Insights into Entangled Variations in the Red Edge Position and Red to Far-Red Ratios of Soybean Leaves

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Outline

- Introduction
- Materials and Methods
- Results
- Discussion
- Concluding Remarks

Introduction

➢ Context

- Soybean crops have a strategic importance for food production

- Besides their high protein content, these C3 legumes can fix atmospheric nitrogen for their own growth, which minimizes the use of inorganic fertlizers

- A diverse array of monitoring and management procedures have been proposed to increase the crops' yield while mitigating environmental risks related to:
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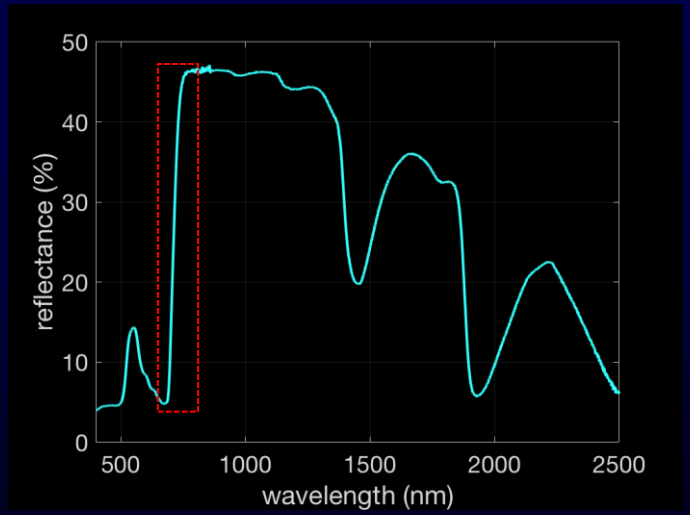
- These procedures are often associated with the use of spectral features relating the plants' foliar radiometric parameters to their nutrient (*e.g.*, nitrogen) status

- Among the most employed spectral features in this area is the red edge: the foliar reflectance increase in the 680 to 800 *nm* region of the light spectrum



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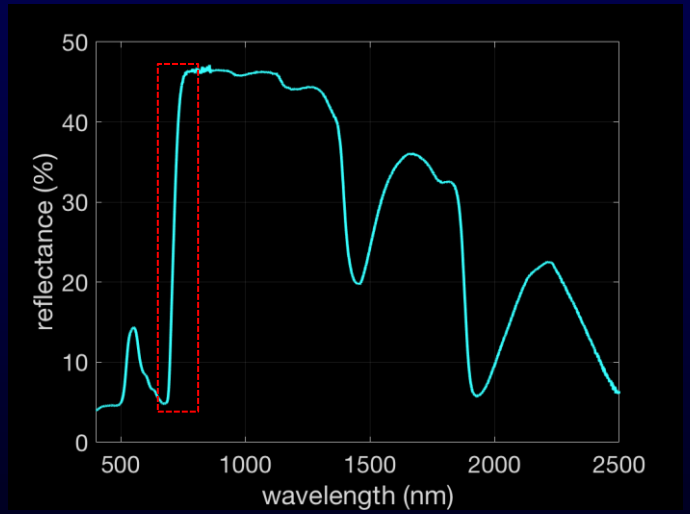
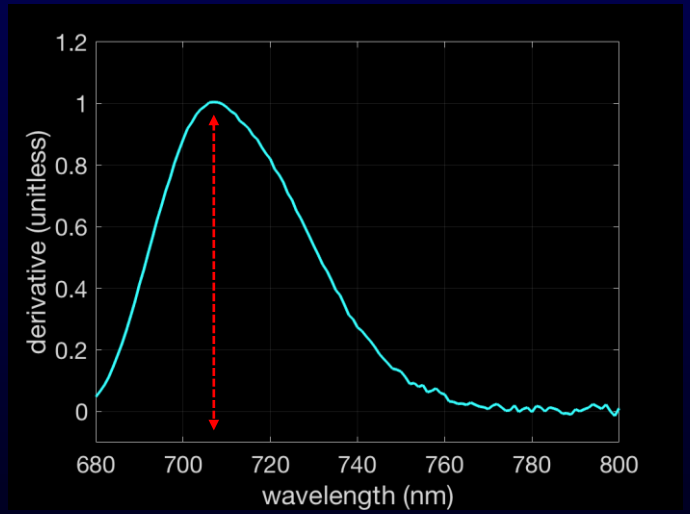


- This feature is directly associated with the combined effects of light absorption by pigments (*e.g.*, chlorophyll) and scattering by internal foliar structures (*e.g.*, cells)

- The red edge position (REP), in turn, corresponds to the wavelength associated with the maximun slope of the red edge, *i.e.*, the peak value of its first derivative



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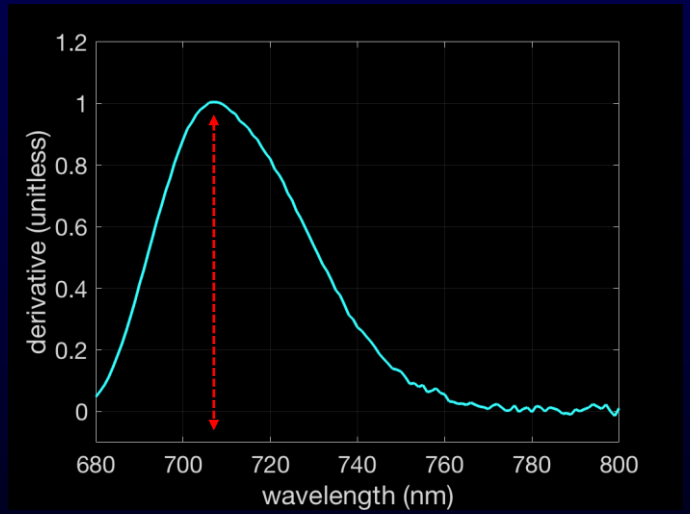

- The use of this spectral index facilitates comparisons of reflectance data obtained under different measurement conditions and for distinct species

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- Accordingly, the REP can be employed, for instance, in the evaluation of crop nutrient status, which can prompt in-season adjustments to fertilizer applications

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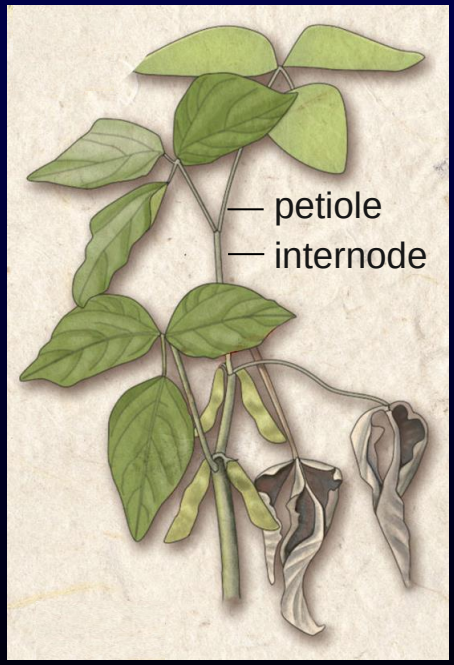

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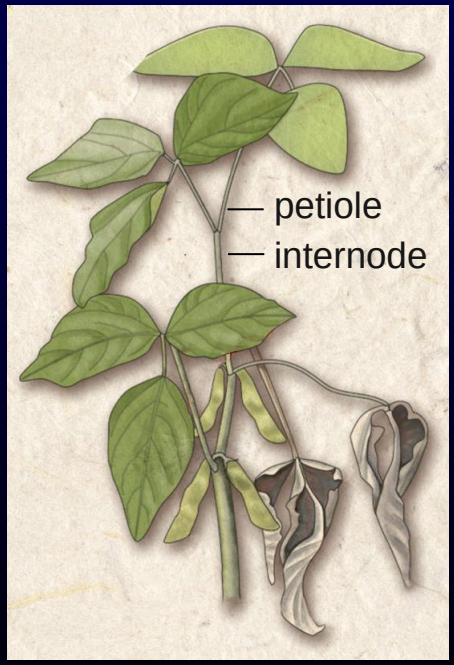
- Since leaves that develop under shade tend to present a reduced photosynthetic capacity, this trait of soybeans also contributes to their photosynthetic efficiency



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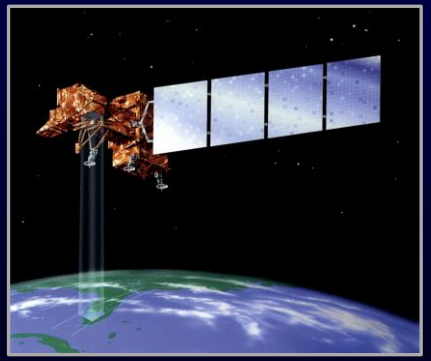
- If such a connection exists, it can have relevant implications for the monitoring (*in situ* & remote) as well as the management of soybean crops



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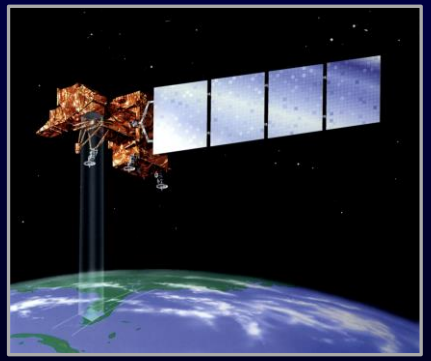


- In this work, we assess this possibility through the analysis of the REP values and R/FR ratios of soybean leaves with different biochemical characteristics

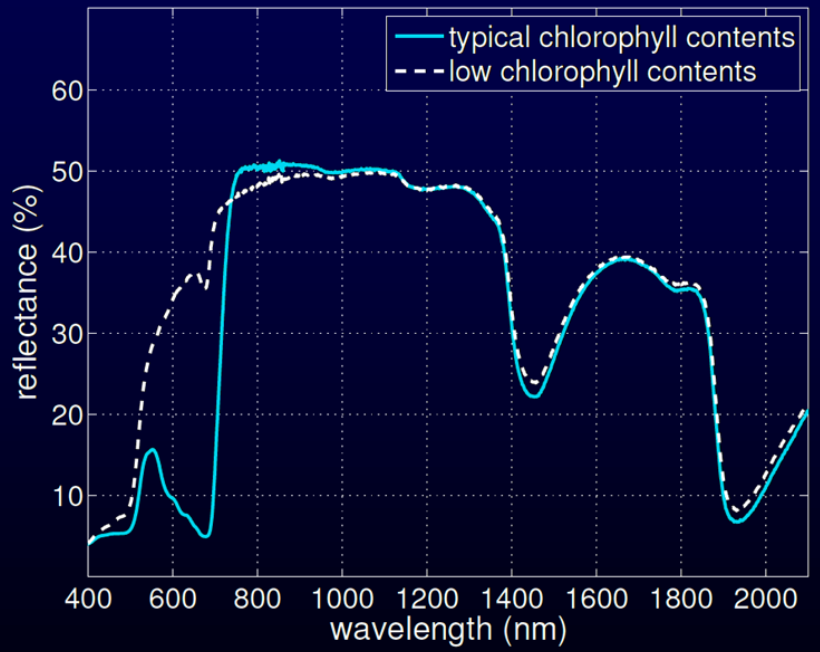
Materials and Methods

➢ Materials

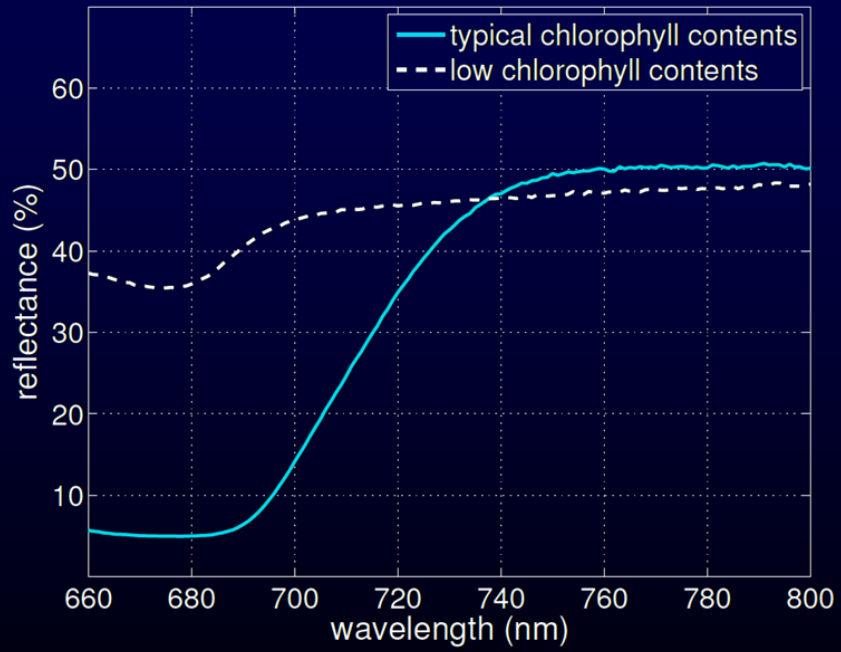
- We used measured reflectance and transmitance datasets provided by the multidisciplinary *LOPEX* (Leaf Optical Properties Experiment, 1996) project
  - Radiometric curves from 400 to 2500 *nm*, with a resolution of 1 *nm*
  - Each curve was obtained considering an angle of incidence of 8º
  - Two batches of specimens with markedly distinct chlorophyll (Ch) contents
    - ❖ Batch 1: Typical Cha and Chb contents (2.9 and 0.8 *mg/g*, respectively)
    - ❖ Batch 2: Low Cha and Chb contents (0.09 and 0.05 *mg/g*, respectively)

- Reflectance data for representative specimens of Batch 1 and Batch 2

Vis-IR Range

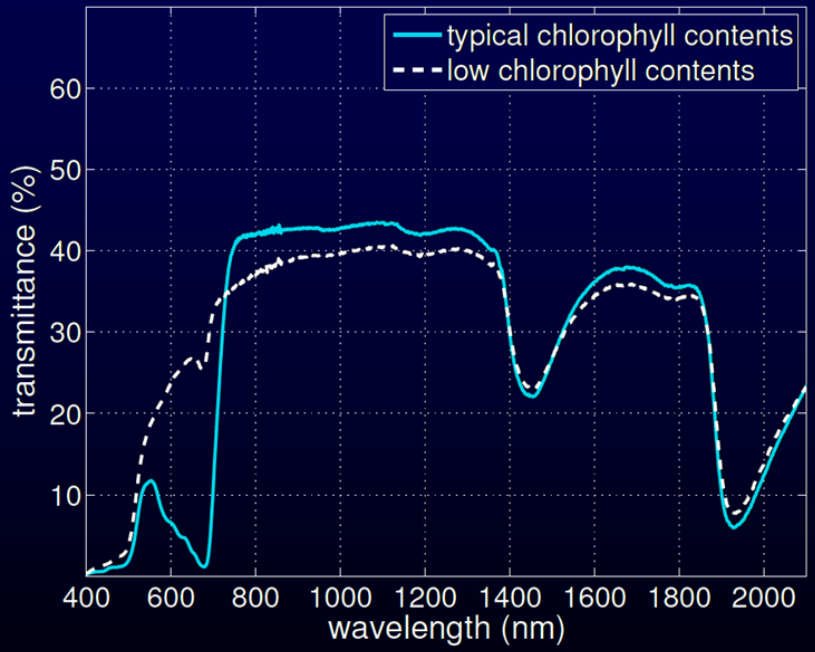


Zoom-in



- Transmittance data for representative specimens of Batch 1 and Batch 2

Vis-IR Range



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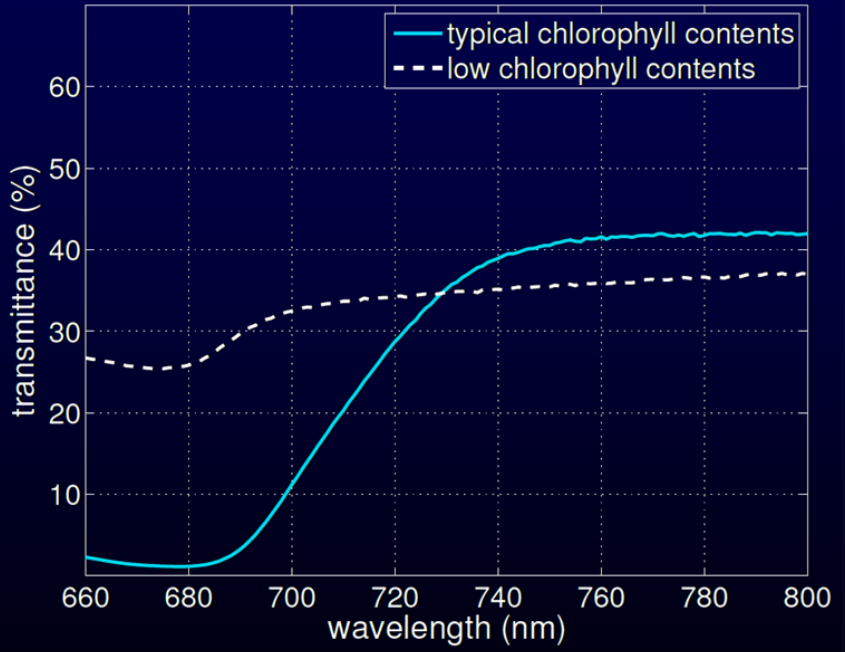
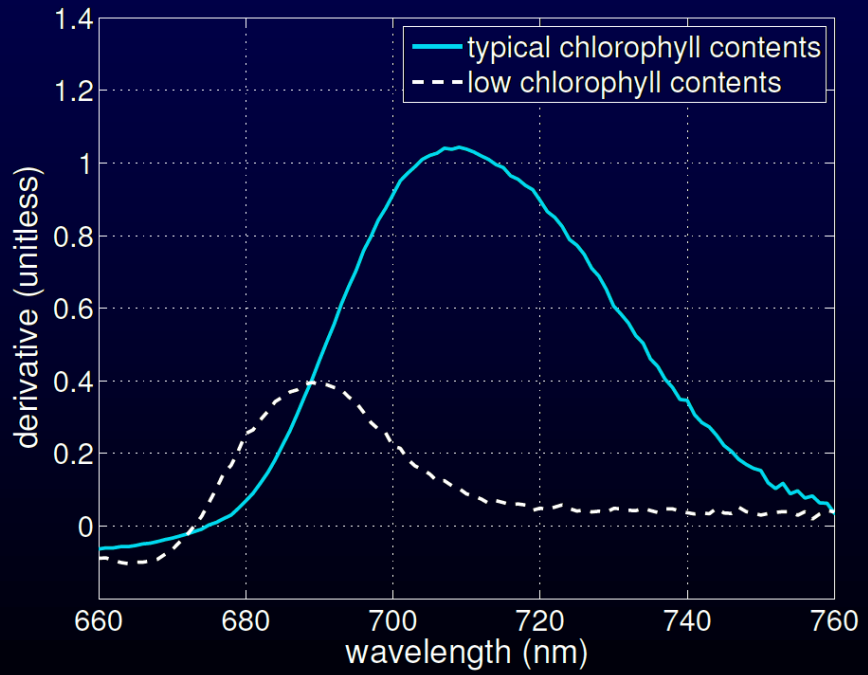


➢ Methods

- To obtain the REP, we compute the first derivative of the specimens' reflectance curves using a three point numerical differentiation formula:

$$\rho'(\lambda) = (\rho(\lambda+10) - \rho(\lambda\text{-}10)) \times 0.05,$$

where $\rho(\lambda)$ denotes the reflectance at a given wavelength (λ)



- To quantify the red to far-red ratios of reflected the light, we use as sampling references the wavelengths that correspond to the chlorophyll absorption peaks

  - under *in vitro* conditions (660 and 730 *nm*): $R/FR_{\rho} = \rho(660)/\rho(730)$

  - under *in vivo* conditions (645 and 735 *nm*): $R/FR_{\rho}^{*} = \rho(645)/\rho(735)$

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  - under *in vivo* conditions (645 and 735 *nm*): $R/FR_{\rho}^{*} = \rho(645)/\rho(735)$
- To quantify the red to far-red ratios of transmitted light, R/FR_{τ} and R/FR_{τ}^{*}, we replaced the reflectance values by transmittance (τ) values

Results

- Batch 1 (typical chlorophyll contents): calculations for reflected light

Batch 1			
Leaf Specimen	REP	R/FR_ρ	R/FR_ρ^*
B1a	710	0.1122	0.1210
B1b	707	0.1282	0.1399
B1c	707	0.1285	0.1430
B1d	709	0.1332	0.1499
B1e	709	0.1364	0.1479
Average	708.4	0.1277	0.1393

➢ Batch 2 (low chlorophyll contents): calculations for reflected light

Batch 2			
Leaf Specimen	REP	R/FR_ρ	R/FR_ρ^*
B2a	690	0.7740	0.7759
B2b	686	0.7860	0.7301
B2c	685	0.7808	0.6987
B2d	689	0.8089	0.8062
B2e	688	0.6619	0.5604
Average	687.6	0.7623	0.7142

- Lower REP values and higher R/FR_ρ and R/FR_ρ^* ratios

- Batch 1 (typical chlorophyll contents): calculations for transmitted light

Batch 1		
Leaf Specimen	R/FR_τ	R/FR^*_τ
B1a	0.0836	0.1298
B1b	0.1044	0.1544
B1c	0.0782	0.1167
B1d	0.0651	0.0966
B1e	0.0749	0.1140
Average	0.0812	0.1223

➢ Batch 2 (low chlorophyll contents): calculations for transmitted light

Batch 2		
Leaf Specimen	R/FR_τ	R/FR_τ^*
B2a	0.7814	0.7741
B2b	0.7882	0.7676
B2c	0.7861	0.7265
B2d	0.7690	0.7640
B2e	0.7450	0.6796
Average	0.7739	0.7423

- Higher R/FR_τ and R/FR_τ^* ratios

Discussion

➢ Implications for shade-avoidance and chlorophyll monitoring

- Low R/FR ratios may act as shade-avoidance signals for soybean leaves

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- Low R/FR ratios may act as shade-avoidance signals for soybean leaves
- Consequently, a substantial reduction of their cholorophyll contents followed by an increase in their R/FR ratios can diminish their shade-avoidance responses
- This aspect, in turn, can be detrimental to the plant's photosynthetic capacity and significantly reduce the yield of soybean crops

- The REP is routinely employed as an indicator of a number of factors, notably chlorophyll contents, affecting crop productivity

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- Its putative (inverse) connection with the R/FR ratios, upon confirmation, may extend its scope of applications to the monitoring of shade avoidance capabilities

- Conversely, noticeable variations in the R/FR ratios of reflected light could potentially assist the detection of significant reductions in chlorophyll contents

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- We note that the calculation of R/FR ratios requires fewer samples (2) than those (3 or 4) usually used in REP estimations

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- For many species, the breaking of seed dormancy tends to be inhibited by low R/FR ratios and stimulated by relatively high R/FR ratios

- Again, upon confirmation of the REP and R/FR ratios (inverse) connection, REP values could be used as supporting data for weed management strategies

➢ Implications for intercropping cultivation systems

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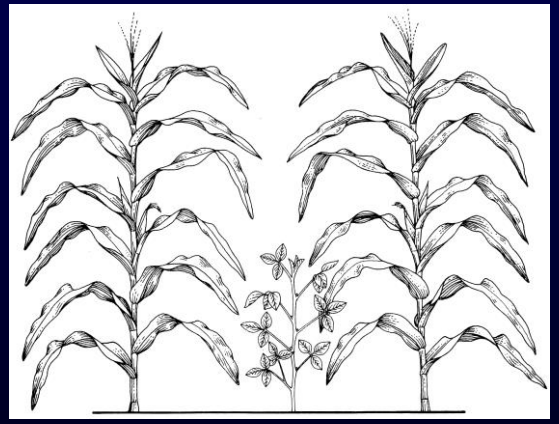
- However, intercropped species may affect each other's light exposure conditions in adverse ways



  - R/FR ratios of light propagated by corn leaves increase as their chlorophyll contents decrease

  - Thus, light propagated by chlorophyll-depleted corn leaves may exacerbate the reduction of shade avoidance responses of neighbour soybean plants

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- It would strengthen the foundation required for the design of more cost-effective procedures to evaluate these crops' aggregated and individual health status

Concluding Remarks

➢ What's next?

- Our findings suggesting an inverse connection between the REP values & R/FR ratios of soybean leaves with markedly distinct Chl contents need confirmation

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- Given the potential implications of this putative entanglement, future laboratory and field experiments are warranted to evaluate its photobiological basis

- In view of the ever-increasing demand for high-yield and environmentally-friendly crops, such experiments could also be extended to other cultivated plant species

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Thank you!

Questions?