

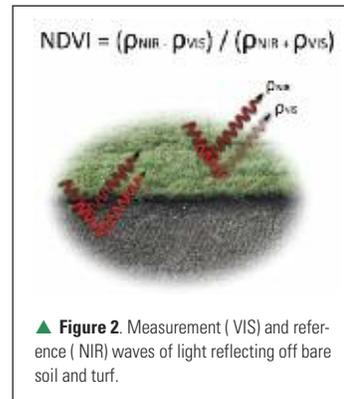
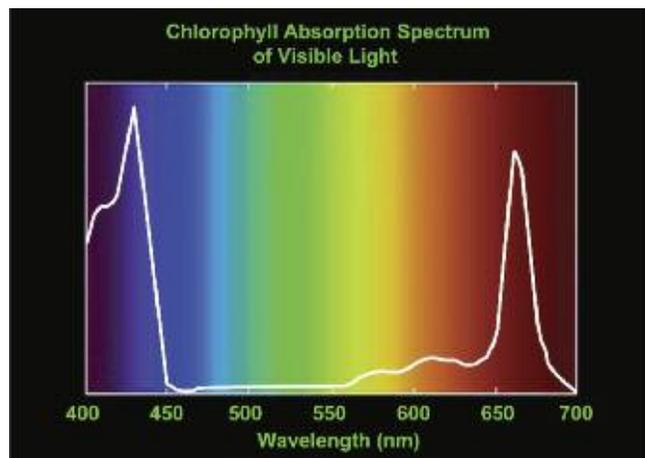
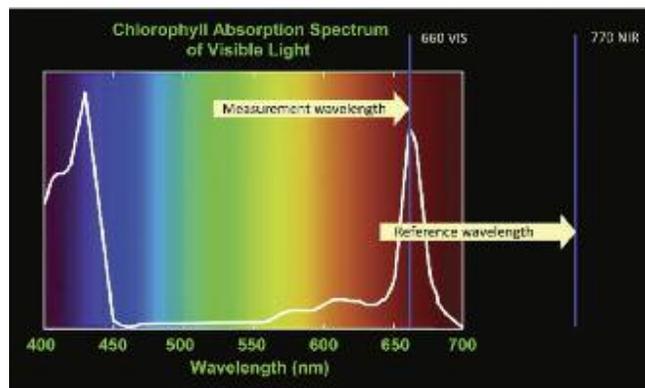
# Using canopy reflectance tools in turfgrass management

Turfgrass managers can tell a lot about turf just by looking at it—and the more experienced they are, the better their judgment. Nutrient status, pest damage, abiotic stresses (drought, traffic, etc.) are all visible to the trained eye. Sometimes, however, it's good to have some tools to help; the highly trained manager may not be available to see everything, or the problem may produce very subtle effects. This article discusses some recent innovations in assessing turfgrass, developed and widely used in turf research, which might be useful to the turfgrass manager.

What we see when we look at a turfgrass sward could be termed “canopy reflectance”; it's just the ambient sunlight reflected off the leaves in the full visible light spectrum. A trained

▼ **Figure 1. Top:** The peaks show the wavelengths of visible light that are absorbed by chlorophyll (Photosynthetically active radiation).

▼ **Figure 3. Bottom:** Measurement (660 nm) and reference (770 nm) wavelengths used by the Greenseeker to calculate NDVI.



▲ **Figure 2.** Measurement (VIS) and reference (NIR) waves of light reflecting off bare soil and turf.

researcher or turfgrass manager learns to record and interpret the details of what they see, whether it's the off color of nutrient deficiency or spray damage, or the darkening of drought stress. However, both in research and in practical management situations, we work with less well-trained helpers, and

will benefit from techniques that remove the subjectivity and observer bias, and reduce the need for training.

One very familiar tool is a camera, and with improved digital cameras this is a very useful adjunct to assessing problems. However, even though they can form an important permanent record, the digital photos still need to be interpreted. Researchers are working on improving software to analyze digital images to document and quantify turf characteristics (weed and disease infestation, drought and nutrient stress), but these full spectrum techniques are still relatively early in development for widespread turf use.

A more mature, and somewhat simpler, technology for assessing turf involves restricting the wavelengths observed to ones that we have learned through experience are indicative of turfgrass problems. Photosynthesis in plants involves chlorophyll absorbing light to power the plant, and the wavelengths that chlorophyll absorbs are a subset of the sunlight hitting the plant (Fig. 1). Light that chlorophyll absorbs is not reflected, and the light hitting the plant looks different from that reflected. Of the visible wavelengths, chlorophyll absorbs red light, generally, so the light reflected is white minus red = green. The wavelengths that chlorophyll absorbs are often termed photosynthetically active radiation or PAR.

Various sensors have been developed which all function in a similar fashion, comparing the reflectance off a surface (e.g. turf) of a wavelength that chlorophyll absorbs (measurement wavelength), with one that chlorophyll does not absorb (reference wavelength). Fig. 2 shows light reflecting from turf and bare soil. The longer (reference) wavelength is not absorbed by chlorophyll and is reflected equally from both surfaces; the shorter (measurement) wavelength is partly absorbed by the plant, and the reflected amount is reduced. Usually the meas-



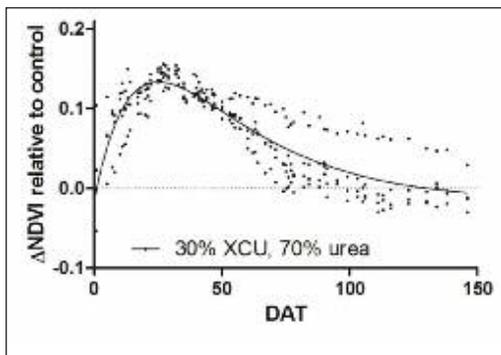
◀ **Figure 4. Left:** Greenseeker canopy reflectance sensor system.  
 ▶ **Figure 5. Right:** Spectrum FieldScout chlorophyll meter.

urement wavelength used is in the red (visible) part of the spectrum and the reference in the near-infrared (Fig. 3). Canopy reflectance sensors like this will report/record an index which is usually of the form  $(\rho_{NIR} - \rho_{VIS}) / (\rho_{NIR} + \rho_{VIS})$ . Rho ( $\rho$ ) is the reflectance, and you can see from the formula that when there is no absorbance by chlorophyll ( $\rho_{NIR} = \rho_{VIS}$ ) the top of the ratio is zero, and the index is zero. When all of the measurement wavelength is absorbed ( $\rho_{VIS} = 0$ ), the ratio becomes  $\rho_{NIR} / \rho_{NIR}$  or 1. Some sensor systems, like the Greenseeker (Fig. 4), will report an index between 0 and 1 (sometimes called the normalized-difference vegetation index, or NDVI), others like the Spectrum FieldScout (Fig. 5) multiply the index and report a value between 0 and 1000 (chlorophyll index).

**CANOPY REFLECTANCE IN TURF MANAGEMENT**

The key feature of canopy reflectance indices like NDVI and the chlorophyll index is that the values observed in turfgrass are very sensitive to a multitude of things of interest to a turf manager. Changes in nutrient status, moisture status, traffic, insects, disease, rootzone problems, and other biotic and abiotic stresses can all produce subtle shifts in canopy reflectance, some of which are even undetectable by a trained human eye.

Canopy reflectance, especially as it is affected by nutrient status, has become an important tool in precision agriculture, where maximizing yields and optimizing fertilizer inputs is tied to systems that measure reflectance. The uses in turfgrass management will likely be more complex as they develop, since yield and nutrient stress are



▲ **Figure 6.** Change in canopy reflectance following a single application of slow-release nitrogen fertilizer (points represent data from four replicate plots; the line is the best fit release curve; DAT = days after treatment).

only a small part of the stresses that turf experiences. For example, research is currently being done to examine the potential in water management, but most of the current use is in turf research.

A few examples of the power and sensitivity of

the system will, we hope, convince you that it is a technique to watch. The more the system is used in research, the faster the applications to the real world will be developed.

**FERTILIZER PERFORMANCE AND RELEASE CHARACTERISTICS**

Fig. 6 shows a sample of data collected from recent fertilizer performance trials at the Guelph Turfgrass Institute (GTI). The points show the change in NVI as a fertilizer application at day 0 gradually releases and increases the absorption of PAR to the maximum at ~25 days after treatment, then gradually declines as the fertilizer runs out at ~100 days. Using these techniques we can help fine tune release characteristics of fertilizers, but the same data could help a turf manager track nutrient status.

**GERMINATION, ESTABLISHMENT AND COVER DEVELOPMENT IN TURF**

Canopy reflectance can be used to track the establishment of newly seeded turf. In research trials, we can use this to assess different cultivars, blends and mixtures, or different management techniques in establishment. Fig. 7 shows cover development in a recent trial at the GTI, and Fig. 8 shows the change in canopy reflectance in one of the entries over the first 26 days after seeding. Fig. 9 shows data from an earlier trial, in this case using the chlorophyll index rather than NDVI. Sixteen Kentucky bluegrass cultivars show clear differences in speed of establishment as measured by canopy reflectance.



▲ **Figure 7.** Cover development in turf trial.

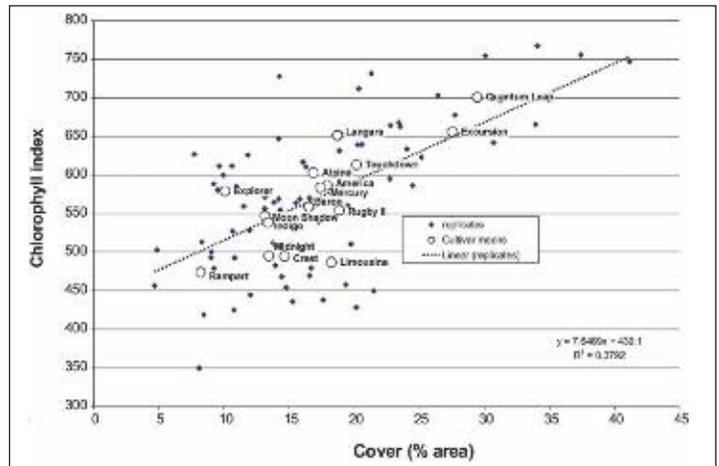
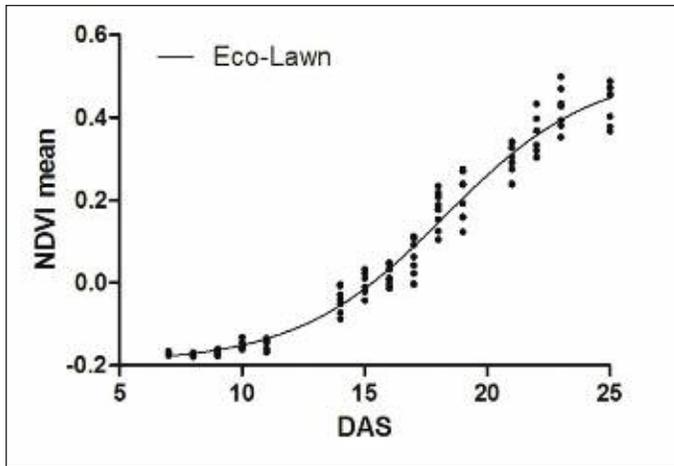
**DROUGHT STRESS, WATER USE AND LOCALIZED DRY SPOT**

Fig. 10 shows localized dry spot and treatment effects of wetting agents in a recent trial. If we look at the canopy reflectance and independent assessments of soil moisture (Fig. 11) and localized dry spot (Fig. 12), the potential of canopy reflectance to detect and help manage water problems is clear. We have also used the technique in assessing the effectiveness of different irrigation regimes in establishing turf from dry seeding, hydroseeding, and sod.

**OTHER BIOTIC AND ABIOTIC STRESSES**

As mentioned above, many stresses that affect turfgrass will be detectable in changes in canopy reflectance. We routinely use the

▼ **Figure 8. Left:** Increase in canopy reflectance with germination and cover development in seeded turf. ▼ **Figure 9. Right:** Association between grass cover and canopy reflectance (chlorophyll index) in Kentucky bluegrass cultivars.



technique in assessing trials involving dollar spot disease, for example. Fig. 13 shows symptoms of dollar spot as they develop in a recent trial, and Fig. 14 shows how the disease pressure shows up in the canopy reflectance data.

**WHAT'S NEEDED BEFORE THE TOOLS ARE WIDELY USED BY TURF MANAGERS?**

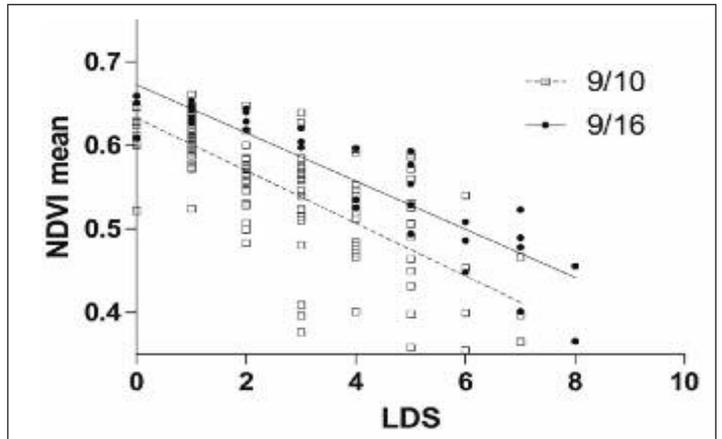
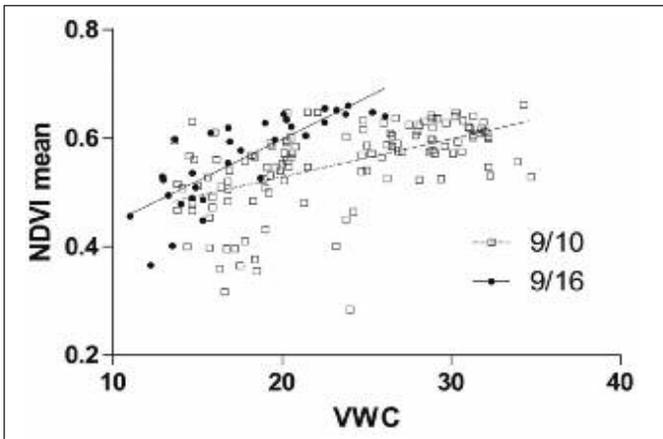
Experience. We need to have a better grasp of how the numbers change across species, management conditions, etc. It is a very

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▼ **Figure 11. Left:** Association between soil moisture (volumetric water content – VWC) and canopy reflectance in wetting agent trial. ▼ **Figure 12. Right:** Association between localized dry spot (rated visually) and canopy reflectance in wetting agent trial.



**Figure 10.** Localized dry spot in bentgrass turf; some plots are treated with wetting agents.

young technique outside of research applications.

**Calibration.** The sensitivity of the tool to so many factors means that in order to isolate effects of interest, we need to learn to calibrate to remove extraneous noise (we use untreated control plots in research, and similar techniques can be used in management).

**History.** The more the tools are used on a particular turf area, the better the information. The advantage of these tools is that they automatically record and time-stamp the information, and if so-

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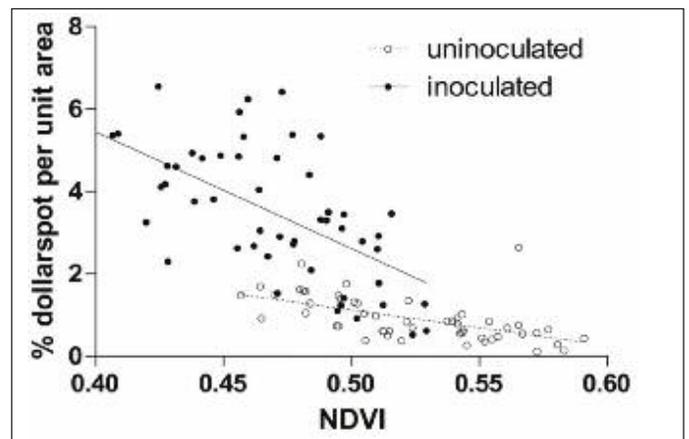
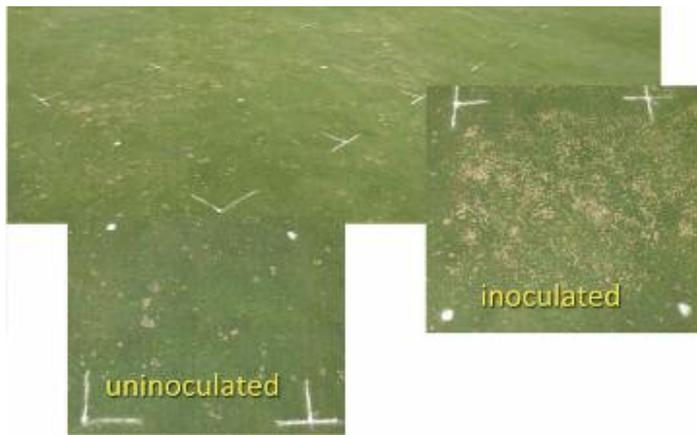


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▼ **Figure 13. Left:** Dollar spot disease on inoculated and uninoculated plots. ▼ **Figure 14. Right:** Association between canopy reflectance and dollar spot disease levels in trial plots.



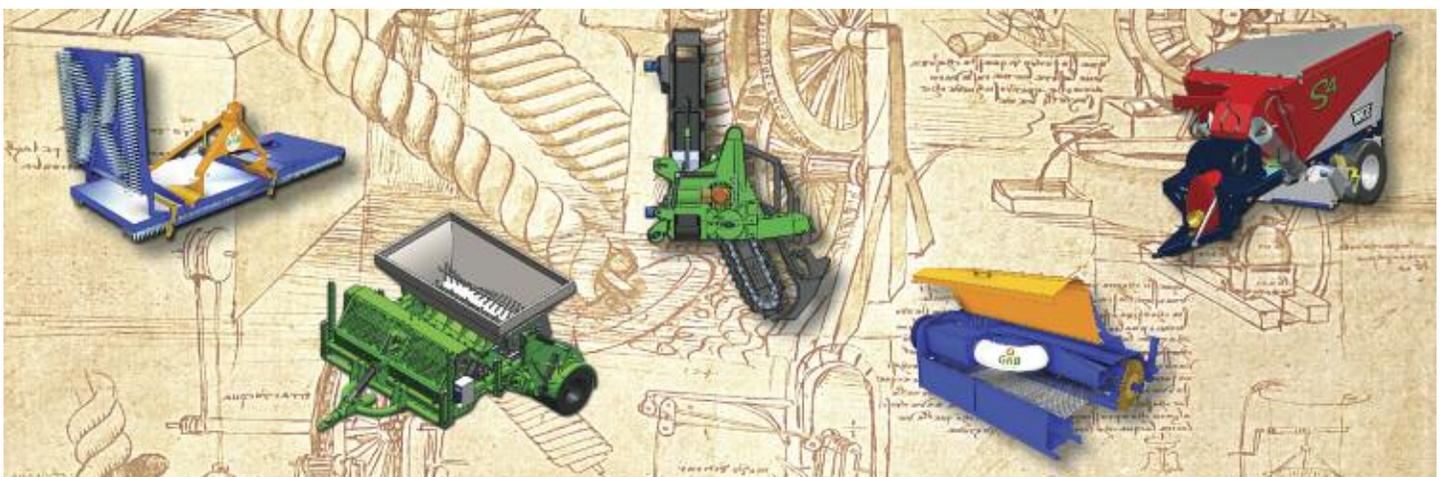
equipped will even record GPS information.

More computer tools. Recording, analyzing, and interpreting canopy reflectance data is dependent on computer software and training. At the moment the tools are research tools; widespread use of the techniques in industry will require computer tools that assist in the analysis and interpretation.

The tools and techniques are powerful, the equipment is easy to use and becoming more and more affordable all the time (currently

low four figures for the equipment we use in research), and worth keeping an eye on if you're a turfgrass manager. Someday in the not too distant future you may be sending your crew out to take routine canopy reflectance readings of your turf, and using the data to make your job easier. ■

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