Botanical Scans as a Learning Aid in Plant Identification Courses

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Summary. **High-resolution scans of plant cuttings were made for a plant identification course to create additional study resources. Stems, flowers, leaves, and other parts with identifiable features were cut and placed on a high-quality flatbed scanner. A framework suspended a black background cloth above the cuttings to create a dark scanning environment, and it was placed far enough away from the scanner glass so as not to appear in the scanned image. Botanical scans can be shared, manipulated, composed, and otherwise provided to students for study materials. Scans are complementary to other common study aids such as pressed herbarium samples or photography.**

Plant identification courses are common in horticulture-, botany-, ecology-, and agriculture-based curricula worldwide (Kirchoff et al. 2014; Randler 2008; Stagg and Donkin 2013; Weigelt et al. 2021). These courses teach students to identify a variety of species using morphological features. Depending on the course and the instructor, students may also be required to know the common name, family, genus, specific epithet, and cultivar (Wilson and Miller 2015). Two such courses are taught at Iowa State University (Ames, IA, USA)—HORT 240: Landscape Trees, Shrubs, and Woody Vines for Landscaping and HORT 330: Herbaceous Annuals and Perennials. High-quality teaching materials are used in both courses for lectures, laboratories, and for out-of-class study to show distinguishing features among plants. We sought to complement existing teaching materials, including live materials (cut, greenhouse, or field), pressed herbarium specimens, and photography with botanical scans.

Scanning existing herbarium specimens has enhanced access to herbaria via the Internet and has allowed for digital backup of physical specimens (Kovtonyuk et al. 2021; Seregin 2016). Scanners used in conjunction with custom software algorithms have been used to estimate leaf area and measure root structure (Easlon and Bloom 2014; Suchoff et al. 2017). Botanical scanning has been used by artists to capture plants as still-life displays (Hoverkamp 2022), in collegiate art of horticulture courses (Eames-Sheavly 2016), and for use with image manipulation software to create dramatic effects (Cramer 2018, 2021). Scans have also been used in entomology to digitize pinned specimens (Buchmann 2011).

Methodology of botanical scanning

Botanical scans are created using plant organs and a high-resolution, large-format graphic scanner [e.g., Expression 12000XL (Epson America, Inc., Los Alamitos, CA, USA)]. High-end graphic scanners have large scanning areas (e.g., 12.2 × 17.2 inches) and scan at a high resolution [e.g., 2400 × 4800 dots per inch (dpi)] compared with traditional office-type flatbed scanners, which are more limited in size (e.g., 8.5 × 14 inches) and have a lower maximum resolution (e.g., 1200 × 1200 dpi). Plant cuttings can be arranged as desired, including in formal arrangements or with different features exposed, such as a dissected inflorescence or fruiting structure. Multiple plants or plant organs may be scanned, allowing simultaneous front, side, and top views of specimens to be captured in one scan (Fig. 1). Similarly, multiple cultivars of flowers could be arranged on the scanner to capture comparative compositions. In each case, the plant material rests on top of the scanner surface thus, minimal distortion occurs, compared with pressed specimens.

After the cuttings are placed on the scanner, a framework (e.g., 0.5-inch-diameter polyvinyl chloride tubing) is placed over the scanner to suspend a black backdrop cloth above the scanner (Fig. 2). The cloth should be large enough to drape over the framework and enclose the scanner to make a light-excluding chamber. The framework should be tall enough to keep the draped fabric off the plant material and away from the scanner glass. If held far enough from the glass, the cloth will be beyond the scanner's depth of field and will result in a dark, uniform background to the scan. The cloth should be a nonreflective material, such as felt.

The scanner software settings will determine the scanned image resolution, with maximum resolution scans resulting in larger file sizes and slower scanning speed. Maximum resolution scans may take 1 to 2 min per scan and a few more minutes to process the image. Lower quality scans, which are still superior to office-grade flatbed scanners, may be a good compromise between image quality and processing speed. Scanned images can be postprocessed with imaging software and saved to multiple image sizes. Some image software may allow batch processing of images, which can automate some tasks, such as image resizing for smaller file sizes.

Botanical scans compared with alternatives

Botanical scans offer an alternative to dried herbarium specimens,

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
2.54	inch(es)	cm	0.3937

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Fig. 1. Botanical scans of hibiscus [*Hibiscus* sp. (left)] and snowflake [*Leucojum vernum* (right)] showing the ability to capture multiple morphological features, true color, and scale within single scans to aid in botanical identification courses.

live specimens, and photography, which are commonly used in identification courses and offer some complementary benefits. Mounted herbarium specimens have been used for plant identification and are stable for decades (Baskauf and Kirchoff 2008; Kovtonyuk et al. 2021). However, herbarium specimens have drawbacks. When cut specimens are pressed between drying sheets, it can be difficult to maintain a desired arrangement where inadvertent overlapping, leaf folding, and other problems can occur. The flattening process can distort some delicate features or render the depth of a feature poorly. As specimens dry and age, discoloration—typically browning, darkening, or fading—occurs, making specimens less representative of the original cutting (Baskauf and Kirchoff 2008). Botanical scans do not need to be dried, may offer more forgiveness in the arrangement of leaves and flowers, are not pressed on the scanner bed, and are not distorted during the scanning process. Botanical scans also capture the full color of the cuttings and do so with even lighting. Both botanical scans and herbarium specimens maintain the scale of the plants proportionally to one another. When a botanical scan is viewed "full size" or at the same zoom amount in image-viewing software, the sizes of items between two different scans are the same, making cross comparison possible.

Fig. 2. Botanical scans are captured when plant samples are arranged on the flatbed glass of a high-end scanner over which a polyvinyl chloride framework supports a suspended black-felt background cloth. The cloth is positioned to cover the scanner and framework completely before scanning.

Live cut specimens are challenging to maintain, may age and store unreliably, and are subject to seasonality. Greenhouse-grown live specimens work well for annuals and perennials, but are difficult or impossible for woody plant material. Botanical scans made with fresh live cuttings can be made available to students at any time and do not lose quality if they can be collected and scanned in season.

Photography, particularly digital photography, is fast, cheap, and offers the ability to zoom for far-away or high-up items or for detailed, close-up macro photography (Baskauf and Kirchoff 2008). Color rendering in photos is affected by sunlight, time of day, and atmospheric conditions, thus leading to some variability in photos. The sense of scale in photographs can also be difficult to tell unless visual cues or image scales are included. Botanical scans are evenly lit by the scanner light and will be consistent scan-to-scan for most of the scanner's life until the lighting element deteriorates. It is simple to place a scale in the corner of the scanner, and scans made using the same capture settings will be the same size at the same zoom scale in image-viewing software.

It is worth noting drawbacks to this technique. Scanning is best done with fresh cuttings and of a size that will fit on a scanner bed. Even with large graphical scanners, this is limited to about a 12- × 17-inch area. If cuttings cannot be obtained or if the features are larger than the scanner, this method is not suitable. High-end graphical scanners can be expensive ($3000–$4000) but are of a similar cost range of high-end digital cameras with good or multiple lenses. Once captured, scans can be saved to different sizes and image formats, used in lectures and assessments, and manipulated to form compositions to compare different morphological features of similar plants.

Conclusion

Botanical scans produce an additional study resource for students that complement the shortcomings of more commonly used herbarium specimens and plant photography. Botanical scanning is reproducible, at a known scale, and is an efficient use of plant material and time that yields a high-quality, multiuse product. Future research will assess student perceptions of botanical scans compared with other study materials for plant identification courses.

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