Using Portable Low-Cost Chlorophyll Sensors to Assess Plant Health and Improve Crop Quality in Hydroponics

When you grow plants hydroponically you become responsible for delivering the exact amount of every essential nutrient. Getting nitrogen right is particularly challenging since plants can require dramatically different amounts depending on their growth stage. Traditional methods to assess nitrogen status require sending leaf samples to a lab, which is expensive, destructive, and provides results too late to make timely corrections. Portable chlorophyll meters offer a practical solution.

A DIY chlorophyl meter compared to some commercial alternatives (taken from (9)).

What Are Portable Chlorophyll Meters?

Portable chlorophyll meters are handheld devices that non-destructively estimate the chlorophyll content in plant leaves. The most widely used device is the SPAD-502 meter, which works by measuring light transmission through a leaf at two wavelengths: 650 nm (red light, which chlorophyll absorbs) and 940 nm (infrared, which chlorophyll does not absorb). The device calculates a dimensionless SPAD value based on the transmission ratio (1). Since 50-70% of leaf nitrogen is contained in chlorophyll molecules, these readings provide a reliable proxy for nitrogen status (2).

These meters are particularly useful in hydroponic systems where you have complete control over nutrient delivery and can make rapid adjustments when deficiencies are detected. Research has demonstrated strong correlations between chlorophyll meter readings and nitrogen status in major hydroponic crops including tomato (3), lettuce (4), and greenhouse vegetables (5).

Major Advantages

The primary advantage is that measurements are instantaneous and non-destructive. You can measure the same leaf repeatedly throughout the growing season without harming the plant. This is especially valuable in hydroponics where you might want to monitor nitrogen status weekly or even daily during critical growth periods.

The correlation between SPAD readings and leaf nitrogen concentration is typically very strong. In romaine lettuce grown in soilless culture, SPAD readings showed correlation coefficients of $R^2 = 0.90$ with nitrogen concentration and $R^2 = 0.97$ with chlorophyll content (4). Similar results have been

reported for greenhouse tomatoes, where R^2 values ranged from 0.86 to 0.94 (6).

Unlike laboratory analysis, chlorophyll meters provide immediate feedback. When you detect that SPAD readings are dropping below your target range, you can adjust your nutrient solution that same day, particularly advantageous in fertigation systems (7).

Low-Cost Alternatives

The SPAD-502 meter typically costs $2,000-$2,600, which can be prohibitive for small growers. Several low-cost alternatives have been developed and validated. The atLEAF meter costs around $200-$300 while providing equivalent performance (8). Studies found strong correlations (R^2 = 0.96) between SPAD and atLEAF meters across multiple crop species (8).

Functional chlorophyll meters can even be built from scratch using simple electronic components for under $100. A recent study described construction using 3D-printed hardware and off-the-shelf LEDs and photodiodes that achieved strong correlations with both the SPAD-502 and atLEAF meters (9).

Device	Cost (USD)	Wavelengths (nm)	Key Features
SPAD-502	2,000-2,600	650, 940	Industry standard
atLEAF+	200-300	660, 940	Data logging, SPAD conversion
MC-100	400-600	653, 931	Larger measurement area
Custom Arduino	<100	650, 940	Requires assembly

The atLEAF meter is available through agricultural supply retailers, while various manufacturers offer devices in the $100-$300 range through online platforms.

Research in Hydroponic Crops

Chlorophyll meters have been successfully used to guide nitrogen management in various hydroponic crops. In tomato production, using SPAD readings to trigger nitrogen applications resulted in the highest yields compared to fixed-rate applications, with improved nitrogen use efficiency (3). Researchers established critical SPAD values for different physiological stages, allowing growers to apply nitrogen only when needed.

For lettuce grown in high tunnels with fertigation, both SPAD and atLEAF meters accurately estimated nitrogen status, fresh weight, and chlorophyll concentration with R^2 values above 0.90 (4). Research on basil with different nitrogen rates showed that SPAD, atLEAF, and MC-100 meters all provided reliable estimates with R^2 values of 0.93-0.98 (10).

Important Limitations

While valuable, chlorophyll meters have limitations growers need to understand. The relationship between SPAD readings and actual nitrogen content can vary between species. Research on seven crop species found that while the relationship between SPAD and chlorophyll content was consistent, the relationship between SPAD and leaf nitrogen varied widely (1). You cannot use the same threshold values across different crops.

Environmental factors also affect readings:

- **Time of day**: Chloroplast movement can cause SPAD readings to decrease by 13-28% at midday under low nitrogen conditions (1). Take readings in early morning or maintain consistent measurement times.
- **Light history**: Short-term changes in growth light affect nitrogen allocation to chlorophyll (1).
- **Leaf position and age**: Chlorophyll content varies across

leaf positions and with age. Always measure the same leaf position.

Chlorophyll meters provide relative rather than absolute measurements. To use them effectively, you need to establish calibration curves for your specific crop and growing conditions.

Best Practices

Establish Baseline Values: Grow plants at different nitrogen levels and measure both SPAD readings and leaf nitrogen concentration via lab analysis. This establishes your calibration curve.

Use Reference Strips: Maintain a section of plants receiving optimal nitrogen. Compare readings from your bulk crop to these reference plants. If bulk readings drop more than 5-10% below reference, increase nitrogen delivery (7).

Standardize Protocol: Always measure the same leaf position. For leafy greens, measure the most recently fully expanded leaf. For tomatoes, measure leaflets on the leaf closest to the most recent fruit cluster. Take measurements at the same time daily, preferably early morning (5).

Take Multiple Readings: SPAD readings can vary 10-15% between individual plants. Measure at least 20-30 plants per zone and use the average (7).

Species-Specific Calibration: If you grow multiple crops, establish separate calibration curves for each.

Crop	Optimal Range	Action Threshold	Measurement Location
Lettuce	35-45	<32	Youngest fully expanded leaf

Crop	Optimal Range	Action Threshold	Measurement Location
Tomato	45-55	<42	Leaflet near newest fruit cluster
Cucumber	40-50	<37	3rd fully expanded leaf
Basil	35-45	<32	Terminal leaves

Note: These are general guidelines. Establish specific thresholds for your cultivars through calibration with lab analysis.

Conclusions

Portable chlorophyll meters represent an excellent investment for hydroponic growers optimizing nitrogen management. Low-cost alternatives make this technology accessible even for hobby growers. While these devices have limitations related to species-specific calibration and environmental factors, following standardized protocols allows effective use for management decisions.

The key is understanding that chlorophyll meters provide relative measurements. Take time to establish proper baseline values for your crops and conditions. Once calibrated, these devices help fine-tune nitrogen delivery, reduce fertilizer waste, prevent deficiencies, and improve crop yield and quality.

For growers ready to adopt this technology, starting with an atLEAF meter or similar low-cost device provides an affordable entry point with performance comparable to expensive options.