Plant, Waste, Solution, and Media Analysis Lab
Agronomic Division
NC Dept. of Agriculture & Consumer Services

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Fee Schedule

Plant tissue analysis

http://www.ncagr.gov/agronomi/uyrplant.htm

- **Standard analysis** includes measurement of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, zinc, copper, boron, and sodium concentrations. Interpretation indexes are also provided for most crops.
- **Sampling instructions**: http://www.ncagr.gov/agronomi/pdffiles/sampta.pdf http://www.ncagr.gov/agronomi/pdffiles/tissuehandling.pdf
- **Sample submission form**: http://www.ncagr.gov/agronomi/pdffiles/isplant.pdf

Plant Tissue Analysis Fee Schedule

Standard tissue analysis of most crops ***for N.C. residents***	**$5**
Standard tissue analysis of most crops ***for non–N.C. residents***	**$25**
Additional services available by request	
—Petiole nitrate (NO_3-N)	**+$2**
—Molybdenum (Mo)	**+$2**
—Chloride (Cl^-)	**+$2**
Tissue analysis for crops **with required special services** **(**N.C. residents**)** —**std. analysis + molybdenum**: alfalfa, broccoli, cabbage, cauliflower, collards, kale, poinsettia, spinach, turnip greens, canola (rapeseed), brassicas —**std. analysis + petiole nitrates**: cotton, strawberry	**$7**
Tissue analysis for crops **with required special services** **(**non–N.C. residents**)** — see list of crops in previous bullet	**$27**
Contact Kristin Hicks for Research sample fees	**Contact lab**

Waste and compost analysis

http://www.ncagr.gov/agronomi/uyrwaste.htm

- **Standard analysis** for all waste codes includes measurement of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, zinc, copper, boron, and sodium concentrations. For some waste types (i.e. compost), measurements of carbon, pH, and soluble salts are also provided with the standard analysis. See the **NCDA&CS Waste and Compost Analysis Guide** http://www.ncagr.gov/agronomi/pdffiles/wasteguide.pdf for further information.
- **Sampling instructions:** http://www.ncagr.gov/agronomi/pdffiles/samwaste.pdf
- **Sample submission form**: http://www.ncagr.gov/agronomi/pdffiles/iswaste.pdf

Waste Analysis Fee Schedule

Standard waste analysis ***for N.C. residents***	**$8**
Standard waste analysis ***for non–N.C. residents***	**$25**
Additional services by request	
—Nitrogen breakout (measurement of NO_3-N and NH_4-N)	**+$10**
—Heavy metals (cadmium, lead, nickel)	**+$10**
—Liming equivalent (CCE)	**+$10**
Contact Kristin Hicks for Research sample fees	**Contact lab**

Solution analysis

http://www.ncagr.gov/agronomi/uyrsoln.htm

- **Standard analysis** includes measurement of nitrate-nitrogen, ammonium-nitrogen, urea, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, zinc, copper, boron, sodium, and chloride concentrations. Measurements of pH, soluble salts, and total alkalinity as well as values of hardness and sodium absorption ratio (SAR) are reported. For irrigation water codes, the amount of sulfuric acid needed to adjust alkalinity is included.
- **Sampling instructions:** http://www.ncagr.gov/agronomi/pdffiles/samsoln.pdf
- **Sample submission form**: http://www.ncagr.gov/agronomi/pdffiles/issoln.pdf

Solution Analysis Fee Schedule

Standard solution analysis ***for N.C. residents***	**$5**
Standard solution analysis ***for non-N.C. residents***	**$25**
Contact Kristin Hicks for Research sample fees	**Contact lab**

Soilless media analysis

http://www.ncagr.gov/agronomi/uyrmedia.htm

- **Standard analysis** includes measurement of nitrate-nitrogen, ammonium-nitrogen, urea, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, zinc, copper, boron, sodium, and chloride concentrations. Measurements of pH and soluble salts are also reported.
- **Sampling instructions:** http://www.ncagr.gov/agronomi/pdffiles/samsme.pdf
- **Sample submission form**: http://www.ncagr.gov/agronomi/pdffiles/ad8.pdf

Solution Analysis Fee Schedule

Standard soilless media analysis ***for N.C. residents***	**$5**
Standard soilless media analysis ***for non-N.C. residents***	**$25**
Contact Kristin Hicks for Research sample fees	**Contact lab**

Plant/Waste/Solution/Media Analytical Procedures – Summary

Sample Type & Test	*Sample Amount*	*Analytical Method*
PLANT		
N	5-7 mg	Elemental Analyzer (oxygen combusion with gas chromotography)
P thru B	0.5 -1.0 g	ICP following HNO_3 closed vessel microwave digestion (1.0 g when Mo analyzed)
NO_3-N	0.25 g	Electrode
Mo	1.0 g	ICP following HNO_3 closed vessel microwave digestion
Cl^-	0.25 g	DI water (25 mL) extraction (30 min. on recip. Shaker, then heated to boiling); Skalar (spectrophotometric)
WASTE - SOLID		
C and/or N	7-30 mg	Elemental Analyzer (Oxygen combusion w/ gas chromotography) (10-30 mg compost/ash/lime)
P thru B	0.5-1.0 g	ICP following HNO_3 closed vessel microwave digestion (1.0 g when HM are analyzed)
pH	10 cc	1 DI water : 1 dried/ground substrate (by volume); allow to stand 60 minutes
EC	10 cc	2 DI water : 1 dried/ground substrate (by volume); volume added to pH cup; filter
CCE	1.0 g	Caustic titration for ALE determination
HM (Cd, Ni, Pb)	1.0 g	ICP following HNO_3 closed vessel microwave digestion
Al, Li, Se	1.0 g	ICP following HNO_3 closed vessel microwave digestion
NO_3-N/NH_4-N	1.0 g	DI water (25 mL) extraction (30 min. on recip. Shaker); Skalar (spectrophotometric)
ALE	calc	ALE = ((1800/DM/100)) * ((CCE/100) * 2000)
WASTE - LIQUID		
N	10 mL	TKN - H_2SO_4 digestion (EPA method 351.2 skalar); Skalar (spectrophotometric)
P thru B	5 mL	ICP following HNO_3 closed vessel microwave digestion
pH		As received
EC		As received or filtered if necessary
NO_3-N/NH_4-N	10 mL	Filtered; Skalar (spectrophotometric)
HM (Cd, Ni, Pb)	5 ml	ICP following HNO_3 closed vessel microwave digestion
Al, Li, Se	5 ml	ICP following HNO_3 closed vessel microwave digestion
ALE	calc	ALE = 1800 ÷ [(CCE% ÷ 100) × 8340]
SOLUTION		
NO_3-N/NH_4-N/Urea/Cl^-	10 mL	Filtered; Skalar (spectrophotometric)
P thru B	5-10 mL	Filtered; ICP
pH		As received
EC		As received
CO3 and HCO3	25-50 mL	Acid titration for Total Alkalinity Determination; AOAC Method 31.018
MEDIA		
NO3-N/NH4-N/Urea/Cl	10 mL	Saturated media extraction; Skalar (spectrophotometric)
P thru B	5-10 mL	Saturated media extraction; ICP
pH	10-100 cc	1 DI water : 1 as received (fresh) substrate (by volume); allow to stand 60 minutes
EC	20 mL	Saturated media extraction

Plant Sample Methodology

Sample handling

Prior to analysis, samples are dried overnight (12–24 hr) at 80°C, then processed through a stainless steel grinder (Wiley Mini-Mill; Thomas Scientific; Swedesboro, NJ) with a 20-mesh (1 mm) screen (Campbell and Plank 1992).

Nitrogen

Total nitrogen concentration is determined by oxygen combustion gas chromatography with an elemental analyzer (NA1500s2; CE Elantech Instruments; Lakewood, NJ) (AOAC 1990b; Campbell 1992) on a 5-7 mg aliquot of the dried/ground sample. Results are expressed in percent (%) on a dry-weight basis.

Phosphorus (P), potassium (K), calcium (Ca), sulfur (S), magnesium (Mg), boron (B), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), sodium (Na), and molybdenum (Mo).

Total concentrations of P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, Na, and Mo are determined with Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) (Spectro Arcos EOP, Spectro Analytical: A Division of Ametek; Mahwah, NJ) (Donohue and Aho 1992; adapted USEPA 2001), after closed-vessel Nitric acid (HNO_3) digestion in a microwave digestion system (MARS 6 Microwaves; CEM Corp.; Matthews, NC) (Campbell and Plank 1992). A 0.5 g dried/ground aliquot is digested in 10 mL 15.6N HNO_3 for 30 minutes in a microwave, and the prepared sample volume is brought to 50 mL with deionized water and then filtered through acid-washed filter paper (Laboratory Filtration Group, Houston, TX) prior to measurement. Elements are measured using a six point calibration (five point calibration for Mo) at wavelengths listed in Table 1 below. Results are expressed either as a percentage (%) or in parts per million (ppm) [as milligrams per kilogram (mg/kg)] on a dry-weight basis.

Table 1. Wavelengths to quantify total elemental concentrations in Plant Analysis Lab

Element	Wavelength (nm)	Element	Wavelength (nm)
Boron (B)	208.959	Molybdenum (Mo)	202.095
Cadmium (Cd)	226.502	Nickel (Ni)	231.604
Calcium (Ca)	183.801, 315.887	Phosphorus (P)	178.287
Copper (Cu)	324.754	Potassium (K)	404.721, 766.491
Iron (Fe)	259.941	Sodium (Na)	330.237, 589.592
Lead (Pb)	220.353	Sulfur (S)	182.034
Magnesium (Mg)	279.079	Zinc (Zn)	213.856
Manganese (Mn)	257.611		

Nitrate-nitrogen

Nitrate-nitrogen (NO_3-N) concentration is determined with an ion selective electrode (ISE) (Orion Model 93-07; Thermo Fisher Scientific Inc., Waltham, MA) following a 0.25 M $Al_2(SO_4)_3$ extraction (25 mL) (Baker and Smith 1969) on a 0.25 g dried/ground aliquot of sample. Results are expressed in parts per million (ppm) [as milligrams per kilogram (mg/kg)] on a dry-weight basis. Nitrate-nitrogen will be analyzed on all strawberry and cotton samples for an additional

cost of $2 (total cost of $7 per sample). Nitrate-nitrogen can also be analyzed on any sample per request for an additional cost of $2 (total cost of $7 per sample).

Chloride (Cl^-)

Chloride determination is available on any plant sample for an additional cost of $2 (total cost of $7 per sample). Chloride concentration is determined by a hot water extraction (G. Ghosh and M. C. Drew., 1991) of 0.25 g dried/ground sample. The extract is filtered and then used for Chloride determination by the thiocyanate displacement method (Zall et al., 1956; Skalar Analytical 1995, Issue 6) with an auto-flow spectrophotometric analyzer (San^{++} Segmented Flow Auto-Analyzer, Skalar Instruments; Breda, The Netherlands). Results are expressed in parts per million (ppm) [equivalent to mg/L].

References for Plant Analysis Methodology

[AOAC] Association of Official Analytical Chemists. 1990a. AOAC modified method 963.05: chlorides in tobacco. In: Official methods of analysis. 15th ed. Arlington (VA): AOAC International. p 64.

[AOAC] Association of Official Analytical Chemists. 1990b. AOAC official method 972.43: microchemical determination of carbon, hydrogen, and nitrogen. In: Official methods of analysis. 15th ed. Arlington (VA): AOAC International. p 341.

Baker AS, Smith R. 1969. Extracting solution for potentiometric determination of nitrate in plant tissue. J Agric Food Chem 17:1284–7.

Campbell CR. 1992. Determination of total nitrogen in plant tissue by combustion. In: Plank CO, editor. Plant analysis reference procedures for the southern region of the United States. Athens (GA): Georgia Cooperative Extension Service. p 20–2. Southern Cooperative Series Bulletin 368. Available at www.ncagr.gov/agronomi/pdffiles/sera368.pdf (verified 2011 Aug 24).

Campbell CR, Plank CO. 1992. Sample preparation. In: Plank CO, editor. Plant analysis reference procedures for the southern region of the United States. Athens (GA): Georgia Cooperative Extension Service. p 1–12. Southern Cooperative Series Bulletin 368. Available at www.ncagr.gov/agronomi/pdffiles/sera368.pdf (verified 2011 Aug 24).

Donohue SJ, Aho DW. 1992. Determination of P, K, Ca, Mg, Mn, Fe, Al, B, Cu, and Zn in plant tissue by inductively coupled plasma (ICP) emission spectroscopy. In: Plank CO, editor. Plant analysis reference procedures for the southern region of the United States. Athens (GA): Georgia Cooperative Extension Service. p 34–7. Southern Cooperative Series Bulletin 368. Available at www.ncagr.gov/agronomi/pdffiles/sera368.pdf (verified 2011 Aug 24).

G. Ghosh and M. C. Drew. 1991. Comparison of analytical methods for extraction of chloride from plant tissue using ^{36}Cl as tracer. Plant and Soil, Volume 136 Issue 2, pp. 265-268.

Haddad PR, Alexander PW, Smythe LE. 1975. Spectrophotometric and fluorometric determination of traces of molybdenum in soils and plants. Talanta 22:60–9.

[USEPA] US Environmental Protection Agency. 2001. Method 200.7. Trace elements in water, solids, and biosolids by inductively coupled plasma–atomic spectrometry, revision 4.4. Cincinnati (OH): USEPA Office of Research and Development. EPA-821-R-01-010. Available at nepis.epa.gov/EPA/ (verified 2011 Sep 12).

Waste Analysis Methodology

Solid Waste Analysis Methodology

Sample handling

Prior to analysis, a subsample (~250 cm^3) is weighed (Mettler PM4800; Mettler-Toledo, Hightstown, NJ), dried overnight (12–36 hr) at 80ºC, reweighed, and ground with a stainless steel grinder (Intermediate Wiley Mill; Arthur H. Thomas Co.; Philadelphia, PA) to pass through a 20-mesh (1 mm) screen (adapted from Hoskins et al., 2003). Percent solids, or dry matter percent (DM%), is calculated by the following equation: DM% = (dry weight ÷ fresh weight) × 100.

Nitrogen (N) and carbon (C)

Total N or Total N and C concentrations are determined by oxygen combustion gas chromatography with an elemental analyzer (NA1500 or EA1112; CE Elantech Instruments; Lakewood, NJ) (AOAC 1990b; Campbell 1992) on a 7-30 mg aliquot of the dried/ground sample. Results are expressed in parts per million (ppm) [equivalent to mg/kg] on a dry-weight basis.

Inorganic-nitrogen (IN-N) fraction concentrations include nitrate-nitrogen plus nitrite-nitrogen (NO_3-N + NO_2-N) (reported as NO_3-N on the Waste Analysis Report) and ammonium-nitrogen (NH_3-N + NH_4-N) (reported as NH_4-N on the Waste Analysis Report). NO_3-N is determined by nitrate-hydrazine reduction (Kempers 1988; Skalar Analytical 1995b) and NH_4-N is determined modified Berthelot reaction (adapted from Krom 1980; Skalar Analytical 1995a) with an auto-flow spectrophotometric analyzer (San^{++} Segmented Flow Auto-Analyzer, Skalar Instruments; Breda, The Netherlands) following a deionized water (1 g / 25 mL) 30-minute extraction on a reciprocating shaker (Wrist Action Model 75; Burrell Corp. Pittsburgh, PA). Results are expressed in parts per million (ppm) [equivalent to mg/kg] on a dry-weight basis.

Organic-nitrogen (OR-N) is calculated as the difference between total N and IN-N concentrations. Results are expressed in parts per million (ppm) [equivalent to mg/kg] on a dry-weight basis.

Phosphorus (P), potassium (K), calcium (Ca), sulfur (S), magnesium (Mg), boron (B), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), sodium (Na), nickel (Ni), cadmium (Cd), and lead (Pb)

Total concentrations of P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, Na, Ni, Cd, and Pb are determined with Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) (Spectro Arcos EOP, Spectro Analytical: A Division of Ametek; Mahwah, NJ) (Donohue and Aho 1992; adapted USEPA 2001), after closed-vessel Nitric acid (HNO_3) digestion in a microwave digestion system (MARS 6 Microwaves; CEM Corp.; Matthews, NC) (Campbell and Plank 1992). A 0.5 g aliquot of dried/ground sample is digested in 10 mL 15.6N HNO_3 (1.0 g in 15 mL HNO_3 when Ni, Cd, and Pb are analyzed) for 30 minutes in a microwave, and the prepared sample volume is brought to 50 mL with deionized water and then filtered through acid-washed filter paper (Laboratory Filtration Group, Houston, TX) prior to measurement. Elements are measured using a six point calibration (five point calibration for Cd, Ni, and Pb) at wavelengths

listed in Table 1. Results are expressed in parts per million (ppm) [equivalent to mg/kg] on a dry-weight basis.

pH and electrical conductivity (EC)
The pH measurement is taken with a hydrogen electrode (Orion 920A; Thermo Fisher Scientific; Beverly, MA) on a 1:1 (v/v) slurry of sample to deionized water [10 cm^3 of sample in 10 cm^3 (mL) water] that has been allowed to stand for 60 minutes (Eaton et al. 2005; Wolf 2003b). Following pH measurement, an additional 10 cm^3 of deionized water is added to the slurry, and the sample is filtered with folded 110 mm filters (Laboratory Filtration Group, Houston, TX). Electrical conductivity (EC) (a measure of soluble salts) is measured on this 1:2 (v/v) filtrate using a conductivity meter (Orion 550A; Thermo Fisher Scientific; Beverly, MA) (USEPA 1983; Wolf 2003a). Results of EC are expressed in 10^{-5} S/cm.

Calcium carbonate equivalence (CCE%)
CCE% is a measure of the acid-neutralizing capacity of a waste material. The process involves dissolving a 1.0 g aliquot of dried/ground sample in 50 mL 0.5N HCl (with heat) and back-titrating to pH 7 with 0.25N NaOH, according to the potentiometric titration method (AOAC, 1990a). Results are expressed as percentage of pure calcium carbonate.

Agricultural lime equivalent (ALE)
ALE indicates the amount of waste that provides a liming effect equivalent to one ton of agricultural grade limestone (assuming 90% calcium carbonate). This value is calculated as follows: ALE = 1800 ÷ [(DM% ÷ 100) × (CCE% ÷ 100) × 2000]. Results are expressed in tons. The factor 1800 represents 90% of one ton (in units of pounds).

Liquid Waste Analysis Methodology

Sample handling
Prior to analysis, samples are homogenized by shaking.

Nitrogen (N)
Total Kjeldahl Nitrogen (TKN) is determined by modified EPA Method 351.2 using an auto-flow spectrophotometric analyzer (San^{++} Segmented Flow Auto-Analyzer; Skalar Instruments; Breda, The Netherlands) (Skalar Analytical 1995c; USEPA 1993). A 10 mL aliquot of homogenized sample is digested in 10 mL concentrated H_2SO_4 for 45–60 minutes on a digestion block, and the volume is brought to 100 mL with deionized water prior to measurement. Results are expressed in parts per million (ppm) [equivalent to mg/L].

Inorganic-nitrogen (IN-N) fraction concentrations include nitrate-nitrogen plus nitrite-nitrogen (NO_3-N + NO_2-N) (reported as NO_3-N on the Waste Analysis Report) and ammonium-nitrogen (NH_4-N). NO_3-N is determined on ~10 mL homogenized, filtered (Laboratory Filtration Group, Houston, TX) sample by nitrate-hydrazine reduction (Kempers 1988; Skalar Analytical 1995b) and NH_4-N is determined by a modified Berthelot reaction (adapted from Krom 1980; Skalar Analytical 1995a), with an auto-flow spectrophotometric analyzer (San^{++} Segmented Flow Auto-Analyzer, Skalar Instruments; Breda, The Netherlands). Results are expressed in parts per million (ppm) [equivalent to mg/L].

Phosphorus (P), potassium (K), calcium (Ca), sulfur (S), magnesium (Mg), boron (B), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), sodium (Na), nickel (Ni), cadmium (Cd), and lead (Pb)

Total concentrations of P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, Na, Ni, Cd, and Pb are determined with Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) (Spectro Arcos EOP, Spectro Analytical: A Division of Ametek; Mahwah, NJ) (Donohue and Aho 1992; adapted USEPA 2001), after closed-vessel Nitric acid (HNO_3) digestion in a microwave digestion system (MARS 6 Microwaves; CEM Corp.; Matthews, NC) (Campbell and Plank 1992. A 5 mL aliquot of homogenized sample is digested in 10 mL 15.6N HNO_3 for 15 minutes in a microwave, and the volume is brought to 50 mL with deionized water and then filtered through acid-washed filter paper (Laboratory Filtration Group, Houston, TX) prior to measurement. Elements are measured using a six point calibration (five point calibration for Cd, Ni, and Pb) at wavelengths listed in Table 1. Results are expressed in parts per million (ppm) [equivalent to mg/kg] on a dry-weight basis.

pH and electrical conductivity (EC)

The pH and electrical conductivity (EC) (a measure of soluble salts) values are measured directly on homogenized samples. Filtration may be required prior to measuring EC on some samples. The pH is measured using a hydrogen electrode (Orion 920A; Thermo Fisher Scientific; Beverly, MA) (Eaton and others 2005; Wolf 2003b). Electrical conductivity is measured using a conductivity meter (Orion 550A; Thermo Fisher Scientific; Beverly, MA) (USEPA 1983; (Wolf 2003a). Results of EC are expressed in 10^{-5} S/cm.

Calcium carbonate equivalence (CCE%)

CCE% is a measure of the acid-neutralizing capacity of a waste material. The process involves dissolving a 10 mL, homogenized aliquot in 50 mL 0.5N HCl (with heat) and back-titrating to pH 7 with 0.25N NaOH, according to the potentiometric titration method (AOAC, 1990a). Results are expressed as percentage of pure calcium carbonate.

Agricultural lime equivalent (ALE)

ALE indicates the amount of waste that provides a liming effect equivalent to one ton of agricultural grade limestone (assuming 90% calcium carbonate). This value is calculated as follows (assuming 1 gal. of liquid waste weighs 8.34 lb): $ALE = 1800 \div [(CCE\% \div 100) \times 8340]$. Results are expressed in 1000 gal.

References for Waste Analysis Methodology

[AOAC] Association of Official Analytical Chemists. 1990a. AOAC official method 955.01: neutralizing value for liming materials. In: Official methods of analysis. Volume 1. 15th ed. Arlington (VA): AOAC International. p 1–2.

[AOAC] Association of Official Analytical Chemists. 1990b. AOAC official method 972.43: microchemical determination of carbon, hydrogen, and nitrogen. In: Official methods of analysis. Volume 1. 15th ed. Arlington (VA): AOAC International. p 341.

Campbell CR. 1992. Determination of total nitrogen in plant tissue by combustion. In: Plank CO, editor. Plant analysis reference procedures for the southern region of the United States. Athens (GA): Georgia Cooperative Extension Service. Southern Cooperative Series Bulletin 368. p 20–2. Available at www.ncagr.gov/agronomi/pdffiles/sera368.pdf (accessed 2009 Dec 17).

Campbell CR, Plank CO. 1992. Sample preparation. In: Plank CO, editor. Plant analysis reference procedures for the southern region of the United States. Athens (GA): Georgia Cooperative Extension Service. Southern Cooperative Series Bulletin 368. p 1–12. Available at www.ncagr.gov/agronomi/pdffiles/sera368.pdf (accessed 2009 Dec 17).

Donohue SJ, Aho DW. 1992. Determination of P, K, Ca, Mg, Mn, Fe, Al, B, Cu, and Zn in plant tissue by inductively coupled plasma (ICP) emission spectroscopy. In: Plank CO, editor. Plant analysis reference procedures for the southern region of the United States. Athens (GA): Georgia Cooperative Extension Service. Southern Cooperative Series Bulletin 368. p 34–7. Available at www.ncagr.gov/agronomi/pdffiles/sera368.pdf (accessed 2009 Dec 17).

Eaton AD, Clesceri LS, Rice EW, Greenberg AE, editors. 2005. SM 4500 H^+B: pH value in water by potentiometry using a standard hydrogen electrode. In: Standard methods for the examination of water and wastewater. 21st ed. Washington (DC): Public Health Association, Water Environment Federation, and American Water Works Association. 1368 p.

Wolf N. 2003a. Determination of manure electrical conductivity. In: Peters J, editor. Recommended methods of manure analysis. Madison (WI): University of Wisconsin Cooperative Extension. Publication A3769. p 50–1. Available at uwlab.soils.wisc.edu/pubs/A3769.pdf (accessed 2009 Dec 17).

Wolf N. 2003b. Determination of manure pH. In: Peters J, editor. Recommended methods of manure analysis. Madison (WI): University of Wisconsin Cooperative Extension. Publication A3769. p 48–9. Available at uwlab.soils.wisc.edu/pubs/A3769.pdf (accessed 2009 Dec 17).

Hoskins B, Wolf A, Wolf N. 2003. Laboratory procedures, dry matter analysis. In: Peters J, editor. Recommended methods of manure analysis. Madison (WI): University of Wisconsin Cooperative Extension. Publication A3769. p 14–7. Available at uwlab.soils.wisc.edu/pubs/A3769.pdf (accessed 2009 Dec 17).

Kempers AJ, Luft AG. 1988. Re-examination of the determination of environmental nitrate by reduction with hydrazine. Analyst 113:1117–20.

Krom M. 1980. Spectrophotometric determination of ammonia: a study of modified Berthelot reaction using salicylate and dichloroisocyanurate. Analyst 105:305–16.

Skalar Analytical B.V. 1995a. Ammonia. In: The SAN^{++} segmented flow analyzer — water analysis. Breda (The Netherlands): Skalar Analytical B.V. p 73–5.

Skalar Analytical B.V. 1995b. Nitrate + Nitrite. In: The SAN^{++} segmented flow analyzer — water analysis. Breda (The Netherlands): Skalar Analytical B.V. p 190–2.

Skalar Analytical B.V. 1995c. Nitrogen (total). In: The SAN^{++} segmented flow analyzer — water analysis. Breda (The Netherlands): Skalar Analytical B.V. p 198–200.

[USEPA] United States Environmental Protection Agency.1983. Method 120.1. Conductance (specific conductance, µmhos/cm at 25 °C). In: Methods for chemical analysis of water and wastes. Cincinnati (OH): USEPA Office of Research and Development. EPA/600/4-79-020.

[USEPA] United States Environmental Protection Agency. 1993. Method 351.2. Determination of total Kjeldahl nitrogen by semi-automated colorimetry, revision 2. In: Methods for

chemical analysis of water and wastes. Cincinnati (OH): USEPA Office of Research and Development. EPA-600/4-79-020. Available at www.epa.gov/waterscience/methods/method/files/351_2.pdf (accessed 2008 Dec 11).

[USEPA] United States Environmental Protection Agency. 2001. Method 200.7. Trace elements in water, solids, and biosolids by inductively coupled plasma–atomic spectrometry, revision 5.0. Cincinnati (OH): USEPA Office of Research and Development. EPA-821-R-01-010. Available at h2o.enr.state.nc.us/lab/qa/epamethods/200_7.pdf (accessed 2008 Dec 11).

Solution Analysis Methodology

Sample Handling

Samples are analyzed as received or filtered.

Nitrogen

Inorganic-nitrogen (IN-N) fraction concentrations include nitrate-nitrogen plus nitrite-nitrogen (NO_3-N + NO_2-N) (reported as NO_3-N on the Solution Analysis Report) and ammonium-nitrogen (NH_3-N + NH_4-N) (reported as NH_4-N on the Solution Analysis Report). Organic-nitrogen fraction concentration includes urea. NO_3-N is determined on ~10 mL homogenized sample, filtered using acid washed filter paper (Laboratory Filtration Group, Houston, TX) by nitrate-hydrazine reduction (Kempers 1988; Skalar Analytical 1995a); NH_4-N is determined by a modified Berthelot reaction (adapted from Krom 1980; Skalar Analytical 1995b); and urea concentration is determined with the diacetyl monoxime thiosemicarbazide colorimetric method (Sullivan and Havlin, 1991; Skalar Analytical 1995, Issue 6) with an auto-flow spectrophotometric analyzer (San^{++} Segmented Flow Auto-Analyzer, Skalar Instruments; Breda, The Netherlands). Results are expressed in parts per million (ppm) [equivalent to mg/L].

Phosphorus (P), potassium (K), calcium (Ca), sulfur (S), magnesium (Mg), boron (B), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), and sodium (Na)

Total concentrations of P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, and Na are determined on ~10 mL homogenized sample, filtered using acid washed filter paper (Laboratory Filtration Group, Houston, TX) with Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) (Spectro Arcos EOP, Spectro Analytical: A Division of Ametek; Mahwah, NJ) (Donohue and Aho 1992; adapted USEPA 2001). Elements are measured using a six point calibration at wavelengths listed in Table 1. Results are expressed in parts per million (ppm) [equivalent to mg/kg].

Chloride (Cl^-)

Chloride concentration is determined on ~10 mL homogenized sample, filtered using acid washed filter paper (Laboratory Filtration Group, Houston, TX) by the thiocyanate displacement method (Zall et al., 1956; Skalar Analytical 1995, Issue 6) with an auto-flow spectrophotometric analyzer (San^{++} Segmented Flow Auto-Analyzer, Skalar Instruments; Breda, The Netherlands). Results are expressed in parts per million (ppm) [equivalent to mg/L].

pH

The pH values are measured directly on homogenized samples. The pH is measured using a hydrogen electrode (Orion 920A; Thermo Fisher Scientific; Beverly, MA) (Eaton et al., 2005).

Electrical conductivity (EC)

The electrical conductivity (EC) [a measure of soluble salts (SS)] values are measured directly on homogenized samples. Electrical conductivity is measured using a conductivity meter (Orion 550A; Thermo Fisher Scientific; Beverly, MA) (USEPA 1983). Results of EC are expressed as mS/cm and SS are expressed in 10^{-5} S/cm.

Carbonate, bicarbonate, and total alkalinity

Carbonate (CO_3) and bicarbonate (HCO_3) concentrations are measured by titration using phenolphthalein and methyl orange as endpoint indicators (AOAC, 1990). Results of carbonate and bicarbonate are expressed in units of meq/L. Total alkalinity (expressed in units of ppm $CaCO_3$) is calculated as follows: CO_3 (meq/L) + HCO_3 (meq/L) × 50.

References for Solution Analysis Methodology

[AOAC]American Organization of Analytical Chemists. 1990. AOAC official method 920.194: carbonate and bicarbonate in water—titrametric method, final action. In: Official methods of analysis. 15th ed. Arlington (VA): AOAC International. p 322.

Donohue SJ, Aho DW. 1992. Determination of P, K, Ca, Mg, Mn, Fe, Al, B, Cu, and Zn in plant tissue by inductively coupled plasma (ICP) emission spectroscopy. In: Plank CO, editor. Plant analysis reference procedures for the southern region of the United States. Athens (GA): Georgia Cooperative Extension Service. Southern Cooperative Series Bulletin 368. p 34–7. Available at www.ncagr.gov/agronomi/pdffiles/sera368.pdf (accessed 2009 Dec 17).

Eaton AD, Clesceri LS, Rice EW, Greenberg AE, editors. 2005. SM 4500 H^+B: pH value in water by potentiometry using a standard hydrogen electrode. In: Standard methods for the examination of water and wastewater. 21st ed. Washington (DC): Public Health Association, Water Environment Federation, and American Water Works Association. 1368 p.

Kempers AJ, Luft AG. 1988. Re-examination of the determination of environmental nitrate by reduction with hydrazine. Analyst 113:1117–20.

Krom M. 1980. Spectrophotometric determination of ammonia: a study of modified Berthelot reaction using salicylate and dichloroisocyanurate. Analyst 105:305–16.

Skalar Analytical B.V. 1995 Issue 6. Nitrate + Nitrite. In: The SAN^{++} segmented flow analyzer — water analysis. Breda (The Netherlands): Skalar Analytical B.V. p 190–2.

Skalar Analytical B.V. 1995 Issue 6. Ammonia. In: The SAN^{++} segmented flow analyzer — water analysis. Breda (The Netherlands): Skalar Analytical B.V. p 73–5.

Skalar Analytical B.V. 1995 Issue 6. Urea. In: The SAN^{++} segmented flow analyzer — water analysis. Breda (The Netherlands): Skalar Analytical B.V. p 241-243.

Skalar Analytical B.V. 1995 Issue 6. Chloride. In: The SAN^{++} segmented flow analyzer — water analysis. Breda (The Netherlands): Skalar Analytical B.V. p 103-105.

Sullivan DM, Havlin JL. 1991. Flow injection analysis of urea nitrogen in soil extracts. Soil Sci Soc Am J 55: 109–13.

[USEPA] United States Environmental Protection Agency.1983. Method 120.1. Conductance (specific conductance, µmhos/cm at 25 °C). In: Methods for chemical analysis of water and wastes. Cincinnati (OH): USEPA Office of Research and Development. EPA/600/4-79-020.

[USEPA] United States Environmental Protection Agency. 2001. Method 200.7. Trace elements in water, solids, and biosolids by inductively coupled plasma–atomic spectrometry, revision 5.0. Cincinnati (OH): USEPA Office of Research and Development. EPA-821-R-01-010. Available at h2o.enr.state.nc.us/lab/qa/epamethods/200_7.pdf (accessed 2008 Dec 11).

Zall DM, Fisher D, Garner MQ. 1956. Photometric determination of chloride in water. Anal Chem 28: 1665–8.

Media Analysis Methodology

All measurements except pH are made on the saturated media extract solution.

Sample Handling

Samples are analyzed as received. pH is measured on a 1:1 v/v ratio of fresh sample to DI water following a 60 minute equilibration. The saturated media extract is obtained by adding DI water to a fresh ~400 mL sample until it reaches a saturation point. The sample is allowed to equilibrate for 60 minutes, and then the liquid is extracted from the sample by vacuum filtration (Whatman 1 Qualitative Circles, 110 mm).

Nitrogen

Inorganic-nitrogen (IN-N) fraction concentrations include nitrate-nitrogen plus nitrite-nitrogen (NO_3-N + NO_2-N) (reported as NO_3-N on the Media Analysis Report) and ammonium-nitrogen (NH_3-N + NH_4-N) (reported as NH_4-N on the Media Analysis Report). Organic-nitrogen fraction concentration includes urea. NO_3-N is determined on the saturated media extract, (~10 mL) by nitrate-hydrazine reduction (Kempers 1988; Skalar Analytical 1995a); NH_4-N is determined by a modified Berthelot reaction (adapted from Krom 1980; Skalar Analytical 1995b); and urea concentration is determined with the diacetyl monoxime thiosemicarbazide colorimetric method (Sullivan and Havlin, 1991; Skalar Analytical 1995, Issue 6) with an auto-flow spectrophotometric analyzer (San^{++} Segmented Flow Auto-Analyzer, Skalar Instruments; Breda, The Netherlands). Results are expressed in parts per million (ppm) [equivalent to mg/L].

Phosphorus (P), potassium (K), calcium (Ca), sulfur (S), magnesium (Mg), boron (B), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), and sodium (Na)

Total concentrations of P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, and Na are determined on a homogenized sample (~10 mL) of saturated media extract with Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) (Spectro Arcos EOP, Spectro Analytical: A Division of Ametek; Mahwah, NJ) (Donohue and Aho 1992; adapted USEPA 2001). Elements are

measured using a six point calibration at wavelengths listed in Table 1. Results are expressed in parts per million (ppm) [equivalent to mg/kg].

Chloride (Cl^-)

Chloride concentration is determined on the saturated media extract (~10mL) by the thiocyanate displacement method (Zall et al., 1956; Skalar Analytical 1995, Issue 6) with an auto-flow spectrophotometric analyzer (San^{++} Segmented Flow Auto-Analyzer, Skalar Instruments; Breda, The Netherlands). Results are expressed in parts per million (ppm) [equivalent to mg/L].

pH

The pH values are measured on a 1:1 v/v ratio of fresh sample to DI water following a 60 minute equilibration. The pH is measured using a hydrogen electrode (Orion 920A; Thermo Fisher Scientific; Beverly, MA) (Eaton and others 2005).

Electrical conductivity (EC)

The electrical conductivity (EC) [a measure of soluble salts (SS)] values are measured on the saturated media extract. Electrical conductivity is measured using a conductivity meter (Orion 550A; Thermo Fisher Scientific; Beverly, MA) (USEPA 1983). Results of EC are expressed as mS/cm and SS are expressed in 10^{-5} S/cm.

References for Soilless Media Methodology

Donohue SJ, Aho DW. 1992. Determination of P, K, Ca, Mg, Mn, Fe, Al, B, Cu, and Zn in plant tissue by inductively coupled plasma (ICP) emission spectroscopy. In: Plank CO, editor. Plant analysis reference procedures for the southern region of the United States. Athens (GA): Georgia Cooperative Extension Service. Southern Cooperative Series Bulletin 368. p 34–7. Available at www.ncagr.gov/agronomi/pdffiles/sera368.pdf (accessed 2009 Dec 17).

Eaton AD, Clesceri LS, Rice EW, Greenberg AE, editors. 2005. SM 4500 H^+B: pH value in water by potentiometry using a standard hydrogen electrode. In: Standard methods for the examination of water and wastewater. 21st ed. Washington (DC): Public Health Association, Water Environment Federation, and American Water Works Association. 1368 p.

Kempers AJ, Luft AG. 1988. Re-examination of the determination of environmental nitrate by reduction with hydrazine. Analyst 113:1117–20.

Krom M. 1980. Spectrophotometric determination of ammonia: a study of modified Berthelot reaction using salicylate and dichloroisocyanurate. Analyst 105:305–16.

Skalar Analytical B.V. 1995a. Nitrate + Nitrite. In: The SAN^{++} segmented flow analyzer — water analysis. Breda (The Netherlands): Skalar Analytical B.V. p 190–2.

Skalar Analytical B.V. 1995b. Ammonia. In: The SAN^{++} segmented flow analyzer — water analysis. Breda (The Netherlands): Skalar Analytical B.V. p 73–5.

Skalar Analytical B.V. 1995 Issue 6. Urea. In: The SAN^{++} segmented flow analyzer — water analysis. Breda (The Netherlands): Skalar Analytical B.V. p 241-243.

Skalar Analytical B.V. 1995 Issue 6. Chloride. In: The SAN^{++} segmented flow analyzer — water analysis. Breda (The Netherlands): Skalar Analytical B.V. p 103-105.

Sullivan DM, Havlin JL. 1991. Flow injection analysis of urea nitrogen in soil extracts. Soil Sci Soc Am J 55: 109–13.

[USEPA] United States Environmental Protection Agency.1983. Method 120.1. Conductance (specific conductance, µmhos/cm at 25 °C). In: Methods for chemical analysis of water and wastes. Cincinnati (OH): USEPA Office of Research and Development. EPA/600/4-79-020.

[USEPA] United States Environmental Protection Agency. 2001. Method 200.7. Trace elements in water, solids, and biosolids by inductively coupled plasma–atomic spectrometry, revision 5.0. Cincinnati (OH): USEPA Office of Research and Development. EPA-821-R-01-010. Available at h2o.enr.state.nc.us/lab/qa/epamethods/200_7.pdf (accessed 2008 Dec 11).

Warnke, Darryl. 2011. Recommended Test Procedures for Greenhouse Growth Media. In J. Thomas Sims and A. Wolf (eds.) Recommended Soil Testing Procedures for the Northeastern United States, 3rd Ed.. Northeast Regional Bulletin #493. Agricultural Experiment Station, University of Delaware, Newark, DE. (Chapter 13) http://ag.udel.edu/extension/agnr/soiltesting%20-%20TOC.html (verified 01/09/2012)

Zall DM, Fisher D, Garner MQ. 1956. Photometric determination of chloride in water. Anal Chem 28: 1665–8.