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BG2.7
REMOTE SENSING APPLICATIONS IN THE BIOGEOSCIENCES

GAMA-DT

Potassium estimation of cotton leaves based on hyperspectral reflectance

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PPGEA PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA AGRÍCOLA

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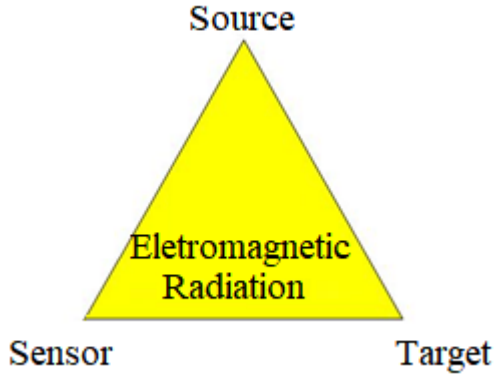
Wednesday, 6 May 2020

1. INTRODUCTION

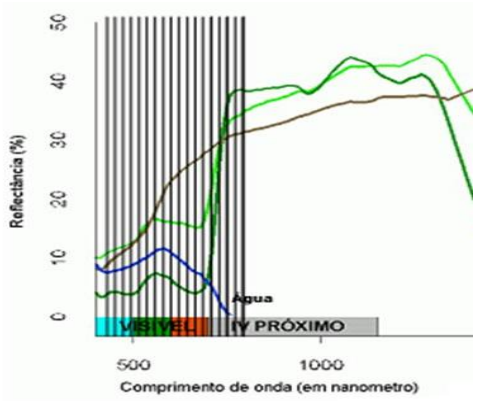
❖*Remote Sensing*



➢Hyperspectral Data

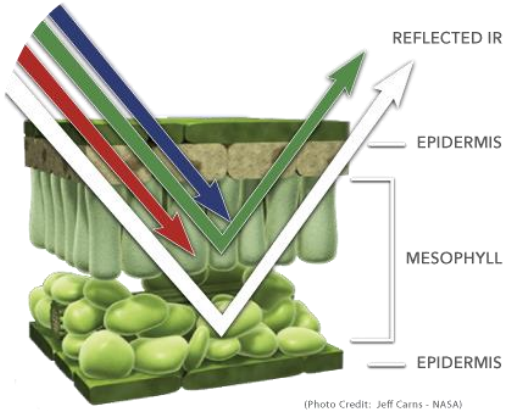
✓Leaf Biochemical Attributes;

✓ Reflectance Spectrometry;



✓*"[...] measures the **electromagnetic energy reflected** from the surface of objects at **different wavelengths**."* *(MENESES, 2001)*

*"[...] detection of changes in **biophysical attributes** and **metabolic factors** in plant tissues. "*(CHEN *et al.*, 2010)



❖ *Herbaceous Cotton*

revistarural.com.br

✓*Gossypium hirsutum L.*

✓*Malvaceae;*

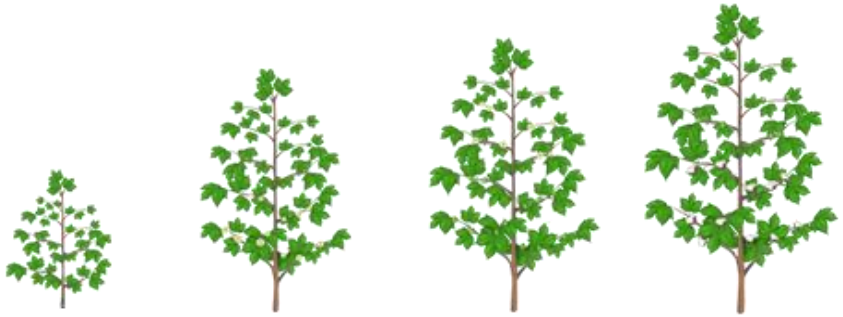
World's top producers	*Export*
India	USA
China	India
USA	***Brazil***
Brazil *(7.44%)*	

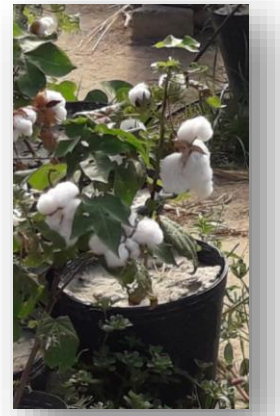
(USDA, 2018)

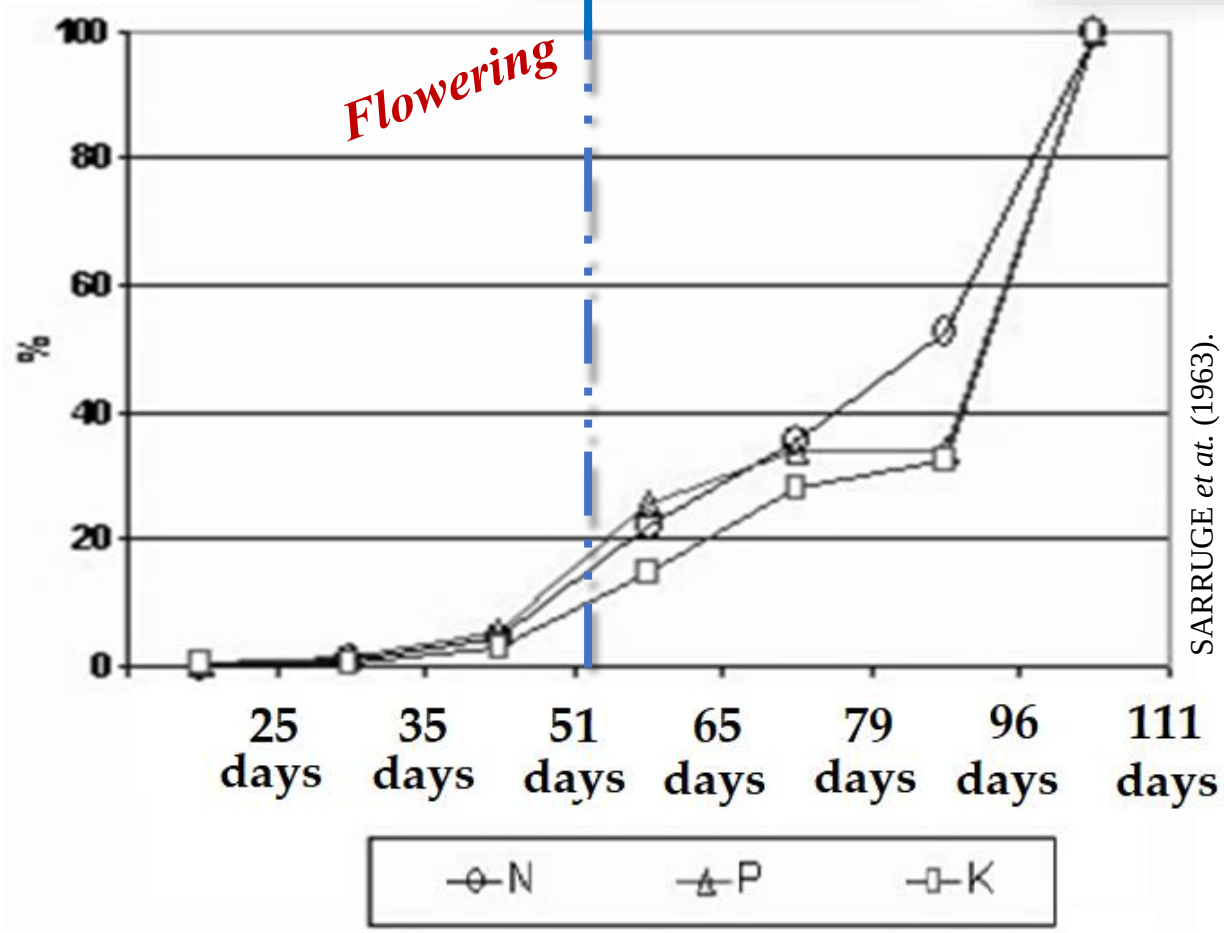
✓Osmoregulation;

*"[...] the **displacement of potassium ions (K +)**, highly soluble and of low molecular weight, keeps **water potentials balanced for longer**."*

(BELTRÃO *et al.*, 2008).







Absorption of Nitrogen, Phosphorus and Potassium throughout the cycle for cotton, in DAE

❖*Precision Farming Strategies*

➢ The detailed study of ***hyperspectral data on leaves*** can, therefore, be a strong ally in the ***nutritional diagnosis of plants***.

➢Potassium estimation on plant leaves ***can help monitor metabolic processes and plant health.***

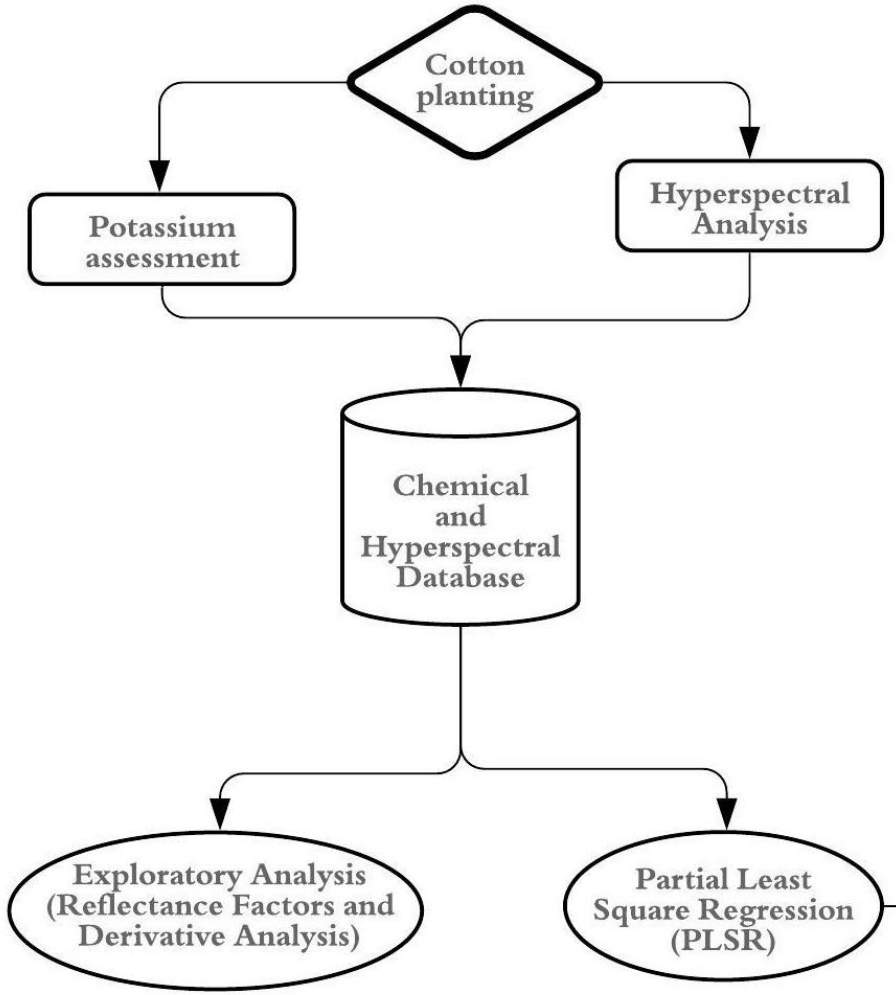
GOALS

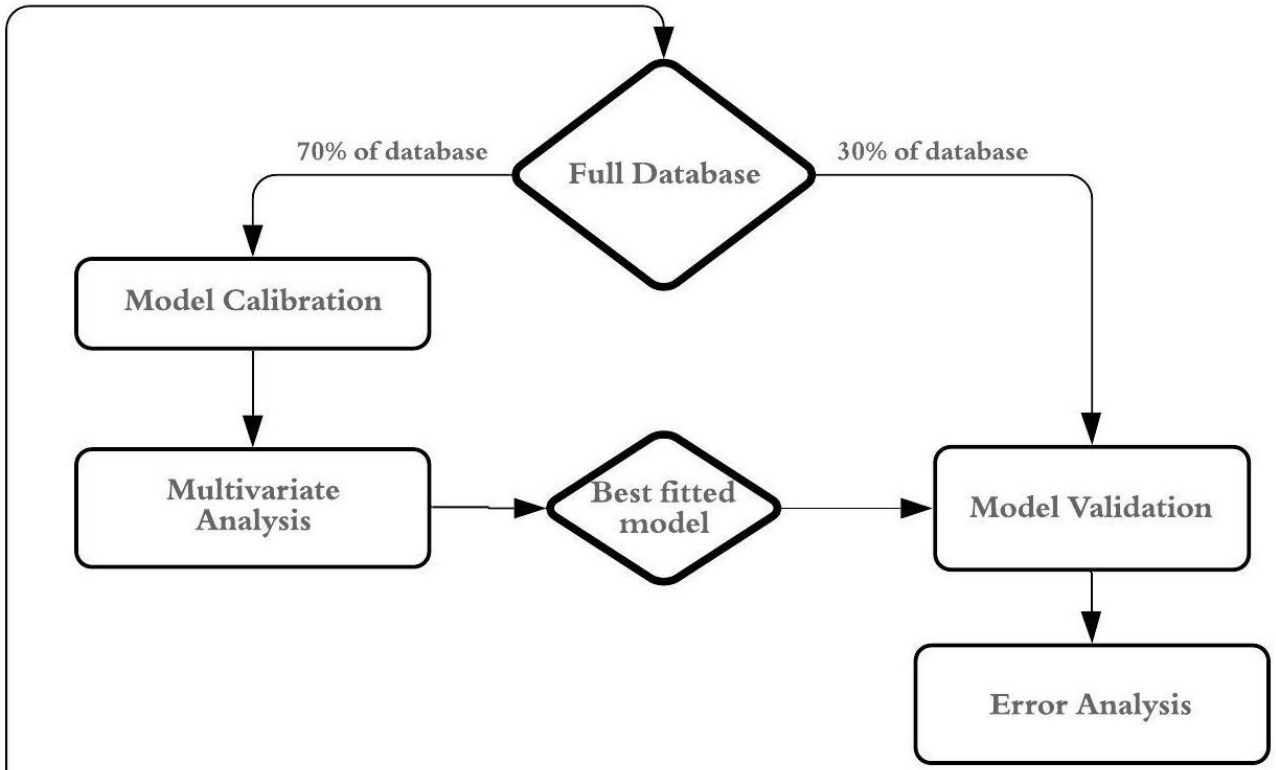
i) ***To investigate the wavelengths*** most sensitive to the leaf K content;

ii) ***Apply*** hyperspectral remote sensing data to ***e***valuate the performance of the Least Squares Regression (PLSR) models in ***estimating potassium content in cotton leaves*** during the flowering stage.

2. MATERIAL AND METHODS

❖ Workflow





❖Field Trials

- ➢Cultivar “BRS 293”.
- ➢Side-opened Greenhouse;
- ➢Cotton seeds planted into containers;
- ➢Experimental area of the Hydraulics and Irrigation Laboratory at UFC (Campus Pici);
- ➢May, 2 to September 3, 2018;
- ➢*Same irrigation level* for all K plots.
  - ✓Pressure compensating drippers (Q = 3.75 L/h)

❖ Experimental setup

N1	N4	N2	N3	N3	K1	K2	N1
N3	K1	K3	K2	N2	N1	N3	K1
N4	N1	N3	N2	N4	K2	K3	N2
N2	K2	K4	N4	K2	N3	K3	N4
K1	K3	N4	K2	N2	K1	N1	N3
N3	K4	K1	N1	N4	K3	K4	K4
N1	N2	K4	K3	K4	N2	N4	K2
K2	K4	K4	N3	N2	K4	K1	N1
N4	N1	K3	K2	K3	N4	N2	K3
N2	K2	N4	N1	N4	N1	K4	K4
K1	K4	K4	K4	K1	K2	N3	N1
N1	N3	N2	K1	N3	K4	K3	K4
K3	K4	K3	N3	K2	K4	N2	K1
N3	N2	N4	K3	N1	N4	K4	N4
K3	K1	K2	K4	K3	N1	N3	N2
N1	N3	N1	N1	N3	K1	K3	K2
K1	K2	K3	K2	N4	K3	K2	N1
N4	K3	K1	N4	N2	N1	N2	K1
N2	N3	K2	N2	K1	K3	K2	N4
K1	N4	N2	K1	K2	N3	K1	N3
T1(-k)	T2(-k)	T3(-k)		T1(-n)	T2(-n)	T3(-n)	

➢Completely Randomized Design;

✓4 treatments, with 20 replications;

➢2 Fertilization Events;

✓20 and 41 DAE, *before blooming*;

✓ Urea (CO(NH2)2;

✓ Potassium Chloride (KCl).

➢Treatment Levels

✓K1 = ***50%***, K2 = ***75%***, K3 = ***100%*** and K4 = ***125%*** K ***recomended for cotton crops***.

73 kg/ha or 4.67 g/plant

(FERREIRA & CARVALHO, 2005)

❖Lab measurements of K in the leaves

➢K+ content;

➢Laboratory of Water, Soil and Plant Relations (Ag. Engineering Department - UFC);

➢**Method Flame Spectrometry →** *Dry matter crushed in liquid nitrogen and equally diluted was sprayed over a flame. The intensity of the emitted energy showed the K+ content.* (BARNES *et al*, 1945)

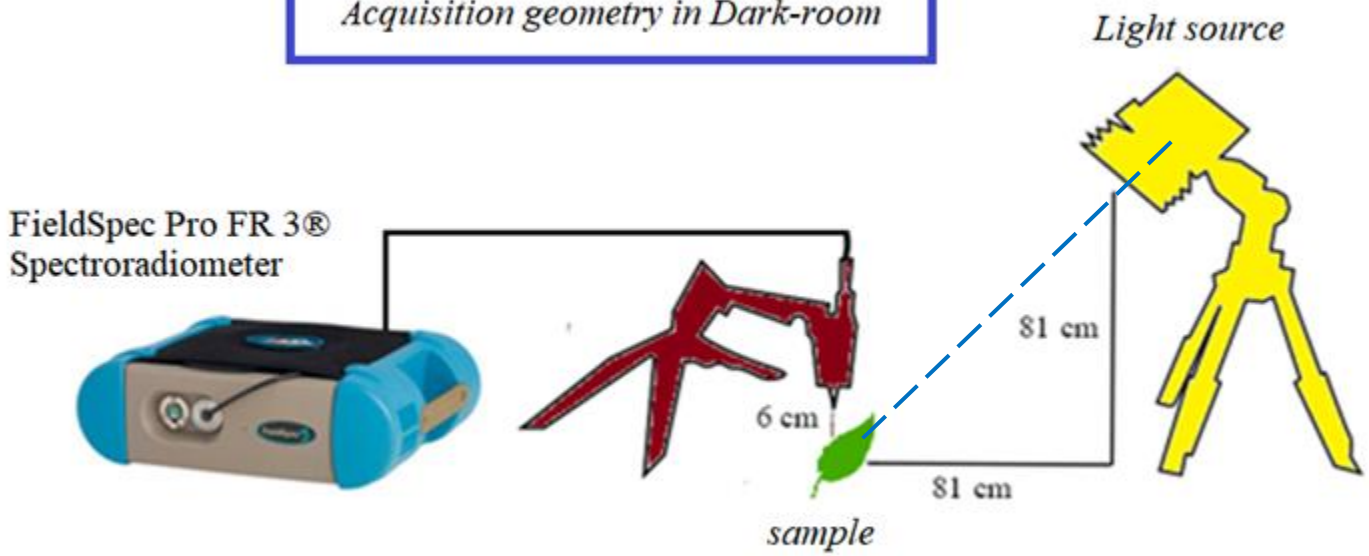
➢Flame photometer;

❖Acquisition of hyperspectral reflectance factors

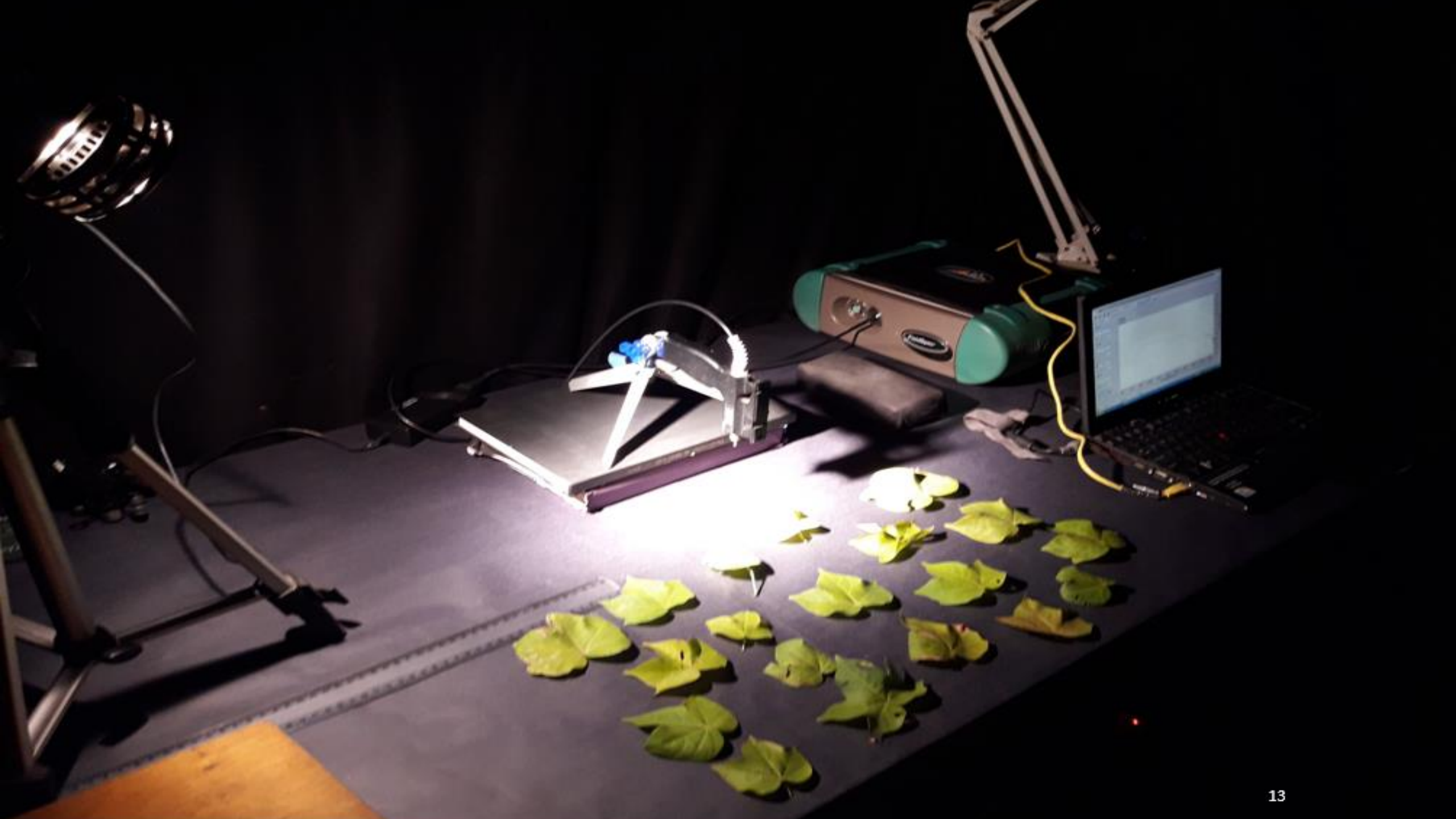
- ✓ Dark-room (*92 meters away from the greenhouse*);
- ✓ Halogen lamp (*50W*);
- ✓ Spectralon plate (*White Reference*);
- ✓ **FieldSpec Pro FR 3® Spectroradiometer** (*Analytical Spectral Devices Inc.);*
- ✓ **350 to 2500 nm** (*spectral resolution of 1 nm*).

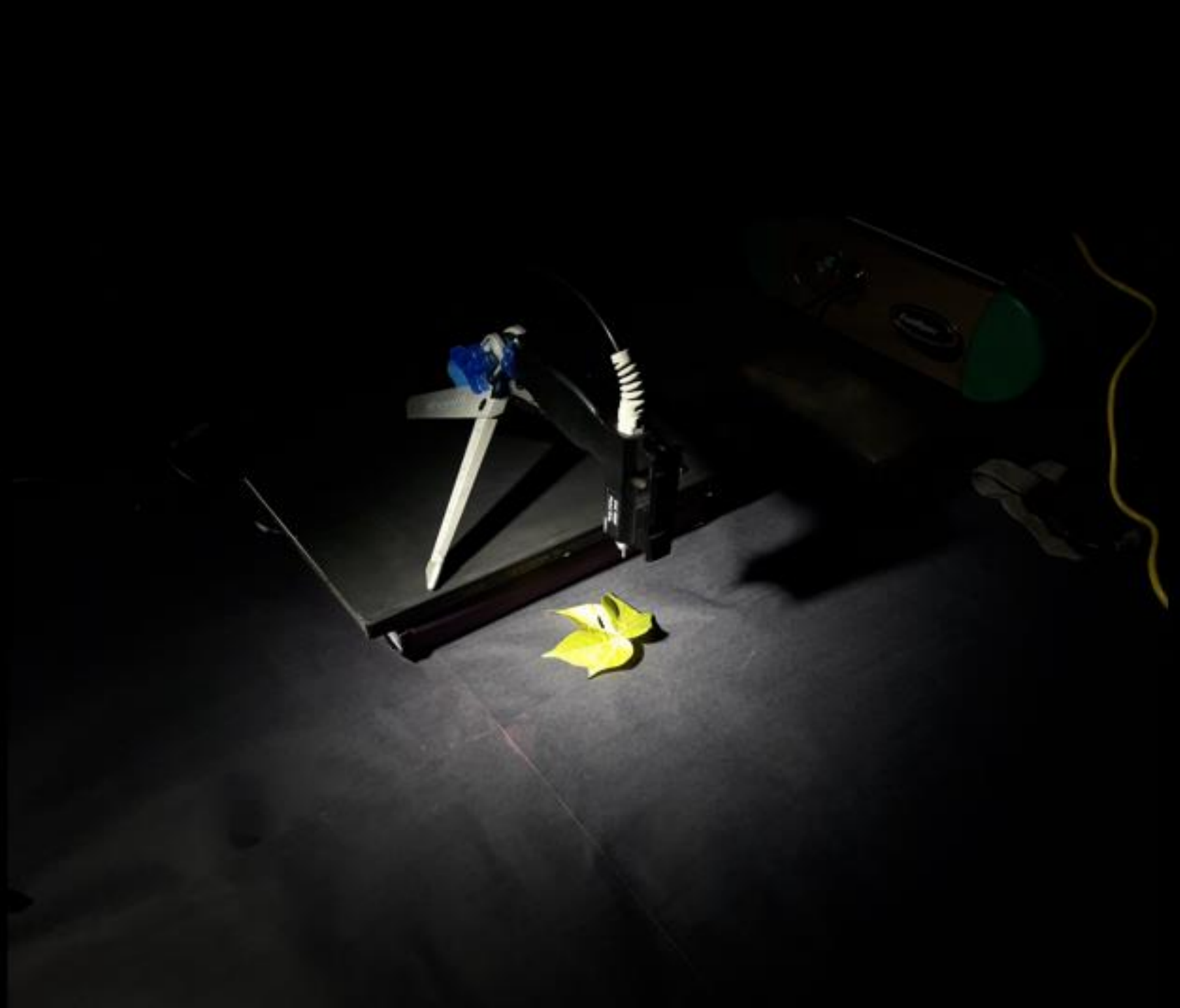
- ✓ 81 cm;
- ✓ 45º zenith angle on the leaf;
- ✓ 6 cm from the sensor, orthogonally fixed.

Acquisition geometry in Dark-room



Campelo(2018), adapted by author.





❖Data pre-treatment:Derivative analysis

✓ Highlight each ***oscillation between consecutive wavelengths***, pointing out the most sensitive ones.

$$\frac{dR_\lambda}{dx} \cong \frac{R_{i+1}-R_{i-1}}{\Delta x}$$

$$\frac{d^2 R_\lambda}{dX^2} = \frac{d}{dx}\left(\frac{dR}{dx}\right) \cong \frac{R_{i+1}-2R_i+R_{i-1}}{(\Delta x)^2}$$

❖Multivariate Statistical Analysis ***on Calibration***

➢ Ranking of Adjusted coefficient of determination (R^2ajust);

✓ Minimum of **80.0%**;

✓ Detect the most sensitive wavelengths in model;

❖Error Analysis *on Validation*

- Adjusted coefficient of determination; (R^2ajust)

$$R^2_{ajust} = 1 - \frac{(N-1).(1-R^2)}{N - (k+1)}$$

- Root of the mean square error; (RMSE);

$$RMSE = \sqrt{\frac{\sum_{j=1}^{N}\left(y_j^{'} - y_i\right)^2}{N}}$$

- Residual Prediction Deviation; (RPD)

$$RPD = \sqrt{\frac{\sigma}{\sqrt{\frac{\sum_{j=1}^{N}\left(y_j^{'} - y_i\right)^2}{N}}}}$$

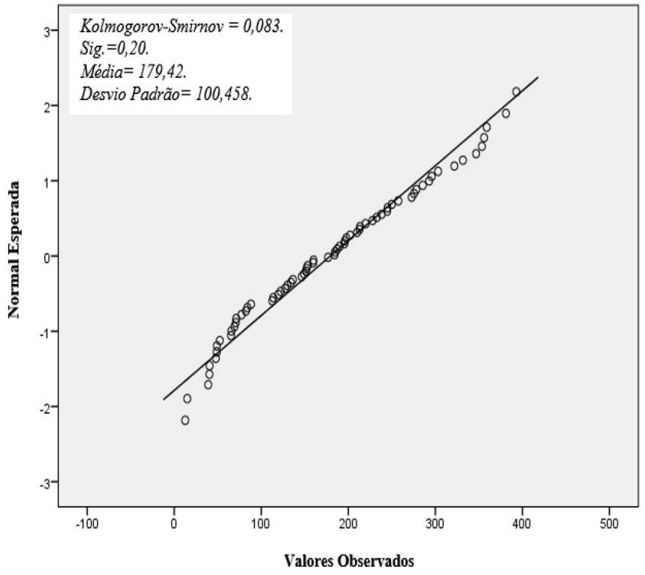
3. RESULTS AND DISCUSSION

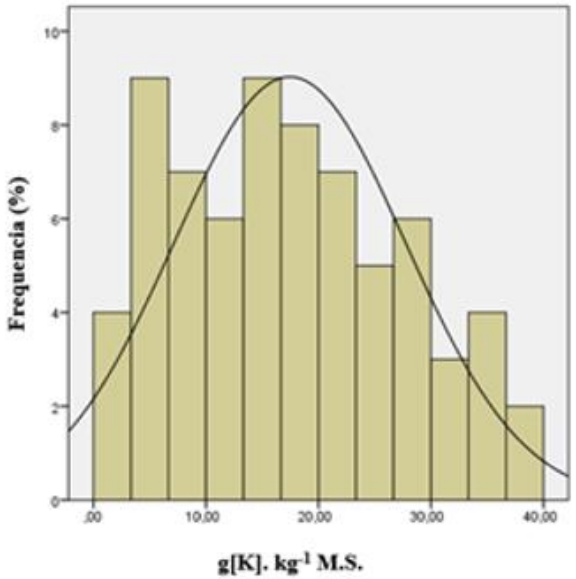
❖Leaf content of K

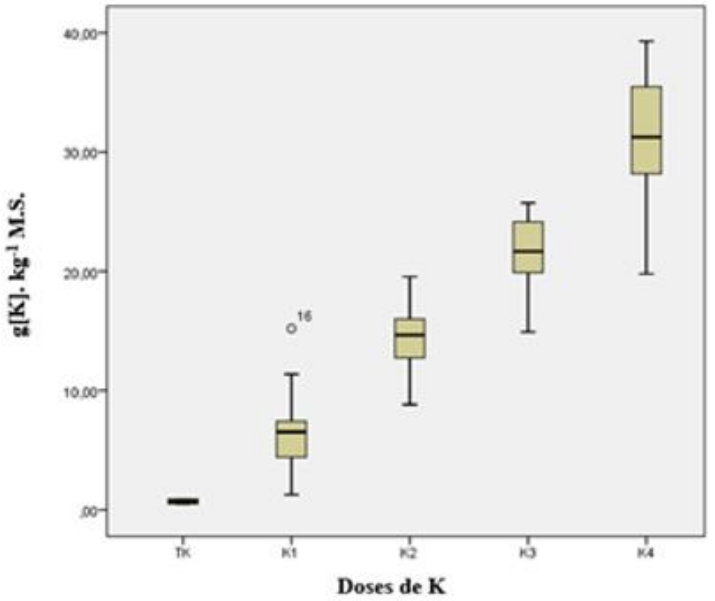
- Progressive accumulation of K+ levels;
- Normal expected range of [K+] in cotton leaves → ***15 to 25*** g/kg (Leaf Dry Matter - LDM).

(CARVALHO et al., 2007).

- This work registered K+ contents from ***0.0 to 39.3*** g/kg LDM.





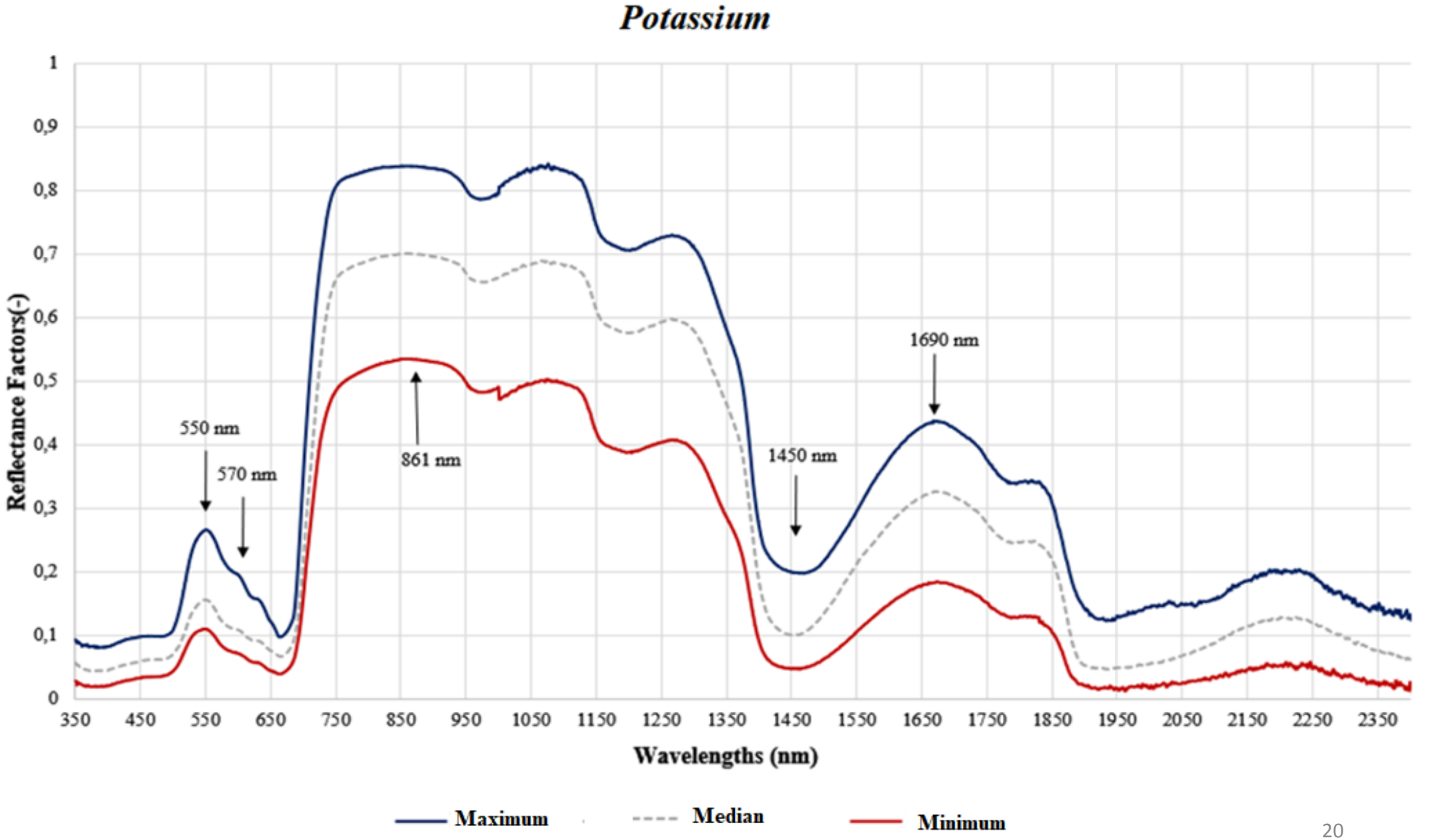


Potassium Deficiency Symptoms Observed

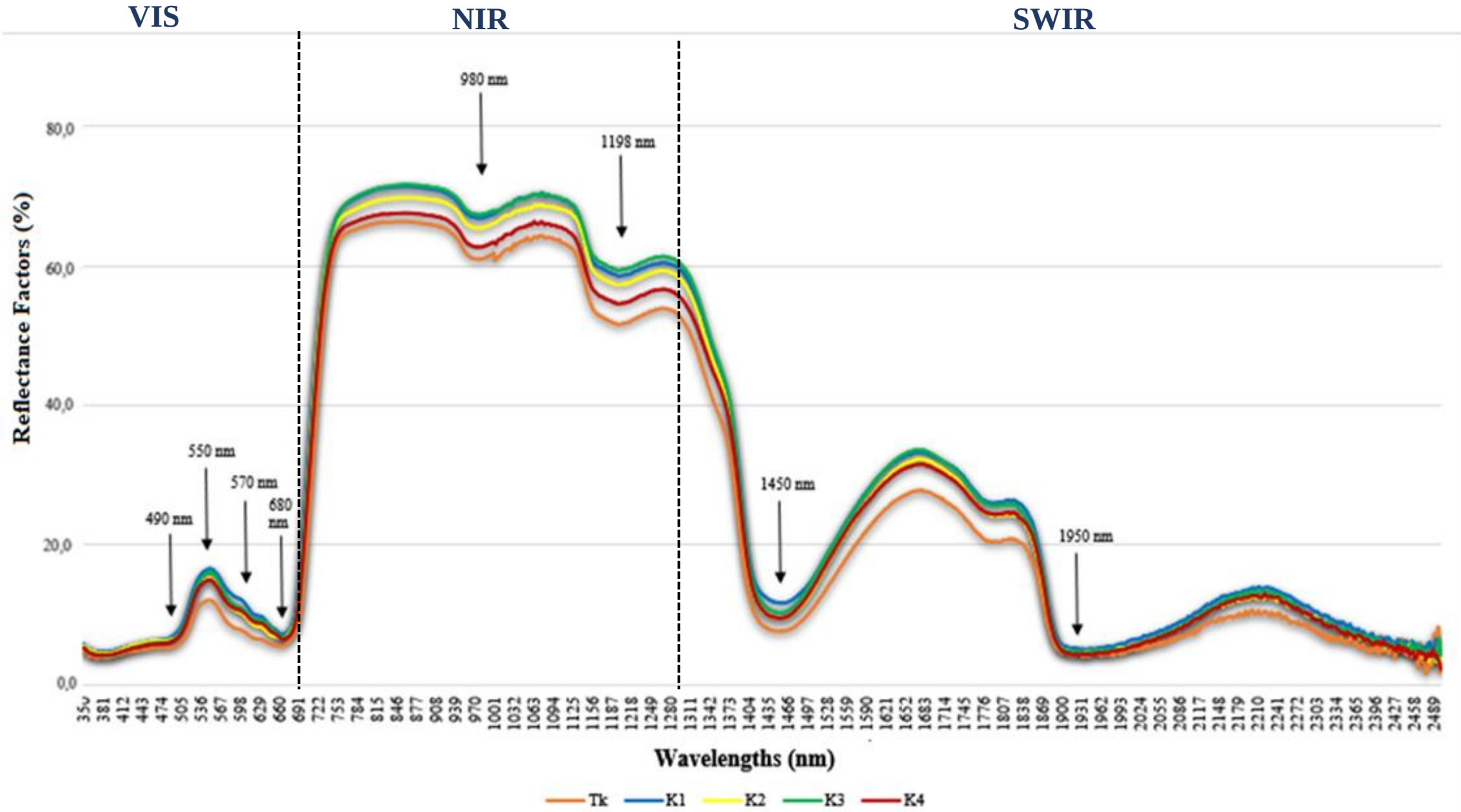
Potassium Deficiency Symptoms Observed

- **Leaf wilt under the hottest hours of the day;**
- **Marginal necrosis of older leaves;**
- **Delay in flowering;**
- **Flowers abortion;**
- **Plant lodging;**
- **Early fruit ripening;**
- **Less fiber and seed production;**
- **Low quality of fibers;**
- **Inhibition of root and plant growth.**

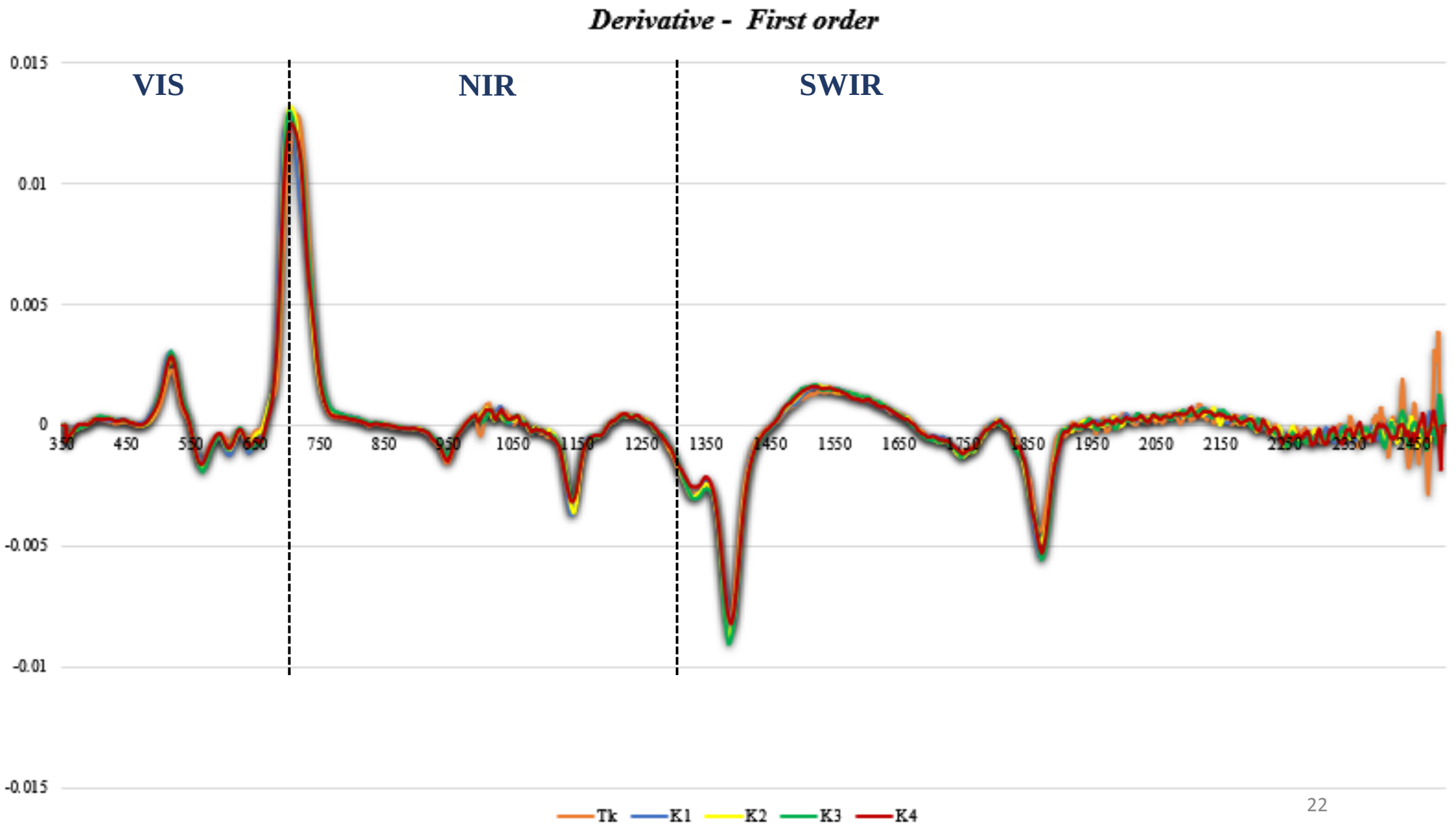
❖Reflectance Factors (*Full Database*)



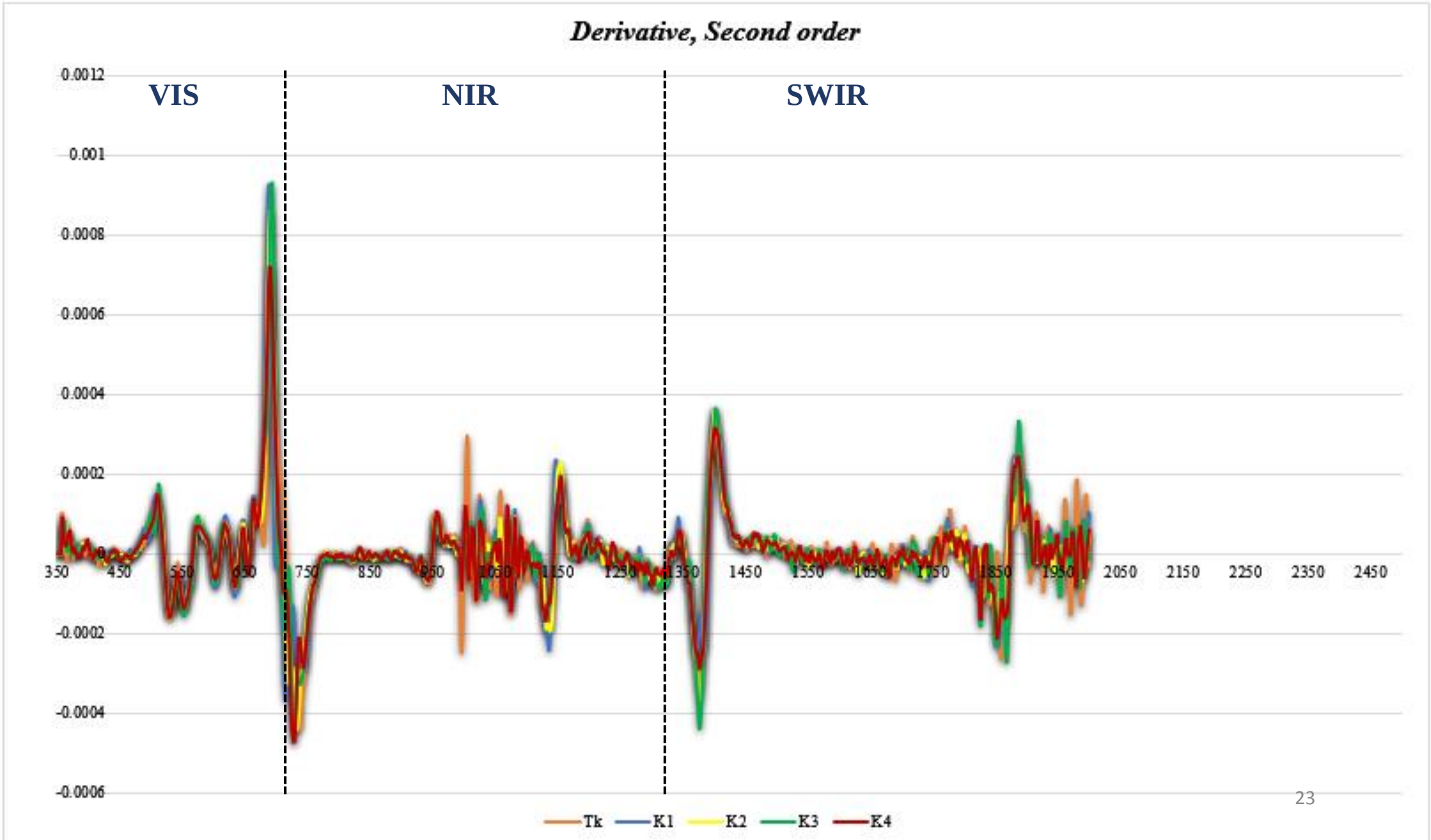
❖Reflectance Factors (*Median*)



❖ Derivative Analysis, First order



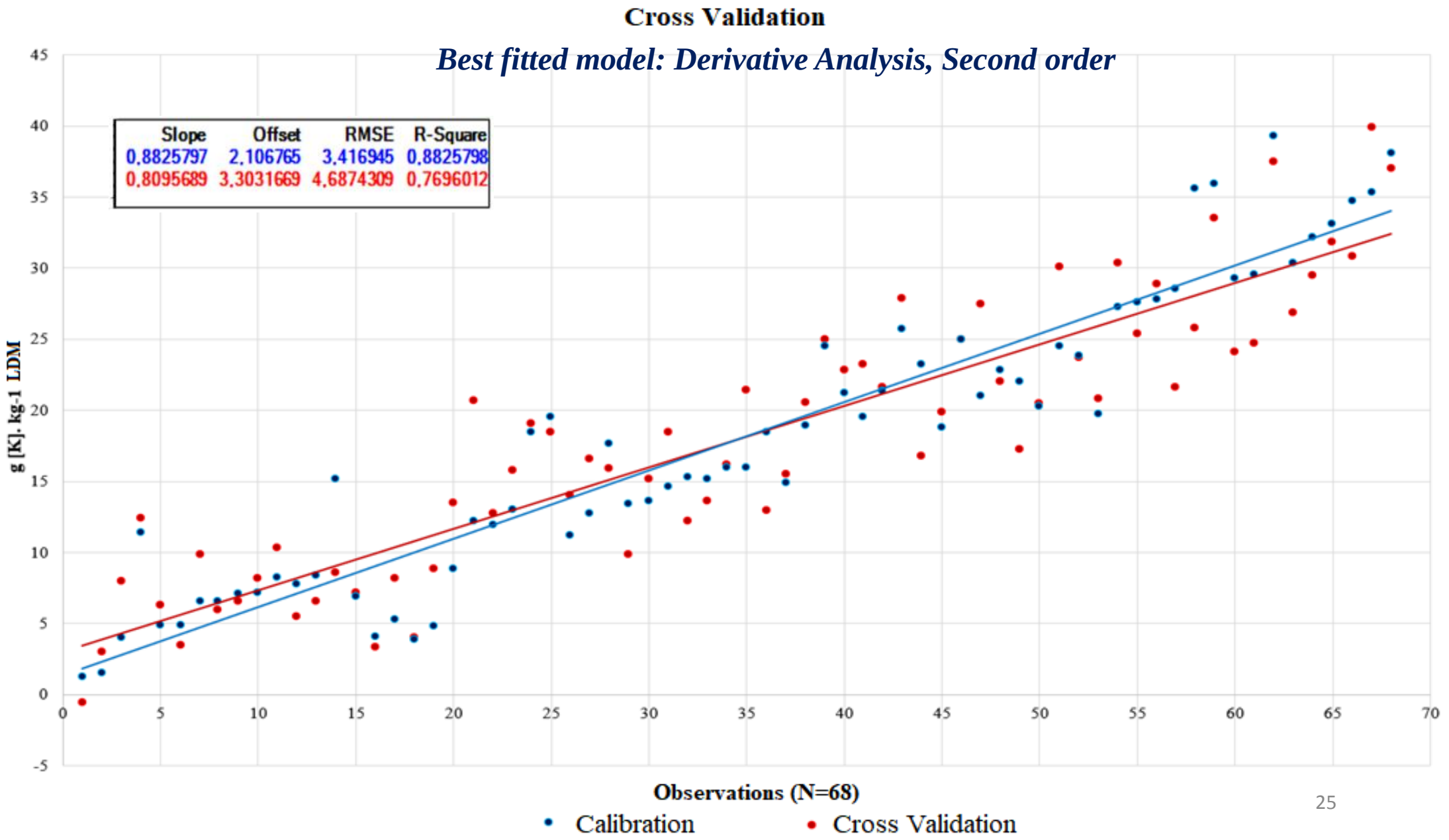
❖ Derivative Analysis, Second order



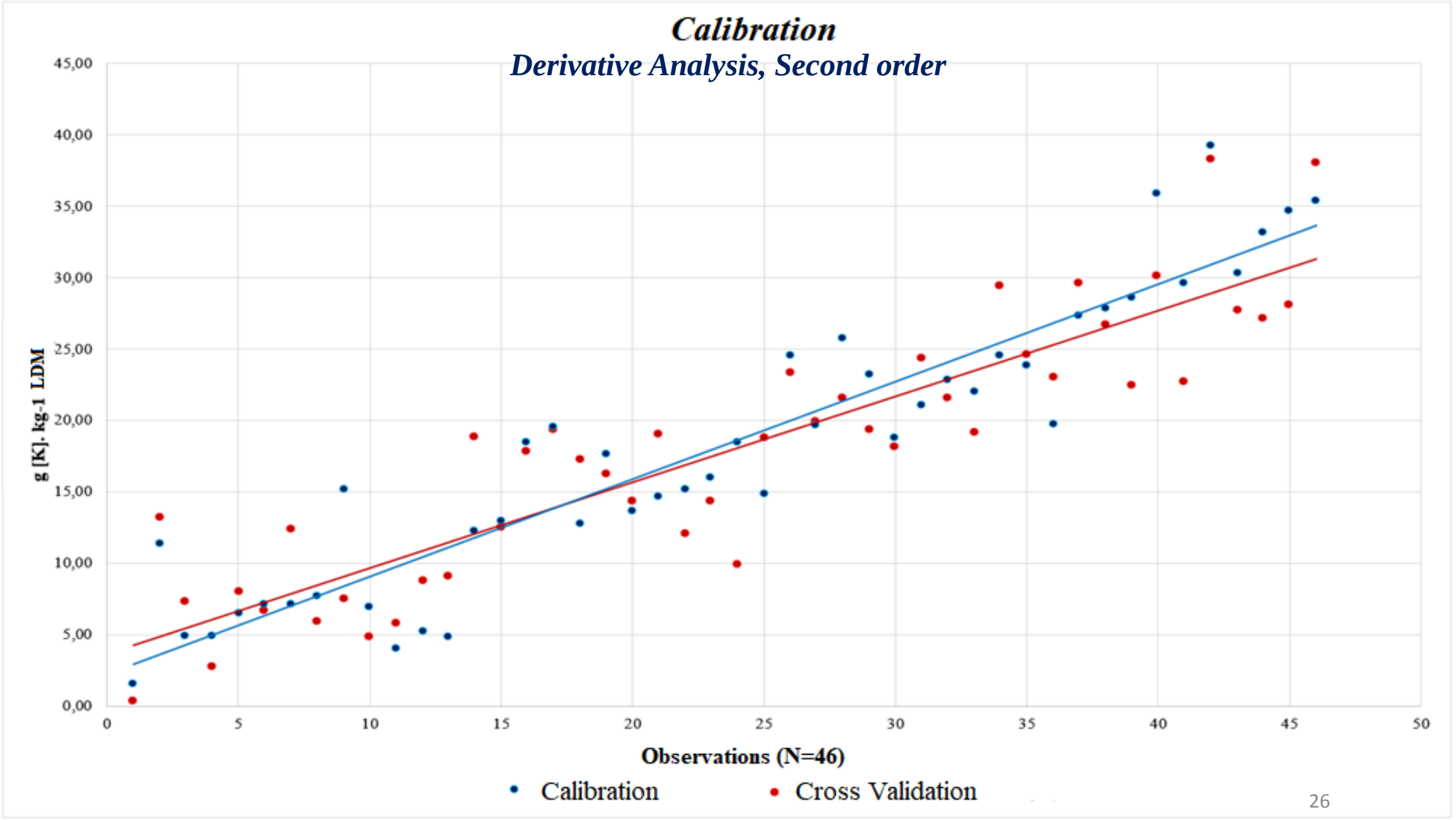
❖*Specific notes*

- *Greater differentiation between K doses occurred at **1198 nm**.*
- *The highest reflectance level measured at **550 nm** was **16%**.*
- *For these laboratory conditions, in NIR region, the factors did not exceed **72%**.*
- *First order derivative registered peaks around **red-edge** (**707 nm**) and in the **moisture absorption** features (**1140** , **1380** and **1860 nm**), pointing out the greater transitions (+/-) of spectra.*
- *These regions are highlighted in the 2nd order derivative by crossing the axis at the same wavelengths.*

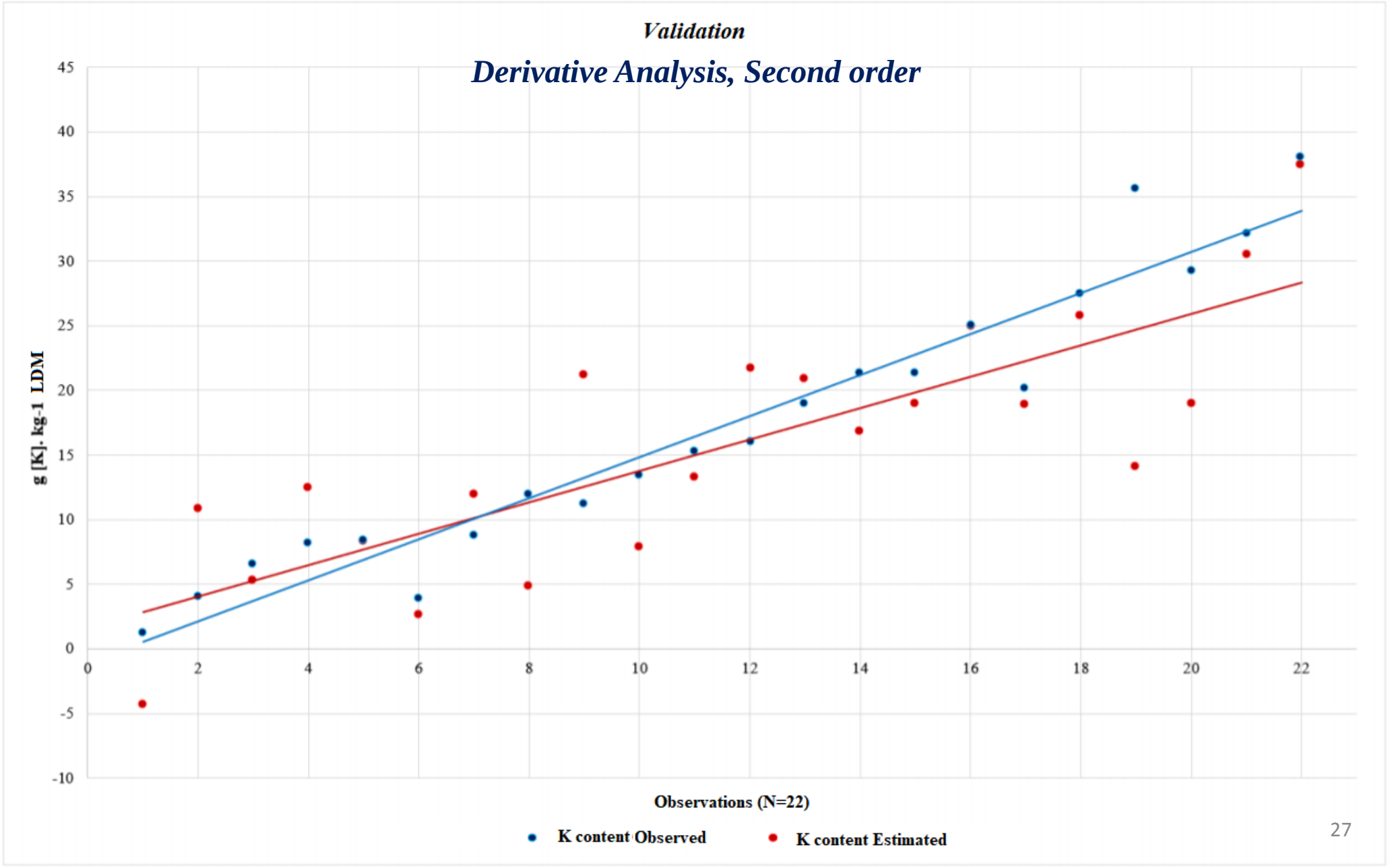
❖ MODEL SELECTION: PLSR – Cross Validation (N=68)



❖PLSR Model – Calibration (N=46)



❖PLSR Model – Validation (N=22)



❖Proposed Estimate Model

Reflectance Factor transformed → Derivative Analysis, Second order

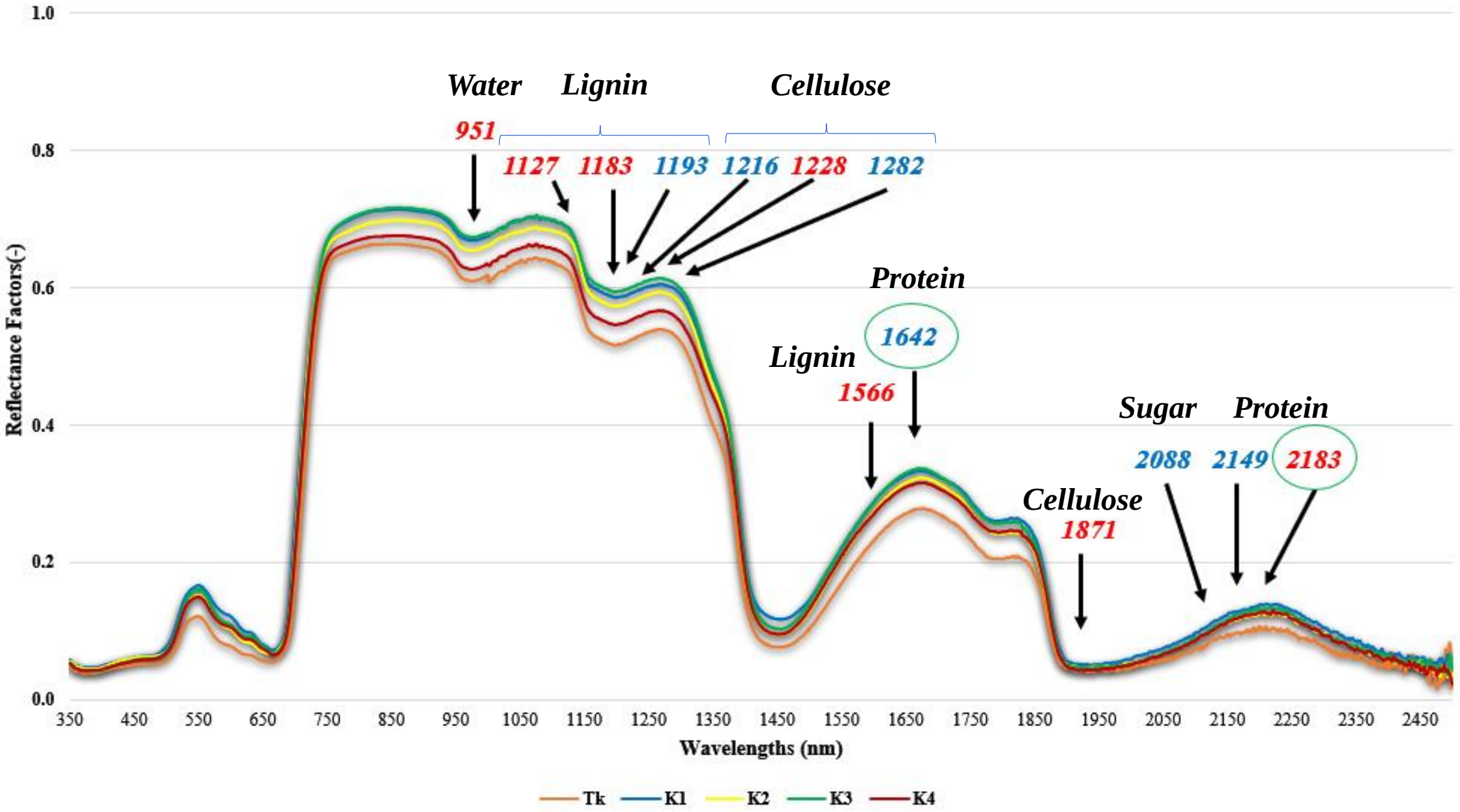
$$[K+] = 13{,}36801 + 226877{,}5_{\rho 1193nm} + 105424{,}9_{\rho 2088nm} + 399471{,}7_{\rho 1642nm} - 296681{,}7_{\rho 1228nm} - 278306{,}8_{\rho 951nm} - 77290{,}33_{\rho 1127nm} - 137076{,}5_{\rho 1566nm} + 67643{,}57_{\rho 1216nm} + 221400{,}4_{\rho 1282nm} - 7340{,}64_{\rho 2183nm} + 33362{,}11_{\rho 2149nm} - 119047{,}0_{\rho 1183nm} - 27478{,}12_{\rho 1871nm}$$

❖Error Measurements

Model	Std. Dev	R²ajust	RMSE	RPD
Cross Validation (N=68)	9,97	0,88	3,41	1,71
Calibration (N=46)	9,73	0,82	3,74	1,61
Validation (N=22)	10,42	0,66	6,50	1,27

❖Main Wavelengths Detected

(JENSEN, 2011 / CURRAN, 1989 / ASD, 2005)



❖*Final Considerations*

✓The discrimination of potassium deficiencies in cotton using hyperspectral data was satisfactorily performed by a **PLSR model** composed of **13 wavelengths** (DERIVATIVE ANALYSIS, SECOND ORDER), of which most are commonly associated with ***moisture***, ***lignin***, ***cellulose***, ***sugar*** and ***protein*** contents in leaves.

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