IV — FERTILIZER USE

Lime and Fertilizer Suggestions for Field, Pasture, and Hay Crops

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For best results, apply lime and nutrients (except nitrogen and boron) based on soil test information. If this information is unavailable, use these suggestions as general guidelines. Ranges in rates are given for P_20_5 and K_20. Sandy soils generally respond to higher rates of K_20 than clayey ones, but the opposite is true for P_2O_5. Also, attend to lime needs. For row crops (including corn, cotton, sorghum, soybean, and tobacco), experimental data across North Carolina demonstrate that starter P is not necessary on soils with very high P levels (P-index >100). On soils with P indexes between 50 and 100, starter band P may be useful with no-till management or when soils are cool and wet.

A liming program is essential to manage acidity in North Carolina soils. Base lime rates and frequency of applications on a routine soil sampling and testing program. In the absence of soil tests, most fields should receive 1 ton of lime per acre every 3 to 4 years. Liming more frequently at lesser rates may be necessary on sandy, light-colored soils where fertility changes more rapidly than in clay or organic soils, especially in years with excessive rainfall. Although liming is imperfect, over liming can cause micronutrient deficiencies, particularly manganese deficiency in small grain and soybeans grown on sandy soils. Dolomitic lime contains magnesium and is generally preferred over calcitic lime, especially on sandy soils. Lack of lime is the dominant soil fertility problem in North Carolina, even though liming is known to be a highly economical practice on either a short- or long-term basis.

Nitrogen rates are not based on soil testing. Use the RYE (Realistic Yield Expectation) for the soil and the appropriate nitrogen factor (NF) to establish the nitrogen rate. A range of NFs is found in Table 4-1A. The appropriate NF for each crop is determined by the soil mapping unit. Nitrogen rates based on RYE and NF are provided for each county by soil series at: http://nutrients.soil.ncsu.edu/yields/

Table 4-1A. Lime and Fertilizer Suggestions — Field Crops

		Plant Nutrient Suggestions When Soil Test is Unavailable[1]			
Area of State or Soil Type	**Optimum pH**	**N factor**	**P_2O_5 lb/acre**	**K_2O lb/acre**	**Remarks**
Corn Grain					
Mineral soils	6.0	1.0 to 1.25 lb/bu	10 to 20	80 to 100	Banded starter fertilizer with 20 to 30 pounds per acre of both N and P_20_5 is recommended under no-till management or on cool, wet soils, especially when planting early. Starter P not likely to benefit on soils with very high initial P levels (P-index >100). Apply 1/4 to 1/3 of the N at planting. Sidedress remaining N when plants are 15 to 24 inches high. Under irrigation increase N rate by 10% to 15%. Starter band P if using no-till management or when soils are cool and wet. On deep sandy soils, apply K just before planting or use a split application of K at planting and at sidedress. Mineral soils that are sandy or greater than 18 inches to clay should receive 20 pounds S per acre. Test organic soils to determine copper needs.
Mineral-organic soils	**5.5**				
Organic soils	**5.0**				
Corn Silage					
Mineral soils	6.0	10 to 12 lb/ton	10 to 20	100 to 120	
Mineral-organic soils	5.5				
Organic soils	5.0				
Cotton					
Mineral soils	6.2	0.06 to 0.12 lb/lb lint	10 to 20	50 to 70	Apply 20 to 30 pounds N per acre at or before planting. Apply remaining N 2 to 3 weeks after first square. Starter P not likely to benefit on soils with very high initial P levels (P-index >100). After peanuts or soybeans, reduce total N by 25 to 30 pounds per acre. Apply 0.5 pound per acre B at planting or as foliar spray at first bloom. On deep sands (more than18 inches to clay), use higher end of pounds per RYE range and apply 1/2 the remaining N at early square and 1/2 just prior to bloom. Deep sands should also receive 20 to 25 pounds S per acre.
Mineral-organic soils	5.5	0.05 to 0.09			
Organic soils	5.0	0.03 to 0.06 lb/lb lint			
Peanut					
Coastal plain	6.0	0	10 to 20	0	To minimize Ca deficiency risk, reduce unnecessary application of other cations. Apply K based on soil test recommendations and incorporate. During the growing season, at early to mid-flowering (late June-early July), apply gypsum to all Virginia market types. Use soil testing to determine Ca need for small-seeded runner market types. For larger-seeded "jumbo" runners, use half the rate as for Virginia market types. See *Peanut Information* series (http://www.peanuts.ncsu.edu/) for more information on gypsum products and rates. Apply Mg only as recommended based on soil test. Apply 0.5 pound B per acre (liquid or dry) at peak flower. Apply *Bradyrhizobia* inoculant to seed or in the seed furrow regardless of previous rotation history to ensure peanut is capable of fixing N. Inoculation is especially important on land where peanut has not been grown recently. Peanut taproot should have 10 or more nodules approximately 45 days after planting or supplemental N is needed. Apply 600 pounds/acre of ammonium sulfate (i.e., 125 pounds of N/acre) as soon as possible if roots are not nodulating effectively and foliage is N deficient. Zinc toxicity may occur in fields with soil test zinc indices greater than 250 or at lower indices with pH less than 6.0. Apply Mn at 0.5 to 1.0 pound Mn per acre when deficiency symptoms appear, often associated with high pH. See *Peanut Information* series for selection of appropriate B and Mn products if needed.
Small Grain, Grain					
Mineral soils	6.0	Wheat, Rye: 1.7 to 2.4 lb/bu	10 to 20	80 to 100	Apply 15 to 20 pounds N at planting (sometimes can be skipped if after soybean or peanut). If tiller density at spring green up (Feekes GS-3) is low, split N topdress (Feb., March). If tiller density is high, apply all N just before jointing. Use a tissue test at GS-5 to find the optimum nitrogen rate for wheat. Test organic soils to determine copper needs. Mineral soils that are sandy or greater than 18 inches to clay should receive 20 pounds S per acre. Sensitive to manganese deficiency when soil pH is greater than 6.2.
Mineral-organic soils	5.5	Barley, Triticale: 1.4 to 1.6 lb/bu			
Organic soils	5.0	Oats: 1.0 to 1.3 lb/bu	10 to 20	60 to 80	

Table 4-1A. Lime and Fertilizer Suggestions — Field Crops

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Area of State or Soil Type	**Optimum pH**	**N factor**	**P_2O_5 lb/acre**	**K_2O lb/acre**	**Remarks**
Sorghum, Grain					
Mineral soils	6.0	1.5 to 2.0 lb/bu	10 to 20	50 to 70	Apply 20% to 25% of the N before planting. Apply remainder as a topdressing. If used for silage, increase N and K_2O by 40 pounds per acre. Sensitive to manganese deficiency when soil pH is greater than 6.2.
Mineral-organic soils	5.5				
Organic soils	5.0				
Soybean					
Mineral soils	6.0	0	10 to 20	50 to 70	Fertilizer may be applied on preceding crop. Inoculate when planting in new land. If soil pH is low and lime is not applied, use 0.5 ounce of sodium molybdate per acre seed treatment to facilitate N fixation (not a recommended substitute for lime). Test organic soils to determine copper needs. Soybean is sensitive to manganese deficiency when soil pH is greater than 6.2.
Mineral-organic soils	5.5				
Organic soils	5.0				
Tobacco, Burley Greenhouse or Outdoor Float System - Float system: 5 to 7 days after seeding					
	5.5 to 6.0 (water)	See Remarks	See Remarks	See Remarks	75 to 100 ppm N from 20-10-20 or similar ratio fertilizer. Choose fertilizers with no more than 0.2% boron. Avoid fertilizers with 50% or more of N from urea. Test source water before using, and solutions during the season for nutrient levels, alkalinity, and conductivity.
Tobacco, Burley Greenhouse or Outdoor Float System - 4 weeks after seeding					
	5.5 to 6.0 (water)	See Remarks	See Remarks	See Remarks	75 to 100 ppm N from 20-10-20 or similar ratio fertilizer. Test solutions for nutrient concentrations.
Tobacco, Burley Field - Planting					
	6.0 (5.5 if history of Black Shank)	See Remarks	10 to 20	40 to 200	Apply 80 to 100 pounds N per acre under conditions where no manure or legume is involved. Avoid excess chloride by using only fertilizers formulated for tobacco.
Tobacco, Burley Field - Sidedressing					
	6.0 (5.5 if history of Black Shank)	See Remarks	0	0	Apply 100 to 150 pounds N per acre 2 to 3 weeks after transplanting. It may contain up to 75% ammonium-N. For most soils, total N application (planting + sidedressing) of 180 to 200 pounds per acre is adequate for optimum yield in the mountains and 250 pounds is adequate in the piedmont.
Tobacco, Flue-Cured Greenhouse - Float system: 5 to 7 days after seeding					
Coastal plain and piedmont	5.5 to 6.0 (water)	See Remarks	See Remarks	See Remarks	100 to 150 ppm N from 20-10-20 or similar ratio fertilizer. Choose fertilizer with no more than 0.2% boron. Avoid fertilizers with 50% or more of N from urea. Test source water before using, and solutions during the season for nutrient levels, alkalinity, and conductivity.
Tobacco, Flue-Cured Greenhouse - Float system: 4 weeks after seeding					
Coastal plain and piedmont	5.5 to 6.0 (water)	See Remarks	See Remarks	See Remarks	100 ppm N from 20-10-20 or similar ratio fertilizer or ammonium nitrate. Test solutions for nutrient concentrations.
Tobacco, Flue-Cured Field - Planting					
Coastal plain and piedmont	6.0	See Remarks and *Flue-Cured Tobacco Infor-mation*, AG-187	10 to 20	90 to 110	Apply 35 to 40 pounds N per acre from tobacco fertilizer containing up to 75% ammonium-N. If needed, apply P_2O_5 at or within 7 days after transplanting. Piedmont soils are more likely to require fertilizer P than those in the coastal plain.
Tobacco, Flue-Cured Field - Sidedressing					
0 to 10 in. to clay		See Remarks	0	See Remarks	Apply 20 pounds N per acre 2 to 3 weeks after transplanting. N source may contain up to 75% ammonium-N. N-P-K ratios of 1-0-0 or 1-0-1 are sufficient for most tobacco soils if 90 to 110 pounds of K_2O per acre were supplied by the base fertilizer at planting. Use plant tissue analysis to identify nutrient deficiencies that need to be corrected.
11 to 15 in. to clay		See Remarks	0	See Remarks	Apply 30 pounds N per acre under conditions described in remarks for 0 to 10 inches to clay. Use plant tissue analysis to identify nutrient deficiencies that need to be corrected.
Over 15 in. to clay		See Remarks and *Flue-Cured Tobacco Information*, AG-187	0	See Remarks	Apply 40 pounds N per acre under conditions described in remarks for 0 to 10 inches to clay. Use plant tissue analysis to identify nutrient deficiencies that need to be corrected.
Tobacco, Flue-Cured Field - Adjustment for leaching					
		See Remarks and *Flue-Cured Tobacco Information*, AG-187			Replace N and K that are lost by leaching as early as conditions permit. Adjustments are normally not needed on soils with clay less than 10 inches from the surface. Magnesium and sulfur leaching may also be a concern on deep sandy soils. Use plant tissue analysis as a guide for determining nutrient deficiencies that need to be corrected.

[1] Suggested rates may overestimate or underestimate actual needs. Take soil samples to assure accurate nutrient requirements.

Table 4-1B. Lime and Fertilizer Suggestions — Pasture and Hay Crops

Commodity	Purpose	Area of State	Optimum pH	Plant Nutrient Suggestions When Soil Test is Unavailable[1]			Remarks
				N Based on RYE	P_2O_5 lb/acre	K_2O lb/acre	
Alfalfa	Seeding	All	6.5	See Remarks	90	150	Apply 20 pounds N per acre before planting. Apply 3 pounds boron per acre. Use inoculant at seeding.
	Annual maintenance	All	6.5	0	45	130	Apply first topdressing in spring of second year, following seeding. Each annual topdressing should include 2 pounds boron per acre.
Ladino Clover/Grass Mixture (>30% clover)	Seeding	All	6.5	See Remarks	90	150	Apply 20 pounds N per acre before planting.
	Annual maintenance	All	6.5	0	45	150	Apply first topdressing in spring of second year, following seeding. When legumes make up 30% of stands, yield will be similar to pure grass receiving 150 to 200 pounds of N per acre.
Bluegrass/ White Clover Mixture (>30% clover)	Annual maintenance	Mountain	6.0	0	40	90	
Tall Fescue Orchardgrass, Timothy, Prairiegrass	Seeding	All	6.5	See Remarks	45	70	Apply 40 to 60 pounds N per acre at planting.
	Annual maintenance	All	6.0	40 to 50 lb/ton[2]	40	90	Use higher N rate for maximum production. Apply 1/2 N in February to March and 1/2 N in August to September; or 1/3 N in February, 1/3 N in April, and 1/3 N in August.
Bermudagrass, hybrid and improved seed cultivars	Sprigging	All	6.0	See Remarks	45	90	Apply 60 to 80 pounds N per acre before planting. If sprigged in March, apply 1/2 N in May and 1/2 N in July first year. May apply additional 60 to 80 pounds N/acre if complete soil covered before Sept. 1. If planted with a companion legume, lime to soil pH 6.5.
	Annual maintenance	All	6.0	40 to 50 lb/ton[2]	40	180	Apply N in three or four applications, but not later than Sept. 1. If planted with a companion legume, lime to soil pH 6.5.
Sudan Hybrid Sorghum — Sudan hybrids Pearl Millet Ryegrass Small Grain	Seeding	All	6.0	See Remarks	40	90	Apply 50 to 60 pounds N per acre planting. Apply N in two to four applications following each harvest except the last one.
	Topdressing	All	6.0	40 to 60 lb/ton[2]	0	0	Apply N in 2 to 4 applications following each harvest except the last one.
Red Clover, Fescue, Orchardgrass Mixture (>30% clover)	Seeding	Piedmont	6.5	See Remarks	90	150	Apply 20 pounds N per acre before planting.
	Annual maintenance	Piedmont	6.5	0	25 to 35	60 to 80	Apply in second and third year if stand is adequate.
Switchgrass Flaccidgrass Caucasian Bluestem Eastern Gammagrass	Seeding	All	5.5 to 6.0	See Remarks	20	80	Apply 40 pounds N per acre after plants are 6 to 10 inches high to minimize grassy weed competition.
	Maintenance	All	5.5 to 6.0	Switchgrass: 30 to 40 lb/ton All others: 35 to 45 lb/ton	20	80	Apply 1/2 N in May, 1/2 N in July, or 1/3 each in May, June, and July.

[1] Suggested rates may overestimate or underestimate actual needs. Take soil samples to assure accurate nutrient requirements.

[2] Rate is for tons of dry matter produced. Recognize that while hay and silage crops remove most or all of the above ground vegetation and the nutrients contained therein, grazing animals excrete 90% or more of the nutrients they consume from feed. Therefore, consider how grazing animals are managed to uniformly distribute the excreta over the pasture. To minimize N loss to the environment, N requirements for pastures should be reduced by 25% to 50% compared to what would be used for hay-silage production; yields may or may not be reduced.

Fertilizer Suggestions for Tree Fruit

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Table 4-2. Fertilizer Suggestions for Tree Fruit

Purpose	Material	Amount	Precautions and Remarks
Apples			
Preplant	Lime and P fertilizer	Depends on soil test.	Prepare soil as deep as possible before planting. Take soil samples at least 12 inches deep (preferably 0 to 8 inches and 8 to 16 inches) for lime and phosphorus recommendation. Apply one-half of total, adjusted for the depth of incorporation, and plow down; apply other half and work in well.
Improve and/or maintain growth of young trees	10-10-10 or its equivalent	1 lb for each year of age until tree begins bearing. Then as recommended from leaf analysis.	Apply before rainfall or irrigate after application before buds swell in the spring.
To raise boron level of tree	Solubor	1 lb/100 gal of spray at first cover	If leaf analysis shows a deficiency, use additional cover sprays as recommended from leaf analysis to reduce “cork spot.” Dry years and large fruit may enhance the incidence of “cork spot.”
Growth and fruit development	Nitrogen	1.25 lb of actual N for trees producing 10 to 15 bu of apples	Annual terminal growth should be about 12 inches. Use observations of growth, crop size, and fruit condition plus the leaf analysis to determine the yearly application.
Increase foliar level	Potassium	Apply according to leaf analysis. Rate dependent upon soil analysis.	Leaf analysis is a good indicator of the need for a soil application.
Increase calcium level of tree	Gypsum ($CaSO_4$)	15 to 50 lb/tree with a 6- to 10-ft radius.	Apply only as needed by low soil or tissue calcium. One application will usually last 3 to 5 years.
	Calcium nitrate	Apply in late fall or early spring at rate to supply recommended nitrogen.	Applied as soil applications to increase calcium supply and reduce “Bitter Pit.”
Foliar application	Calcium nitrate	3 lb/100 gal for sprays two weeks apart and ending 2 to 3 weeks before harvest.	Apply to reduce the incidence of “Bitter Pit.” Excessive use of $CaNO_3$ may result in excessive tree vigor, which may actually worsen Bitter Pit. Both soil and foliar applications may be needed on large-fruited varieties. Leaf analysis may be beneficial.
	Calcium chloride	Same time as calcium nitrate. 2 lb/100 gal water.	Apply to reduce incidence of “Bitter Pit.” DO NOT apply when temperature is 85 degrees F or above.
Peaches			
Preplant	Lime and Phosphorus	Depends on soil test.	Apply dolomitic lime necessary to raise soil pH above 6.0. Apply phosphorus to raise levels to desired range as indicated by soil test.
Tree growth, first year	N, P_2O_5, & K_2O	5 lb/acre of each per application.	Broadcast 0.5 pound of 10-10-10 around trees after growth starts in spring (April). Repeat every 4 to 6 weeks until August on sandy soils. On heavier soils, apply 0.5 pound of 10-10-10 one month after planting and 0.5 pound of 10-10-10 in May.
Tree growth, second year	N, P_2O_5, and K_2O	10 lb/acre of each per application.	Double amounts used first year. Make first application before growth starts in March and repeat in May. In sandy soils or if leaching is severe, an additional application may be made in July.
Tree growth, third year	N, P_2O_5, and K_2O	30 lb/acre of each	Make first application of 15 pound of each before growth starts and repeat in 6 to 8 weeks. If leaching is severe, repeat in July.
Growth and fruit development of young, bearing trees	N, P_2O_5, & K_2O	70 lb/acre of each (Determine by soil and foliar analysis.)	Broadcast under trees 40 pounds/acre each of N, P_2O_5, and K_2O (for example 400 pounds/acre 10-10-10) before growth starts. Add 30 pounds/acre each of N, P_2O_5, and K_2O after fruit set. If soil phosphorus test is high, omit P in second application. If leaching is severe, apply 20 to 30 pounds N/acre after harvest.
Growth and fruit development of mature trees	N, P_2O_5, and K_2O	70 lb/acre of each (Determine by soil and foliar analysis.)	Broadcast under trees 40 pounds/acre each of N, P_2O_5, and K_2O (for example, 400 pounds/acre 10-10-10) before growth starts. Add 30 pounds/acre of N, P_2O_5, and K_2O after fruit set. If soil test phosphorus is high, omit P in second application. If leaching is severe, apply 30 pounds N/acre after harvest.
Increase boron level of tree	Solubar		Apply boron to producing trees by spraying foliage with Solubor or equivalent product at a rate of 0.75 pounds Solubor/100 gallons of water once each year.
Soil pH maintenance	Dolomitic lime		Maintain soil pH above 6.0.

Fertilizer Suggestions for Small Fruit

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For best results, fertilize using soil and tissue test information. If unavailable, use the general suggestions below.

Table 4-3. Fertilizer Suggestions for Small Fruit

Purpose	Material	Amount	Precautions and Remarks
Blackberries			
Preplant	Lime, P_2O_5, and K_2O	Apply based on a recent soil test report.	Blackberries can be grown on a variety of soil types. Regardless of the soil type, however, organic matter additions, pH adjustments, and incorporation of phosphorus (P) and potassium (K) should be completed before planting to optimize productivity. Take a soil test three to six months prior to planting to ensure that soil amendments are added appropriately.
Growth first year	N	20 to 50 lb/acre	Apply N in a split application: 1-2 weeks after an early spring planting and again 30 days later. Optimally, N can be portioned out through the drip irrigation system on a weekly basis.
	P_2O_5 and K_2O	30 to 60 lb/acre	Assuming pre-plant P and K were applied according to soil test recommendations, additional P and K during the first year should not be needed. If this is not the case, apply P and K in 4-inch bands around but not closer than 6 inches from stems. Optimally, portion out P and K through the drip irrigation system on a weekly basis during the growing season.
Growth second year	N	35 to 60 lb/acre (up to 65 lb/acre on sandy soil)	Apply N in single or split application. For single application, apply in March. Spread fertilizer uniformly in 4-inch bands around but not closer than 6 inches from stems. For split application, apply N between the spring flush of growth and harvest with the greater portion applied as spring growth begins. Optimally, N can be portioned out through the drip irrigation system on a weekly basis. Only apply N after harvest if tissue analysis indicates it is low. Use primocane leaf tissue analysis 10-14 days post-harvest to optimize N fertilization. Monitor growth and adjust N appropriately to achieve optimal growth rate; check excessive vegetative growth with a reduction in N rate.
	P_2O_5 and K_2O	30 to 60 lb/acre	P and K can be applied in the fall if this is most convenient. Optimally, apply P and K during the growing season as per N recommendations. Adjust P and K rates as needed according to tissue analysis.
Growth third year and mature planting	N	60 to 80 lb/acre	Apply N, P and K according to recommendations for second year. Use primocane leaf tissue analysis 10-14 days post-harvest to optimize and manage fertilization program.
	P_2O_5 and K_2O	30 to 60 lb/acre	
Blueberries			
Site modification one year to six months prior to planting	Raised beds, Sulfur, organic additions of peat moss or pine bark, P_2O_5, and K_2O	Apply based on a recent soil test report	Most NC soils require modification (raised beds, organic additions) to grow blueberries successfully, with the exception of certain high-organic, acid soils in the coastal plain. Blueberries require an acid soil with an organic matter content (HM%) above 3%, with good aeration and constant moisture. A soil pH of 5.0 or less is needed for highbush and southern highbush blueberries. Rabbiteye blueberries will tolerate slightly higher pH, up to 5.3. Sulfur at a rate of 1 pound per 100 square feet can be used to lower pH one point (for example, from 6.0 down to 5.0). Use 2 pounds per 100 square feet on heavier soils. Where needed, apply sulfur one year in advance and re-test prior to planting. Do not over-apply sulfur.
Growth first year	N, P_2O_5, and K_2O	40 to 80 lb 14-28-14/acre per application	Apply after first flush of growth and repeat every 4 to 6 weeks until mid-August. Extend application interval during dry periods until rainfall has totaled 4 inches Based on 1,360 plants per acre.
Growth second year	N, P_2O_5, and K_2O	Double first year amount at first application only	Use same schedule and amounts after first application as first year.
Growth and fruit development of bearing plants	N, P_2O_5, and K_2O	150 to 250 lb 14-28-14/acre	Apply 2/3 of this amount before bloom and 1/3 4 to 6 weeks later (early May). Apply 10 to 30 pounds additional N/acre immediately after harvest if more vigorous growth is desired. Apply 50 pounds per acre of diammonium phosphate (18-48-0) in mid-August to maintain plant vigor if P_2O_5 is low or leaching has been severe.
Grapes, Bunch			
Same as muscadine schedule. Petiole analysis can show which nutrients are limiting. Collect petioles opposite the first or second flower/fruit cluster at full bloom to veraiso. Contact your county Cooperative Extension agent for further information.			
Grapes, Muscadine			
Preplant	Lime, P_2O_5, and K_2O	Apply based on a recent soil test report.	Any pH adjustments and incorporation of phosphorus (P) and potassium (K) should be completed before planting to optimize productivity. Take a soil test three to six months prior to planting to ensure that soil amendments are added appropriately.
First year	N, P_2O_5, and K_2O	0.25 lb 10-10-10 per vine per application	Apply after growth starts (late April to early May) and repeat in June and July (but no later than mid-July as winter injury may occur). Broadcast in a circle at least 18 inches from the trunk.
Second year	N, P_2O_5, and K_2O	0.5 lb 10-10-10 per vine per application	Apply in March and again in May and early July. To minimize the potential for winter cold injury, Piedmont and foothills growers should omit the July fertilizer application. Do not put fertilizer closer than 21 inches from the trunk.
Third year	N, P_2O_5, and K_2O	0.75 lb 10-10-10 per vine per application	Apply in March, in May and again in late June. Piedmont and foothills growers should omit the late June fertilizer application. Do not put fertilizer closer than 21 inches from the trunk.
Mature vines	N, P_2O_5, and K_2O	200 lb 10-10-10/acre per application	Apply in March (near bud break), and again in late May. If more vigorous growth is desired, add an additional 20 pounds N per acre in late June (from 200 pounds 10-10-10). Omit this last application in the piedmont and foothills. In Eastern NC, an alternative fertilizer to 10-10-10 that shows promise involves the application of 6-6-18 in March and mid-to-late May at the rate of 333 pounds/acre per application (instead of 10-10-10 at 200 pounds/acre per application). A final application of calcium nitrate is applied in late June at 133 pounds /acre (provides 20 pounds N per acre). Use leaf tissue analysis to monitor nutrient uptake and fine-tune fertilization program. Tissue samples should be collected in early to mid-June. Collect a double fist full of mature leaves located opposite fruit clusters on fruiting shoots. Detach the petioles from the leaves before placing the leaf blades in a paper bag. Send samples to the Agronomic Division, NC Dept. of Agriculture and Consumer Services (see Chapter 3).
	B	1 lb Solubor/acre	For mature vineyards, a common recommendation has been to apply 1 pound of Solubor (20% boron) annually with 100 gallons of water per acre just before bloom. Boron deficiency is more likely on sandy soils with high pH. Excessive boron causes injury; do not exceed boron recommendations.

Table 4-3. Fertilizer Suggestions for Small Fruit

Purpose	Material	Amount	Precautions and Remarks
Raspberries			
Preplant	Lime, P_2O_5, and K_2O	Apply based on a recent soil test report.	Test before planting and apply P_2O_5, and K_2O and lime according to soil test.
Growth first year	N, P_2O_5, and K_2O	250 to 500 lb10-10-10/acre	Fertilize 30 to 60 days after planting. Apply fertilizer in a band at the side of the row but not closer than 6 inches from stems. If using a drip system, the nutrients can be added via the drip system. Portion out the fertilizer at the recommended rates weekly or as needed.
Growth second year	N, P_2O_5, and K_2O	350 to 500 lb10-10-10/acre	Apply fertilizer in a band at the side of the row but not closer than 6 inches from stems. If using a drip system, the nutrients can be added via the drip system. Portion out the fertilizer at the recommended rates weekly or as needed.
Growth third year and mature planting	N, P_2O_5, and K_2O	500 to 800 lb10-10-10/acre	Apply fertilizer in a band at the side of the row but not closer than 6 inches from stems. If using a drip system, the nutrients can be added via the drip system. Portion out the fertilizer at the recommended rates weekly or as needed.
Strawberries, Matted-row			
Growth of new planting	N	30 to 40 lb N/acre	Apply in May and repeat in August or September on sandy soils. An additional 20 to 30 pounds N per acre may be applied in January.
	P_2O_5, K_2O, and lime	Depends on soil test	Test before planting and apply P_2O_5, K_2O, and lime based on soil test.
Growth and fruit development	N	30 to 40 lb N/acre	Apply in August or September and in sandy soils again in January.
	N, P_2O_5, and K_2O	300 to 400 lb 10-10-10	Apply after harvest. If soil test for P and K are high, 30 to 40 pounds of N may be used rather than 10-10-10.
Strawberries, Plasticulture			
Preplant (fall)	N	60 lb/acre	Broadcast and incorporate before bedding. Calcium ammonium nitrate (CAN) or a complete fertilizer (if P and K recommended) may be used.
	P_2O_5, K_2O, and lime	Refer to soil test. If not available, apply 60 lb P_2O_5 and 120 lb K_2O/acre.	Soil test 3-6 months prior to planting. Apply lime at least 3 months before planting. Broadcast and incorporate recommended nutrients before bedding.
Preharvest (spring)	N	1/2 to 1 lb/acre/day (3.5 to 7 lb/acre/week) based upon petiole nitrate test	Begin biweekly tissue testing when plants begin growing in the spring. Adjust rate or omit applications depending on tissue test interpretation. Weekly injection of fertilizer is preferred; however, biweekly applications are a common practice. N fertilizer needs to be greenhouse-grade to ensure solubility and avoid clogging the drip tape emitters [i.e., Calcium Nitrate, Potassium Nitrate, Urea Ammonium Nitrate (UAN)].
	Other nutrients	Depends on tissue test	Biweekly tissue tests will indicate need. If B is needed, apply at 1/8 pound B per acre. If tissue tests indicate the need for multiple nutrient supplements, do not assume that all fertilizer components will be compatible for a single injection. Perform a jar test with a small batch to check for mixture solubility and compatibility.

Lime and Fertilizer Suggestions for Lawns

Charles Peacock, Grady Miller, and Matt Martin, Crop Science

Suggested Establishment Fertilization

Collect a soil sample for NCDA&CS analysis and follow lime and fertilizer recommendations. If the soil has not been tested, incorporate 75 pounds of ground limestone, except for centipedegrass, and 15 pounds of 0-14-14 fertilizer (or equivalent) per 1,000 square feet into the soil to a depth of 4 to 8 inches before seeding. At seeding, apply 1 pound nitrogen per 1,000 square feet from a turf-grade fertilizer in which one-fourth to one-half of the nitrogen is slowly available (e.g., 12-4-8 or 16-4-8). Use half of this fertilization rate when establishing centipedegrass. For more information, see *Carolina Lawns* or the lawn maintenance calendar for your specific grass. These can be found at http://www.turffiles.ncsu.edu. You can also request copies at your county North Carolina Cooperative Extension center.

Table 4-4A. Suggested Maintenance Fertilization for Coastal Plain[1]

	Monthly Nitrogen Application Rate per 1,000 Square Feet[2]												Total lb N/ 1,000 sq ft/yr
Lawn Grass Type	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug[3]**	**Sept**	**Oct**	**Nov**	**Dec**	
Bermudagrass													
Basic				1		1		1					3
High				1	1	1	1	1	1				6
Centipedegrass[3]													
Basic					1								1
High					1			1					2
Fescue, Tall													
Basic		0.5							1		0.5		2
High		1	0.5						1	1	0.5		4
St. Augustinegrass													
Basic					1			1					2
High				0.5	1	0.5	1	0.5	0.5				4
Zoysiagrass (Emerald and Meyer cultivars)													
Basic					1			1					2
High				1		1		1					3
Zoysiagrass (other cultivars)													
Basic					1			1					2
High				1	0.5	1	0.5	1					4

[1] All rates are per 1,000 square feet. Multiply by 43.5 to convert to an acre basis. Follow table suggestions in the absence of soil test recommendations to the contrary. With the exception of centipedegrass, use a complete (N-P-K) turf-grade fertilizer in which 1/4 to 1/2 of the nitrogen is slowly available and that has a 3-1-2 or 4-1-2 analysis (e.g., 12-4-8, 16-4-8).

[2] In the absence of soil test recommendations, apply about 1 pound potassium per 1,000 square feet using 1.6 pounds of muriate of potash (0-0-60), 5 pounds of sul-po-mag (0-0-22), or 2 pounds of potassium sulfate (0-0-50) to bermudagrass, centipedegrass, and St. Augustinegrass.

[3] Centipedegrass should be fertilized very lightly after establishment. Fertilize established centipedegrass using a low-phosphorus, high-potassium fertilizer with an analysis approaching 1-1-2 or 1-1-3. Fertilizers absent of phosphorus are preferred if soils supporting centipedegrass exhibit moderate to high levels of phosphorus.

Table 4-4B. Suggested Maintenance Fertilization for Central Piedmont[1]

Lawn Grass Type	Monthly Nitrogen Application Rate per 1,000 Square Feet[2]												Total lb N/ 1,000 sq ft/yr
	Jan	Feb	March	April	May	June	July	Aug[3]	Sept	Oct	Nov	Dec	
Bermudagrass													
Basic					1		1		1				3
High				1	1	1	1	1	1				6
Centipedegrass[3]													
Basic					1								1
High					1			1					2
Fescue, Tall													
Basic		0.5							1		0.5		2
High		1	0.5						1	1	0.5		4
Kentucky Bluegrass													
Basic		0.5							1		0.5		2
High		1	0.5						1	1	0.5		4
Kentucky Bluegrass-Fine Fescue Mix													
Basic		0.5							1		0.5		2
High		1	0.5						1	1	0.5		4
Kentucky Bluegrass-Tall Fescue Mix													
Basic		0.5							1		0.5		2
High		1	0.5						1	1	0.5		4
Kentucky Bluegrass-Tall Fescue-Fine Fescue Mix													
Basic		0.5							1		0.5		2
High		1	0.5						1	1	0.5		4
Kentucky Bluegrass-Perennial Ryegrass Mix													
Basic		1							1		1		3
High		1	0.5						1	1	0.5		4
St. Augustinegrass													
Basic					1								2
High					1		1		1				3
Zoysiagrass (Emerald and Meyer cultivars)													
Basic					1								1
High				1			1						2
Zoysiagrass (other cultivars)													
Basic					1		1						2
High				1		1		1					3

[1] All rates are per 1,000 square feet. Multiply by 43.5 to convert to an acre basis. Follow table suggestions in the absence of soil test recommendations to the contrary. With the exception of centipedegrass, use a complete (N-P-K) turf-grade fertilizer in which 1/4 to 1/2 of the nitrogen is slowly available and that has a 3-1-2 or 4-1-2 analysis (e.g., 12-4-8, 16-4-8).

[2] In the absence of soil test recommendations, apply about 1 pound potassium per 1,000 square feet using 1.6 pounds of muriate of potash (0-0-60), 5 pounds of sul-po-mag (0-0-22), or 2 pounds of potassium sulfate (0-0-50) to bermudagrass, centipedegrass, St. Augustinegrass, and zoysiagrass.

[3] Centipedegrass should be fertilized very lightly after establishment. Fertilize established centipedegrass using a low-phosphorus, high-potassium fertilizer with an analysis approaching 1-1-2 or 1-1-3. Fertilizers absent of phosphorus are preferred if soils supporting centipedegrass exhibit moderate to high levels of phosphorus.

Table 4-4C. Suggested Maintenance Fertilization for the Mountains[1]

Lawn Grass Type	Monthly Nitrogen Application Rate per 1,000 Square Feet[2]												Total lb N/ 1,000 sq ft/yr
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	
Bermudagrass													
Basic					1		1						2
High					1	1	1	1					4
Fescue, Tall													
Basic			0.5					1		0.5			2
High			1					1		1			3
Kentucky Bluegrass													
Basic			1					1					2
High			1					1					3
Kentucky Bluegrass-Fine Fescue Mix													
Basic			1					1					2
High			1					1		1			3
Kentucky Bluegrass-Tall Fescue Mix													
Basic			1					1					2
High			1					1		1			3
Kentucky Bluegrass-Tall Fescue- Fine Fescue Mix													
Basic			1					1					2
High			1					1		1			3
Kentucky Bluegrass-Perennial Ryegrass MIx													
Basic			1					1		0.5			2.5
High			1					1	1	0.5			3.5
Zoysiagrass (other cultivars)													
Basic					0.5			0.5					1
High					1		1						2

[1] All rates are per 1,000 square feet. Multiply by 43.5 to convert to an acre basis. Follow table suggestions in the absence of soil test recommendations to the contrary. With the exception of centipedegrass, use a complete (N-P-K) turf-grade fertilizer in which 1/4 to 1/2 of the nitrogen is slowly available and that has a 3-1-2 or 4-1-2 analysis (e.g., 12-4-8, 16-4-8).

[2] In the absence of soil test recommendations, apply about 1 pound potassium per 1,000 square feet using 1.6 pounds of muriate of potash (0-0-60), 5 pounds of sul-po-mag (0-0-22), or 2 pounds of potassium sulfate (0-0-50) to bermudagrass, St. Augustinegrass, and zoysiagrass.

Fertilizer Suggestions for Ornamental Plants in Landscapes

B. Fair, Horticultural Science

The fertilizer suggestions given in the table are intended as a general guide. They are not a replacement for soil analyses from samples taken on a regular basis to assure maintenance of good nutrient availability and soil pH. It is always a good idea to collect samples for a foliar analysis as well to determine if the plant itself is functioning properly.

Table 4-5. Fertilizer Suggestions for Ornamental Plants

Kind of Plant	Ratio	Type	Amount to Use	When to apply	Remarks
Trees	3-1-1 or 3-1-2	Slow Release	2-4 lbs. N/1,000 sq.ft of root zone (at least 70% of dripzone) Do not exceed 6 lbs.N/1,000 sq ft. per year	Apply slow-release split application between spring budbreak and leaf color in fall. Fall application does not necessarily predispose a plant to winter injury or promote additional growth.	Refer to ANSI A300 (Part 2) - 2011 Soil Management a. Modification, b. Fertilization, c. Drainage. Before applying fertilizer to any woody plant, you should outline your goals for fertilizing the plant(s). Acceptable reasons for fertilizing are to increase growth, flowering/fruiting, increase vigor/vitality, balance root and shoot growth, and to address a visible deficiency. Fertilizing with too much nitrogen can lead to increased herbivory or susceptibility to insects and some disease. Best application method is sub-surface liquid injection. Use broadcast dry granules only where no turf is present and only for nitrogen application. Be sure to irrigate or apply prior to a rain event. Phosphorous will bind to soil before plant roots are able to obtain sufficient quantities. Other methods include sub-surface dry drill-hole application, surface liquid application, foliar application, tree injection or implants. The last few methods should be used only when other options are impractical or under special circumstances. Always use products in accordance with manufacturer's recommendations.
		Quick Release	1-2 lbs.N/1,000 sq ft root zone	With sandy soils and areas with heavy rainfall or constant irrigation, multiple applications will be necessary. Split total dose evenly over these applications. Do not fertilize during drought periods. Do fertilize when soil is moist. Only use quick release when a sufficient response cannot be accomplished with slow-release products.	
Palms	3-1-3	15-5-15 including micronutrients, calcium and mangnesium	1-1.5 lbs. N/1,000 sq ft in root zone (maybe 2-3 times out from the dripline on some palm species)		
Shrubs	3-1-1 or 3-1-2	Slow Release	2-4 lbs. N/1,000 sq.ft of root zone (at least 70% of dripzone) Do not exceed 6 lbs.N/1,000 sq ft. per year		
		Quick Release	1-2 lbs.N/1,000 sq ft root zone		
Flowers	1-2-2 or 1-2-1 or 1-1-1	Slow release Quick release	4-6 lbs. N/1,000 sq ft	Incorporate half slow release granular forms before planting; apply second half 6 weeks after planting. If using liquid quick release form, apply every 1-4 weeks throughout growing season, using 1 qt. per sq ft	Refer to Horticultural Information Leaflet 551, *Bed Preparation and Fertilizer Recommendations for Bedding Plants in the Landscape*.

Fertilizer Suggestions for Nursery Crops

A. V. LeBude, Horticultural Science, and K. Hicks, NCDA&CS

Table 4-6. Fertilizer Suggestions for Nursery Crops

Kind of Production	Amount to Use[1]	Remarks
Deciduous Tree Seedling Beds	Year 1: 50 lb nitrogen (N) per acre or 18 oz N per 1,000 sq ft of bed. Year 2: Beds receive 100lb N per acre.	Year 1: Surface apply after first true leaves appear. Base applications of other elements upon a soil test.
Field Production	Year 1: 50 lb of nitrogen per acre incorporated as preplant. Year 2: 0.5 to 1 oz N per plant. Year 3: 1 to 2 oz N per plant. Do not exceed 100 to 200 lb N per acre. For liquid fertilizer applications through drip irrigation, reduce N application by 1/2 rate of annual field grade fertilizer. Apply equal rates of N during several irrigation events.	Year 1: Incorporate nutrients into the soil before planting. For field grade fertilizers, apply 0.67 of total amount before bud swell, 0.33 in June. Base applications of other elements upon a soil test. For more information, see http://www.ces.ncsu.edu/depts/hort/nursery/cultural/cultural_docs/field-bmps/building_nursery_soils.pdf
Container Production	All essential elements must be provided when soilless mixes are used to produce nursery crops in containers. Controlled release fertilizers offer a consistent and reliable source of nutrients through the growing season. Formulations of nutrients and their release over time differ by fertilizer company and the optimal product chosen depends upon the species being grown as well as the location of the nursery in the state. Irrigation water quality can contribute significant amounts of some nutrients, such as calcium, magnesium, and iron. Test water quality of irrigation supplies at least once a year (e.g., mid-summer) to determine if nutrient adjustments are required. Diagnosis of whole production system nutritional problems requires analysis of foliar nutrient content (sample uppermost fully expanded leaves), collection of approximately 8 ounces of leachate solution (collect from containers approximately 30 minutes after irrigation), and an irrigation water sample (collect from the irrigation head). Current research suggests that dolomitic limestone rates depend upon the calcium and magnesium content in irrigation water. As a result, limestone may not be required if provided by irrigation, however if dolomitic limestone is needed add only 2 to 5 pounds per cubic yard of pine bark and sand potting mixes. Minor element supplements included in either NPK controlled release fertilizer products or from separate minor element packages are necessary in all pine bark mixes and should be incorporated if possible. Potting mixes containing composts, however, generally do not require dolomitic limestone or minor element supplements. Leachates, irrigation water, and foliar samples can be analyzed for $5 each by the Agronomic Division, NCDA&CS, 4300 Reedy Creek Road, Raleigh, NC 27607-6465.	

[1] Rates may change with irrigation and soil type.

Lime and Fertilizer Suggestions for Vegetable Crops

J. R. Schultheis, and J. M. Davis, Horticultural Science;
C. R. Crozier, and D. L. Osmond, Soil Science

Important Notes:

1. Consult the Southeastern U.S. Vegetable Crop Handbook: http://www.thegrower.com/south-east-vegetable-guide/ for numerous crop management suggestions.
2. Since optimum fertilizer management practices vary widely due to the specific vegetable production system, soil type, weather, and previous management, plant tissue analysis may be needed to fine-tune decisions. Plant tissue samples can be analyzed for essential plant nutrients at a nominal fee by the N.C. Department of Agriculture and Consumer Services, Agronomic Services Lab, 1040 Mail Service Center, Raleigh, NC 27699-1040; (919) 733-2655. When using a private carrier to deliver the samples or dropping them off in person, use the physical address of 4300 Reedy Creek Road, Raleigh, NC 27607-6465. Consult the new plant tissue analysis guide for instructions for each specific crop http://www.ncagr.gov/agronomi/pdffiles/plantguide.pdf.
3. For most vegetables grown on light-textured soils, apply the total recommended P_2O_5 and K_2O together with 25 to 50 percent of the recommended nitrogen before planting. The remaining nitrogen can be sidedressed with a fertilizer containing nitrogen only. Sidedressing or topdressing potash (K_2O) is recommended only on extremely light sandy soils with very low cation exchange capacities.
4. It may be desirable to build up the phosphorus and potassium levels in infertile loam and silt loam soils more rapidly than provided by these recommendations. In such instances, add an additional 40 to 50 pounds of P_2O_5 and K_2O, respectively, to the recommendations listed in the table for soils testing low in phosphorus and potassium. Apply the additional amounts as a broadcast and plow down or broadcast and disk-in application.
5. In the absence of soil tests, use recommendations listed under medium phosphorus and medium potassium levels on light-textured soils that have been in intensive vegetable production.
6. For Piedmont growers producing vegetables on clay loam soils: Reduce the recommended nitrogen and potassium rates by 20 percent and increase the phosphorus rate by 25 percent of the rates indicated in this table.

Table 4-7. Lime and Fertilizer Suggestions for Vegetable Crops

Crop	Desirable pH	Nitrogen (N) lb/acre	Recommended Nutrients Based on Soil Tests								Total Amount of Nutrient Recommended and Suggested Methods of Application
			Soil Phosphorus Level				Soil Potassium Level				
			Low	Med	High	Very High	Low	Med	High	Very High	
			P_2O_5 lb/acre				K_2O lb/acre				
Asparagus	6.5										
Growing crowns		100	200	100	50	0	200	150	50	0	Total recommended.
		50	200	100	50	0	100	75	50	0	Broadcast and disk in.
		50	0	0	0	0	100	75	0	0	Sidedress after cutting.
New Planting Crowns and direct seeding		50	200	100	50	0	200	100	100	0	Total recommended.
		0	200	100	50	0	100	75	50	0	Broadcast and plow down.
		50	0	0	0	0	100	25	50	0	Sidedress at first cultivation.
Cutting Bed or Nonhybrids		100	150	100	50	0	200	150	100	0	Total recommended.
		50	150	100	50	0	100	150	100	0	Broadcast and disk in.
		50	0	0	0	0	100	75	50	0	Sidedress at first cultivation.
New hybrids		100	200	150	100	0	300	225	150	0	Total recommended.
		50	200	150	100	0	150	100	75	0	Broadcast before cutting season.
		50	0	0	0	0	100	125	75	0	Sidedress after cutting.
		Apply 2 pounds boron (B) per acre every 3 years on most soils.									
Bean, Lima Single crop	6 to 6.5	70 to 110	120	80	40	20	160	120	80	20	Total recommended.
		25 to 50	80	40	20	0	120	80	60	0	Broadcast and disk-in.
		20	40	40	20	20	40	40	20	20	Band-place with planter.
		25 to 40	0	0	0	0	0	0	0	0	Sidedress 3 to 5 weeks after emergence.
Bean, Snap	6 to 6.5	40 to 80	80	60	40	20	80	60	40	20	Total recommended.
		20 to 40	40	40	0	0	40	40	0	0	Broadcast and disk-in.
		20 to 40	40	20	40	20	40	20	40	20	Band-place with planter.
Beet	6 to 6.5	75 to 100	150	100	50	0	150	100	50	0	Total recommended.
		50	150	100	50	0	150	100	50	0	Broadcast and disk-in.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress 4 to 6 weeks after planting.
Broccoli	6 to 6.5	125 to 175	200	100	50	0	200	100	50	0	Total recommended.
		50 to 100	150	100	50	0	150	100	50	0	Broadcast and disk-in.
		50	50	0	0	0	50	0	0	0	Sidedress 2 to 3 weeks after planting.
		25	0	0	0	0	0	0	0	0	Sidedress every 2 to 3 weeks after first sidedressing.
		Apply 2 pounds boron (B) per acre with broadcast fertilizer.									

Table 4-7. Lime and Fertilizer Suggestions for Vegetable Crops

Crop	Desirable pH	Nitrogen (N) lb/acre	Recommended Nutrients Based on Soil Tests								Total Amount of Nutrient Recommended and Suggested Methods of Application
			Soil Phosphorus Level				Soil Potassium Level				
			Low	Med	High	Very High	Low	Med	High	Very High	
			P_2O_5 lb/acre				K_2O lb/acre				
Brussel Sprout, Cabbage, and Cauliflower	6 to 6.5	100 to 175	200	100	50	0	200	100	50	0	Total recommended.
		50 to 75	200	100	50	0	200	100	50	0	Broadcast and disk-in.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress 2 to 3 weeks after planting.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress if needed, according to weather.
		Apply 2 to 3 pounds boron (B) per acre and molybdenum (mo) per acre as 0.5 pound sodium molybdate per acre with broadcast fertilizer.									
Carrot	6 to 6.5	50 to 80	150	100	50	0	150	100	50	0	Total recommended.
		50	150	100	50	0	150	100	50	0	Broadcast and disk-in.
		25 to 30	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	Sidedress if needed.
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer.									
Celery	6 to 6.5	75 to 100	250	150	100	0	250	150	100	0	Total recommended.
		50	250	150	100	0	250	150	100	0	Broadcast and disk-in or drill deep.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress 2 to 3 weeks after planting.
		Apply 2 to 3 pounds boron (B) per acre with broadcast fertilizer.									
Corn, Sweet	6 to 6.5	110 to 155	160	120	80	20	160	120	80	20	Total recommended.
		40 to 60	120	100	60	0	120	100	60	0	Broadcast before planting.
		20	40	20	20	20	40	20	20	20	Band-place with planter.
		50 to 75	0	0	0	0	0	0	0	0	Sidedress when corn is 12 to 18 in. tall.
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer. NOTE: On very light sandy soils, sidedress 40 pounds N per acre when corn is 6 in. tall and another 40 pounds N per acre when corn is 12 to 18 in. tall.									
Cucumber	6 to 6.5	80 to 160	150	100	50	25	200	150	100	25	Total recommended.
		40 to 100	125	75	25	0	175	125	75	0	Broadcast and disk-in.
		20 to 30	25	25	25	25	25	25	25	25	Band-place with planter 7 to 14 days after planting.
		20 to 30	0	0	0	0	0	0	0	0	Sidedress when vines begin to run, or apply in irrigation water.
		Drip fertilization: See “cucumber” in specific recommendations in the current Southeastern Vegetable Crop Handbook.									
Eggplant Bareground	6 to 6.5	100 to 200	250	150	100	0	250	150	100	0	Total recommended.
		50 to 100	250	150	100	0	250	150	100	0	Broadcast and disk-in.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress 3 to 4 weeks after planting.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress 6 to 8 weeks after planting.
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer..									
Plasticulture		145	250	150	100	0	240	170	100	0	Total recommended.
		50	250	150	100	0	100	100	100	0	Broadcast and disk in.
		95	0	0	0	0	140	70	0	0	Fertigate.
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer. Drip fertilization: See “eggplant” in specific recommendations in the current Southeastern Vegetable Crop Handbook.									
Endive, Escarole, Leaf Lettuce	6 to 6.5	75 to 125	200	150	100	0	200	150	100	0	Total recommended.
		50 to 75	200	150	100	0	200	150	100	0	Broadcast and disk-in.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress 3 to 5 weeks after planting.
Iceberg Lettuce	6 to 6.5	85 to 175	200	150	100	0	200	150	100	0	Total recommended.
		60 to 80	200	150	100	0	200	150	100	0	Broadcast and disk-in.
		25 to 30	0	0	0	0	0	0	0	0	Sidedress 3 times beginning 2 weeks after planting.
Leafy Greens, Collard, Kale, Mustard	6 to 6.5	75 to 80	150	100	50	0	150	100	50	0	Total recommended.
		50	150	100	50	0	150	100	50	0	Broadcast and disk-in.
		25 to 30	0	0	0	0	0	0	0	0	Sidedress, if needed.
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer.									
Leek	6 to 6.5	75 to 125	200	150	100	0	200	150	100	0	Total recommended.
		50 to 75	200	150	100	0	200	150	100	0	Broadcast and disk-in.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress 3 to 4 weeks after planting if needed.
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer.									

Table 4-7. Lime and Fertilizer Suggestions for Vegetable Crops

Crop	Desirable pH	Nitrogen (N) lb/acre	Recommended Nutrients Based on Soil Tests								Total Amount of Nutrient Recommended and Suggested Methods of Application
			Soil Phosphorus Level				Soil Potassium Level				
			Low	Med	High	Very High	Low	Med	High	Very High	
			P_2O_5 lb/acre				K_2O lb/acre				
Cantaloupes and Mixed Melons Bareground	6 to 6.5	75 to 115	150	100	50	25	200	150	100	25	Total recommended.
		25 to 50	125	75	25	0	175	125	75	0	Broadcast and disk-in.
		25	25	25	25	25	25	25	25	25	Band-place with planter.
		25 to 40	0	0	0	0	0	0	0	0	Sidedress when vines start to run.
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer.									
Cantaloupes and Mixed Melons Plasticulture	6 to 6.5	75 to 150	150	100	50	25	200	150	100	25	Total recommended.
		25	150	100	50	25	100	75	50	25	Broadcast and disk in.
		50 to 100	0	0	0	0	100	75	50	0	Fertigate.
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer. Drip fertilization: See “muskmelon” in specific recommendations in the current Southeastern Vegetable Crop Handbook.									
Okra	6 to 6.5	100 to 200	250	150	100	0	250	150	100	0	Total recommended.
		50 to 100	250	150	100	0	250	150	100	0	Broadcast and disk-in.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress 3 to 4 weeks after planting.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress 6 to 8 weeks after planting.
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer. NOTE: Where plastic mulches are being used, broadcast 50 to 100 pounds nitrogen (N) per acre with recommended P_2O_5 and K_2O and disk incorporate prior to laying mulch. Drip fertilization: See “okra” in specific recommendations in the current Southeastern Vegetable Crop Handbook.									
Onion, Bulb	6 to 6.5	75 to 125	200	100	50	0	200	100	50	0	Total recommended.
		50 to 75	200	100	50	0	200	100	50	0	Broadcast and disk-in.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress 4 to 5 weeks after planting.
Onion, Green		150 to 175	200	100	50	0	200	100	50	0	Total recommended.
		50 to 75	200	100	50	0	200	100	50	0	Broadcast and disk-in.
		50	0	0	0	0	0	0	0	0	Sidedress 4 to 5 weeks after planting.
		50	0	0	0	0	0	0	0	0	Sidedress 3 to 4 weeks before harvest.
		Apply 1 to 2 pounds boron (B) and 20 pounds sulfur (S) per acre with broadcast fertilizer.									
Parsley	6 to 6.5	100 to 175	200	150	100	0	200	150	100	0	Total recommended.
		50 to 75	200	150	100	0	200	150	100	0	Broadcast and disk-in.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress after first cutting.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress after each additional cutting.
Parsnip	6 to 6.5	50 to 100	150	100	50	0	150	100	50	0	Total recommended.
		25 to 50	150	100	50	0	150	100	50	0	Broadcast and disk-in.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress 4 to 5 weeks after planting.
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer.									
Pea, English Spring plowed	5.8 to 6.5	40 to 60	120	80	40	0	120	80	40	0	Total recommended. Broadcast and disk-in before seeding.
Pea, Southern	5.8 to 6.5	16	96	48	0	0	96	48	0	0.	Broadcast and disk-in.
Pepper Bareground	6 to 6.5	100 to 130	200	150	100	0	200	150	100	0	Total recommended.
		50	200	150	100	0	200	150	100	0	Broadcast and disk-in.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress after first fruit set.
		25 to 30	0	0	0	0	0	0	0	0	Sidedress later in season if needed.
Pepper Plasticulture		100 to 185	200	150	100	0	365	300	235	0	Total recommended
		50	200	150	100	0	100	100	100	0	Broadcast and disk in.
		50 to 135	0	0	0	0	265	200	135	0	Fertigage
		Drip fertilization: See “pepper” in specific commodity recommendations in *Plasticulture for Commercial Vegetables* (AG-489).									
Potato, Irish Loams and silt loams	5.8 to 6.2	100 to 150	110	90	70	50	200	150	50	50	Total recommended.
		85 to 135	60	40	20	0	200	150	50	50	Broadcast and disk in.
		15	50	50	50	50	0	0	0	0	Band-place with planter at planting.
Sandy loams and loamy sands		150	200	150	100	50	300	200	100	50	Total recommended.
		50	200	150	100	50	300	200	100	50	Broadcast and disk in.
		100	0	0	0	0	0	0	0	0	Sidedress 4 to 5 weeks after planting.
Pumpkin and Squash (Winter) Bareground	6 to 6.5	80 to 90	150	100	50	0	200	150	100	0	Total recommended.
		40 to 50	150	100	50	0	200	150	100	0	Broadcast and disk in.
		40 to 45	0	0	0	0	0	0	0	0	Sidedress when vines begin to run.

Table 4-7. Lime and Fertilizer Suggestions for Vegetable Crops

Crop	Desirable pH	Nitrogen (N) lb/acre	Recommended Nutrients Based on Soil Tests								Total Amount of Nutrient Recommended and Suggested Methods of Application
			Soil Phosphorus Level				Soil Potassium Level				
			Low	Med	High	Very High	Low	Med	High	Very High	
			P_2O_5 lb/acre				K_2O lb/acre				
Pumpkin and Squash (Winter) Plasticulture		80 to150	150	100	50	0	200	150	100	0	Total recommended.
		25 to50	150	100	50	0	100	75	50	0	Disk in row
		55 to 100	0	0	0	0	100	75	50	0	Sidedress when vines begin to run.
Radish	6 to 6.5	50	150	100	50	0	150	100	50	0	Total recommended. Broadcast and disk-in or drill deep.
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer.									
Rutabaga and Turnip	6 to 6.5	50 to 75	150	100	50	0	150	100	50	0	Total recommended.
		25 to 50	150	100	50	0	150	100	50	0	Broadcast and disk in.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress when plants are 4 to 6 in. tall.
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer.									
Spinach Fall	6 to 6.5	75 to 125	200	150	100	0	200	150	100	0	Total recommended.
		50 to 75	200	150	100	0	200	150	100	0	Broadcast and disk in.
		25 to 50	0	0	0	0	0	0	0	0	Sidedress or topdress.
Overwinter		80 to 120	0	0	0	0	0	0	0	0	Total recommended for spring application on overwintered crop.
		50 to 80	0	0	0	0	0	0	0	0	Apply in late February.
		30 to 40	0	0	0	0	0	0	0	0	Apply in late March.
Squash, Summer	6 to 6.5	100 to 130	150	100	50	0	200	150	100	0	Total recommended.
		25 to 50	150	100	50	0	150	100	50	0	Broadcast and disk in.
		50	0	0	0	0	0	0	0	0	Sidedress when vines start to run.
		25 to 30	0	0	0	0	0	0	0	0	Apply through irrigation system.
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer. Drip/trickle fertilization: See “summer squash” in specific recommendations in the current Southeastern Vegetable Crop Handbook.									
Sweet Potato	5.8 to 6.2	50 to 80	200	100	50	0	300	200	150	0	Total recommended.
		0	150	60	30	0	150	50	30	0	Broadcast and disk in.
		50 to 80	0	0	0	0	150	150	120	120	Sidedress 21 to 28 days after planting.
		Add 0.5 pounds of actual boron (B) per acre 40 to 80 days after planting.									
Tomato Bareground for sandy loams and loamy sands	6 to 6.5	80 to 90	200	150	100	0	300	200	100	0	Total recommended.
		40 to 45	200	150	100	0	300	200	100	0	Broadcast and disk in.
		40 to 45	0	0	0	0	0	0	0	0	Sidedress when first fruits are set and as needed.
TOMATO Bareground for loams and clay	6 to 6.5	75 to 80	200	150	100	0	250	150	100	0	Total recommended.
		50	200	150	100	0	250	150	100	0	Broadcast and plow down.
		25 to 30	0	0	0	0	0	0	0	0	Sidedress when first fruits are set and as needed.
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer.									
Tomato Plasticulture		130 to 210	200	150	100	0	420	325	275	0	Total recommended.
		50	200	150	100	0	295	220	125	0	Broadcast and disk in.
		80 to 160	0	0	0	0	295	220	125	0	Fertigate
		Apply 1 to 2 pounds boron (B) per acre with broadcast fertilizer. Drop fertilization: See “tomato” in specific recommendations in the current Southeastern Vegetable Crop Handbook.									
Watermelon Nonirrigated	6 to 6.5	75 to 90	150	100	50	0	200	150	100	0	Total recommended.
		50	150	100	50	0	200	150	100	0	Broadcast and disk in.
		25 to 40	0	0	0	0	0	0	0	0	Topdress when vines start to run.
Irrigated		100 to 150	150	100	50	0	200	150	100	0	Total recommended.
		50	150	100	50	0	150	150	100	0	Broadcast and disk in.
		25 to 50	0	0	0	0	0	0	0	0	Topdress when vines start to run.
		25 to 50	0	0	0	0	0	0	0	0	Topdress at first fruit set.
Plasticulture		125 to 150	150	100	50	0	200	150	100	0	Total recommended.
		25 to 50	150	100	50	0	100	75	50	0	Disk in row.
		100	0	0	0	0	100	75	50	0	Fertigation
		NOTE: Excessive rates of N may increase hollow heart in seedless watermelons. Drip fertilization: See “watermelon” in specific recommendations in the current Southeastern Vegetable Crop Handbook.									

Fertilizer Rules and Regulations

D. L. Osmond, C. R. Crozier, and D.A. Crouse, Soil Science Department; D. Turner, NCDA&CS

Fertilizer, lime and landplaster are regulated by Plant Industry- NCDA&CS and rules and regulations in their entirety are found at http://www.ncagr.gov/plantindustry/pubs.htm.

Chlorine Guarantees for Tobacco Fertilizer

The maximum chlorine (Cl) guarantees permitted for tobacco plantbed fertilizer shall be:

1. For fertilizers with a nitrogen (N) guarantee up to and including 6 percent, 0.5 percent chlorine (Cl).
2. For fertilizers with a nitrogen (N) guarantee above 6 percent, 1 percent chlorine (Cl).

The maximum chlorine (Cl) guarantees permitted on field crop tobacco fertilizer shall be:

1. For fertilizer with a nitrogen (N) guarantee up to and including 4 percent, a maximum chlorine (Cl) guarantee of 2 percent.
2. For fertilizer with a nitrogen (N) guarantee greater than 4 percent, a maximum percent chlorine (Cl) guarantee not more than one-half of the respective total nitrogen (N) guarantee.

The maximum chlorine (Cl) permitted in tobacco top-dressers shall be 2 percent.

Size Standards for Agricultural Liming Material

Agricultural liming material shall conform to the following minimum screening standards:

1. Ninety percent must pass through U.S. Standard 20-mesh screen, with a tolerance of 5 percent.
2. For dolomitic limestone, 35 percent must pass through U.S. Standard 100-mesh screen; for calcitic limestone, 25 percent must pass through U.S. Standard 100-mesh screen, with a tolerance of 5 percent.

Additional Criteria for Agricultural Liming Material

1. A product must contain at least 6 percent magnesium (Mg) from magnesium carbonate to be classified as a dolomitic limestone.
2. There is no minimum calcium carbonate equivalent (CCE) requirement for limestone sold in North Carolina. However, the product must be labeled to show the amount necessary to equal that required from a liming material having a 90 percent CCE. Lime recommendations in North Carolina are based on 90 percent CCE. For example, a product having a CCE of 50 percent would be labeled “3,600 pounds of this material equals 1 ton of standard agricultural liming material.”
3. Pelleted lime must slake down when it comes in contact with moisture, thereby meeting the size standards for agricultural liming materials given above.

Nutrient Content of Fertilizer Materials

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Although fertilizer materials may contain two or more nutrients, usually only one of the nutrients is commonly associated with the material. The content of that nutrient is generally well-known, but the contents of other associated nutrients are less well-known. Information on the contents of lesser-known nutrients in fertilizer materials exists but is often not readily available. Information presented below gives the nutrients and their contents that are normally found in fertilizer materials. In the case of micronutrient fertilizers, only the principle micronutrient is considered relevant. This information should be considered only as a guide, since actual nutrient contents may vary slightly, depending on the source of the fertilizer material. Additional information about the nutrient content of fertilizer and organic materials can be found in the N.C. Cooperative Extension Service publications AG-439-18, AG-439-19, and AG-467 or on the Internet at http://www.bae.ncsu.edu/bae/programs/extension/publicat/wqwm/ag473_14.html.

Table 4-8. Composition of Selected Micronutrient Fertilizers

Element	Fertilizer	Chemical Formula	Elemental Percentage (%)
Mn	Manganese sulfate Manganous oxide Manganese chloride Manganese oxide	$MnSO_4•3H_2O$ MnO $MnCl_2$ MnO_2	27 41 to 68 7 62 to 70
Mo	Sodium molybdate	$Na_2MoO_4•H_2O$	38
Cu	Copper sulfate	$CuSO_4•5H_2O$	25
Zn	Zinc sulfate Zinc oxide	$ZnSO_4•H_2O$ ZnO	22 to 36 78
Fe	Ferrous sulfate Ferric sulfate	$FeSO_4•7H_2O$ $Fe_2(SO_4)_3•4H_2O$	20 23
B	Borax Solubor	$Na_2B_4O_7•10H_2O$ $Na_2B_8O_{13}•4H_2O$	11 20

Table 4-9. Composition of Selected Organic Fertilizer Materials

Nutrient Source	Analysis (%)[1] N	P_2O_5	K_2O	Relative Rate of Nutrient Release
Animal tankage	7	9	0	Medium
Bone meal				
Raw	3	22	0	Very slow
steamed	2	28	0	Slow
Castor pomace	5	1	1	Slow
Cotton seed meal	7	2	2	Slow
Dried blood	12	3	0	Fast
Feather meal	14	0.3	0.1	Fast
Hardwood ashes[2]	0.5	1	5	Slow
Linseed meal	5	2	2	Slow
Municipal yard and leaf compost[4]	0.5	0.4	0.8	Slow
Sheep wool pellets	5.8	0.9	2.4	Fast/Slow
Softwood ashes[2]	0.5	2	4	Slow
Tobacco stems	2	1	7	Slow
Turkey litter compost[3]	1.5	3.5	1	Slow
Food waste vermicompost	2.11	0.79	1.47	Slow
Animal manure vermicompost	1.67	3.04	0.55	Slow

[1] Percentages of nutrient elements may vary depending upon source. Values given are approximations.

[2] Plant-available N less than or equal to 0.25%.

[3] Compost products must be stabilized before use, or they may cause nutrient depletion.

[4] Municipal yard and leaf waste composts may contain measurable concentrations of metals, such as lead and zinc. A complete analysis of these soil amendments should be conducted before use.

Table 4-10. Composition of Typical N Solutions[1]

Contents (%)		No-Pressure Nonammonia Solutions[2]					Low Pressure Ammonia Solution	Aqua-Ammonia
Total N	16.0	19.0	21.0	28.0	30.0	32.0	37.0	20.0
NH_3	0	0	0	0	0	0	16.6	24.4
NH_4NO_3	45.8	54.3	60.0	40.0	42.2	44.3	66.8	0
Urea	0	0	0	30.0	32.7	35.4	0	0
Water	54.2	45.7	40.0	30.0	25.1	20.3	16.6	75.6
NO_3-N	8.0	9.5	10.5	7.0	7.4	7.7	11.7	0
NH_4-N	8.0	9.5	10.5	7.0	7.4	7.8	25.4[3]	20.0[3]
Urea-N	0	0	0	13.8	15.2	16.4	0	0
		Salt-out Temperatures (F)[4]						
		41	41	0	15	32	56	-58

[1] Values may vary depending on product.

[2] Several companies provide N solutions containing 3.5% to 5.0% sulfur.

[3] Includes N present as NH_3.

[4] Proprietary additives can alter salt-out temperatures; this should be verified with the dealer.

Table 4-11. Composition of Selected Fertilizer Materials[1]

Fertilizer Material	Chemical Formula	Nutrient Percentage (%)							
		NO_3-N	NH_4-N	Total N	P_2O_5	K_2O	Ca[4]	Mg	S
Ammonium nitrate	NH_4NO_3	17	17	34					
Monoammonium phosphate	$NH_4H_2PO_4$		11	11	48		1		2
Diammonium phosphate	$(NH_4)_2HPO_4$		16 to 18	16 to 18	46 to 48				
Ammonium sulfate	$(NH_4)_2SO_4$		21	21					24
Ammonium thiosulfate	$(NH_4)_2S_2O_3$			12					26
Anhydrous ammonia	NH_3		82	82					
Urea-Form[2]			38	38					
Calcium nitrate	$Ca(NO_3)_2$	15		15			19	1	
Nitrate of soda potash	$NaNO_3$•KNO_3	15		15		14			
Sodium nitrate	$NaNO_3$	16		16					
Urea	$CO(NH_2)_2$•H_2O		45 to 46	45 to 46					
Single superphosphate	$Ca(H_2PO_4)_2$ + $CaSO_4$				18 to 20		18 to 21		12
Triple superphosphate	$Ca(H_2PO_4)_2$•H_2O				42 to 50		12 to 14		1
Basic slag[3]	5CaO•P_2O_5•SiO				2 to 17		3 to 33	3	
Potassium chloride	KCl					60 to 62			
Potassium nitrate	KNO_3	13		13		44			
Potassium sulfate	K_2SO_4					50 to 53		1	18
Potassium-magnesium sulfate	K_2SO_4•2$MgSO_4$					22		11	23
Epsom salt	$MgSO_4$•7H_2O						2	10	14
Gypsum	$CaSO_4$•2H_2O						23		18.5

[1] Values may vary depending on product.

[2] Slow release N source.

[3] Lime value — about 0.67 agricultural limestone.

[4] Evaluate gypsum products marked as Ca sources based on guaranteed fertilizer analysis. Pure calcium sulfiate is 29 percent calcium. Landplasters typically contain 70 to 85 percent calcium sulfate (21 to 25 percent calcium), while phosphogypsum and other products may contain 50 percent or less calcium sulfate (15 percent calcium). See Table 4-1 for rate recommendations for peanut.

Table 4-12. Composition of Selected Specialty, Alternative, or Fertilizer Efficiency Enhancer Materials

(Not intended to be all inclusive, and inclusion does not imply endorsement.)

Product (Source)	Ingredient(s)	Primary Uses	Typical rate	Nutrient supply at typical rate (lb/ac)	Comments
AG-TEK™ BIO-D 4200 (Global Green Products)	Protein synthesized with aspartic acid, 4-0-0	in furrow and sidedress	1-2 qt/ac	If 2 qt/ac N-0.2	Product literature states this is not a fertilizer replacement and must be used with a normal soil fertility program with full fertilizer rates, mentions enhanced rooting and solution chemistry benefits.
Agrotain Dry, ADII (Koch)	NBPT(urease inhibitor)	Mix with urea or UAN solutions			Duration of urease inhibition shorter at higher temperatures and perhaps organic matter-dependent. Affects urea component of mixed N sources. Potential to reduce volatilization losses, especially in dry high pH situations.
Agrotain Plus (Koch)	NBPT+DCD (urease + nitrification inhibitors)	Mix with UAN solutions			Duration of urease and nitrification inhibition shorter at higher temperatures and perhaps organic matter-dependent. Affects urea and ammonium components of mixed N sources. Potential to reduce volatilization and leaching losses, especially in dry high pH situations or in sandy soils with heavy rainfall after application.
AVAIL (SFP)	Maleic itaconic copolymer 0-0-0	Broadcast or band with P fertilizer			Indirect mechanism, intended to increase soil CEC and influence soil cation interactions
Bio-forge (Stoller)	diformyl urea + potassium hydroxide (2-0-7)	In furrow	1 pt/ac	N-0.025 K_2O-0.09	Marketed as gene regulator intended to enhance production of proteins involved in stress tolerance
ESN (Agrium)	Urea (plastic-encapsulated) 44-0-0	broadcast		Each 1 lb 44-0-0: N-0.44	Temperature-dependent slow release, duration shorter at higher temperatures. Potential to reduce volatilization and leaching losses, especially in dry high pH situations or in sandy soils with heavy rainfall after application.
Grasshopper (Grasshopper Fertilizer)	Multiple products (e.g. 30-8-10)	Foliar (also other products)	10 lb/ac	10 lb of 30-8-10:N-3, P_2O_5-0.8, K_2O-1,B-.005, Cu-.005, Fe-.05, Mn-.005, Zn-.01, Mo-.0001	Multiple products with highly soluble ingredients and many with chelated micronutrients. Product list includes slow release N provided as methylene urea source.
GYP-Soil	Calcium sulfate (FGD source)	broadcast			Considered equivalent sources of Ca and S as conventional gypsum when rate adjusted based on composition. Potential effects on soil physical properties and subsoil aluminum toxicity.
Instinct (Dow)	Nitrapyrin (nitrification inhibitor)	Mix with UAN solutions			Duration of nitrification inhibition lower at higher temperatures and lower in soils with high organic matter content. Affects urea and ammonium components of mixed N sources. Potential to reduce leaching losses, especially in sandy soils with heavy rainfall after application.
MicroPack (Agriculture Solutions)	11-8-5 + B, Cu, Fe, Mn, Zn, Co, Mo	Foliar	2 qt/ac, possibly 2-3 times	N-0.55, P_2O_5-0.4, K_2O-0.25, B-.001, Cu-.0025, Fe-.005, Mn-.0025, Zn-.0025, Co-.000025, Mo-.000025	
Nachurs Solutions Multiple NPKS and micronutrient blends	Multiple products (e.g. HKW18 =3-18-18)	In furrow (IF), foliar	IF:2-6 gpa Foliar:1-3 gpa	2 gpa of 3-18-18: N-0.7, P_2O_5-4.2, K_2O-4.2	Multiple products with highly soluble ingredients formulated to minimize salt index.
Nutrisphere (SFP)	Maleic itaconic copolymer 0-0-0	Band or broadcast with N fertilizers			Indirect mechanism, intended to increase soil CEC and influence soil cation interactions
N Zone (AgXplore International)	Adjuvant, glycols & poly-saccharides 0-0-0	Mix with urea, UAN, liquid manures			Marketed as penetrant aid for N sources. Most likely effect is with foliar application.
Optimize (Novozymes)	Rhizobial inoculants plus LCO promoter	Seed trt			Not intended to replace in-furrow inoculation on land not previously planted to soybean.
Pentilex (Biovante)	0-37-37	Seed trt	1-1.25gal /1000 lb	If 1 gal on 35k seed/ac: P_2O_5-0.007, K_2O-0.007	
Quick-Sol	Sodium silicate	Soil, foliar	14-20 oz/ac		Soluble silicon source, of potential benefit to some crops. Advertised effects on soil ion exchange capacity & nutrient leaching.
Riser (Loveland Products)	7-17-3 + Cu, Fe, Mn, Zn	In furrow	2-5 gpa	If 3 gpa: N-2.2, P_2O_5-5.4, K_2O-1, Cu-.02, Fe-.06, Mn-.02, Zn-.3	
Soygro [Soygro (Pty) Ltd]	Microbial inoculants				Unspecified on public website, but could include rhizobial and non-nodulating species.

Solubility of Selected Fertilizer Materials

To be available to plants, at least some of a nutrient must be slightly soluble in the soil solution. The amount of substance that will dissolve at a given temperature in water is known as its solubility. Solubility of most chemicals is slightly higher at higher temperatures; that of others, especially ammonium and potassium nitrates, increases rapidly with temperature. The presence of other substances in the solution may either increase or decrease solubility. The solubility of selected pure fertilizer materials in water at 32 degrees F is shown below.

Table 4-13. Solubility of Selected Fertilizer Materials

Fertilizer Material	Chemical Formula	Solubility (lb/100 gal)	Salt Index (relative effect on the soil solution)
Ammonia	NH_3	750	47.1
Ammonium nitrate	NH_4NO_3	983	104.7
Ammonium sulfate	$(NH_4)_2SO_4$	592	69.0
Borax	$Na_2B_4O_7•10H_2O$	25	
Calcium carbonate (limestone)	$CaCO_3$	0.050	4.7
Calcium metaphosphate	$Ca(PO_3)_2$	0.008	
Calcium nitrate	$Ca(NO_3)_2•4H_2O$	1,117	52.5
Calcium sulfate	$CaSO_4•2H_2O$	2	8.1
Copper sulfate	$CuSO_4•5H_2O$	267	
Diammonium phosphate	$(NH_4)_2HPO_4$	209	29.9
Dicalcium phosphate	$CaHPO_4•2H_2O$	0.168	8
Magnesia	MgO	0.005	1.4
Magnesium sulfate	$MgSO_4•7H_2O$	580	44
Manganese sulfate	$MnSO_4•4H_2O$	875	
Monoammonium phosphate	$NH_4H_2PO_4$	358	34.2
Monocalcium phosphate	$CaH_4(PO_4)_2•H_2O$	See below[1]	15.4
Potassium chloride	KCl	233	116.3
Potassium-magnesium sulfate	$K_2SO_4•2MgSO_4$	200	
Potassium nitrate	KNO_3	108	73.6
Potassium sulfate	K_2SO_4	67	46.1
Sodium nitrate	$NaNO_3$	608	100.0
Urea	$CO(NH_2)_2$	559	75.4
Zinc sulfate	$ZnSO_4•6H_2O$	584	

[1] Material decomposes with a small amount of water and is soluble in a large amount. The solubility varies with the conditions.

Mixing Herbicides with Nitrogen Solutions or Fluid Fertilizers

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Tank-mixing and applying herbicides with nonpressure nitrogen solutions or fluid fertilizers may offer savings in labor and time by eliminating at least one trip over the field. Effectiveness of some postemergence-directed herbicides for corn and sorghum is increased by applying them in nitrogen solution.

Herbicide labels will indicate if the product can be mixed with sprayable fertilizer. Herbicides may not always mix evenly throughout a sprayable fluid fertilizer, or the components may separate too quickly to make their combined use practical. Therefore, test every batch of fertilizer for compatibility before adding the herbicide. Batches can vary in pH, salt content, and salt concentration. Even these minor differences may affect compatibility. Sulfur-containing nitrogen solutions can be particularly troublesome.

The information presented below is intended as a guide only. The term “compatibility” as used here refers to chemical and physical compatibility and is not intended to supplant label directions.

A guide for making your own compatibility test follows. Also, herbicide labels give information on compatibility, tank-mix combinations, and procedures for testing compatibility with sprayable fluid fertilizer. Be sure to read the label!

Precautions

To help ensure successful results from application of herbicides and nonpressure nitrogen solutions or fluid fertilizers:

1. Always check compatibility by making a small scale test (directions given below) before mixing in field.
2. Use a compatibility agent if indicated on the herbicide label or if your small-scale test indicates the need.
3. Vigorously agitate tank contents while mixing and applying. The spray application equipment should use a high-capacity (eight-roller, internal gear, or centrifugal) pump. Spray tanks should be equipped with hydraulic jet agitators mounted in the bottom of the tank. Bypass lines usually do not provide adequate agitation. Jet agitators should be attached to a separate line from the pump.
4. Do not connect agitators to by-pass lines. For simple hydraulic jet agitators, a flow rate of 6 gallons per minute for every 100 gallons of tank capacity is sufficient. If volume-booster nozzles are used for agitation, the flow rate can be reduced to 2 to 3 gallons per minute for every 100 gallons of tank capacity. If a liquid-fertilizer type applicator is used with a metering pump, agitation must also be supplied. The best method is to use a separate power takeoff pump for extra circulation.
5. If a wettable powder or dry flowable is used, make a slurry with water and add slowly to the tank. Add wettable powder first, dry flowables second, flowables third, and liquids last.
6. A number of dry flowable herbicides now come packaged in water-soluble film packets. These packets usually will not dissolve in nitrogen solution or fluid fertilizer. When using nitrogen solution or fluid fertilizer as the carrier for a product packed in these film packets, slurry the herbicide in clean water before adding to the spray tank.
7. If a flowable product is used, premix one part flowable with one part water and add diluted mixture slowly to tank. The fluid fertilizer may be substituted for the water after compatibility has been checked.
8. Premix liquid products with two parts water or the fertilizer carrier before adding into the tank.
9. Reduce drift by choosing an appropriate nozzle size to put out the desired amount of solution without causing excessive pressure.
10. *Caution:* Take extra care in applying herbicide-fluid fertilizer mixtures to ensure that the correct herbicide rate is applied, that the herbicide is distributed uniformly, and that all directions concerning application of the herbicide are followed. Sprayer output will not be the same using fluid fertilizer as when using water as the carrier. Recalibrate sprayers for the fertilizer carrier. Do not apply herbicide-fluid fertilizer mixes overtop any crop except small grains, as injury will result.

How to Test Compatibility of Herbicides with Fluid Fertilizers

W. Everman, Crop Science, and C. R. Crozier, Soil Science

Follow the compatibility test procedures on the herbicide label. If not on the label, follow the directions listed below.

1. Put 1 pint of fluid fertilizer in each of two 1-quart jars.
2. Following the adjacent table, add 0.25 to 0.375 teaspoon of a compatibility agent to one jar and shake for 5 or 10 seconds to mix. One-fourth teaspoon is equivalent to 2 pints/100 gallons of fluid fertilizer. Mark the jar “with” to indicate the compatibility agent has been added.
3. Next, add the proper amount of herbicide to each jar, according to the table. For herbicides used in small quantities per acre, one will need a greater volume of fluid fertilizer for the compatibility test. Adjust the herbicide/fertilizer ratio as follows:

   1 ounce dry flowable per acre = 0.7 teaspoon in 1 gallon
   1 fluid ounce liquid per acre = 0.25 teaspoon in 1 gallon

   If more than one herbicide is to be used in the mixture, add them separately with the wettable powders or dry flowables first, flowables second, and liquids last. Shake the jar gently for 5 to 10 seconds after each addition.
4. Let the jars stand for 5 minutes, then check for formation of large flakes, sludge, gels, or other precipitates, or to see if the herbicide remains as small, oily particles in the solution.
5. Allow both jars to stand for 30 minutes, checking them periodically. An emulsifiable concentrate normally will go to the top after standing, whereas wettable powders or dry flowables will either settle to the bottom of the jar or float to the top, depending on the density of the fertilizer and the herbicide. If the separate layers of fluid fertilizers and additives (herbicide and compatibility agent) can be resuspended by shaking, commercial application is possible.
6. If incompatibility of any form occurs in the jar with the compatibility agent added, do not mix the fluid fertilizer and herbicide in the same spray tank. If incompatibility occurs only in the jar without the compatibility agent, use of a compatibility agent is recommended.

Table 4-14. Amounts of Herbicide to Use to Test Compatibility[1]

Application Rate Product Per Acre	Add to 1 Pint of Fluid Fertilizer
Wettable powders or dry herbicides	
1 pound	1.4 teaspoon
2 pound	2.9 teaspoon
3 pound	4.3 teaspoon
4 pound	5.8 teaspoon
5 pound	7.2 teaspoon
Emulsifiable concentrates, flowables, liquids, or solutions	
1 pint	0.5 teaspoon
1 quart	0.9 teaspoon
2 quart	1.9 teaspoon
3 quart	2.9 teaspoon
1 gallon	3.8 teaspoon
5 quart	4.8 teaspoon

[1] This compatibility test is designed for 25 gallons of spray per acre with the maximum labeled rate of herbicide. For changes in spray volume or herbicide concentration, make the appropriate proportional change in the ingredients in the test. Regardless of spray volume, the amount of compatibility agents should be equal to 2 to 3 pints (0.25 teaspoon equals 2 pint; 0.375 teaspoon equals 3 pints) per 100 gallons of fertilizer.

Fertilizer Placement

C. R. Crozier and D. L. Osmond, Soil Science, and D. H. Hardy, NCDA&CS

Proper fertilizer placement can be as important as what kind of fertilizer you use. The first step, though, is a soil test to determine phosphorus and potassium needs and the use of realistic yield expectations to determine nitrogen. Once fertilizer needs are determined, fertilizer placement should be assessed.

Starter P (along with N) does not always lead to yield increases, but it can be an effective tool to enhance early season growth and reduce risks of losses associated with billbugs, competitive weeds, and summer droughts (see SoilFacts: Starter Phosphorus Fertilizer and Additives in North Carolina Soils: Use, Placement, and Plant Response, http://www.soil.ncsu.edu/publications/Soilfacts/AG-439-75.pdf). Use of starter fertilizers is more important in no-till since soil warming is delayed, and the cooler temperatures can reduce the rate of crop growth. For fields that already have very high soil test P levels (P-index >100), numerous North Carolina tests have shown there is no advantage to applying additional P in a starter band. Even most mineral soils testing greater than a 50 P-Index generally do not need starter P.

Fertilizer placed in contact with or too close to seeds and young plants can cause salt injury, resulting in poor stands and slow starts. Nonuniform broadcasting of fertilizer with shallow mixing just before planting may give streaks through the field due to delayed germination or seedling injury. Salt injury is most severe in dry weather or following light rains that dissolve the fertilizer salts and leave highly concentrated salt solutions in the root zone. Nitrogen and potassium salts account for most of this injury.

To reduce salt injury risk, a side-band placement of starter fertilizer at planting is generally preferred over application directly in contact with the seed, commonly referred to as “pop-up” placement. Good results are often achieved for seeded crops like corn, cotton, sorghum, and soybeans using a 2 by 2-inch placement, placing the fertilizer 2 inches to the side and 2 inches below the planted seed. The risk of salt injury is also related to the amount of salt applied. Generally, a maximum rate of 80 pounds per acre of nitrogen alone, K_2O alone, or a combination of nitrogen plus K_2O is suggested for 2 x 2 band placement. When a greater rate is necessary, make a split application; broadcast part and apply the remainder in the row at seeding. If side placement is not possible or practical and starter fertilizer is placed directly in the seed furrow, the maximum rate should be much lower; 5 gpa of typical starter solution products contain less than 20 pounds N plus K2O per acre and is the maximum rate that should be used. An alternative method is to broadcast fertilizer prior to planting, with thorough mixing into the soil preferred, except for conservation tillage systems. The lack of soil mixing is an additional reason that banded starters are advantageous with no-till management.

For tobacco, place the band 3 to 5 inches from the transplants. This distance reduces the chance of placing plants in fertilizer bands. If side placement equipment is not available, place the fertilizer deep in the row so it will be 3 to 5 inches below the roots of the transplants.

Seedlings of small grain or plants such as clovers, grasses, and alfalfa respond very early to phosphate; consequently, it can be advantageous to place phosphate close to the seed as is done with the conventional grain drill.

Livestock & Poultry Manure Production Rates and Nutrient Content

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The use of livestock and poultry manure as a fertilizer supplement in crop production has come full circle. Before the advent of inexpensive inorganic fertilizers, farmers routinely used manure to supply essential plant nutrients. Today, because of rising costs of commercial fertilizers and increasing emphasis on good manure management practices to protect water quality renewed interest has been focused on optimizing the nutrient benefits of manures.

Manure production and characteristics are influenced by on-farm management practices. For example, manure from open housing systems or from open storage ponds is diluted by rainfall. Drying and storing solid manures can increase ammonia loss and reduce the nitrogen content and fertilizer value. Microbial digestion in a waste treatment lagoon reduces total nitrogen by 50 to 85% and converts as much as 90% of the phosphorus to forms that settle into the sludge rather than remaining in lagoon liquid. All of the practices ultimately affect the total amount of recoverable nutrients that can be used in crop production.

Manure Production (Volume and Weights)

The total manure produced in volume or weight is related to the animal production system, the number of animals in that system, and the manure collection and treatment system. In liquid systems, the production of manure is often reported in gallons per animal per year or gallons per 1,000 birds capacity per year (Table 4-15). For dry or solid systems, the production is reported in tons per animal per year or tons per 1,000 birds capacity per year (Table 4-15).

Manure Nutrient Content

The manure nutrient content varies with animal age, diet, and waste (manure) management system. Nutrient data reported in Table 4-16 are statewide averages and may not reflect the actual nutrient content on any individual farm. Because of the variability of end products in the numerous different animal production and waste management systems manure must be sampled and analyzed within 60 days of application to land to determine its actual nutrient content. Manure samples can be analyzed for 11 essential plant nutrients for a nominal fee by the N.C. Department of Agriculture and Consumer Services. The Waste/Compost Analysis Laboratory (http://ncagr.gov/agronomi/uyrwaste.htm) provides details on collecting and submitting manure samples for waste analysis).

Plant Availability Coefficients

Two factors are important in the plant availability of nutrients in manure: mineralization potential and application method. Since the nutrients in manure are primarily in organic compounds, they must undergo microbial mineralization in order to become plant available. Once in the plant-available form, some nutrients are at risk of loss to the environment. For example, nitrogen is susceptible to gaseous losses due to volatilization of ammonia (a mineralized form of N). As a result, the availability of nitrogen for plant uptake is dependent on the mineralization potential of the manure. Further, the application method plays an important role in the availability of nutrients. Subsurface placement such as soil incorporation tends to reduce volatile losses whereas surface placement such as irrigation tends to increase volatile losses. Most nutrients including phosphorus and potassium are not subject to volatile losses, meaning the application method has minimal impact on their availability. Plant availability coefficients (Table 4-17) are used to estimate the nutrients that would be available to the first crop, taking into consideration both the mineralization potential and the application method.

Calculating On-Farm Availability of Manure Nutrients

Land application of manures is an integral part of the overall soil-fertility management strategy on many farms. For farm nutrient budgeting, an assessment of the nutrients available for plant utilization must be completed. Using Tables 4-15 through 4-17, the calculation is simple:

$$\textit{Total Plant Available Nutrients} = \frac{\textit{No. of Animals}}{\textit{Year}} \times \frac{\textit{Weight or Volume}}{\textit{Animal}} \times \frac{\textit{Total Nutrients}}{\textit{Weight or Volume}} \times \textit{Availability Coefficient}$$

For example, consider a 900-sow farrow to finish operation where the lagoon effluent is soil incorporated following application but before planting of a grain crop.

$$\textit{Total Plant Available N } (\textit{PAN}) = \textit{No. of Sows} \times \frac{\textit{gallons}}{\textit{sows/year}} \times \frac{\textit{Total N}}{1{,}000\ \textit{gal}} \times \frac{\textit{X lbs PAN}}{\textit{lbs Total N}}$$

$$\textit{Total Plant Available N } (\textit{PAN}) = 900 \times \frac{10{,}478\ \textit{gallons}}{\textit{sows/year}} \times \frac{3.6\ \textit{Total N}}{1{,}000\ \textit{gal}} \times \frac{0.6\ \textit{lbs PAN}}{\textit{lbs Total N}}$$

$$\textit{Total Plant Available N } (\textit{PAN}) = 20{,}369\ \textit{lbs of N available for the grain crop in the first year}$$

This same calculation can also be performed for other nutrients such as P, Zn, and Cu.

Management Considerations

Always apply manure as close to the period of maximum plant demand for nutrients as possible. Base manure application rates on the available portion of the nutrients and not the total concentration. Do not apply more than the receiver crop needs since excessive amounts not only waste valuable nutrients but may result in surface and/or groundwater pollution. Nutrient management planning guidelines (http://nutrients.soil.ncsu.edu) should be used to determine if application rates should be based on N or P content. Monitoring of Zn and Cu may be needed to avoid accumulation in soils to toxic levels. Use soil testing (http://ncagr.gov/agronomi/sthome.htm) to predict nutrient and lime requirements and proper application rates of the manure. Use plant analysis (http:/ncagr.gov/agronomi/uyrplant.htm) to monitor the crop nutritional status (actual uptake of soil nutrients) and effectiveness of the nutrient management program.

Additional manure management information is available in at http://www.soil.ncsu.edu/publications/extension.htm

Table 4-15. Manure Volume and Weights in Typical North Carolina Animal Production Systems

Animal Production System	NCDA&CS Waste Code	Accumulated Manure
		gallons/animal/year[1]
Anaerobic Lagoon Liquid - Swine	**ALS (except Farrow-to-Wean)**	
Farrow-to-Wean (per sow)	ALF	3,203
Farrow-to-Feeder (per sow)		3,861
Farrow-to-Finish (per sow)		10,478
Wean-to-Feeder (per pig)		191
Wean-to-Finish (per pig)		776
Feeder-to-Finish (per pig)		927
Anaerobic Lagoon Sludge – Swine	**ASS**	
Farrow-to-Wean (per sow)		433
Farrow-to-Feeder (per sow)		522
Farrow-to-Finish (per sow)		1,417
Wean-to-Feeder (per pig)		30
Wean-to-Finish (per pig)		26.3
Feeder-to-Finish (per pig)		135
Dairy – Slurry	**LSD**	
Calf		1,876
Heifer		5,535
Milk Cow		7,749
		gallons/1,000 bird capacity/year[1,2]
Anaerobic Lagoon Liquid – Poultry	**ALP**	
Pullet (non-laying)		9,110
Pullet (laying)		22,201
Layer		25,373
Anaerobic Lagoon Sludge – Poultry	**ASP**	
Pullet (non-laying)		1,659
Pullet (laying)		4,147
Layer		4,739

Table 4-15. Manure Volume and Weights in Typical North Carolina Animal Production Systems

Animal Production System	NCDA&CS Waste Code	Accumulated Manure
		tons/1,000 bird capacity/year[2]
Poultry Litter – Breeders	**HBB**	**24**
Poultry Litter – Broilers	**HLB**	
Whole House		7.2
Cake		4.0
Poultry Litter – Broiler Pullets	**HBP**	**7.2**
Poultry Litter – Layers	**HLL**	**24**
Poultry Litter – Layer Pullets	**HLP**	**24**
Poultry Litter – Turkeys	**HLT**	
Poult		5.3
Hen		17
Tom		25
Breeder		37
		tons/animal/year
Dairy – Scraped	**SSD**	
Calf		4.1
Heifer		12
Milk Cow		17
Beef – Scraped	**SSB**	
Stocker		1.5
Feeder		2.2
Brood Cow		3.0
Horse – Scraped	**SSH**	**9.1**

[1] To convert gallons to acre-inches, divide gallons by 27,154.

[2] Capacity is based on the maximum number of birds on the farm at any time, which is a measure of the size of the flock and not the total annual production on the farm.

Table 4-16. Total Nitrogen (N), Phosphorus (P AS P_2O_5), and Potassium (K AS K_2O) from Manure Sources

Production System	NCDA&CS Waste Code	N	P_2O_5	K_2O
		pounds of total nutrient per 1,000 gallons[1]		
Anaerobic Lagoon Liquid - Swine	ALS			
Boar		3.6	1.4	8.3
Farrow-to-Wean	ALF	2.4	0.9	4.1
Farrow-to-Feeder		3.6	1.4	8.3
Farrow-to-Finish		3.6	1.4	8.3
Wean-to-Feeder		3.6	1.4	8.3
Wean-to-Finish		3.6	1.4	8.3
Feeder-to-Finish		3.6	1.4	8.3
Anaerobic Lagoon Sludge – Swine	ASS	20.4	30.6	7.5
Anaerobic Lagoon Liquid - Poultry	ALP	3.1	1.0	13.8
Anaerobic Lagoon Sludge - Poultry	ASP	24.4	38.1	10.3
Dairy - Slurry	LSD	16.7	9.1	15.4
		pounds of nutrient per ton		
Dairy - Scraped	SSD	11.2	7.0	9.8
Horse - Scraped	SSH	9.3	7.0	9.8
Beef - Scraped	SSB	13.0	8.3	13.6
Poultry Litter - Breeders	HBB	47.6	44.7	39.5
Poultry Litter - Broilers	HLB	57.8	40.0	48.6
Poultry Litter – Broiler Pullets	HBP	57.8	40.0	48.6
Poultry Litter – Layers	HLL	47.6	44.7	39.5
Poultry Litter – Layer Pullets	HLP	47.6	44.7	39.5
Poultry Litter - Turkeys	HLT	54.0	48.2	33.8

[1] To convert gallons to acre-inches, divide gallons by 27,154.

Table 4-17. First-Year Nutrient Availability Coefficients for Nitrogen (N), Phosphorus (P) and Potassium (K) from Manure Sources

		N		P		K	
Production System	**NCDA&CS Waste Code**	**Broadcast or Irrigated**	**Incorporated or Injected**	**Broadcast or Irrigated**	**Incorporated or Injected**	**Broadcast or Irrigated**	**Incorporated or Injected**
Aanerobic Lagoon Liquids							
Swine	ALS	0.5	0.6	1.0	1.0	1.0	1.0
Swine Farrow to Wean	ALF	0.5	0.6	1.0	1.0	1.0	1.0
Poultry	ALP	0.5	0.6	1.0	1.0	1.0	1.0
Other	ALO	0.5	0.6	1.0	1.0	1.0	1.0
Anaerobic Lagoon Sludges							
Swine	ASS	0.5	0.6	1.0	1.0	1.0	1.0
Poultry	ASP	0.5	0.6	1.0	1.0	1.0	1.0
Other	ASO	0.5	0.6	1.0	1.0	1.0	1.0
Slurries							
Beef	LSB	0.4	0.6	1.0	1.0	1.0	1.0
Dairy	LSD	0.4	0.6	1.0	1.0	1.0	1.0
Swine	LSS	0.4	0.6	1.0	1.0	1.0	1.0
Other	LSO	0.4	0.6	1.0	1.0	1.0	1.0
Scraped or Stockpiled Manure							
Beef	SSB	0.4	0.6	1.0	1.0	1.0	1.0
Dairy	SSD	0.4	0.6	1.0	1.0	1.0	1.0
Horse	SSH	0.4	0.6	1.0	1.0	1.0	1.0
Swine	SSS	0.4	0.6	1.0	1.0	1.0	1.0
Other	SSO	0.4	0.6	1.0	1.0	1.0	1.0
Poultry Litters							
Breeders	HBB	0.5	0.6	1.0	1.0	1.0	1.0
Broilers	HLB	0.5	0.6	1.0	1.0	1.0	1.0
Broiler Pullets	HBP	0.5	0.6	1.0	1.0	1.0	1.0
Layers	HLL	0.5	0.6	1.0	1.0	1.0	1.0
Layer Pullets	HLP	0.5	0.6	1.0	1.0	1.0	1.0
Turkeys	HLT	0.5	0.6	1.0	1.0	1.0	1.0
Other	HLO	0.5	0.6	1.0	1.0	1.0	1.0

Beneficial Use of Municipal Biosolids

J. G. White, and D. L. Osmond, Soil Science

Biosolids are the nutrient-rich organic residuals of wastewater (sewage) treatment, i.e., sludge that has been treated to meet US-EPA standards for land application. These standards include limitations on pathogens, potentially toxic metals, and disease-vector attractants. Biosolids can be recycled via land application to sustainably improve and maintain productive soils and foster plant growth. Most biosolids contain sufficient plant nutrients (e.g., N, P, K) to have fertilizer value, and some have liming value. Previous concerns regarding the levels of potentially toxic metals in biosolids have been alleviated by current US-EPA standards. However, most biosolids do contain small quantities of substances such as pharmaceuticals, steroids, hormones, and flame retardants. These might pose risks to crops, the livestock or humans that consume them, and/or to the environment. Currently, these substances are not regulated in biosolids, and any potentially adverse effects are not well characterized.

Anyone who wants to use biosolids for land application must comply with all relevant federal and state regulations. In some cases a permit may be required and obtained from the North Carolina Department of Environment and Natural Resources (DENR). Typically, any municipality wishing to apply biosolids to its own land or to private farmland must obtain a permit. To obtain a permit, sufficient data must be submitted to show that the biosolids meet federal and state limits for pathogens, potentially toxic metals, and vector attraction, and that the proposed site is suitable to receive biosolids. Some of the factors considered in site selection include topography; soil type; distance from streams, wells, and property lines; flood hazard; and depth to bedrock and the water table. If the site is suitable, then application rates are calculated based on biosolids composition, crop nutrient requirements, previous history of biosolids application, and soil pH. The primary purposes of these criteria are to: 1) protect ground and surface water from contamination by biosolids nitrogen and phosphorus and 2) foster crop nutrient-use efficiency. If a property owner wishes to apply certain biosolids to his or her land, he or she, must obtain a permit. Biosolids meeting the strictest land application standards are known as Class A Exceptional Quality. These may be applied by the general public in reasonable quantities without permit.

The preparation of permit applications is the responsibility of the municipality, industry, and land owner. The process is somewhat involved, and we do not attempt to outline it here. Information on permitting may be obtained from any NCDENR regional office or the NCDENR Water Quality Permitting Non-Discharge Permitting Unit, http://portal.ncdenr.org/web/wq/aps/lau.

Many biosolids are treated with materials to raise sludge pH to reduce pathogens and vector attraction. These biosolids often possess liming capabilities that should be identified before use. If ignored and land-applied as a nutrient source, over-liming may occur and negatively affect plant growth.

Since most biosolids produced in North Carolina are suitable for use on agricultural land, we encourage interested farmers to contact their county Cooperative Extension Service center about possible sources of biosolids in their area. Table 4-18 shows average characteristics of some biosolids available in North Carolina. The user is strongly advised to obtain actual, current analysis of any product that is to be land-applied.

Table 4-18. Plant Nutrient and Metal Contents of Some Municipal Biosolids from or Available in North Carolina[1]

Biosolids Source	Total Nitrogen	Plant-available Nitrogen[2]	P_2O_5	K_2O	Ca	Mg	Cu	Zn	Ni	Cr	Pb	Cd	Mo	As
	Constituents in pounds per dry ton of biosolids													
Cape Fear Public Utility Authority (Wilmington): Class B[3]	97	32	69	3	38	4	0.464	1.3	0.3	0.07	0.05	0.002	0.02	0.02
Charlotte: Class B														
Irwin Creek WWTP[4]	95	32	68	3	46	8	0.6	1.9	0.11	0.16	0.19	0.004	0.03	0.02
Mallard Creek WWTP	126	45	126	5	35	13	0.48	1.7	0.04	0.12	0.09	0.002	0.02	0.01
McDowell Creek WWTP	142	49	170	9	56	12	0.34	1.4	0.03	0.07	0.02	0.002	0.02	0.01
Elizabeth City: Class B	3	0.8	3	0	641	24	0.01	0.01	0.01	—	0.01	0.001	0.010	0.01
Goldsboro: compost Class A Exceptional Quality	45	7	8	22	31	10	0.18	0.28	0.04	—	0.01	0.001	0.003	0.02
Milwaukee Metro Sewage District: “Milorganite” Class A Exceptional Quality	108	32	89	—	—	—	0.48	0.99	0.07	—	0.11	0.003	0.01	0.01
Orange County: Class B	286	118	276	—	—	—	0.49	1.3	0.02	—	0.02	0.002	0.01	0.003
Raleigh (Neuse River WWTP): “Raleigh Plus” Class A Exceptional Quality	14	4.6	8	10	618	6	0.09	0.19	0.02	0.02	0.014	0.001	0.004	0.01
Raleigh (Neuse River WWTP): Class B	126	56	221	14	22	8	0.54	1.09	0.03	0.06	0.04	0.01	0.02	0.01

[1] Results vary between samples. This table represents average or median values. Data from NC-DENR Division of Water Quality, 2011-2012.

[2] PAN, plant-available nitrogen estimated for the year of application. PAN depends on waste processing and land application methods and N forms in the biosolids. PAN is some fraction of total N = organic N + inorganic N (ammonium + nitrate + nitrite). Values here are for surface application; if injected or incorporated, PAN will be somewhat greater. For current methods to estimate PAN, see the North Carolina Department of Agriculture and Consumer Services Waste and Compost Analysis Guide (http://www.ncagr.gov/agronomi/pdffiles/wasteguide.pdf).

[3] Class B biosolids meet minimum US-EPA land-application standards for pathogens, potentially toxic metals, and vector-attraction; Class A biosolids meet stricter pathogen standards; Class A Exceptional Quality biosolids are Class A biosolids with very low metal content.

[4] WWTP, Waste water treatment plant.

Certified Organic Farm Management Alternatives

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Although crop nutritional requirements are the same for organic and conventional farms, organic producers need to be more creative due to the limitations on allowable inputs. See the "North Carolina Organic Grain Production Guide" http://www.cefs.ncsu.edu/resources/organicgrainfinal.pdf for additional information. Since use of some soil amendments is limited to cases of nutrient deficiency, organic producers should maintain soil testing and plant tissue analysis records documenting specific nutrient deficiencies that need correction. With tissue testing, the appropriate plant part must be collected at the proper growth stage as specified by laboratory guidelines. See a detailed plant tissue analysis guide at www.ncagr.gov/agronomi/pdffiles/plantguide.pdf or contact your local county Extension Center for more details.

Certain inputs are allowable on organic production systems, if applied according to guidelines. These include many (not all) natural and certain synthetic materials. Current USDA regulations can be found at http://www.ams.usda.gov/AMSv1.0/nop. Find the section on "Organic Standards" and select "National List and Petitioned Substances," then find "National List and Petitions" and select "Current National List (eCFR)" to see a detailed listing of allowed and prohibited substances. See a list of commercially available materials that have been reviewed by the Organic Materials Review Institute (OMRI) at http://www.omri.org/omri-lists. In all cases, input use should be considered prohibited unless included in the farm plan and confirmed by the certifying authority prior to application.

Critical aspects of soil fertility management include pH, major nutrients (N, P, K,S, Ca, Mg), and micronutrients (especially B, Cu, Mn, Zn; but also Fe, Mo, Cl, etc.). A summary of soil fertility parameters and organic management options is given in Table 4-19 below.

Specific guidelines must be followed when applying composts and manures in organic production systems. Materials must be applied at agronomic rates in compliance with any applicable nutrient management guidelines (http://nutrients.soil.ncsu.edu/), and which avoid excess nutrients. Raw animal manures must either be: 1) composted according to specific criteria specified in the USDA National List, 2) applied to land used for a crop not intended for human consumption, 3) incorporated into the soil at least 90 days prior to the harvest of an edible product not contacting soil or soil particles, or 4) incorporated into the soil at least 120 days prior to the harvest of an edible product that does contact soil or soil particles. The guidelines for compost production for organic agriculture state that the initial C:N ratio must be between 25:1 and 40:1; and a temperature between 131 and 170 degrees Fahrenheit must be achieved and maintained for at least 3 days for in-vessel or static aerated pile systems, or for at least 15 days during which there are at least 5 turnings for windrow systems. Composts not meeting these criteria must be applied based on other raw manure criteria, which also apply to animal waste lagoon liquids and solids, and stockpiled poultry litter. Human or industrial wastes such as lime stabilized sludges or composted biosolids are not allowed. Ashes of manures may not be used, but ashes from other untreated plant and animal materials may be applied if not combined with any prohibited substances. Avoid over-reliance on animal manures, since this could lead to accumulation of excess P, Cu, and Zn in soils. Sporadic use of manures in conjunction with more frequent use of legume cover crops, green manures or other N sources is an excellent way to supply several plant nutrients in appropriate amounts.

Table 4-19. Soil Fertility Parameters and Management Options

Parameter	Problem Documentation	Supply Options[1]	Not Allowed
pH	Soil test	Standard calcitic or dolomitic agricultural ground limestone; pH can be lowered by adding elemental sulfur.	Hydrated or burnt lime [$Ca(OH)_2$, CaO], industrial wastes, slags, lime-stabilized biosolids
Major Nutrients			
Nitrogen (N)	Tissue analysis	Legumes, manures[3], animal by-products (blood, fish), plant by-products (cotton, apple, fermentation wastes), mined sodium nitrate ($NaNO_3$)[3]	Synthetic fertilizers, sewage sludges, municipal waste composts
Phosphorus (P)	Soil test, tissue analysis	Manures[3], rock phosphate, animal by-products (bone meal; fish, shrimp, and oyster scraps; leather)	Processed rock phosphates
Potassium (K)	Soil test, tissue analysis	Manures[3], plant by-products (ash, dried seaweed), greensand, sulfate of potash (K_2SO_4)[4], possibly muriate of potash (KCl)[3,4]	KCl if excess chloride
Sulfur (S)	Tissue analysis	Manures[3], plant by-products (cotton motes, peanut meal), elemental sulfur[4], gypsum ($CaSO_4$), Epsom salt ($MgSO_4$)[4], sulfate of potash (K_2SO_4)[4]	Synthetic fertilizers
Calcium (Ca)	Soil test, tissue analysis	Standard calcitic or dolomitic agricultural ground limestone, gypsum ($CaSO_4$), bone meal, ash	$Ca(OH)_2$, CaO, calcium nitrate [$Ca(NO_3)_2$]
Magnesium (Mg)	Soil test, tissue analysis	Standard dolomitic agricultural ground limestone, Epsom salts ($MgSO_4$)[4], sulfate of potash magnesium, bone meal, plant by-products (cottonseed meal, wood ash)	Synthetic fertilizers
Micronutrients[2]			
Boron (B)	Tissue analysis	Manures, animal and plant by-products, soluble boron fertilizers[4]	
Copper (Cu)	Soil test, tissue analysis	Manures, animal and plant by-products, sulfates & oxides[4]	chlorides
Manganese (Mn)	Soil test, tissue analysis	Manures, animal and plant by-products, sulfates & oxides[4]	chlorides
Zinc (Zn)	Soil test, tissue analysis	Manures, animal and plant by-products, sulfates & oxides[4]	chlorides
Co, Fe, Mo, Se	Tissue analysis[5]	Manures, animal and plant by-products, sulfates, carbonates, oxides, or silicates[4]	Chlorides, nitrates

[1] Inputs must be on the National Organic Program or the OMRI-approved source list and approved by the certifying agents.

[2] Avoid over-application of micronutrients since toxicities can occur.

[3] Note restrictions.

[4] Documentation of nutrient deficiency required.

[5] Deficiencies of Co, Mo, and Se are not common in North Carolina, and these elements are not included in routine tissue analysis performed by the North Carolina Department of Agriculture and Consumer Services, although Mo can be included upon request and for an additional fee. Consult a Cooperative Agricultural Extension office for information regarding private agricultural laboratories.