dakota State University

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North Central Soybean Research Program
ND Soybean Council