On-Farm NIRS Systems

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Let's say you're sold on benefits of near-infrared reflectance spectroscopy (NIRS) but aren't sure which instrument meets your needs. To aid you, we have researched several NIRS systems (Table 1).

Table 1. Initial/annual costs for various on-farm NIRS systems.

Instrument	Contact	Form Factor	List Price
HarvestLab™	John Deere	Portable[1]	$25,000
AuroraNIR™	RCI Engineering	Hand-held	$19,500
X-NIR™	Dinamica Generale	Hand-held[1]	$14,000
poliSPEC	ITPhotonics	Hand-held[1]	$18,500
Moisture Tracker™	Digi-Star	Hand-held	$7,350
StellarCASE-NIR	StellarNet	Portable	$20,500

[1]Also offered with connectivity and mounting hardware for on-harvester use. Additional costs apply.

How do NIRS systems work? When light interacts with matter, some is absorbed, some scattered, and some is reflected depending on the light's wavelength and chemical and physical properties of the matter. The spectrometer is designed to measure reflected light, which we assume is related to light absorbed and, consequently, to the material chemical makeup observed.

This is where things get challenging. Although we cannot visibly see near-infrared light, it obeys the same physical laws as visible light. Not only does the sample's chemical makeup influence the light measured, but the physical properties do as well. For example, have you ever misjudged the color of an object because its surface finish has affected how the light is scattered or reflected? Similarly, the physical characteristics, as well as interaction and overlapping absorption of light by chemicals, make prediction a complex task.

Managing this variability is the job of the spectrometer's calibration, the most important part of the NIRS system. We surveyed various calibrations available for the NIRS systems (Table 2). As you'll note, a separate calibration is utilized for each crop species and for fresh and ensiled crops; performance can be improved by this separation. In calibration development it is important to control variability so it doesn't influence the calibration, or include it so the calibration can account for it. However, including too much variability not related to the chemical or physical feature you're trying to predict (e.g., dry matter) can impact how accurately one can predict that feature.

Table 2. Crop species calibrations available for on-farm NIRS systems[1].

	Fresh				Ensiled				Dry		
Instrument	Alfalfa	Whole-Plant Corn	Whole-Plant Small Grains	Grass	Haylage	Corn Silage	Whole-Plant Silage	Grass Silage	Alfalfa Hay	Grass Hay	TMR
HarvestLab™	✓	✓	✓	✓	✓	✓	✓	✓			
AuroraNIR™	✓	✓	✓	✓	✓	✓	✓	✓			✓
X-NIR™	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
poliSPEC		✓	✓	✓		✓	✓	✓	✓	✓	✓
Moisture Tracker™	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	

[1]This data was provided by the manufacturer and are continually updated. Check with them for the latest capabilities.

Will results be as accurate as my forage testing laboratory? Probably not. Recall our variability discussion. Laboratories work tirelessly not only to dry (water is a strong absorber of near-infrared light) and grind forage samples but also to scrupulously maintain instruments and calibrations. They also implement protocols to monitor performance on a daily basis. There is a consortium of laboratories monitoring calibration performance and sharing samples to improve prediction accuracy.

Also, the reference method to calibrate your NIRS system may be different from the one used by your laboratory. It's worth asking a manufacturer to provide its reference methods before investing, especially if you plan to use the instrument with periodic laboratory testing – a good practice, in my opinion. We surveyed chemical constituents predicted by the NIRS systems (Table 3).

Table 3. Chemical constituents predicted by on-farm NIRS systems.

Instrument	Dry Matter	NDF/ADF	Starch	Sugar	Crude Protein	Crude Fat
HarvestLab™	++	++	+-	+	++	--
AuroraNIR™	++	++	++	--	++	++
X-NIR™	++	++	+	+-	++	++
poliSPEC	++	++	++	+	++	++
Moisture Tracker™	++	--	--	--	--	--

++ available for all crop species, + available for most crop species, +- available for some crop species, -- not available

On-farm NIRS does have some advantages over laboratory NIRS. Results are rapid and can be readily incorporated

into management decisions. Also, you can scan more samples to ensure you're working with analysis from a more representative sample, assess variability in your feedstuffs, and make decisions based on historical trends in analysis.

Are there any hardware differences among on-farm options? Most systems now employ a similar hardware strategy, but there are some differences. As an end-user, I wouldn't be too concerned about these differences as the utility of the sensor will be more dependent on calibration performance. That said, there are some indications a manufacturer has done its homework.

Recall our discussion on variability. Internal electronics of the spectrometer are sensitive to temperature. An internal reference helps account for this reality by exposing the optical sensing path to both a highly reflective and dark standard (often turning the light source off temporarily). Implementing such a system adds cost to the spectrometer and is the sign of a more premium model. Other features offered are connectivity to smart phones, tablets, and harvesters. Premium instruments also use high quality light sources and rugged materials (e.g., sapphire, gorilla glass) to prevent scratches on the sensing window. All that said, sophisticated calibration models based on artificial intelligence are improving the performance of lower cost instruments. Stay tuned!

Why do some manufacturers charge an annual maintenance fee? Just as your forage testing laboratory monitors and maintains calibrations, so do those offering on-farm NIRS systems. Knowing the variability in chemical and physical properties of forages from year to year (e.g., environment, plant genetics, processing), I would be concerned about a manufacturer who is not investing in regular calibration updates.

Can I build my own calibration? Some manufacturers allow you to "side-load" calibrations and this is one reason I've included the StellarCASE instrument in our survey. Why would you build your own calibration? It may allow you to predict chemical constituents not currently offered and you may be able to gain prediction accuracy with a calibration for your operation. Contact the manufacturer to determine whether it supports farm-developed calibrations. In many cases, it may be willing to help or may have relationships with laboratories for calibration development. You may also contact your forage testing laboratory as some offer calibration services.

I hope this article "sheds some light" on options you have for on-farm forage analysis with NIRS!