Characterization of Soybean Yield as Affected by Tissue Chloride Concentration and Cultivar Chloride Rating

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Grain yield of soybean cultivars begins to decline at leaf-Cl concentrations of **2365 mg Cl kg^{-1}** for Cl-includer cultivars and **986 mg Cl kg^{-1}** for Cl-excluder cultivars. Chloride-includer cultivars accumulate approximately **10 times greater** Cl concentrations than Cl-excluder cultivars, warranting the need for two separate critical concentrations to predict yield loss.

Introduction

Chloride (Cl) toxicity is recognized as a yield-limiting problem for irrigated soybean [*Glycine max* (L.) Merr.] produced in Arkansas and other soybean-producing states in the mid-South USA (Abel and MacKenzie, 1964; Parker et al., 1983). Poor soil drainage, Cl-containing irrigation water, and nutrient sources (e.g., muriate of potash fertilizer and poultry litter) contribute to salinity problems (Gilmour et al., 1983; Parker et al., 1983; White and Broadley, 2001). In most years and in many fields, potassium fertilization and irrigation water are inputs critical for the production of high soybean yields, yet the Cl added in these inputs can contribute to Cl toxicity. Chloride toxicity is known to limit soybean yield, but criteria for diagnosing Cl toxicity are not available. **Our objective was to define critical trifoliolate leaf-Cl concentrations at which yield loss begins for two soybean cultivar categories, Cl-includers and Cl-excluders.**

Materials and Methods

- **Experimental site in 2014**
  - Pine Tree Research Station (PTRS, Colt, AR)
    - Calloway silt loam (pH 7.1)
  - Rohwer Research Station (RRS, Rohwer, AR)
    - Desha/Sharkey clays (pH 7.3)
- **Seeded on 23 May 2014**
  - 370,650 – 383,005 seed ha^{-1}
- **Six soybean cultivars**
  - Armor 48-R66 (Cl includer)
  - Northrup King S45-V8 (Cl includer)
  - Pioneer 94Y82 (Cl includer)
  - Armor 49-R56 (Cl excluder)
  - Northrup King S46-L2 (Cl excluder)
  - Pioneer 49T80R (Cl excluder)

- **Plant sampling and analysis**
  - Seeded on raised beds (76 or 96 cm spacing) & furrow irrigated
  - Season-total Cl rates of 0, 280, 560, 840 kg Cl ha^{-1} made in five separate applications
  - Cl solution ($MgCl_2$ and $CaCl_2$) applied with a CO_2 backpack sprayer with spray directed underneath canopy
  - 12 mature trifoliolate leaves per plot collected at the R2, R3, R5, and R6 growth stages
  - Leaf Cl extracted with water and concentration determined by ICP-AES
- **Parameters measurement**
  - Grain yield
  - Trifoliolate leaf-Cl concentration
- **Statistical analysis (SAS V9.4)**
  - Randomized complete block design with a split-plot structure
    - Main plot: Cl rate
    - Subplot: Cl Rating
  - Relative yield regressed against leaf-Cl concentration at each growth stage using linear and quadratic models

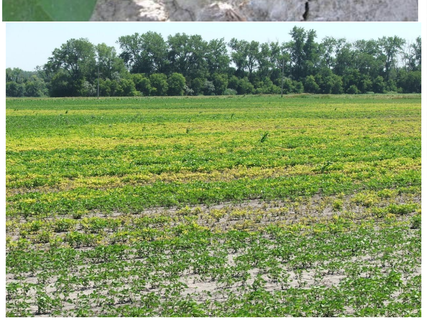

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Fig. 1. Actual yield, averaged across Cl rates and cultivar, as affected by cultivar Cl rating at Pine Tree in 2014.

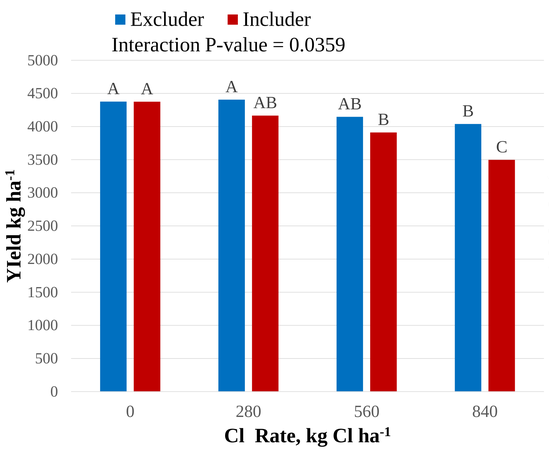


Fig. 2. Actual yield, averaged across Cl rates and cultivar, as affected by cultivar Cl ratings at Rohwer in 2014.

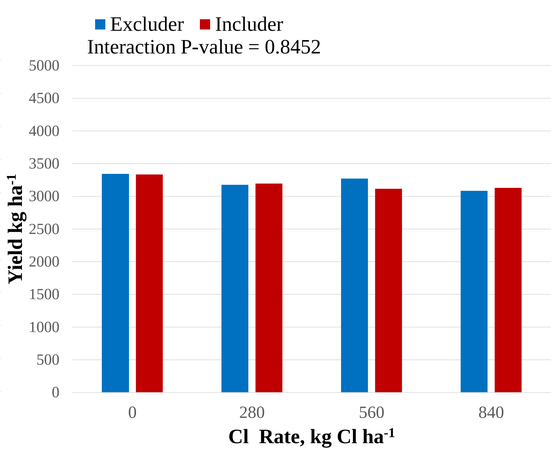


Fig. 3. Leaf-Cl concentration at R2 stage, averaged across Cl rates and cultivar, as affected by cultivar Cl rating at Pine Tree in 2014.

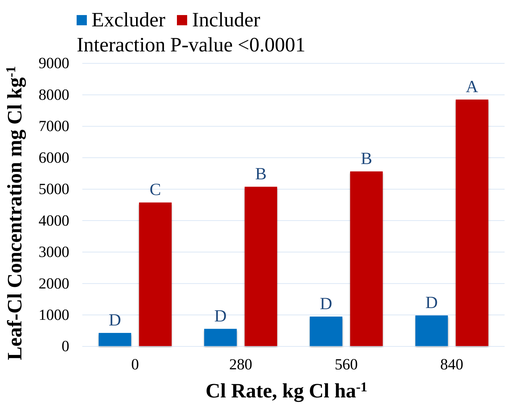


Fig. 4. Leaf-Cl concentration at R2 stage, averaged across Cl rates and cultivar, as affected by cultivar Cl rating at Rohwer in 2014.

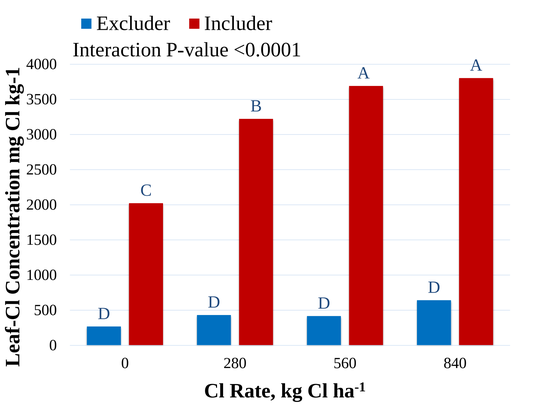
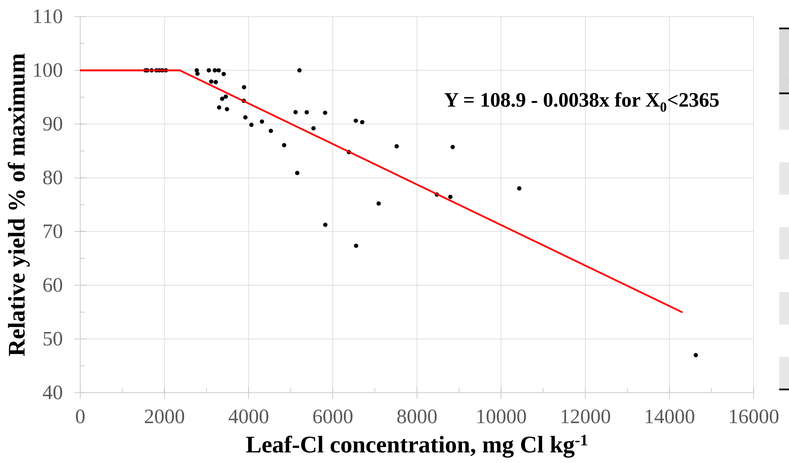
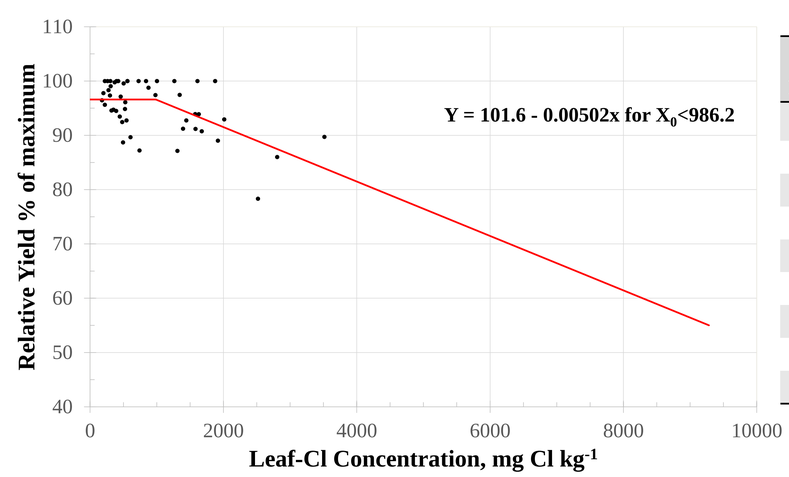


Fig. 5. Relative soybean yield regressed across leaf-Cl concentration at the R3 growth stage for Cl-includer soybean cultivars. The summary table located to the right depicts predicted yield loss at leaf-Cl concentrations in 5% yield loss increments. Relationship includes data from 2014 and 2015.



Relative Yield	Leaf Cl
%Yield Loss	mg kg^{-1}
5%	3,687
10%	5,013
15%	6,340
20%	7,666
25%	8,992
30%	10,318
35%	11,645
40%	12,971

Fig. 6. Relative soybean yield regressed across leaf-Cl concentration at the R3 growth stage for Cl-excluder soybean cultivars. The summary table located to the right depicts predicted yield loss at leaf-Cl concentrations in 5% yield loss increments. Note the leaf-Cl concentrations for yield loss >20% are beyond the scope of our data. Relationship includes data from 2014 and 2015.



Relative Yield	Leaf Cl
% Yield Loss	mg kg^{-1}
5%	1,949
10%	2,911
15%	3,874
20%	4,837
25%	5,799
30%	6,762
35%	7,725
40%	8,687

Results

Grain Yield

- Maximum yields for all cultivars were produced with 0 or 280 kg Cl ha^{-1}, regardless of Cl rating or location (Figs. 1-2).
- At the PTRS, grain yields of Cl-includer cultivars declined 930 kg ha^{-1} (20%) when 840 kg Cl ha^{-1} was applied. In comparison, the yield of Cl-excluder cultivars was reduced 337 kg ha^{-1} (8%) from application of 840 kg Cl ha^{-1} (Fig. 1).
- At the RRS, grain yield was not significantly influenced by Cl rate (*Pr* = 0.14), Cl rating (0.50) or their interaction (0.85).

Tissue Cl Concentration

- Leaf-Cl concentration was similar among cultivars with the same Cl rating. Leaf-Cl concentration increased numerically with increasing Cl rate, and the highest Cl concentrations were produced by soybean receiving 560 and 840 kg Cl ha^{-1}, regardless of Cl rating (Figs. 3-4).
- Cultivars rated as Cl includers contained 7 to 11 times greater leaf-Cl concentrations than Cl-excluder cultivars when grown in the same environment suggesting screening can be performed by collecting leaf tissue from field trials.
- Leaf-Cl concentration explained 60, 62, 61 and 47% of variation in soybean relative yield at the R2, R3, R5, and R6 growth stages, respectively (not shown).

Relative Yield and Leaf-Cl Concentration

- Two critical leaf-Cl concentrations, one each for Cl-includer and -excluder cultivars, are needed to diagnose Cl toxicity. In our field trials leaf scorch symptoms did not appear until the late R5 stage.
- At the R3 stage, the linear plateau model suggested soybean yield begins to decline when leaf-Cl concentrations exceed 2365 mg kg^{-1} in Cl-includer cultivars and 986 mg kg^{-1} in Cl-excluder cultivars (Figs. 5-6).
- A substantial increase in leaf-Cl concentration occurred once seed fill was completed (not shown) and corresponded to the eventual appearance of Cl toxicity symptoms in the upper leaves, most prominently in the Cl-includer cultivars.

Practical Application

- ✓ Knowledge of how soybean cultivars accumulate Cl in tissue and the magnitude of yield loss from too much Cl can aid researchers in developing management strategies to minimize the negative effects of Cl toxicity.
- ✓ Choosing a Cl-excluder soybean cultivar can help minimize yield loss attributed to Cl toxicity in at risk fields.
- ✓ Knowledge of irrigation water quality and in-season analysis of tissue for Cl concentration can be useful for proper cultivar selection and monitoring the potential for yield loss from Cl toxicity.
- ✓ Critical leaf-Cl concentrations will aid in our understanding of how widespread and large yield losses from Cl toxicity are in Arkansas and aid in developing best practices to manage Cl-toxicity.

Acknowledgments

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