Foliar Spectral Responses of Sugarcane and Maize: How Comparable are They?

Gladimir V. G. Baranoski

Natural Phenomena Simulation Group

University of Waterloo, Canada

SPIE Remote Sensing

Amsterdam, Netherlands, September 3-6, 2023

Outline

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

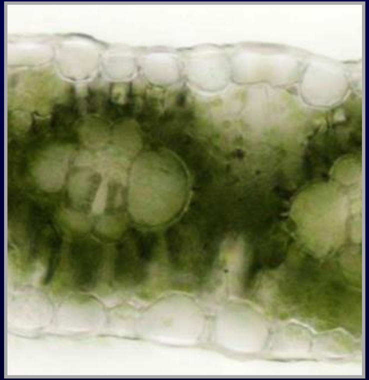
Introduction

➢ Context

- Sugarcane and maize crops are extensively used in the production of food and biofuel worldwide

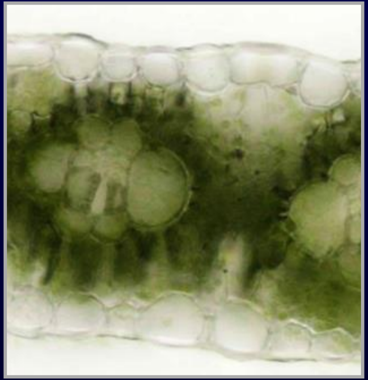
- These plants share important physiological and morphological traits:
  - C4 photosynthesis pathway
  - adaptation mechanisms to abiotic stress factors
  - unifacial leaves characterized by Kranz anatomy

Leaf Cross-Section



- These plants share important physiological and morphological traits:
  - C4 photosynthesis pathway
  - adaptation mechanisms to abiotic stress factors
  - unifacial leaves characterized by Kranz anatomy

Leaf Cross-Section



- Given these aspects and their economical importance, one would expect that there is no shortage of foliar spectral data for sugarcane and maize

- However, this is not the case, with spectral data scarcity being markedly more serious for sugarcane

- However, this is not the case, with spectral data scarcity being markedly more serious for sugarcane

- Accordingly, considering their physiological and morphological similarities, investigations involving the spectral responses of C4 plants are usually conducted using spectral data obtained for maize specimens

- However, this is not the case, with spectral data scarcity being markedly more serious for sugarcane

- Accordingly, considering their physiological and morphological similarities, investigations involving the spectral responses of C4 plants are usually conducted using spectral data obtained for maize specimens

➢ Question: Are the spectral responses of sugarcane and maize leaves similar enough to support such an approach?

- We aim to contribute to the elucidation of this question

- We aim to contribute to the elucidation of this question

- To assess possible discrepancy trends, we use measured reflectance datasets obtained for maize and sugarcane specimens to compute key spectral features:

  - Red edge position (REP)

  - Red to far-red ratio (R/FR)

- We aim to contribute to the elucidation of this question

- To assess possible discrepancy trends, we use measured reflectance datasets obtained for maize and sugarcane specimens to compute key spectral features:

  - Red edge position (*REP*)

  - Red to far-red ratio (*R/FR*)

- We also discuss data availability and quality issues in this area

Data and Methods

Materials

- For sugarcane, we used reflectance datasets provided by Johnson *et al.* (2008)
  - Two representative sugarcane varieties: noble cane and wild cane
  - Three sugarcane cultivars: L97-128, TUCCP77-042 and LPLP85-384
  - Reflectance curves from 350 to 850 *nm,* with a resolution of 5 *nm*
  - Each curve depicts the average of eight measurements obtained considering a normal (perpendicular) light incidence geometry

- For maize, we used reflectance datasets provided by the *LOPEX* project (1996)
  - Four groups of leaf specimens (batches 1 to 4)
  - Each group containing specific spectral files for five maize specimens
  - Reflectance curves from 400 to 2500 *nm*, with a resolution of 1 *nm*
  - Each curve was obtained considering an angle of incidence of 8º

- For maize, we used reflectance datasets provided by the *LOPEX* project (1996)
  - Four groups of leaf specimens (batches 1 to 4)
  - Each group containing specific spectral files for five maize specimens
  - Reflectance curves from 400 to 2500 *nm*, with a resolution of 1 *nm*
  - Each curve was obtained considering an angle of incidence of 8º
- Note that small deviations from normal light incidence (*e.g.*, less than 10º) have a negligible impact on the reflectance of maize leaves (Walter-Shea *et al*., 1989)

- Methods

  - Computation of selected spectral features using reflectance (ρ) values sampled at specific wavelengths (λ)

    - Red edge position (*REP*), *i.e.*, the peak value of the reflectance curve' first derivative in the region between 680 to 800 *nm*, which is obtained using:

      $\rho'(\lambda) = (\rho(\lambda+10) - \rho(\lambda-10)) \times 0.05$

- Methods

  - Computation of selected spectral features using reflectance (ρ) values sampled at specific wavelengths (λ)

    - Red edge position (*REP*), *i.e.*, the peak value of the reflectance curve's first derivative in the region between 680 to 800 *nm*, which is obtained using:

      $$\rho'(\lambda) = (\rho(\lambda+10) - \rho(\lambda-10)) \times 0.05$$

    - Red to far-red ratio (*R/FR*) calculated considering the wavelengths (660 and 730 *nm*) of the absorption peaks of chlorophyll under *in vitro* conditions

      $$R/FR = \rho(660) / \rho(730)$$

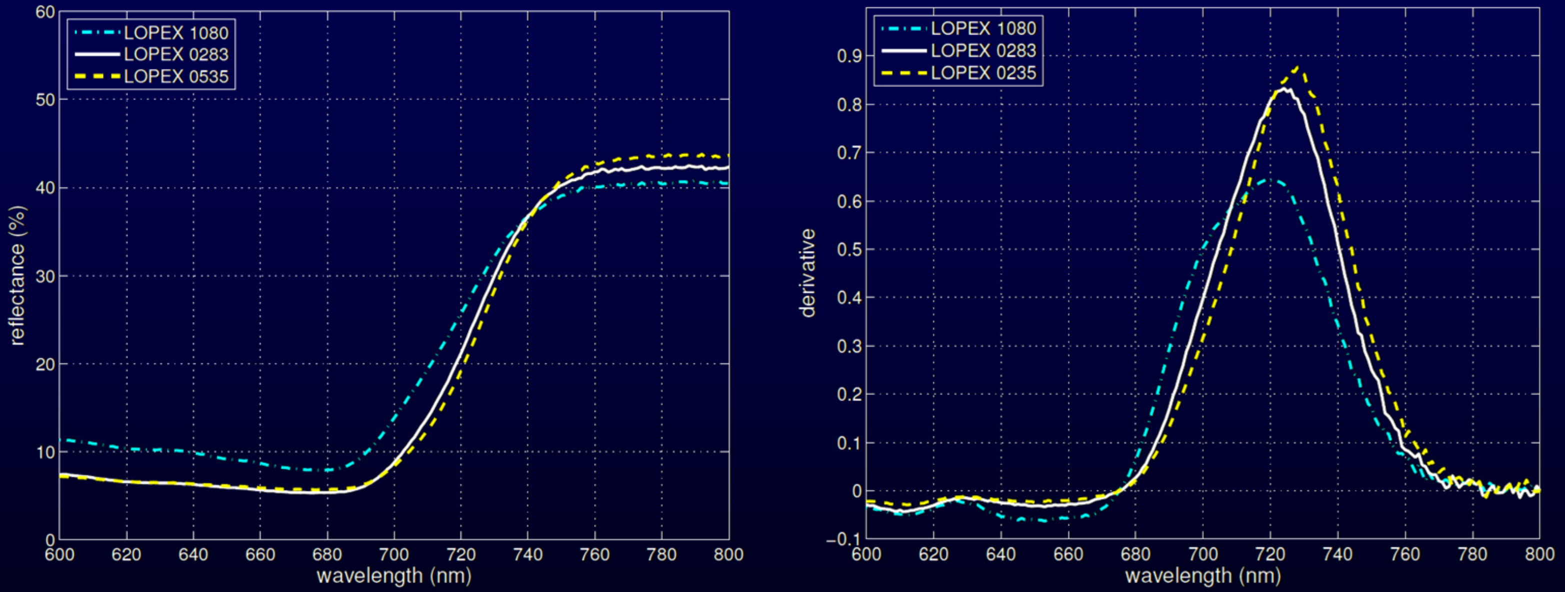
Results

- Maize specimens

Batch 1			Batch 2		
File	REP	R/FR	File	REP	R/FR
0141	727	0.220	1076	727	0.251
0143	727	0.221	1078	726	0.271
0145	726	0.189	1080	720	0.268
0147	723	0.183	1083	727	0.215
0149	722	0.202	1084	722	0.267
Average	725	0.203	Average	724.4	0.255

Batch 3			Batch 4		
File	REP	R/FR	File	REP	R/FR
0.277	723	0.185	0535	729	0.207
0279	727	0.196	0537	729	0.211
0281	728	0.186	0539	727	0.202
0283	725	0.187	0541	729	0.203
0285	724	0.184	0543	726	0.184
Average	725.4	0.188	Average	728	0.201

Representative Plots of Red Edge (left) and Red Edge Position (right)

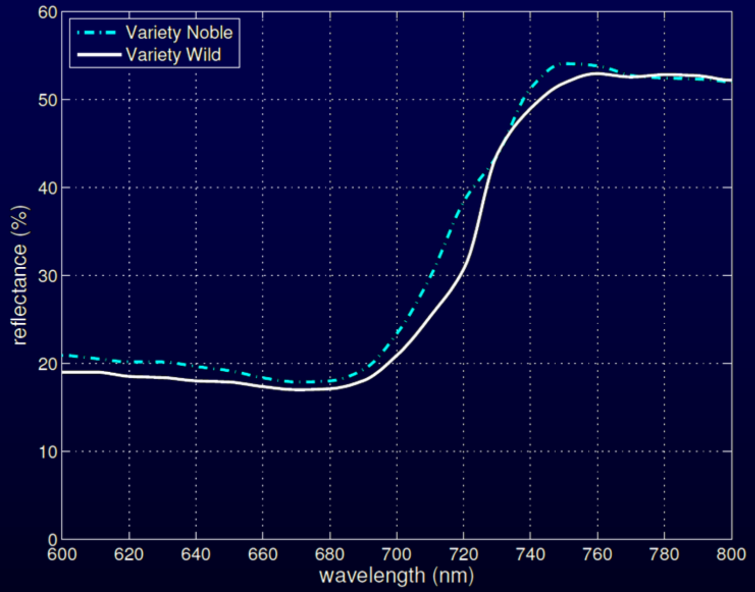


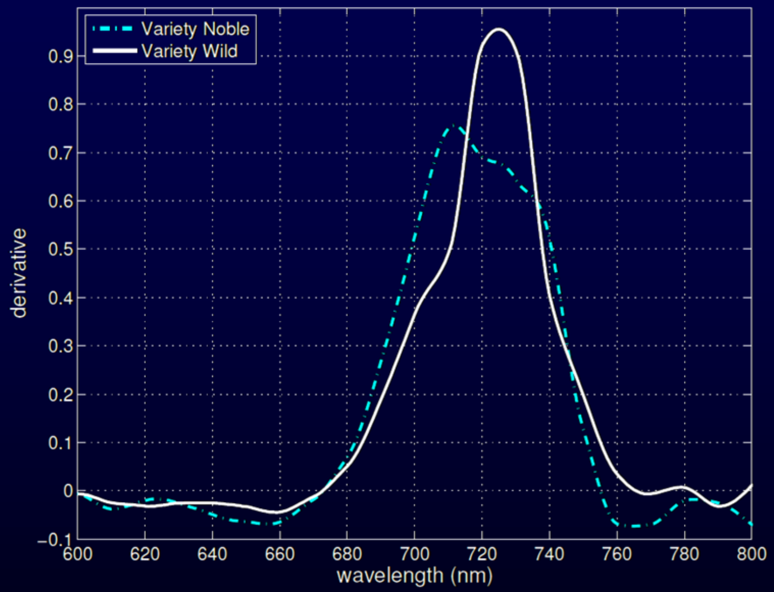
- Sugarcane specimens

Variety	REP	R/FR
Noble	712	0.421
Wild	725	0.397

  - Wider range of REP values
  - Higher R/FR values

Representative Plots of Red Edge (left) and Red Edge Position (right)

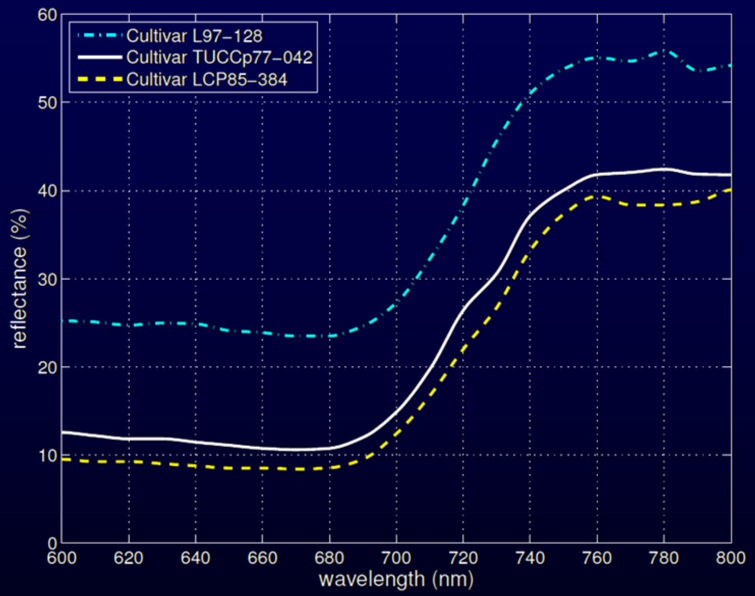


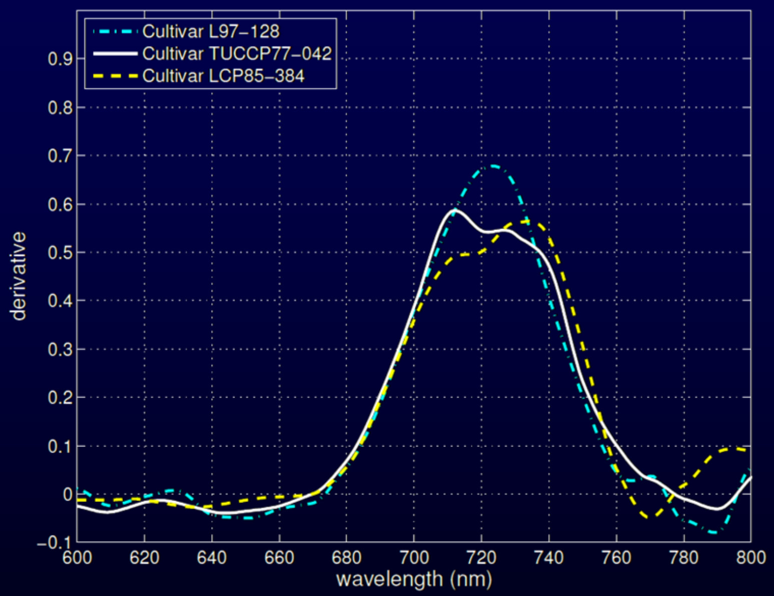


Cultivar	REP	R/FR
L97-128	724	0.522
TUCCP77-042	712	0.350
LPCP85-384	734	0.317

- Wider range of REP values
- Higher R/FR values

Representative Plots of Red Edge (left) and Red Edge Position (right)





Discussion

- General observations

  - Clearly, the relatively small number of examined specimens does not allow one to draw definitive conclusions

General observations

- Clearly, the relatively small number of examined specimens does not allow one to draw definitive conclusions

- Nonetheless, some aspects could be verified:
  - Data scarcity is a serious issue in this area

➢ General observations

- Clearly, the relatively small number of examined specimens does not allow one to draw definitive conclusions

- Nonetheless, some aspects could be verified:
  - Data scarcity is a serious issue in this area
  - Despite the physiological and morphological similarities of sugarcane and maize leaves, their reflective behaviours may present pivotal differences
    - ❖ distinct ranges for the *REP* values
    - ❖ distinct bounds for the *R/FR* ratios

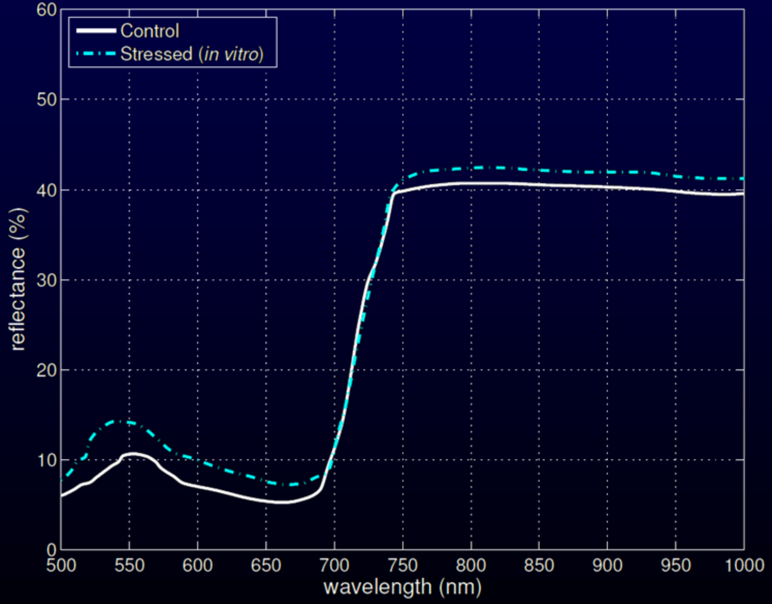
- Data scarcity: case study of moderate water stress

  - Most of the current knowledge about the spectral responses of sugarcane and maize to water stress conditions have been derived from *in vitro* experiments

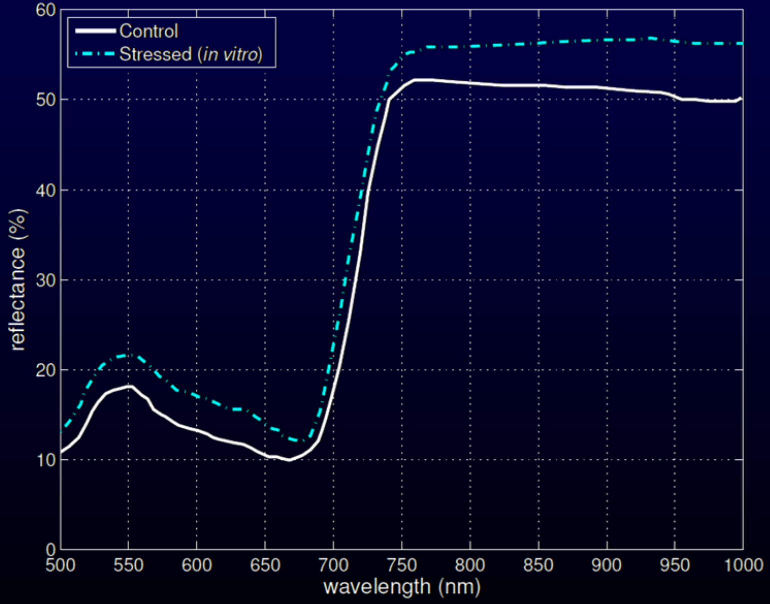
➢ Data scarcity: case study of moderate water stress

- Most of the current knowledge about the spectral responses of sugarcane and maize to water stress conditions have been derived from *in vitro* experiments

Maize (Source: Thomas *et al.*, 1971)



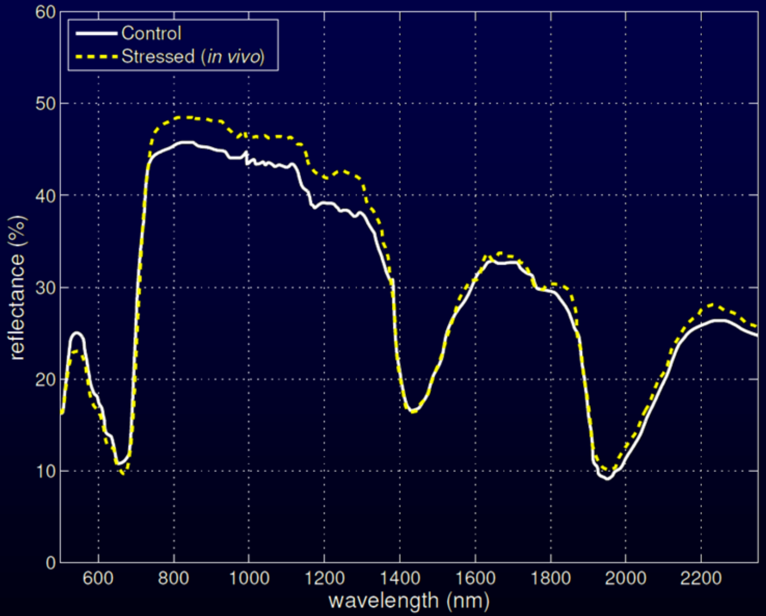
Sugarcane (Source: Maeda *et al.*, 2005)



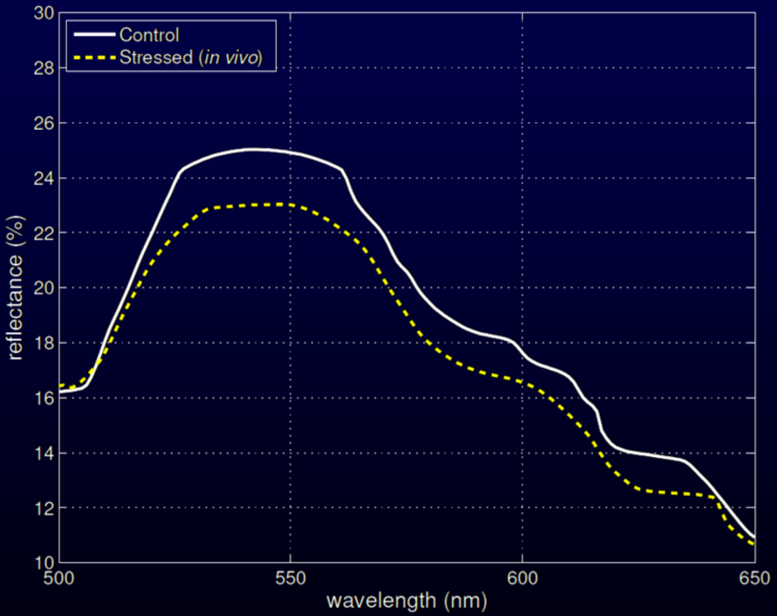
- By contrast, little is known of the spectral responses of maize and sugarcane leaves under *in vivo* water stress

- By contrast, little is known of the spectral responses of maize and sugarcane leaves under *in vivo* water stress

Maize (Source: Maracci *et al.*, 1991)



Range: 400 to 2300 *nm*



Zoom-in

- The *in vivo* water stress scenario underscores the boundaries of the existing knowledge about key processes affecting C4 crops like maize and sugarcane

- The *in vivo* water stress scenario underscores the boundaries of the existing knowledge about key processes affecting C4 crops like maize and sugarcane

- Data scarcity also affects studies connecting variations in R/FR ratios to weed competion, for which the R/FR ratios of transmitted light are also relevant

- The *in vivo* water stress scenario underscores the boundaries of the existing knowledge about key processes affecting C4 crops like maize and sugarcane

- Data scarcity also affects studies connecting variations in R/FR ratios to weed competion, for which the R/FR ratios of transmitted light are also relevant

- We note that transmittance data for sugarcane leaves is not readily available in the current literature

Concluding Remarks

Challenges and Perspectives

- Data scarcity poses a significant challenge for the advance of the current knowledge about the spectral responses of maize and sugarcane

➢ Challenges and Perspectives

- Data scarcity poses a significant challenge for the advance of the current knowledge about the spectral responses of maize and sugarcane

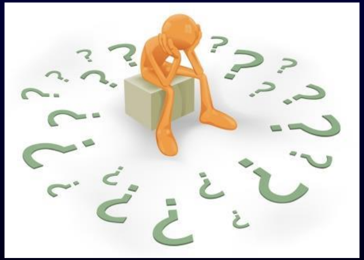
- Besides increasing spectral data availability, notably for sugarcane, efforts should also be focused on obtaining good quality spectral data

➢ Challenges and Perspectives

- Data scarcity poses a significant challenge for the advance of the current knowledge about the spectral responses of maize and sugarcane

- Besides increasing spectral data availability, notably for sugarcane, efforts should also be focused on obtaining good quality spectral data

- In the meantime, may one consider using data obtained for unifacial maize leaves as references for qualitative studies involving unifacial sugarcane leaves?



- Our preliminary findings indicate that there may be subtle, albeit significant differences between the spectral responses of these C4 species

- Our preliminary findings indicate that there may be subtle, albeit significant differences between the spectral responses of these C4 species

- These differences may preclude the use of inferences from spectral data of one species to guide studies demanding a high degree of specificity for the other

- Our preliminary findings indicate that there may be subtle, albeit significant differences between the spectral responses of these C4 species

- These differences may preclude the use of inferences from spectral data of one species to guide studies demanding a high degree of specificity for the other

- Example of such studies include those aiming at increasing crop yield while avoiding the excessive use of fertilizers and water

(Source: CSIRO, Australia, 2007)

- Good news: this situation may offer new opportunities for comprehensive measurement initiatives that can benefit a wide range of crop species

Thank you!

Questions?