Spectral behavior of tree species of individuals of the families Fabaceae and Myrtaceae, present in the Botanical Garden of the Federal University of Santa Maria (UFSM)

https://doi.org/10.56238/sevened2024.004-015

Roberta Aparecida Fantinel[1], Ana Caroline Paim Benedetti[2], Claire Delfini Viana Cardoso[3], Renato Giovani Chaves de Sá[4], Natália Melos Duarte[5] and Vinícius Henrique Fernandes[6]

ABSTRACT

The objective of this study was to analyze the spectral behavior of individuals of six species present in the Botanical Garden of the Federal University of Santa Maria. The individuals were randomly chosen, taking into account three species belonging to the Myrtaceae families and three species belonging to the Fabaceae family. The leaves selected by means of visual diagnosis were green and healthy, with no presence of symptoms of pest or disease on the adaxial or abaxial surface of the leaf. The spectral behavior of the leaves was recorded with the FieldSpec® HandHeld spectroradiometer sensor, which acts in the range between the wavelengths of 325nm to 1075nm of the electromagnetic spectrum. In the SAMS application, the reflectance factor (ρ) graphs were generated as a function of the wavelength (nm) for each species. The differences between the spectral behaviors of the species were tested by analysis of variance (ANOVA) and Tukey's test, using the R software. It was observed that Psidium guajava and Eugenia involucrata differ from each other regarding the means of reflectance in all visible spectral bands. The species Acca sellowiana and Psidium guajava differ from each other in the blue, red and near-infrared bands. For the other comparisons, no significant differences were found. For individuals of the Fabaceae family, the species Libidibia ferrea differed from the species Senna multijuga and Cassia leptophylla in the three bands of the visible spectrum. Libidibia ferrea differed from Cassia leptophylla in the near-infrared spectrum. The spectroradiometer proved to be efficient in the analysis and identification of differences between the species of the Myrtaceae and Fabaceae families.

Keywords: Remote Sensing, Reflectance Factor, Spectroradiometer.

[1] Doctor - UFSM
[2] Doctor - UFSM
[3] Doctor - UFSM
[4] Geoprocessing Technician - UFSM
[5] Geomatics Specialist
[6] Geoprocessing Technologist - UFSM

INTRODUCTION

With the development of Remote Sensing, the possibility of quantifying individual photosynthetic pigments contained in vegetation has been expanded, providing in other studies the aid in determining the physiological state of vegetation (identification of stress), discrimination of different species (monitoring of phenological characteristics), estimation of productivity (absorption of photosynthetically active radiation) (FERRI et al., 2001).

More in-depth studies on the spectral behavior of vegetation in the most diverse landscapes require the acquisition of punctual data, and in this context, spectroradiometry is fully used, since it enables the detection of the spectral response through direct contact with the target, without the interference of external and environmental factors (SCHRODER et al., 2015). Also according to Santos et al. (2017), spectroradiometry aims to analyze the radiometric properties of a given material through reflectance spectroscopy, an advanced technique within Remote Sensing that records the flux of electromagnetic radiation reflected by materials.

According to Ponzoni and Shimabukuru (2010), photosynthetically active vegetation behaves differently in different regions of the electromagnetic spectrum in relation to its spectral response: in the visible region it has a low reflectance, due to the absorption of incident radiation carried out by the chlorophyll and carotenoids of the plant, while in the near infrared region it is characterized by a high reflectance due to the cellular structure of the leaf. It should also be noted that such conditions can be altered when subjected to stressful situations, influencing leaf reflectance in the regions of the electromagnetic spectrum mentioned above (LIPPERT et al., 2015).

Therefore, it is considered the hypothesis that the reflectance differs along the electromagnetic spectrum, varying according to the morphological and physiological characteristics of the vegetative material, and in this purpose, the present work aims to analyze the spectral behavior, in different bands of the electromagnetic spectrum, of individuals of six species that are part of the families Myrtaceae and Fabaceae present in the Botanical Garden of the Federal University of Santa Maria.

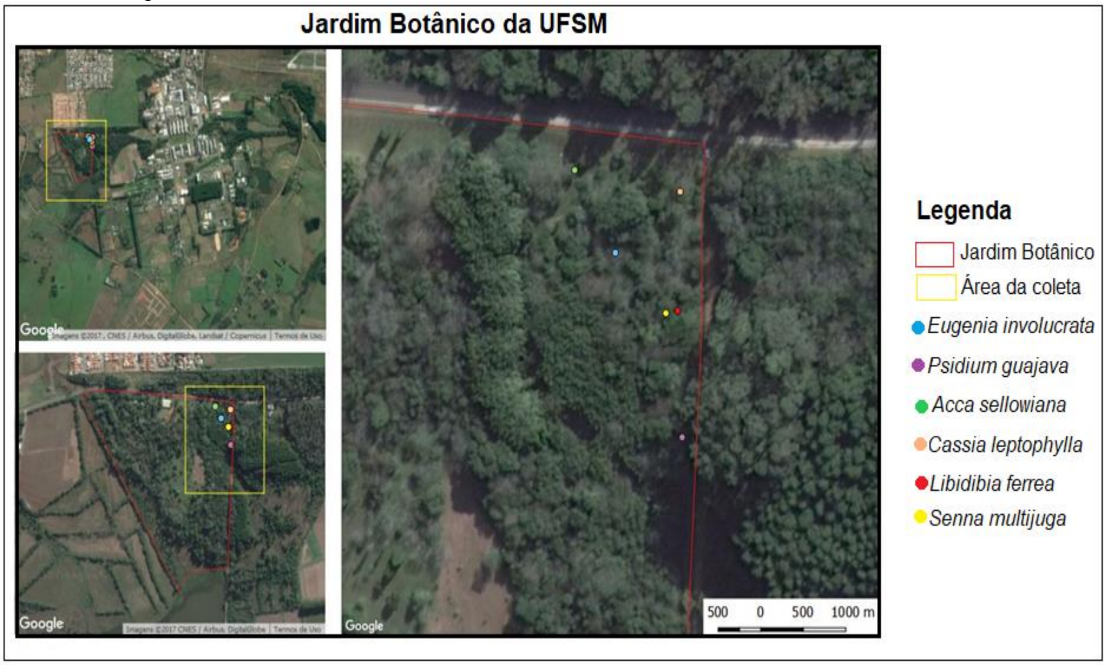
MATERIAL AND METHODS

AREA OF STUDY

The material was collected on October 17, 2017, between 2 pm and 3 pm; during this period, the temperature was approximately 28°C and the relative humidity was 50%, according to INMET (2017). Five leaves were collected and chosen through visual diagnosis, being green and healthy, without the presence of symptoms of pest or disease on the adaxial or abaxial surface.

The choice of individuals occurred randomly at the Botanical Garden of UFSM, taking into account only the representativeness of three species of the two different families, thus selecting six forest species, among them: *Acca sellowiana* (O.Berg), Burret (guava-da-serra), *Eugenia involucrata* (D. C.) (cherry), *Psidium guajava* (L.) (common guava), belonging to the Myrtaceae family and the species *Cassia leptophylla* (Vogel) (false-barbatimão), *Senna multijuga* (Rich.) H.S. Irwin & Barneby (cicada wood) and *Libidibia ferrea* (Mart. ex Tul.) L. P. Queiroz (ironwood) of the Fabaceae family. Figure 1 shows the location of the Botanical Garden within the UFSM campus, as well as the random distribution of the individuals chosen for the removal of vegetative material.

Figure 1 - Location of the Botanical Garden on the campus of the Federal University of Santa Maria – RS and distribution of the sampled individuals.



The spectral behavior of the leaves was recorded with the FieldSpec® HandHeld 2™ spectroradiometer sensor, which reads the reflectance factor *(ρ)* between wavelengths between 325nm and 1075nm, i.e., it operates from the visible to the near-infrared region of the electromagnetic spectrum, with a spectral resolution of 10nm.

To perform the readings in the spectroradiometer, the sheets were positioned with the adaxial face to the interior of the integrating sphere of the equipment. Three sample readings were taken for each of the five sheets taken from the individual, totaling 15 readings per species. Therefore, 45 sample readings were counted for each of the families.

The reflectance factor *(ρ)* values were processed using ASD *ViewSpec* Pro version 4.05, Microsoft Office Excel 2010, *Spectral Analysis and Management System* (SAMS) version 3.2 and R x 64 version 3.4.2. To generate the reflectance factor curves and subsequent analysis of the spectral behavior of the individuals, the values referring to the wavelengths between 400nm and 1075nm (visible spectra up to the near infrared) were considered, and the values recorded in the region of the ultraviolet spectrum (between 325nm and 400nm) were eliminated.

The tabulation of the data was organized in order to represent the different spectral bands, having adapted from Jensen (2009), the wavelength intervals: blue (400 to 500nm), green (500 to 600nm), red (600 to 700nm) and near infrared (IVP), with interval (700 to 1075nm).

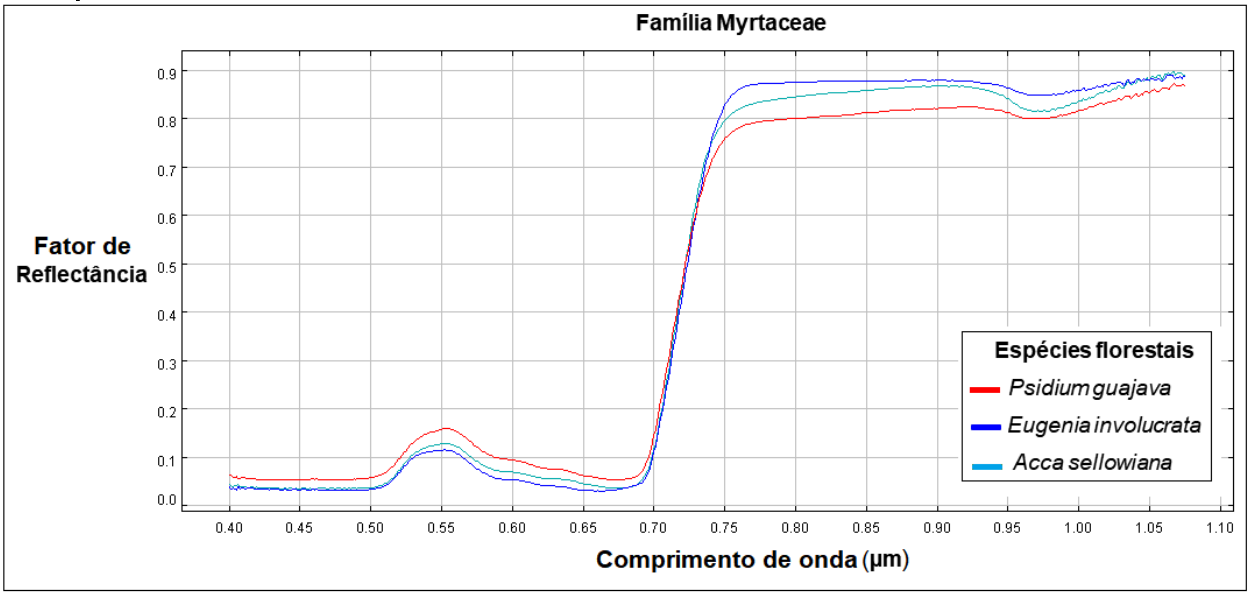
In the *Spectral Analysis and Management System* (SAMS) application, graphs of the reflectance factor *(ρ)* as a function of wavelength (nm) for each species were generated in order to visualize spectral differences between species of the same family. Subsequently, in the R software, the hypothesis of the existence of differences in the reflectance factor of the species of the same family, in the different spectral bands (blue, green, red and IVP) was tested. To this end, we used analysis of variance (ANOVA) and the Tukey HSD (*Honestly Significant Difference*) test at 5% probability for multiple comparisons of the reflectance means in each band.

RESULTS AND DISCUSSION

SPECTRAL BEHAVIOR OF INDIVIDUALS OF THE MYRTACEAE FAMILY

The spectral behavior shown in Figure 2 is characterized by the typical response of healthy green vegetation, but reveals some particularities, probably attributed to the species and its own morphological and physiological characteristics.

Figure 2 - Spectral response of three individuals of the Myrtaceae family, present at the Botanical Garden of the Federal University of Santa Maria – RS.



In the visible spectrum (blue, green and red bands) the low reflected energy (around 5% of the incident radiation) between 400 and 500 nm and between 600 and 700 nm are observed for the three species; as a result of the higher energy absorption in this region. Typically, between 500 and 600nm, it is found that more than 10% of the energy is being reflected. Photosynthetic leaf pigments such as chlorophyll and carotenoids are responsible for the amount of energy absorbed or reflected by the leaf in this region of the electromagnetic spectrum. According to Sims and Gamon (2002), these photosynthesizing leaf pigments exert a great influence on the leaf spectral behavior in these regions, thus occurring a high correlation between the concentration of chlorophyll pigments and the absorption of energy by the leaves.

Psidium guajava showed a higher reflectance factor in the visible spectrum, especially in the green region (between 500 and 600nm), compared to the other species analyzed in the same family. Studies carried out by Käfer et al. (2016), found high reflectance in the green region for the species of *Psidium cattleianum*, *Eugenia uniflora* and *Eugenia involucrata*, also belonging to the Myrtaceae family. In the visible spectrum, probably due to the lower presence of photosynthetic pigments in relation to the others.

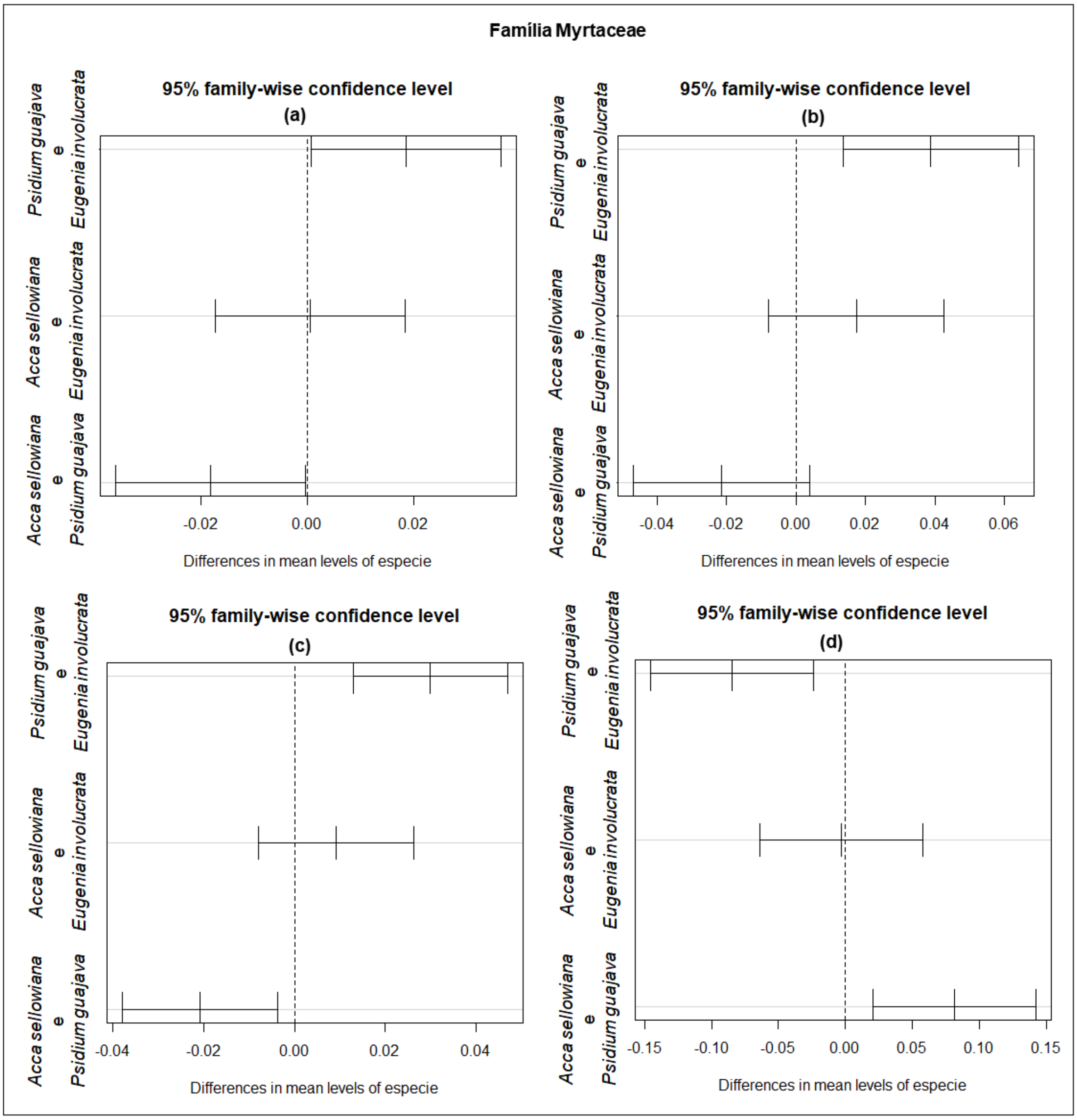
Eugenia involucrata (cherry) was the species of this family that showed the highest reflectance in the IPV. This fact can probably be explained by the structures of the cells that make up the leaf tissues and the environmental conditions in which the species is inserted. Between 750 and 800nm, the species is reflecting almost 90% of the incident radiation, denoting the intensity of its photosynthetic activity.

By applying the analysis of variance (ANOVA) using the mean reflectance values in each band (visible and PVI) it was found that there were significant differences at the 5% probability level. In the blue band, ANOVA resulted in a calculated F (calc.) of 0.00876 > F tabulated (tab.) to (0.05). In the green band, F calc was obtained. = 0.00364 > F tab. (0.05). For red, the F calc. = 0.00427 > F tab. (0.05) and in IVP F calc. = 0.0263 > F tab. (0.05).

In order to verify which species differ in terms of spectral behavior in each band, the Tukey HSD test was performed. Figure 3 shows between which forest species the significant differences detected in ANOVA occurred.

Among the individuals of the Myrtaceae family, it was observed that the species *Psidium guajava* and *Eugenia involucrata* differ from each other regarding the means of reflectance in all visible bands. The species *Acca sellowiana* and *Psidium guajava* differ from each other in the blue, red and near-infrared bands. For the other comparisons, no significant differences were found. These differences between the species may be linked to their different leaf shapes, mesophyll size, which has different behavior in the absorption, transmission and reflection of the waves of the electromagnetic spectrum, in addition, the leaves are made up of a fibrous structure of organic matter, within which there are pigments, cells containing water and air (COURA et al., 2005). Thus, each of these elements: pigments, physiological structure and water content have an effect on the reflectance, absorptance and transmittance properties of the green leaf (CURRAN, 1986).

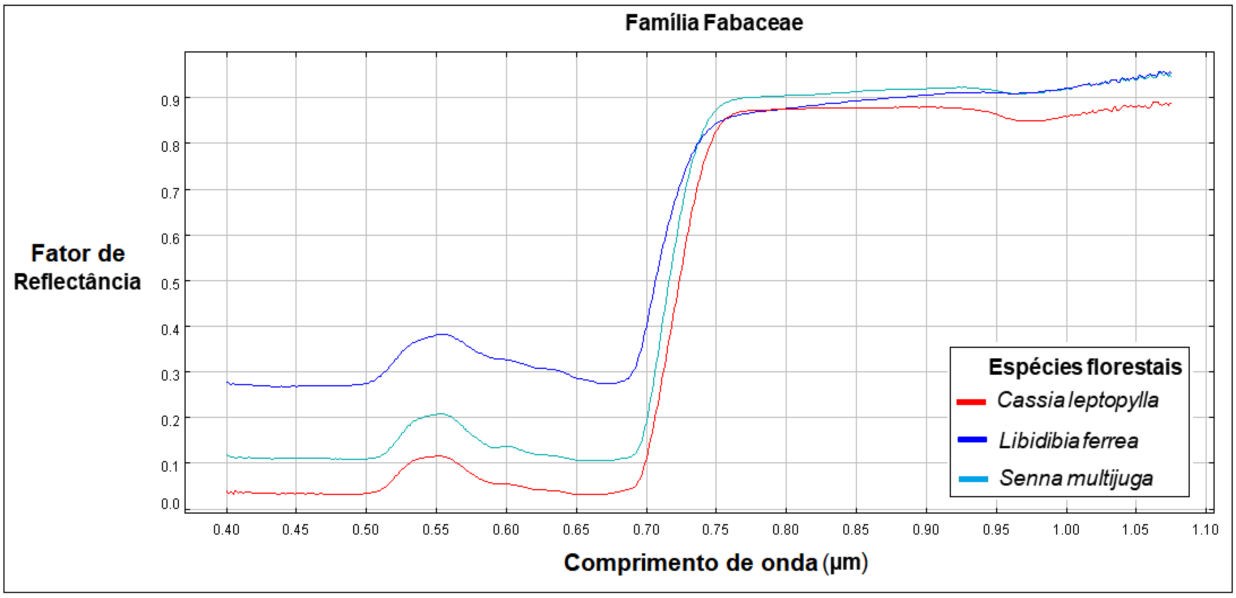
Figure 3 - Plot of the Tukey HSD test for the comparison of the reflectance means in the blue (a), green (b), red (c) and IVP (d) bands between the species of the Myrtaceae family.



SPECTRAL BEHAVIOR OF INDIVIDUALS OF THE FABACEAE FAMILY

The visual analysis of the spectral behavior of the individuals of the Fabaceae family, shown in Figure 4, also reveals some specificities of the species *Cassia leptophylla* (false barbatimão), *Senna multijuga* (cicada wood) and *Libidibia ferrea* (ironwood).

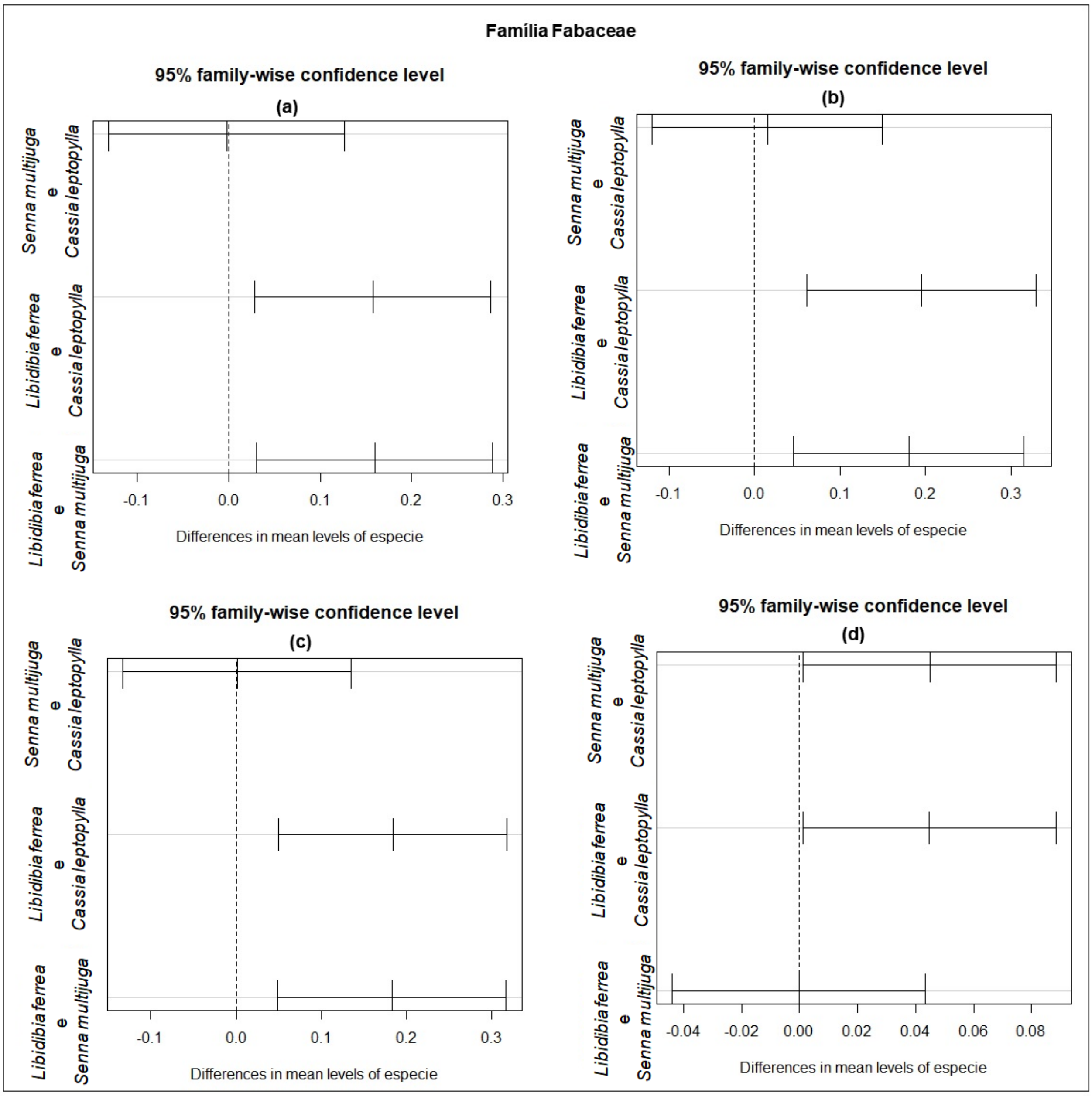
Figure 4 - Spectral response of individuals of the Fabaceae family, present at the Botanical Garden of the Federal University of Santa Maria – RS.



Libidibia ferrea stands out from the other species due to the reflectance of approximately 40% of the energy in the green band (between 500 and 600nm). This response may be associated with differences in chlorophyll content in relation to other species, which tends to produce large differences in leaf reflectance and transmittance (GITELSON et al., 2005). In addition, what may have contributed to this differentiation of the ironwood species from the others is the morphology of its leaves (pinnate or bipinnate), since the spectral behavior of a leaf is a function of the composition, morphology and internal structure (Ponzoni et al., 2012). As can be seen, in the IVP range (between 700 and 1100nm), there is a decrease in the reflectance of *Cassia leptophylla*. The variation of the reflectance value in the spectral region of the IVP for Guyot et al. (1989) is proportional to the number of layers and size of the cells, as well as the orientation of the leaf walls.

ANOVA showed that the reflectance averages in each spectral band were different between species. In the blue band, an F calc was obtained. = 0.0254 > F tab. (0.05), in the green band F calc. = 0.00526 > F tab. (0.05). In the red F calc. = 0.00161 > F tab. (0.05) and in IVP F calc. = 0.00433 > F tab. (0.05). Subsequently, the Tukey test compared the species two by two to indicate which ones differed from each other in terms of the mean reflectance value in each band (Figure 5).

Figure 5 - Plot of the Tukey HSD test for the comparison of the reflectance averages in the blue (a), green (b), red (c) and IVP (d) bands between the species of the Fabaceae family.



Among the individuals of the Fabaceae family, the species *Libidibia ferrea* differed from the species *Senna multijuga* and *Cassia leptophylla in the* three bands of the visible spectrum. *Libidibia ferrea* also differed from *Cassia leptophylla in the* near-infrared spectrum. Similarly, *Senna multijuga* and *Cassia leptophylla* showed significant differences in this range, as shown in the zero-free intervals in Figure 6. The fact that *Libidibia ferrea* differs from other species may be related to the level of illumination, number of leaves (composite, with 4-6 pairs of leaflets) and the roughness of the canopy, factors that influence the spectral response (CARVALHO, 2010; FARIAS, 2015).

CONCLUSION

The analyzed species of the Myrtaceae and Fabaceae families, present in the UFSM Botanical Garden, showed relevant differences in spectral responses. *Psidium guajava* showed a higher reflectance factor in the visible spectrum, while *Eugenia involucrata* showed a higher reflectance in the IPV. The species *Acca sellowiana* and *Psidium guajava* showed differences between them in the visible and near-infrared (PVI) bands. As for the species belonging to the Fabaceae family, *Libidibia ferrea* stood out from the others due to the energy reflectance in the green band, while in the IVP range there was a decrease of the species *Cassia leptophylla* when compared to *Libidibia ferrea* and *Senna multijuga*.

REFERENCES

1. Carvalho, P. E. R. (2010). Espécies arbóreas brasileiras. Coleção espécies Arbóreas, v. 4 Brasília, DF: Embrapa informações Tecnológica; Colombo, PR: Embrapa Florestas.

2. Coura, S. M. D. C., Piromal, R. A. S., Canavesi, V., Gomes, M. N., Quirino, V. F., Ponzoni, F. J. (2005). Comparação das características espectrais das espécies Ligustrum japonicum Thunb. e Cassia macranthera DC. *Anais... XII Simpósio Brasileiro de Sensoriamento Remoto*, Goiânia, INPE, p. 1477-1484.

3. Curran, P. (1986). Principles of remote sensing. New York, USA.

4. Faria, R. M. (2015). Classificação temporal de imagens Landsat 8 para o monitoramento das mudanças do uso da terra. Monografia Graduação em Geografia da Universidade Federal de Viçosa, Minas Gerais – MG.

5. Ferri, C. P., Formaggio, A. R., & Schiavinato, M. (2001). Avaliação de índices de pigmentos fotossintéticos na estimativa da concentração de clorofila a, clorofila b, clorofila total e carotenóides nas diferentes fases de desenvolvimento da cultura da soja (Glycine max [L], Merril). *Anais... X Simpósio Brasileiro de Sensoriamento Remoto*, Foz do Iguaçu, INPE, p. 71-78.

6. Gitelson, A., Viña, A., Ciganda, V., Rundquist, D., & Arkebauer, T. (2005). Remote estimation of canopy chlorophyll content in crops. *Geophysical Research Letters, 32*(8).

7. Guyot, G., Guyon, D., & Riom, J. (1989). Factors affecting the spectral response of forest canopies: a review. *Geocarto International, 4*(3), 3-18.

8. INMET. Instituto Nacional de Meteorologia. [Link](http://www.inmet.gov.br/sonabra/pg_dspDadosCodigo_sim.php?QTgwMw). Acessado em: 17 de abr. de 2018.

9. Jensen, J. (2009). Sensoriamento Remoto do Ambiente: uma perspectiva em Recursos Terrestres. São José dos Campos, SP: Parênteses.

10. Käfer, P. S., Rex, F. E., Santos, M., & Sebem, E. (2016). Caracterização espectral e NDVI de espécies florestais das famílias Fabaceae, Myrtaceae, Rutaceae e Salicaceae. *Enciclopédia Biosfera, 13*(23).

11. Lippert, D. B., Benedetti, A. C. P., Muniz, M. F. B., Pereira, R. S., Biernaski, C. A. J., Finkenauer, E., & Berra, E. F. (2016). Comportamento espectral de folhas de Eucalyptus globulus (Labill.) atacadas por Mycosphaerella spp. nas regiões do visível e do infravermelho próximo do espectro eletromagnético. *Ciência Florestal, 13*(23), 262-275.

12. Ponzoni, F. J., & Shimabukuro, Y. E. (2010). Sensoriamento remoto no estudo da vegetação. São Jose dos Campos: Parêntese.

13. Ponzoni, F. J., Shimabukuro, Y. E., & Kuplich, T. M. (2012). Sensoriamento Remoto da vegetação. São José dos Campos, SP: Oficina de Textos.

14. Santos, J. J. D., Chaves, J. M., Souza, D. T. M., Rocha, W. D. J. S. D. F., & Santos, S. M. B. D. (2017). Análise do comportamento espectral das espécies vegetais Algaroba e Catingueira em

ambiente semiárido: um estudo em Curaçá-BA. *In: Anais... XVIII Simpósio Brasileiro de Sensoriamento Remoto*, Santos, INPE, 5492-5498 p.

15. Sims, D., & Gamon, J. (2002). Relationships between leaf pigment content and spectral reflectance across a wide range of species, leaf structures and developmental stages. *Remote Sensing of Environment, 81*(2-3), 337-354.

16. Schröder, T., Pereira, R. S., Zimmermann, A. P. L., Redin, C., Machado, L. M., Fleck, M. D., & Rocha, N. S. D. (2015). Influência de métodos de coleta de dados espectrorradiométricos sob índices de vegetação em eucalipto. *Revista Eletrônica de Gestão, Educação e Tecnologia Ambiental, 19*(3), 690-701.