

Strawberry Fertility Management



The key to optimizing strawberry fertility is effective and timely use of two essential agronomic tools: *soil testing* and *plant tissue analysis*. Low soil pH (acidity) is the most significant fertility problem identified in soil samples from NC strawberry fields. Soil acidity reduces the availability of essential plant nutrients and potentially damages roots, limiting plant uptake of nutrients and water. Additionally, low calcium and magnesium levels are common in highly acidic soils. Use of dolomitic lime to raise soil pH and increase calcium and magnesium levels takes many months to correct and should be a routine part of mid-summer land preparation activities. Finally, pre-planting fertilizer applications should be based on soil test recommendations rather than a fixed rate.

Plant tissue analysis should start when spring growth begins and should be done every two weeks throughout blooming and fruiting stages. Whereas the soil test measures the amount of nutrients present in the soil, plant tissue testing determines the level of nutrients that the strawberry plants are actually taking up. The NCDACS laboratory measures concentrations of essential nutrients within the strawberry leaves and compares them to established target concentrations at each growth stage. Nutrient deficiencies can be detected and corrected before visual symptoms manifest and crop yields, quality, or both are impacted. Additionally, strawberry tissue analysis measures the petiole nitrate-nitrogen concentrations, which provide the basis for a precise nitrogen rate recommendation during bloom and fruit development.

In high-value crops such as strawberries, using a combined strategy of pre-season soil testing and in-season plant tissue analysis is an inexpensive and highly effective way to optimize strawberry yield and quality.



LAND PREPARATION AND PRE-PLANTING FERTILIZATION SCHEDULE (June – early September)

Collect soil samples. One or more soil samples (depending on production size) should be submitted to the [NCDA&CS Soil Testing laboratory](#) in mid-summer (around early to mid-June). Sample turnaround time in mid-summer is typically five to seven working days from sample receipt. For detailed instructions on how to collect and submit a soil sample, refer to the [NCDA&CS Soil Testing Laboratory](#).

Apply lime. Apply lime according to soil test recommendations three to four months prior to bed formation (around mid- to late June). Lime should be incorporated into the soil during tillage activities. Dolomitic lime ($\text{CaMg}(\text{CO}_3)_2$) is most commonly used, but calcitic lime (CaCO_3) can also be used when soil tests indicate adequate magnesium, especially on finer textured soils. The target soil pH for strawberries is 6.0 for mineral soils (most soils), 5.5 for mineral/organic soils, and 5.0 for organic soils.

Apply fertilizers. Evenly broadcast fertilizers over the growing area and lightly incorporate into the soil profile immediately before bed formation. For **phosphate (P_2O_5)** and **potash (K_2O)** follow the rates recommended on the soil test report. Pre-planting phosphate and potash fertilizers commonly used in strawberry production are:

- for phosphate—diammonium phosphate or DAP (18-46-0) or triple superphosphate (0-46-0)
- for potash—potassium chloride or muriate of potash (0-0-60)

For **nitrogen (N)** apply 60 lb/acre. This is about half of the total 120 lb N/acre seasonal requirement. The remainder of the nitrogen is applied in ~5 lb/acre increments over the 12-week growing season as determined by the petiole nitrate-nitrogen ($\text{NO}_3\text{-N}$) analysis.

Commonly used pre-plant N fertilizers are:

- diammonium phosphate or DAP (18-46-0)
- ammonium sulfate (21-0-0)
- potassium nitrate (13-0-44)

Sulfur (S). Apply 15 lb/acre. Sulfur can be acquired in fertilizer blends or can be applied using potassium sulfate (0-0-50 18% S). Two other sources are potash magnesium sulfate (0-0-22-23% S) and gypsum (17% S).

Boron (B). Growers can soil-apply boron during pre-planting or supply boron during spring fertigation. If applying to soil during pre-planting, a rate of 1 lb/acre is recommended. Growers are encouraged to be careful with B applications due to potential toxicity if over-applied.

POST-PLANTING FERTILIZATION AND TISSUE SAMPLING SCHEDULE (March thru May)

Nitrogen. With strawberries as with all crops, nitrogen fertilization must be managed correctly. Overfertilization can result in soft fruit, poor flavor, increased disease susceptibility and reduced yield. It is also a poor use of resources because N fertilizer is expensive and overapplication does not net additional income. On the other hand, under fertilization can result in poor growth and also reduced yield.

Strawberry plants need a substantial and steady supply of N during the growing season. Start weekly applications of N as soon as spring growth begins, often around March 1 (or around 45 days from the first planned harvest). This date may be earlier in the southern and eastern parts of North Carolina and later in the western parts. Apply 5.25 lb N/acre at this time. For the remainder of the season, the weekly N application should depend on tissue testing results. Commonly used post-planting N fertilizers for strawberries are:

- calcium nitrate (15.5-0-0)
- potassium nitrate (13-0-44)
- ammonium sulfate (21-0-0)

After the initial week of fertigation, *tissue sample every two weeks to adjust fertility as needed.* The plant tissue analysis report will provide an N recommendation rate of 0 lb to 7 lb N/acre/week, depending on tissue results.

The N rate recommended on the plant tissue analysis report is derived from measuring the nitrate-nitrogen (NO₃-N) levels in the strawberry petioles. Petiole NO₃-N levels represent a snapshot of N moving from the soil into the plant and are a better predictor of N needs than leaf tissue N. The target ranges for each growth week are presented in Table 1.

Sulfur (S). If tissue analysis indicates that S is low or deficient, a one-time application of 1-2 lb S/acre will be recommended on the plant tissue analysis report. Common fertilizers used are Epsom salts (magnesium sulfate) (13% S) and potassium sulfate (18% S). The equivalent weights of each required to meet the S recommendations are listed below:

- 7–14 lb Epsom salts (13% S) will provide ~1–2 lb S/A
- 2–4 lb potassium sulfate (0-0-50) will provide ~1–2 lb S/A

If the nitrogen to sulfur (N:S) ratio is high (> 18:1), sulfur application of 1 lb S/acre will be recommended. An elevated N:S can lead to poor assimilation of either of these nutrients and often causes yellowing of the leaves. If the nitrogen to sulfur (N:S) ratio is high and the tissue concentration of S is low, a sulfur application of 2 lb S/acre will be recommended. A recommendation of 1–2 lb S/acre is equivalent to 7–14 lb Epsom salts/acre.

Potassium (K). If tissue analysis indicates that K is low or deficient, a one-time application of 7–14 lb K₂O/acre will be recommended on the plant tissue analysis report. Commonly used K fertilizers in postplanting fertigation are potassium sulfate (50% K₂O), potassium nitrate (44% K₂O), or potassium chloride. The equivalent weight required to meet the K recommendation is listed below:

- 15 – 30 lb of potassium sulfate (0-0-50) will provide 7 – 14 lb K₂O /A
- 16 – 32 lb of potassium nitrate (13-0-44) will provide 7 – 14 lb K₂O /A
- 11 – 22 lb of potassium chloride (0-0-60) will provide 7 – 14 lb K₂O /A

Boron (B). If B was not applied pre-planting, apply a one-time application of 0.125 lb B/acre with the first or second fertigation. Any additional B application should be based on tissue analysis. Boron deficiency causes many symptoms, but among the most obvious are deformed berries, asymmetrical leaves, and stubby roots. If B is low or deficient, 0.125 lb B/acre will be recommended on the soil test report. Common B fertilizers include borax (11% B) and Solubor (20.5% B).

- 1 lb borax (11% B) will provide 0.125 lb B/A.
- 0.5 lb Solubor (20.5% B) will provide 0.125 lb B/A.

Note: Be careful to apply only the recommended amount of B as the line between B sufficiency and B toxicity is very narrow.

Although the nutrients listed above tend to require the most attention from the grower, other plant nutrients can also affect strawberry health and yield. The plant tissue test also measures phosphorus (P), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu). Sufficiency ranges and nutrient recommendations where nutrients fall below sufficiency are listed in Table 2.

Table 1. Strawberry petiole nitrate-nitrogen (NO₃-N) (ppm) target ranges for growth stage and week (Campbell and Minor, 2000). B= Bloom; F = Fruit. Note: In 2016, NCDA&CS changed the NO₃-N analysis method on strawberry petioles from Ion Specific electrode (ISE) to continuous flow analysis. Petiole NO₃-N target ranges were re-calibrated at that time to account for changes between the two methods. Laboratories using ISE to measure plant nitrate should continue to reference the earlier target ranges.

Growth Stage	Week	Petiole NO ₃ -N Target Range (ppm)	Nitrogen Rate Recommendation when Petiole NO ₃ -N is:		
			LOW	SUFFICIENT	HIGH
B	1	<500			
B	2	2,500 – 4,000			
B	3	2,500 – 4,000	7 lb N/A/wk	5.25 lb /A/wk	None
B	4	2,000 – 4,000			
B	5	1,700 – 3,200			
F	6	1,700 – 3,200			
F	7	1,700 – 3,200			
F	8	1,700 – 3,200			
F	9	900 – 2,800	7 lb N/A/wk	5.25 lb /A/wk	None
F	10	900 – 2,500			
F	11	600 – 1,700			
F	12	<900			

Table 2. NCDA&CS nutrient rate recommendation based on leaf blade interpretations.

Nutrient	Sufficiency Range	One-time Nutrient Application Recommendations when Plant Index is Low (L) or Deficient (D)
N (%)	3.0 – 4.0	—
P (%)	0.2 – 0.4	10 lb P ₂ O ₅ /A
K (%)	1.1 – 2.5	7 – 14 lb K ₂ O /A
Ca (%)	0.1 – 1.5	Varies*
Mg (%)	0.25 – 0.45	1-2 lb Mg /A
S (%)	0.15 – 0.40	1-2 lb S/A
Fe (ppm)	50 – 300	Varies*
Mn (ppm)	30 – 300	0.125 lb Mn/A
Zn (ppm)	15 – 60	0.125 lb Zn/A
Cu (ppm)	3 – 15	0.125 lb Cu/A
B (ppm)	25 – 50	0.125 lb B/A
If N:S is High (H) (>18:1) → 1 lb S/A		
If N:S is High (H) (>18:1) and S is Low (L) → 2 lb S/A		

*Low leaf tissue concentrations of Ca are often associated with low pH soils. Low leaf concentrations of Fe are often associated with high pH soils. In these situations, recommendations will vary by site and the grower may be referred to the regional agronomist for their county or other advisor for individual assistance.

STRAWBERRY TISSUE SAMPLING

Routine tissue sampling starts when spring growth begins and continues throughout flowering and fruiting stages (approximately March 1 – May 30) in North Carolina. Growers should submit strawberry tissue samples every two weeks throughout the blooming and fruiting stages. It normally takes 1-2 business days for the Agronomic Division laboratory to measure nutrient levels in each sample and post the test results and recommendations online at the [PALS customer portal](#).

Sample Collection

Plant tissue samples for strawberries consist of (1) the *most recently mature trifoliolate leaf* (MRML) and (2) the associated detached *petiole*. MRMLs are fully expanded and consist of one petiole (leaf stalk) with three leaflets. They are usually located three to five leaves back from the growing point. See Fig. 1.

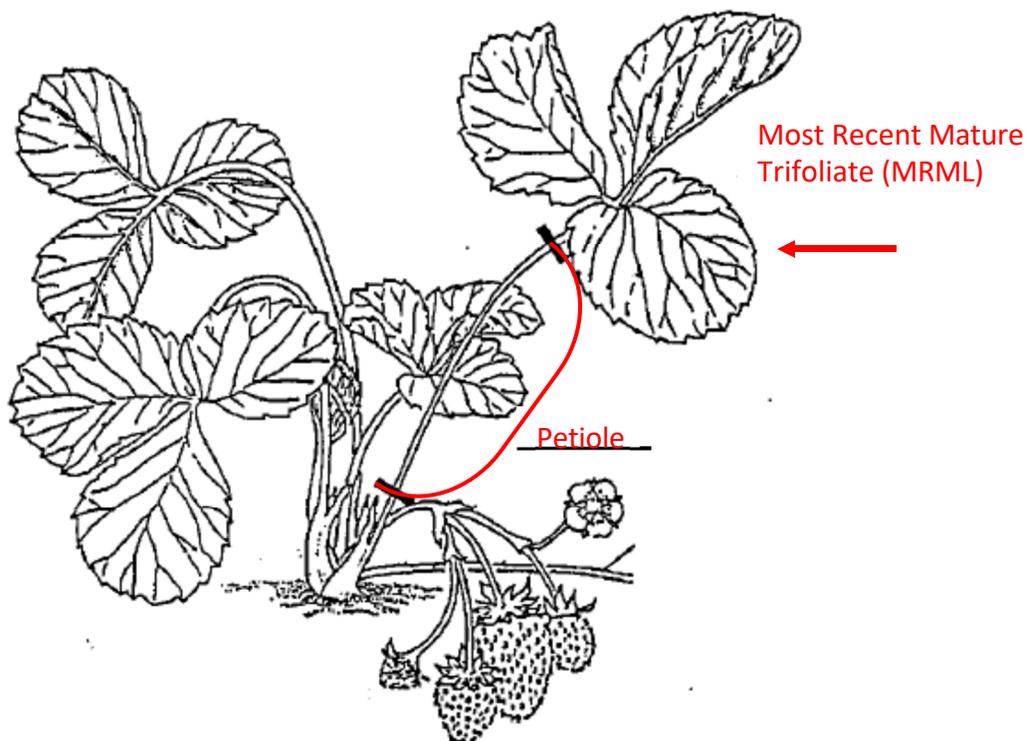


Fig. 1. Anatomy of a strawberry plant with most recent mature trifoliolate (MRML) and petiole indicated.

Collect a trifoliolate leaf with petiole from 20 to 25 plants randomly selected within a uniform area for a representative sample. For example, all of the plant material in a single sample should be the same variety, growing on the same soil type, planted at the same time and having the same fertilization history. Additionally, collect samples before noon on noncloudy days. Solar exposure strongly effects petiole nitrate-nitrogen levels in strawberry tissues.

Immediately detach petioles from the trifoliate leaves. This action stops nutrient transfer between the two plant parts, which are analyzed separately and for different purposes. *Leaf analysis* detects nutrient deficiencies and imbalances within the plant—it reports the nutritional condition of the plant. *Petiole analysis* is more sensitive to changes in available soil nitrate, which allows for a more precise nitrogen rate recommendation that is responsive to changing soil nitrogen conditions.



Fig. 2. Collecting a strawberry sample for plant tissue analysis.

Sample Submission

Fill out the [NCD&CS Plant Sample Submission form](#). Provide specific information about fertilization history, environmental conditions, and varieties grown. Most importantly, list the growth stage beginning with the first week of bloom and ending with the 12th week after bloom. For example, the first week of bloom would be recorded as growth stage B (bloom) and week 1. At about the sixth week after bloom, plants have harvestable berries, so this should be coded as growth stage F (fruit) and week 6. Providing the correct growth stage code and week has a direct impact on the accuracy of the subsequent nitrogen recommendations. See Fig. 3 for an example of how to correctly complete a Plant Sample Information form.

Predictive versus Diagnostic Tissue Samples

When submitting strawberry leaf and petioles samples for analysis, the grower should specify on the Plant Sample Information form whether the analysis is predictive or diagnostic.

The routine biweekly samples that growers submit during the 12-week active growth period would be considered *predictive*.

If the grower is submitting samples due to an observed problem (such as unhealthy-looking plants, weak growth, poor yield or quality), the samples should be submitted as *diagnostic*. When submitting diagnostic samples, be sure to collect both “good” and “bad” plant tissue and soil samples for comparison.

There is no difference between predictive and diagnostic samples in terms of cost or laboratory tests.

*** REQUIRED**

In State (\$5) OR Out of State (\$25)

 Predictive OR Diagnostic

PLANT SAMPLE SUBMISSION

NCDA&CS Agronomic Division Plant Tissue Section
 Mailing Address (USPS): 1040 Mail Service Center, Raleigh NC 27699-1040
 Physical Address (UPS/FedEx/DHS): 4300 Reedy Creek Rd, Raleigh NC 27607
 Phone: (919) 664-1600 <https://www.ncagr.gov/divisions/agronomic-services>

OFFICE USE ONLY
 REPORT # _____
 DATE REC'D _____
 INITIAL _____



PAYMENT		* CLIENT			ADVISOR			
FARM ID Berry	FEE TOTAL \$ _____ AMT PAID \$ _____	LAST NAME Farmer	FIRST NAME Jill	LAST NAME	FIRST NAME			
SAMPLING DATE 04/24/24	* METHOD OF PAYMENT: <input type="radio"/> CASH /CHECK <input type="radio"/> PAY ONLINE (CC) <input type="radio"/> ESCROW ACCOUNT: (provide Account Name or #)	MAILING ADDRESS 123 Strawberry Ln			MAILING ADDRESS			
* COUNTY (WHERE COLLECTED) Chatham	* Party Responsible for Payment: [Redacted]	CITY Berryville	STATE NC	ZIP 27275	CITY	STATE	ZIP	
NUMBER OF SAMPLES 2		EMAIL ADDRESS jillfarmer@berryfarm.com		EMAIL ADDRESS				
		PHONE (123) 123-4567	PALS Client Account # 123456	PHONE		PALS Client Account #		
LAB NUMBER <i>(lab use only)</i>	* SAMPLE ID	* CROP NAME	* GROWTH STAGE <i>(S, E, B, F, M) see p.2</i>	WEEK	* PLANT PART <i>(M, W, T, E, H, P)</i>	PLANT APPEARANCE	CORRESPONDING SAMPLE ID <input type="checkbox"/> Soil <input type="checkbox"/> Waste <input type="checkbox"/> Media <input type="checkbox"/> Nematode <input type="checkbox"/> Solution	SPECIALTESTS (\$2 EACH) Mo Cl NO ₃
	Good	Strawberry	F	6	M	healthy		<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
	Bad	Strawberry	F	6	M	yellowing		<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
								<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
								<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
								<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
GROWING CONDITIONS				DIAGNOSTIC SAMPLE COMMENTS				
Planting date: 10/07/20 Date of last soil test: 09/01/20				Camarosa variety. Bad plants show yellowing of the upper leaves in spots spread across a 2 acre field.				
Rainfall <input type="checkbox"/> Below normal <input checked="" type="checkbox"/> Normal <input type="checkbox"/> Above normal <input type="checkbox"/> Drip Irrigation								
Temperature <input type="checkbox"/> Below normal <input checked="" type="checkbox"/> Normal <input type="checkbox"/> Above normal								
Production System <input type="checkbox"/> Greenhouse <input checked="" type="checkbox"/> Field <input type="checkbox"/> High Tunnel <input type="checkbox"/> Outdoor Container								
Nutrient supply <input checked="" type="checkbox"/> Granular fertilizer <input type="checkbox"/> Liquid fertilizer <input type="checkbox"/> CRF <input type="checkbox"/> Organic								
Growth substrate <input checked="" type="checkbox"/> Soil <input type="checkbox"/> Potting Media <input type="checkbox"/> Hydroponic solution <input type="checkbox"/> Other _____								

Thank you for using agronomic services to manage nutrients and safeguard environmental quality. — Steve Troxler, Commissioner of Agriculture

Fig. 3. NCDA&CS Plant Sample Submission form example.

Tips

- Ship samples to the lab in a paper bag or envelope within 24 hours. Do not use plastic bags as they will speed plant tissue decay.
- Do not ship plant samples in the same package as soil samples.
- Address packages to the NCDA&CS Agronomic Division Plant Analysis Lab.
 - USPS: Ship to 1040 Mail Service Center. Raleigh, NC 27699
 - FedEx or UPS: Address to 4300 Reedy Creek Rd. Raleigh, NC 27607
- The turnaround time for sample reports is 1-2 days from delivery at the Reedy Creek Road location.

References

Campbell, C.R. 1992. Strawberry tissue analysis. In: 1st Annual Southeastern Strawberry Expo guide. NC Strawberry Assoc., Pittsboro.

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Campbell, C.R. and G.S. Miner. 1998. Nutrient management for strawberry production. In: Strawberry plasticulture notebook: a guide to strawberry plasticulture production. NC Strawberry Assoc., Pittsboro.

Campbell, C.R. and G.S. Miner. 2000. Strawberry, annual hill culture. In: Campbell C.R., (ed.). Reference sufficiency ranges for plant analysis in the southern region of the United States. Southern Cooperative Series Bulletin 394. NC Dept of Agri. & Consumer Serv., Raleigh. 4 Feb. 2015.
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