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Relation of *Peperomia obtusifolia's* Anomalous Leaf Reflectance to its Leaf Anatomy

Light absorptance by water stored in the cells of *Peperomia's* leaf hypodermis caused the absence of a near-infrared light reflectance peak at about the 2.2 μm wavelength.

In 1966-1967 it was noted that succulent leaves of *Peperomia* (plant species unknown) had an anomalous near-infrared light reflectance; i.e., the leaf reflectance peak at about the 2.2-μm wavelength, characteristic of nonsucculent plant leaves (Gausman *et al.*, 1973), was lower or absent. Data, published by Sinclair (1968), confirmed this observation. Moreover, we found (H. W. Gausman and D. E. Escobar, unpublished data, Weslaco, Texas) that Peperomia's leaf reflectance and anatomy are not characteristic of some other succulents (plants with developed water-storing tissue in their flat stems (platyclades) or leaves (Fahn, 1967)).

Our objective was to find the cause of the absent leaf reflectance peak at about the 2.2-μm wavelength, within the 2.0- to 2.5-μm waveband, for *Peperomia obtusifolia* A. Dietr. Such information is needed to increase the knowledge about the interaction of light with plant leaves' anatomy and to help discriminate among plant species with remote sensing techniques.

Abstract: *We explained the absence of a near-infrared light reflectance peak, at about the 2.2-μm wavelength, from Peperomia obtusifolia A. Dietr. leaves by comparing their spectrophotometric measurements for upper and lower surfaces and anatomical components, including untreated, dehydrated, and hydrated hypodermises. This absence was caused by light absorptance by water stored in the cells of Peperomia's leaf hypodermis. This additional knowledge about the interaction of light with plant leaf anatomy supports previous evidence that future design of multispectral scanners might include a waveband centered about the 2.2-μm wavelength to enhance plant species discrimination, such as succulents versus nonsucculents, by remote sensing, providing there is sufficient soil-vegetation contrast. The knowledge also will be of interest to researchers in the area of leaf-irradiance dynamics.*

Materials and Methods

Total diffuse reflectance was measured for five replications of upper (adaxial) and lower (abaxial) surfaces of *Peperomia obtusifolia* A. Dietr. leaves and for *Peperomia*'s partitioned (either stripped-off or hand-dissected) leaf components: palisade-spongy

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parenchyma-lower epidermis; upper epidermis-hypodermis; and hypodermis—untreated (fresh), dehydrated, and rehydrated. We compared *Peperomia's* and grain sorghum's (*Sorghum bicolor* (L) Moench) (Gausman *et al.*, 1973) leaf reflectance spectra, as representative of succulent vs. nonsucculent plant species, respectively.

Total diffuse reflectance of single leaves on both plants were measured over the 0.5- to 2.5-μm waveband with a Beckman* Model DK-2A spectrophotometer, equipped with a reflectance attachment. Data were corrected for decay of the barium sulfate standard (Allen and Richardson, 1971) to give absolute radiometric data.

Measurements of reflectance and fixation of tissue for histological study were completed within 2.5 hours after leaves were collected. Untreated hypodermal section, about 1.5 × 3.0 cm, were dehydrated from a 97.4 percent mean water content to 2.2 percent by oven drying at 68°C for about 1 hour (a longer drying time caused leaf sections to curl and become brittle); these sections were rehydrated to an average water content of 92.0 percent by vacuum infiltration. Water contents of untreated and rehydrated hypodermal sections were determined on a dry-weight basis by oven drying at 68°C for 48 hours.

Tissue pieces sampled from the center of leaves were fixed in formalin-acetic acid-alcohol, dehydrated with a tertiary butanol series, embedded in paraffin, stained with the safranin fast-green combination, and transversally microtomed at 12-μm thickness (Jensen, 1962). Photomicrographs were obtained with a Zeiss standard Universal Photomicroscope.

Reflectance data at the 2.2-μm wavelength were analyzed for variance (Steel and Torrie, 1960) to determine the statistical significance among untreated, dehydrated, and rehydrated hypodermises.

Results and Discussion

Reflectance spectra for grain sorghum's upper and *Peperomia's* lower leaf surfaces had similar symmetry (figure 1) typical of nonsucculent leaf spectra of crop plants (Gausman *et al.*, 1973). However, *Peperomia's* reflectance spectrum for its upper leaf surface was atypical, especially over the 1.45- to 2.5-μm waveband; the most consistent anomaly was within the 2.0- to 2.5-μm waveband where there was no reflectance peak centered at about the 2.2-μm wavelength. Therefore, this waveband was selected for further study.

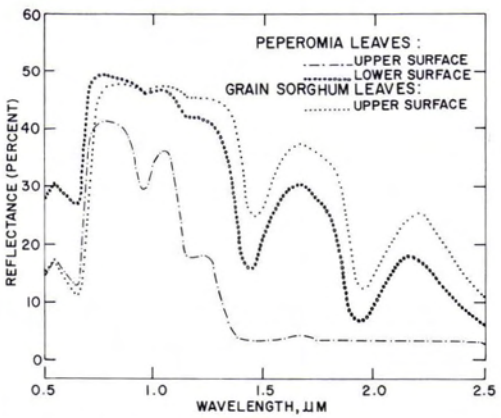

Fig. 1. Total diffuse light reflectance spectra over the 0.5- to 2.5-μm waveband of grain sorghum's upper and *Peperomia*'s upper and lower leaf surfaces.

We deduced that *Peperomia*'s leaf anatomy (Figure 2) was involved in these results because its upper surface gave atypical reflectance, whereas its lower surface gave "typical" reflectance as compared with crop plant spectra (Figure 1). Consequently, spectral measurements were made on *Peperomia*'s leaf components (Figure 3). The stripped-off palisade-spongy parenchyma-lower epidermis combination gave the "typical" reflectance spectrum, whereas the upper epidermis-hypodermis component gave the anomalous reflectance spectrum. The upper epidermis alone did not give the anomalous reflectance spectrum. Thus, we showed that the hypodermis caused the anomalous reflectance, but further research was needed to determine what factor within the hypodermis was causing the anomaly.

Hypodermal cells store water (Fahn, 1967), and water in leaves is a strong ab-

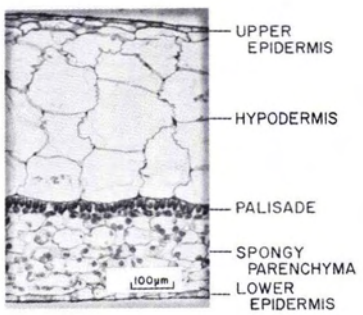

Fig. 2. Transection of a *Peperomia obtusifolia* A. Dietr. leaf, identification of leaf components after Murty (1960).

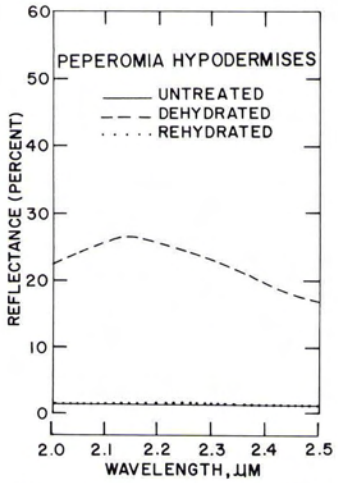

FIG. 3. Total diffuse light reflectance spectra over the 2.0- to 2.5-μm waveband of *Peperomia's* untreated, dehydrated, and rehydrated hypodermises.

sorber of near-infrared light over the 1.45- to 2.5-μm waveband (Thomas *et al.*, 1971). Therefore, we measured reflectance spectra for (1) untreated (fresh), (2) dehydrated, and (3) rehydrated hypodermal sections, respectively (Figure 3). The "typical" reflectance peak at about the 2.2-μm wavelength was obtained for dehydrated but not for either untreated or rehydrated sections. The reflectance difference between hydrated and dehydrated sections was statistically significant, $p = 0.01$. These results clearly showed that absorption of near-infrared light by the water stored in the cells of *Peperomia's* hypodermis was responsible for the absence of the reflectance peak centered at about the 2.2-μm wavelength within the 2.0- to 2.5-μm waveband.

CONCLUSION

We believe that this work is the first to relate reflectance to a leaf's hypodermal layer, and it supports our contention that a waveband centered about 2.2 μm might be considered in sensor design for plant species discrimination with suitable soil-vegetation contrast (Gausman *et al.*, 1972), such as possibly distinguishing some succulent from non-succulent plant species although, the energy level at the 2.2-μm wavelength is low. Intensive research is presently being conducted to characterize the reflectance spectra and anatomy of other succulent leaves or platyclades of several plant genera.

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