Correlation between soil test phosphorus and potassium and corn and soybean yields in North Carolina

FRST Collaborator Meeting

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Soil test correlation in North Carolina

- Critical soil test value is the soil test value (P or K) at which optimum plant yield can be achieved.
- Soybean and corn are the largest row crops grown in North Carolina.
- Current fertilizer recommendations in NC apply the same CSTVs of P (54 mg kg^{-1}) or K (88 mg kg^{-1}) to corn and soybean at 0–20 cm depth.

(Cox, 1992; Gatiboni et al., 2021; Jalali et al., 2025)

Crop response to fertilization may vary by species and soil properties

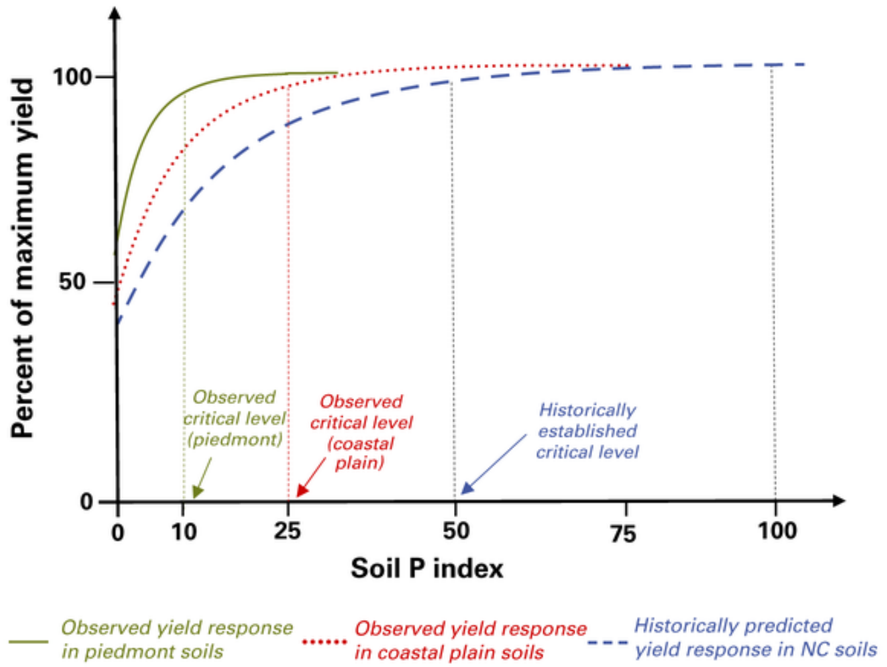
Soil properties (clay content)

P CSTV usually decreases as clay content increases

- P CSTV is ~**30** mg kg^{-1} in Coastal Plain soils, while in Piedmont soils, it is ~**12** mg kg^{-1}

K CSTV usually increases as CEC content increases

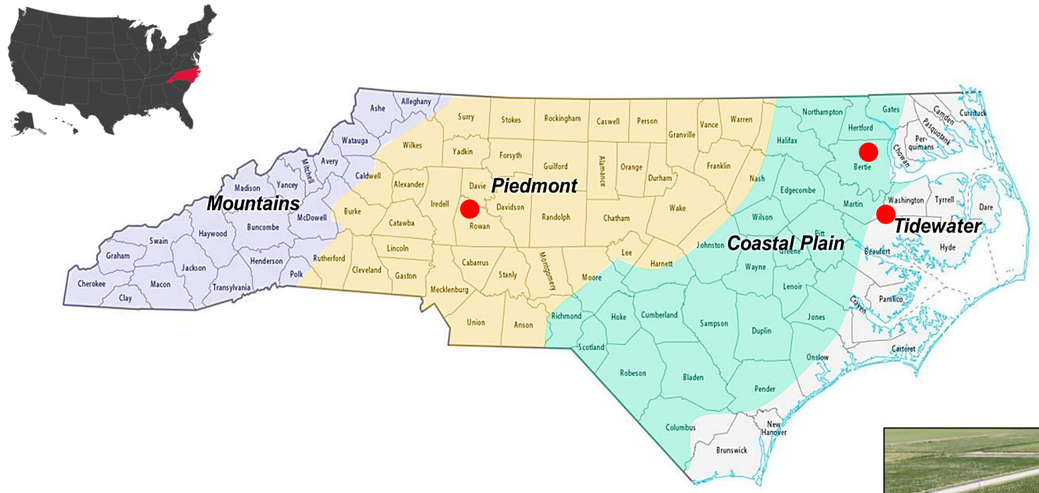
- K CSTV is ~**27–49** mg kg^{-1} in Coastal Plain soils, while in Piedmont soils, it is **~93–163** mg kg^{-1}



(Cox, 1992; Gatiboni et al., 2021; Jalali et al., 2025)

Long-term soil fertility trials in NC

Piedmont trial (1985)
- **Soil:** Hiwassee sandy clay loam (31% clay)
- **Tillage system:** No-till
- **P treatments:** Four rates of P
- **K treatments:** Four rates of K



Coastal Plain trial (1982)
- **Soil:** Goldsboro sandy loam (9% clay)
- **Tillage system:** Conventional tillage
- **P treatments:** Five rates of P
- **K treatments:** Four rates of K

Tidewater trial (1955)
- **Soil:** Portsmouth sandy loam (9% clay)
- **Tillage system:** Minimum tillage
- **P treatments:** Five rates of P
- **K treatments:** Five rates of K

Study I.

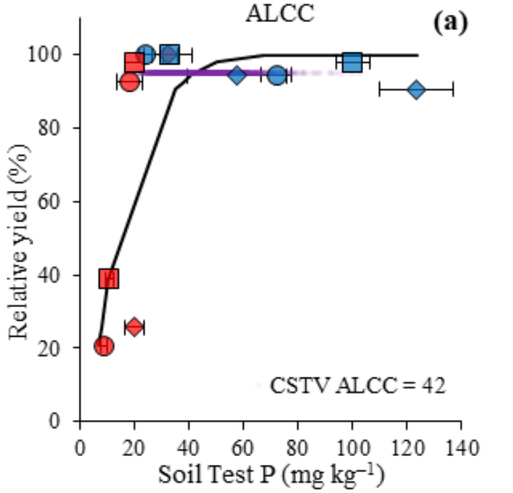
Effect of model choice on critical soil test value of phosphorus for corn in long-term trials in North Carolina

Using historical corn data from 2010, 2012, and 2014 from long-term trials:

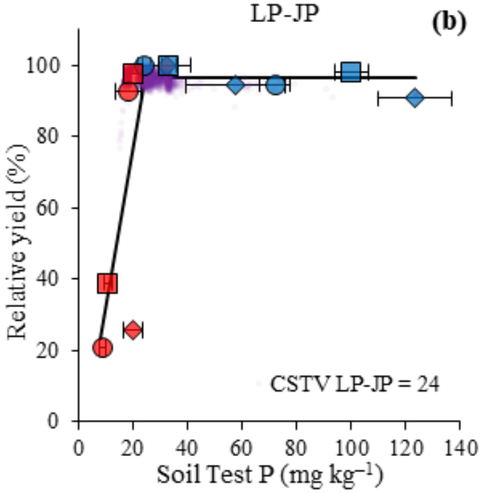
- Compared the P CSTVs for corn using four mathematical models
- Calculated the frequency of crop response to increasing soil test P

Phosphorus CSTV at the Coastal Plain site (0–20 cm depth)

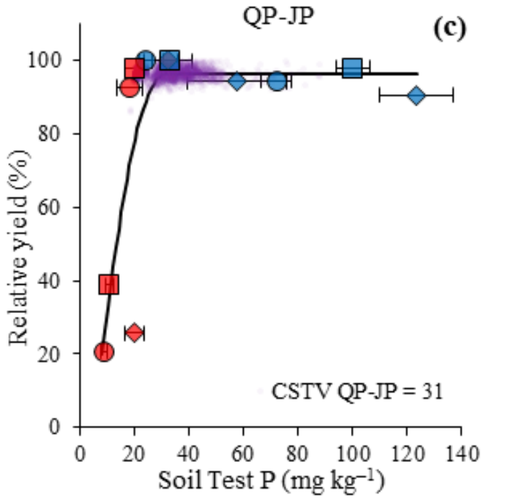
Modified arcsine-log calibration curve



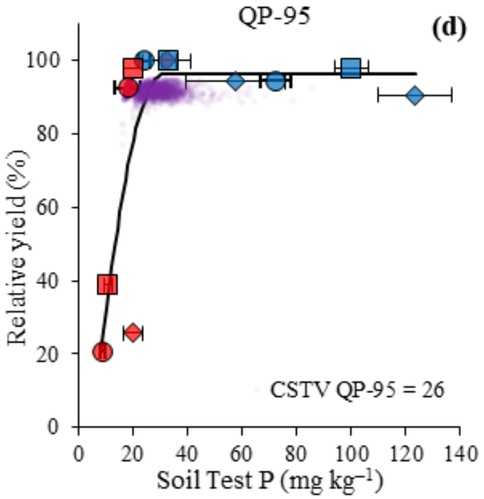
Linear plateau – join point (100%)



Quadratic plateau – join point (100%)

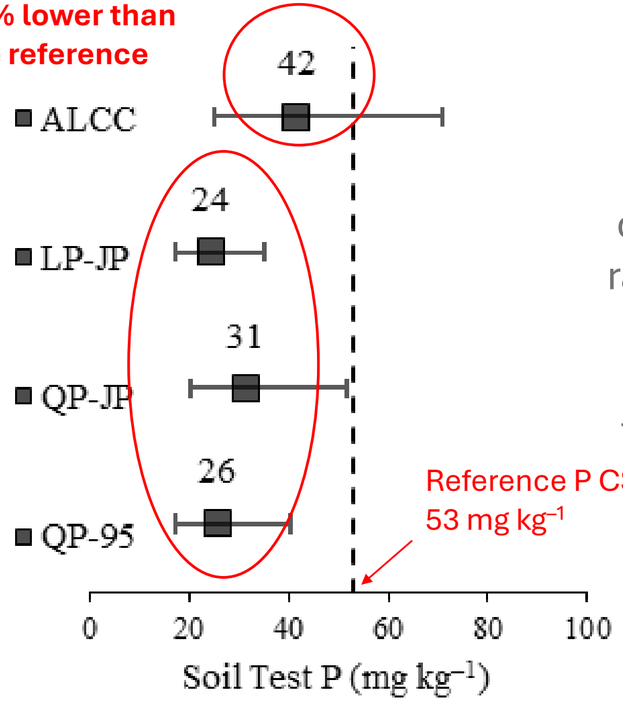


Quadratic plateau – 95% RY



22% lower than the reference

49% lower than the reference



The 95% confidence limit range overlapped for all CSTVs calculated with the four models

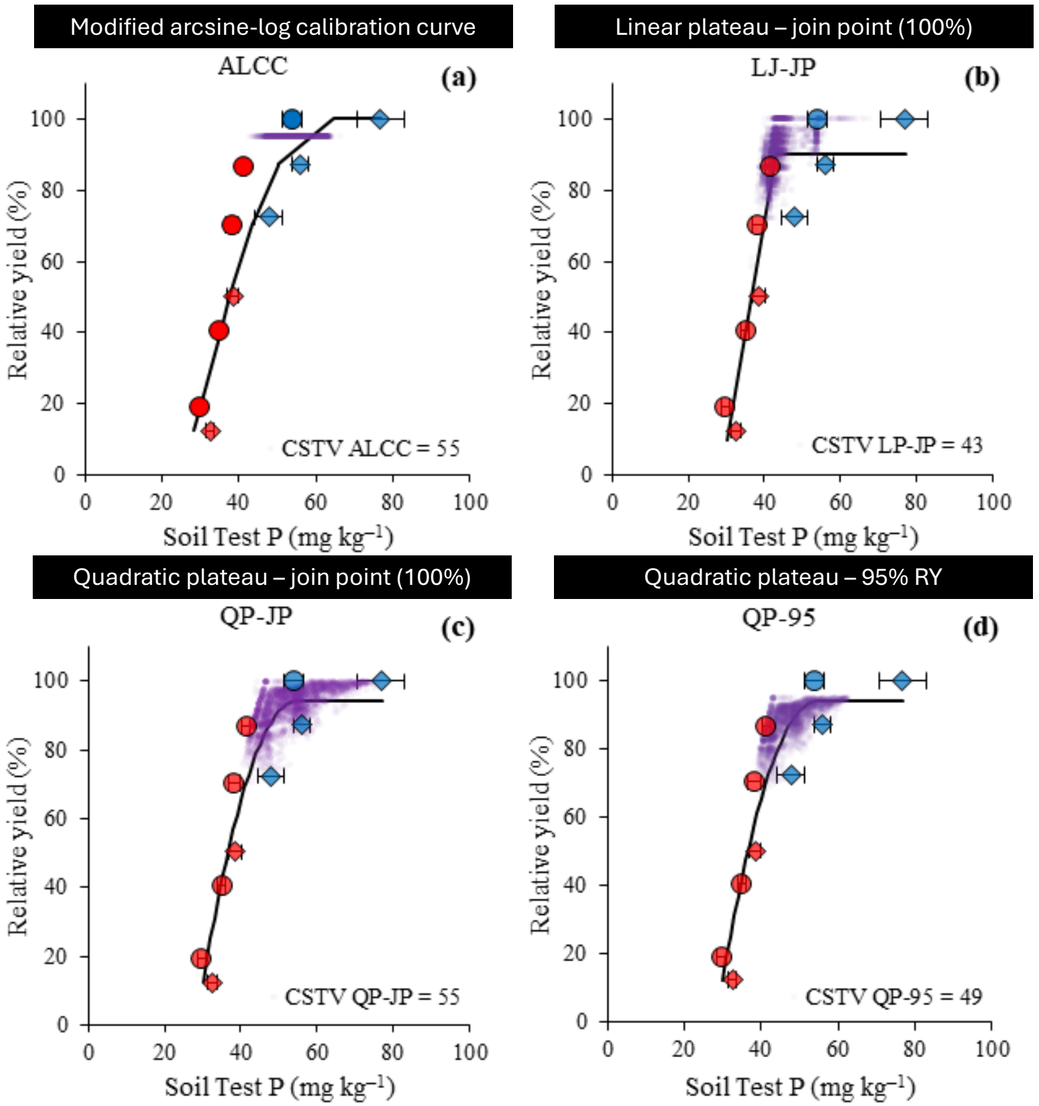
P CSTVs reported over 37 years in this trial (LP-JP)

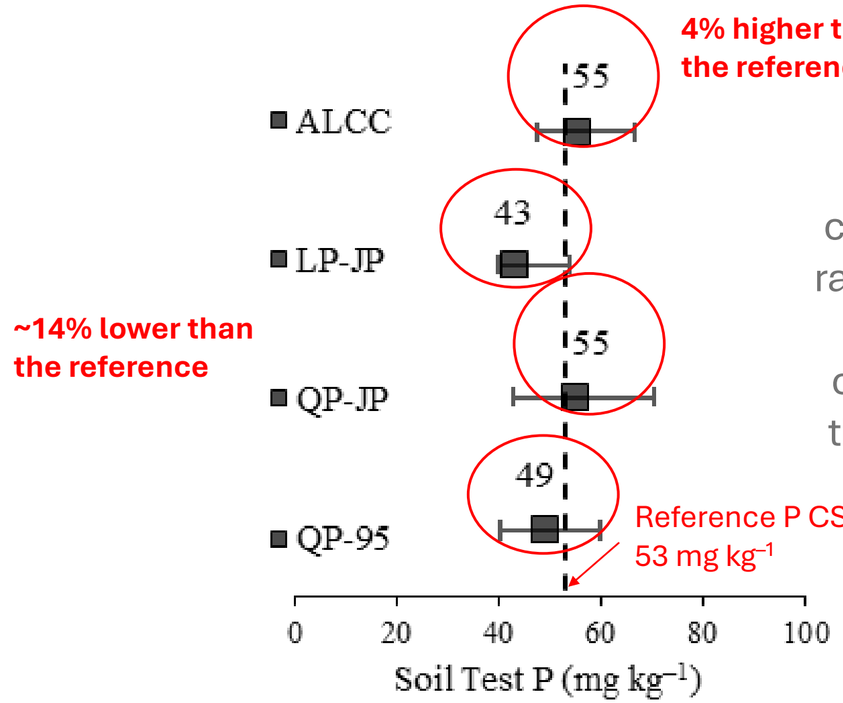
- From 1987–1997 (corn) = 18 mg kg^{-1}
- From 1998–1999 (cotton) = 21 mg kg^{-1}
- From 2020–2021 (soybean/corn) = 48 mg kg^{-1}

(Cox & Barnes, 2002; Crozier et al., 2004; Morales et al., 2023)

Study I. Effect of model choice on critical soil test value of phosphorus for corn in long-term trials in North Carolina.

Phosphorus CSTV at the Tidewater site (0–15 cm depth)





The 95% confidence limit range overlapped for all CSTVs calculated with the four models

P CSTVs reported over 59 years in this trial

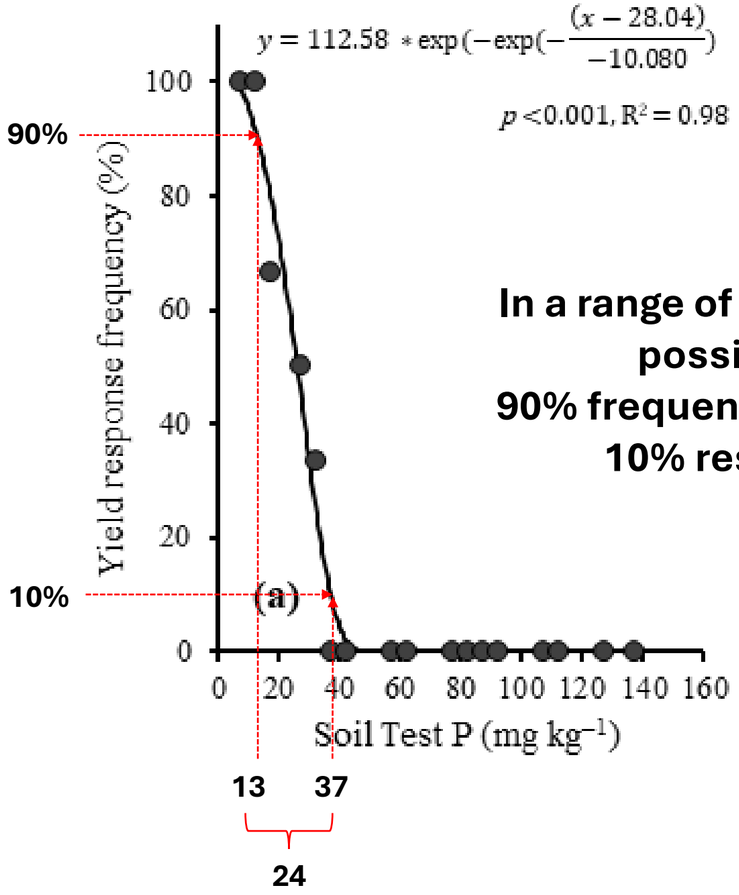
- From 1955–1963 (corn) = 43 mg kg^{-1}
- From 1998–1999 (cotton) = 40 mg kg^{-1}
- From 2020–2021 (soybean/corn) = 51 mg kg^{-1}

(Crozier et al., 2004; McCollum, 1991; Morales et al., 2023)

Study I. Effect of model choice on critical soil test value of phosphorus for corn in long-term trials in North Carolina.

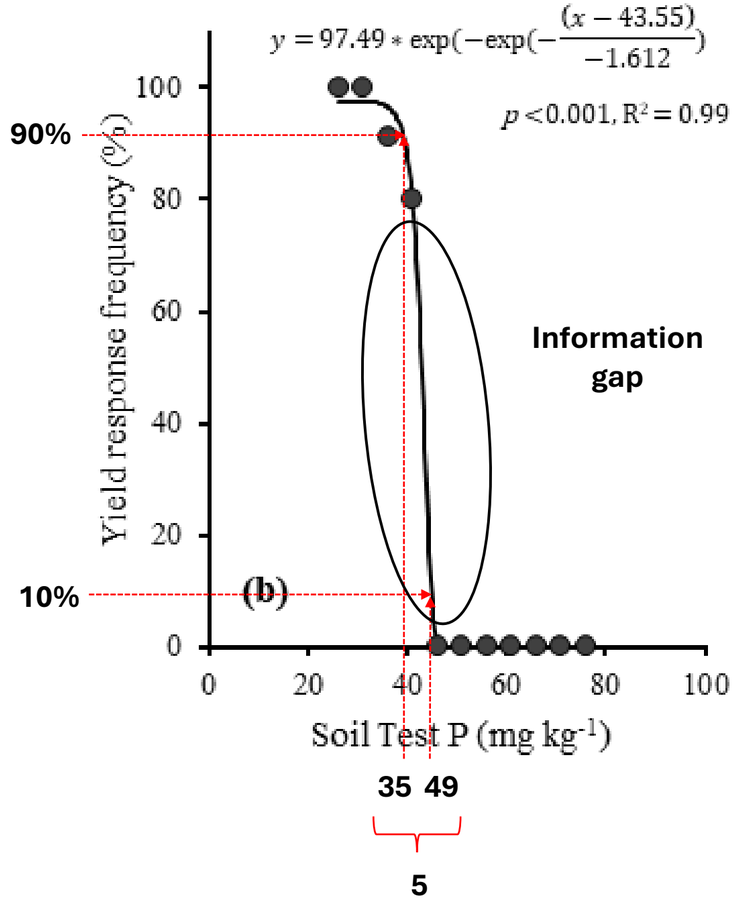
Frequency of corn response to increasing soil test P

Coastal Plain site



In a range of 24 and 5 STP units, it is possible to go from a 90% frequency of response to a low 10% response threshold

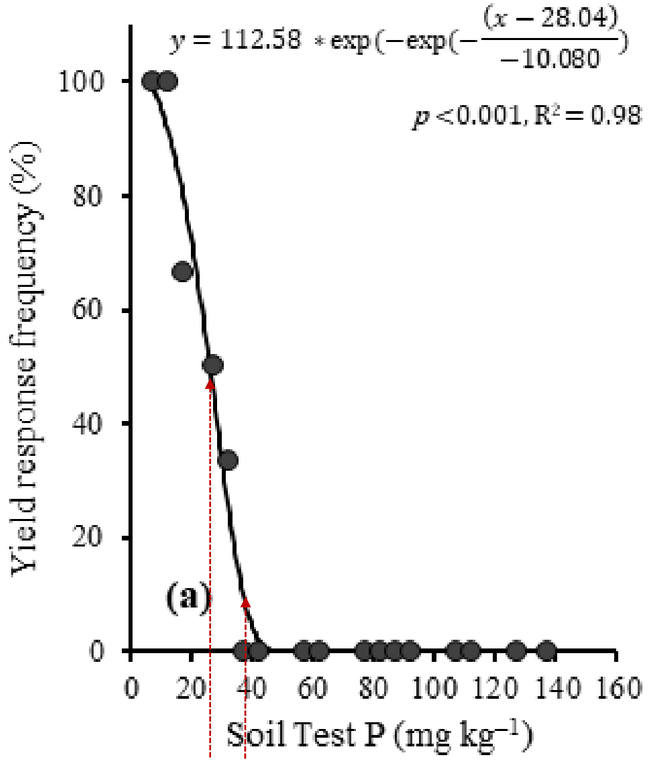
Tidewater site



Study I. Effect of model choice on critical soil test value of phosphorus for corn in long-term trials in North Carolina.

Critical Soil Test Range (CSTR)

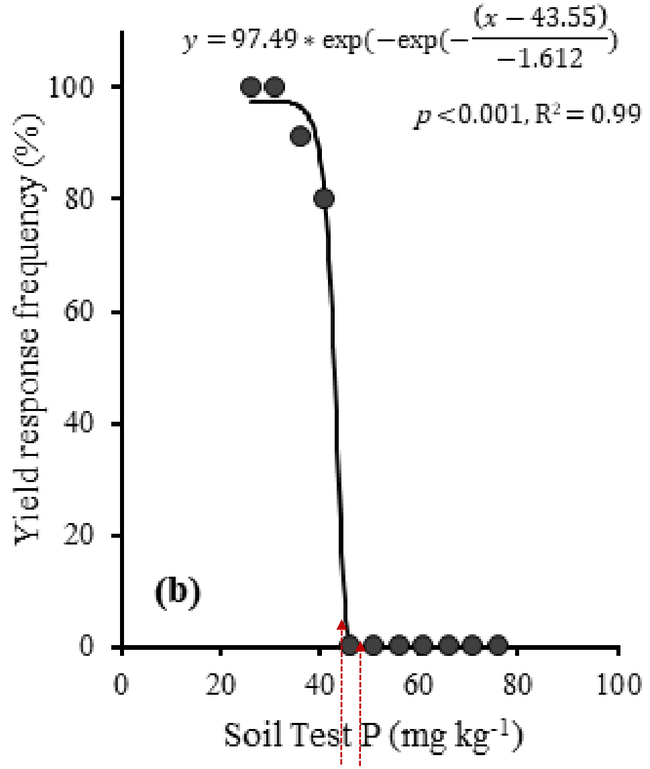
Coastal Plain site



26 CSTV QP-95

37 10% yield response frequency

Tidewater site



45 10% yield frequency response

49 CSTV QP-95

Further studies should evaluate this approach to define CSTR in broader and more diverse datasets.

Study I. Effect of model choice on critical soil test value of phosphorus for corn in long-term trials in North Carolina.

Conclusions

CSTVs were driven by models and sufficiency interpretation. However, the 95% confidence interval of the CSTV did not differ significantly for the tested models and sites analyzed.

A low frequency of crop response to increasing soil test P is expected in a critical soil test range greater than 26–37 and 45–49 mg kg^{-1} at the Coastal Plain and Tidewater sites.

Study II.

Correlation of soil test phosphorus and potassium for corn and soybean on long-term trials in North Carolina

Using the model chosen in Study I:

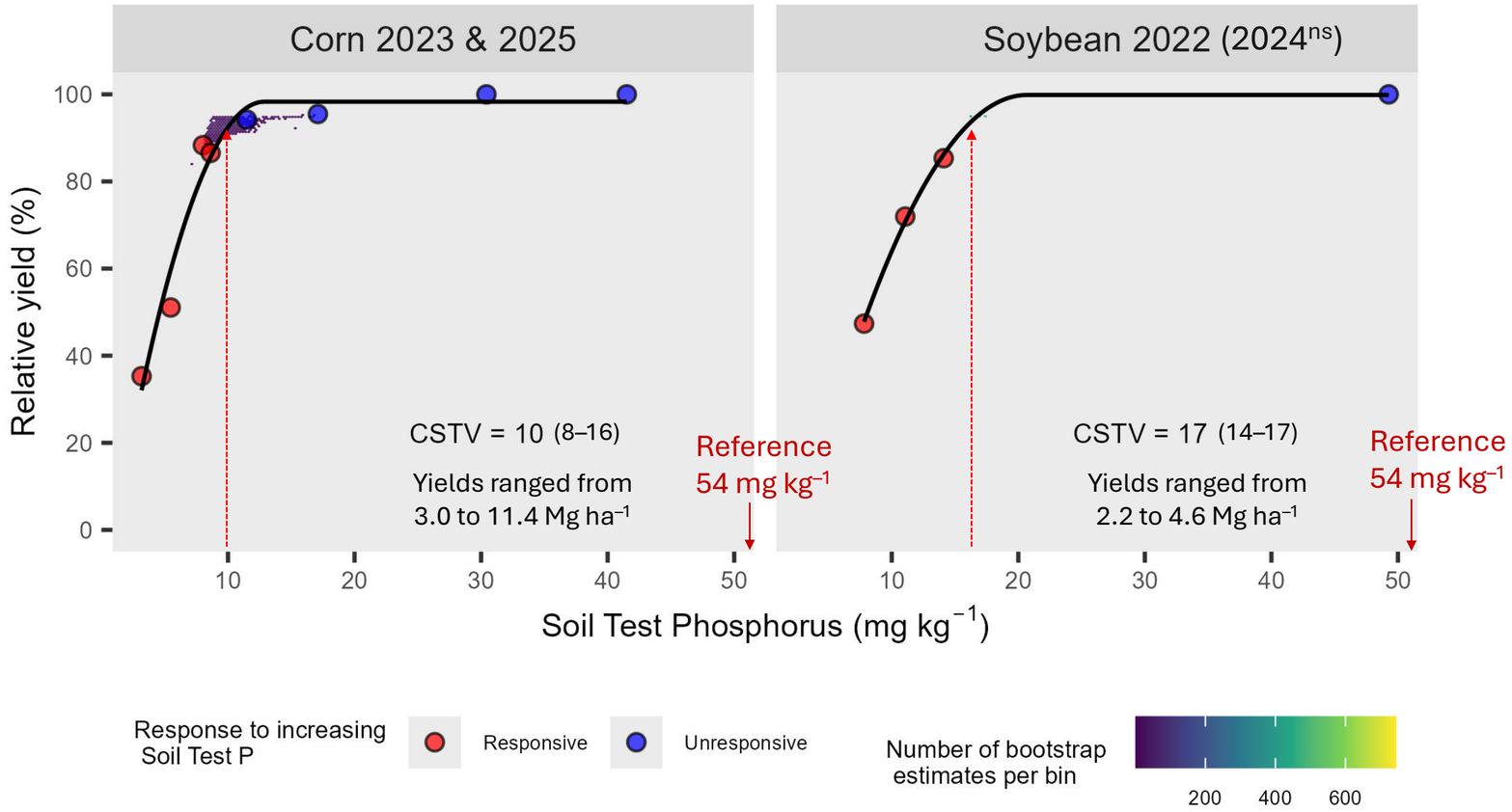
- Determined the P and K CSTVs for corn and soybean grown from 2022 to 2025
- Determined the critical P and K leaf tissue concentration

Piedmont site

- P + P

- P + P

Phosphorus CSTV at the Piedmont site (0–10 cm depth)



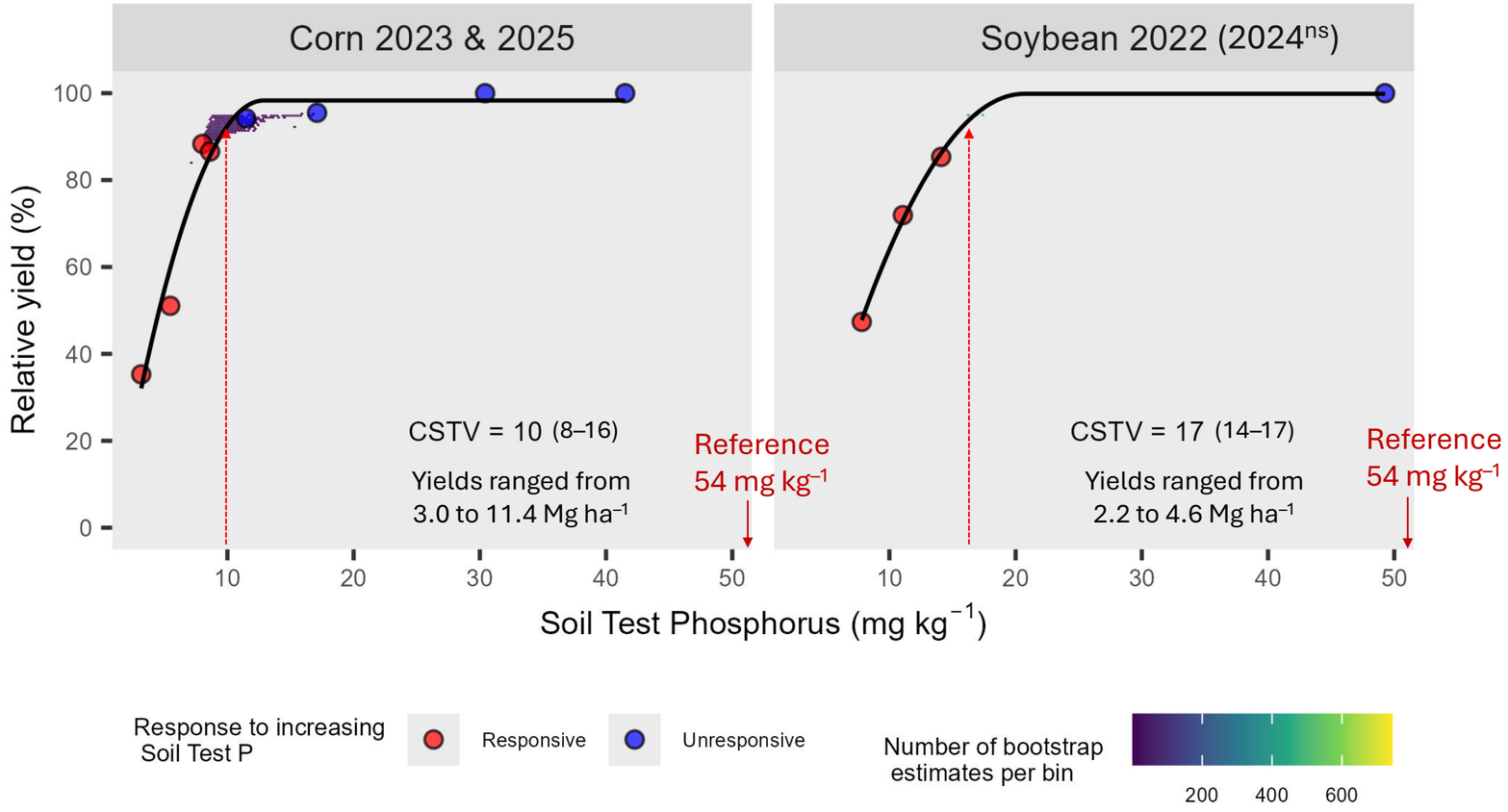
- P CSTVs reported for Piedmont soils:
  Corn = 9–12 mg kg^{-1}
  Soybean = 15 mg kg^{-1}

Implications:

- Soil sampling depth (10 cm *vs.* 20 cm)

(Gatiboni et al., 2021; Hardy et al., 2014; Morales et al., 2023; Tiecher et al., 2023)

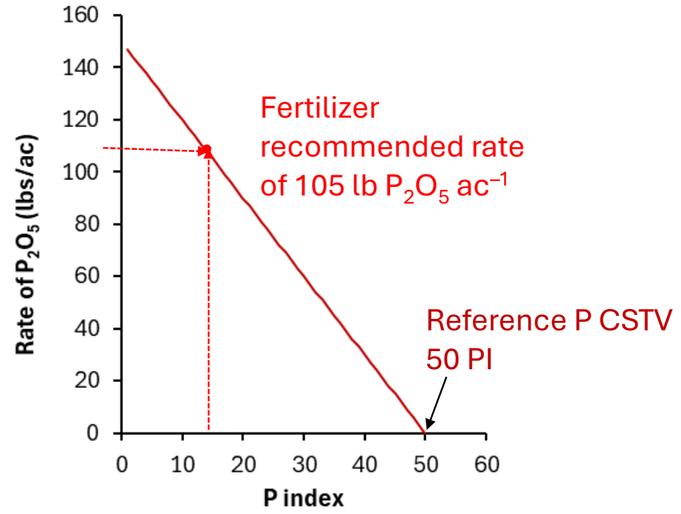
Phosphorus CSTV at the Piedmont site (0–10 cm depth)



- P CSTVs reported for Piedmont soils:
  Corn = 9–12 mg kg^{-1}
  Soybean = 15 mg kg^{-1}

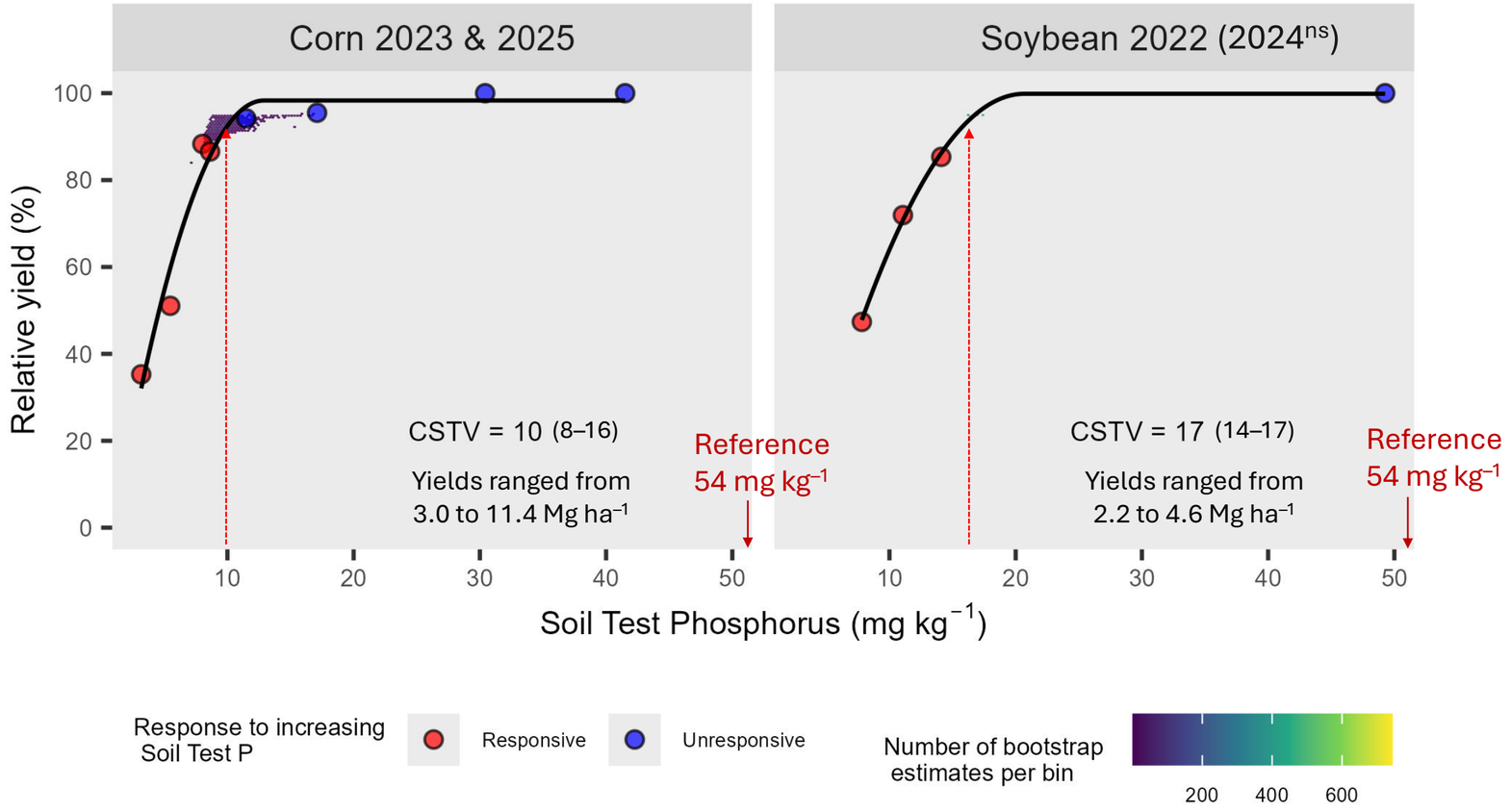
Implications:

- Soil sampling depth (10 cm *vs.* 20 cm)
- P fertilizer rate recommendations



(Gatiboni et al., 2021; Hardy et al., 2014; Morales et al., 2023; Tiecher et al., 2023)

Phosphorus CSTV at the Piedmont site (0–10 cm depth)



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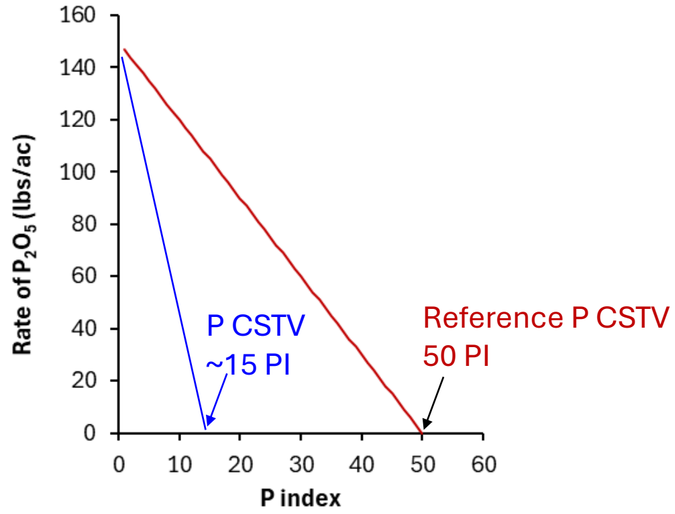


(Gatiboni et al., 2021; Hardy et al., 2014; Morales et al., 2023; Tiecher et al., 2023)

Coastal Plain site

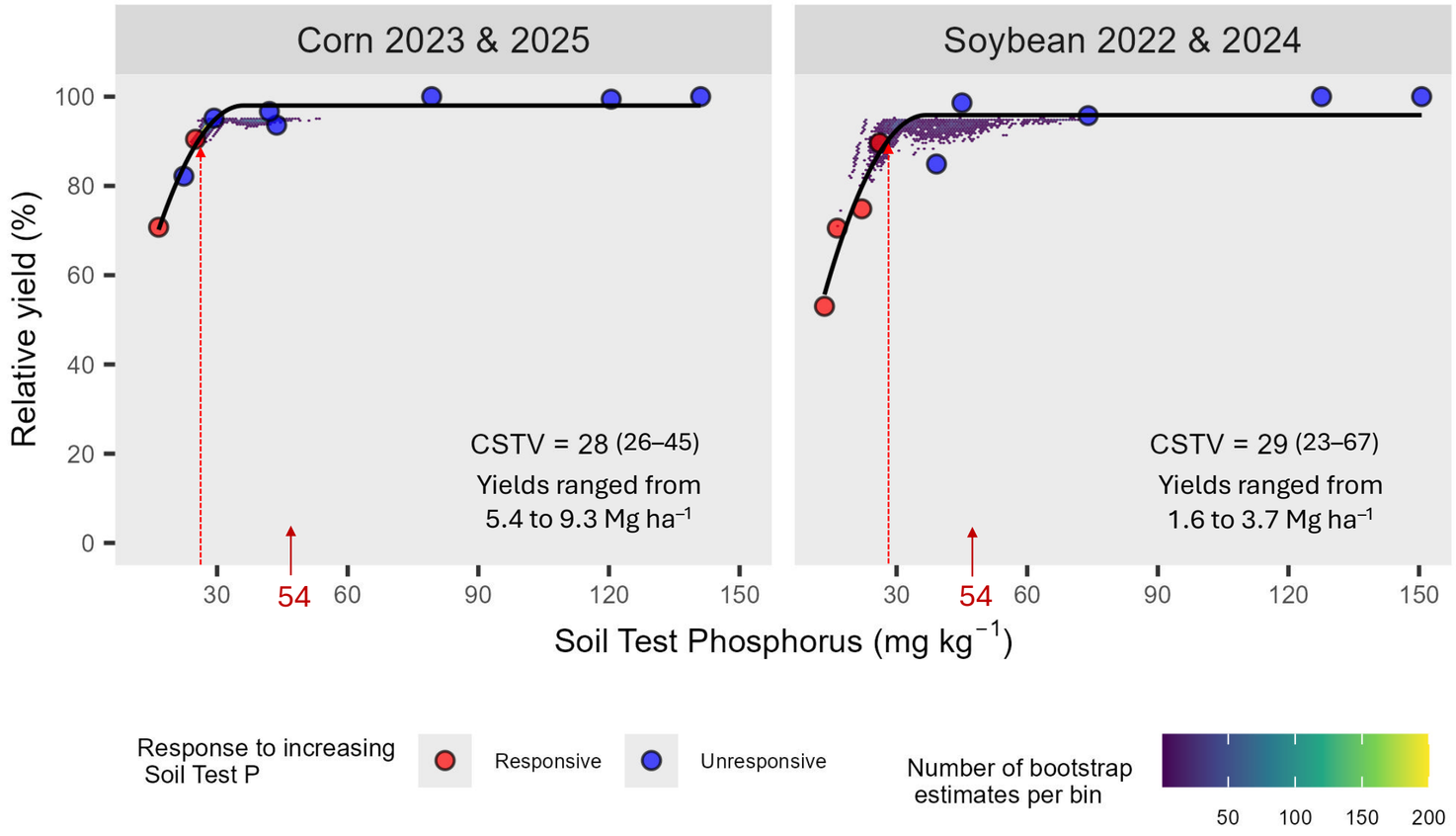
- P

+ P

- P

+ P

Phosphorus CSTV at the Coastal Plain site (0–20 cm depth)



- P CSTVs reported for Coastal Plain soils:
  Corn = 18–66 mg kg^{-1}
  Soybean = 67 mg kg^{-1}

Implications:

- Soybean did not respond to fertilization in sites with P levels > P CSTV
- Retrieving historical data to evaluate potential temporal shift in CSTV

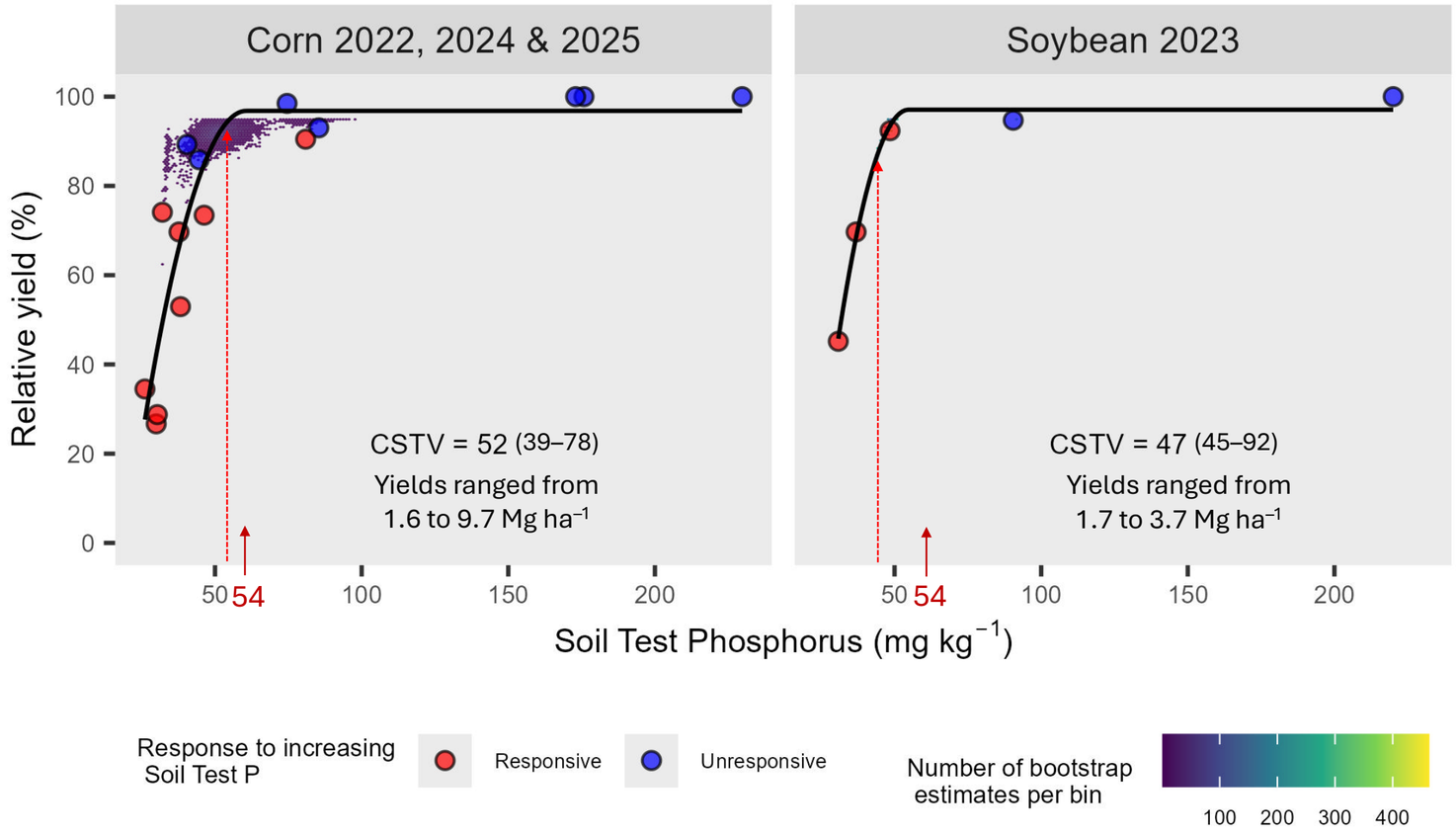
(Filippi et al., 2025; Gatiboni et al., 2021; Hardy et al., 2014; Miles, 2024; Morales et al., 2023)

Tidewater site

+ P - P

+ P - P

Phosphorus CSTV at the Tidewater site (0–20 cm depth)



- P CSTVs reported for this trial:
  Corn = 43–49 mg kg^{-1}
  Soybean = 30–53 mg kg^{-1}

(Filippi et a., 2025; Gatiboni et al., 2021; Hardy et al., 2014; McCollum, 1991; Morales et al., 2023)

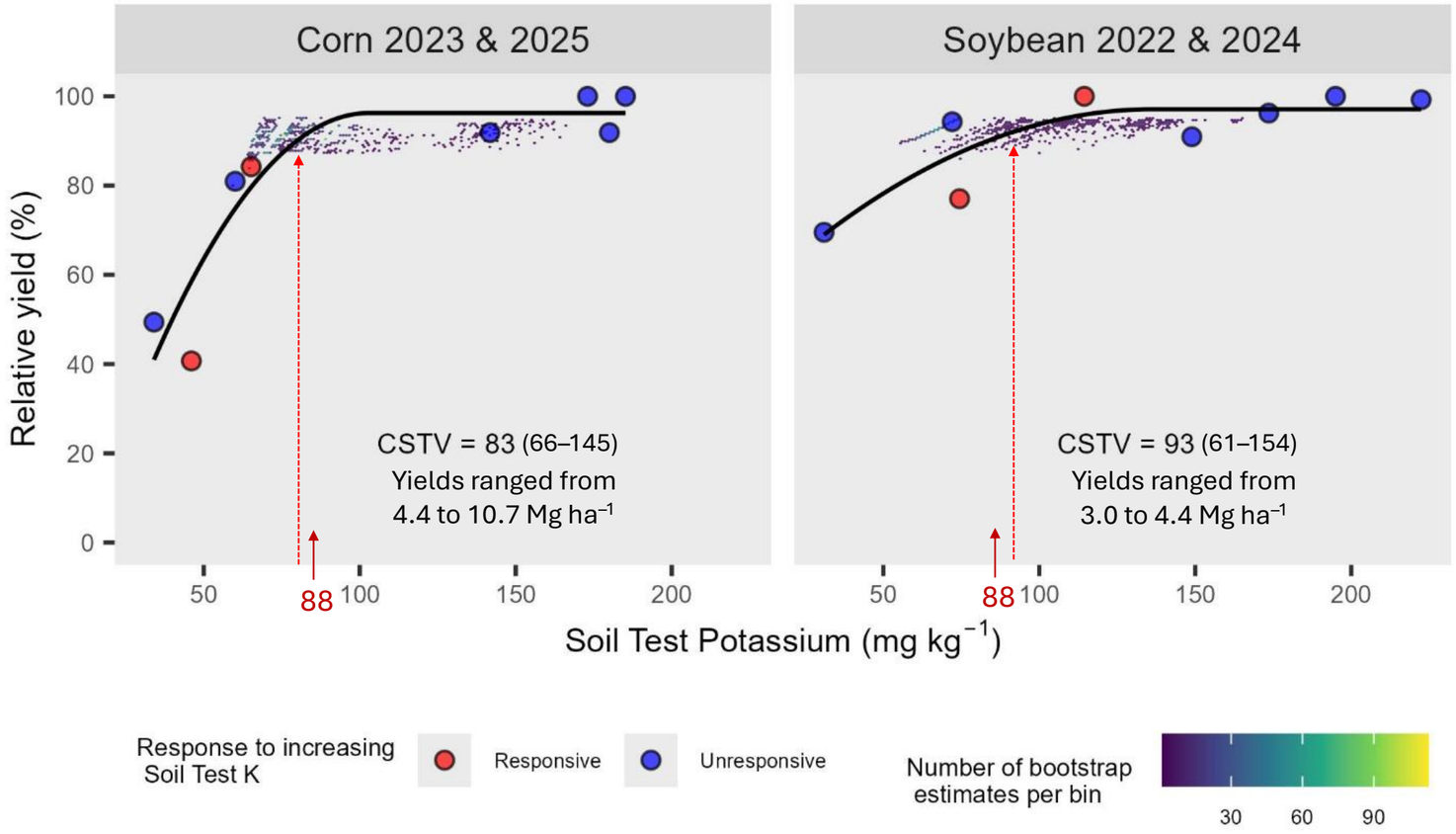
Piedmont site

- K

- K

+ K

Potassium CSTV at the Piedmont site (0–10 cm depth)



K CSTVs reported for Piedmont soils:
Cotton = 137 mg kg^{-1}
Soybean = 96 mg kg^{-1}

Implications:

- Soil sampling depth (10 cm *vs.* 20 cm)
- Few K data are reported for this site

(Crozier et al., 2004; Morales et al., 2023)

Coastal Plain and Tidewater sites

- K

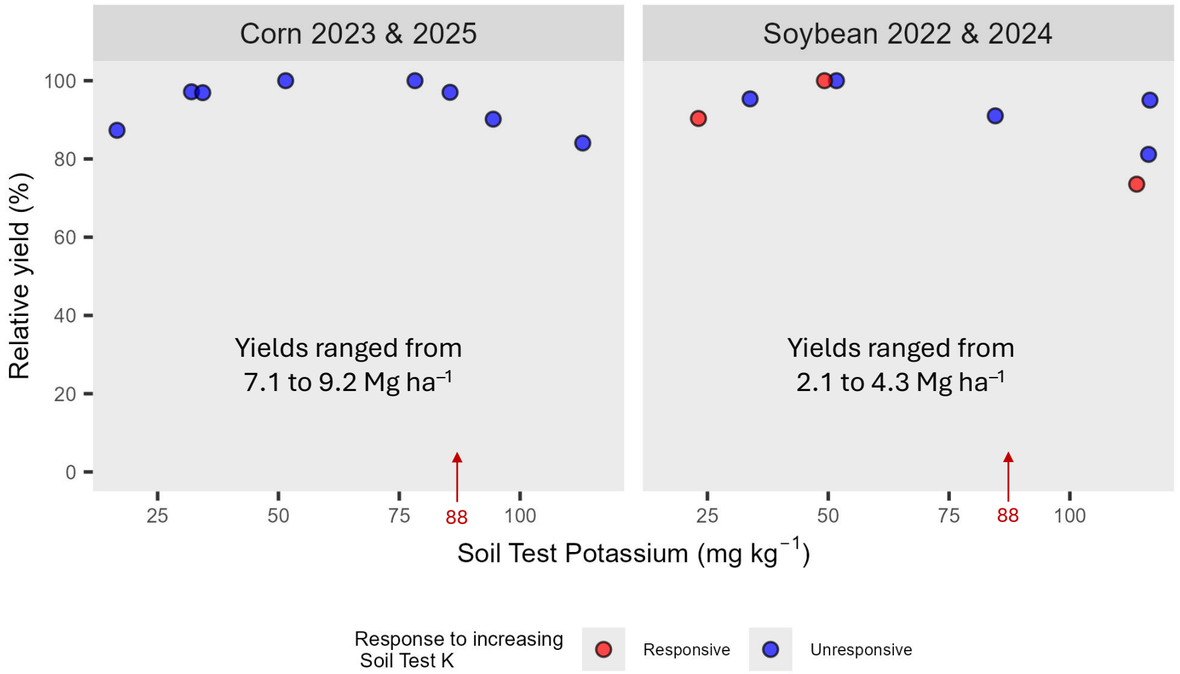
+ K

- K

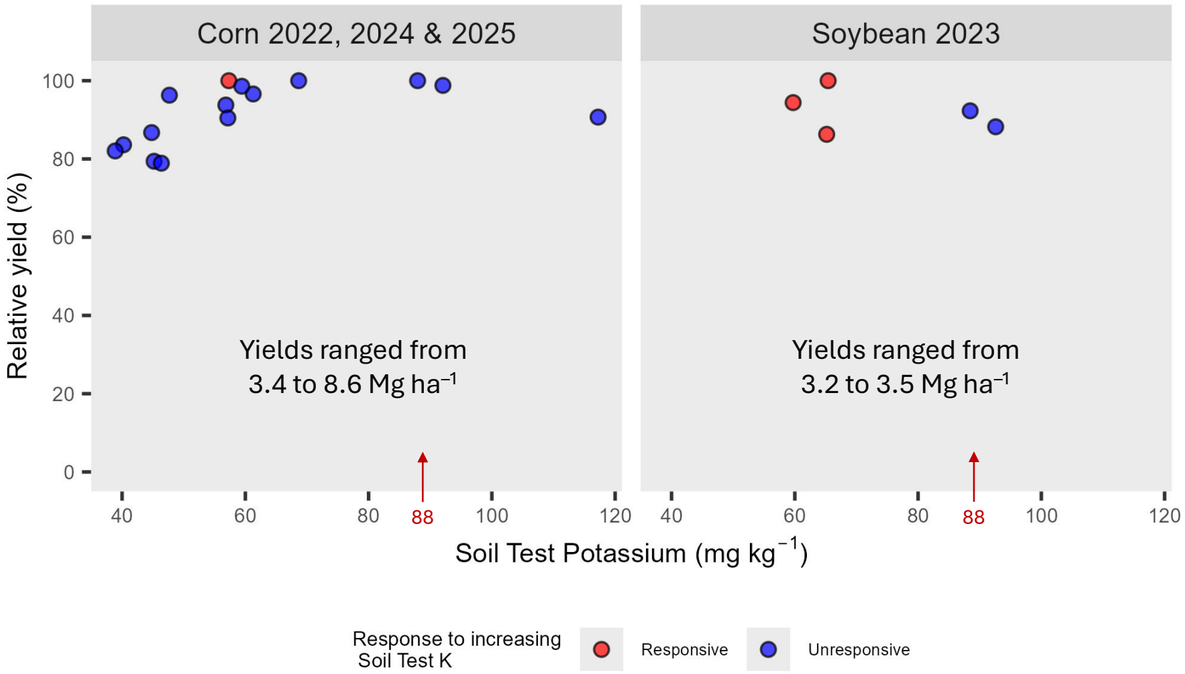
+ K

Study II. Correlation of soil test phosphorus and potassium for corn and soybean on long-term trials in North Carolina.

Potassium at the Coastal Plain site (0–20 cm)



Potassium at the Tidewater site (0–20 cm)

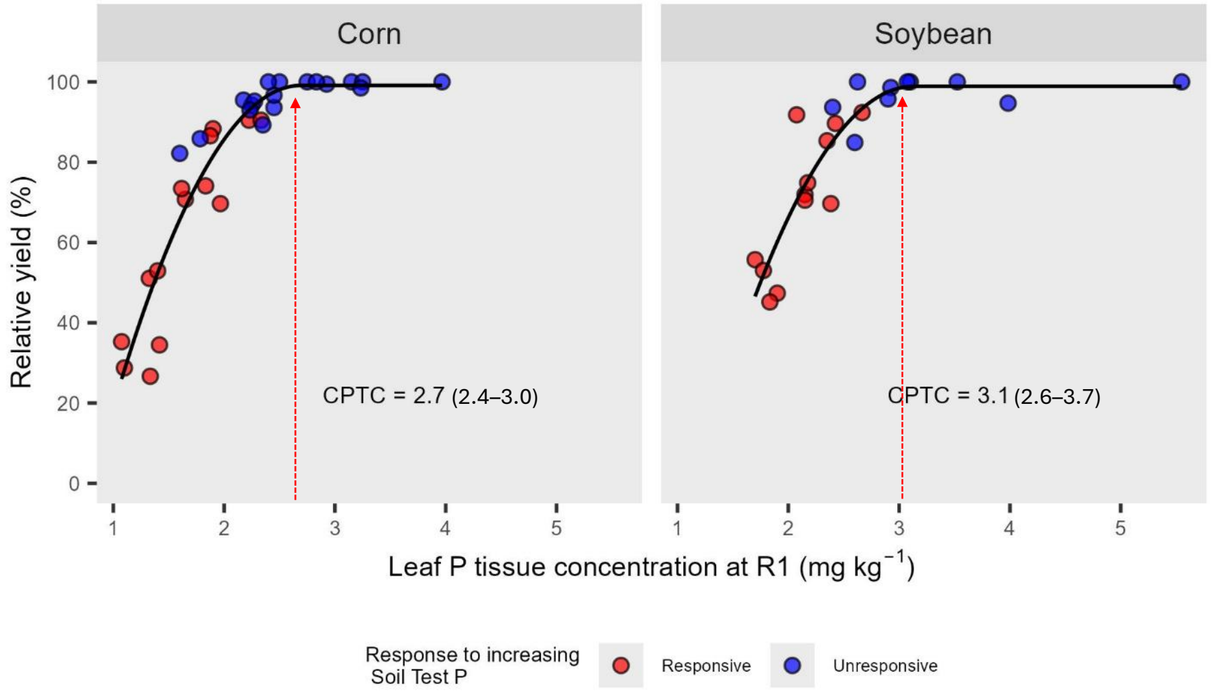


Reasons for lack of response:

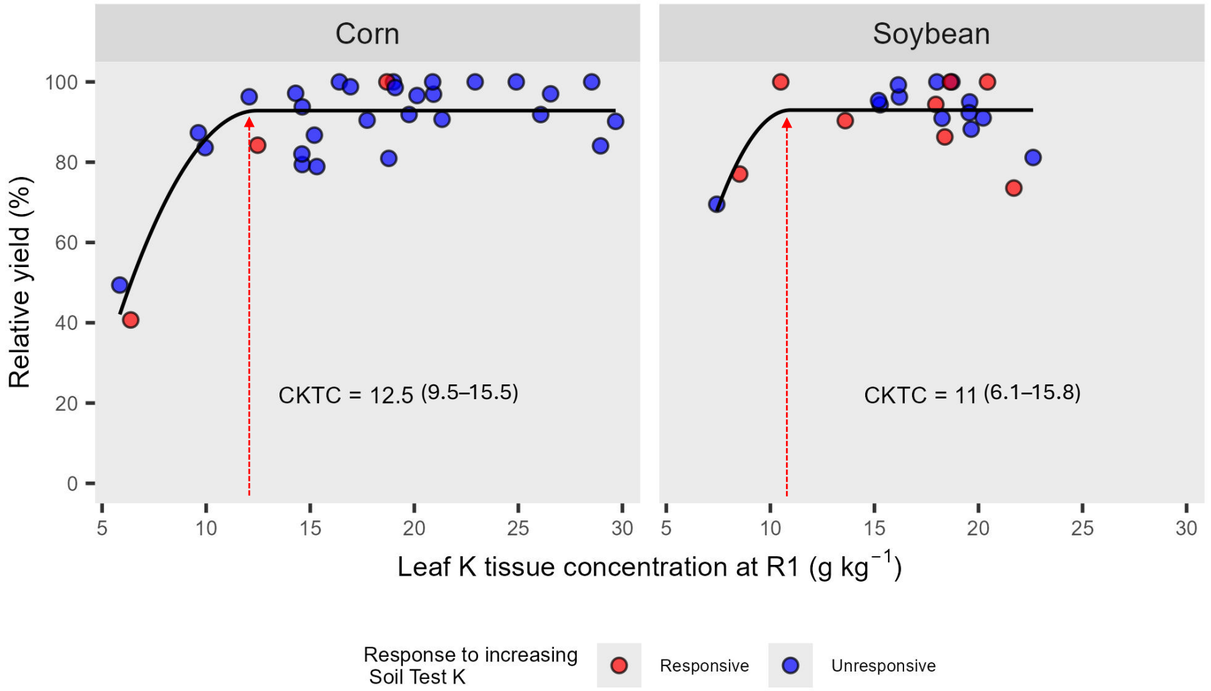
- K-bearing minerals in the clay fraction (e.g., feldspars and micas)
- K uptake from deeper layers

Critical phosphorus and potassium leaf tissue concentration

Crop RY and leaf P tissue concentration



Crop RY and leaf K tissue concentration



Sufficiency ranges:

- Corn 2.5–5.0 g kg^{-1}
- Soybean 3.0–6.0 g kg^{-1}

(Campbell, 2000)

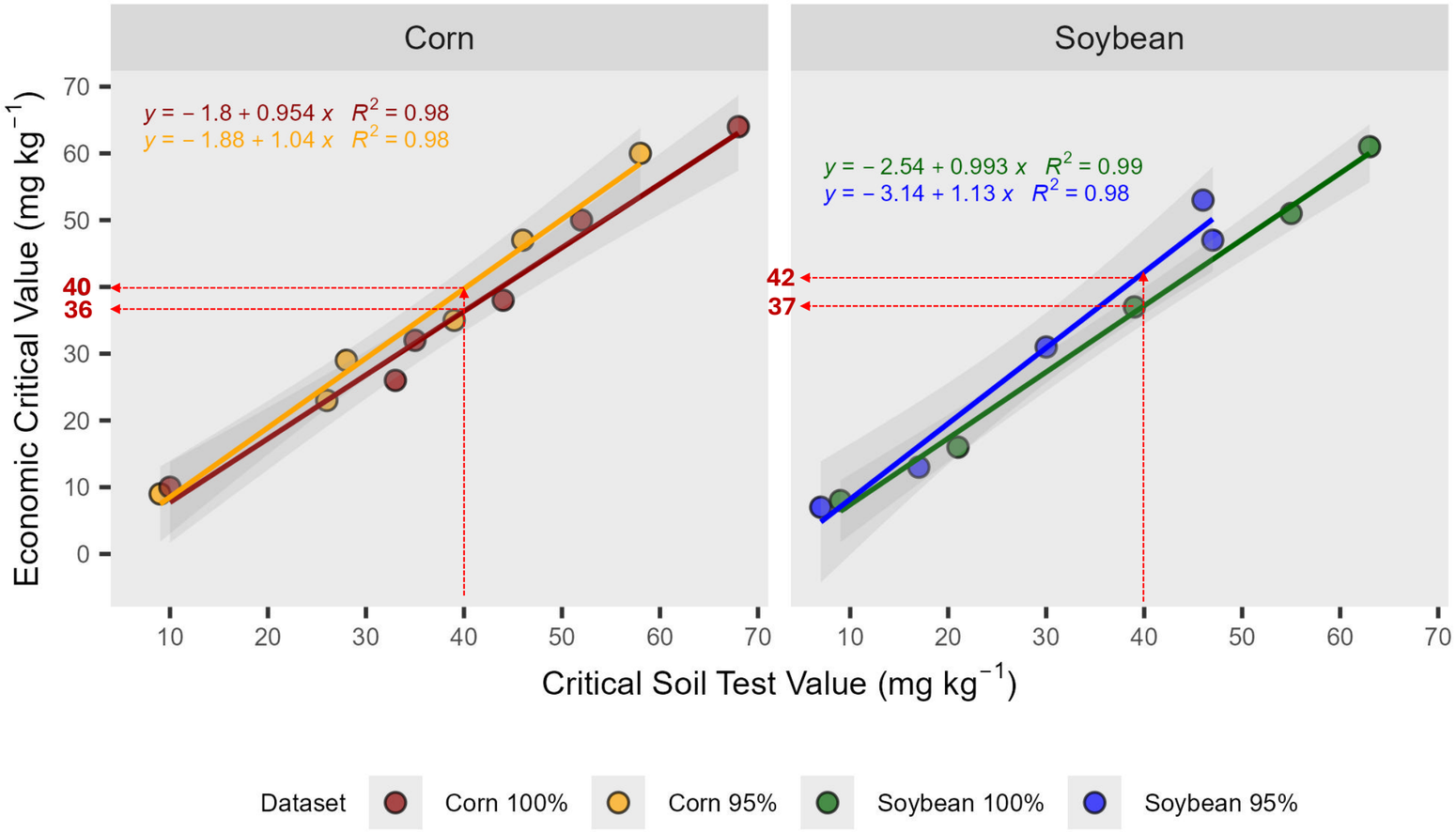
Sufficiency ranges:

- Corn 18.0–30.0 g kg^{-1}
- Soybean 15.0–25.0 g kg^{-1}

Correlation between the CSTVs and economic critical values of phosphorus for corn and soybean

The net return (US$ ha^{-1}) of each site-year was calculated as: $Net\ return = Gross\ receipts - Variable\ costs$

Net return was correlated with soil test P, and the economic critical value was estimated at 95% and at 100% of the plateau.



- The **economic critical values** closely **align** with the **CSTVs**, regardless of the sufficiency interpretation (95% or 100%).

- **At the same CSTV, the economic critical value was:**
  - similar for both crops
  - overall, lower at 100% than at 95%

Conclusions

Phosphorus and K CSTVs varied by location but not by crop. These results highlight the importance of region-specific CSTVs for optimizing P and K fertilization.

Correlation between leaf tissue concentration and RY can increase the reliability of the actual sufficiency range, reducing the bias of luxury nutrient accumulation by plants.

Maintaining soil test P levels near the critical thresholds is agronomically and economically efficient, as crop yields do not respond to additional P beyond those levels.

Future directions

Build a CSTV database for North Carolina to evaluate potential changes over time.

Integrate CSTV results into the Fertilizer Recommendation Support Tool (FRST) to enhance nutrient management decisions.

Refine recommendations by applying different CSTVs across North Carolina regions.

Develop CSTVs based on return on investment (ROI) to improve economic efficiency.