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SPECTRA OF THE MONTH

EXPLORING FLOWER REFLECTIONS ACROSS VISIBLE, UV, AND NIR SPECTRUMS

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INTRO

BACKGROUND OF APPLICATION

May is synonymous with blooming flowers and lush greenery, echoing the ancient adage, “April showers bring May flowers,” believed to date back nearly a thousand years. As spring flourishes and summer approaches, it's fitting that May Day, celebrated on May 1st, heralds the onset of summer. Although it falls technically at the midpoint between the Northern Hemisphere's spring equinox and summer solstice, it marks a festive transition into the warmer season.The earliest known May celebration was the Floralia, of festival of Flora, which celebrated the Ramon goddess of flowers. Indeed, even the earliest May holidays celebrated the beauty of flowers. This month, we wished to continue this tradition by performing measurements on a few of the many flowers present around our U.S. office building. While reflection color measurements of each flower would be the most obvious technique, we also extended the measured spectral range into the UV and NIR spectral ranges to determine if any flowers showed reflection spectra outside the visible range.

This experiment aims to measure the reflectance of various flower samples in the visible, UV, and NIR spectral ranges. Multiple flower samples were selected outside of our U.S. office building and were measured without removing any samples from their main plant (Figure 1). To perform these measurements, we employed our new Spectroscopy Field Kit that allows a single user to take spectroscopic measurements in the field and record data to a tablet computer.

FIGURE #1 Flower samples measured for this experiment (from left to right: Flower 1, 2, 3, 4, 5, and 6.

DESCRIPTION OF SPECTROSCOPY SETUP

The setup for this experiment (Figure 1) utilized our new Spectroscopy Field Kit, only available in the Americas. This compact, all-in-one product allows a single user to take measurements and save data in the field, or provides a concise preconfigured package for those looking to perform specific data collection. The heart of this specific bundle was our AvaSpec-NXS2048CL, more commonly known as the NEXOS™. This compact instrument is the next-generation photonics backbone spectrometer, designed to empower a wide range of applications in various industries. This device is built using our new semi-automated manufacturing technique that ensures higher levels of consistency and reproducibility unit-to-unit. The NEXOS™ offers USB2.0 communication as well as RS232 and SPI communication protocols, a CMOS linear array detector, ultra-low stray light as low as 0.1%, and a signal/noise ratio of 375:1. Furthermore, this spectrometer can be customized with a wide range of gratings (13 total available) and the replaceable slit option is now standard for non-OEM units, which provides even more flexibility for a variety of application needs. The unit used in this experiment was optimized for the visible range as well as portions of the UV and NIR ranges, with a 2000-1100 nm wavelength range and a 25-micron slit installed.

FIGURE #2 Experimental Setup for Flower Measurements: The spectrometer, light source, and battery were carried in a small backpack. The spectrometer connected to a tablet via USB extension, and the trigger connected to both the spectrometer and light source with a custom interface cable. A reflection probe, linked to the spectrometer and light source, was mounted in the trigger. Measurements were taken by pointing the trigger perpendicular to each flower sample and pressing the trigger button to save the spectra.

The light source used with this bundle was the AvaLight-Hal-S-Mini, a compact, stabilized halogen light source. Designed to work from visible light to near-infrared, the AvaLight-Hal-S-Mini is equipped with an adjustable focusing on the fiber connection to maximize output power at desired wavelengths. Other features of the AvaLight-Hal-S-Mini include an internal TTL shutter that is controllable from an AvaSpec spectrometer, and the ability to direct attach a cuvette holder, attenuator, or a combined cuvette holder and attenuator.

Other accessories included in experiment included a 200-micron core reflection probe (FCR-7UVIR200-1.23-PBX), a Microsoft Surface Go 3 tablet to run AvaSoft in the field, a USB extension cable, a battery pack to power the Hal-S-Mini remotely, a WS-2 reference tile with custom 3D-printed mount attached to the tablet, a custom 3D-printed trigger with internal electrical components built in-house to point the reflection probe at the samples and externally trigger data collection, a custom interface cable to connect the trigger to the spectrometer and light source, and a holster to hold the trigger when not in use. The spectrometer, light source, and battery were carried in a small backpack (not pictured).

DESCRIPTION OF METHODOLOGY

The flower samples used for this experiment were all flowers blooming outside our office building, with the exception of Flower 5, which was the leaf of a flowering plant. No preparation was performed for the samples, and they were measured directly outside without clipping any samples off the main plant. To perform the measurements in the field, the spectrometer, light source, and battery were stored and carried in a small backpack (not pictured). The spectrometer was connected to the tablet using a USB extension cord, and the trigger was connected to the spectrometer and light source with a custom interface cable. The reflection probe was connected to the spectrometer and light source and then mounted into the trigger. Flower measurements were taken by pointing the trigger about perpendicular to each flower sample and pressing the trigger button to save the spectra. The trigger is equipped with a 3-position switch that takes a dark measurement in the first position (along with shuttering the light source), a reference measurement in the second position, and saves a spectrum in the third position.

For data analysis, we used the Reflectance mode in AvaSoft, our exclusive custom software package. This mode is designed for reflection applications, where the reference measurement will report 100% and the dark measurement will report 0%. In this experiment, our WS-2 white reference tile was used as the reference We used an integration time of approximately 800 microseconds, which can be adjusted to increase or decrease the amount of light being measured at one time and affects the overall magnitude of the reported spectrum. We set averaging to 100, meaning 100 measurements were averaged together for each reported spectra to provide more consistent spectral results. There is a limitation of the trigger saving the spectra as Scope data, though by taking the dark and reference measurements beforehand, the data can be analyzed in Reflectance mode.

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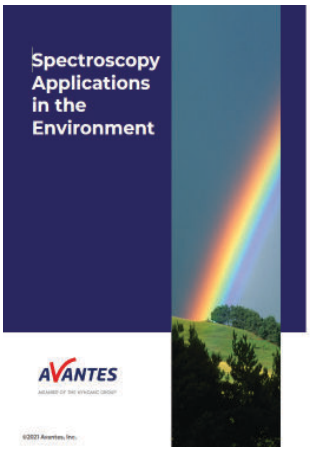

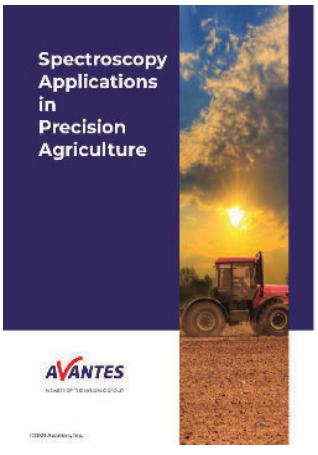

TEST DATA AND RESULTS

Displayed below are the reflectance spectra of the flower samples.

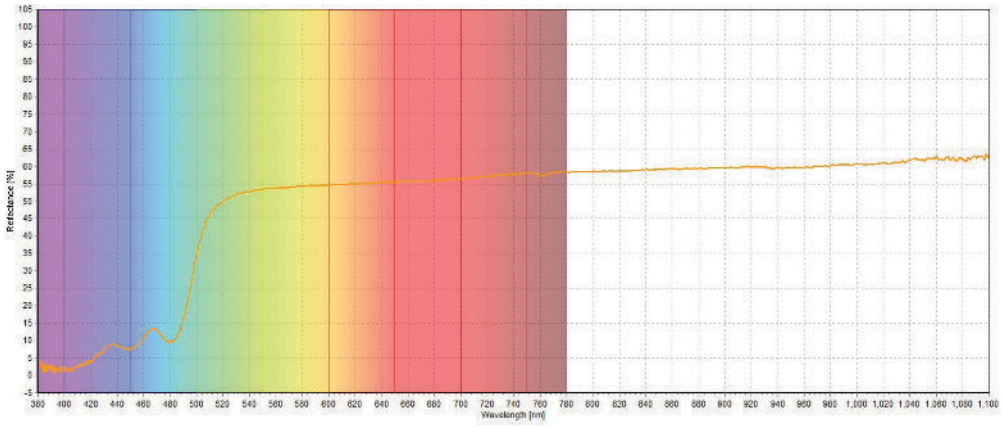

FIGURE #3: Reflectance spectrum of Flower 1.

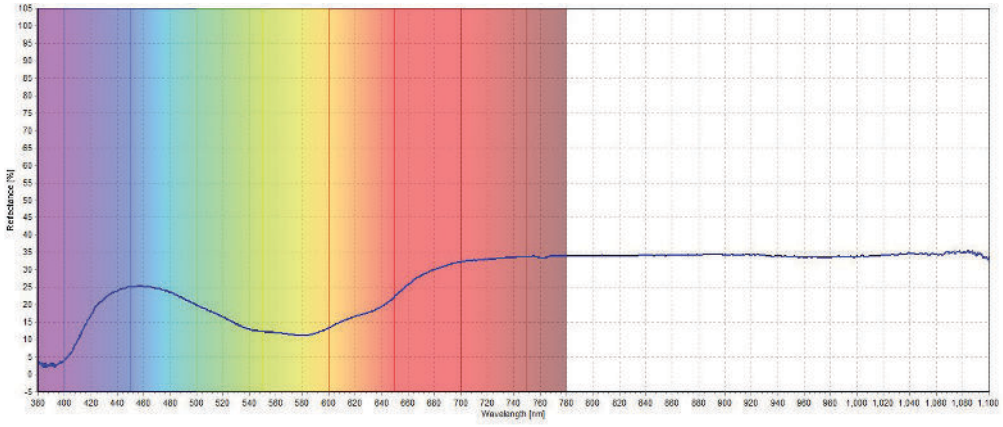

FIGURE #4: Reflectance spectrum of Flower 2.

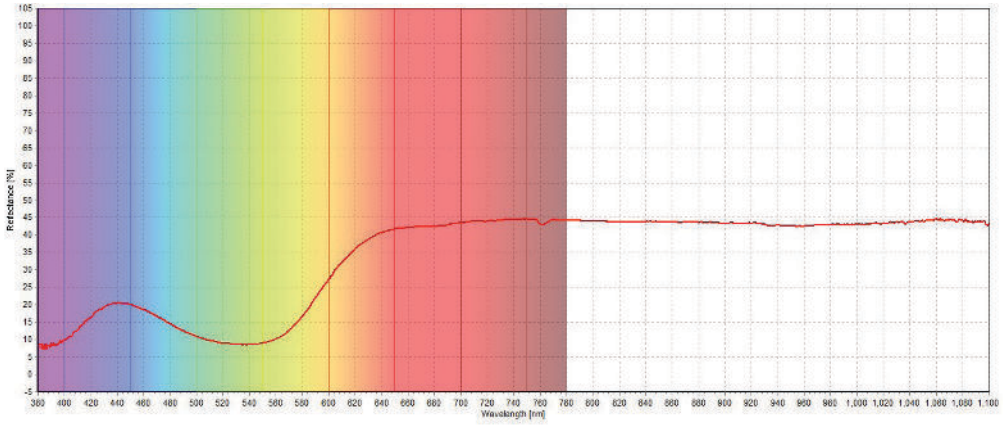

FIGURE #5: Reflectance spectrum of Flower 3.

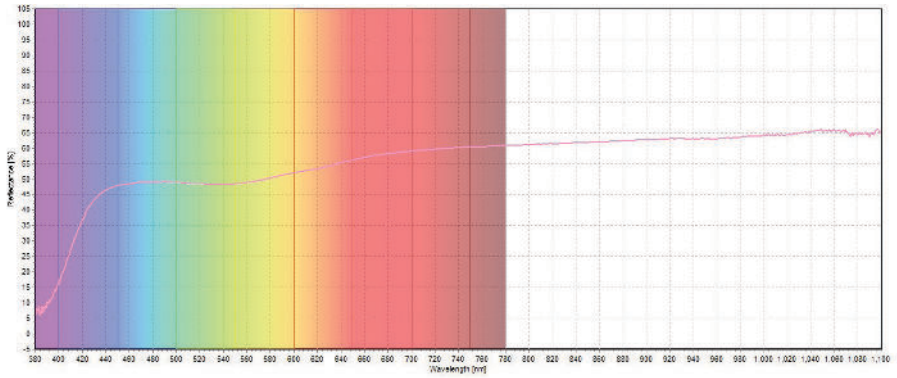

FIGURE #6: Reflectance spectrum of Flower 4.

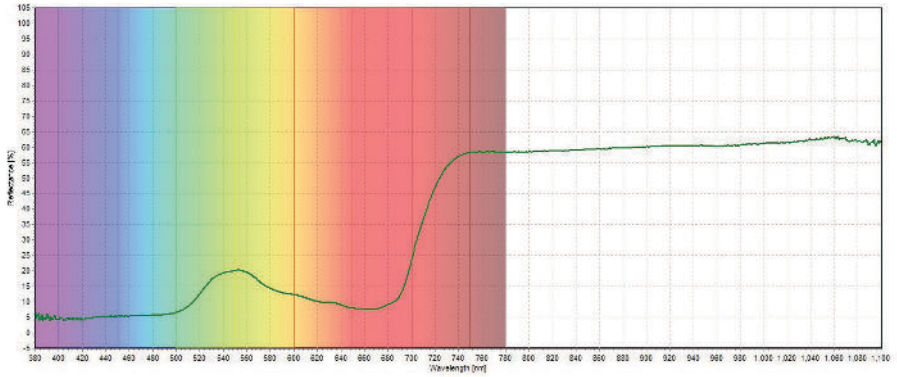

FIGURE #7: Reflectance spectrum of Flower 5.

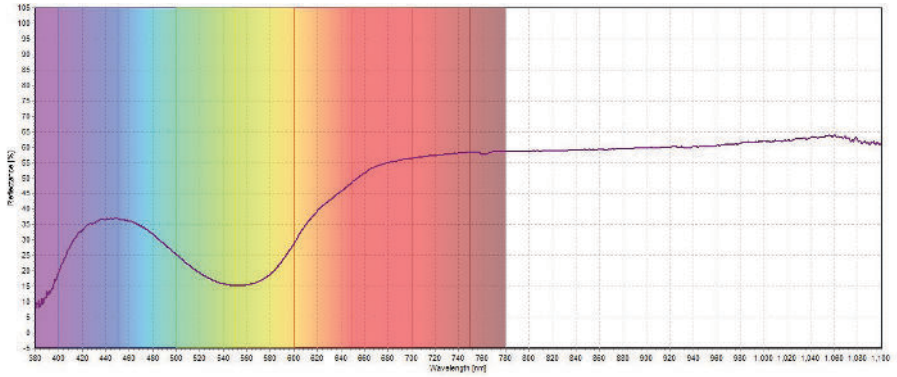

FIGURE #8: Reflectance spectrum of Flower 6.

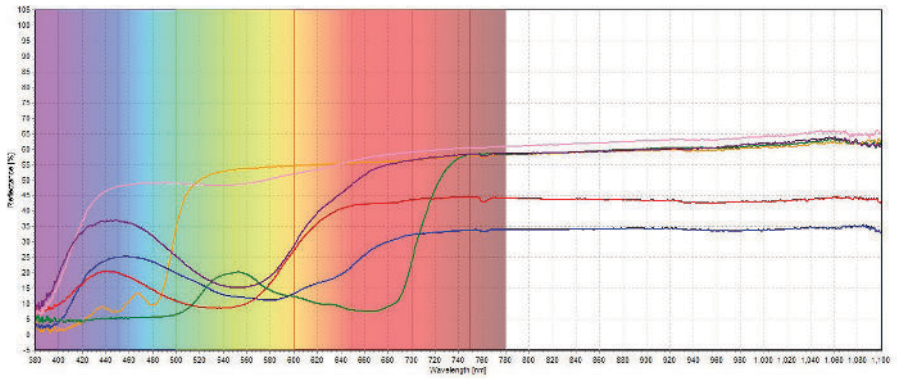

FIGURE #9: Reflectance spectra of Flower 1 (orange), Flower 2 (blue), Flower 3 (red), Flower 4 (pink), Flower 5 (green), and Flower 6 (purple), shown together for comparison.

ANALYSIS

All six flower samples show reflection peaks in areas of the visible spectrum that match their perceived colors. Flower 1 appeared as a bright yellow and showed significant reflectance from around 520 nm to 1100 nm as well as some minor peaks around 435 nm and 465 nm (Figure 3). Flower 2 appeared as a deep blue with some purple hues and showed a reflectance peak around 455 nm (Figure 4). Flower 3 appeared as a less saturated red with some purple hues and showed significant reflectance from around 650 nm to 1100 nm as well as a reflectance peak around 440 nm (Figure 5). Flower 4 was a bright flower with an almost white color in the center of each petal with some pink and purple shades that became more present near the edge of each petal. This flower showed noticeable reflectance values from around 430 nm to 1100 nm, with a shallow peak around 475 nm (Figure 6). Flower 5 was a leaf from a flowering plant that appeared as a vibrant green and showed almost no reflection in the visible range except for a peak around 550 nm (Figure 7). Lastly, Flower 6 had a magenta color and showed a reflection peak around 450 nm as well as a higher reflectance from 650 nm to 1100 nm, indicating hints of red (Figure 8). A graph of all the spectra together is included for comparison of all samples (Figure 9).

The NIR ranges of each flower sample were relatively flat, indicating uniform reflectance of the whole wavelength range. Beyond this, the reflectance of the NIR range seemed to correlate with the perceived lightness of each flower sample, with the bright yellow Flower 1, almost white color of Flower 4, and bright magenta of Flower 6 showing higher reflectance in the NIR range compared to Flower 2 and Flower 3. Flower 5, or the leaf, was an interesting exception, as the color did not appear as vibrant despite showing similar reflectance as the lighter or brighter flower samples. This, along with by far the lowest reflectance in the visible range besides the peak around 550 nm, could indicate that the leaf is much more efficient in its reflective properties since it plays a key part in capturing light for photosynthesis. While we aimed to also analyze part of the UV spectrum for this study, the light source used did not produce a significant amount of light in this region, leading to extremely noisy data that could not be analyzed. As such, this wavelength range was excluded in the presented spectra and only 380-1100 nm was analyzed. Replacing this light source with one with more signal and stability in the UV region, such as a pulsed xenon source, may have yielded better results for this range.

CONCLUSION

In conclusion, the present experiment highlights our new Spectroscopy Field Kit and its ease of use in taking field measurements. Multiple floral specimens were quickly measured for reflectance, and these spectra showed reflectance peaks that matched the visible color of the samples. All samples showed a rather flat reflectance in the NIR range, suggesting uniform reflection of this wavelength range. The halogen light source used for this experiment had very little power in the UV range, so the reflectance spectra for all samples in this range were not useful and excluded. The AvaSpec-NXS2048CL is a highly versatile, compact spectrometer that is an ideal solution for OEM applications or for any measurements where a smaller instrument is preferred, such as the field work we performed for this study. The AvaLight-Hal-S-Mini is an equally versatile light source that provides broad spectral coverage from 360-2500 nm thanks to a tungsten-halogen bulb.

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