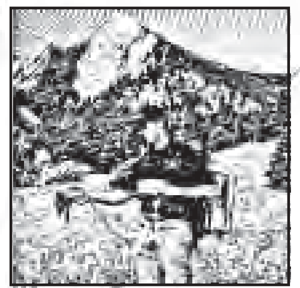
◄ *Measuring light interception and leaf area index in plant canopies with AccuPAR.*



◄ *FieldSpec Pro spectroradiometer's high-quality spectral data, displayed in real-time.*

► *First Growth calculates percent cover for the current image and average for the plot.*

PLANT CANOPY
2002 DECAGON
NEWS

GOOD IRRIGATION MANAGEMENT requires the answer to two questions: when do I turn the water on, and when do I turn it off?

Answering those questions correctly is serious business to modern vineyard managers. With the right knowledge and the right tools, irrigation can be managed to control vine growth, maximize fruit set, and regulate fruit quality. Water management in annual crops, like potatoes or sugar beets, requires irrigating so that the crop is never stressed for water. Grapevine production is more complicated. Stress needs to be avoided during flowering, but is used later to control assimilate partitioning and vine growth. Canopy size and shape, and a variety of fruit quality factors depend on maintaining precise stress levels. But how can that be done in the face of wildly varying water supply and evaporative demand?

Growers use a variety of methods to decide when to turn the water on. Some involve monitoring the plant. Stress is indicated by changes in the rate of shoot elongation and leaf expansion, by reduction in stomatal conductance (which leads to increase in leaf temperature), and by more negative leaf water potentials. It can also be inferred from soil moisture measurements. They often use estimates of evaporative demand to decide when to turn the water off (or how much water the crop needs). CONTINUED Page 3 ►

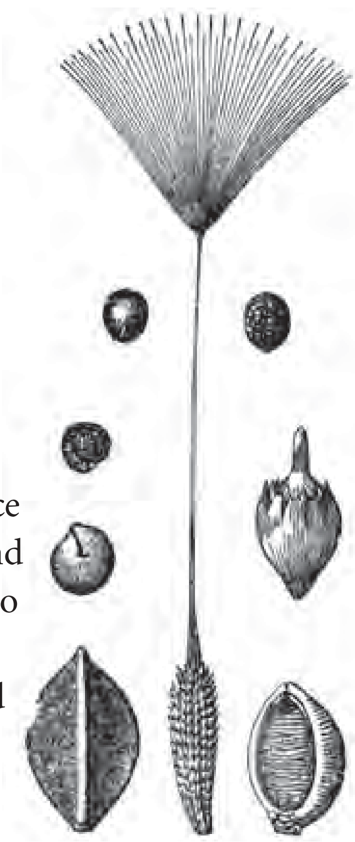


Figure A. Iowa weed seeds eaten by birds. a. Wild buckwheat (Poldonum Convolvus); b. & d. Amaranth or Pigweed; c. Chickweed; e. Spotted Spurge; f. Ragweed g. Foxtail; h. Dandelion.

Photosynthesis and Canopies

Wild Parsnip
Pastinaca sativa L.

OUR ULTIMATE SOURCE OF ALL ENERGY on earth is the sun. Availability of this energy to most organisms occurs through photosynthesis, the conversion of CO_2 and H_2O to carbohydrates *(stored energy)* and O_2. Photosynthesis occurs when pigments in photosynthesizers absorb the energy of photons, initiating a chain of photochemical and chemical events. Where does this energy and material exchange occur? In plant canopies. The amount of photosynthesis that occurs in canopies depends on the amount of photosynthetically active radiation *(PAR, see sidebar)* intercepted by leaves in canopies.

It's more complicated than you might think.

The rate at which photosynthesis occurs in one leaf might be calculated, but in canopies, leaves function collectively. Extrapolating photosynthesis from individual leaves to entire canopies is complex; the sheer numbers of leaves and their arrangement in the canopy structure can be overwhelming. Leaf area, inclination, and orientation all affect the degree to which light is captured and used in a canopy.

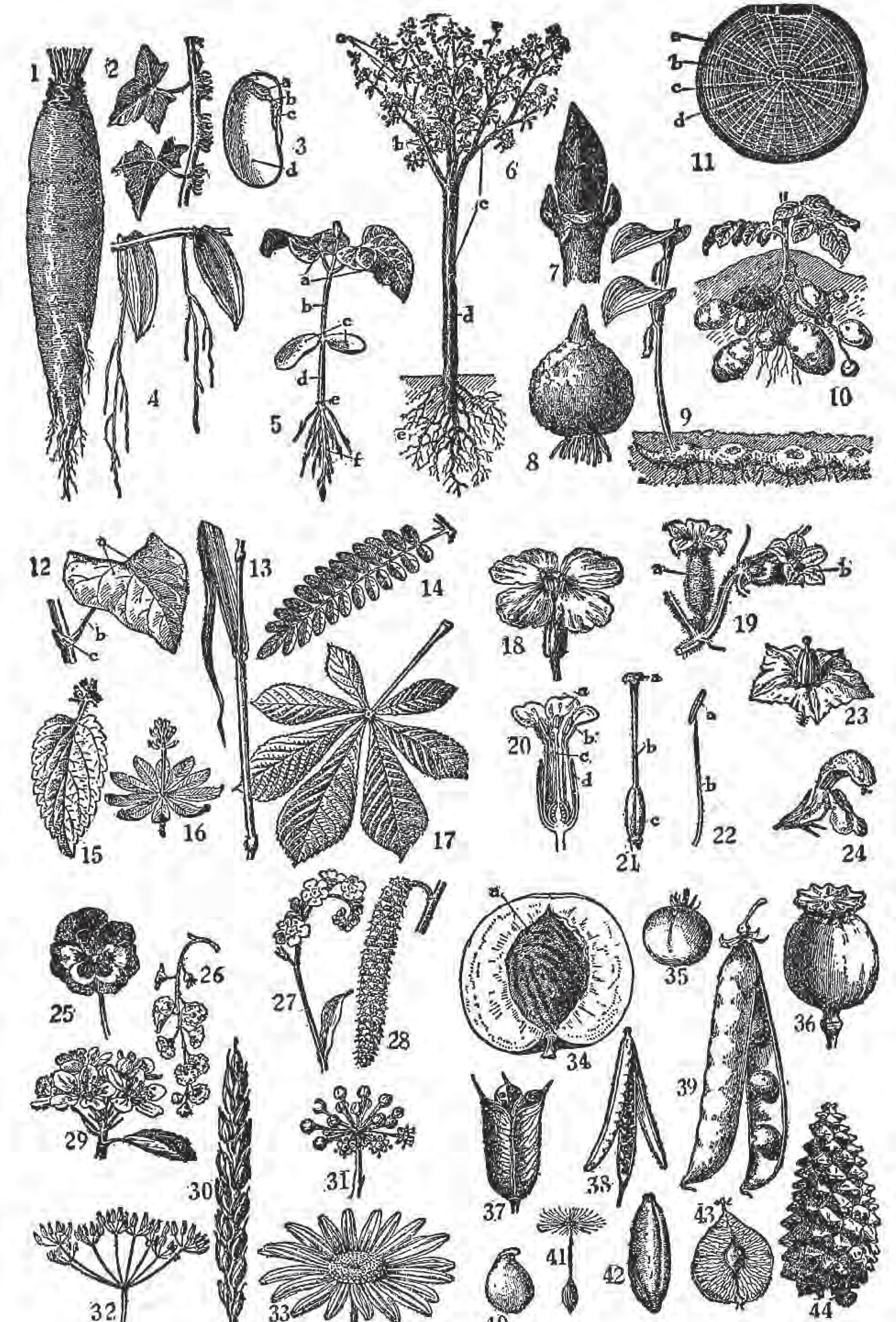
CONTINUED Page 5 ►

PAR: Photosynthetically Active Radiation

NOT ALL SOLAR RADIATION is available for photosynthesis by plants. The visible range of the spectrum is about 380 (ultraviolet) to 750 nm (red). Solar radiation with wavelengths ranging from 400 to 700 nm is referred to as photosynthetically active radiation (PAR); this is the portion of the spectrum that plants use to convert CO_2 and H_2O to carbohydrate and O_2. Photosynthetic efficiency is the fraction of PAR that is converted to stored energy by photosynthesis. Ultimately, about 27% of the total available PAR is used.

Absorbed PAR depends on daily PAR values and various phases of growth; it's also affected by canopy structure (primary factor), climate (radiation penetrates further into the canopy on cloudy days), and location with respect to the equator, which affects incident angle of sunlight. Interception and absorption of PAR are also affected by diurnal variations in radiation, changes of the sun angle, weather, etc. Plant communities have unique spatial patterns that affect the interception and absorption of PAR. For example, in coniferous forests the maximum photosynthetic rates may occur below the crown. ■

MORE INSIDE



Light affects all plant life.

Using AccuPAR to Find Crop Coefficients for Irrigated Grapevine Production

Continued from the Front Cover

CONTINUED Evaporative demand is typically computed as the product of a crop coefficient, K_c, and the potential evapotranspiration, PET. Values for PET are available *(sometimes as a fee service)* from local weather stations. Light interception, wind speed, vapor pressure deficit, available water, and air temperature all can affect K_c, but the most important of these is light interception by the crop. Recent studies show that variation in light interception accounts for more than 85% of the variation in crop coefficient *(L.E. Williams, 2001; Johnson, 2000)*. This makes sense, since evaporation requires energy, and the energy comes from the sun.

Your canopy and water loss.

To make this a little clearer, evapotranspiration is the total evaporative water loss from a field. It consists of evaporation (loss from the soil) and transpiration (loss from the crop or vegetation). To a good approximation, the fraction of PET that is transpiration is equal to the fraction of incoming solar radiation that is intercepted by the crop. When the soil is wet, the non-intercepted fraction all goes to evaporation, but when the soil is dry, evaporation from the soil is much smaller than the potential rate. When the soil surface is wet, K_c is around 1.0, but when the soil surface is dry and the canopy is sparse, K_c can be much smaller than 1. The value of K_c therefore varies depending on whether drip or overhead irrigation is used, and on frequency of irrigation, but is mainly dependent on interception of radiation by the crop canopy.

Several methods exist for measuring interception. Williams *(2001)* photographically measured the shaded area under the canopy around mid-day and developed correlations between these values and Kc. These mid-day values are directly proportional to the whole-day interception (see the **DECAGON** AccuPAR operator's manual). Other methods use light measurements above and below the canopy.

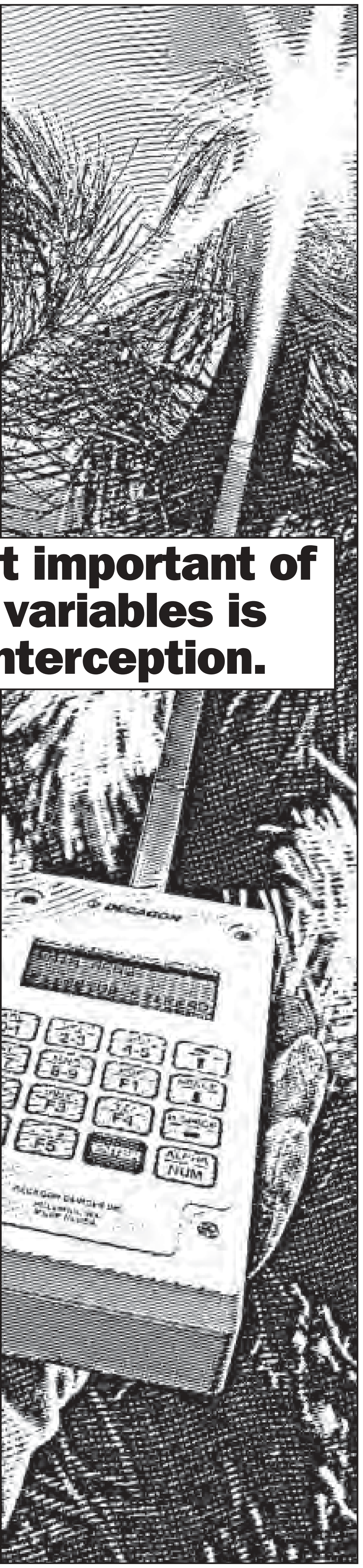
Computing crop coefficient.

AccuPAR is an instrument for measuring light in plant canopies. It measures photosynthetically active radiation (PAR) in the waveband 0.4 to 0.7 micrometers. Eighty sensors in an 80 cm long probe are averaged, so the highly variable light levels below a canopy are easily and quickly averaged. Interception is computed as $1 - \tau$, where τ, the fractional transmission, is the ratio of one or more measurements below the canopy to one or more measurements above. The procedure for computing a crop coefficient for a vineyard using the AccuPAR and Williams *(2001)* correlation is as follows. Make measurements on a clear day within a couple of hours of noon. Make one PAR measurement above the canopy and several equally spaced measurements below the canopy from row center to row center following the instructions in the AccuPAR manual. Don't sample preferentially in sun or shade areas, and take enough samples to give a good average for the area. The AccuPAR automatically computes τ. Subtract this value from 1.0 to get the interception. Williams' (2001) correlation multiplies this value by 1.7 to get K_c, so, if τ were 0.60, interception would be $1 - 0.60 = 0.40$, and K_c would be $1.7 \times 0.40 = 0.68$.

The most important of these variables is light interception.

When to turn the water off.

To summarize, let's return to the questions we started with: when to turn the water on and when to turn it off. Managers monitor vine growth rates, leaf water potential, or stomatal conductance to decide when to begin irrigation. They decide when to turn the water off by knowing the rate of water application, the storage capacity of the soil, and the rate of vine water use. The rate of use is the PET *(computed from local weather data)* multiplied by the crop coefficient. The crop coefficient is directly proportional to the intercepted radiation, which is measured with AccuPAR. ■



AccuPAR light interception meter

Williams, L. E. *2001. Irrigation of Wine Grapes in California. Practical Winery and Vineyard. November/December. pp. 42-55.*
Johnson, R. S., *J. Ayars, T. Trout, R. Mead and C. Phene. 2000. Crop coefficients for mature peach trees are well-correlated with midday canopy light interception. Acta Hort. 537:455*

First Growth

Percent Ground Cover

“All truths are easy to understand once they are discovered; the point is to discover them.”

—Galileo Galilei

AccuPar has 80 photodiodes on a probe to measure average PAR and LAI.

CONTINUED FROM THE FRONT COVER

Photosynthesis & Canopies

Marsh Mallow

CONTINUED

What happens to light in a canopy?

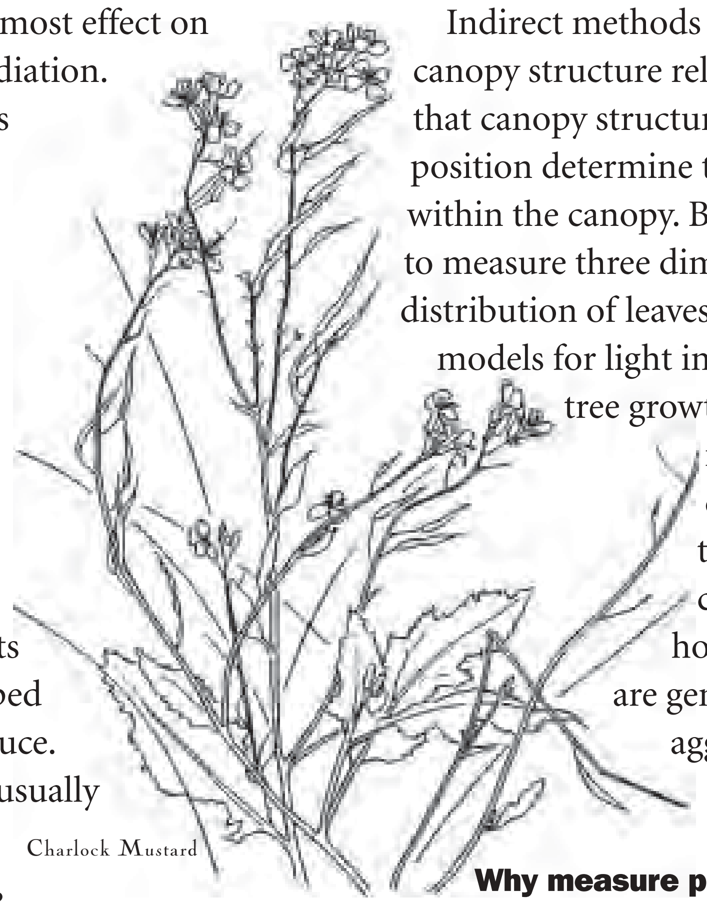
Light varies dramatically both spatially and temporally through canopies. The average light level decreases more or less exponentially downward through the canopy, as the amount of leaf surface encountered increases. For some canopies, the greatest amount of leaf area occurs near the center. Therefore, canopy structure analysis becomes increasingly complex as one proceeds from a single plant to stands of the same plant, or to plant communities because of the variety of plants and growth forms.

Absorption of radiation and resulting photosynthesis depend on leaf orientation, sun elevation in the sky, spectral distribution and multiple reflections of light, and the arrangement of leaves. Patterns of light and shaded areas can be complicated and change with the sun's position. In addition, seasonality of foliage can result in fairly small canopy interceptance of PAR for much of the year. PAR might also be intercepted by non-photosynthetic parts of plants (bark, flowers, etc).

Leaf arrangement.

Leaf display (angular orientation) affects light interception. Strictly vertical or horizontally oriented leaves are extreme cases, but a large range of angles occurs. Vertical leaves absorb less radiation when the sun is at a high angle, and more radiation when the sun is at a low angle; the converse is true for horizontal leaves. The greatest photosynthetic capacity can be achieved by a change from nearly vertical to nearly horizontal leaves lower down. This arrangement leads to effective beam penetration and a more even distribution of light.

Leaf area index (LAI), a measure of the foliage in a canopy, is the canopy property that has most effect on interception of radiation. LAI usually ranges between 1 and 12. Values of 3-4 are typical for horizontal-leafed species such as alfalfa; values of 5-10 occur in vertical-leafed species such as grasses and cereals, or in plants with highly clumped leaves, such as spruce. The highest LAIs usually occur in coniferous forests, which have overlapping generations of leaves. These forests have a photosynthetic advantage due to longevity of individual needles.



Charlock Mustard

Measuring light in a canopy.

Variability of leaf distribution in canopies results in wide variations in light. To determine light at any height in the canopy, PAR must be measured at a number of locations and then averaged. Direct methods of measurement include using the horizontal line sensors whose output is the spatial average over the sensor length. The appropriate sensor length or number of sampling points depends on plant spacing. Decagon's AccuPar has an array of 80 photodiodes on a probe that can either measure average PAR or PAR along specific segments of the probe.

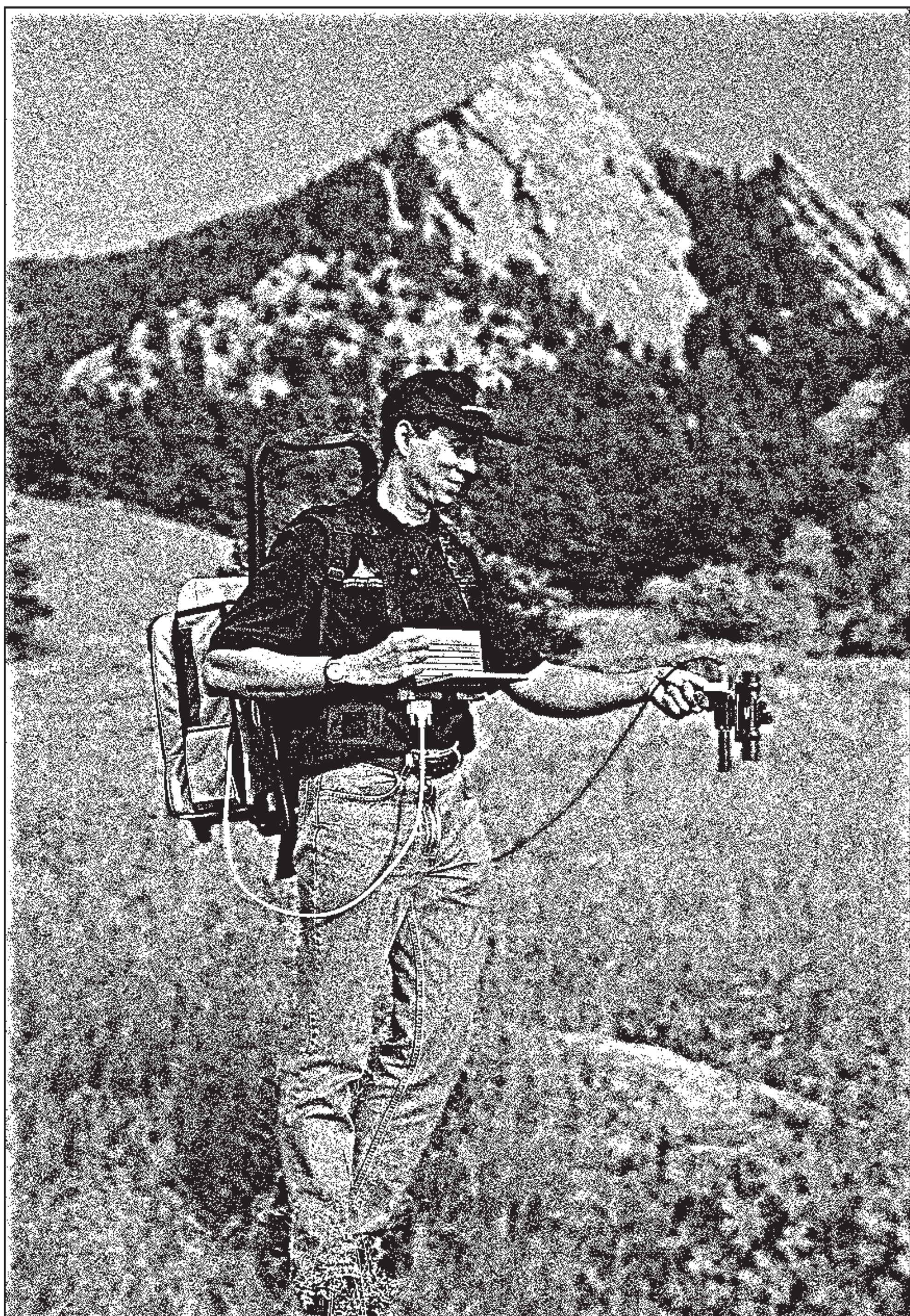
Indirect methods for measuring canopy structure rely on the fact that canopy structure and solar position determine the radiation within the canopy. Because it's hard to measure three dimensional distribution of leaves in a canopy, models for light interception and tree growth often assume random distribution throughout the canopy; however, leaves are generally aggregated or grouped.

Why measure photosynthesis or PAR?

The ability to measure PAR assists with understanding the unique spatial patterns that different plants have for displaying photosynthetic surfaces. Since effective use of PAR influences plant production, knowledge of the structural diversity of canopies aids research on plant productivity. One result: researchers can use information about different plant's ability to intercept and use PAR to engineer canopy structure modifications that significantly improve crop yield. ■

Fastest, highest-quality spectral data, displayed in real-time.

Field-portable Spectroradiometers



■ *FieldSpec Pro portable spectroradiometer is available in five different models.*

FieldSpec

Model Chart	Spectral Range
FieldSpec ProVNIR	350 –1050nm
FieldSpec Pro Dual VNIR	350 – 1050 nm
FieldSpec Pro JR	350 – 2500 nm
FieldSpec Pro FR	350 – 2500 nm
FieldSpec Handheld	355 – 1075 nm

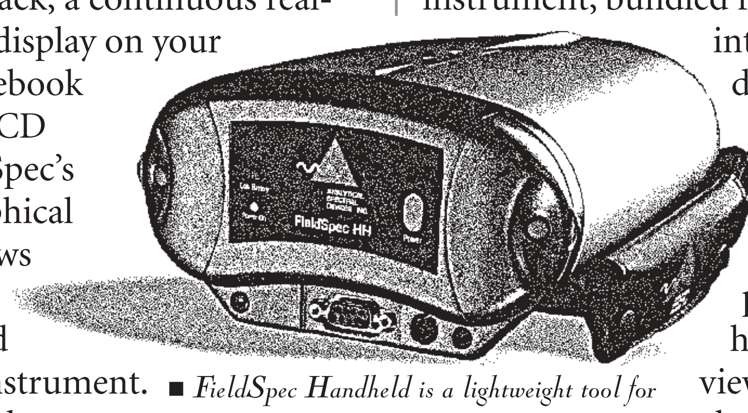
■ FieldSpec Pro VNIR is another spectrometer model covering the visible to near infrared range.

■ FieldSpec Pro dual VNIR model has two fiber-optic inputs allowing for simultaneous measurement of atmospheric irradiance and reflectance.

■ FieldSpec Pro JR model combines three spectrometers to measure the full range of the solar spectrum.

All three of these models can be upgraded to measure a wider range. Start today with a VNIR and upgrade later to top-of-the-line JR or FR models. ■

FIELDSPEC PRO translates measurements into instant feedback; a continuous real-time display on your included notebook computer's LCD screen. FieldSpec's intuitive graphical interface allows you to easily configure and control the instrument. The interface has uncomplicated pull-down menus and screens.



■ *FieldSpec Handheld is a lightweight tool for convenient measurement in the Visual NR range.*

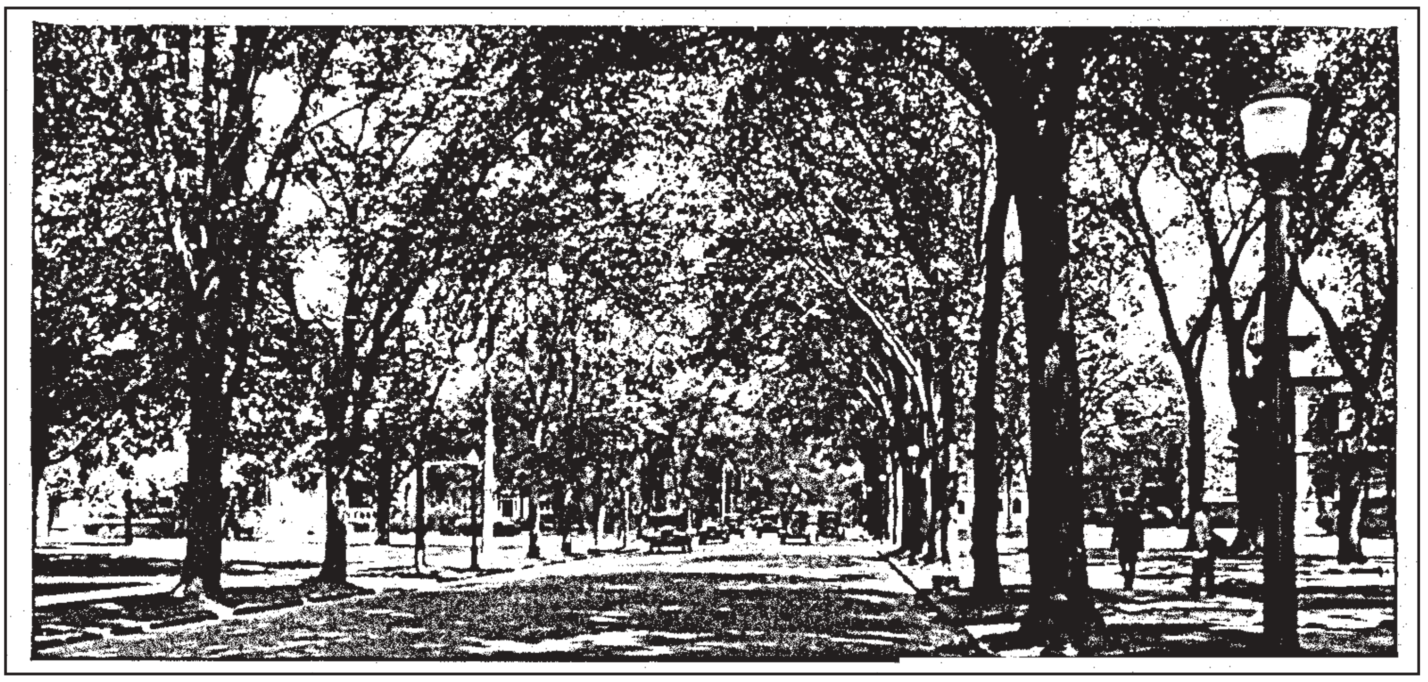
Light input to the FieldSpec Pro's sensors is through a fiber optic bundle, 1.4 meters in length. The optical fibers carry light to internal spectrometers. Fibers are packaged as a single bundle exterior to the instrument. Once inside the instrument, bundled fibers separate into distinct fibers delivering collected light to individual spectrometers. The bundled probe terminus has a 25° field-of-view and may be fed through the included tripod mountable pistol grip.

The portable instrument is controlled, and data displayed and stored, using the supplied sub-notebook computer. Spectra are coupled by software and electronics forming a continuous graph of your FieldSpec's range.

You get the fastest, highest-quality spectral data, displayed in real-time, showing you solar reflectance, absorbance radiance, irradiance, or transmittance. You can configure FieldSpec to rapidly collect many spectra. Or, you can select the averaging mode and collect fewer, higher signal-to-noise spectra. Choose from optional fore-optics, like cosine receptor or others, to customize FieldSpec Pro to your application. ■

Tropical Orchid

■ *You can capture auto-corrected real time vegetation spectra even under harsh conditions. Field movement is easy with FieldSpec Pro. The 16-pound instrument mounts on a backpack. Faster movement between sites and minimal set-up allows for greater data collection in a shorter period.*



July 8, 2000
Florida's Gainesville Sun

AccuPAR used in study of tree shade in Ocala, Gainesville

AccuPAR has been a useful instrument for determining information about canopy architecture and density for quite some time. Though its use has been primarily in test plots and forest or rangeland, it has recently proved useful in another application: determining how shade trees affect your need for an air conditioner. An article from the July 8, 2000 edition of Florida's Gainesville Sun explained how research there determined that thicker tree canopies in Gainesville led to lower consumer power usage per capita than in Ocala. The study was performed by Dr. Ryan Jensen, now an associate professor at Indiana State University, for his doctoral dissertation.

Ocala and Gainesville were chosen because of their similar geographical location and because they are the two biggest cities in north central Florida. Using the AccuPAR and remote sensing imagery, the leaf area index of the canopies for both cities were measured. The results showed an overall LAI for Gainesville of 4.61, while Ocala's was almost half of that—2.13. This was surprising to some, since Ocala has been designated a "Tree City USA" for over 10 years in a row, and has a 28-page tree ordinance, with hundreds of detailed provisions.

Jensen attributes Gainesville's higher LAI to stricter zoning rules with regard to tree removal. According to the article, residential homeowners in Gainesville need a permit before they can remove a tree with a trunk more than 30 inches in diameter. However, in Ocala, single-family homes on less than three acres of land don't need a permit to remove trees. The tree experts in Gainsville, however, were not surprised:

"The results come as no surprise to city of Gainesville Arborist Meg Niederhofer, who enforces tree regulations. One 50-year-old live oak, she said, citing a factoid from the American Forestry Association, has the cooling capacity of five heavy-duty air conditioners running full time. And Gainesville residents have fought long and hard to maintain laws that protect those older, bigger trees. City surveys show the amount of land in Gainesville covered by trees jumped from 47 percent in 1984 to 60 percent in 1994, Niederhofer said. 'We're all nuts about trees here,' she said. City commissioners 'didn't put on a city arborist out of the goodness of their hearts,' she said. 'They got tired of citizens complaining so often about bulldozed trees.'"

According to Ocala city officials, other factors might be at play as well. In the article they state that "Gainesville obviously has far more apartments because of the large student population. Those dwellings tend to need less power to cool down than single-family homes." Regardless of the various factors that contribute to the lower energy costs, the fact remains that more trees generally mean more shade, and cooler environments. And, though Ocala planning Director Bill Hunt was disturbed by the findings, his position on the matter was encouraging. "Anything that can inspire people to plant more trees – that's a very good thing." ■

■ Nothing tends so much to the advancement of knowledge as the application of a new instrument. The native intellectual powers of men in different times are not so much the causes of the different success of their labours, as the peculiar nature of the means and artificial resources in their possession.

—Sir Humphrey Davy

Thomas Hager, Force of Nature, Simon and Schuster, New York, 1995, p 86.

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Plant Canopy NEWS

INFO: Photosynthetically Active Radiation, Crop Irrigation Management, Percent Ground Cover, Solar Reflectance, Absorbance Radiance, Irradiance, Transmittance, and more ...

In this newsletter, you'll find out how AccuPAR is helping people optimize watering practices in vineyards and helping keep cities cool in the South. You'll also find out more about some of our newer instruments: First Growth and Spectroradiometers. Feel free to call or email me if you have any questions about your application. **800-755-2751**

Sincerely— Matt Galloway, *product manager*

CAMERA

■ *There is no need to measure emerging leaflets destructively. First Growth color segmentation algorithm detects cover directly.*

Percent Ground Cover

FIRST GROWTH

FIRST GROWTH makes ground cover analysis simple with its digital camera made just for canopy cover research. First Growth identifies green plant tissue in every digital image. Custom software calculates the ratio of green pixels to total pixels. Image processing takes place inside the digital camera, so you get your readings right in the field.

Versatile user-options customize First Growth to researcher needs.

First Growth calculates percent cover for the current image and average for the plot. The instrument stores numerical cover values, with date and time stamps. First Growth saves a black and white image of your cover. You can also save RGB color images in standard file formats. This portable instrument tracks your data plot by plot, saving everything you need for lab analysis.

Snap-shots save more than time.

First Growth technology is a long-awaited breakthrough for seedling and ground cover research. Eliminate destructive sampling, researcher subjectivity, and reduce time spent on painstaking measurements. Spend less time breaking your back in the field, and more time interpreting results. ■