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Agronomy Handbook

Virginia Cooperative Extension

Virginia Tech
Invent the Future

Virginia State University

Introduction

Agronomy is a diverse science that includes field crops, turfgrasses, variety selection, seed science, soil management, nutrient management, and soil suitability for urban purposes. This publication is a source of agronomic information that does not change frequently. Pesticide and varietal recommendations change frequently and are, therefore, not included. This type of information is published annually in the Virginia Tech Pest Management Guides and commodity specific publications such as the Virginia Corn Hybrid and Management Trials. Contact your local Extension agent for a copy of the latest publication or visit the Virginia Cooperative Extension web page at http://www.ext.vt.edu.

For specific updates on crop production in Virginia, contact your local Extension agent for the latest information from the Virginia Agricultural Statistics Bulletin or contact the Virginia Agricultural Statistics Service in Richmond, Virginia, directly at (804) 771-2493, or at their website http://www.nass.usda.gov/va/.

VIRGINIA POLYTECHNIC INSTITUTE
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PART I
Crop Description

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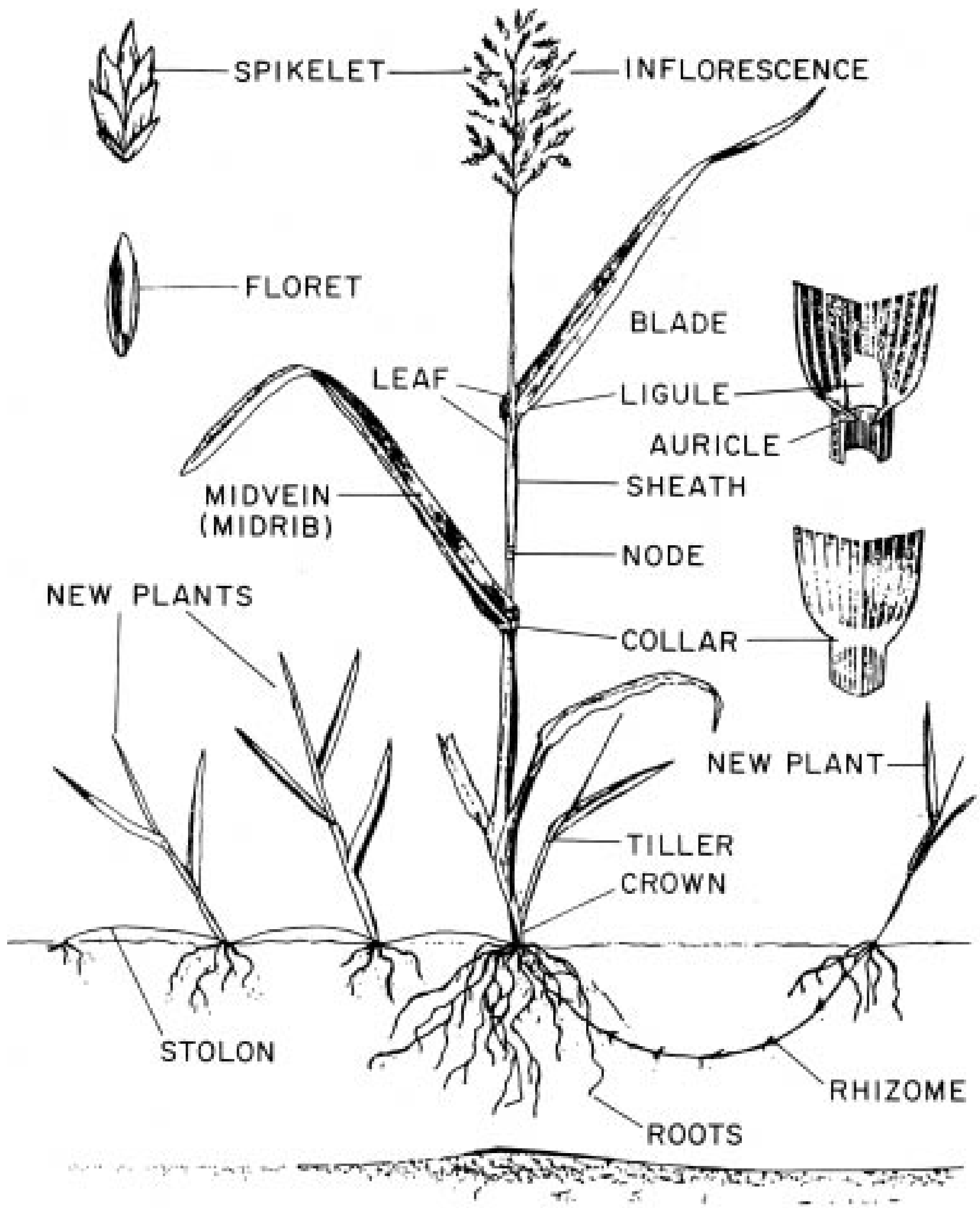
This section provides basic, detailed information about most plants used for cropping in Virginia. All values are generalizations which may vary with specific conditions. Rates of fertilizer application depend, to a large extent, on initial soil test levels and the productive potential of the soil. The fertilizer recommendations presented assume an average or medium soil test level and soils that are average to above average in productivity. For more specific recommendations, rely on soil test results. **Fertilizer application rates and crop yields in this section are expressed on a per acre basis.**



Parts of the grass plant used for field identification.

Alfalfa – Perennial – *(Medicago sativa)*

Description:	Distinct deep tap root; erect stems 2-3' tall from woody crown; purple flowers for most improved varieties; stem and leaves smooth; leaves arranged alternately on stem; each leaf has 3 leaflets with smooth edges.
Uses:	Hay, pasture, and silage
Varieties:	Consult varietal information published annually by Virginia Cooperative Extension.
Weight per bushel:	60 lbs
Seeds per lb:	220,000
Germinating time:	7 days
Fertilizer:	At seeding, Zero N, 110-140 lbs P_20_5, 110-140 lbs K_20 at medium soil test levels. Use borate fertilizers (2-4 lbs B) annually. For top-dressing 70-90 lbs P_20_5 and 220-360 K_20 annually for medium soil test levels. Split application: half in fall and half in spring. Lower levels required for pasture.
pH Range:	6.8-7.0
Soil Adaptation:	Deep, well drained soils, with sandy clay loam to clay subsoils.
Inoculation:	<u>Essential.</u> Use commercial inoculants. Cross inoculates with sweet and bur clover.
Time of Planting:	30-60 days before first killing frost in fall or 30 days before last killing frost in spring at 15-25 lbs alone, or 10-20 lbs with 3- 5 lbs of orchardgrass.
Method of Planting:	6"-8" rows or solid seeded. Conventional seeding – cover no deeper than 1/4" – 1/2", preferably with cultipacker. A firm and compact seedbed is essential. No-till seeding (graze or mow to have sod short). Kill all vegetative competition with herbicide, use insecticide, plant 1/2" – 3/4" deep with no-till drill.
Harvesting: **(hay or silage)**	Harvest at late bud to 1/4 bloom, except first cutting. First cutting should be made in bud stage or when orchardgrass begins to head. Alfalfa may be cut 3-5 times/year at 30-40 day intervals, depending upon location in state and average rainfall. Make last cutting 3-4 weeks before average date of first killing frost in fall or in time to allow 6-8" of regrowth. Allow at least one harvest to reach 1/10 bloom to help persistence.
Harvesting (pasture):	Use grazing-tolerant varieties under continuous stocking. Hay-type varieties should be rotationally stocked with 1-7 day grazing periods and 25-40 day rest periods. Avoid bloat by seeding with grass, turning cattle into new paddock only after forage is dry (no dew), and not allowing cattle to get too hungry prior to turn in.
Approximate Yield:	3-6 tons hay/A

Alsike Clover – Perennial – (*Trifolium hybridum*)

Description:	Tillers from crown and stem, leaves smooth; pink or white blooms; stems do not terminate in a flower.
Uses:	Hay and pasture; however, it does not make sufficient recovery after the first cutting for a second hay crop.
Weight Per Bushel:	60 lbs
Seeds per lb:	680,000
Germination time:	7 days
Fertilizer:	At medium soil test levels apply 40-60 lbs P_20_5 and 85-110 lbs K_20 per season
pH Range:	5.8-6.5
Soil Adaptation:	Well-drained to somewhat poorly drained soils. More tolerant to a high water table and acid soils than other clovers.
Inoculation:	Important. Cross-inoculates with red, crimson, ladino, and white clover
Planting:	30-60 days before last killing frost in spring, or 30-45 days before first killing frost in fall at 3-4 lbs in mixtures; 5-8 lbs alone

Alsike Clover – Perennial – (*Trifolium hybridum*) *(cont.)*

Harvesting (hay):	1/2 to full bloom about June 1-20
Harvesting (seed):	When about 3/4 of the heads are ripe. Handle as other clover.
Approximate Yield:	1-2 tons hay/A

Austrian Winter Pea – Annual – (*Pisum arense*)

Description:	Winter annual with purple flowers. Plants resemble garden pea.
Uses:	Forage or cover crop
Weight Per Bushel:	60 lbs
Seeds per lb:	5,000
Germinating time:	8 days
Fertilizer:	Zero N. Apply 60-80 lbs P_20_5 and 60-90 lbs K_20 on medium testing soils. Adjust rates based on soil test levels.
pH Range:	6.0-6.5
Soil Adaptation:	Well drained soils
Inoculation:	Cross inoculates with garden peas, vetch, and Canadian field peas.
Planting:	Fall, September 15-October 15; Spring, March 1-April 15 in 6-8” rows or solid seeded at 20-30 lbs with small grains; 30-40 lbs alone.
Harvesting (hay):	When barley or other small grain is in soft dough for silage or in full bloom for hay. Difficult to cure for hay.
Harvesting (seed):	When pods begin to turn brown.
Approximate Harvest Dates:	Hay- May 1 – June 1
Approximate Yield:	Hay, 1 1/2 to 2 tons, Silage, 6-9 tons, or Seed, 300-500 lbs./acre

Barley– Annual – (*Hordeum vulgare*)

Description:	Leaves are green with long clasping auricles and a long ligule. Seed usually contains the husk (lemma and palea) that gives the seed a wrinkled appearance. Newer varieties may be “hulless” since the lemma and palea are removed at harvest.
Uses:	Grain is used for animal feed in Virginia. Also used for silage and in mixtures with other small grains for cover crops and winter grazing. Limited use in human food.
Weight Per Bushel:	48 lbs (Hulled); 57.6 lbs (Hulless-for feed); and 60.0 lbs (Hulless-for human consumptionion)
Seeds per lb:	13,000
Germination Time:	6-7 days
Fertilizer:	20 lbs of N in the fall plus 40-80 lbs each of P_20_5 and K_20. Top dress with 80 lbs of nitrogen in February or early March. These rates assume no carry over N from the previous crop. In general, a high yielding crop will take up to 20-25 lbs/A fall N plus at least 80 lbs in the March-May period. For best results the winter–early spring N should be split into an application in February and one in late March.
pH Range:	6.0-6.5. Barley is very sensitive to low pH.
Soil Adaptation:	Any well drained soil. Barley will not tolerate poor drainage.
Time of Planting:	About 2 weeks before first average frost in Fall: September 15-October 10 west of the Blue Ridge and Northern Piedmont; October 1-November 1 in Eastern and Southern Piedmont Virginia. Aphids should be controlled if they build up in the fall or early winter.
Rate of Seeding:	120 lbs/A (Hulled) or approximately 30 seeds/sq ft (18 seeds/drill foot in 7” rows)

Barley– Annual – (*Hordeum vulgare*) *(cont.)*

Method of Planting: Planting with a grain drill is best; but broadcast disk-in to a depth of 1-1 1/2 inches can be successful.

Harvesting: Combine grain when fully ripe and 12-14% moisture. Cut for silage in the soft dough stage or boot stage depending on forage requirements.

Approximate Harvest Dates: Grain: June 1-June 20; Silage: May 1-June 1

Approximate Yields: 80–120 bushels grain or 6-12 tons 35% dry matter silage/acre

Bentgrass – Creeping – Perennial (*Agrostis paulustris*)

Description: A stoloniferous grass used for golf greens; high maintenance is required; some varieties can be seeded while others must be vegetatively planted.

Seeds per lb: 7,800,000

Rate of Seeding: Seeds 1/2 to 1 lb

Germination time: 10-14 days

pH Range: 6–6.5

Stolonized Bents: 2-7 bushels of stolons per 1,000 sq ft

Time of Planting: Early spring or late summer

Bermudagrass – Perennial – (*Cynodon dactylon*)

Description: Spreads by soil surface runners (stolons) and underground modified stems (rhizomes); stems 6-12 in tall; flowers are slender spikes, usually with 3 per cluster, similar to crabgrass; ligule a fringe of hairs.

Uses: A warm-season grass which makes most of its growth during June, July, and August in Virginia; pasture, hay, silage, and turf. Greatest forage potential in the Southern Piedmont and Coastal Plain.

Types and strains: Common-Occurs naturally in Virginia and throughout the South. Propagated by sprigs (rhizome and stolon pieces) and seed. Can be major weed in crop fields. Hybrid Forage Types-Improved strains which are high yielding, leafy, and cold-tolerant enough for use in Southern Piedmont and Coastal Plain. Midland, Tifton 44, and Quickstand have more cold tolerance then Coastal. All must be established using vegetative sprigs.
Fine-Textured Bermudagrass—Developed for athletic fields, lawns, golf greens, fairways, etc. All improved varieties propagated by sprigs or sod. Seed is available for common bermudagrass.

Seed weight per bushel: 35-36 lbs

Seeds per lb: 1,800,000

pH Range: 6.0-6.5

Soil adaptation: Will grow on all types of soil, but is better suited to sandy and droughty soils than other grasses. Prefers well drained soils.

Time of planting: April 1-June 1

Rate of planting: For pasture use 15-20 bushels of sprigs per acre, in rows or 30-40 bu/acre if broadcast. For turf, use 1 lb of seed, or 2-7 bushels of sprigs per 1,000 sq ft

Fertilizer: At planting, 70 lbs N, plus 70-90 lbs. P_2O_5, and 70-90 lbs K_2O for medium testing soil. For turf, see Turfgrass Section. For Hay, 175-300 lbs N, 80 lbs P_2O_5 and 80-205 lbs K_2O annually, based on soil test levels . Lower rates required when used as pasture.

Bermudagrass – Perennial – (*Cynodon dactylon*) *(cont.)*

Method of planting: Seed broadcast by hand or seeder. Sprigs planted in rows manually or with planter. May be broadcast, disked in, and cultipacked. Cover sprigs with 2-4” of soil.

Harvesting (hay): Cut when 8-12” tall before heading, or every 35-45 days.

Harvesting (pasture): Can be continuously stocked if grazed no shorter than 2-3”. Rotational stocking is preferred; turn in at 6-8”; move cattle at 2-3”. Minimize seed production to maintain quality and growth rate. Don’t graze during establishment year; cut for hay instead.

Approximate yield: 4-8 tons hay/A

Uses: A warm-season grass which makes most of its growth during June, July, and August in Virginia; pasture, hay, silage, and turf. Greatest forage potential in the Southern Piedmont and coastal Plain.

Birdsfoot Trefoil – Perennial – (*Lotus cornicalatus*)

Description: A fine-stemmed legume with a branching taproot. Adapted to higher elevations in Virginia. Grows 12-30” or more in length from a branching crown; flowers are orange-yellow in groups of 4-8 at end of stems; leaves consist of 5 leaflets alternately arranged, two are at the base near the stem; several seed pods attached to a single point give appearance of bird toes. Short-lived perennial that can reseed.

Uses: Hay or pasture (non-bloating)

Varieties: No varieties have been developed for Virginia conditions. The erect or European types have been most satisfactory. These varieties include Viking, Granger, Cascade, and Mansfield. The Empire variety is a decumbent pasture type.

Weight Per Bushel: 60 lbs

Seeds Per lb: 375,000

Germinating Time: 7 days

Fertilizer: Zero N—medium soil test levels; apply 40-70 lbs P_20_5 and 50-80 lbs K_20.

pH Range: 5.8-6.5

Soil Adaptation: Does best on well drained soil, but can be grown with impervious subsoils.

Inoculation: Essential. Does not cross-inoculate with other legumes.

Planting: March 1-April 15 or August 1-September 1. Should be sown with a grass such as orchardgrass or Kentucky bluegrass. In mixtures 4-8 lbs; alone 8-10 lbs.

Method of Seeding: 6-8” rows or solid seeded. Well prepared, compact seedbed is needed. Cover not more than 1/2” deep. Use cultipacker if surface-seeded. Can also be no-till drilled or frost seeded on killed sod. Poor seedling vigor.

Management: Permit seedlings to become well established before grazing or harvesting. Clip weeds. Use rotational or moderate continuous grazing for pastures.

Harvesting (hay): When in-bloom. Avoid clipping close if extremely dry.

Bluegrass – Kentucky – Perennial (*Poa pratensis*)

Description: A low-growing, sod-forming, perennial grass that spreads by underground rhizomes; the narrow leaves have tips shaped like the bow of a boat and reach a length of 7”; sheath flattened; short ligule.

Uses: Permanent pasture and lawns. Requires several years to become well established. Good early grazing, goes dormant in summer, revives in fall to furnish good grazing.

Weight Per Bushel: 14 lb

Seeds/lb: 2,200,000

Germinating Time: 14 days

Bluegrass – Kentucky – Perennial (*Poa pratensis*) *(cont.)*

Fertilizer: With white clover at seeding, 20 lbs N; at medium soil test levels apply 90-120 lbs P_20_5 and 60-90 lbs K_20. For pasture topdressing every 3 or 4 years, 40-125 lbs P_20_5 and 40-125 lbs K_20 at medium soil test levels. For turf, see turfgrass section.
pH Range: 6.0-6.5
Soil Adaption: Best suited to fine-textured, well drained soils.
Planting: late summer or early spring at 4-5 lbs in mixture for forage.

Bluegrass—Canada-perennial—(*Poa compressa*)

Description: Sod-forming from underground rhizomes; blue-green foliage; sheath distinctly flattened, with a short, compact seed head; short ligule.
Uses: Pasture, but not recommended for Virginia. Makes very little regrowth when grazed.
Weight per bushel: 14 lb
Seeds per lb: 2,500,000
pH Range: 5.0-6.5
Soil adaptation: Best suited to fine-textured, well drained soils. Will dominate Kentucky bluegrass on acid, droughty or low-fertility soils.

Bromegrass – Smooth – Perennial – (*Bromus inermis*)

Description: Sod-forming since it spreads by underground rhizomes; leafy and grows to height of 3-4 feet; head is an open panicle; stem smooth and round; short ligule, fused leaf sheath.
Uses: Hay and pasture-drought tolerant
Varieties: Historically, not well adapted to Virginia because of diseases. However, newer varieties may have potential.
Weight Per Bushel: 14 lbs
Seeds Per lb: 137,000
Germinating: 14 days
Fertilizer: 100-200 lbs N. Lower levels required when used as pasture in split applications, 40-90 lbs P_20_5, and 85-185 lbs K_20 annually on soils testing medium.
pH Range: 5.8–6.7
Soil adaptation: Well drained, fertile soils
Planting: Early spring, or with small grain in fall, Seeded at 10 lbs in mixture. Do not seed alone.
Harvesting : Early bloom stage. Do not graze or cut during stem elongation.

Buckwheat – Annual – (*Fagopyrum esculentum*)

Description: Erect plant, 2-4’ tall; single stem may have several branches; flowers light green, pink, or red in color.
Uses: Grain used for livestock, especially poultry; ground into flour (middlings for livestock). Good honey and green manure crop.
Weight per bushel: 48 lbs
Seeds /lb: 15,000
Germinating time: 6 days
pH Range: 5.5-6.0
Fertilizer: 20-30 lbs N, at medium soil test levels apply 40-50 lbs P_20_5 and 40- 50 lbs K_20
Soil adaptation: Any well drained soil. Will grow on infertile, acid soils better than most crops, but responds well to proper treatment.
Depth of Planting: 1/2”-2”. Do not plant deeper than 2”.
Planting: Latter part of May to middle of July. Seeds do not set well in warm weather. Likes cool, moist climate. Seed at 48-72 lbs in 6-8” rows or solid seeded. No-till can work well.

Buckwheat – Annual – (*Fagopyrum esculentum*) *(cont.)*

Harvesting (grain): Combine when the maximum number of seeds have matured and plants have lost most of their leaves. Drying may be necessary for safe storage.
Approximate harvest dates: September 1-15
Approximate Yield: 20-25 bushels/A

Caucasian Bluestem (*Bothriochloa caucasica*) Warm-season Perennial

Description: Long lived perennial bunch grass. It is an erect, fine-stemmed, leafy bunch grass which produces many seedheads above the leaf base throughout the summer. Begins growth two to three weeks later than switchgrass in spring.
Uses: Primarily for pasture, but also for hay
Seeds Per lb: 1,000,000
Germination Time: 3-30 days
Fertilizer: Responds to N, apply 60-120 lbs N/A/Yr. in split applications. Maintain P and K at medium levels.
pH Range: 5.5-6.2
Soil Adaptation: Adapted to wide range of soils. It performs better on the finer textured soils such as loams, clay loams, and silty loams but will also grow well on sandy loam soils. Caucasian bluestem does not do well on extremely sandy soils, and wetland soils.
Time of Planting: After soil temperature reaches 65˚F in late May or early June.
Rate of Planting: 2-3 lbs/A pure live seed.
Method of Planting: Plant into a prepared, firm seedbed no deeper than 1/4 inch. However, no-till seeding can be done if plant residue is not thick enough to prevent seed to soil contact.
Harvesting (hay): Harvest in boot stage.
Harvest (pasture): Maintain in vegetative stage. Losses palatability after seedhead emergence. Tolerates close grazing. Rotational stocking best.
Approximate Yields: 3-5 tons hay/A

Comfrey, Quaker (also called Russian Comfrey) – Perennial – (*Symphytum peregrinum*)

Description: Grows to a height of 3-4 feet; very large leaves feel somewhat sticky; large, fleshy roots that grow to 8-10 feet deep; purple or red-purple flowers borne in clusters at tips of stems.
Uses: Green manure-can be fed as forage.
Fertilizer: 60 lbs N; Apply 60 lbs P_20_5 and 60 lbs K_20 at medium soil test levels.
pH Range: 6.0-6.5
Soil Adaptation: Wide range
Planting: Fall or early spring. Root cuttings in rows 3 feet apart in prepared seedbed.
Harvesting: Cut to a 2” stubble when leaves reach a length of 18-24 inches.
Approximate Yield: Hay, 3-5 tons/A

Corn – Field Corn – Annual - (*Zea mays*)

Description: Often referred to as maize. Leaves are arranged alternately on the stem. The tassel or male part of the flower is at the top of the plant, and the ear located below the tassel is the female portion. Even number of rows of kernels on each ear.
Uses: Grain and silage
Weight Per Bushel: Shelled, 56 lbs; ear corn, 70 lbs at 15.5% moisture.

Corn – Field Corn – Annual - (*Zea mays*)*(cont.)*

Seeds Per lb:	1,200-1,400
Germinating Time:	7 days
Fertilizer:	For grain, 125-150 lbs N; Apply 40-60 lbs P_20_5 and 40-60 lbs K_20 at medium soil test levels. For silage, increase the amount of P_20_5 applied by 1/3, and double the amount of K_20. Follow soil sample results for zinc and manganese and use tissue analysis to evaluate other micronutrient needs. Consideration should be given to nitrogen and phosphorus residual from previous crops or organic sources.
pH Range:	5.8 – 6.2
Soil Adaptation:	Well drained to somewhat poorly drained soils
Time of Planting:	Full-season corn should be planted one week before to one week after average date of last killing frost in spring. Corn will germinate at 50˚F, but growth rate is slow until temperatures reach 60˚F. Double-crop corn can be planted up to July 1.
Rate of Planting:	On soils with high production potential, where good production practices are followed, plant 22,000 to 26,000 kernels per acre. If planted on droughty soils, the rate of planting should be decreased by 10-15%.
Pesticides:	Herbicides are used on almost all corn grown in Virginia and insecticides are used on considerable acreage. For pesticide recommendations, contact your Extension agent.
Cultivation:	Cultivation may aid in weed control and reduce surface compaction on some soils, but most of the corn currently grown in Virginia is not cultivated.
Reduced-tillage or No-till Corn:	An annual cover such as small grain or permanent sod or a mulch from a previous crop is important for success with no-till. Herbicides are used to kill existing vegetation and reduce weed competition throughout the season. A specially designed planter is used to plant the corn in the mulch with no soil preparation. Research has shown that yields of no-till corn average higher than corn grown on plowed land. Other advantages are water conservation and reduction in soil erosion.
Harvesting (silage):	Hard dough stage when kernels are dented and a black layer is formed at their bases; lower leaves and husks are turning brown. Dry matter content should be 35-42%.
Harvesting (grain):	Corn is mature at 30-35% moisture. A black layer of cells is formed at the base of the kernel at maturity. If corn is harvested with picker and cribbed, the moisture content should be no more than 20%. The optimum moisture for field shelling is between 18% and 26%. It should be dried to 13% moisture before storage.
Approximate Harvest Dates:	Silage, August 15-October 1; Grain, September 1-November 1.
Approximate Yields:	Silage, 14-25 tons of 35% dry matter; Grain, 75-225 bushels/A

Corn – Popcorn – Annual – (*Zea mays everta*)

Description:	*See field corn*
Uses:	Confection and meal
Fertilizer:	Same as field corn
pH Range:	Same as field corn
Planting:	1-2 weeks after date of last killing frost at 22,000-28,000 seeds per A.
Seeds Per lb:	3,000-6,000, depending on grade
Germinating Time:	7 days
Isolation:	Do not plant where it will cross with other corn. Crossing reduces popping qualities.
Harvesting (grain):	Yields from 1/3 to 2/3 as much grain per acre as ordinary field corn. Shuck from standing stalks after it is thoroughly ripe. Do not put in crib until well cured. Maximum popping expansion is reached when kernel moisture is about 13-14%.
Cultivation:	Refer to field corn for information on fertilization and weed control.
Rotation:	Same as field corn when grown commercially.

Cotton–Annual — (*Gossypium hirsutum*)

Uses:	Grown primarily for fiber; seed used for stock feed, fertilizer, and oil; primarily adapted to the eastern shore and southeastern area of the state.
Weight Per Bushel:	30 lbs
Seeds per lb:	4,800 acid-delinted
Germinating time:	12 days
Fertilizer:	50-70 lbs N; At medium soil test levels apply 60-120 lbs P_20_5 and 10-80 lbs K_20. Side-dress with 25-75 lbs N.
pH Range:	5.8-6.2
Soil Adaptation:	Well drained sandy loans and loams, but does well on some fine-textured upland soils.
Time of Planting:	After soil begins to warm, usually about April 5-May 1

Crimson Clover – Annual – (*Trifolium incarnatum*)

Description:	Central taproot with many fibrous roots; 3 leaflets per leaf; stem and leaves hairy; pointed,conical flower at top of stem is bright crimson color; plants 1-3' tall.
Uses:	Green manure, hay and pasture crop
Weight Per Bushel:	60 lbs
Seeds Per lb:	150,000
Germinating Time:	7 days
Fertilizer:	Zero N; 40-120 lbs P_20_5 and 60-90 lbs K_20 at medium soil test levels
pH Range:	5.8-6.5
Soil Adaptation:	Well drained and moderately well drained soils; best suited to the Coastal Plain and Eastern Piedmont.
Inoculation:	Important--Cross-inoculates with red, alsike, ladino, and white clovers.
Planting:	In the fall, 30-60 days before frost. Plant 20-30 lbs hulled seed alone; 15 lbs in mixtures.
Harvesting (hay):	Cut when most advanced heads are beginning to show faded flowers at base. *Dangerous as horse feed if cut when ripe.*
Approximate Yield:	Hay, 1-2 tons/A
Seed Yield:	6-10 bushels; shatters easily when ripe
Approximate Harvest Dates:	Hay, May 15-June 1; seed June 15-July 1. For green manure, spray or till 20-30 days before planting succeeding crop

Crownvetch – Perennial – (*Coronilla varia*)

Description:	Creeping underground roots; stems are leafy, hollow, and weak, reaching a height of 2-4' if supported; flowers white with shading to rose or violet; blooms all summer; seed pods break apart at maturity.
Uses:	Ornamental, erosion control, and stabilization; limited potential for pasture and hay because of limited regrowth after defoliation.
Weight Per Bushel:	55 lbs
Seeds per lb:	110,000
Fertilizer:	Zero N; 90-120 lbs P_20_5 and 60-90 lbs K_20 at medium soil test levels.
pH Range:	5.5 – 6.5
Soil Adaptation:	Does best on well drained soils, but will persist on moderately acid, rather infertile soils.
Inoculation:	Important. Specific inoculum required
Planting:	Late winter or early spring at 5-10 lbs scarified seed. Plant in rows or solid seeded. Rhizomes can be planted.

Dallisgrass—Perennial—*(Paspalum dilatatum)*

Description:	Leaves broad and flat; grows in clumps of a few to many stems; extremely short rhizomes; stems slender and usually drooped from weight of flower clusters; flowers arranged in 2 rows along tip of seed stalk. Grows 10-20" tall.
Uses:	Dallisgrass is a hay and pasture grass in the more southern states, but is not generally recommended for Virginia. It is a slow-starting grass and usually takes 2 or more years to establish a stand.
Weight per bushel:	12-15 lbs
Seed per lb:	340,000
germinating time:	21 days
Fertilizer:	40-60 lbs N, 30-40 lbs P_2O_5 and 30-60 lbs K_2O at medium soil test levels.
pH Range:	5.8-6.2
Soil adaptation:	Well drained to somewhat poorly drained soils.
Planting:	Spring at 10-15 lbs per A alone; 3-5 lbs in mixtures

Eastern Gamagrass (*Tripsacum dactyloides*) Warm-season Perennial

Description:	3 to 8 feet tall, erect bunch grass. Stem flattened at the purplish base and growing from stout, scaly rhizomes. The blades are wide with rough and sharp margins. The inflorescence with 1-3 spikes, sometimes a foot long. It has both male and female parts in the same spike (male spikelets above and female spikelets below the spike). Crowns of established plants can be 3 feet across.
Uses:	Primarily for grazing, but also for hay, silage, erosion control and wildlife.
Fertilizer:	Responds well to N. Apply 100-150 lbs N/A/Yr, in split applications. Maintain P and K in medium range.
pH Range:	5.8-6.5
Soil Adaptation:	Grows in fertile bottomland, swamps, and along stream banks.
Time of Planting:	Seed dormancy is high, so special treatment is needed before planting. Plant wet chilled seed about 1 to 1.5" deep after the soil temperatures reaches 60 to 65˚F. Alternatively, dormant seed can be sown in November-December.
Rate of Planting:	8-10 lbs/A
Method of Planting:	Best stands are obtained when planted in 6 to 10 inch rows using conventional or no-till drill. Alternatively, a corn planter can be used to seed in 30-36" rows.
Harvesting:	Harvest 2-3 times per year in vegetative to early head stages. Can harvest to 5" **(hay and silage)** stubble.
Harvest (pasture):	Use rotational stocking; turn in at 18-24", graze to 8" residual.
Approximate Yield:	3-7 tons hay/A

Fescue—Meadow—Perennial—*(Festuca Elatior)*

Description:	Tufted, deep rooted, long lived, with dark green leaves; no rhizome but forms strong sod; small auricles; short ligule.
Uses:	Pasture. Found in many native pastures in Virginia, but not usually seeded.
Weight per bushel:	10-15 lbs
Seeds per lb:	230,000
Germinating time:	21 days
Soil adaptation:	Prefers rich, moist soils; does not do well on sandy soil.

Fescue—Creeping Red—Perennial—*(Festuca rubra)*

Description:	Narrow leaves that are folded with a very short ligule; base of stem is usually red.
Uses:	Primarily for lawns in shade. Very similar to sheep's fescue except leaves are bright green instead of bluish and it spreads by underground-modified stems (rhizomes).
Weight per bushel:	10-15 lbs
Seeds per lb:	400,000
Germinating time:	14 days
Fertilizer:	*See Turfgrass section.*
pH Range:	5.0-6.2
Soil adaptation:	Well drained to moderately well drained soils. Does best on sandy soils. Will tolerate shade and low pH better than ryegrass or bluegrass.
Planting:	September or early spring at 3-5 lbs per 1000 sq ft for turf.

Fescue—Sheep's—Perennial—*(Festuca ovina)*

Description:	A long-lived bunch grass which forms dense turf; numerous stiff, rather sharp, nearly erect, bluish-gray leaves; a tough grass, eaten eagerly by sheep but to a lesser degree by cattle.
Uses:	Pastures, seldom seeded.
Weight per bushel:	10-15 lbs
Seeds per lb:	530,000
Germinating time:	21 days
Fertilizer:	40-60 lbs N, 30-40 lbs P_2O_5 and 30-60 lbs K_2O
pH Range:	5.0-6.2
Soil adaptation:	Most well drained soils. Does better than most grasses on sandy soils.
Planting:	August or early fall is best, but may be sown in spring at 25 lbs along; 10-12 lbs in mixtures. *Note: Commercial seed comes from Europe.*

Fescue—Tall—Perennial—*(Festuca arundinacea)*

Description:	Long lived, tufted, deep-rooted; noted for early spring and late fall growth; leaves are dark green, shiny, and barbed along the edges, making them feel rough; leaves rolled in bud, very short ligule, sheath reddish pink below ground. Most existing tall fescue stands are infected with a fungal endophyte that induces fescue toxicosis in cattle. Varieties: Endophyte-free varieties are somewhat less hardy than endophyte-infected tall fescue, requiring more careful management. Modern endophyte-free varieties are stronger than earlier varieties. Endophyte-enhanced varieties have potential.
Uses:	Pasture, hay, and turf. Excellent when seeded at high rates for turf. Widely used for winter grazing.
Weight per bushel:	24 lbs
Seeds per lb:	220,000
Germinating time:	14 days
Fertilizer:	Establishment – 40 lbs N, 120-140 lbs P_2O_5 and 120-140 lbs K_2O at medium soil test levels. Pasture topdressing 30 lbs P_2O_5 and 30-60 lbs K_2O annually or 40-125 lbs P_2O_5 and K_2O every 3-4 years. (For winter grazing, apply 60-75 lbs N in mid-august). Hay topdressing –120-200 lbs N, 40-90 lbs P_2O_5 and 85-185 lbs K_2O. For turf, see Turf section.

Fescue—Tall—Perennial—*(Festuca arundinacea) (cont.)*

pH Range:	5.6-6.2
Soil adaptation:	Adapted to practically all tillable soils. Tolerant to both dry and wet soils.
Planting:	Early fall or spring at 15-25 lbs when seeded alone, and 6-12 lbs in mixtures for pasture; 4-6 lbs per 1,000 sq ft for turf.
Harvesting (hay):	1st cut when heads begin to emerge. Stems and seedheads of endophyte-infected fescue are Highly Toxic. Approximate yields: 2-6 tons hay/acre
Harvesting (seed):	When field takes on yellowish-brown cast and heads droop.
Harvesting (pasture):	Tolerant of continuous stocking. With rotational stocking, turn in at 8", remove cattle at 2-3". Keep vegetative to reduce potential problems with endophyte. Remove pregnant mares from endophyte-infected fescue during last 3 months of gestation.

Field Peas — Canadian – Annual — *(Pisum arvense)*

(See Austrian Winter Pea)

Johnsonsgrass – Perennial – *(Sorghum halepense)*

Description:	A coarse, tall-growing grass of the sorghum group that spreads by seed and strong underground stems; used as hay and pasture in some of the southern states, but is considered a serious pest in crop fields in Virginia and most of the eastern U.S.
Grazing precautions:	Johnsongrass is considered a NOXIOUS weed in Virginia and is prohibited as a seed contaminant. It is also against the law to seed this plant. It spreads easily by seeding to other fields. Precautions are similar to sudangrass.

Kudzu– (Perennial) – *Pueraria thunbergiana)*

Description:	Legume, deep-rooted, long lived, coarse-growing vine with runners which often grow 50-100' per season. Produces few seeds, but once established can be a serious pest.
Uses:	For reclaiming gullies and wasteland. Tolerates medium acidity. May be used for pasture and hay.
Fertilizer :	At 3-yr intervals, 60-100 lbs P_2O_5 and 60-100 lbs K_2O
pH Range:	5.5-6.2
Inoculation:	Cross-inoculates with cowpeas, peanuts, and lespedezas. Method of planting: Plant crown in holes or trench 15" deep and 18" wide. On gullied areas, plant in hole 15" deep and 18" wide on 20' squares. On wasteland, plant in deep furrows 20' apart and space crowns 4' in furrow.

Lespedeza – Bicolor – Perennial – *(Lespedeza bicolor)*

Description:	Bushy shrub; grows 3-6 ft tall; strongly ridged and grooved stems.
Uses:	Primarily as food for game birds and for erosion control. Not adapted to high altitudes because seed will not ripen in short season. Not adapted to wet areas.
Weight per bushel:	60 lbs
Seeds per lb:	85,000
Germination time:	21 days.
Fertilizer:	Zero N, 60-90 lbs P_2O_5 and 30-60 lbs K_2O
pH Range:	5.5-6.2
Planting:	In spring after frost
Rate of Planting:	Seed in rows 3' apart at rate of 10 lbs per A, or set plants 2' apart in rows spaced 3' apart. Use scarified seed.

Lespedeza – Annual – Korean – *(Lespedeza stipulaceae)* – Common – *(Lespedeza striata)*

Description:	Warm-season reseeding legume. Slender, branched stems; branched taproot; three leaflet stipules at base of leaf; stipules very prominent on Korean. Non-bloating.
Uses:	Hay, pasture, and wildlife cover. Killed by frost and furnishes poor winter cover. Seed in mixtures with grasses or other legumes; or, if seeded alone, use winter cover crop. May not reseed above 2,500' elevation.
Weight per bushel:	Kobe, 30 lbs; Korean, 45 lbs
Seeds per lb:	Kobe 185,000; Korean 240,000
Germinating time:	14 days
Fertilizer :	At seeding, zero N, 60-90 lbs P_2O_5 and 60-90 lbs K_2O
pH Range:	5.5-6.2
Soil adaptation:	Will grow on almost any well drained soil. Korean adapted to all areas of Virginia. Kobe adapted to southeastern section. Tolerant of acidity and low soil P. Cross-inoculates with perennial lespedezas, peanuts, and cowpeas.
Planting:	February and March at 15-25 lbs alone; 10 lbs in mixtures. Plant in 6-8" rows or solid seeded in small-grain fields. Harrow grain before seeding if soil is hard on top. Can be frost seeded in late winter.
Harvesting (Hay):	Early bloom stage
Harvesting (seed):	Combine in fall when ripe
Approximate harvest dates:	Hay: August 1-September 1; seed: September 15-November 1
Approximate yield:	Hay, 1-2 tons, seed, 200-500 lbs/A

Lespedeza –Sericea– Perennial – *(Lespedeza cuneata)*

Description:	Growth habit similar to alfalfa; stems grow from crown buds in a height of 2-4"; deep branched taproot. Warm season, drought tolerant, non-bloating.
Varieties:	High- and low-tannin types. Low-tannin varieties AV-Lotan and AV-Donnelly more palatable but less persistent.
Uses:	Erosion control, hay, pasture, and cover for wildlife.
Weight per bushel:	60 lbs
Seeds/lb:	335,000
Germination time:	28 days
Fertilizer:	Zero N, 60-90 lbs P_2O_5 and 30-60 lbs K_2O
pH Range:	5.0-6.2
Inoculation:	Cross-inoculates with annual lespedezas, cowpeas, and peanuts.
Soil adaptation:	Will grow on almost any well drained soil. Very tolerant of acid soil and low fertility.
Planting:	Unhulled seed, late fall or early spring; scarified seed, March or April. Plant unhulled seed, 30-40 lbs; scarified seed, 15-20 lbs in 6-8" rows or solid seeded. Slow establishment.
Harvesting (hay):	When plants are about 15-24" tall. High tannin levels drop when harvested for hay, improving palatability and digestibility.
Harvesting (seed):	Direct combined. Second growth produces seed more uniformly and is easier to thresh than first crop, but yield of first crop usually higher.
Harvest (pasture):	Begin grazing at 8-10", do not graze lower than 4".
Approximate harvest dates:	Hay, June 15-July 1; seed, August 15-September 15.
Approximate yield:	Hay, 2-3 tons; seed, 300-600 lbs/A

Matua Prairie Grass – (Kunth) – Perennial – *(Bromus willdenowii)*

Description:	Matua, also known as "rescuegrass" is a cool-season, short-lived perennial grass. Matua is an erect growing plant with bunch-type growth habit. It grows up to 2-3 feet, including the inflorescence. It looks like orchardgrass except that basal leaf sheaths of prairie grass are densely covered with fine hairs and the ligule is shorter and has no auricles. Additionally, matua grass leaves are light green to green rather than bluish green like orchardgrass.
Uses:	Suited for hay, greenchop, or silage and can be used for dairy or beef pastures under rotational stocking management. It is not suited for continuous grazing.
Seeds per lb:	90,000
Fertilizer:	Requires high level of nitrogen; 40 lbs N/A at seeding recommended. For high level of production apply 50-60 lbs N/A following mechanical harvest or 30-40 lbs N/A following each grazing. Apply 40-90 lbs P_2O_5/acre and 85-185 lbs K_2O/A annually. Lower P and K amounts needed on pasture.
pH Range:	6.0 to 7.0
Soil adaptation:	Adapted to well drained, high fertility soils.
Planting:	May be seeded in the fall or spring when the soil temperatures are at least 55°F. Seed treatment with fungicide prior to seeding may control head smut.
Rate of planting:	25 lbs/acre for drilled plantings; 30-40 lbs/acre for broadcast seeding; and 10-15 lbs/acre in mixture.
Method of planting:	No-till or conventional planing methods may be used. Seed must be planted no more than 1/4-1/2" deep.
Harvesting (hay):	Mechanical harvest for hay or grazing should begin at the boot stage for best quality, yield and longevity. A regrowth/rest period of 30-42 days depending on the season is essential. Matua has a yield potential of 3-6 tons/year/acre. One regrowth per year must be allowed to set seed to maintain the stand.
Seeds per lb:	335,000
Germinating time:	28 days

Millet – Pearl – Annual – *(Pennisetum glaucum)*

Description:	Erect growth habit; thick stems that grow 3'-7' tall; spike head. Regrows after cutting/grazing.
Uses:	Supplemental pasture, hay crop, green chop. Requires 60-70 days to mature.
Weight per bushel:	40-55 lbs
Seeds per lb:	86,000
Germination time:	10 days
Fertilizer:	At seeding, 60-80 lbs N, 70-90 lbs P_2O_5 and 70-90 lbs K_2O at medium soil test level; after each cutting, 40-60 lbs N
pH Range:	5.5-6.5
Planting:	May 1-July 1 at 25-40 lbs alone, 15-20 lbs in mixtures in 6-8" rows or solid seeded.
Harvesting (hay):	Cut when heads begin to emerge from boot or at 30-40".
Harvesting (pasture):	Requires high stocking rate, preferably with rotational stocking.
Approximate first harvest date:	July 1-July 15.
Approximate yield:	Hay, 2-4 tons/A

Millet – Foxtail – Annual – *(Setaria italica)*

Description:	Erect growth; slender, leafy stems 2'-5' tall; spike-like head.
Uses:	Supplemental pasture and hay crop, nurse crop for late spring and early summer forage seedings, smother crop prior to late summer no-till forage seedings. Requires 60-70 days to mature. Lower yield and regrowth than pearl millet.
Weight per bushel:	40-55 lbs
Seeds per lb:	220,000
Germinating time:	10 days
Fertilizer:	60-80 lbs each of N, P_2O_5 and K_2O, at medium soil test levels.
pH Range:	5.8-6.2
Planting:	May 1-July 1 at 15-30 lbs along; 15-30 lbs in mixtures in 6-8" rows or solid seeded.
Harvesting (hay):	Cut at seedhead emergence. <u>Do not feed to horses.</u>
Approximate yield:	Hay, 1-3 tons/A

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(Please see sorghum, grain)

Oats-Annual – *(Auena sativa)*

Description:	Panicle type head; long ligule, auricles absent; leaf margins are heavy; seed usually retains the husk (lemma and palea), which has a very smooth surface; seed color varies with variety from white, yellow, gray to somewhat red. Winter oats require a period of cold temperature to initiate heading. Spring oats have no temperature requirement.
Uses:	For grain, hay, and grazing. Excellent rotational crop for wheat or barley because it is not susceptible to the same species of diseases. Does not get "take all".
Weight per bushel:	32 lbs
Seeds per lb:	14,000
Germinating time:	10 days
Fertilizer:	20 lbs of N in the fall plus 40-90 lbs each of P_2O_5 and K_2O at medium soil test levels. Topdress with 60-80 lbs of N in February or early March. These rates assume no carry over N from the previous crop.
pH Range:	6.0-6.5
Soil Adaptation:	Well drained loams and silt loams are best.
Planting:	<u>Winter oats</u>: (Not recommended west of the Blue Ridge.) Fall, September 25-October 15 in eastern Virginia, and September 1-October 1 in Piedmont; midwinter: February 1-March 1 for the entire State. <u>Spring oats:</u> March 5-April 1 in Piedmont; March 15- April 10 west of the Blue Ridge. Spring oats not recommended in eastern Virginia. Plant at 65-80 lbs or 12-15 seeds/drill foot in 6-8" rows or solid seeded.
Harvesting (hay):	Cut in boot to early dough stage.
Harvesting (seed):	Combine when fully ripe at 10-15% moisture.
Approximate harvest dates:	Winter, June 20-July 15, Spring, July 1-July 15
Approximate yield:	80-120 bushels or 2 tons hay/A

Orchardgrass – Perennial – *(Dactylis glomerata)*

Description: Long-lived, deep-rooted bunch grass; leaves light green and folded and flat at the base; tufted seed heads; long ligule. Flowers only in spring. Regrowth is vegetative with no stem or seedhead production.

Uses: Pasture, hay, and silage.

Weight per bushel: 14 lbs

Seeds per lb: 590,000 unhulled, 625,000 hulled

Germinating time: 10 days

Fertilizer: At medium soil test levels. Establishment—When seeded alone, 40-50 lbs N, 120-140 lbs P_2O_5 and 120-140 lbs K_2O. Maintenance (hay)—120-200 lbs N applied 1/2 in early spring and the other 1/2 after 1st cutting plus 40-90 lbs P_2O_5 and 85-185 lbs K_2O. When seeded with clover, nitrogen rate should be reduced to 20 lbs. For maintenance where there is more than 35% clover, no nitrogen is needed.

pH Range: 5.8-6.2

Soil adaptation: Does best on well drained, loam soil.

Planting: In eastern Virginia, seed after first good rain in September and up to October 15, or during February or early March. In the Piedmont and west of the Blue Ridge, seed after first good rain in August and up to September 15, or from March 1-April 15. Plant 8-12 lbs alone; 3-6 lbs in mixtures

Harvesting : (hay and silage) Cut in boot to early head stage. Fiber percentage increases rapidly after blooming.

Harvesting (pasture): Do not graze below 3”. Rotational stocking with 1-4 day grazing periods is best.

Approximate first harvest dates: Hay, May 15-June 1, seed, June 1-July 1

Approximate yield: Hay, 2-5 tons/A/year; seed, 200-600 lbs/A

Peanuts – Annual – *(Archis hypogeae)*

Description: Legume plant native to South America. Growth habit varies from prostrate to upright. Bright yellow flowers on either the main stem or lateral branches. Flowers contain both male and female parts and are self-fertile. Following fertilization a “peg” bearing ovaries in its top elongates from the leaf axil and penetrates the soil. The peg then turns horizontally and pod and seed formation takes place. Seed per pod varies from 1-5 depending on market type. A pod will most often have two seeds.

Uses: Food for humans and livestock.

Weight per bushel: 18-22 lbs in shell; 48-52 lbs shelled

Seeds per lb: Virginia-type, 500-800; runner-type, 700,000; Spanish-type, 1,000-1,400 lbs in shell

Germinating time: 7-10 days

Fertilizer: Direct fertilization not recommended. Increase the fertilizer application on the crop that precedes peanuts in rotation by 50-100 lbs P_2O_5 and 10-60 lbs K_2O. Apply 900 lbs gypsum broadcast or 600 lbs banded over the row as plants begin to bloom.

pH Range: 5.8-6.5

Inoculation : Cross-inoculates with lespedezas, cowpeas, and kudzu.

Soil adaptation: Best quality peanuts are produced on well drained, light, sandy soils. May be produced anywhere east of mountains, but yield and quality are usually poor on heavier soils. Rotate peanuts with other non-legume crops.

Planting: April 20-May 10. Soil temperature should be at least 65°F for three consecutive days.

Rate of planting: Peanuts should be planted 3-4” apart in 30-36” rows. This requires approximately 75-175 lbs of shelled nuts, depending on seed size. Plant 1 1/2-2” deep.

Peanuts – Annual – *(Archis hypogeae) (cont.)*

Weed control:	Herbicides and cultivation may be used. Cultivation should be shallow and often enough to control weeds until pegs enter the ground. Do not cover any portion of the vine with soil. Rotary hoeing when crust forms can be beneficial.
Harvesting:	Dig when about 70% of the shells turn brown on the inside, usually 130-170 days after planting.
Approximate harvest date:	September 15-November 1
Approximate yield:	2,500-5,000 lbs/A
Storage:	Contain about 50% moisture when dug; must be dried to 10% moisture for storage.

Rape – Annual – *(Brassica napus)*

Description:	Cool-season plant in the mustard family. Closely resembles kale with large, dark green leaves. At maturity it reaches a height of 3-6' with brilliant yellow flowers and pods that produce 15-40 small black seeds. Winter and spring varieties are available
Uses:	Pasture and as oil crop. Usually ready for grazing about 8 weeks after seeding. Sometimes causes bloating in sheep.
Weight per bushel:	50 lbs
Seeds per lb:	160,000
Germinating time:	7 days
Fertilizer:	60-80 lbs N, 30-50 lbs P_2O_5 and 30-50 lbs K_2O at medium soil test levels.
pH Range:	5.2-6.2
Soil adaptation:	Well drained and moderately well drained loams and silt loam soils.
Planting:	February and March, or August and September at 2-3 lbs in rows; 6-9 lbs broadcast ; 4-6 lbs when seeded with oats.

Red Clover – Perennial – *(Trifolium pratense)*

Description:	Numerous leafy stems arising from a crown growing to a height of about 2' ; stems and leaves are hairy; flowers reddish purple on heads at tips of branches; branched taproot. Short-lived perennial that often behaves as biennial.
Varieties:	New varieties are more persistent.
Uses:	Hay, pasture, silage, and commercial seed production
Weight per bushel:	60 lbs
Seeds per lb:	260,000
Germinating time:	7 days
Fertilizer:	At seeding, 120-140 lbs P_2O_5 and 120-140 lbs K_2O; for topdressing, 40-90 lbs P_2O_5 and 85-185 lbs K_2O at medium soil test levels. Lower amounts needed when used as pasture.
pH Range:	5.8-6.5
Soil adaptation:	Well drained to moderately well drained loams and silt loam soils properly limed and fertilized.
Inoculation:	Important. Cross-inoculates with alsike, crimson, ladino, and white clovers.
Planting:	45 days before last killing frost in spring, or 30 days before first killing frost in fall. Plant at 8-10 lbs alone; 2-6 lbs in mixtures. Plant in 6-8" rows or solid seeded usually with a grass. Broadcast or drill on small grain or closely grazed grass pasture in later winter or early spring.
Harvesting (hay):	1/4-1/3-bloom stage. Early harvesting for hay favors good seed yield by second crop. Second cutting of hay may cause slobbering in livestock.

Red Clover – Perennial – *(Trifolium pratense) (cont.)*

Harvesting (seed): Cut with combine when heads have turned brown, flowers and stalks are deep yellow, and seeds have begun to show a distinct violet color. Will shatter badly if cut later. May use a dessicant to aid in drying plant.

Approximate first harvest dates: Hay, June 1 – June 20. Seed, August 15-September 1.

Approximate yield: Hay 2-4 tons over season. Seed, 120-240 lbs/A

Redtop (Herdsgrass) – Perennial – *(Agrostis alba)*

Description: Produces numerous stems from a well-developed base; spreads by rhizomes but does not produce a strong sod; flat, light green, sharp-pointed leaves; lacks leafiness under close grazing; long prominent ligule.

Uses: Primarily for erosion control and soil stabilization.

Seeds per lb: 5,100,000

Weight per bushel: 14 lbs

Germinating time: 10 days

Fertilizer: 40-60 lbs N, 60-100 lbs P_2O_5 and 60-100 lbs K_2O. The N is for annual applications, the P_2O_5 and K_2O are rates for 3-4 years

pH Range: 5.8-6.2

Soil adaptation: Well drained and moderately well drained loams and silt loams. Tolerant to wet conditions.

Planting: August and September. May be seeded in spring. Plant at 3-5 lbs alone; 3 lbs in mixtures. Plant in 6-8” rows or solid seeded.

Harvesting (hay): Shortly before full bloom.

Reed Canarygrass – Perennial – *(Phalaris arundinacea)*

Description: Tall, coarse, sod-forming cool-season grass; grows 2’-5’ tall; spreads underground by short, scaly rhizomes; semi-dense, spike-like panicle.

Uses: Hay, pasture, and silage. Conservation cover in wet areas and areas irrigated for disposal of liquid wastes.

Weight per bushel: 45 lbs

Seeds per lb: 430,000

Germinating time: 21 days

Fertilizer: Establishment- 50 lbs N, 120-140 lbs P_2O_5 and 120-140 lbs K_2O. Maintenance (pasture)—40-60 lbs N, 30-40 lbs P_2O_5, and 30-60 lbs K_2O. Maintenance (hay)—120-200 lbs N applied 1/2 in early spring and the other 1/2 after 1st cutting plus 40-90 lbs P_2O_5 and 85-185 lbs K_2O. When seeded with clover-nitrogen rate should be reduced to 20 lbs. For maintenance where there is more than 35% clover, no nitrogen is needed.

pH Range: 5.8-6.2

Soil adaptation: Tolerates poorly drained soils. More drought tolerant than many other cool-season plants.

Planting: Early fall or spring. Often slow to establish. Plant 12-14 lbs alone; 6-8 lbs in mixtures. Plant in 6-8” rows or solid seeded.

Harvesting: 1st cut when heads begin to emerge.

Approximate harvest dates: Hay, May 15-June 15.

Approximate yield: Hay, 2-4 tons/A

Rye – Annual – *(Secale cereale)*

Description:	The most winter-hardy of small grains. Seedings often have a reddish coloration; leaves have small auricles with short ligules; seeds are round with the germ-end distinctly pointed; seed color varies from greenish gray and tan to dark brown or black.
Varieties:	Abruzzi types provide earlier grazing in late winter-early spring.
Uses:	Cover crop, grain, silage, winter and spring pasture.
Weight per bushel:	56 lbs
Seeds per lb:	18,000
Germinating time:	7 days
Fertilizer:	20 lbs of N in fall plus 40-80 lbs each of P_2O_5 and K_2O. Topdress with 60 lbs of nitrogen in February or early March.
pH Range:	5.8-6.2
Soil adaptation:	Any well drained soil. Will do better on poor soils than wheat, oats, or barley.
Planting:	60-90 lbs; 90-100 lbs for grazing. Plant 2 weeks before to 4 weeks after first killing frost. Plant in 6-8” rows or solid-seeded.
Harvesting (yield):	Combine when fully ripe at 10-15% moisture. Rye ripens slowly and seed is easily damaged during harvesting.
Harvesting (silage):	Harvest at the boot stage
Harvesting (pasture):	Earlier fall planting allows some late fall grazing. Stock heavily and rotationally to maintain leafy growth.
Approximate harvest date:	Grain: June 20-July 10; silage: April 10-May 1
Approximate yield:	25-50 bushels grain; 5-8 tons 35%-dry-matter silage/A

Ryegrass – Annual (Italian) – *(Lolium multiflorum)*

Description:	Shiny, smooth leaves rolled in the bud, auricles narrow and long; short ligule; spikelets edgewise on stem with awns on seed. Bunchgrass
Uses:	Grows rapidly and in bunches to height of 3’. Used for hay and pasture, especially as a supplementary pasture mixed with crimson clover and/or small grain. Also used for green manure, winter turf and over-seeding bermudagrass. An annual that can volunteer in small-grain fields to become a pest.
Weight per bushel:	24 lbs
Seeds per lb:	227,000
Germinating time:	7 days
Fertilizer:	Pasture, 20 lbs N in fall and 30-50 lbs each of P_2O_5 and K_2O. Add 50-70 lbs N top dressed in spring.
pH Range:	5.8-6.2.
Soil adaptation:	Will grow well on most soils used for crops in Virginia.
Planting:	August 15 to November 15. Use the earlier seeding date for Northern Piedmont and west of the Blue Ridge. Plant <u>for pasture</u>, 10-15 lbs in mixtures, 20-30 lbs alone. <u>For turf</u>, 3-5 lbs/1,000 sq ft
Harvesting (pasture):	Tolerates close, continuous stocking

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Ryegrass – Perennial – (English Ryegrass) – *(Lolium perenne)*

Description:	Similar to Italian in use, adaptability, and all other ways, but can be distinguished from Italian by flowers being awnless and leaves folded in the bud, not rolled. Special varieties adapted for turf purposes.
Use:	Pasture. High yielding during first year, but decreased yields in subsequent years due to poor persistence.
Planting:	In mixtures, 10 lbs; alone, 20-30 lbs
Approximate yield:	2-6 tons hay/A

Sorghum, forage – Annual – *(Sorghum bicolor)*

Description:	Sorghum is very similar to corn in the vegetative stage. Leaves tend to be more narrow than for corn. Heavily covered with a white waxy coating that can be rubbed off the leaf sheath. Flowers are perfect in that both male and female parts are produced in a panicle type head on top of the plant. Forage sorghum is 6’-10’ tall with large stem, medium-size grain head.
Uses:	silage, hay, grazing.
Weight per bushel:	56 lbs
Seeds per lb:	13,000-20,000
Germinating time:	10 days
Fertilizer:	60-80 lbs each of N, P_2O_5 and K_2O
pH Range:	5.8-6.2
Soil adaptation:	Well drained to somewhat poorly drained soils
Planting:	1-2 weeks after corn. Soil needs to be warm (at least 60˚ F). Plant 5-20 lbs in rows with a drill or corn planter.
Harvesting:	Do not graze until 30” tall. Cut for hay or wilted silage no later than early head emergence. Cut in dough stage for direct ensiling.
Approximate yield:	Hay or wilted silage, 3-5 tons dry matter. Silage, 14-18 tons 35% dry matter/A

Sorghum, Grain – Annual – *(Sorghum bicolor)*

Description:	See forage sorghum. Same genus and species except plant types that are shorter and producelighter grain have been bred Plant height 3-5’ with high grain yield. Will recover from high temperature and drought better than corn.
Uses:	Grain and silage
Weight per bushel:	56 lbs
Seeds per lb:	13,000-20,000
Germinating time:	10 days
Fertilizer:	Apply approximately the same amount that would be applied to corn when grown under comparable conditions.
pH Range:	5.8-6.2
Soil adaptation:	Well drained to somewhat poorly drained soils
Planting:	1-2 weeks after corn. Early-medium maturing hybrids can be planted following small grain harvest in eastern Virginia. Plant for grain at 5-7 lbs in rows; forage alone, 7-10 lbs. Increase seeding rate 10-20% with late seedings. Grain sorghum should be planted in rows as narrow as possible. Seed 1-1 1/2” deep.
Harvesting:	Harvest grain with combine when seed is mature and shells easily from head. Chop for silage when grain is in the dough stage. Artificial drying can be a problem because the small seed size reduces air flow through the grain.
Approximate yield:	Grain, 80-90% of adapted hybrid corn yield. Silage, 11 tons 35% dry matter/A

Sorghum, Sweet– Annual – *(Sorghum bicolor var saccharum)*

Description:	Similar in appearance to forage sorghum
Uses:	Syrup
Weight per bushel:	45-60 lbs
Seeds per lb:	28,000-40,000
Germinating time:	10 days
Fertilizer:	30-50 lbs N, 60-90 lbs P_2O_5 and 60-90 lbs K_2O. Side-dress with N to make a total of no more than 70 lbs N when plants are 25-35 days old.
pH Range:	5.8-6.2
Soil adaptation:	Any well drained soil suited for corn.
Planting:	2-4 weeks after corn at 3-5 lbs in rows 30-36” apart. Plant 1-1 1/2” deep.
Cultivation:	Shallow, level, and often enough to keep down weeds. Chemical control also practiced.
Harvesting (syrup):	When seeds are in hard-dough stage.
Approximate harvest date:	September 1-October 1
Approximate syrup yield:	100-300 gallons/A

Soybean – Annual – *(Glycine max)*

Description:	Legume 2-4’ tall. Broad trifoliate leaves with small white or purple flowers. Flower initiation is very sensitive to day length, but all plants do not respond the same way. Some cultivars bloom under relatively short days while others bloom under longer days. In Virginia, shorter-day cultivars are classified as maturity group 3 or 4; longer-day cultivars are classified as maturity groups 5 and 6. Two types of growth habit -- determinate and indeterminate. Indeterminate cultivar’s terminal bud continue to grow several weeks after flowering; determinate cultivar’s terminal bud cease to grow when the plant starts to flower. Tan or brown seedpod contain 2 to 3 round yellow seed. Stems, leaves, and pods are covered with gray or tawny hairs.
Uses:	Seed, hay, and silage.
Weight per bushel:	60 lbs
Seeds per lb:	Small-3,600; medium-3,000; large-2,500; extra large-1,600
Germination time:	3-6 days
Fertilizer:	Zero N, 40-60 lbs each of P_2O_5 and K_2O
pH Range:	5.8-6.5
Inoculation:	Use soybean inoculum where soybeans are not grown regularly. Does not cross-inoculate with other legumes.
Soil adaptation:	Well drained to somewhat poorly drained soils. Rotate with other non-legume crops.
Planting:	Two weeks after corn planting time for the area (full-season); double-cropped with small grain, generally after June 15. Planting prior to June 10 results in maximum potential yield. Yield declines rapidly if planted later due to lack of time to develop adequate growth. Planting in 20-inch rows or less is recommended in order to meet canopy requirements and maximize yield. No-tillage planting requires the use of a “burndown” herbicide to kill existing vegetation either mixed together with a preemergence herbicide or followed approximately two to three weeks later by a postemergence herbicide.
Pest Management:	An integrated approach with cultural, biological, and chemical controls is necessary. Control weeds by three weeks after planting and maintain control until canopy closure. Rotation with non-host crops become necessary to prevent buildup of several nematode species. Several insect pest species are occasionally a problem in Virginia. Frequent scouting is needed to detect infestations. Control measures should be implemented when pests exceed economic thresholds.

Soybean – Annual – *(Glycine max) (cont.)*

Harvesting: (hay and silage)	When lower leaves begin to turn yellow and pods are about half-filled.
Harvesting (seed):	When leaves have fallen and pods are brown and dry, seed moisture will be 10-15 %.
Approximate harvest dates:	Hay, August 15-October 1 Seed, September 20-December 1
Approximate yield:	Hay, 2-4 tons; Seed, 25-70 bushels/A

Sudangrass – Annual – *(Sorghum sudanense)* or Sorghum—Sudangrass Hybrid—Annual

Description:	Smooth, erect stems reach height of 5’-7’; open panicle head; large leaves
Uses:	Supplemental pasture in 40-45 days.
Weight per bushel:	25-40 lbs
Seeds per lb:	Sudangrass, 55,000; Sorghum-Sudangrass hybrids, 20,000
Germination time:	10 days
Fertilizer:	60-80 lbs each of N, P_2O_5 and K_2O; plus 40-60 lbs N after each cutting
pH Range:	5.8-6.2
Soil adaptation:	Well drained to somewhat poorly drained soils.
Planting:	Two weeks after corn. Sudangrass, 25-35 lbs broadcast, 15-20 lbs in rows. Sorghum-Sudangrass, 30-40 lbs broadcast, 20-30 lbs in rows. Plant in narrow rows or solid seeded.
Precaution:	*Do not graze or harvest for green chop until plants are 24”-30” tall to reduce danger of prussic-acid poisoning*
Harvesting (hay):	Cut just as heads emerge.
Harvesting (silage):	Cut direct when grain is in dough stage, or as heads emerge and wilt.
Approximate harvest dates:	Hay or silage, July 1-July 15
Approximate yield:	Hay or wilted silage, 2-5 tons dry matter. Silage, 12-15 tons 35% dry matter/A

Sugar Beets – Biennial – *(Beta vulgaris)*

Description:	Same species as the red garden beet but grows much larger. Leaves are large and shiny; white roots averaging 1-3 lbs. Sugar content 14-16%.
Uses:	Sugar production and livestock feed.
Seeds per lb:	72,000
Germination time:	10-14 days
Fertilization:	40 lbs N, 100 lbs P_2O_5 and 100 lbs K_2O prior to seeding. An additional 40 lbs N will be needed 4-6 weeks later. Use a borated fertilizer.
pH Range:	6.0-6.5
Soil adaptation:	Well drained silt or silty loam soil free of stones and roots.
Planting:	Late winter or early spring. If field is to be thinned, drop one seed per inch of row. Thin when plants have 4-6 leaves, spacing plants 10-12” apart.
Approximate harvest dates:	October-December.
Approximate yield:	20-30 tons/A

Sunflower – Annual – *(Helianthus annus)*

Description:	Plants with large leaves and bright yellow flowers. Young leaves and flowers tend to face the sun. Very susceptible to bird damage.
Uses:	Oil crop, bird feed, snack food.
Weight per bushel:	26-30 lbs
Seeds per lb:	5,000-8,000
Germination time:	10-14 days
Fertilization:	100 lbs of N plus 40-60 lbs each of P_2O_5 and K_2O
pH Range:	5.8-6.0
Soil adaptation:	Any well drained soil
Planting date:	Tolerates freezing temperatures better than most crops. Can plant 2-3 weeks prior to last killing frost. Because of early maturity, planting can continue until August 1 in eastern Virginia.
Planting rate:	Plant 19,000-20,000 plants/A
Cultivation:	1-2 cultivations will usually be necessary to control weeds. Herbicide selection limited.
Harvesting:	110-120 days required from planting to harvest. Mature when the backs of heads turn yellow. Special attachments necessary on small grain combine headers to prevent shatter loss.
Approximate yield:	Seed, 1,200-2,000 lbs/A

Sweet Clover – Biennial – *(Melilotus alba; Melilotus officinalis)*

Description:	Erect with many branches; deep taproot; stems grow from crown second year; yellow or white flowers; 2-5’ tall, leaflets notched on edges toward tips (unlike alfalfa with smooth edges). Plants and flowers have a sweet vanilla odor.
Varieties:	Biennial white sweet clover preferred. Stems of the biennial yellow are finer and plant does not grow so high. Yellow blooms 10 days earlier.
Uses:	Pasture, hay, and green manure. <u>Poorly cured hay can result in hemorrhaging in livestock due to accumulation of dicoumarin.</u>
Weight per bushel:	60 lbs
Seeds per lb:	250,000
Germinating time:	10 days
Fertilizer:	Zero N, 40-70 lbs P_2O_5 and 50-80 lbs K_2O
pH Range:	6.5-7.0
Soil adaptation:	Well drained to moderately well drained soils.
Inoculation:	Important. Cross-inoculates with alfalfa and bur clover.
Planting:	February, using unhulled seed. Use scarified seed in late March or April. Hulled, 15 lbs; unhulled, 25 lbs. Drill on grain in February or March, or sow on frozen ground.
Harvesting (hay):	Cut in bud stage before any bloom appears.
Approximate harvest dates:	Hay, May 10-June 1
Approximate yield:	Hay, 2-3 tons/A

Switchgrass – Perennial – *(panicum virgatum)*

Description:	Native warm-season sod-forming tall grass (3-6’) that produces an open panicle seed head. Scaly creeping rhizomes. Can be identified by the cluster or nest of hair at the base of the blade where it joins the sheath.
Uses:	Summer pasture or hay. Will not persist under close or frequent grazing.
Seeds per lb:	330,000

Switchgrass – Perennial – *(panicum virgatum) (cont.)*

Germinating time:	14-21 days
Fertilizer:	Generally low fertility requirement. At establishment, zero N, 80 lbs each of K_2O and P_2O_5. Maintain K_2O and P_2O_5 test in the medium soil test range. Apply 40-60 lbs N annually if legumes are not present.
pH Range:	5.5-6.5
Soil adaptation:	Deep, well drained to moderately well drained soils.
Planting:	May 15-July 15 using 6-8 lbs pure live seed.
Harvesting (hay):	Cut prior to seed head emergence.
Harvesting (pasture):	Begin grazing when 18”-24” tall. Do not graze below 8”.
Approximate first harvest dates:	July 15- August 1.
Approximate yield:	Hay, 2-5 tons /A

Tall Meadow Oatgrass – Perennial – *(Arrhenatherum elatius)*

Description:	Bunchgrass that grows 3-5’ tall; open panicle head likes oats.
Uses:	Hay and pasture. Makes early spring growth but very little aftermath growth.
Weight per bushel:	10-15 lbs
Seeds per lb:	150,000
Germinating time:	14 days
Fertilizer:	40-60 lbs N, 30-40 lbs P_2O_5 and 30-60 lbs K_2O
pH Range:	5.8-6.2
Soil adaptation:	Well drained to moderately well drained sandy loam to silt loam soils.
Planting:	Late summer or fall using 15-20 lbs alone or 10-12 lbs in mixtures.
Harvesting (hay):	Cut at early heading stage.
Approximate harvest dates:	Hay, May 15 – June 1
Approximate yield:	Hay, 1-2 tons/A

Timothy – Perennial – *(Phleum pratense)*

Description:	Semi-bunch grass; erect and dull green leaves gradually tapering to a point; in late spring, the lower joint swells to form a small bulb; spike-like head; shallow fibrous roots; round stem with prominent ligule.
Uses:	Primarily hay; best adapted to the northern United States, but does fairly well in northern Piedmont and western Virginia. Makes very little regrowth after spring cutting compared to orchardgrass or tall fescue.
Weight per bushel:	45 lbs
Seeds per lb:	1,230,000
Germinating time:	10 days
Fertilizer:	40-60 lbs N, 30-40 lbs P_2O_5 and 30-60 lbs K_2O
pH Range:	5.8-6.2
Soil adaptation:	Well drained to somewhat poorly drained, fine-textured soils.
Planting:	8-10 lbs alone; 2-8 lbs in mixtures. Usually seeded in mixtures with clovers or alfalfa.
Harvesting (hay):	When alone, in full bloom; in mixtures, when legume is in early bloom.
Approximate harvest dates:	Hay, June 1-July 1
Approximate yield:	Hay, 1-3 tons/A

Tobacco– Burley – Annual – (*Nicotiana tabacum)*

Description:	See flue-cured tobacco. Plants typically larger than flue-cured. Stalk and leaf midribs are light green to cream-colored. Typical culture is for 18-22 leaves that are lighter green than flue-cured. The crop is grown from transplants historically produced in plant beds but now typically produced in greenhouses.
Uses:	Primarily cigarette blends with a small amount used in the manufacture of pipe and chewing tobacco products. Approximately 30% is exported.
Seeds per oz:	330,000
Germinating time:	7 - 12 days
Viability of seed:	6-8 years under proper conditions (temperature in ^oF and relative humidity should add to 100).
Fertilizer:	175-200 lbs of N, 60-120 lbs of P_2O_5 and 150-300 lbs of K_2O per acre. Follow soil test recommendations.
pH range:	When checked in the spring, a pH of 5.8-6.2 is preferred. If the pH drops to 4.9 during the season, there is a danger of manganese toxicity.
Soil adaptation:	Fertile silt loam soils that have good internal and surface drainage.
Planting:	Transplant from seed beds May 15 – June 1 using 6,225-8,300 plants per acre in 3.5’ rows with plants spaced 18”-24” in the row.
Disease control:	The most successful disease management program utilizes multiple control strategies. Crop rotation and the use of disease resistant varieties should be used in combination with chemical control methods.
Weed control:	Herbicides alone will not control certain weeds closely related genetically to tobacco. Tobacco benefits from some soil aeration, so always cultivate tobacco at least one time, usually at lay-by time, even though weeds are not a problem.
Insect control:	The Integrated Pest Management (IPM) approach to insect control recognizes that a certain amount of insect damage will not reduce tobacco yield or quality enough to pay for the cost of treatment. Natural control should be promoted by delaying insecticide applications until a pest insect reaches an economic threshold level and by using the insecticides that are least harmful to beneficial insects.
Sucker control:	Top the tobacco when the 50% bloom stage has been reached. Growth of suckers is controlled through the use of plant growth regulators. Typical control is through back-pack sprays of maleic hydrazide or a combination of maleic hydrazide and a local sys-temic material.
Method of harvest:	Hand-harvest plants by stalk cutting. Spear 5-6 plants onto each stick according to size of tobacco. Leave tobacco in the field on standing sticks long enough to wilt sufficiently to handle without breakage of the leaves.
Method of curing:	Air-cure in ventilated barns by placing sticks of speared tobacco 9” apart on the tier rails. Any temperature from 65^oF to 95^oF is satisfactory as long as the daily average relative humidity is between 65% and 70%. An alternative curing methods utilizes labor saving field curing structures covered with black plastic.
Approximate harvest date:	August 15-October 1.
Approximate yield:	2,400-2,800 lbs/A of cured leaves.

Tobacco – Dark-fired – Annual – *(Nicotiana tabacum)*

Description:	*See flue-cured tobacco*
Uses:	The majority is exported for the manufacture of smoking tobacco, chewing tobacco, and cigars. The domestic use is for dry snuff.
Seeds per oz:	330,000
Germination time:	7-12 days

Tobacco – Dark-fired – Annual – *(Nicotiana tabacum) (cont.)*

Viability of seed:	6-8 years under proper conditions (temperature in ^{o}F and relative humidity should add to 100).
Fertilizer:	135 lbs N, 40-100 lbs P_2O_5 and 100-175 lbs K_2O
pH Range:	5.6-6.0
Soil adaptation:	Well drained loams and silt loams.
Planting:	May 1-June 1 using 5,000-5,300 plants/A. Rows, 42-48" apart; plants, 24-30" in row
Topping and sucker control:	Plant should be topped at 12-14 leaves, depending on the vigor of the plant after the bud has formed, before the flowers begin to open. Growth of suckers is controlled through the use of plant growth regulators. Foliar sprays of contact fatty alcohols and maleic hydrazide (in sequential applications) are effective with minimal hand labor. Alternative control utilizes treatment of individual plants with local systemic plant growth regulators.
Method of harvest:	Cutting stalk.
Method of curing:	Numerous small smoldering fires on barn floor. Hardwood or sawdust may be used to generate smoke. Smoke several times during 6 week curing period.
Approximate harvest date:	August 15-September 1
Approximate yield:	1,200-2,500 lbs cured leaf.

Tobacco– Flue-cured – Annual – *(Nicotiana tabacum)*

Description:	Central taproot with numerous short lateral roots. Single round stem 4-8' tall when not topped. Leaves are alternate, forming an ascending spiral up the stem. Leaves are 1' or more in width and 3-4' long with a unique ability to accumulate nicotine. All green parts of the plant are covered with sticky hairs. Flowers are pink or rose colored and self-pollinated. The crop is grown from transplants historically produced in plant beds but now typically produced in greenhouses.
Uses:	Primarily used in cigarettes. Approximately 40% is exported as unmanufactured leaf.
Seeds per oz:	330,000
Germinating time:	7-12 days
Viability of seed:	6-8 yrs under proper conditions (temperature in ^{o}F and relative humidity should add to 100).
Fertilizer:	50-80 lbs N, 40-100 lbs P_2O_5 and 100-150 lbs K_2O. If necessary to topdress, use nitrate source of N. Use materials low in chlorine (less than 2%).
pH Range:	5.5-6.0
Soil adaptation:	Well drained soils with sandy loam surface and sandy clay loam subsoils.
Time of planting:	Transplant between April 25-May 20
Rate of Planting:	6,000-6,500 plants per acre; 44-48" rows, plant 20-24" in row. The optimal number of leaves per acre is 110,000-120,000.
Side-dressing:	Preplant fertilizer rates should not exceed 40 lbs of N and 120 lbs K_2O per acre. Additional N and K_2O can be applied as a side application to obtain the total amount of nutrients desired. Side-dressing applications of the base rate of nutrients should be made as soon as the stand is established. When leaching occurs, N and K_2O in addition to the base amounts recommended may be necessary. The quality of N and K_2O required would depend on the amount of water that percolates through the plow layer, and the stage of plant growth at the time this occurs.
Topping:	Plants should be topped at the button to early flower stage of development that is about the time harvest begins. Plants should be topped at 17-22 leaves depending upon plant vigor and weather conditions.

Tobacco– Flue-cured – Annual – *(Nicotiana tabacum) (cont.)*

Suckering:	After topping, suckers develop in the leaf axils and should be removed or controlled. Growth and suckers is controlled through the use of plant growth regulators. Foliar sprays of contact fatty alcohols and maleic hydrazide (in sequential applications) are effective with minimal hand labor. Alternative control utilizes treatment of individual plants with local systemic plant growth regulators.
Method of harvest:	Leaves harvested individually by removing or priming as ripening begins at the bottom of the stalk and progresses upward.
Method of curing:	Typically in bulk curing barns following a schedule lasting 6-7 days regulating temperature and drying rate. Supplemental heat (maximum (165-170^{o}F) is required to first yellow the leaf, than dry the lamina, and finally dry the leaf midrib.
Approximate harvest date:	Typically three harvests or primings as leaves ripen. Harvest period may last 8-12 weeks, beginning as early as mid-July and ending as late as October.
Approximate yield:	2,000–3,000 lbs of cured leaves/A

Tobacco – Sun-cured – Annual – *(Nicotiana tabacum)*

Description:	See Flue-cured tobacco. Smaller plants than flue cured.
Uses:	Primarily exported for making smoking and chewing tobacco. A small portion is used domestically for plug chewing tobacco.
Seeds per oz.:	330,000
Germination time:	7-12 days
Viability of seed:	6-8 yrs under proper conditions (temperature in ^{o}F and relative humitity should add to 100).
Fertilizer:	125 lbs N, 40-100 lbs P_2O_5 and 100-175 lbs K_2O
pH Range:	5.6-6.0
Soil adaptation:	Well drained loams and silt loams.
Planting:	May 1 – June 1
Rate of planting:	5,000-5,300 plants/A. Rows, 3 1/2’; plants 28-30” in row
Topping and sucker control:	Plants should be topped at 12-14 leaves, depending on the vigor of the plant after the bud has formed, before the flowers begin to open. Growth of suckers is controlled through the use of plant growth regulators. Typical control is from hand application of a local systemic plant growth regulator to individual plants.
Method of harvest:	Cutting Stalk.
Method of curing:	Air-cured in barns constructed to permit good ventilation. Heat needed only in periods of extremely high humidity.
Approximate harvest date:	August 15-September 1
Approximate yield:	1,000-2,000 lbs/A

Tobacco Greenhouses

Production system:	Transplants typically grown in styrofoam plug trays floating in shallow plastic-lined pools containing a nutrient solution. An overhead watered production system utilizing plastic plug trays is an alternative production system.
Plant density:	80-157 plants per sq ft in trays containing 200-392 plants.
Seeding time:	Seed greenhouse with highest quality pelletized seed approximately 7-8 wks before expected transplanting.

Tobacco Greenhouses *(cont.)*

Fertilization: Use a complete (N-P_2O_5-K_2O) water-soluble fertilizer. Greater than 50% of fertilizer nitrogen should be derived from nitrate nitrogen. Fertilizer is added to the nutrient solution at a concentration of 100-150 ppm N.

Clipping: Clipping with a rotary mower is used to increase transplant uniformity, remove excess oliage, and regulate seedling growth. clipping should begin when seedlings are 2-2 1/2 inches tall to the bud and clip 1-1 1/2 inches above bud. Clip 4-6 times before transplanting, raising blade height with successive clippings. Proper sanitation is critical for disease prevention.

Tobacco Plant Beds

Seeding: Use 1/8-1/6 oz. of seed per 100 sq yds of bed.

Plant bed space: 75-100 sq yds/A to be transplanted

Fertilizer: 1/2-3/4 lb of 12-6-6 to each sq yd

Soil adaptation: Locate beds near a source of clean water on well drained sandy loams or loams. Do not locate beds in a shady area or in low lying areas along creeks or rivers.

Vetch – Hairy – Annual – *(Vicia villosa)*

Description: Semi-viney legume with tendrils; plants hairy; stems 3-5’ long; flowers bluish violet and white.

Uses: Hay, pasture and winter cover. Sometimes called winter vetch. Because of the hardness of the seed, it often becomes a weed in small grain crops that follow.

Weight per bushel: 60 lbs

Seeds per lb: 21,000

Germinating time: 14 days

Fertilizer: 90-120 lbs P_2O, and 60-90 lbs K_2O

pH Range: 6.0-6.5

Inoculation: *Important.* Cross-inoculates with garden peas and field peas.

Soil adaptation: Well drained to moderately well drained sandy loams to clay loams.

Planting: August 1 – November 1, depending upon location. Plant 20-30 lbs alone; 10-15 lbs in mixtures; usually mixed with 1/2-1 bushel of small grain. Plant in 6-8” rows with small grains or solid seeded.

Harvesting (hay): When seeds in lower half of the plants are half developed.

Harvesting (seed): Cut when first pods are well developed.

Approximate harvest dates: Hay, May 1-June 1

Approximate yield: Hay 1-2 tons or seed, 200-600 lbs/A

Weeping Lovegrass – Perennial – *(Eragrostis curvula)*

Description: A warm season perennial bunchgrass. Long slender drooping leaves that grow to a height of 2’-5’ but usually do not remain upright. Seed head is an open pannicle 6”-10” long. Produces relatively poor quality pasture and hay. Several varieties available. Virginia is northern limit of adapted area.

Uses: Limited hay and pasture, relatively low in palatability. Its primary use in Virginia is for soil stabilization and critical areas.

Seeds per lb: 1,500,000

Germination time: 14 days

Fertilizer: 40-50 lbs N, 60-70 lbs P_2O_5 and 40-50 lbs K_2O

pH Range: 4.5-6.2. Tolerance to low pH enhances its value for soil stabilization.

Soil adaptation: Best adapted to sandy soils, but will grow in heavier soil types.

Weeping Lovegrass – Perennial – *(Eragrostis curvula) (cont.)*

Planting:	April 15-June 1 is best but can also be seeded June 1-August 15, 1-2 lbs in rows, 2-3 lbs solid seeded.
Harvesting:	Cut for hay before seed head forms. For grazing, stock at high rates to utilize all forage and then rotate as needed.

Wheat – Annual – *(Triticum aestivum)*

Description:	Dark green leaves with short hairy auricles and long ligule. Seeds thresh free of their husks and are caramel colored with smooth surface and a whitish brush on the end opposite the germ. Soft red wheat is the traditional class of wheat grown in Virginia.
Uses:	Grain, grazing, and cover crops.
Weight per bushel:	60 lbs
Seeds per lb:	13,000-16,000
Germinating time	7 days at 65°F. 14 days at 50°F
Fertilizer:	20 lbs of N in the fall plus 40-80 lbs each of P_2O_5 and K_2O at medium soil test levels. Topdress with 30-50 lbs of N in February if the stand is thin or shows obvious nitrogen deficiency. Additional nitrogen should be applied in late March (40-80 lbs).
pH Range:	5.8-6.2
Soil adaptation:	Any moderately well drained or well drained soil.
Planting:	One week before to one week after the first killing frost, October 15-November 15 in eastern Virginia; October 1-November 1 in the Piedmont; October 1-October 25 west of the Blue Ridge. Plant 120-150 lbs per acre (36 seeds per sq ft or 20 seeds per drill ft in 7” rows). Plant in 6-8” rows or solid seeded.
Harvesting:	Combine when fully ripe at 10-15 % moisture. Cut for silage in the soft dough stage.
Approximate harvest dates:	June 20-July 10
Approximate yield:	50-100 bushels grain; 8-12 tons 35% dry matter silage/A

White Clover – Common – Perennial – *(Trifolium repens)*

Description:	Low growing, short-lived legume; smooth leaves with 3 leaflets; shallow rooted; spreads by soil surface stolons that root at nodes; white flower.
Uses:	Pastures, especially with bluegrass. Tolerates close, continuous grazing.
Weight per bushel:	60 lbs
Seeds per lb:	700,000
Germinating Time:	10 days
Fertilizer:	With bluegrass at seeding, 0-20 lbs N, 90-120 lbs P_2O_5 and 60-90 lbs K_2O. For topdressing, 60-100 lbs each of P_2O_5 and K_2O every 3-4 years.
pH Range:	5.8-6.5
Inoculation:	Cross-inoculates with alsike, crimson, ladino, and red clover.
Soil adaptation:	Well drained and moderately well drained loams and silt loams.
Planting:	45 days before last killing frost in spring or 30 days before first killing frost in fall using 1-2 lbs in mixtures.

White Clover –- Ladino – Perennial – *(Trifolium repens latum)*

Description:	Giant variety of white clover which resembles white clover in every respect except size.
Uses:	Primarily for pasture with tall growing grasses such as orchardgrass. May be used for silage and hay, but hay is difficult to cure. Less persistent and grazing tolerant than common white clover.

White Clover –- Ladino – Perennial – *(Trifolium repens latum) (cont.)*

Weight per bushel: 60 lbs
Seeds per lb: 700,000
Germinating Time: 10 days
Fertilizer: Alone at seeding, zero N, 90-120 lbs P_2O_5 and 60-90 lbs K_2O. Topdressing, no N, 30-40 lbs P_2O_5 and 30-60 lbs K_2O annually.
pH Range: 6.0-6.5
Soil adaptation: Well drained and moderately well drained loams and silt loams.
Inoculation: *Important.* Cross-inoculates with alsike, crimson, red and white clovers.
Planting: 30-60 days before average date of the first killing frost in fall or 30-45 days before the average date of the last killing frost in spring. Fall seedings are preferred, especially in the Tidewater area. Plant 1-2 lbs with grasses. May be seeded alone at rate of 3-5 lbs when usedfor hog or poultry pasture.

Zoysia – Perennial — Japanese lawn grass – *Zoysia japonica Steud.)* – Korean or Matrella lawn grass – *(Zoysia matrella L.)*

Description: Closely resembles bermudagrass. Spreads by stolons and short rhizomes. Turns brown with frost but greens up earlier than bermuda in the spring. Ligule is a fringe of hairs with some hairs found on upper surface of leaf blade. Forms a dense turf with leaves upright, which provides more cushion than bermuda. Flower is a weak spike and seldom branched.
Uses: General lawn areas. Sometimes used for lawns, athletic fields, and play areas.
Growth habit: Often sod-forming with both stolons and rhizomes. Slow growing, particularly in areas having cold nights. *Matrella* similar to *Japonica* except finer texture.
Climatic adaptation: Both species have low moisture requirements. *Japonica* adapted best intermediate zone between cool humid and warm humid regions. *Matrella* is a warm season grass best adapted to warmer sections of warm humid regions. Severely injured by cold weather. Becomes dormant early in fall and starts late in spring.
Soil adaptation: Grows best on soils of medium or good fertility. Will survive at low fertility levels. Tolerates medium acidity, but needs good drainage. Moderately shade-tolerant.
Fertilizer: For fertilizer and other management practices, see Turfgrass section.
Method of establishment: Sod, sprigs, and plugs. The latter two are slow to establish, usually requiring at least 2 seasons.
Planting: Spring: 4-7 bu/100 sq ft from May 15-July 1 in Northern Piedmont and mountains, and April 30-July 15 in Coastal Plains and Southern Piedmont. Plugs: 4,000 on 6” centers/ 1000 sq ft. Plant from May 1-July 15 in Northern Piedmont and mountains, and April 15-August 1 in Coastal Plains and Southern Piedmont.

PART II
Forage Crops

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Pastures

Pastures are the backbone of Virginia's beef and sheep industries and are of increasing importance to the dairy industry. The over 2 million acres of pasture in Virginia provide feed for grazing livestock with minimal requirements for labor and equipment. Pasture plants growing in areas inaccessible to machinery and equipment or on soils unsuitable for cropping serve as a feed for livestock in the production of meat and fiber for human use. Forage crops can be grown successfully throughout Virginia if species and management are tailored to match the soils and climate in that region of the state.

Year-round grazing

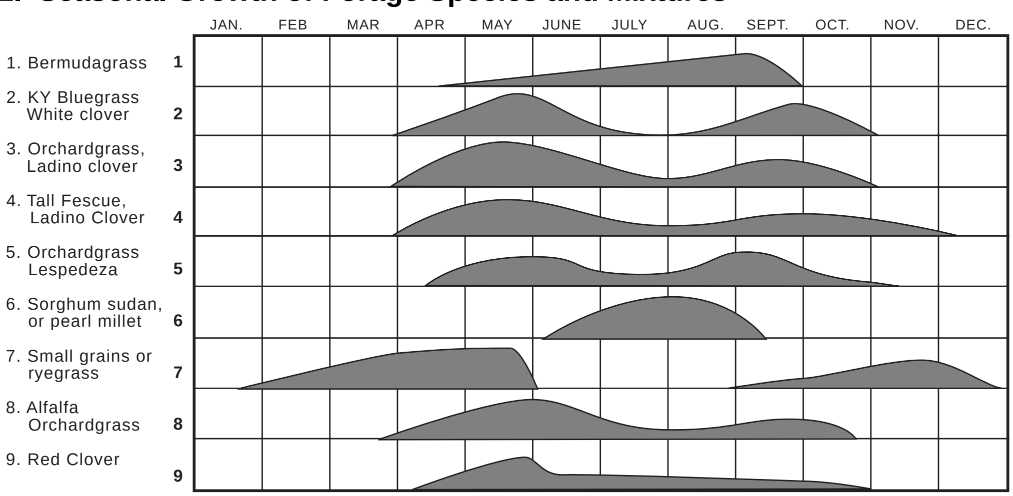
Year-round grazing should be an objective of most pasture-based livestock systems. Utilizing combinations of plant species which make their growth at different times of the year is key to successful year-round grazing programs.

Seeding

Pasture seeding recommendations are dependent upon the types of pasture already available in the system, the use for which it is intended, the type of soil, climatic conditions, and the intended management. Details given in the "Pasture Seedings" table will be helpful in selecting the mixture for individual needs. Seeding may be done in seedbeds prepared by plowing, disking, and firming with cultipacker or roller. New stands may also be established using no-till seeding equipment and management techniques. Before seeding, consult an Extension Agent who is familiar with local growing conditions and can provide specific recommendations for pasture establishment.

Seed after the first good rain in August or September or between February 15 and April 15, depending on the area of the state. Generally, moving from west to east, seeding can be done later in the fall and earlier in the spring. A reliable rule to follow is to seed 30-40 days before the first killing frost in the fall or 30 days before the last frost in the spring.

Figure 1. Seasonal Growth of Forage Species and Mixtures



December-March are the traditional winter feeding months. Most plants make little or no growth when temperature is much below 50°F.
Small grains and rye will grow anytime the average temperature is above 32°F. Plan to feed hay or silage for 60 to 120 days. Small grains and stockpiled tall fescue for pasture help reduce the need for harvested feeds.
April, May, and June are the surplus grass months. Save excess growth by making silage or hay.
July and August are the critical pasture months. Make definite plans for these months.

Managing pastures

Pastures can be limed and fertilized, according to soil test results, any time of the year, but late summer and fall applications are preferred. Tall-grass pastures should be fertilized every year. Native pastures are normally fertilized every three years.

High quality pastures will consist of 25-40% clover. Significant improvement in animal performance is realized when clover is present in a grass-based stand of forage. Because of clover's ability to fix nitrogen into the soil, no supplemental nitrogen is required for grass-clover pastures with significant clover content.

Overseeding clover is an excellent procedure for establishing clover in grass sods. Graze or mow the sod very closely by late February, then broadcast the seed on the soil surface. Freezing and thawing of the soil, plus traffic and early spring grazing by livestock, should result in good seed to soil contact for clover establishment.

The goal in grazing pastures is to *utilize* the forage that is produced without injuring the sod. Undergrazing produces high rates of gain per animal but low animal production per acre. Overgrazing results in low gains per animal and per acre. The challenge is to maintain optimal animal performance without compromising plant vigor.

Harvest excess pasture growth, especially in the spring, for hay. Graze only those pastures that livestock will keep grazed down. When growth slows during the summer, make more pasture acreage available.

Occasional clipping of pastures helps to remove tough, mature plant growth and prevents seed production by weeds. Mid June and late August are the most critical times for clipping. Proper grazing management helps to minimize the need for clipping.

When a pasture is grazed to a height of 2-3 inches, rotate livestock to another pasture. Plan pasture rotations so that young, growing livestock have access to the highest quality grazing. For example, permit steers to graze lush pastures first, then let the cows remove what is left. Plan to have calves "creep graze" high-quality pasture by placing small openings in the fence so they can leave their mothers to graze an adjacent pasture or hay field. Winter grazing can be obtained by grazing or clipping tall fescue stands in August, fertilizing with 70-80 lbs nitrogen per acre, then permitting plant growth to accumulate through late fall. One acre of "stockpiled" growth can provide 120 days of winter grazing for a beef cow.

An animal unit (AU) is usually defined as a 1000 lb cow and her calf, two 500 lb steers, or five ewes with lambs. Generally, one acre of *excellent* pasture is required to carry an AU through the grazing season, or 1.5 acres of *good* pasture per AU, or 3.0 acres of *average* pasture per AU, or 6.5 acres of *poor* pasture per AU. An animal unit month (AUM) is defined as the amount of pasture (400 lb TDN) required to provide adequate grazing for an AU for one month.

Refer to the **Recommendations for Pasture Seedings in Virginia Table** on the following page.

Hay

Red clover, alfalfa, orchardgrass, and tall fescue are the most widely grown hay crops in Virginia. However, any plant that can be cut, dried, and stored can be utilized for hay. The following table provides details on the most commonly used mixtures.

Crushing stems (conditioning) at the time of mowing will permit the stems to dry at nearly the same rate as the leaves. Curing time is decreased by about one day for large-stemmed plants. Raking while hay is moist (about 40% moisture) and baling before hay is crisp (16 -20% moisture) reduces field losses.

Refer to the **Recommendations for Hay and Haylage Seedings in Virginia Table** on the following page.

Recommendations for Pasture Seedings in Virginia

Use	Species	Seeding Rate (lb/acre)	Soil Adaptation	Management Tips
Frost seeding legume in grass pasture	Red clover White or Ladino clover or Annual lespedeza	3-6 1-2 10-15	Any medium to heavy textured soil with pH > 5.8 and medium or better fertility for clovers. Annual lespedeza for acid, lower fertility soils .	Graze grass sod closely by February then broadcast seed and allow cattle to tread the seed into the ground for 1 week. Frost seed every 2-3 years. Use to add legume to thinning alfalfa pasture.
Continuous Stocking	Tall fescue (E+ or E-)* White clover Red clover	10- 15 1-2 3-5	Broad drainage tolerance with pH > 5.8.	Should broadcast red clover every 2-3 years in late winter. E+ tall fescue will persist better than E- but will provide lower animal performance. Use more grazing pressure on E+ tall fescue to keep vegetative.
Continuous Stocking	Alfalfa (grazing tolerant variety) White clover Tall fescue (E+ or E-)*	10-15 1-2 6- 10	Well drained, deep, fertile soils with pH > 6.5.	E+ will persist better than E- but will provide lower animal performance. Use more grazing pressure on E+ tall fescue to keep vegetative.
Rotational Stocking	Alfalfa and Orchardgrass or Matua bromegrass or Tall fescue(E-)*	10-15 3-6 or 10-15 or 6-10	Well drained, deep, fertile soils with pH > 6.5	Graze when alfalfa is bud to early bloom down to 2-3" residual to reduce grass competitiveness. Grazing periods <7 days, rest periods 25-40 days. Maintain P and K in high range to maintain alfalfa. Be careful of bloat if alfalfa is predominate. Allow Matua mixture 45 days in late summer to reseed.
Rotational Stocking	Orchardgrass Red Clover Ladino Clover	8-12 3-5 2	Well drained to somewhat poorly drained soils with moderate or better fertility and pH > 6.0	Turn in at 6-10" and graze to 3" crop height.
Continuous or Rotational Stocking - Summer production	Bermudagrass or Caucasian bluestem	12-20 bu sprigs 2-3 PLS**	Any soil. Bermudagrass prefers lighter textured soils. Caucasian needs deep soils with pH > 5.5.	Use adequate stocking rate to maintain vegetative stage and palatability. With rotation, turn in at 8-12" and graze to 3-4". Best to graze lightly or hay during establishment year.
Rotational Stocking - Summer production Rotational Stocking-Summer	Switchgrass or Dwarf, pearl millet or Sudangrass or Sorghum-Sudan Hybrids	7-10 PLS** 15-30D, 25-40B or 15-20D,25-35B or 20-30D,30-45B	Any deep soil. Good flooding tolerance. Medium to well drained soils. Pearl millet higher yielding on heavy-textured soils.	Turn in at 18-24", graze down to 8-10". Best to graze lightly or hay during establishment year. Turn in at 18-24", "30" for sorghum-sudan and graze to 6". Avoid prussic acid poisoning in sudan and sorghum-sudan by NOT grazing young seedlings, young regrowth, stunted growth, and frosted plants. All can accumulate nitrates during drought -- wait one week after rain before grazing.

*E+=High endophyte
E-=Low endophyte
**PLS= Pure live seed

D = Drilled
B = Broadcast

Recommendations for Hay and Haylage Seedings in Virginia

Species	Seeding Rate (lb/acre)	Soil Adaptation	Management Tips
Alfalfa Orchardgrass	15-20 3-7	Fertile, well drained soils with pH > 6.5	Cut when alfalfa is bud to early bloom stage. Allow at least one harvest to reach early bloom. Take first cutting when alfalfa is in bud stage.
Alfalfa	18-25	Fertile, well drained soils with pH > 6.5	Cut when alfalfa is bud to early bloom stage. Allow at least one harvest to reach early bloom. Take first cutting when alfalfa in bud stage.
Alfalfa and Matua bromegrass or Timothy or Smooth bromegrass	12-15 and 10-15 or 4-6 or 10-12	Fertile, well drained soils with pH > 6.5	Timothy and smooth bromegrass provide little forage after first cutting; best adapted west of Blue Ridge; avoid cutting during stem elongation to insure persistence. Smooth bromegrass is more drought tolerant than Timothy. Allow > 45 days between cuttings in late summer to allow Matua bromegrass to reseed.
Red clover and Orchardgrass or Tall fescue (E-)*	5-8 and 8 -12 or 8-12	Moderately to poorly drained soils not suitable to alfalfa with pH > 6.0	Cut when grass is in boot stage. Red clover may not persist beyond 2-3 years. Thus one should inter-seed every 2-3 years to maintain red clover component.
Tall fescue (E-)*	20-25	All types of soils with pH > 5.8.	Take first cutting before head emergence; subesequent cuttings every 30-40 days; does not produce seedheads after first harvest.
Matua bromegrass	20-30	Any fertile soil.	Cut in boot stage. Allow > 45 days between cuttings in late summer to allow reseeding.
Timothy or Smooth bromegrass	6-8 or 15-25	Light to medium-textured soils with at least moderate drainage.	Cut in boot stage to early heading. Avoid cutting during stem elonga-tion. Timothy will not persist in southern Piedmont or Coastal Plain; limited production after first cutting in most of state. Smooth bromegrass is more drought toler-ant.
Orchardgrass	10-15	Light to medium-textured soils with at least moderate drainage	First cutting at boot to early bloom stage. Subsequent regrowth will be vegetative and can be harvested every 30-40 days.
Reed canarygrass	6-8	Very tolerant of flooding and poorly drained soils. Also most drought tolerant of cool-season grasses. Tolerates pH of 5 to 8.	Cut during stem elongation to boot. Coarse at later maturity. Slow initial establishment; fills in with time from rhizome spread.
Switchgrass or Eastem Gamagrass	7-10 PLS** or 8-10 PLS**	Any deep soil. Good flooding tolerance	Cut in boot stage. Coarse at later maturity. Slow initial establishment fills in with time from rhizome spread in switchgrass, and crown widening in gamagrass.

*E+= High endorphyte *E-=Low endophyte **PLS = pure live seed

Hay storage

Losses in dry matter and quality of hay during storage can be high, particularly with round bales stored outside. On some farms, hay storage and feeding losses combine to account for over 10% of livestock production costs. Producers often do not realize how large their hay losses are or that with relatively little effort and expense they can be reduced considerably.

When hay is baled above 20% moisture, mold growth and heating occur. Dry matter losses are greater. Safe moisture levels for storage are 20% for rectangular bales, 18% for round bales, and 16% for large rectangular bales. Whereas storage losses are typically around 5% for hay stored inside at safe moisture levels, losses several times higher occur with extremely moist hay. Heating of hay is related to temperature. Peak temperature is usually reached within a week after baling, but with higher moisture hay and conditions which limit heat escape, it may take as much as three weeks.

The extent of weathering damage that occurs with hay stored outside varies with climatic factors, forage species, and bale diameter. Weathering primarily affects hay in the outside circumference of a large round bale. The percentage of hay lost decreases as bale size increases because a smaller proportion of the bale volume is contained in the surface layer. A weathered layer 6" deep on a 5' x 5' bale contains over one-third of the hay volume, a serious amount of loss. Half of the outside storage losses occur at the bale/soil interface due to the bale drawing moisture from the soil.

Total crude protein declines with weathering, but crude protein percentage may increase since protein is less subject than other plant constituents to weathering loss. The proportion of digestible crude protein will decrease, however, if hay undergoes excessive heating. Highly digestible soluble carbohydrates decline in weathered hay resulting in higher ADF concentration and lower digestibility. Losses in quality are usually greater for legumes than for grasses.

Measuring hay

To find the capacity of a stack, rick, or mow in tons, determine the volume of space occupied by the material in cubic feet and divide this volume by the number of cubic feet occupied by one ton of the respective kind of hay or straw.

Determining Storage Space (approximate) Occupied by One Ton of Hay or Straw

	Storage Space Required in Cu Ft
Hay, loose, barn cured	300 to 350
Square baled (loose)	200 to 250
Square baled (tight)	100 to 150
Hay, chopped, barn cured	250 to 325
Straw, loose	500 to 600
Straw, square baled (tight)	150 to 200
Straw, square baled (loose)	250 to 300

Factors that reduce outside storage losses with round bales

1. The denser or more tightly hay is baled, the lower the amount of spoilage as long as hay is baled at or below 18% moisture. Bale density is affected by the baling machine, the care/experience of the operator, and forage species with fine-stemmed hays naturally producing a tighter bale. The density of round bales should be a minimum of 10 pounds of hay per cubic foot.

2. Reducing twine spacing reduces storage losses, but increases costs. Net wrap usually reduces storage losses compared to twine. Although it costs more than twine, it is faster than twine wrap and bales are often better stabilized, making handling and storage easier.

3. Store bales in well drained upland sites. Hay/soil contact should be avoided if possible. Wooden pallets, telephone posts, scrap pipe, cross ties, and rock pads are all effective.

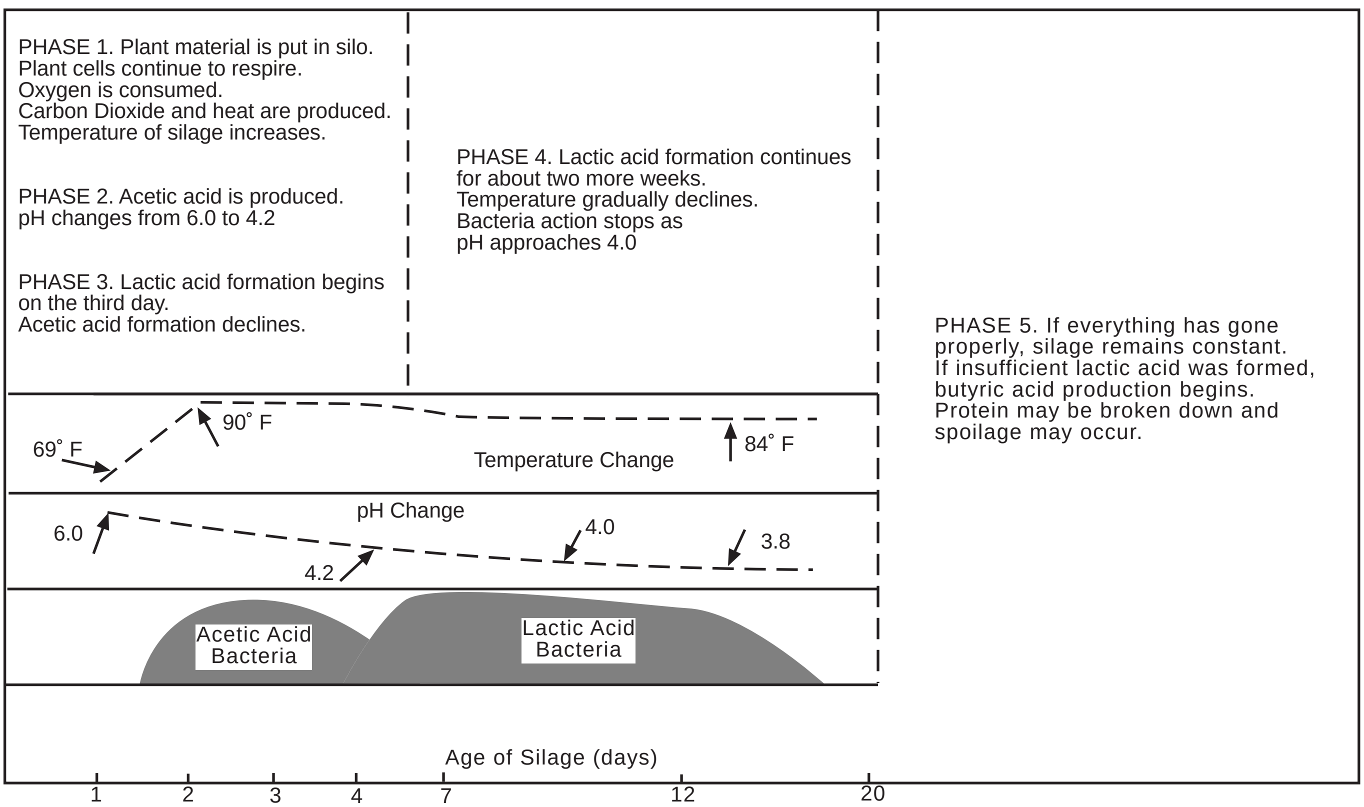
4. If a multiple-bale cover is NOT being used, bales should be stored in rows with rounded sides at least 3' apart. Flat ends should be firmly butted against one another. Align rows north and south to allow maximum exposure of the rounded sides to the sun. A gently sloping site will allow rapid drainage of rainwater. Bales should be oriented up and down the slope near the top of slope, preferably with southern exposure. Never store bales under trees.

5. Place three or five rows of bales in triangular stacks under a tarp or plastic sheet that is secured firmly. Inside storage is the best way to ensure low storage losses. The more valuable or porous the hay, the higher and/or more frequent the rainfall, and/or the longer the period of storage, the more easily barn construction can be justified. For example, with an estimated construction cost of $7.50 per square foot, it pays to build a barn to store hay valued at $60 per ton that otherwise would experience losses of 20% or more when stored outside. Hay valued at $100 per ton justifies barn construction if outside storage losses approach 15%.

Silage

Most crops grown for livestock feed can be allowed to ferment and be fed as silage. Handling of the crop for silage should always favor proper fermentation. Figure 2 below describes what actually occurs in the silo.

Figure 2. Changes in Bacteria Concentrations, pH, and Temperature During the Ensiling Process



The quantity and quality of siage varies with crop species. The following table gives generally expected yields, crude fiber and acid detergent fiber.

Annual Yield and Composition of Silage Crops

Crop	Stage	Yield, Tons/Acre 35% Dry Matter	Dry Matter Basis % Crude Protein	Dry Matter Basis % Acid Detergent Fiber
Corn	Hard Dough	15-25	8	28
Grain Sorghum	Dough	10-15	9	42
Forage Sorghum	Early Head	10-15	11	29
Sorghum Sudan	Early Head	7-15	12	45
Barley	Dough	7-15	9	36
Wheat	Dough	7-15	9	36
Oats	Dough	5-10	10	38
Rye	Boot	4-6	13	40
Alfalfa (4x)	Late Bud-Early Bloom	10-12	18	33
Red Clover	Early Bloom	7-8	12	43

Silage Statistics

Dry matter content	32-42%
Moisture content	68-58%
Length of cut	1/4-3/4 inch
Time required for complete fermentation	14 days
Density in upright silo	40-45 lbs/cu ft
Density in wagon, freshly chopped	20-25 lbs/cu ft

Approximate Capacity for Corn Silage in Trench or Bunker Silos with Sides Sloped Outward 1 1/2” for Each Foot of Depth*

Bottom width (feet)	Approximate tons per foot of length — Depth -- feet: 8	10	12	16	20
20	3.1	4.0			
30	4.6	5.9	7.1	9.6	
40	6.1	7.7	9.3	12.6	16.0
50	7.6	9.6	11.6	15.6	19.8
60		11.5	13.8	18.6	23.6
70			16.1	21.6	27.4
80			18.3	24.6	31.0
100				30.6	38.6

*Iowa State University Pm-417.

Direct cut vs. wilted silage

The grain-crop silages such as corn, barley, wheat, oats, and grain sorghum are normally chopped directly as they stand in the field when the grain reaches the dough stage. The relatively high dry matter content of the grain in such silage, plus the drying effects of advancing maturity, results in silage within the desirable dry matter range (35-42%).

When these same crops are harvested at a less mature stage, or when the traditional hay crops are handled as silage, it is necessary to partially dry or “wilt” the plants in the field before ensiling. Such wilting usually requires about one day under favorable drying conditions. Crushing the stems with a conditioner hastens the drying process.

Experience and good judgement are needed to determine when the crop is wilted to the proper dry-matter level. The “grab test” is useful as a guide to the dry matter content of forage. Squeeze very tightly for 90 seconds a fistful of finely chopped forage. Then observe the condition of the ball:

Description of the Forage Ball	Approximate Dry Matter Content
Holds its shape but has considerable free juice	Less than 25%
Holds its shape, hand is moist, but there is very little free juice	25-30%
Expands slowly, with no free juice	30-40%
Springs out and falls apart rapidly	More than 40%

High moisture corn and earlage

Harvesting the entire corn plant for silage makes full utilization of the corn plant. In some instances, harvesting a portion of the corn acreage by chopping only the ears for ensiling provides a source of grain for balancing the ration. Another variation is to shell the grain and allow it to ferment. These procedures provide grain storage without the costs of drying. Such high-moisture material can be easily mixed and fed with silage. Fewer harvest losses from shattering occur, and harvesting can be done 2-3 weeks earlier than dry corn, thus reducing lodging losses some years and providing additional time for establishing cover crops.

High-moisture shelled corn and earlage should be harvested when the ear reaches physiological maturity. At this stage, kernels are well dented and those near the center of the ear show the typical black layer at the base where they are attached to the cob.

Conventional concrete stave silos or oxygen-limiting units are an effective means for storing high-moisture shelled corn or earlage. If stored in concrete stave silos higher than 60 to 70 feet, placing extra hoops around the bottom 30 feet of the silo is suggested. Fermentation is complete in 15-20 days. The suggested moisture level for storing high-moisture shelled corn is 28%, with a range between 25-30%. It should be ground or rolled before being fed.

In earlage, the moisture range of the kernel is 28-30%, with 28% considered ideal. At this point, the cob will contain 40-50% moisture, making the moisture content of the ear corn silage about 32%. Earlage must be ground before it is stored. The main objective is to break the kernels, so fine grinding is not necessary. Holes in the screens of hammer mills or recutters range in size from 1/2 to 1 inch.

Approximate Dry Matter Capacity of Upright Silos*

Depth of settled silage	Silo diameter, ft										
	10	12	14	16	18	20	22	24	26	28	30
ft	tons of dry matter										
20	8	12	16	21	27	33	40	47	56	65	74
22	9	14	19	24	30	38	48	54	64	74	85
24	11	15	21	27	34	43	52	61	72	83	96
26	12	17	23	30	38	48	58	68	81	94	107
28	13	19	26	35	44	53	64	76	90	104	119
30	15	21	29	38	47	59	71	84	99	115	132
32	16	23	32	41	52	65	78	93	109	127	145
34	18	25	34	45	57	70	85	101	119	137	158
36	19	28	37	48	62	76	92	109	129	150	172
38	21	30	41	53	67	82	100	118	139	161	185
40	22	32	44	57	72	89	107	127	150	173	199
42		34	47	61	77	95	115	137	161	186	214
44		37	50	65	82	102	123	146	172	200	229
46		39	53	69	88	108	131	155	183	212	244
48		42	56	74	93	115	140	166	195	226	260
50		44	60	78	99	122	148	175	206	239	274
52			64	83	105	129	157	186	219	254	291
54			67	88	111	137	165	197	231	267	306
56			71	93	117	144	174	207	243	282	324
58			74	98	123	151	183	218	261	297	339
60			78	102	129	159	192	228	273	309	357
62					135	167	201	239	287	324	374
64					142	174	210	250	301	339	391
66					149	182	219	260	314	354	407
68					155	190	228	271	328	369	424
70					162	198	237	282	342	384	441
72								293	356	400	458
74								305	371	415	476
76								316	385	431	493
78								328	400	446	511
80								339	414	462	528

To estimate tons of silage of various moisture contents, use the following formula:

$$\frac{\text{tons of dry matter}}{\text{estimated \% dry matter in silate}} \times 100 = \text{tons actual silage}$$

*From Dairy Housing and Equipment Handbook, Iowa State University.

PART III
Turfgrass

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Current publications on turfgrass management and other turfgrass industry related information can be found in the Virginia Tech Turfgrass Science World Wide Web Home Page at the following website location: http://sudan.cses.vt.edu/html/Turf/turfhome.htm

Turfgrass Establishment

Steps involved in successful establishment of turfgrasses:

Submit a soil test sample to the Virginia Tech Soil Testing Laboratory and determine lime and fertilizer needs.

Control any perennial grass or broadleaf weeds present.

Where soil compaction is severe, phosphorus or lime needs to be incorporated, or significant surface re-grading is required, complete soil tilling will be necessary. On other areas, light surface tillage will suffice.

Grade the area to establish surface drainage. Save the topsoil by moving it to the side if extensive grading or internal drainage is required.

Apply the recommended lime and soil amendments. Apply 2/3 of the establishment fertilizer recommended by soil test.

Till above materials into a depth of 4-6”

Finish grade by fine raking.

Apply the remaining 1/3 of the establishment fertilizer and rake into the surface inch.

Seed, sod, sprig, or plug the area.

If seeding, rake the area very lightly to incorporate the seed in the surface 1/4 - 1/2”

Roll the area with a moderately heavy roller.

If seeding in the spring, apply Siduron preemergence herbicide for crabgrass control. Follow label recommendations closely. Siduron should not be used on bermudagrass.

Uniformly mulch the area (1 1/2 - 2 bales of weed-free straw per 1000 sq ft) if frequent and uniform irrigation is unavailable. Other mulching solutions could include granular-type products made from shredded newsprint or other recycled paper fiber. Some mulch products are suitable to be applied as a hydromulch using a hydroseeder.

Keep the seed zone moist. New seedings may require several shallow waterings per day to insure rapid germination. Only the top 1/4 - 1/2” needs to be kept moist. Sprigs easily desiccate without frequent daily irrigation immediately after planting. Sod and plugs also require frequent, sometimes daily irrigation in the first three to four weeks after planting.

After seed germination, maintain moisture in the soil to a depth of 4 - 6” until plants are well established.

Planting, sodding, and seeding

Plugging and Sprigging. Zoysiagrass and bermudagrass can be vegetatively established, using either plugs or sprigs. The plugs should be fitted tightly into pre-cut holes on 6 - 12”centers and tamped into place. Sprigs can be broadcast and lightly disced or pressed into shallow rows on 6 - 12” centers and covered with soil. Sprigging rates for bermudagrass and zoysiagrass range from 7 - 10 bushels per 1000 sq ft and frequent irrigation is required for establishment. Zoysiagrass is very slow to establish from sprigs.

Sodding. Soil preparation is similar to that described for seeding; a smooth, firm surface is needed. On hot days, moisten the soil to cool it before laying sod. Premium quality, certified sod is easier to transport and install than inferior grades. Good sod is light; does not tear easily; and quickly puts a root system into prepared, well-watered soil. Install sod as soon as you get it; it is perishable and should not remain in a stack longer than 36 hours. Establish a straight line lengthwise through the lawn area; lay the sod on either side of the line with the ends staggered as when laying bricks. A sharp masonry trowel is very handy for cutting, forcing the sod tight, and leveling small depressions. Roll and water the new lawn immediately; irrigate to moisten the soil below the sod until it is well rooted into the soil.

Seed versus sod. Successful**,** weed-free establishment is more difficult with seed than with sod. Also, because of the time required for germination and root growth of seed, the area is exposed to erosion. Sod use practically eliminates such problems, an especially important factor on steep slopes.

Seeding and mulching. Prepare a smooth, firm seedbed. Rake the seedbed to create shallow, uniform depressions (rows) about a quarter-inch deep and 1 - 2” apart. Divide seed in half; sow first half of seed in one direction (north/south); sow the remaining seed in the opposite direction (east/west). Cover the seed by raking lightly. Next, the seedbed should be rolled. Mulch the area with straw or other suitable material so that approximately 50 - 75% of the soil surface is covered. This is normally accomplished by spreading 1/2 - 2 bales of high quality, weed-free straw per 1000 sq ft. A light mulch does not need to be removed after establishment of the turfgrass.

Seeding rates

Turfgrass Species	Seeding Rate lbs/1000 sq. ft
Kentucky bluegrass	2 to 3
Tall fescue	4 to 6
Fine fescue	3 to 5
Perennial ryegrass	3 to 5
Bermudagrass (hulled)	1 to 1 1/2
Bermudagrass (unhulled)	5 to 10

When to plant cool-season grasses*

Area of Virginia	Seed	Sod
Northern Piedmont, areas in and west of the Blue Ridge	Aug 15 to Sept 15 or March to early April	Anytime soil is not frozen
Southern Piedmont and Eastern Virginia	Sept 1 to Oct 15 or Feb and March	Anytime soil is not frozen

When to plant warm-season grasses**

Area of Virginia	Seed	Sod	Sprigs	Plugs
Northern Piedmont, areas in and west of the Blue Ridge	Not recommended for this area	June 1-July 15	June 1-July 1	June 1-July 15
Southern Piedmont and Eastern Virginia				
a) hulled and Eastern bermudagrass	May to July 15			
b) hulled bermudagrass	late fall or winter prior to growing season	Late May-Aug 15	Late May-Jul 15	Late May-Jul 15

* Cool season grasses include Kentucky bluegrass, tall fescue, creeping red fescue, and creeping bentgrass.
**Warm season grasses include bermuda, zoysiagrass, centipedegrass, and St Augustinegrass.

Soil testing and determination of nutrient needs

Samples should be taken 1 - 2 months prior to establishment. Standard tests will provide recommendations for phosphorus, potassium, and lime. Exchangeable calcium and magnesium are also determined in the standard test.

If soil tests are not available, incorporate 0 - 2 1/2 lbs of nitrogen (N), 3 1/2 - 5 lbs of phosphate (P_2O_5), 2 - 3 1/2 lbs of potash (K_2O), and 80 lbs of agricultural limestone per 1000 sq ft. See the following table for specific nitrogen recommendations. Extreme care should be taken with regard to excessive application of nitrogen and phosphorus due to their possible movement off-site through surface runoff or nitrogen leaching. Such movement into ground-water and surface water threatens water quality. Use soil testing to determine soil phosphorus requirements and consider incorporating slowly available forms of nitrogen.

When the sod is rooted or the seed is established, fertilize in accordance with maintenance fertilization recommendations. Begin mowing with a sharp mower as soon as the grass reaches a height 1/3 greater than the recommended mowing height.

Water-soluble nitrogen to be incorporated to a 4-6" depth prior to seed or sod establishment. If fertilizers used contain more than 50% water-soluble nitrogen, multiply recommended amounts by 1.5.

	Sod		Seed	
Date	**Cool-season***	**Warm-season****	**Cool-season**	**Warm-season**
		lb N per 1000 sq ft		
Aug 15 to Jan 15	2	0	2.5	0
Jan 16 to June 15	1	2	2.0	2.5
June 16 to Aug 14	0	2	1.0	2.0

*Cool-season grasses include Kentucky bluegrass, tall fescue, creeping red fescue, perennial ryegrass, and creeping bentgrass.
**Warm-season grasses include bermudagrass, zoysiagrass, centipedegrass and St. Augustinegrass. These are normally established between May 1 and August 15.

Fertilization of established turfgrass

Phosphorus and potassium requirements should be determined by soil test. Turf grown on irrigated sandy soils, or turf subjected to frequent and heavy traffic, may require higher amounts of nutrients. Turf grown in the shade requires less nitrogen.

Do not apply readily-available nitrogen sources in excess of 1.0 lb of actual nitrogen per 1000 sq ft in any single application. Phosphate (P_2O_5) and potash (K_2O) may be applied in single or multiple applications, but no more than 2 lbs of K_2O per 1000 sq ft should be applied in any one application. If possible, water-in all fertilizers following application.

Timing and rate of fertilization is influenced by turf species, existing turf conditions, desired level of quality, type of fertilizer, time of year, etc. Established cool-season turfs are fertilized predominantly in the fall and lightly in late spring, while established warm-season turfs are fertilized from late spring through August. Avoid summer fertilization on cool-season grasses if at all possible. Do not apply urea within two weeks of liming.

Phosphorus and potassium levels can be high enough in the soil that there is no need to apply additional amounts of these nutrients. This can be determined by soil test.

Nitrogen fertilizers will state from what source (or carrier) the nitrogen is derived. The nitrogen carrier has a great impact on how you fertilize because different nitrogen carriers make nitrogen available to the turf at different rates. Consequently, the carrier will affect how much nitrogen to apply as well as when to apply it.

Nitrogen fertilizers are generally broken down into two categories: those with readily-available (RA) nitrogen and those with slowly-available (SA) nitrogen. Nitrogen fertilizers that are readily-available have all of their nitrogen immediately available for plant use. After 3 - 6 weeks, this type of nitrogen is used up by the turfgrasses and results in short periods of turfgrass response. Slowly-available nitrogen, however, can last from 8 - 12 weeks or more.

Some of the nitrogen in slow-release fertilizers can be water-insoluble nitrogen (WIN). The percent WIN is usually stated on the fertilizer container. The fraction of nitrogen not listed as WIN should be regarded as readily-available nitrogen. To effectively gauge the type of plant response from using slow-release fertilizers, calculate the percent of the total nitrogen in the container that is WIN by the following example:

Fertilizer label 16-4-8: Total Nitrogen……………………16.00%
5.6% water insoluble nitrogen or WIN
Available phosphoric acid (P_2O_5)...4.00%
Sulfate of potash (K_20)……………8.00%

To find % of N that is WIN, use the following calculation:

$$\frac{5.6\%\ \text{WIN} \times 100}{16.0\%\ \text{Total N} \times 100} = 35\%\ \text{WIN}$$

In this example, 35% of the nitrogen is WIN while the other 65% of the nitrogen is considered readily-available nitrogen. In using such a fertilizer, one could expect to get an immediate response due to the high amount of readily-available nitrogen. As a general guideline, if the fertilizer you are using has 50% or less WIN or other slowly available N sources, it should be used in the same manner as a readily-available nitrogen source in fertilizer programs. If the fertilizer has greater than 50% WIN or other slowly available N sources, it should be used in fertilizer programs as a slowly-available form of nitrogen.

Typical nitrogen carriers, along with their inherent characteristics, are listed in the table shown below.

Nitrogen Fertilizers Commonly Used On Turf

Nitrogen Carrier	Common Abbreviation	% Nitrogen	Lbs Needed for 1 lb of Nitrogen	Nitrogen Availability	Foliar Burn Potential	Acidifying Effect[1]	Cold Water Solubility[2]
Ammonium nitrate	$(NH_4)NO_3$	33.0	3.0	Fast	Very High	1.8	710
Ammonium sulfate	$(NH_4)_2SO_4$	20.5	4.8	Fast	High	5.3	1810
Sodium nitrate (nitrate of soda)	$NaNO_3$	16.0	6.2	Fast	Very High	1.8B	876
Calcium nitrate	$Ca(NO_3)_2$	15.5	5.9	Fast	Very High	1.3B	1212
Urea	$CO(NH_2)_2$	45.0	2.2	Fast	High	1.8	780
Urea formaldehyde	UF	38.0	2.6	Slow*	Low	-	SV
Isobutylidene diurea	IBDU	31.0	3.2	Slow**	Low	-	SS
Sulfur-coated urea	SCU	32.0	3.1	Mod***	Low	-	SR
Methylene urea	-	Var	-	Moderate	Low	-	SV
Methylol urea	-	Var	-	Fast	Low	-	SV

[1]=Pounds of pure lime $CaCO_3$ equivalent needed to neutralize the acidifying effect per 1 lb of applied actual nitrogen.
[2]=Expressed in grams/liter.
SS=Slightly soluble.
SR=Slowly released.
SV=Solubility varies with formulation.
*=Release is dependent upon microbial activity and factors that affect it (i.e. temperature, soil, pH, aeration, moisture, etc.).
**=Release rate is dependent upon moisture availability, particle size, and soil pH.
***=Release rate is dependent upon particle size, soil temperature, soil moisture, mechanical breakage, and thickness of the sulfur coating.

Calculating how much fertilizer to purchase

In deciding what type of fertilizer to purchase, it is usually helpful to first look at the Virginia Tech recommendations for fertilizer programs that best fit your situation (grass species and location). Recommendations are commonly made on the basis of the number of lbs of actual nitrogen (N) per 1000 sq ft of lawn area. To convert lbs/1000 sq ft to lbs/acre, just multiply the lbs N/1000 sq ft by 43.5 (which is the number of 1000 sq ft units in one acre).

The amount of fertilizer to be purchased for any one application will depend upon the percent of nitrogen (N) contained in the fertilizer. For example, to apply 1 lb N/1000 sq ft from ammonium nitrate (33% N), divide the desired application rate by the analyses (1 lb N/0.33 N = 3 lbs of ammonium nitrate fertilizer are needed to apply 1 lb N/1000 sq ft). The total quantity of fertilizer material needed for an area is calculated by multiplying 3 lbs of material by the number of 1000 sq ft units of lawn area to be fertilized. For example, if a homeowner had 8500 sq ft of lawn area and wanted to use a 46-0-0 (46% N) fertilizer to apply 1.25 lbs of actual nitrogen per 1000 sq ft of lawn, he would make the following calculations:

$$\frac{1.25}{0.46} = 2.72/1000 \text{ sq ft}$$

2.72 lbs of fertilizer per 1000 sq ft x 8.5 units of 1000 sq ft = 23.12 lbs of fertilizer needed /8500 sq ft lawn

Applying the right amount of fertilizer

Getting the most out of every fertilizer dollar involves knowing how to accurately apply fertilizer to your lawn. Most lawn fertilizers are usually applied by the homeowner as dry granules using either a drop-type or spinner-type fertilizer spreader. Each fertilizer spreader will have a dial to adjust the spreader openings that determine how much fertilizer is applied as the spreader travels across the lawn. Changing to a fertilizer of different granule size or weight and varying speed of spreader operation can alter application rates. Therefore, homeowners should be able to calibrate or adjust their fertilizer application.

Calibrating a drop-type spreader

1. Attach a pan, bag, bucket, or other apparatus to the spreader to collect the fertilizer during operation.
2. Fill the spreader.
3. Determine the width of spreader application.
4. Operate the spreader to cover 435.6 sq ft. NOTE: for a spreader 18” wide, the distance should be

$$\frac{435.6 \text{ sq ft}}{1.5 \text{ ft}} = 290.4 \text{ ft}$$

5 . Weigh the amount of fertilizer collected.
6. Multiply the weight collected by 2.3 to calculate fertilizer applied per 1000 sq ft.
7. If a per acre delivery rate is desired, multiply the weight collected by 100 to calculate fertilizer applied per acre.
8. Repeat this procedure and continue by trial and error adjusting the applicator dial each time until the desired application rate is reached.

Calibrating a spinner-type spreader

The procedure and calculations are the same as the drop-type spreader except the width of the fertilizer throw is used as the spreader width.

Example: If a spinner spreader has an application width of 5 ft, then the operating distance would be:

$$\frac{435.6 \text{ sq ft}}{5 \text{ feet}} = 87 \text{ ft}$$

This type of applicator gives the best results when half of the desired fertilizer application rate is applied traveling in one direction while the other half is applied in a direction at a 90 degree angle (right angle) to the first in a crisscrossing pattern. This ensures more uniform coverage by minimizing the effect of leaving too much space between swaths. However, when using this half plus half crisscrossing method, be sure to calibrate the spreaderto apply half of the fertilizer to the 435.6 sq ft area because the lawn area will be covered twice.

Spreader calibration without a collection device:

Method A: The procedure and calculations are the same except the fertilizer material is repeatedly applied onto wrapping paper or a smooth concrete floor until an area of 435.6 sq ft is covered. The material is then swept up and weighed to determine the application rate per 435.6 sq ft.

Method B: A quantity of fertilizer is weighed and then put in the spreader. The spreader is operated over a 435.6 sq ft lawn area (this fertilizer material cannot be recovered) and the fertilizer remaining in the spreader is then weighed. Subtracting the weight of the remaining fertilizer from the weight you started with will equal the fertilizer application rate per 435.6 sq ft.

Applying at the proper time

Proper timing of nitrogen applications is different for warm-season and cool-season turfgrasses because of their different growth cycles. The following four charts show the recommendations for pounds of actual nitrogen per 1000 square feet of established lawn area using both quick release and slow release nitrogen sources for both warm- and cool-season grasses. The charts can be used to determine the most effective times of application for different levels of turfgrass quality.

Programs for Cool-season grasses. The best time to fertilize cool-season grasses, including Kentucky bluegrass, tall fescue, perennial ryegrass, and fine fescue (creeping red fescue, hard fescue, sheep fescue, and chewings fescue), in Virginia is from August 15 through November. Excessive spring application of nitrogen to cool-season grasses in Virginia leads to excessive leaf growth at the expense of stored food reserves and root growth, increasing injury to lawns from summer disease and drought.

Program 1. Nitrogen Fertilization of Cool-season Grasses Using Quickly Available Nitrogen Fertilizers (less than 50% slowly available nitrogen)

	Nitrogen Application by Month - lbs N/1000 sq ft			
Acceptable Quality	**Sept**	**Oct**	**Nov**	**May 15-June 15**
Low	0	1	0	0 - 1/2
Med	1	1	0	0 - 1/2
High	1	1	1	0 - 1/2

Program 2. Nitrogen Fertilization of Cool-season Grasses Using Slowly Available Fertilizers (50% or more slowly available nitrogen or WIN)

	Nitrogen Application by Month - lbs N/1000 sq ft		
Acceptable Quality	**Aug 15 to Sept 15**	**Oct 1 to Nov 1**	**May15 to June 15**
Low	1.5	0	0
Med	1.5	1.5	0
High	1.5 to 2	1.5	0 to 1.5

Important comments about Programs 1 and 2.

1. Fine fescue performs best at 1 - 2 lbs of nitrogen per 1000 sq ft per year.
2. Applications in successive months should be approximately four weeks apart
3. Natural organic and activated sewage sludge products should be applied early in the application periods in Program 2 to maximize their effect.
4. One lb of nitrogen in Program 1, and up to 1.5 lbs of nitrogen in Program 2, may be applied per 1000 sq ft in the May 1 - June 15 period if nitrogen was not applied the previous fall, or to help a new lawn get better established.

Fertlizer Programs for Warm-Season Grasses. Warm-season grasses, including bermudagrass, zoysiagrass, St. Augustinegrass and centipedegrass, perform best when fertilized between April 1 and August 15 in Virginia.

Program 3. Nitrogen Fertilization of Warm-season Grasses Using Quickly Available Nitrogen Fertilizers (less than 50% slowly available nitrogen)

	Nitrogen Application by Month - lbs N/1000 sq ft			
Acceptable Quality	**April**	**May**	**June**	**July/Aug**
Low	1	1	0	0
Med	1	1	1	0
High	1	1	1	1

Program 4. Nitrogen Fertilization of Warm-season Grasses Using Predominantly Slowly Available Nitrogen Fertilizers (50% or more slowly available nitrogen or WIN)

	Nitrogen Application by Month - lbs N/1000 sq ft	
Acceptable Quality	**April/May**	**June/July**
Low	2.0	0
Med	1.5	1.5
High	2.0	2.0

Important notes about Programs 3 and 4:

1. If overseeded for winter color add 1/2 to 1 lb of readily available nitrogen per 1000 sq ft in October and November.
2. Applications in successive months should be approximately four weeks apart.
3. Centipedegrass and mature zoysiagrass perform best at 1 to 2 lbs of nitrogen per 1000 sq ft per year.
4. Improved winter hardiness on bermudagrass will result from the application of potassium in late Aug. or Sept.

Description of cool-season grasses used in Virginia

Kentucky Bluegrass is a medium textured turfgrass best suited to well-drained soils and moderate to high levels of sunlight and management. It can be established from seed or sod. Mixtures or blends of 3 or 4 Kentucky bluegrass varieties are recommended in Virginia since they are more likely to provide good quality turf over the wide range of management conditions. Kentucky bluegrass is best suited for full sun or moderate sunlight conditions under high levels of maintenance in the central and northern Piedmont and areas in and west of the Blue Ridge mountains in Virginia.

Tall Fescue is well adapted throughout Virginia. It has a somewhat coarser texture than Kentucky bluegrass and is well suited for many different turf situations. Varieties of tall fescue have been especially developed for turf. These varieties have come to be called “turf-type” tall fescues. The main management problem with tall fescue is the summer occurrence of *Rhizoctonia* brown patch disease. It is not uncommon for tall fescue sod to contain up to 10 percent Kentucky bluegrass

Fine Fescue— For use in low maintenance areas or in partial to full shade. Summer quality can be poor in open sun and under close summer mowing. Limited research does not indicate any advantage to blending or mixing varieties from the different fine fescues (e.g.; creeping red fescue, chewings fescue, hard fescue or sheep fescue). Fine fescues are best adapted in the Northern Piedmont and areas in and west of the Blue Ridge Mountains in Virginia. Fine fescues sometimes are mixed with Kentucky bluegrass to provide a seed mixture that will perform well in shade and open sun.

Turfgrass Management Table Based Upon Use And Location In Virginia

Grass Species & Recommended Use	Adaptation[1]: Northern Piedmont & Areas West of The Blue Ridge	Adaptation[1]: Southern Piedmont & Eastern Virginia Areas	Fertilization Requirements[2] lbs nutrients/ 1000 sq ft/yr: Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)	Mowing Height[3]	Overseeding Rate[4] lbs/1000 sq ft
Bermudagrass [5, 6]							
Lawns	NA	A	2-4.5	0-3	1-3	1 1/2-1"	2-10
Athletic Fields	SA*	A	2.5-4.0	0-3	0-3	1/2-1 1/2"	5-10
Fairways	SA*	A	2.5-4.0	0-3	0-4	1/2-3/4"	2-7
Tees	SA*	A	3.0-6.0	0-3	0-4	1/2"	5-10
Greens	NA	SA*	7.0-10 1/2	0-3	0-4	1/4" or less	40-50
Zoysiagrass [5, 6]							
Lawns	A*	A*	1-2.0	0-3	1-3	3/4-1"	2-10
Tees	A*	A*	2-4.0	0-3	1-3	1/2-3/4"	5-10
Kentucky Bluegrass							
Lawns	A	NA	1-4.5	0-3	0-3	1 1/2-2 1/2"	
Athletic Fields	A	NA	3-5.0	0-3	0-3	1 1/2-2 1/2"	
Fairways	A	NA	2-4.0	0-3	0-3	3/4-1 1/4"	
Tees	A	NA	3-5.0	0-3	0-3	3/4-1 1/4"	
Tall Fescue							
Lawns	A	A	1-4.5	0-3	0-3	2-3"	+
Athletic Fields	A	A	3-4.5	0-3	0-3	1 3/4-2 1/2"	+
Fine-leaf fescues (Red, chewings, hard and sheep fescue)							
Shaded lawns and low maintenance areas	A	SA	1-2	0-3	0-3	1 1/2-3"	
Creeping bentgrass							
Tees	A*	A*	3-5.5	0-3	0-4	1/4"	
Greens	A*	A*	2.5-6	0-3	0-4	3/16"or less	
Perennial ryegrass [7]							
Lawns	SA	NA	1-4.5	0-3	0-3	1 1/2-2"	+
Athletic Fields	SA	NA	3-5.0	0-3	0-3	1 1/4-2"	+
Fairways	SA	NA	2-4.0	0-3	0-3	3/4-1"	+
Tees	SA	NA	3-5.0	0-3	0-3	3/4"	+
St. Augustinegrass [5]							
Lawns	NA	SA*	2-5	0-3	0-3	2-2.5"	
Centipedegrass [5]							
Lawns	NA	SA	1-2'0	0-3	0-3	1-2"	
Buffalograss [5]							
Lawns	NA	NA	2-3	0-3	0-3	1.5-2.5"	

A = Adapted.
SA = Semi-adapted (may not persist under normal management).
NA = Not adapted (better grass species are available for that use).
[1] = Turfgrass species may become more adaptive to a climate through increased management (i.e., irrigation, variety selection, fungicide applications, traffic control, proper fertilization, proper mowing, and supplemental cultural practices).
[2] = Fertilization requirement will depend upon geographical locations and management level, nitrogen source, and soil test results.
[3] = The ability of a specific turf species to tolerate a particular mowing height is dependent upon the variety and time of the year. Raising the mowing height toward the high end of the range during summer stress will help cool season grass tolerance to heat and drought stress. Never remove more than 1/3 of the leaf tissue in any one mowing.
[4] = Mono-stands or blends of perennial ryegrass varieties are satisfactory for winter overseeding of lawns, athletic fields, fairways, and tees at those rates listed. However, a mixture of 65% perennial ryegrass, 30% fine fescue, and 5% bentgrass will produce superior quality on greens and the rate listed for greens is for using this mixture only. Zoysiagrass, St. Augustinegrass and centipedegrass are typically not winter overseeded.
[5] = All varieties of these species go off-color, turning brown at the first frost and remaining dormant until spring.
[6] = The yearly nitrogen requirement will depend upon whether the turf is overseeded in the fall for winter turf.
[7] = Not recommended for planting as mono-stands except under special circumstances.
* = Requires high levels of management and appropriate variety selection.
+ = May need to be periodically overseeded to maintain adequate density, to repair damaged areas, or to make up for the lack of persistence from year to year.

Ryegrass is available in two types, perennial and annual. Annual (Italian) ryegrass will provide rapid germination and fast growth but will live only 1 year. This, along with poor persistence under adverse conditions, makes annual ryegrass only suitable where a temporary turf is desired. However, there are a number of good perennial ryegrasses available for lawn use. Perennial ryegrass lawns perform best at the higher elevations (>1000 ft) in Virginia. The best use for the perennial ryegrasses for Virginia is in a mixture with Kentucky bluegrass where the perennial rye-grass component is less than 15% by weight. A pure ryegrass lawn is not recommended since summer quality often declines in July and August due to its lack of drought tolerance and susceptibility to heat stress and fungal diseases.

Description of warm-season grasses used in Virginia

Bermudagrass is a warm season turfgrass that is best adapted in eastern Virginia. It does best in open sun and is not shade tolerant. Some varieties do not produce viable seed and are therefore only vegetatively established using sprigs, plugs or sod. Commonly used varieties that are vegetatively propagated include Vamont, Midiron, Midlawn, Tifway, and Tufcote. Typically, seeded-type varieties have had the greatest persistence in eastern Virginia while the more cold hardy varieties (Midiron, Vamont, and Midlawn) have been established on athletic fields and golf course fairways as far west as Roanoke and Charlottesville. Varieties vary greatly in cold tolerance, texture and color. Bermudagrass is sometimes overseeded with perennial ryegrass in early autumn to provide winter color while dormant. However, spring transition back to bermudagrass can be hindered by spring-summer conditions that favor perennial ryegrass growth and delay bermudagrass spring regrowth.

Zoysiagrass is a warm season grass that can be used on lawns, golf course fairways and areas that do not receive concentrated traffic. Zoysiagrass is very suited as a low maintenance turf; it grows slowly and does not recover quickly from severe damage. There are varieties that can only be vegetatively propagated by using sod or plugs. Sprigging zoysiagrass is difficult due to its slow rate of establishment. The more cold hardy varieties like Meyer are adapted from just east of the Blue Ridge mountains to eastern Virginia.

St. Augustinegrass and centipedegrass are both lawn grasses that grow best in the Hampton Roads area of Virginia, benefiting from the coastal climate. Both are vegetatively propagated (stolons, plugs or sod) while centipedegrass can also be established from seed. St. Augustinegrass requires more management and higher nitrogen levels than does centipedegrass. However, these grasses are not as common to coastal Virginia as they would be in more southern states.

Mixtures versus single species or variety

The individual species and the conditions under which they are grown determine whether a pure species, variety or mixture of species or varieties are preferred. Under Virginia conditions these general rules have given best results.

1. Mixtures or blends of adapted Kentucky bluegrass varieties have been superior to single varieties grown alone.
2. In shady areas, adding an adapted variety of creeping red fescue improves the turf.
3. Tall fescue may be grown alone or in mixtures with Kentucky bluegrass, but in mixtures 90% or more of the mixture should be tall fescue.
4. Single varieties grown alone are preferred for all warm season grasses.

When purchasing turfgrass seed, it is extremely important to buy quality seed. Consumer protection programs have been devised to identify quality seed of the varieties recommended by Virginia Cooperative Extension.

Purchasing quality turfgrass seed

The purchase of lawn seed is a long-term investment, because the seed you buy will greatly influence whether you succeed in developing a beautiful lawn that is perennial in nature. It is not possible to evaluate the quality of seed by looking at it. However, information printed on seed packages can help you make a wise choice when buying turfgrass seed.

There are large differences in lawn seed, and it pays to compare. The price you pay for the seed is only a small portion of the total cost of planting, fertilizing, mowing, etc. Don't let low cost be the only factor you use when selecting lawn seed. Choose those varieties that have been tested and have proven to be best suited for your area of Virginia.

Certified seed

The best guarantee of varietal purity is to purchase CERTIFIED SEED. Such seed will contain fewer weed and other crop seed contaminants and will be free of unneeded inert filler. Certified seed of single grass varieties and certain grass mixtures and blends are available in Virginia. Even with uncertified seed, it is still very important to buy seed by variety name. Varietal purity would not be certain, but there would be an indication that a percentage of the seed is of the variety claimed. When seed is purchased by kind (species) only (e.g., Kentucky bluegrass, red fescue, tall fescue, etc.) you have no indication as to variety adaptation or expected performance. Purchasing turfgrass seed without some assurance that it contains adapted varieties should be avoided except where the quality or persistence of the turfgrass stand is unimportant.

Purchasing quality turfgrass seed

When purchasing turfgrass seed there are several questions you need to consider. The following list is offered to assist you in making the best choice of grass for your location:

1. Most types of turfgrass are perennials and are expected to grow back year after year. When you select and purchase grass seeds consider it a long term investment. You usually get what you pay for so consider purchasing a recommended variety that has been tested in Virginia.
2. Deal with a reliable retail store that can answer your questions and provide good information and advice.
3. Factors such as temperature, moisture, and light determine the kinds of grasses that are adapted to your location.

In order to make the best selection, take the time to consider **a few basic questions** such as:
1. In what <u>temperature zone</u> or region of the state will the grass be grown? Examples: Eastern, Northern Piedmont, Southern Piedmont, or Western Virginia.
2. Under what <u>moisture conditions</u> will the grass be grown?

Examples: irrigated or non-irrigated with light sandy well drained soil, loamy deep medium texture soil, or heavy clay soil.
3. Is the area to be planted an open area with full sun, partially shaded or heavily shaded?
4. What type of <u>use</u> will the area have, and how much traffic and maintenance will it receive?

Examples: home lawn with low or high maintenance, commercial business with high visibility, athletic field, or other use.

After gathering this information, consult with a knowledgeable garden center or Extension Service professional and review your turfgrass options.

Over the past several years many new turfgrass varieties have been introduced in the Virginia market. The University of Maryland, USDA, and VA Tech conduct extensive turfgrass variety trials to identify which varieties perform well in the different regions of the state. Performance data from these trials, along with seed quality are reviewed and published annually, and the varieties that have the best performance are recommended. The **Virginia Turfgrass Variety Recommendations** list is available through your local Extension Service office.

The best way to insure you are purchasing quality turfgrass seed is to ask for **blue tag certified.** This insures that the seed has been inspected by an independent third party and has met established standards of quality.

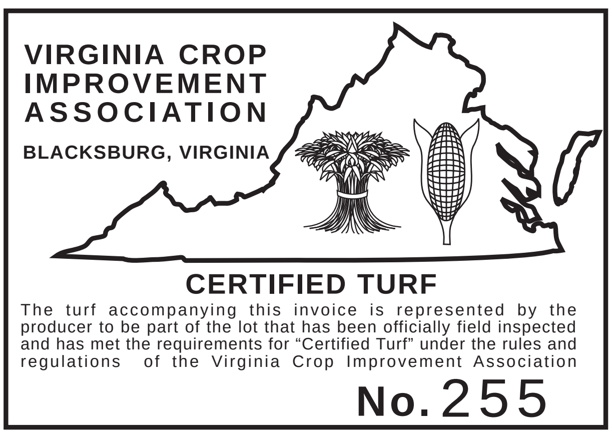
Purchasing quality sod in Virginia

There are several types of sod being grown in Virginia. The basic types are Kentucky bluegrass blends, Kentucky blue grass mixtures, tall fescue Kentucky bluegrass mixtures, bermudagrass, and zoysiagrass. Each of these types of sod is best suited to particular uses and geographic areas of Virginia. Some sod producers grow sod in the Virginia Crop Improvement Association (VCIA) certified sod program, which means that the sod produced must meet established standards of quality.

VCIA certified sod is of high quality, meeting rigid standards requiring pre-planting field inspections, prescribed varieties and mixtures, periodic production inspections, and a final preharvest inspection. This program serves as a marketing tool and provides the consumer with guaranteed standards of quality. Consumers purchasing VCIA certified turf will receive a blue certified turf label as proof of purchase.

VCIA certified turf label (Blue)

High-quality sod is also available outside of the VCIA certified sod program. When purchasing this sod, the consumer is encouraged to be aware of factors which are important in determining sod quality. High-quality sod will contain the best varieties and be free of serious disease, insect, or weed problems. It will be dense, have good color, and hold together well.



PART IV
Seed Facts

David L. Whitt, Extension Seed Programs Leader

Seed inoculation

Legumes have the ability to gather available nitrogen from the air and utilize it for their growth. Grasses growing in association with legumes, or following legumes in rotation, also benefit. Legumes are able to accomplish this through the presence of nitrogen-fixing bacteria that form colonies on the legume roots.

Most soils contain native strains of nitrogen fixing bacteria (rhizobia), but these are often not efficient in fixing nitrogen. Whenever a legume is seeded, especially in soil where that legume has not been grown in the previous 2 or 3 years, commercial strains of bacteria should be included with the seed to “inoculate” the soil and the plant roots. This insures that bacteria of a productive strain are present in sufficient quantities to fix nitrogen for the plant.

The rhizobia are usually mixed with black peat that serves as the carrier for the bacteria. This black “inoculum” is mixed with the seed just prior to seeding. It may be mixed thoroughly with dry seed, but better seed contact is obtained by slightly moistening the seed with sugar water or a commercial sticker before adding the inoculum. Pre-inoculated seed, which is coated with the appropriate rhizobia by the seed company, is also available.

When the seed germinates in the soil, the rhizobia bacteria invade the root hairs of the seedlings and begin to multiply to form nodules. A symbiotic relationship exists between the bacteria in these nodules and the plant. The plant provides food and a supply system for the bacteria and, in return, the bacteria convert atmospheric nitrogen into ammonia nitrogen which the plant utilizes.

Well nodulated plants have large nodules that are pink or red inside. Ineffective bacteria produce small nodules that are white, gray, or green inside. Nodules should be present by about four weeks after seed germination. If the plants are not properly nodulated, emergency inoculum can be applied to the soil surface by broadcasting or spraying in rainy weather. Under hot and dry conditions, it is necessary to drill the inoculum into the soil.

There are several different strains of rhizobia. It is important to use the correct strain to inoculate the legume being seeded. The table below indicates those groups of legumes or individual legumes requiring specific strains.

Precautions in utilizing inoculum:

1. Use the correct strain for each legume.
2. Use fresh inoculum - check the expiration date on the bag.
3. Remember that the bacteria in the inoculum are living organisms and must be kept alive. Store at temperatures between 40˚ and 70˚F.
4. Inoculate seed immediately before planting, especially if the seed is treated with a pesticide.
5. Prevent exposure of inoculum to direct sunlight.
6. Do not mix fertilizer with inoculated seed.

Certified seed

The use of viable seed of adapted varieties is an essential part of successful crop production. Like livestock, seed are living bodies subject to the influences of weather, disease, and breeding. It is not enough that the seed produce a plant, it must also contain the genes which will enable the plant to resist disease, produce high yields, and utilize high levels of soil fertility.

CROSS-INOCULATION OF LEGUMES

	Bur clover	Alfalfa	Sweet clover	Black medic	Red clover	White clover	Ladino clover	Alsike clover	Crimson clover	Hairy vetch	Garden pea	Canada field pea	Austrian winter pea	Birdsfoot trefoil	Crown vetch	Graden bean	Soybean	Cowpea	Partridge pea	Peanut	Lespedeza	Kudzu
Bur clover	+	+	+	+																		
Alfalfa	+	+	+	+																		
Sweet clover	+	+	+	+																		
Black medic	+	+	+	+																		
Red clover					+	+	+	+	+													
White clover					+	+	+	+	+													
Ladino clover					+	+	+	+	+													
Alsike clover					+	+	+	+	+													
Crimson clover					+	+	+	+	+													
Hairy vetch										+	+	+	+									
Garden pea										+	+	+	+									
Canada field pea										+	+	+	+									
Austrian winter pea										+	+	+	+									
Birdsfoot trefoil														+								
Crown vetch															+							
Garden bean																+						
Soybean																	+					
Cowpea																		+	+	+	+	+
Partridge pea																		+	+	+	+	+
Peanut																		+	+	+	+	+
Lespedeza																		+	+	+	+	+
Kudzu																		+	+	+	+	+

(Note: Cross marks indicate which legumes are inoculated by bacteria from other legumes. For example, alfalfa is inoculated by bacteria from bur clover, sweet clover, and black medic.)

Certifying agency

The Virginia Crop Improvement Association has been designated as the official seed certifying agency in Virginia by the State Certified Seed Council. The Association is an incorporated non-profit organization of seed growers.

The Virginia Crop Improvement Association works in cooperation with seed growers, seedsmen, research, extension, and teaching divisions of Virginia Polytechnic Institute and State University, the Virginia Department of Agriculture and Consumer Services, and the United States Department of Agriculture.

Purpose of certification

The purpose of certification is to reproduce and make available to the public, through certification, high-quality seed and propagating material of superior plant varieties grown and distributed as to insure genetic purity and a minimum of seed-borne diseases. The word seed, or seeds, includes all propagating material that may be certified.

Classes and sources of certified seed

Four classes of seed shall be recognized in seed certification; namely, (a) Breeder, (b) Foundation, (c) Registered, (d) Certified.

Breeder seed is seed or vegetive propagating material directly controlled by the originating or sponsoring plant breeder or institution, and which provides the source for the initial increase of foundation seed. Breeder seed is not available for commercial distribution.

Foundation seed is seed stock that is so handled as to most nearly maintain specific genetic identity and purity. Production must be carefully supervised and approved by the certifying agency and/or the agricultural research station.

Registered seed is the progeny of foundation or registered seed that is so handled as to maintain satisfactory genetic identity and purity and a minimum of seed-borne diseases, and that has been approved and certified by an official certifying agency.

Certified seed is normally the progeny of foundation or registered seed. However, when foundation or registered classes of a variety are not available, certified seed may be produced from certified seed that was grown under the supervision of the certifying agency and so handled as to maintain genetic identity, purity, and a minimum of seed-borne diseases.

Application for certification

Application for inspection of a crop for certification may be made on an official Association application blank that may be obtained from Extension agents, vocational teachers, or by writing to the Association office. The application must be properly filled out and mailed to the Virginia Crop Improvement Association, 9142 Atlee Station Road, Mechanicsville, VA 23116 (804) 746-4884.

Field inspection

At least one field inspection is made at a time most appropriate to determine compliance with certification requirements. All inspections are performed by individuals who have been trained for the job.

Sampling of seed

Before sampling, seed lots should be cleaned and ready for sale, except for labeling. A representative sample should be taken from the entire lot.

A 1.5 lb sample is required for small grains, soybeans, and peanuts needing germination and purity tests. A 0.5 lb sample is needed for grasses and small seeded legumes.

Samples may be sent to:

State Seed Testing Laboratory l North 14th Street Richmond, VA 23219

Sources of Seed

The VCIA distributes spring and fall certified seed directories which list sources of registered and certified seed grown in Virginia. The Foundation Seed Farm is located at P.O. Box 78, Mt. Holly, VA 22524 and is responsible for increasing seed of new varieties and maintaining commercially important varieties that have been developed by public institutions.

A quick method for estimating the pounds of seeds broadcast per acre:

After planting, place a sheet of 8 1/2” x 11” paper over the planted area and make an outline in the soil. Remove the paper and count the seeds in the marked area. In Column A, find the number counted. The other columns show pounds of seed per acre. Measure several different areas and take an average. This method could be modified by placing a large cover on the ground before planting to make the small seed more visable.

No. seed Counted Under 8 1/2x11" paper	Alfalfa Fescue (tall)	Red Clover	Bluegrass	Orchard-grass	Wheat Barley
— — — — — — — — —		Pounds of Seed Broadcast per Acre		— — — — — — — — — —	
1	0.3	0.25	0.05	0.1	5
2	0.6	0.5	0.1	0.2	10
4	1.2	1.0	0.1	0.5	20
6	1.8	1.5	0.2	0.7	30
8	2.4	2.1	0.2	0.9	41
10	3.0	2.6	0.3	1.1	51
12	3.7	3.1	0.4	1.4	61
14	3.7	3.1	0.4	1.6	72
16	4.9	4.1	0.5	1.8	82
18	5.5	4.6	0.5	2.0	92
20	6.1	5.2	0.6	2.3	103
25	7.6	6.5	0.8	2.8	129
30	1.9	7.7	0.9	3.4	154
40	12.2	10.3	1.2	4.5	206
50	15.2	12.9	1.5	5.7	258
60	18.3	15.5	1.8	6.8	309
70	21.3	18.1	2.1	7.9	361
80	24.4	20.6	2.4	9.1	412
90	27.4	23.2	2.7	10.2	464
100	30.5	25.8	3.0	11.4	516

Seed Population at Planting

Seeds Per Acre	4"	6"	8"	10"	14"	16"	18"	20"	22"	24"	26"	28"	30"	32"	34"	36"	38"
	Inches Between Seeds																
4,000	392	261	195	156	111	98	87	78	71	65	60	56	52	49	46	43	41
6,000	262	174	131	104	75	66	58	52	48	44	40	37	35	33	31	29	26
8,000	196	131	98	78	56	49	44	39	36	33	30	28	26	25	23	22	21
10,000	157	104	78	63	45	39	35	31	29	26	24	22	21	20	19	17	16
12,000	131	87	65	52	37	33	29	26	24	22	20	19	17	16	15	14	13
14,000	112	75	56	45	32	28	25	22	20	19	17	16	15	14	13	12	11
16,000	98	65	49	39	28	25	22	20	18	16	15	14	13	12	11	10	10
18 000	87	58	43	35	25	22	19	17	16	15	13	12	12	11	10	9.7	9.2
20 000	78	52	39	31	22	20	17	16	14	13	12	11	11	9.8	9.2	8.7	8.2
22,000	71	47	36	28	20	18	16	15	13	12	11	10	9.5	8.9	8.4	7.9	7.5
24,000	65	43	33	26	19	16	15	13	12	11	10	9.3	8.7	8.2	7.7	7.3	6.9
26,000	60	40	30	24	17	15	13	12	11	10	9.3	8.6	8.1	7.5	7.1	6.7	6.3
28 000	56	37	28	22	16	14	12	11	10	9.3	8.6	8.0	7.5	7.0	6.6	6.2	5.9
30 000	52	34	26	21	15	13	12	10	9.5	8.7	8.0	7.4	7.0	6.5	6.2	5.8	5.5
35,000	45	29	22	18	13	11	10	8.9	8.2	7.5	6.9	6.4	6.0	5.6	5.3	5.0	4.7
40,000	39	26	20	16	11	9.8	8.7	7.8	7.1	6.5	6.0	5.6	5.2	4.9	4.6	4.4	4.1
50,000	31	21	16	13	8.9	7.8	7.0	6.3	5.7	5.2	4.8	4.5	4.2	3.9	3.7	3.5	3.3
60 000	26	17	13	10	7.4	6.6	5.8	5.2	4.8	4.4	4.0	3.7	3.5	3.3	3.1	2.9	2.7
70 000	22	15	11	8.9	6.4	5.6	5.0	4.5	4.1	3.7	3.4	3.2	3.0	2.8	2.6	2.5	2.4
80,000	20	13	10	7.8	5.6	4.9	4.4	3.9	3.6	3.3	3.0	2.8	2.6	2.4	2.3	2.2	2.1
90,000	17	12	8.7	6.9	5.0	4.4	3.9	3.5	3.2	2.9	2.7	2.5	2.3	2.2	2.1	1.9	1.8
100 000	16	10	7.8	6.2	4.5	3.9	3.5	3.1	2.9	2.6	2.4	2.2	2.1	2.0	1.8	1.7	1.6
125 000	13	8.4	6.2	5.0	3.6	3.1	2.8	2.5	2.3	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3
150,000	12	7.0	5.2	4.2	3.0	2.6	2.3	2.1	1.9	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1
200,000	7.8	5.2	3.9	3.1	2.2	2.0	1.7	1.6	1.4	1.3	1.2	1.1	1.0	1.0	0.9	0.9	0.8
250,000	6.2	4.2	3.1	2.5	1.8	1.6	1.4	1.3	1.1	1.0	1.0	0.9	0.8	0.8	0.7	0.7	0.7
300,000	5.2	3.5	2.6	2.1	1.5	1.3	1.2	1.0	1.0	0.9	0.8	0.7	0.7	0.7	0.6	0.6	0.5
500,000	3.1	2.1	1.5	1.2	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3
1 000,000	1.5	1.0	0.8	0.6	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
1 500,000	1.0	0.7	0.5	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1

PART V
Seeds and Stored Grains

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Managing stored grains and seed requires the use of various techniques to ensure the quality of the product entering the storage facility does not deteriorate over time. These techniques include: the use of sanitation, storing sound, dry grain, managing temperature and aeration, using chemical protectants, regular sampling, and the use of fumigation. Bin and storage facilities also play an important role in determining the quality of the stored grain. Storage facilities should be inspected regularly for deterioration of any type.

Proper storage moisture varies depending on type of seed, length of storage and storage conditions. Seed moisture content changes until equilibrium is established with the surrounding environment. The equilibrium moisture is different for each kind of seed. High oil content seeds (soybeans, peanuts, sunflowers) will not absorb as much moisture as seed with a high starch content (wheat, barley, corn, sorghum). Oil does not absorb water; therefore, in a seed with 40% oil the seed moisture will be concentrated in the other 60%. The time to reach equilibrium will vary from days to months depending on the kind of seed, humidity and temperature. When there are large differences in seed moisture and the surrounding environment the initial change is rapid and slows as equilibrium temperature/moisture is approached.

Over 60 species of insects infest stored grains. Lesser grain borer, rice weevils, maize weevils, cadelle beetles, flat grain beetles, rusty grain beetles, sawtoothed grain beetles, foreign grain beetles, mealworm beetles, red flour beetles, confused flour beetles, Indian meal moths, book lice and grain mites are considered the main pests. Of those listed, Indian meal moths are the most commonly encountered. Damage by stored grain insects can go unnoticed until the grain is removed from the storage facility. Regular monitoring will ensure that the quality of the grain will be maintained at the highest level possible. Scouting should not be limited to the field. A regular monitoring program should be continued until the grain leaves the storage facility.

Microorganisms are another important consideration when storing seeds or grain. The two major microorganisms involved in seed molds are aspergillus and penicillin. As molds develop in stored grains, temperatures rise resulting in “hot spots”. In these spots, temperatures can reach as high as 125^{o}F. Mold growth is retarded as temperatures increase; seed vigor and germination are also reduced with increased temperatures.

Bin facilities (bulk storage)

Bin facilities should be weather tight, rodent proof, steel, and on a moisture proof concrete base. Bins should be equipped with a perforated-floor aeration system and weather proof-roof vent. All bins should be inspected on a regular basis to guard against leaks and deterioration of any kind. Once filled, attempt to seal the bottom and sides of the bin so insects and rodents can only enter the top of the facility. Do not seal roof aeration exhaust or inlet vents except during fumigation so the top of the bin can be easily sampled and top dressings applied if necessary.

Sanitation

Before adding grain to a storage facility, make sure it is clean and free of old grain, trash and insects. Be sure the walls, ceiling, sills, ledges, floors and the ventilation system (under perforated floors, ducts and fan system) are clean. The area outside the bin should also be free of insects, weeds and grain products. Insects can breed and persist in these areas and infest new grain when placed in the bin. It is best to clean and treat bins at least two weeks prior to adding new grain.

Most insect infestations in stored grain originate in the immediate area of the storage facility. Area sanitation is important since many of the commonly stored grain pests can fly and may move from one bin to another.

Grain moisture

As a general rule, grain should be stored at no more than 12% moisture. Insects and fungi do not develop well in grain with moisture content of 12% or below. For seed to be stored for long periods of time, the maximum safe moisture content is about 2% below the safe storage moisture of the grain. Refer to Table 1 for recommended storage moistures for grains and seed at various storage temperatures. Seed can be stored for 3-5 years in sealed containers at 65–75°F if dried to 5 – 8% moisture. For longer storage periods under these conditions, seed should be dried to 2.5–5% moisture before placing in a sealed container. Seed moisture content can be increased as the temperature is reduced below 60°F. Avoid storing seed in environments that will expose them to high temperatures or humidity. Dry, cold storage is ideal; therefore, a freezer is excellent for seed storage.

Table 1. Suggested Maximum Safe Moisture Storage For Grain and Seed[1]

Seed	2 months	6 months	Grain and Seed Long-term Storage	Storage Temperature Should be Below °F
	Maximum Grain Moisture (%)			
Barley	—	13.4	11.9	77
Buckwheat	—	13.9	12.4	77
Corn, grain	14.8	14.0	12.4	77
Corn, grain	15.2	14.2	12.6	60
Corn, grain	17.7	15.5	13.9	40
Corn, ear[2]	—	20.0	—	50
Oats	—	12.8	11.4	77
Millet	—	10.0	9.0	70
Peanuts, unshelled	11.2	9.6	8.4	70
Peanuts, unshelled	12.0	10.3	8.9	50
Peanuts, shelled	8.8	7.7	6.7	70
Peanuts, shelled	9.1	8.1	7.2	50
Rye	—	13.9	12.3	77
Soybeans	15.8	12.0	9.7	77
Soybeans	16.1	12.4	10.1	60
Soybeans	16.5	12.9	10.4	40
Sunflowers, oil	—	9.6	8.6	77
Sunflowers, non-oil	—	10.0	9.0	77
Sorghum	14.7	13.5	12.4	90
Sorghum	15.2	14.0	13.0	60
Wheat, soft red winter	15.6	13.6	12.1	77
Wheat, soft red winter	15.8	14.0	12.4	70
Wheat, soft red winter	16.0	14.4	13.1	40
Alfalfa	—	—	7.8	73
KY bluegrass	—	—	11.3	73
Clover, red	—	—	9.1	73
Clover, white	—	—	8.7	73
Crown vetch	—	—	9.4	73
Tall fescue	—	—	12.1	73
Orchardgrass	—	—	11.0	73
Ryegrass	—	—	12.8	73
Timothy	—	—	12.5	73

[1] Safe storage depends on many factors such as temperature, humidity, kind and variety of seed, quality, damage, microorganisms, length and kind of storage. Stored grains and seed should be inspected frequently for changes in temperature and moisture as well as pest infestations.

[2] Ventilated cribs 6-8' wide.

Temperature and aeration

A combination of low seed temperature and low moisture aid in insect control. Insect reproduction is reduced at temperatures below 60ºF and as the moisture content of the seed is reduced. These conditions do not provide enough heat and water to meet the needs of the insects. Grains harvested and stored in the hottest part of the year have a greater chance of becoming infested, since insects reproduce rapidly at temperatures in the range of 60-90ºF. Farm stored wheat, rye, barley or oats are more likely to have insect problems than corn or soybeans which are harvested during the cooler months of the year. Aeration during times of low outside temperature and humidity is suggested to reduce temperature and moisture. In the southern United States, it is recommended to maintain warm temperatures and low humidity until cooler temperatures arrive and then cool the grain to 55-65ºF or lower as soon as possible. The amount of air required for good aeration is relatively low, but it should be at least 0.10 cubic foot per minute per bushel.

Resistance to Low Temperatures of Various Insects that Attack Stored Grain and Grain Products

	Days Exposure Required to Kill All Stages at[1]						
Insect	**0º-5ºF**	**5º-10ºF**	**10º-15ºF**	**15º-20ºF**	**20º-25ºF**	**25º-30ºF**	**30º-35ºF**
Rice weevil	1	1	1	3	6	8	16
Granary weevil	1	3	—	14	33	46	73
Saw-toothed grain beetle	1	1	3	3	7	23	26
Confused flour beetle	1	1	1	1	5	12	17
Red flour beetle	1	1	1	1	5	8	17
Indian-meal moth	1	3	5	8	28	90	—
Mediterranean flour moth	1	3	4	7	24	116	—

[1] Storage of Cereal Grains and Their Products, J. A. Anderson and A. W. Alcock, American Association of Cereal Chemist, St. Paul, Minnesota, 1954.

Several practices should be followed when filling bins to permit even aeration of the grain mass. The upper surface of the grain mass should be level or slightly inverted to permit even aeration. The use of a grain spreader will help prevent the accumulation of fines (broken grain, weed seed, dust and debris) in the center when filling bins. If not spread evenly, this material will accumulate in the center of the bin preventing even aeration and providing an excellent environment for insects and fungi to develop.

Figure 1

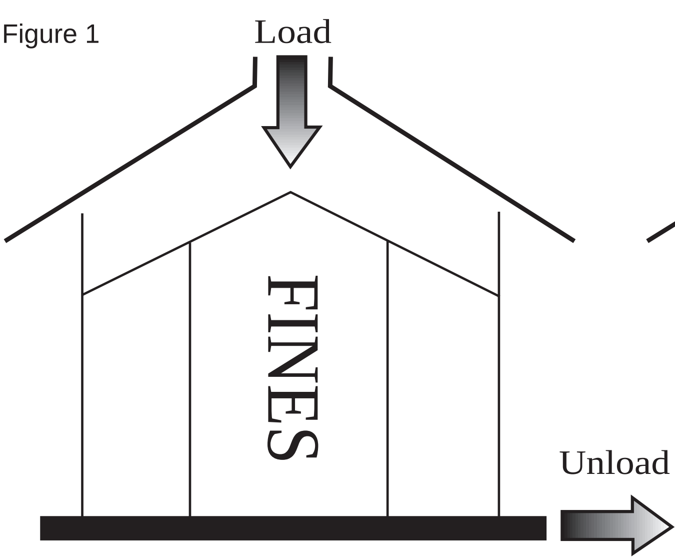
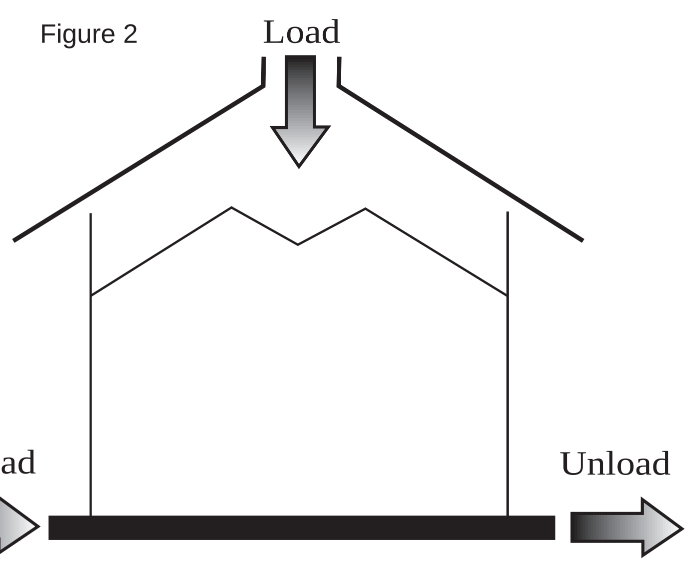


Figure 2



The accumulation of fines in the center of the bin can be greatly reduced by removing a portion of the grain mass after the facility is filled or several times during the loading process. Removing the core from the bottom with the centrally located unloading auger or conveyer will remove the column of fines and invert the peaked grain in the top of the tank (Figure 2). After this process is completed the grain can be left alone or leveled. This process called "coring" will increase aeration efficiency and reduce problems with insects, fungi and hotspots. For grain stored through the winter, aeration in the fall can deter moisture migration in the bin. Moisture migration is caused by differential temperatures in the grain mass resulting in convective flow of air through the grain. The convective flow of air can result in accumulating moisture condensation in the upper center of the grain mass. These factors will contribute to the development of molds and insects. Attempt to maintain grain temperature within 10˚F of the average outside air temperature. Depending on the year and the conditions several aeration events may be required to correct temperature differences. Aeration is very important in grain bins containing 2,000 bushels or more.

Empty bin sprays

Empty bin sprays are recommended for summer stored grain, difficult to clean bins or when there is a history of insect problems. After bins have been properly cleaned and inspected and prior to adding new grain, spray the empty bin with a labeled insecticide. Spray to run-off the inside surface, and as much of the outside including the nearby ground surfaces, aeration ducts, and grain handling equipment, as possible. Sprays should be concentrated on cracks, crevices and areas difficult to clean. Applications should be made at least two weeks prior to adding new grain. Allow 24 hours for sprays to dry. These sprays provide a barrier for insects that may be attracted to the storage facilities and also provide control of the insects not removed during the cleaning operation.

Bacillus thuringiensis grain products

Bacillus thuringiensis (Bt) is a biological insecticide that has activity on some moth larvae. This insecticide has been genetically engineered into many of the grain crops currently produced in the United States. In many of these newer engineered crops, the *Bt* gene is expressed in the grain as well as other parts of the plant thus providing the grain with protection from larval feeding. Although no research has been conducted to determine the effectiveness of *Bt* grains in storage, protection should be equal to or superior to the *Bt* products available for stored product treatments. The expression of the *Bt* toxin in every grain should provide a level of protection greater than any *Bt* topical, bin or grain treatment. Until research has been conducted to determine the effectiveness of the *Bt* gene under storage conditions, sample grain regularly. *Bt* products will not control weevils or other beetles.

Chemical grain protectents

A grain protectant may be added when the bin is being filled to guard against insect damage. Protectants may also be added to the upper surface of the grain in the bin to protect against damage from moths and other insects entering the top of the storage facility. Protectants will not eliminate existing infestations. Protectants are recommended if grain is going to be stored for extended periods, in flat structures, under circumstances that favor pest development, or in facilities with a history of insect damage. The combination of high grain moisture and high temperatures will shorten the residual life of grain protectants. Use only labeled products at the approved rates and check with your miller or buyer before using an insecticide on stored products.

Top dressing and pest strips

It may be necessary to mix an insecticide with the top 4 inches of the grain to deal with an infestation of primarily moths. Moths tend to attack the upper surface of the grain mass. The Indian meal moth is the most common insect to attack stored grain and, unfortunately, it already has resistance to some insecticides.

Resin strips (dichorvos or DDVP) may also be hung in the air space in the top of the bin to help control adult moths. For this treatment to be effective, the top of the bin must be temporarily sealed including the roof vent. Aeration will disrupt this treatment. Remember to open the roof vent before aerating.

Insect Sampling

Bins should be inspected on a regular basis for insects, hot spots, mold growth or any "off odor." As a general guideline, bins should be sampled twice a month under warm conditions and once a month under cool conditions. Regular inspections will reduce the chances of pests becoming established. Take all necessary safety precautions. Bins should be easily accessible and all unloading equipment should be turned off. Be aware of any pesticides applied to the grain, undissipated fumigants, bridged grain, grain dusts, and high temperatures. WORKING IN TEAMS IS THE BEST POLICY WITH AT LEAST ONE PERSON ON THE OUTSIDE OF THE STORAGE FACILITY.

Samplers should be alert for:
• Off odors
• Crusting
• Temperature differences > 10˚F
• Visible water vapor
• Sprouting grain
• Exterior bin conditions and signs
• Uneven snow melt or frosting
• Condensation
• Discoloration
• Fecal matter (birds, rodent and insect)
• Birds (insect feeders)

Use a probe (Figure 4) or scoop to collect the samples. Take five to ten, one-pint samples from various areas over the grain surface. Using a compartmentalized grain trier will allow the sampler to determine differences in grain moisture, insect populations, temperature and grain quality at different depths in the grain mass. Label samples so problem areas within the bin can be identified. Sampling at different depths will greatly increase the chances of finding trouble spots before a large area of grain is damaged.

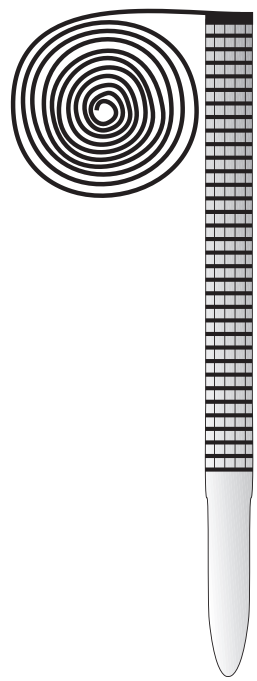


Figure 3. Probe Trap

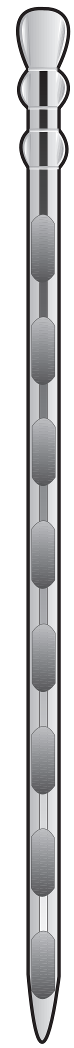


Figure 4. Grain Trier

Grain temperature should be determined as soon as possible after the sample is taken to achieve the most accurate results. Temperature differences in the range 10 - 15˚F indicate a potential problem. Usually aeration will correct the temperature difference. After corrective measures are taken, further sampling is suggested to ensure the problem has been corrected.

When sampling for insects in cool grain, samples should be warmed. Warming will increase the activity of the insects allowing the sampler to easily spot the pests and determine if the insects are alive. Individual samples can be placed in labeled plastic bags to guard against contamination. Each sample should be placed on a sieve, which will hold the grain while allowing the pieces (fines), insects and small debris to pass through. If insects are present, save them for identification, estimate the abundance and determine the distribution. Pest identification is crucial when selecting a control measure. For example, several species of insects feed on fungi. Their presence indicates a moisture problem. Control of the insects with pesticides can be achieved without correcting the primary problem.

Another method of sampling involves using a grain probe trap. (Figure 3) This trap consists of a perforated plastic tube with a funnel collector on the bottom. Traps are inserted in the grain mass and marked with colored string which allows them to be retrieved. Traps are retrieved after 24 hours and are more efficient than probing and sieving for beetles, but they do not adequately detect moth larvae.

Trouble spots can also be identified using a metal rod. Insert the rod into the grain and allow it to remain for about 10 minutes. Hot spots can be detected by running your hand down the rod after removing it from the grain. If temperature differences are sensed, investigate these areas further to determine the reason for the difference in grain temperature.

Accurate records should be kept so changes over time can be detected. Records can be used to refine a management strategy for your individual operation.

Generally, it is suggested to treat grain to control insects:

If Wheat, Rye, or Triticale have one live insect per quart sample

If Corn, Sorghum, Barley, Oats or Soybeans, have one live weevil or five other insects per quart sample

If these thresholds are exceeded, fumigation is suggested. However, if temperatures are below manufacturer suggested levels, fumigation should be delayed. Fumigation effectiveness is greatly reduced under cool conditions. For conditions that do not favor fumigation, the grain mass should be cooled to below 60˚F if possible. At temperatures below 60˚F, insects are for the most part inactive. When temperatures permit, fumigation should be considered.

Primary grain insects

Primary grain insects refer to a group of insects that attacks whole, undamaged grain. The immature stages of these insects occur on the inside of the grain where detection is more difficult. The damage from these insects results in an Insect Damaged Kernels (IDK) sample grade classification. Examples of primary insects include the rice weevils, bean weevils and lesser grain borer.

Secondary grain insects

This group refers to a complex of insects that feeds on fragments of grain and cereals. They can also be referred to as bran bugs. They include various grain moths, mites, psocids and various beetles. Examples of secondary insects include flour beetles, sawtoothed grain beetles, rusty grain beetles and Indian meal moths.

Fumigation

Fumigation should be conducted only by trained, experienced, registered applicators. If insects are found above the suggested thresholds, fumigation is suggested. The goal of fumigation is to maintain a toxic concentration of gas long enough to kill the target pest population. The toxic gasses penetrate into cracks, crevices, the commodity and the facility treated. Fumigants provide no residual protection. Fumigants come in several forms and formulations. All label instructions and precautions should be read and carefully followed.

Fumigant selection should be based on the following factors: pest susceptibility, volatility, penetrability, corrosiveness, safety, flammability, residues, odors, application method, required equipment, and economics. There are two products labeled for treating stored products – methyl bromide and phosphine producing materials such as magnesium phosphide and aluminum phosphide.

Phosphine fumigants

Phosphine has no adverse affects on seed germination when applied according to label directions and at labeled rates. Phosphine does react with certain metals such as copper, brass, bronze, gold and silver. Reactions result in discoloration and corrosion. This is a problem with electrical and mechanical systems that utilize these metals. This problem apparently only occurs when there are high concentrations of phosphine in combination with high humidity and temperature.

If the liberation of hydrogen phosphide occurs in a confined area an explosion or fire may result. Aluminum phosphide has been formulated with ammonium carbamate or aluminum stearate and calcium oxide to control the release and lower the combustibility. In addition to controlling the reaction, formulations that contain ammonium carbamate release a garlic odor that serves as a warning odor. The time required for phosphine release is shorter under warm, humid conditions and longer under cool and dry conditions. Since the gas diffuses through the grain rapidly, structures must be sealed properly, especially under cooler conditions.

Methyl bromide fumigants

Under most conditions, fumigation with methyl bromide will not harm germination. However, high doses (generally used for insects) for more than 24 hours coupled with temperatures above 85˚F and moisture greater than 12% can negatively impact seed germination. Methyl bromide does not harm electronic equipment and wiring, requires less time to kill insects when compared to phosphine but does give certain products containing sulfur, rubber (foam and sponge rubber also), feathers, hairs, and cinder blocks an odor. For other products affected by the methyl bromide refer to the product label. When using methyl bromide at temperatures below 60˚F, the dosage of the fumigant should be increased to compensate for the cooler conditions.

Methyl bromide is 3.27 times heavier than air, causing it to fall when released. Because of the density of the fumigant, grain leveling is important. Unleveled grain results in the fumigant settling to low areas in the grain resulting in poor fumigation of the peaked grain. Recirculation is often used to ensure even distribution of the fumigant.

Methyl bromide comes in small cans or can be obtained in large cylinders. Small cans require special puncture type openers to release the gas. The cans are generally used where small structures and transportation containers require fumigation. Cylinders are primarily used for larger facilities. The cylinders are connected to the bin facility with brass fittings and polyethylene tubing. The end of the tubing is usually placed in the headspace of the bin with a plastic pan or tray under the end of the tube to catch any moisture. The amount of fumigant required is determined based on the size of the structure and environmental conditions present. The cylinder is placed on a set of scales and the weight determined. The valve is opened and then closed once the proper amount of the fumigant has been released.

Grain storage space, capacities and weights

Bushels of grain can be determined either on a weight basis or on a volume basis. Grain test weight can be used to convert from one to the other.

Volume bushels

1.0 bushel shelled grain = 1.25 cubic feet
1.0 cubic foot = 0.8 bushel shelled grain

1.0 bushel ear corn = 2. 5 cubic feet
1.0 cubic foot = 0.4 bushel ear corn

2.0 bushels of ear corn = 1.0 bushel of shelled corn

Bin Storage capacity in bushels
(approximate)

Rectangular bins = length x width x height x 0.8 bu.
Round bins = Diameter2 x height x 0.628 bu.

Weight of Grain Per Bushel at Various Moisture Levels

	Corn		Soybeans	
Moisture %	**Shelled lbs.**	**Ear lbs.**	**Harvest Moisture %**	**Lbs. Grain to Make 60 lbs. Bu at 14%**
10.0	52.6	62.5	10.0	57.6
12.0	53.8	64.7	11.0	58.2
14.0	55.0	66.9	12.0	58.8
15.5	56.0	68.4	13.0	59.4
18.0	57.7	71.3	14.0	60.0
20.0	59.1	74.0	15.0	60.6
22.0	60.6	76.8	16.0	61.2
24.0	62.2	79.8	17.0	61.8
26.0	63.9	82.8	18.0	62.4
28.0	65.7	85.6	19.0	63.0
30.0	67.6	88.5	20.0	63.6
32.0	69.6	91.4	21.0	64.2
34.0	71.7	94.3	22.0	64.8

References

Management of Stored Grain Insects, Part I: Facts of Life. Kansas State Cooperative Extension Service Publication MF-726.

Management of Stored Grain Insects, Part II: Identification and Sampling of Stored Grain Insects. Kansas State Cooperative Extension Service Publication MF-916.

Management of Stored Grain Insects, Part III: Structural Sprays, Pest Strips, Grain Protectents, and Surface Dressings. Kansas State Extension Publication MF-917.

Stored Product Management. Oklahoma Cooperative Extension Service Circulation Number E-912.

PART VI
Soils of Virginia

James C. Baker, Extension Soils and Land Use Specialist

There are more than 600 soil series mapped in Virginia. These soils show great ranges in properties and thus in their suitability for different uses. Much of the difference in soils relates to the geologic parent materials from which they have formed as well as the local topography. The diverse nature of the parent materials is seen in the Physiographic and Soil Parent Material Map of Virginia (Figure 1).

Major soil divisions

A. Appalachian division.

The soils in this area have formed in materials deposited beneath ancient seas. These deposits became sedimentary rocks of which primary types are limestone, shale, sandstone, and conglomerate.

Soils formed from limestone are found primarily in valley areas. In the past, most limestone derived soil areas have been farmed and remain some of the most agriculturally important soils of the region. They are permeable and usually well drained although the major land use problem with these soils is the variation of depth of soil above bedrock. In addition, the subsoils commonly have high contents of clay and some sites have eroded.

Soils formed from shales usually occur on more sloping landscapes in the valleys and along the bases of mountains. These soils commonly range from shallow to moderately deep to bedrock and may contain many shale fragments throughout the soil profile.

Soils formed from sandstone and conglomerates occur along the major ridges and mountains. These soils are usually shallow, sandy, and often stony or gravelly.

In addition to major characteristics discussed above, soils formed in transported materials by gravity (colluvium) and water (alluvium) are common in lower landscape positions and are important agriculturally. Soils formed from colluvium commonly have compacted subsoil layers (called fragipans), high seasonal water tables, and may be stony. Soils formed in alluvium are generally the most productive soils of the region. Some are on floodplain positions and as such may be subject to stream overflow. Those on non-overflow positions, such as stream terraces, are usually well suited to many uses although some have seasonally high water tables.

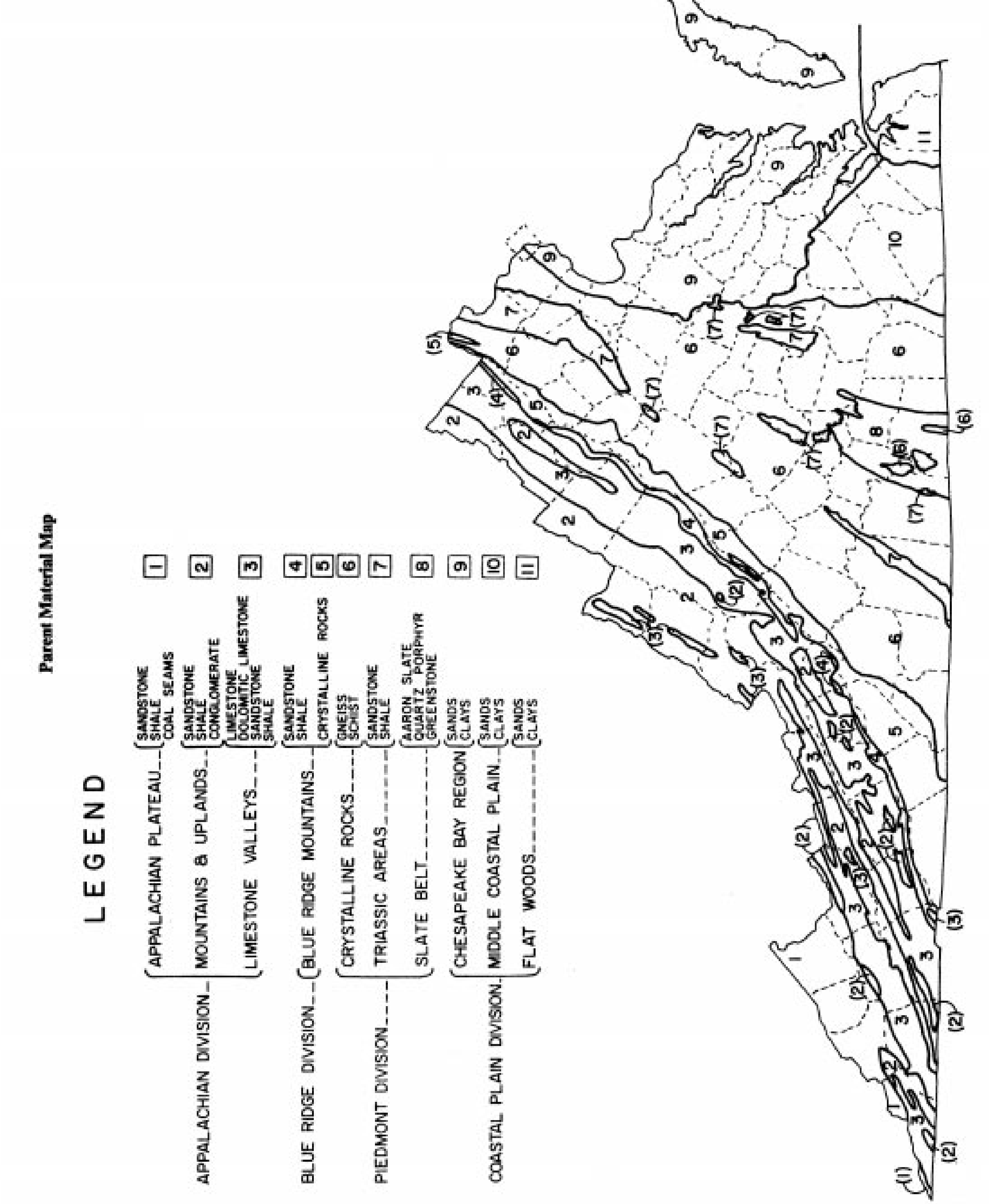
B. Blue Ridge division.

The soils of this area are formed from a combination of sedimentary rocks, igneous rocks formed from molten magma, and metamorphosed rocks formed by heat and/or pressure alteration of other rocks. The igneous and metamorphosed rocks are termed crystalline rocks on the soil parent material map.

In general, the sedimentary rocks are on western slopes of the Blue Ridge and the crystalline rocks are on the eastern slopes. The overriding soil use constraints in the Blue Ridge region are steep slopes, stoniness, and shallow soil over bedrock. The steep slopes associated with much of the area demand that careful attention be given to any activity, either cultivation or construction, that leaves the soil bare. It is imperative to minimize erosion hazards.

The soils derived from sedimentary rocks occur predominantly on steep slopes and are shallow to bedrock. The soils formed from crystalline rock may be on steep slopes but also occur on more gently sloping highland areas along the Blue Ridge. To the north of Roanoke, these gently sloping ridges are narrow, thus limiting uses to forestry and recreation. To the south of Roanoke, the Blue Ridge Highland area is gently sloping and

FIGURE 1. PARENT MATERIAL MAP



several miles wide. This area is intensively used for agriculture and is dominated by deep, well drained soils suitable for many uses. As with all regions where steep slopes may occur, care must be taken to control erosion. Some regions also have locally important areas of soils formed from colluvium which in this region is quite variable in texture and drainage.

C. Piedmont division

This is the largest physiographic region in Virginia. It occurs between the Blue Ridge and a line running between Arlington and Emporia. The Piedmont region is dominated by igneous and metamorphic rocks with important areas of sedimentary rocks in some counties.

The predominant parent material rocks are gneiss, schist, and granite, of which quartz, feldspar, and mica are the dominant primary minerals. Soils developed from these rocks and minerals form acid, infertile soils, with sandy loam surfaces. Many of the clayey subsoils are red or yellowish red due to the oxidized iron weathered from the primary minerals. Natural fertility is low; however, these soils respond well to liming and fertilization. Depth to bedrock varies but in most places, these soils are deeply weathered for several feet. Some areas in this region have particularly high aluminum in the subsoil, which can be an agronomic problem for some crops. Liming is necessary on such soils. Historically, much of the Piedmont region was cleared and farmed intensively, causing extreme erosion over much of the region. Before modern soil fertility and managerial practices were adapted to these soils, agricultural production diminished and most farms reverted back to forests. Over two thirds of this region is wooded today. The best soils are still agriculturally productive through well managed soil fertility and erosion control plans.

Other soils formed in the region were formed from igneous and metamorphic rocks with a high base content of calcium and magnesium. Soils formed from such minerals tend to be more fertile but in some instances they form clayey subsoils with very high capacity to shrink and swell on wetting and drying. Where such soils are eroded this condition poses a particular set of managerial challenges to farmers and even more to developers. Where uneroded, most of these soils are moderately well suited to lawns and gardens if properly managed. The depth to bedrock is generally two to six feet.

Scattered throughout the Piedmont are other soil areas formed from sandstone and shale which were geologic sediments deposited in Triassic age basins. These ancient basins are oriented in a northeast to southwest direction, roughly paralleling the Blue Ridge. The region to the north and east of Charlottesville have shallow to deep soils which can be quite productive when depth to bedrock is not a problem. To the south and east of Charlottesville, such soils may have high clay content, with high water tables and very high aluminum levels. On such soils, it is difficult to establish high productivity for crops, lawns, or gardens. Some soils in this region have high shrink-swell clays which pose severe stability problems for urban uses and tillage and root pruning problems for agricultural uses. Depth to bedrock varies from two to ten feet.

D. Coastal Plains division

Soils of this region are formed from unconsolidated sediments deposited when the ocean level was much higher than at present. As sea levels lowered, many of these deposits were reworked by meandering rivers and streams that originated in the western part of the state and flowed to the east.

In general, the closer to the coast, the nearer the water table to the soil surface.

Soils in the coastal plain are acid, infertile, highly weathered, and vary from sandy textures to very clayey textures. Many of the soils have thick sandy surfaces which make them susceptible to summer droughts. Most landscapes are nearly level to gently sloping and because of this feature the soils are not as susceptible to erosion.

These soils and landscapes, commonly coupled with larger field sizes, accommodate more efficient farming practices. This region has the highest percentage of row crop agriculture. Modern soil fertility/liming managerial practices, high capacity farm implementation, and other production technologies make the more suitable soils of this region competitive with any other part of the state.

There are still significant acres of poorly drained soils with high water tables in the coastal plains region. Many of these areas are in woodland or exist as jurisdictional wetlands which are protected from drainage by current law. These wetland areas provide the essential mechanisms necessary to slow water movement from uplands to estuaries and bays of eastern Virginia, thus serving to maintain high water quality and a sustainable biodiversity for the region.

Soils in natural landscapes and soil surveys.

The discussion above is intended only as a general guide to major land resource areas in Virginia. It must be remembered that drastically different soils may occur within the same landscape. Soils within similar landscapes are somewhat variable in properties, much of this being due to local variations of parent materials. Several soils may occur together within a field of a few acres. Usually, soil bodies are related to landscape positions. The shape of the landscape configuration has a direct effect on soil drainage and soil type. Concave shaped positions are collectors of water while convex positions divert water and thus are usually better drained.

The Virginia Cooperative Soil Survey has produced detailed soil survey maps for nearly 90% of the state. These soil survey maps show the geographic locations of different soil bodies on the landscape. The use of the maps with soil descriptions and interpretative guides provides a means of estimating the suitability of an area for a particular land use. Soil surveys should be available at the local Virginia Tech Extension office or Natural Resources Conservation Service office.

Soils for homesites

The homeowner should be aware of the following soil/site features: 1) surface drainage and permeability, 2) erodibility, 3) presence of expansive clays, 4) relief and soil depth, and 5) if a septic tank and drainfield system is planned, the soil must “perc.”

Drainage and permeability

Surface drainage and internal soil drainage relate to the shedding of water from a site by surface overflow and the removal of excess soil water to give the soil aeration. Well drained soils are not saturated for significant periods of time and the depth of seasonally high water tables is usually greater than 6 feet. Well drained soils are generally the most suitable for building sites and most types of plantings. Poorly drained soils may have water at or near the ground surface during wet periods of the year.

All regions of Virginia have both well drained and poorly drained soils and everything in between these extremes. In some areas of Virginia, over 90 percent of the soils have potential wetness problems. These wet areas present special problems for landscaping, yard drainage, and maintenance of a dry basement.

Permeability is the rate that a soil will transmit water through the profile. This varies from rapid to very slow. Water movement is aided by a network of interconnected pores that extend throughout the soil. Where soil pores are small and total pore space is limited, such as in poorly aggregated subsoils with high clay content, or where compacted layers exist, permeability will be slow to very slow. Layers of expansive clays and compacted layers restrict downward movement or percolation during wet periods and may result in temporarily perched water tables.

In many cases, wetness problems in basements or around footings can be overcome with proper surface drainage by diverting excess water away from problem areas. For new construction, the use of footing drains along with proper grading and surface water control is recommended to reduce the potential for wetness problems. Footing drains installed at construction time are relatively inexpensive but are very costly to install later when a problem arises.

Erodibility
The susceptibility of a home site to soil erosion depends on the kinds of soil but also on the grading and land-forming done by the contractor during development. In many cases, especially on small lots, the natural soils have been completely removed, or at least disturbed, by cutting and filling. The original surface soil on the lot is likely to have been removed from the site or lost during construction, although some contractors make an attempt to reapply the topsoil to the finished grade. The erodibility therefore depends on characteristics of the slope and soil material. Vegetation should be established as soon as possible on any bare soil areas. Any kind of plant debris (straw, grass, mulch) or commercial cloth mesh that covers the ground will help reduce soil erosion until permanent vegetation or sod is in place.

Expansive clays
Soils with a high content of expansive clays will change volume on wetting and drying. These expansive soils may cause severe damage to foundations and footings of buildings, sidewalks, roads, and other structures. Where such clays are at or near the soil surface, severe root pruning of plant seedlings may occur. Where such soils are encountered or expected, an on-site evaluation by a qualified soil scientist is recommended. If construction is planned on such soils, it may be advisable to remove the expansive material from the site. In some instances, special designs, such as rebar reinforcement may be necessary. In other instances it may be advisable to seek an alternative site. In any case, planning ahead of construction is far less costly than remediation of a site once expansive soils have caused building damage.

Relief and soil depth
Home sites with excessive relief (steep slopes) may impose restrictions on basic construction and force other compromises relative to access and maintenance of public utilities. Locating lawns, gardens, play areas, and septic drainfields is difficult on steep slopes. There must be adequate soil depth for growing the kinds of plants desired. Steep slopes or shallow to bedrock conditions are severe limitations.

Managing septic tank drainfield systems

Houses constructed where there are no public sewer systems will have an individual subsurface sewage disposal system. The system is most commonly a septic tank drainfield system. The drainfield will usually be within an area less than 50’ by 100’ in size. The purpose of the system is to carry all the waste water from the house and allow its absorption into the subsoil. Soil areas used for this purpose in Virginia must pass strict evaluations and testing procedures, commonly described in real estate ads as “perced...”. In order to pass this test, soils must be well drained, have good permeability, and be higher in elevation than adjacent drainage ways. The septic tank drainfield system absorbs hundreds of thousands of gallons of sewage effluent and will last many years if the soil is suitable and the system is correctly installed and properly maintained.

Drainfield maintenance

Plantings - A cover of grass should be maintained over the system. It is important to eliminate any erosion since the drainfield lines are often within two feet of the land surface. The species of grass is not as important as the maintenance of a healthy cover. Do not locate trees or shrubs on or near the drainfield since roots may eventually damage and block the distribution lines. Heavy traffic over the drainfield should be avoided.

Cleaning - It is advisable to have the septic tank pumped and cleaned every 3 to 6 years. Contact your local Health Department for recommendations concerning maintenance, cleaning, or any alterations on any part of the septic drainfield system.

Soil water use

A yearly water budget diagram offers a way to show where soil water is being utilized (depleted) and where soil water is being recharged. The diagram (Figure 2) shows an average water budget for three climatic recording stations in eastern Virginia. The left vertical scale is in inches of water. The bars show the difference between precipitation (P) and water usage (ET). Evapotranspiration (ET) is the total of water loss from the soil (evaporation) and the water used or lost from plants (transpiration). A positive number indicates there was an excess in soil water for that month. For months where the average precipitation (P) was less than usage (ET) the number on the left vertical scale is negative. This indicates the soil must have the capacity to supply stored water in order for plants to continue to grow at the maximum rate.

Thus for summer months (mid point of the growing season) there was a deficit for each of the months of June, July, August, and September. The soil has to hold this total amount of water for continued plant growth. The best soils will store about seven inches of water in the upper three feet of soil. This would be enough to make up for the expected water deficit in a climatic setting described by the water budget diagram in (Figure 2).

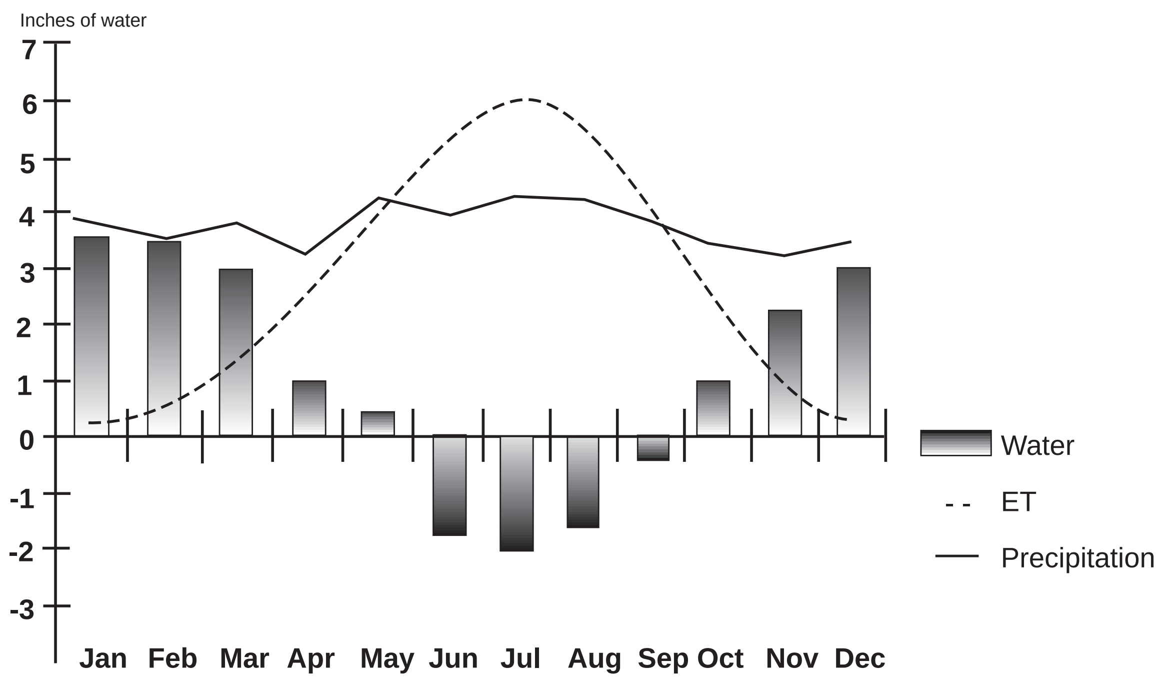
Soil water recharge

In Virginia, the normal climatic pattern has periods of water excess (where ET is less than P) and this is during the period of October to May. This excess precipitation over ET, will recharge the soil with water, month by month, until the soil is fully recharged. The data indicate this recharge would be complete sometime in January of the following year. Now the soil is fully recharged.

Leaching

After recharge is complete, before the growing season starts, the soil will have excess water. At this point, when precipitation events occur, excess water will: 1) run off the soil surface, promoting erosion, or 2) push existing soil water through the soil, causing leaching and percolation losses. This is the time most likely for nitrogen and other chemicals to enter ground waters. This will continue until the growing season begins and plant use of water increases. Maximum leaching and maximum runoff will occur on average during this period when the soil is recharged and before plants begin to use it in the early growing season. This leaching potential will continue until about June, where once again, the soil will give up stored water to maintain maximum growth potential for the crop. Thus to minimize leaching, applications of nitrogen or other soluble fertilizers should be applied as near to planting time as practical and/or added in split applications over the growing season.

Figure 2



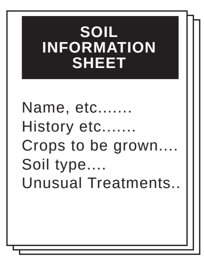
Note: Evapotranspiration (ET) is the total of water loss from the soil (evaporation) and the water used or lost from plants (transpiration).

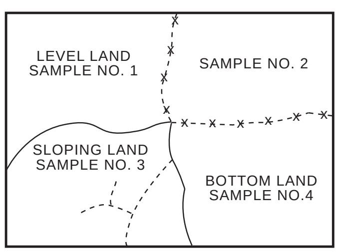
PART VII
Soil Testing and Plant Analysis

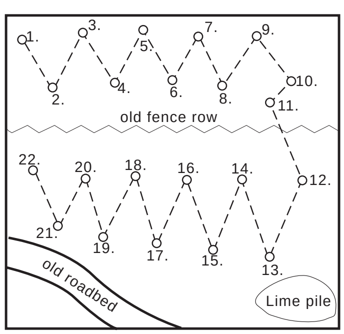
Stephen J. Donohue, Extension Soil Testing and Plant Analysis Specialist

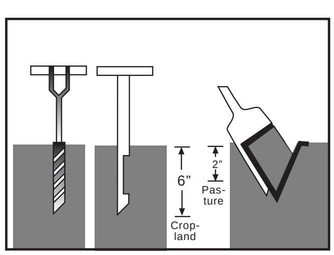
Soil testing and plant analysis are important agronomic tools for determining crop nutrient needs. Soil testing evaluates the fertility of the soil to determine the basic amounts of fertilizer and lime to apply. Plant analysis, on the other hand, is used as a monitoring tool to determine if the fertilization and liming program, as determined by the soil test, is providing the nutrients at the necessary levels for top yields. Plant analysis is the ultimate test; i.e., is the plant obtaining from the soil ample nutrients for good growth and development. If not, nutrients can be added during the existing growing season to improve yields, or the fertilization program can be modified for next year's crop. The following sections discuss how to use soil testing and plant analysis to evaluate crop nutrient needs.

Soil testing









Sampling Instructions – Collecting the sample is one of the most important steps in the soil testing program. When one considers that a 2-lb soil sample must adequately represent 10 million or more lbs of soil in the area being sampled, the importance of doing a good job of sampling becomes apparent. Here are instructions for collecting a good representative soil sample:

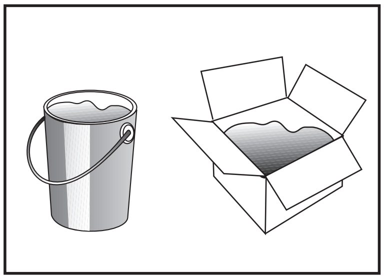
Sampling soil

1. Get **Soil Sample** Information Sheets and Soil Boxes. These may be obtained from your local Extension office or from the Virginia Tech Soil Testing Lab. Follow the directions they provide.

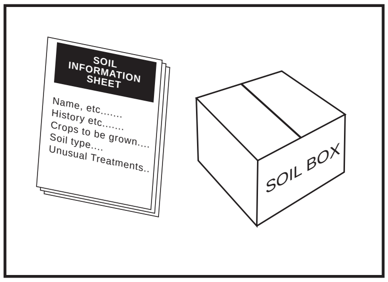
2. **Divide Farm** into Areas or Fields. If the field is uni form, one sample will do. But most fields will have been treated differently, or the slope, drainage, or soil type will make it desirable to divide the field into small areas of 5 to 10 acres each.

3. Obtain **a Good Sample** of Soil. The soil test can be no better than the sample. Take the sample from 20 or more places in the field. Zig-zag across the field or area as shown in the diagram. When taking the sample, avoid unusual places such as old fence rows, old roadbeds, eroded spots, where lime or manure have been piled, or in the fertilizer band of row crops.

4. Use Proper **Sampling Tools**. Sampling may be made with a soil auger, soil tube, or spade. The desired depth for cropland is plow depth (6 to 8" or more), and 2-4" for pasture land, or no-till crop fields. Place sample in clean container.



5. Mix Well in **Clean Plastic Pail.** From the 20 or more stops you have made, you now have one gallon or more of soil. Mix it thoroughly, then send about 1/2 pint of the mixed soil to the lab for analysis.



6. **Fill Out** a Soil Sample Information Sheet for Each Sample. It is essential that your name, address, and sample number be plainly written on the sheet you send with each sample. As a guide in making recommendations for each of your numbered areas, it is important that the history of fertilization, liming and any unusual treatments be stated.

7. **Mail** to Soil Testing Laboratory. Place the Soil Sample Information Sheet inside the top flap of the soil box and mail to the Soil Testing Laboratory, Department of Crop & Soil Environmental Sciences (0465), Virginia Tech, Blacksburg, VA 24061.

Soil sampling for precision farming

Precision farming, also known as **site-specific management**, typically employs intensive soil sampling to map fertility in a field. Fertilizer and lime may then be applied at variable rates, according to the needs of the particular areas in the field. To begin, fields are first divided into grids, with typical grid size being 2.5 acres. For small fields, a one acre grid size will give a more precise representation of the fertility across the field, but for larger fields, this is usually not economically feasible. The grid is established using the Global Positioning Satellite (GPS) system. A radio receiver, connected to a portable computer, and mounted on an ATV, is used to receive satellite coordinate signals to map the field and locate the grid points. Soil samples are then collected at each grid point, with 6-8 subsamples being taken in a 10' circle around the ATV, and mixed together for a composite sample. After lab analysis, soil test information from the field can then be fed into a computer mounted in a variable-rate fertilizer/lime spreader with GPS receiver, and material can then be applied according to the needs of the various areas in the field.

"Smart sampling" techniques may also be employed to sample a field. This may be done in lieu of the above standard (uniform) grid sampling or as a followup to an initial grid sampling of the entire field. "Smart sampling" consists of sampling those areas of the field that are obviously different, such as with respect to topography (hilltops, low areas), or if a combine yield monitor has been used, high-yielding and low-yielding areas in the field. If yield data are not available, one often times has a good idea of the high-yielding and low-yielding areas in his field. These should be sampled separately. If the field has been mapped, it can be divided by soil series (i.e., soil mapping unit). Grid points should be located or grouped in those areas with unique visible or measurable differences.

Using the Soil Test Report – The Soil Test Report will contain the laboratory test results plus fertilizer and lime recommendations. Additional information regarding time and method of fertilizer and lime application will also be provided in the form of a Soil Test Note or Notes which will accompany the report. When several samples have been collected from the same field, the soil test reports should be compared to determine the best rates of fertilizer and lime to use for the field. Large differences in the reports may call for fertilizer and/or lime at two or more different rates. Advice on how to best fertilize a given field can be obtained from your local Extension agent or fertilizer dealer.

Plant Analysis

Sampling Instructions

1. **Avoid** submitting sample tissue that is contaminated with dust or soil. If tissue is dusty or dirty, remove as much of it as you can by shaking, brushing, or washing the tissue in gently-flowing water.
2. **Do not** sample disease, insect, or mechanically damaged plant tissue.
3. **Place** the plant tissue in a clean paper bag. Do *not* use plastic bags. If the sample is wet or succulent, let it air-dry in the open for one day before sending it to the laboratory. Identify each sample by number and crop name.
4. **When using** tissue analysis in the diagnosis of crop productions problems, take one sample from the *problem* area in the field and one from an area where plants appear *normal*.
5. **When sampling**, both the *time* (growth stage) and *plant part* collected are important. Be sure to sample at the recommended time and collect the proper plant part.
6. **If you do not have** specific sampling instructions for the crop you wish to have analyzed, a good rule of thumb is to sample mature leaves that are representative of the current season's growth during the mid period of the growth cycle or just prior to seed set.
7. **Submit samples** to recommended labs for testing. **Virginia Tech does not run tissue analysis.**

Interpreting the Laboratory Results – The Plant Analysis Report will contain the tissue test results plus the optimum nutrient ranges for the crop sample. Note whether levels are deficient, borderline, or adequate for good crop growth. Also, make comparisons in soil nutrient levels between problem versus normal areas, noting any differences and whether they are small or large. Depending on what nutrient or nutrients are deficient and the stage of growth of the crop, it may or may not be worthwhile making additional fertilizer applications for the present crop. If trace element deficiency is noted and it is early enough in the growing season, a foliar application of the trace element can be applied to correct the problem. Following harvest, a more lasting soil application can be made for the next crop in the rotation. If low magnesium and phosphorus plant tissue levels are observed and the corresponding Soil Test Report indicates that the pH is low, it may not be possible to correct the problem for the present crop. Lime needs to be in the root zone to correct the problem and this can be a difficult thing to do if it is not possible to till the lime into the soil. However, remedial action can and should be taken to ensure that the problem does not arise in future crops. The actual treatment needed will depend on the nature and severity of the problem and the economics involved. In most cases, it is usually worth the cost and effort to correct the problem.

Table 1. Sampling Instructions for Field Crops

Crop	Time	Plant Part to Sample	No. of Plants to Sample
Alfalfa	Early bloom	Top 4-6" of plant	30
Bermudagrass	Optimum time for maximum quality hay	Upper half of plant	50
Corn	Prior to 4th leaf stage	Whole plant, cutting at ground level	30
	Prior to tasseling	Entire leaf immediately below whorl, removing at stalk	20
	At silk when silks are still green	Entire ear leaf, removing at stalk	20
Cotton	At full bloom	Youngest recently mature leaves on main stem, collecting 2 leaves per plant	25
Peanut	At bloom stage	Last fully mature leaves at top of the plant, collecting 3 leaves per plant	25
Small Grains	Prior to jointing	Whole plant above ground, remove dead leaves	50
	Jointing to heading	Uppermost fully developed leaf	50
Soybeans	Prior to or at initial bloom	Uppermost fully developed trifoliate leaf set (composed of 3 leaflets) per plant. Remove leaf stem (petiole)	25
Tobacco	Prior to or at bloom	Entire 4th leaf from the top of the plant	15

Table 2. Sampling Instructions for Fruit, Nut,

Crop	Time	Plant Part to Sample	No. of Plants to Sample
Fruit, nut			
Apple	8 to 10 weeks after full bloom	Leaves from spurs or near base of current season's growth, taking 4 to 8 leaves per tree	25 trees
Blueberry	Mid-summer	Mature leaves from mid-portion of of current season's growth, taking 4 to 8 leaves per bush	25 bushes
Cherry	Mid-summer	Mature leaves near base of current season's terminal growth, taking 4 to 8 leaves per tree	25 trees
Grape	4 to 8 weeks after peak bloom	Petioles only (discard leaves) from mature leaves or nodes just beyond fruiting clusters	50 petioles
Peach	12 to 14 weeks after bloom	Mature leaves from mid-portion or near base of current season's terminal growth, taking 4 to 8 leaves per tree	25 trees
Pear	Mid-summer	Mature leaves from spurs, taking 4 to 8 leaves per tree	25 trees
Pecan	July 7 to August 7	Middle pair of leaflets from middle leaf of terminals around periphery of tree	25 trees
Vegetable			
Asparagus	Midgrowth	Mature fern from 18-36" up	10
Beet	Midgrowth	Young mature leaf, 3 leaves/plant	25
Broccoli	Heading	Young mature leaf, 2 leaves/plant	
Brussels sprout	Midgrowth	Young mature leaf, 3 leaves/plant	25
Cabbage	Head half grown	Young wrapper leaf, 2 leaves/plant	30
Cantaloupe	Prior to or at initial fruit set	Mature leaf near growing tip, 3 leaves/plant	25
Cauliflower	Buttoning	Mature leaf with stem removed	30
Collards	Midgrowth	Young mature leaf, 3 leaves/plant	25
Cucumber	Prior to or at initial fruit set	Mature leaf near growing tip, 3 leaves/plant	25
Green beans	Prior to or at early bloom	Uppermost mature leaves, 3 leaves/plant	20
Kale	Midgrowth	Young mature leaf, 3 leaves/plant	30
Onion	Midgrowth	Young mature leaf, 2 leaves/plant	30
Peas	Bud to full bloom	Entire top growth	15
Peppers, bell	Midgrowth	Young mature leaf, 3 leaves/plant	30
Potatoes, Irish	Tubers half grown	Young mature leaf, 3 leaves/plant	25
Spinach	Midgrowth	Young mature leaf, 2 leaves/plant	25
Sweet corn	At silking when silks are green	Entire ear leaf, removing at stalk	20
Sweet potato	Midgrowth	4^{th} leaf from a primary vine, counting down from growing tip	30
Tomato,	Early fruiting	3^{rd} and 4^{th} leaf from growing tip mech. harvest	50
Turnip greens	Midseason	Young mature leaf, 3 leaves/plant	25
Watermelon	Prior to or at initial fruit set	Mature leaf near growing tip, 3 leaves/plant	25
Turf			
Kentucky bluegrass	Normal growing season mowing	Clippings 7 to 14 days after last	1 pint

Table 3. Plant Nutrient Sufficiency Ranges for Field, Forage, Fruit, and Nut Crops*

Crop**	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Mo
	%					ppm					
Field, Forage											
Alfalfa	4.50-5.00	0.35	2.20	0.80	0.40	25	30	15	7	15	0.5
Bermudagrass	2.00-3.00	0.20-0.50	1.50-2.50	0.25-0.75	0.15-0.50	50-250	50-300	5-20	6-20	20-50	-
Corn-up to 12” tall	3.50-5.00	0.30-0.50	3.00-4.00	0.30-0.70	0.20-0.60	30-300	50-250	4-25	3-20	20-60	0.2
Corn-ear leaf at silk or leaf below whorl	3.00-3.50	0.25-0.45	2.00-2.75	0.25-0.80	0.20-0.50	30-200	50-300	3-20	3-20	20-60	0.2
Cotton	3.50-4.50	0.30-0.50	2.00-3.00	2.25-3.00	0.50-0.90	50-350	50-250	20-60	8-20	20-60	—
Peanut	3.50-4.50	0.25-0.50	2.00-3.00	1.25-2.00	0.30-0.80	50-350	50-300	25-60	-	20-50	0.5
Small grains	4.00-5.00	0.20-0.40	1.50-3.00	0.20-0.50	0.15-0.50	25-100	25-100	3-20	5-25	20-70	—
Soybeans	4.25-5.00	0.30-0.50	1.75-2.50	0.50-1.50	0.25-0.80	20-200	50-300	25-60	6-30	20-50	0.5
Tobacco	3.50-4.25	0.25-0.50	2.50-3.20	1.50-3.50	0.20-0.65	30-250	50-200	20-50	15-60	20-80	—
Fruit, Nut											
Apple	2.00-3.00	0.15-0.50	1.25-3.00	1.00-2.00	0.20-0.50	20-200	50-400	20-60	5-20	15-50	—
Blueberry	1.80-2.00	0.10-0.20	0.40-0.60	0.30-0.75	0.20-0.30	20-200	60-150	10-50	10-20	10-50	—
Cherry	2.00-3.00	0.15-0.50	1.25-2.50	1.50-2.50	0.20-0.50	20-200	50-400	20-60	5-20	15-50	—
Grape	0.80-1.00	0.20-0.50	1.50-2.50	1.75	0.40-0.80	30-200	30	40-60	5-20	20-50	—
Peach	2.75-3.50	0.25-0.50	1.20-2.50	1.50-2.50	0.20-0.50	20-200	60-400	20-100	5-20	15-50	—
Pear	2.20-3.00	0.15-0.50	1.00-3.00	1.00-2.00	0.20-0.50	20-200	50-400	20-60	5-20	15-50	—
Pecan	2.50-3.90	0.12-0.30	1.00-1.50	0.70-1.50	0.30-0.60	100-800	50-300	20-45	10-30	50-100	—

*In general, if leaf composition is less than the lower value, yields may be reduced and deficiency symptoms may be visible. When leaf composition values are greater than the upper value, in some cases yields may be reduced and toxicity symptoms may be visible. **It should be noted that** temperature, moisture, and other factors also influence plant nutrient levels and sometimes make the interpretation of results difficult. Where possible, tissue analysis results should be compared between problem and normal growth areas and also compared with soil test results before a diagnosis is made. Information on crop management (planting time, depth, etc.) should also be included in the diagnosis.

****Sufficiency ranges are only applicable to the plant part and time of sampling specified in Tables 1 and 2. These values do not apply to other plant parts or times of sampling.**

Table 4. Common Plant Nutrient Ranges Found in Vegetable Crops and Turf

Crop*	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn
Vegetable	%					ppm				
Asparagus	2.4-3.8	0.30-0.35	1.5-2.4	0.40-0.50	0.15-0.20	10-160	-	50-100	-	20-60
Beet	3.5-5.0	0.20-0.30	2.0-4.0	2.5-3.5	0.30-0.80	70-200	-	60-80	-	15-30
Broccoli	3.2-5.5	0.30-0.70	2.0-4.0	1.2-2.5	0.23-0.40	25-150	100-300	30-100	1-5	45-95
Brussels sprout	2.2-4.2	0.26-0.45	2.4-3.4	0.3-2.2	0.23-0.40	-	-	30-40	-	-
Cabbage	3.0-4.0	0.30-0.50	3.0-4.0	1.5-3.5	0.25-0.45	-	30-60	30-60	-	20-30
Cantaloupe	2.0-3.0	0.25-0.40	1.8-2.5	5.0-7.0	1.0-1.5	-	-	30-80	-	30-50
Cauliflower	3.0-4.5	0.54-0.72	3.0-3.7	0.72-0.79	0.24-0.26	-	-	-	-	43-59
Collards	4.0-5.0	0.30-0.60	3.0-4.0	3.0-4.0	-	-	-	50-80	-	-
Cucumber	-	-	-	-	-	-	-	50-80	-	20-40
Green beans	3.0-6.0	0.25-0.50	1.8-2.5	0.8-3.0	0.25-0.70	30-300	300-450	40-60	15-30	30-60
Kale	4.0-5.0	0.30-0.60	3.0-4.0	3.0-4.0	-	-	-	50-80	-	-
Onion	1.5-2.5	0.25-0.40	-	-	-	-	-	30-45	-	10-15
Peas	3.1-3.6	0.30-0.35	2.2-2.8	1.2-1.5	0.27-0.35	-	-	20-60	-	-
Peppers, bell	3.0-4.5	0.30-0.70	4.0-5.4	0.4-0.6	1.0-1.7	-	-	40-100	10-20	-
Potatoes, Irish	3.0-5.0	0.20-0.40	4.0-8.0	2.0-4.0	0.5-0.8	30-50	70-150	30-40	-	20-40
Spinach	4.0-6.0	0.30-0.50	3.0-4.0	0.6-1.0	1.6-1.8	30-60	220-245	40-60	5-7	50-75
Sweet corn-ear leaf at silk	2.6-3.5	0.20-0.30	1.8-2.5	0.15-0.30	0.20-0.30	-	-	20-30	-	-
Sweet potato	3.2-4.2	0.20-0.30	2.9-4.3	0.75-0.95	0.40-0.80	40-100	-	-	-	-
Tomato, mech. harvest	3.0-6.0	0.50-0.80	2.5-4.0	0.6-0.9	60-100	-	40-80	4-8	15-30	
Turnip greens	3.5-4.5	0.35-0.60	-	3.0-5.0	-	60-80	-	30-60	-	-
Watermelon	2.0-3.0	0.20-0.30	2.5-3.5	2.5-3.5	0.6-0.8	-	-	-	4-8	-
Turf										
KY bluegrass	2.2-3.8	0.30-0.55	1.8-3.0	0.75-1.35	0.25-0.50	150-400	100-200	10-30	10-20	35-45

*Nutrient ranges apply only to the plant part and time of sampling specified in Table 2. These values do not apply to other plant parts or times of sampling.

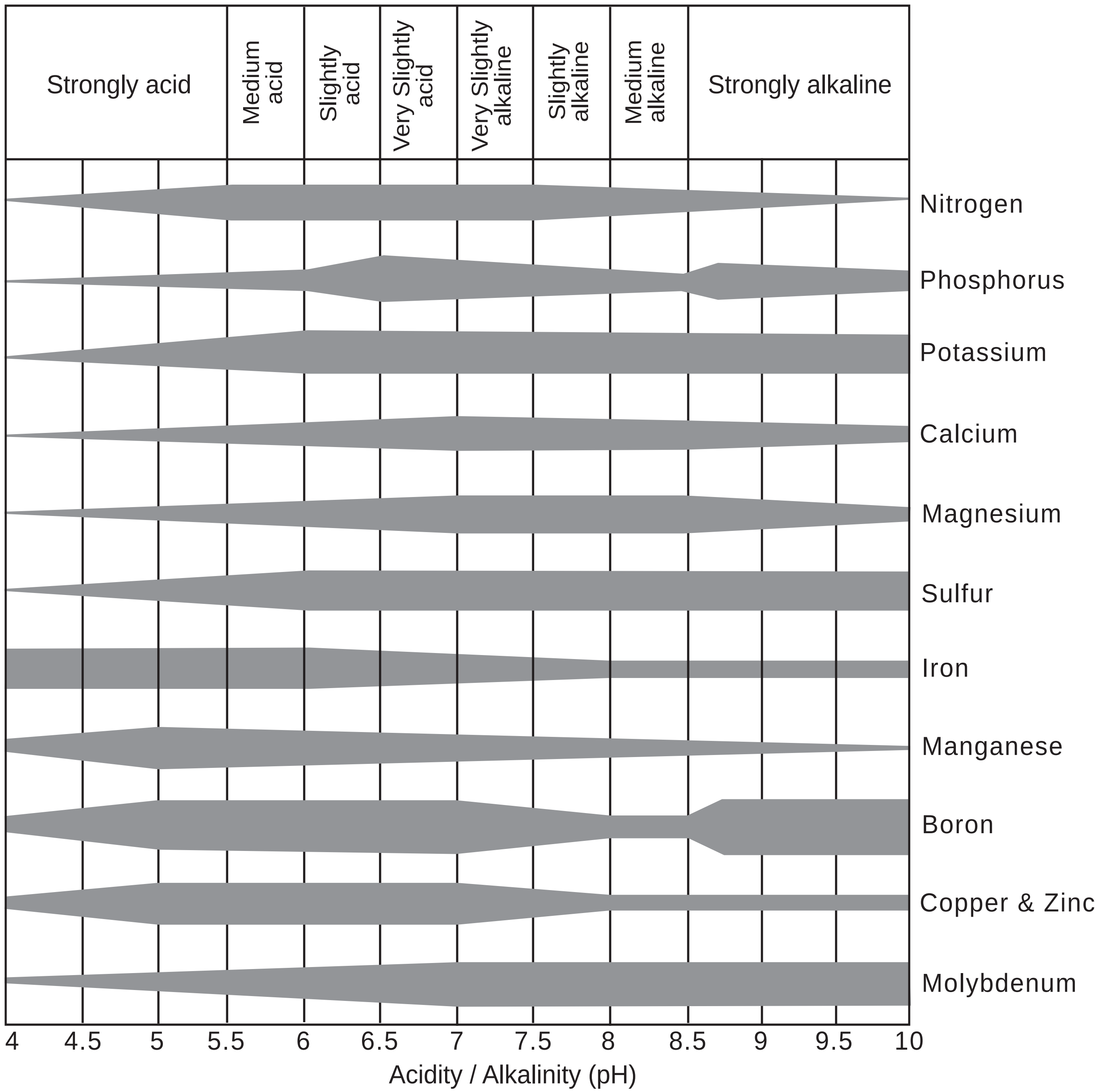
Nutrient Removal By Crops

Crop	Plant part	Acre yield	N	P as P_2O_5	K as K_2O	Ca	Mg	S	Cu	Mn	Zn
					lbs						
Row Crops											
Barley	grain	80 bu	70	30	20	2	4	6	0.06	0.06	0.12
Barley	straw	2 ton	30	10	60	16	4	8	0.02	0.64	0.10
	Total		100	40	80	18	8	14	0.08	0.70	0.22
Corn	grain	150 bu	135	53	40	2	8	10	0.06	0.09	0.15
Corn	stover	4.5 tons	100	37	145	26	20	14	0.05	1.50	0.30
	Total		235	90	185	28	28	24	0.11	1.59	0.45
Cotton	seed and lint	1500 lbs	40	20	15	2	4	3	0.06	0.11	0.32
Cotton	stalks, leaves	2000 lbs	35	10	35	28	8	15	-	-	-
	Total		75	30	50	30	12	18			
Oats	grain	80 bu	50	20	15	2	3	5	0.03	0.12	0.05
Oats	straw	2 tons	25	15	80	8	8	9	0.03	-	0.29
	Total		75	35	95	10	11	14	0.06	-	0.34
Peanuts	nuts	1.25 tons	90	10	15	1	3	6	0.02	0.01	-
Peanuts	vines	4500 lbs	105	25	95	-	-	-	-	-	-
	Total		195	35	110						
Sorghum	grain	60 bu	50	25	15	4	5	5	0.01	0.04	0.04
Sorghum	stover	3 tons	65	20	95	29	18	-	-	-	-
	Total		115	45	110	33	23	-	-	-	-
Soybeans	grain	40 bu	150	35	57	7	7	4	0.04	0.05	0.04
Soybeans	straw		30	10	25	-	-	-	-	-	-
	Total		180	45	80						
Tobacco	leaves	2000 lbs	75	15	120	75	18	14	0.03	0.55	0.07
Tobacco	stalks		35	15	50	-	-	-	-	-	-
	Total		110	30	170						
Wheat	grain	80 bu	100	45	49	2	16	8	0.06	0.18	0.28
Wheat	straw	2.0 tons	34	9	113	12	8	12	0.02	0.32	0.10
	Total		134	54	162	14	24	20	0.08	0.50	0.38
Hay											
Alfalfa		4 tons	180	40	180	112	12	19	0.06	0.44	0.42
Bluegrass		2 tons	60	20	60	16	7	5	0.02	0.30	0.08
Coastal bermudagrass		8 tons	300	70	270	59	24	35	0.21	-	-
Red clover		2.5 tons	100	25	100	69	17	7	0.04	0.54	0.36
Soybean		2 tons	90	20	50	40	18	10	0.04	0.46	0.15
Timothy		2.5 tons	60	25	95	18	6	5	0.03	0.31	0.20
Fruits, Vegetables											
Apples		500 bu	30	10	45	8	5	10	0.03	0.03	0.03
Cabbage		20 tons	130	35	130	20	8	44	0.04	0.10	0.08
Grapes	fruit	5 tons	15	10	25	-	-	-	-	-	-
Grapes	leaves & wood		20	5	20	-	-	-	-	-	-
	Total		35	15	45	-	-	-	-	-	-
Muskmelon	fruit	7 tons	30	11	60	-	-	-	-	-	-
Muskmelon	vines	1.5 tons	20	5	30	-	-	-	-	-	-
	Total		50	15	90	-	-	-	-	-	-
Peaches		600 bu	35	20	65	4	8	2	-	-	0.01
Potatoes	tubers	400 bu	80	30	150	3	6	6	0.04	0.09	0.05
Sweet potatoes	roots	300 bu	45	15	75	4	9	6	0.03	0.06	0.03
Tomatoes	fruit	20 tons	120	40	160	7	11	14	0.07	0.13	0.16

General Crop Nutrient Deficiency Symptoms

Nutrient	Deficiency Symptoms*
Nitrogen (N)	Restricted growth of tops and roots; growth upright and spindly; leaves pale and yellowish-green in early stages, more yellow and even orange or red in later stages; deficiency shows up first on lower leaves.
Phosphorus (P)	Restricted growth of tops and roots; growth is upright and spindly; leaves bluish-green in early stages with green color sometimes darker than plants supplied with adequate phosphorus; more purplish in later stages with occasional browning of leaf margins; defoliation is premature, starting at the older leaves.
Potassium (K)	Browning of leaf tips; marginal scorching of leaf edges; development of brown or light colored spots in some species which is usually more numerous near the margins; deficiency shows up first on lower foliage.
Calcium (Ca)	Deficiency occurs mainly in younger leaves near the growing point; younger leaves distorted with tips hooked back and margins curled backward or forward; leaf margins may be irregular and display brown scorching or spotting.
Magnesium (Mg)	Interveinal chlorosis with chlorotic areas separated by green tissue in earlier stages giving a beaded streaking effect; deficiency occurs first on lower foliage.
Sulfur (S)	Younger foliage is pale yellowish-green, similar to nitrogen deficiency; shoot growth somewhat restricted.
Zinc (Zn)	Interveinal chlorosis followed by die back of chlorotic areas.
Manganese (Mn)	Light green to yellow leaves with distinctly green veins; in severe cases, brown spots appear on the leaves and the leaves are shed; usually begins with younger leaves.
Boron (B)	Growing points severely affected; stems and leaves may show considerable distortion; upper leaves are often yellowish red and may be scorched or curled.
Copper (Cu)	Younger leaves become pale green with some marginal chlorosis.
Iron (Fe)	Interveinal chlorosis of younger leaves.
Molybdenum (Mo)	Leaves become chlorotic, developing rolled or cupped margins; plants deficient in this element often become nitrogen deficient.
Chlorine (Cl)	Deficiency not observed under field conditions.

Relationship Between Soil pH and the Availability of Minerals
That Are Essential for Plant Growth.
The Varying Thickness of Each Band Indicates the Availability of the Minerals. [a]



[a]The Nature and Properties of Soils 12th ed. Nyle C. Brady and Ray R. Weil. Prentice Hall. Pg. 36.
Revised from N. A. Pettinger's, "A Useful Chart for Teaching the Relation of Soil Reaction to the Availability of Plant Nutrients to Crops", Virginia Polytechnic Institute, March, 1935.

Soil Testing Lab Conversion Factors

Periodically we in Extension receive requests for **information on interpretation** of soil test results from laboratories which use procedures that are different than ours. Very simply, different procedures usually extract different amounts of nutrients from the soil. However, any good soil testing procedure, when properly correlated with plant growth, can be used as a basis for making fertilizer recommendations. In the Virginia Tech Soil Testing Laboratory, we use the Mehlich 1 (0.05N HCl + 0.025N H_2SO_4) soil test procedure to extract both phosphorus and potassium since we have done considerable research to correlate test results obtained by this method with plant growth. Other procedures, however, may extract more or less nutrients than the Mehlich 1 procedure does, and therefore, values obtained by these other methods cannot be used directly to make fertilizer recommendations. **They must first be converted to equivalent Virginia Tech test levels.**

The following are **conversion factors** for converting private and other state lab phosphorus and potassium test results to Virginia Tech test values. The conversion factors are approximate values only and they vary depending on soil type, type of clay, past fertilization, etc. However, they should put one in the “ballpark” with respect to Virginia Tech test levels.

1. Converting Bray P_1 (Weak Bray) Phosphorus to Virginia Tech Mehlich 1 Phosphorus

pH < 5.6	Weak Bray P, ppm x 0.6 = Virginia Tech P, ppm
	Weak Bray P, ppm x 1.2 = Virginia Tech P, lb/A
pH 5.6 – 6.2	Weak Bray P, ppm x 0.7 = Virginia Tech P, ppm
	Weak Bray P, ppm x 1.4 = Virginia Tech P, lb/A
pH 6.3 – 6.9	Weak Bray P, ppm x 0.8 = Virginia Tech P, ppm
	Weak Bray P, ppm x 1.6 = Virginia Tech P, lb/A
pH > 6.9	Weak Bray P, ppm x 1.2 = Virginia Tech P, ppm
	Weak Bray P, ppm x 2.4 = Virginia Tech P, lb/A

2. Converting Ammonium Acetate Potassium to Virginia Tech Mehlich 1 Potassium

Ammonium Acetate K, ppm x 0.67 = Virginia Tech K, ppm

Ammonium Acetate K, ppm x 1.33 = Virginia Tech K, lb/A

3. Converting Mehlich 3 Phosphorus to Virginia Tech Mehlich 1 Phosphorus

Preliminary research indicates that, for Mid-Atlantic soils, the Mehlich 3 phosphorus procedure extracts approximately the same amount of phosphorus as the Bray P_1 (Weak Bray) procedure. Therefore, use the same conversion factor as given for Bray P_1 to convert Mehlich 3 phosphorus to Virginia Tech phosphorus.

4. Converting Mehlich 3 Potassium to Virginia Tech Mehlich 1 Potassium

Preliminary research indicates that, for Mid-Atlantic soils, the Mehlich 3 potassium procedure extracts approximately the same amount of potassium as the ammonium acetate procedure. Therefore, use the same conversion factor as given for ammonium acetate to convert Mehlich 3 potassium to Virginia Tech potassium.

5. Calibration of Phosphorus (P) and Potassium (K) Tests, Virginia Tech Soil Testing Laboratory

Soil Test P	lb/A	P-ppm
L-	0-3	0-2
L	4-8	2-4
L+	9-11	5-6
M-	12-20	6-10
M	21-30	11-15
M+	31-35	16-18
H-	36-55	18-28
H	56-85	28-43
H+	86-110	43-55
VH	110+	55+

Soil Test K	lb/A	K-ppm
-	0-15	0-8
L	16-55	8-28
+	56-75	28-38
M-	76-100	38-50
M	101-150	51-75
M+	151-175	76-88
H-	176-210	88-105
H	211-280	106-140
H+	281-310	141-155
VH	310+	155+

6. Other Useful Conversion Factors

P	x	2.3	=	P_2O_5
P_2O_5	x	0.44	=	P
K	x	1.2	=	K_2O
K_2O	x	0.83	=	K
ppm	x	2.0	=	lbs/A
lbs/A	x	0.5	=	ppm

PART VIII
Fertilizers

Marcus M. Alley, Extension Soil Fertility and Crop Management Specialist

Composition of Principle Fertilizer Materials

	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)	Physical State
Material Supplying	**%**	**%**	**%**	
Nitrogen				
Ammonium nitrate	33-34	0	0	solid
Anhydrous ammonia	82	0	0	gas
Ammonium thiosulfate	12	-	26	liquid
Calcium nitrate	15	0	0	solid
Sodium nitrate	16	0	0	solid
Urea-ammonium nitrate	28-32	0	0	liquid
Ammonium sulfate	21	0	0	solid
Urea	45-46	0	0	solid
Phosphorus				
Ammonium polyphosphate (APP)	10	34-37	0	liquid
Diammonium phosphate (DAP)	18-21	46-53	0	sold
Ground bone (raw)	2.5 to 4	20-25	0	solid
Ground rock phosphate	0	25-40 (14-65% avail.)	0	solid
Monammonium phosphate (MAP)	11-13	48-62	0	solid
Steamed bone meal	1 to 2.5	22-30	0	solid
Superphosphate, normal	0	16-22	0	solid
Superphosphate, triple	0	44-53	0	solid
Potassium				
Muriate of potash (potassium chloride	0	0	60-62	solid
Potassium nitrate	13	0	44	solid
Potassium sulfate	0	0	50-53	solid
Potassium thiosulfate	-	0	25	liquid
Potassium orthophosphate	-	30-50		
Potassium magnesium sulfate	0	0	22	solid

Sources of calcium, magnesium, sulfur, and micronutrients

Calcium sources		
Material	**Chemical Formula**	**% Ca**
Calcitic lime	$CaCO_3$	31.7
Calcium nitrate	$Ca(NO_3)_2$	19.4
Dolomitic lime	$CaCO_3+MgCO_3$	21.5
Gypsum	$CaSO_4 \bullet 2H_20$	22.5
Hydrated lime	$Ca(OH)_2$	46.1
Marl	$CaCO_3$	24.0
Superphosphate, normal	$Ca(H_2PO_4)_2$	20.4
Superphosphate, triple	$Ca(H_2PO_4)_2$	13.6
Sulfur sources		
Material	**Chemical Formula**	**% S**
Ammonium sulfate	$(NH_4)_2SO_4$	24
Gypsum	$CaSO_4 \bullet 2H_20$	16.8
K-Mg-sulfate	$K_2SO_4 \bullet 2MgSO_4$	22.0
Sulfur, elemental	S	32-33
Potassium thiosulfate	$(NH_4)_2S_2O_3$	17
Ammonium thiosulfate	$K_2S_2O_3$	26
Boron sources		
Material	**Chemical Formula**	**% B**
Boron frits	Frit	10-17
Borax	$Na_2B_4O_7 \bullet 10H_2O$	11
Boric acid	H_3BO_3	17
Sodium pentaborate	$Na_2B_{10}O_{16} \bullet 10H_2O$	18
Sodium tetraborate		
Fert. borate-46	$Na_2B_4O_7 \bullet 5H_2O$	14
Fert. borate-65	$Na_2B_4O_7$	20
Solubor	$Na_2B_{10}O_{16} \bullet 10H_2O$ + $Na_2B_4O_7 \bullet 5H_2O$	20
Molybdenum sources		
Material	**Chemical Formula**	**% Mo**
Ammonium molybdate	$(NH_4)_6Mo_7O_{24} \bullet 2H_2O$	54
Molybdenum trioxide	MoO_3	66
Molybdenum frit	Frit	1-30
Sodium molybdate	$Na_2MoO_4 \bullet 2H_2O$	39
Copper sources		
Material	**Chemical Formula**	**% Cu**
Copper ammonium phosphate	$Cu(NH_4)PO_4 \bullet H_2O$	32
Copper chelates	$Na_2CuEDTA$	13
	NaCuHEDTA	9
Copper frits	Frit	40-50
Copper sulfate	$CuSO_4 \bullet 5H_2O$	25
Magnesium sources		
Material	**Chemical Formula**	**% Mg**
Dolomitic lime	$MgCO_3+CaCO_3$	11.4
Epsom salt	$MgSO_4 \bullet 7H_2O$	9.6
Magnesia	MgO	55.0
Potassium-magnesium sulfate	$K_2SO_4 \bullet 2MgSO_4$	11.2
Manganese sources		
Material	**Chemical Formula**	**% Mn**
Manganese chelate	MnEDTA	12
Manganese sulfate	$MnSO_4 \bullet 4H_2O$	26-28
Manganese frit	Frit	35
Manganese oxide	MnO	41-68
Zinc sources		
Material	**Chemical Formula**	**% Zn**
Zinc carbonate	$ZnCO_3$	52
Zinc chelates	$Na_2ZnEDTA$	14
	NaZnHEDTA	9
Zinc oxide	ZnO	78
Zinc sulfate	$ZnSO_4 \bullet H_2O$	35
Iron sources		
Material	**Chemical Formula**	**% Fe**
Iron sulfate	$FeSO_4 \bullet 7H_2O$	19
Iron ammonium phosphate	$Fe(NH_4)PO_4 \bullet H_2O$	29
Iron ammonium polyphosphate	$Fe(NH_4)HP_2O_7$	22
Iron frits	Frit	30-40
Iron chelates	NaFeEDTA	5-14
	NaFeDTPA	10
	NaFeEDDHA	6

Conversion factors

Converting the percentage of one material to percentage of another may be done easily with a conversion factor, some of which are listed below. For example, to convert the percentage of K to K_2O, multiply the percentage of K by 1.2051; in like manner, the percentage of K_2O may be converted to K by multiplying the percentage of K_2O by 0.8301.

K to K_2O	multiply K	by 1.2051
K_2O to K	multiply K_2O	by 0.8301
KCl to K	multiply KCl	by 0.5244
KCl to Cl	multiply KCl	by 0.4756
K_2SO_4 to K	multiply K_2SO_4	by 0.4487
Mg to MgO	multiply Mg	by 1.6578
MgO to Mg	multiply MgO	by 0.6032
$MgCO_3$ to MgO	multiply $MgCO_3$	by 0.4782
MgO to $MgCO_3$	multiply MgO	by 2.0913
$MgSO_4$ to Mg	multiply $MgSO_4$	by 0.2020
$MgCO_3$ to $CaCO_3$	multiply $MgCO_3$	by 1.1867
CaO to Ca	multiply CaO	by 0.7147
Ca to CaO	multiply Ca	by 1.3992
$CaCO_3$ to $MgCO_3$	multiply $CaCO_3$	by 0.8426
$CaCO_3$ to CaO	multiply $CaCO_3$	by 0.5603
K_2SO_4 to S	multiply K_2SO_4	by 0.1840
$CaSO_4$ to Ca	multiply $CaSO_4$	by 0.2938
$CaSO_4$ to S	multiply $CaSO_4$	by 0.2350
SO_4 to S	multiply SO_4	by 0.3339
S to SO_4	multiply S	by 2.9963
NaCl to Cl	multiply NaCl	by 0.6066
N to NH_3	multiply N	by 1.2158
N to KNO_3	multiply N	by 7.2162
NH_3 to N	multiply NH_3	by 0.8225
N to $(NH_4)_2SO_4$	multiply N	by 4.7160
$(NH_4)_2SO_4$ to N	multiply $(NH_4)_2SO_4$	by 0.2120
$(NH_4)_2SO_4$ to S	multiply $(NH_4)_2SO_4$	by 0.2427
N to NH_4NO_3	multiply N	by 2.8571
NH_4NO_3 to N	multiply NH_4NO_3	by 0.3500
P to P_2O_5	multiply P	by 2.2910
P_2O_5 to P	multiply P_2O_5	by 0.4365

PART IX
Lime

Marcus M. Alley, Extension Soil Fertility and Crop Management Specialist

Liming materials

The **quality** of agricultural lime is determined by its purity and fineness of grind, or mesh size. Purity affects the amount of aglime required per acre in adjusting soil pH to a given level. Mesh size affects the rate of reaction of lime in neutralizing soil acidity. For example, pulverized lime more coarse than 20 mesh has little value as an aglime material because of its very slow rate of reaction in the soil.

The **calcium carbonate equivalent** (CCE) of agricultural lime is directly related to its purity. Pure calcite, which is 100 percent calcium carbonate ($CaCO_3$), has a CCE value of 100; whereas pure dolomite ($CaCO_3$•$MgCO_3$) has a CCE of 108. The CCE and chemical composition of several common liming materials are shown in the following table. Equivalent amounts of different liming materials can be determined by using the neutralizing value (NV). For example, if 2 tons of calcitic lime with a CCE of 100 are recommended, and marl with a CCE of 75 is to be used, the CCE of calcitic lime (100) divided by the CCE of marl (75) times the recommended rate per acre of calcitic lime equals 2.66 tons. This is the amount of marl that would need to be applied to equal the acid neutralizing potential of two tons of calcitic lime. The lime recommendations of soil testing laboratories are generally based on liming materials which have a CCE of 100 and an assumed plowing depth of 6 inches. Any changes in the CCE of liming material and/or plowing depth will necessitate a recalculation of lime requirement.

Chemical Composition and Calcium Carbonate Equivalent of Certain Liming Materials

Lime material	Calcium carbonate equivalent
Calcitic lime $CaCO_3$ (pure)	100
Dolomitic lime $CaCO_3$•$MgCO_3$ (pure)	108
Burned lime CaO	150-175
Hydrated lime $CaOH_2$	110-135
Marl $CaCO_3$	70-90
Slags $CaSiO_3$	60-90

Liming materials marketed in Virginia

Companies marketing agricultural liming materials in Virginia **must be registered** with the Virginia Department of Agriculture and Consumer Services, PO Box 1163, Richmond, VA 23209 (804-786-3511). Further, the liming materials sold must pass the specifications stipulated in the Virginia Agricultural Liming Materials Law.

The **two types of agricultural limestone**, differing in mesh screen analysis, sold in Virginia are described in the following table. Mesh size is a measure of the number of openings in one square inch of screen. A 20-mesh screen contains 400 openings per square inch, whereas a 100-mesh screen contains 10,000 openings. Crushed limestone material passing a 100-mesh screen is finer and therefore reacts with soil acidity more rapidly than 20-mesh material. Pulverized limestone is, therefore, more reactive than ground limestone. However, reactivity rate does not increase greatly for particle sizes smaller than 100 mesh.

Mesh Screen Analysis of Agricultural Limestone Marketed in Virginia[1]

	Mesh screen size	Percent guaranteed to pass (5% Tolerance)
1. Ground limestone	20	90
	60	50
	100	30
2. Pulverized limestone	20	95
	100	70

[1]Minimum calcium carbonate equivalent of not less than 85%.

In addition to lime types based on mesh screen fractions, there are lime types based on kind of limestone, i.e., calcitic and dolomitic. In Virginia, agricultural limestone that contains 85% or more of the total neutralizing value in the calcium carbonate form is classified as calcitic, whereas limestone that contains 15% or more of the total carbonate content as magnesium carbonate is classified as dolomitic. Both are excellent liming materials; however, dolomitic lime should be used on soils testing low in magnesium.

When buying lime, one must be aware of the cost per unit of calcium carbonate equivalency. Neutralization potential increases with the increase in calcium carbonate equivalency value. In reality, aglime users are buying acid neutralizing potential that is associated with both calcium carbonate equivalence and fineness of grind.

PART X
Nutrient Management

Gregory K. Evanylo, Extension Waste Management, Soil and Water Specialist
Gregory L. Mullins, Extension Nutrient Management Specialist

Purpose of nutrient management planning

In 1983, a $27 million, six-year study by the U.S. EPA (1983) revealed that runoff from farmland is contributing to water quality decline in the Chesapeake Bay. Agricultural practices can adversely affect groundwater as well as surface water. Nutrients, particularly nitrogen (N) and phosphorus (P), are a major component of this form of pollution, termed nonpoint source (NPS) pollution. Life within rivers, streams, lakes and bays could not exist without nutrients, but an excess of nutrients can harm aquatic life.

It is estimated that 67% of the nitrogen and 39% of the phosphorus entering the Bay originate from non-point sources, with cropland agriculture contributing 60% of the nitrogen and 27% of the phosphorus entering the Bay. Nonpoint source pollution loadings from agriculture to the Bay must be reduced and managed in concert with other pollution reduction strategies if the degradation that the Bay and other water sources has undergone is going to be reversed.

Nutrient management involves the implementation of practices that permit efficient crop production and protect water quality from nutrient pollution. A nutrient management plan is a site-specific plan that addresses these issues. The goal of farm nutrient management planning is to minimize adverse environmental effects, primarily upon water quality, while optimizing farm profits. It should be recognized that some level of nutrient loss to the environment will occur even when the best nutrient management practices are employed; however, these losses should be lower than what would occur without nutrient management.

Fate and transport of nutrients of concern

Nitrogen

Nitrogen is an essential element for plant growth and animal nutrition and is the nutrient taken up in the largest amount by crops. Nitrate (NO_3^-), the major inorganic form of nitrogen in most soils, is quite mobile and moves freely with soil water. Nitrogen application to soils beyond that required for plant uptake will generally lead to nitrate leaching and long term groundwater degradation.

Elevated levels of nitrate in drinking water may lead to methemoglobinemia in infants, the formation of carcinogenic nitrosamines in the human stomach, and hypertension. A recent national groundwater study by the United States-Environmental Protection Agency (1990) found detectable nitrate in 52% of the 94,600 community water systems tested, indicating widespread movement to groundwater on a national scale. Movement of excessive amounts of nitrogen to surface waters can result in a number of undesirable effects such as eutrophication (nutrient enrichment) and associated algal blooms and oxygen depletion.

Phosphorus

Phosphorus, another major essential plant element, differs considerably from nitrate nitrogen in its water solubility and mobility. Phosphorus is very immobile in soil and seldom migrates downward to any great extent with soil water because it is strongly bound by and/or precipitated as highly insoluble soil minerals. Much of the fertilizer phosphorus applied to soils is retained in the near-surface layer in various inorganic precipitates and organically combined forms that prevent it from leaching.

While the risk of groundwater contamination by phosphorus from crop production systems is limited, the solid forms of phosphorus that accumulate in surface soil are subject to loss via erosion, the major water quality risk from phosphorus. Where erosion risk increases, such as for annual crops with conventional tillage, the total-P loss increases greatly as the phosphorus is moved in solid particulate form with the eroding soil.

Because phosphorus is strongly bound by soils, phosphorus runoff from permanently vegetated areas (e.g., perennial sods or forests) is minimal and largely occurs as traces of orthophosphate ($H_2PO_4^-$ or HPO_4^{2-}) ions in solution. Phosphorus in runoff can become a potential surface water quality problem where organic wastes (e.g., manures and biosolids) have been applied to supply crop nitrogen needs over long time periods. In these cases, high phosphorus concentrations may develop in the soil because the relative amounts of nitrogen and phosphorus applied in organic wastes are similar, but crops do not deplete soil phosphorus as rapidly as nitrogen. A portion of this phosphorus will occur as water soluble P, which is immediately available for biological uptake. Elevated phosphorus loadings lead to algal blooms and mats, heavy growth of aquatic plants and weeds, deoxygenation, and occasional problems with drinking water taste and odor.

Components of a nutrient management plan

Nutrient management plans must be developed on a site-specific basis and must be carefully tailored to specific soils and crop production systems. The following steps will generally be essential:

1. Obtain accurate soil information for each field or management unit, and analyze representative soil samples from each management unit. This may require a new farm soil map or a revision of existing United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) mapping coverage.

2. Determine the crop yield potential for each field, based on the known productivity of the soils coupled with the intended management practices.

3. Identify the total plant nutrient needs to achieve this expected yield potential.

4. Determine the plant-available nutrients in manures or biosolids to be used, considering the type of organic material to be used and its method of application.

5. Estimate the nutrient contribution that can be expected from residual effects or carryover from previous fertilizer, manure or biosolid applications.

6. Include credit for nitrogen supplied to row crops following a previous legume.

7. Recommend application rates for manure, other organic sources, and/or commercial fertilizers to supply the needed nutrients at the appropriate time for optimal crop production.

This process must be followed for all fields and production systems within a given planning area. The nutrient planning process is totally dependent upon the synthesis of information and data on the soils, cropping systems, manures, and management practices being employed over time. Therefore, care should be taken to ensure that the information used to specify the nutrient management plan is current and accurate.

Recognizing environmentally sensitive sites

The potential for plant nutrients (particularly N and P) to migrate to surface and groundwater is largely dependent upon soil and site conditions. An important part of nutrient management planning for agriculture is the recognition and delineation of environmentally sensitive sites and conditions and the development of specific management practices (Best Management Practices, BMP) to avoid detrimental effects. The soils and landscapes of Virginia vary greatly, but the following soil/landscape features and properties are particularly conducive to the loss of nutrients from agricultural practices:

1. Soils with high leaching potentials: This includes soils with very coarse textures and those where the water table is at or near the surface during the winter. If accurate soil survey information is available, the leaching index for a given soil can be obtained by following the procedures outlined in the USDA-NRCS Field Office Technical Guide (USDA Soil Conservation Service, 1990).

2. Lands with karst (sinkhole) drainage regimes: Sinkholes are landscape features commonly found in areas underlain by limestone bedrock or other highly soluble carbonate bearing parent materials. These areas mainly occur in the Valley and Ridge physiographic province but may also occur in the lower Coastal Plain. Sinkholes are formed by the long term dissolution of carbonates underlying the surface that eventually leaves a cavity that collapses over time. Sinkholes form a direct connection between surface water and groundwater and dye tracer tests have shown that water entering a sinkhole can contaminate nearby drinking wells within hours.

   If a sinkhole is located in an isolated high area of a field, a grassed buffer should be placed around it. If the sinkhole occurs on a sideslope or below a cropped field, significant runoff may drain into the sinkhole. The field area draining into the sinkhole would be best used for hay crops, pasture, or trees to reduce runoff. If the area is cropped, nutrient management practices should be intensive.

3. Shallow soils over fractured bedrock: Soils that are shallow (< 40 in.) to bedrock that is fractured should be managed like soils with a high leaching index. Although many of these soils are not highly leached, the water and any dissolved nutrients can move rapidly to groundwater once the soil water percolates to the fractured rock. Lists of shallow soils in each state can be obtained from the NRCS and by reviewing county soil surveys. Nutrient management should include such practices as split applications of nitrogen on crops and the use of winter cover crops to scavenge residual soil nitrogen in fields containing significant areas of these soils.

4. Tile drained lands: Fields that have been artificially drained should be treated as environmentally sensitive due to the direct connection of the tile outlets to surface watersheds. These lands are typically drained because they have a high seasonal water table, which can potentially pollute both the surface water with their drainage discharge and the local water table if nutrients are over-applied relative to crop uptake.

5. Irrigated lands: Fields receiving irrigation, because of the increased input of water, are prone to runoff and leaching of water and nutrients. The leaching index approach cannot be used on these areas since it would underestimate the actual leaching potential. To maximize water use efficiency and minimize leaching and runoff, irrigation scheduling methods should be used. These include the use of gypsum blocks, tensiometers, or computerized systems. When these indicators show the need for irrigation, rates and amounts of water should be based upon the soil type and water holding capacity to further reduce water and nutrient losses.

6. Excessively sloping lands: Lands with steep (i.e., >12 to 15 percent) and long slopes pose a high risk for the surface loss of applied nitrogen and phosphorus. Significant amounts of nutrients bound to sediment can be lost during heavy rainfall events if tillage is employed to incorporate nutrients. Manure applications on such slopes should be limited by P soil test needs or crop uptake estimates. Injection is the preferred manure application method. Soil conservation measures should be practiced on highly erodible lands.

7. Floodplains and other lands near surface waters: Agricultural land close to surface water can have a more direct impact on surface water quality. Surface flow of runoff water has little chance to be filtered before discharge into adjacent waters if channelized flow develops. Subsurface flow in groundwater can also directly seep into the adjacent surface water body. Wetlands can also reduce the potential for nitrogen contamination of surface waters by identifying nitrate contaminated water that enters the wetland. If manure or biosolids must be applied to a floodplain, incorporation or injection application methods should be used to minimize losses if flooding occurs.

The list of environmentally sensitive sites given above is not all-inclusive, but does include most of the major types of land with these concerns in Virginia. Appropriate setback or buffer areas should be established between these areas and any field receiving nutrient applications, and intensive nutrient management practices should be employed on any lands adjacent to sensitive areas.

On-farm Nutrient management planning

Nutrient cycles and management on different farm types

Considering some representative farm types and the management consequences of the nutrient cycles on each is helpful in understanding nutrient management planning. Nutrients come to a modern cash-crop farm in fertilizers and other materials applied directly to the fields (Figure 1a). Crops harvested from the fields remove a fraction of the applied nutrients which leave the farm when the crops are sold. Improper management of nutrients can result in significant losses other than removal in cash crop and negative economic consequences for the farmer; therefore, the cost of practices that reduce nutrient losses on a cash-crop farm can be at least partially offset by decreased costs in purchased fertilizer.

On farms with livestock (e.g., a dairy), a large proportion of the plant nutrients that were in the crops produced as feed for the animals are returned to the fields in manure from the animals (Figure 1b). Supplementing on-farm crop production with fertilizer, off-farm feeds or other animal inputs is more likely on a modern crop and livestock farm with ruminant animals than on traditional self sufficient crop and livestock farms. Thus, the manure produced by the animals is no longer spread on the fields where the crops were produced. The plant nutrients in the feed inputs can offset the nutrients removed from the farm as sold animal products.

Feed inputs enable farms to have more animals on fewer acres. Sometimes, these off-farm feed nutrients can exceed what is needed for crops grown on-farm and result in excessive manure nutrients that can be potential sources of water contamination. All sources of plant nutrients being applied to fields must be determined to protect the environment from negative impacts associated with the over-application of nutrients to crop fields.

Trends in animal housing and the success of crop production on cash-crop farms in specialized geographic regions have made it possible to concentrate large numbers of animals, such as poultry and swine, on small land areas. Most, if not all, of the feed necessary for these animals can be economically transported to the farm where the animals are housed (Figure 1c). Although poultry and swine farms may produce crops for off-farm sale, the land areas involved can be quite limited because the focus of the management activity is on animal production. The cash-crop farm and the intensive, modern livestock farm are connected by the flow of feed; however, nutrients in this flow often do not cycle back to their original locations. The application of nutrients to the fields on these farms is not closely related to the major production activity of the farm (i.e., selling animals or animal products). This will usually result in levels of nutrients in excess of the crop needs on the farm and a high potential for environmental problems.

Field-based agronomic practices may be of limited effectiveness in assimilating the total quantity of nutrients on intensive livestock farms because of the small land area on the farm. It is unlikely that environmental quality can be protected on poultry and swine farms solely by recycling nutrients for crop production. Successful management of nutrients to protect the environment will depend on support from off-farm people and organizations.

Animal density and nutrient balance

Animal density and the proportion of feed coming from off the farm are important features in determining the nutrient status of a farm. On low animal density farms (<1.25 animal equivalent units [AEU's] per acre) or those where little feed (<50%) comes from off the farm, manure nutrients produced on the farm will not meet total crop nutrient needs. In this group an appropriate management objective would be to maximize nutrient use efficiency on the farm. The environmental impact of these operations can be minimal if sound nutrient management principles are applied. Management decisions should be made based on expected crop response to nutrients (i.e., increasing yields or decreasing purchased inputs). Plans should utilize soil tests and manure analysis to assure distribution and timing of manure applications to maximize nutrient availability from the manure and minimize purchase of commercial fertilizer. Examples of practices that would be appropriate on this group of farms include: spring application of manure, immediate incorporation of manure, use of cover crops to scavenge nutrients, no manure spread on legumes, and efficient manure storage.

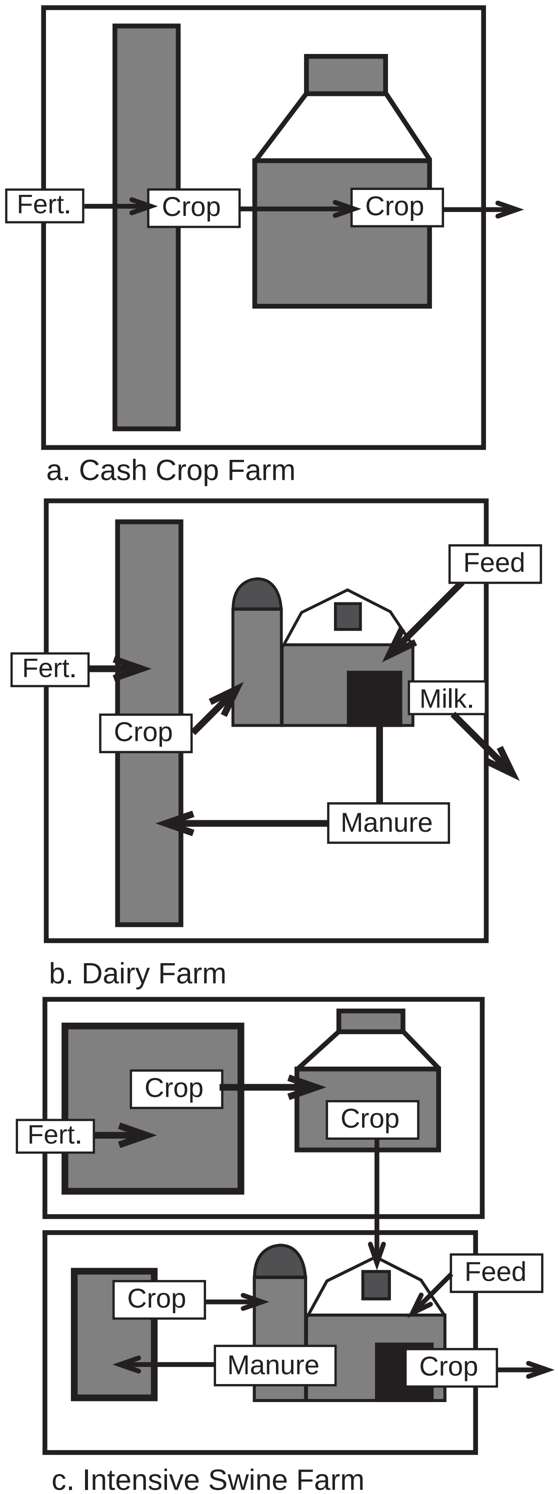


Figure 1. Nutrient Cycles on Different Types of Farms

Farms with medium animal density (1.25 - 2.25 AEU's/acre; 50-80% feed from off farm) supply manure nitrogen roughly equivalent to total crop needs, but excessive phosphorus supply is likely. An appropriate management objective for these farms would be to maximize environmentally safe nutrient use on the farm. Nutrient use efficiency will likely be a secondary concern if there is enough or more than enough nutrients on the farm to meet crop requirements. The major concern will be safely using all of the manure produced. There is good potential for environmental benefits from improved management on these farms. Changes in the overall farm management, such as altering the cropping system, may be necessary on this group of farms. A detailed manure management plan, based on nutrient balance rather than crop response, will probably be necessary on these farms.

On high intensity farms (>2.25 AEU's/acre; >80% feed from off farm), livestock manure production often significantly exceeds total crop nutrient needs. On these farms, the management objective will be to use every available means to remove excess manure not needed for crop production. Alternative off-farm uses for the manure will need to be explored. Often, this will mean locating a market for the manure and arranging the logistics of transportation and appropriate application. The on-farm plans for this group of farms will involve determining the maximum amount of manure that can be safely applied on the farm and the appropriate timing of application to minimize environmental impact. High intensity farms have the highest potential to negatively impact the environment. In many cases, unless a favorable marketing arrangement can be developed, implementing improved nutrient management on this group of farms will have a negative economic impact on the farm.

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PART X
Nutrient Management

Gregory K. Evanylo, Extension Waste Management, Soil and Water Specialist
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   If a sinkhole is located in an isolated high area of a field, a grassed buffer should be placed around it. If the sinkhole occurs on a sideslope or below a cropped field, significant runoff may drain into the sinkhole. The field area draining into the sinkhole would be best used for hay crops, pasture, or trees to reduce runoff. If the area is cropped, nutrient management practices should be intensive.

3. Shallow soils over fractured bedrock: Soils that are shallow (< 40 in.) to bedrock that is fractured should be managed like soils with a high leaching index. Although many of these soils are not highly leached, the water and any dissolved nutrients can move rapidly to groundwater once the soil water percolates to the fractured rock. Lists of shallow soils in each state can be obtained from the NRCS and by reviewing county soil surveys. Nutrient management should include such practices as split applications of nitrogen on crops and the use of winter cover crops to scavenge residual soil nitrogen in fields containing significant areas of these soils.

4. Tile drained lands: Fields that have been artificially drained should be treated as environmentally sensitive due to the direct connection of the tile outlets to surface watersheds. These lands are typically drained because they have a high seasonal water table, which can potentially pollute both the surface water with their drainage discharge and the local water table if nutrients are over-applied relative to crop uptake.

5. Irrigated lands: Fields receiving irrigation, because of the increased input of water, are prone to runoff and leaching of water and nutrients. The leaching index approach cannot be used on these areas since it would underestimate the actual leaching potential. To maximize water use efficiency and minimize leaching and runoff, irrigation scheduling methods should be used. These include the use of gypsum blocks, tensiometers, or computerized systems. When these indicators show the need for irrigation, rates and amounts of water should be based upon the soil type and water holding capacity to further reduce water and nutrient losses.

6. Excessively sloping lands: Lands with steep (i.e., >12 to 15 percent) and long slopes pose a high risk for the surface loss of applied nitrogen and phosphorus. Significant amounts of nutrients bound to sediment can be lost during heavy rainfall events if tillage is employed to incorporate nutrients. Manure applications on such slopes should be limited by P soil test needs or crop uptake estimates. Injection is the preferred manure application method. Soil conservation measures should be practiced on highly erodible lands.

7. Floodplains and other lands near surface waters: Agricultural land close to surface water can have a more direct impact on surface water quality. Surface flow of runoff water has little chance to be filtered before discharge into adjacent waters if channelized flow develops. Subsurface flow in groundwater can also directly seep into the adjacent surface water body. Wetlands can also reduce the potential for nitrogen contamination of surface waters by identifying nitrate contaminated water that enters the wetland. If manure or biosolids must be applied to a floodplain, incorporation or injection application methods should be used to minimize losses if flooding occurs.

The list of environmentally sensitive sites given above is not all-inclusive, but does include most of the major types of land with these concerns in Virginia. Appropriate setback or buffer areas should be established between these areas and any field receiving nutrient applications, and intensive nutrient management practices should be employed on any lands adjacent to sensitive areas.

On-farm Nutrient management planning

Nutrient cycles and management on different farm types

Considering some representative farm types and the management consequences of the nutrient cycles on each is helpful in understanding nutrient management planning. Nutrients come to a modern cash-crop farm in fertilizers and other materials applied directly to the fields (Figure 1a). Crops harvested from the fields remove a fraction of the applied nutrients which leave the farm when the crops are sold. Improper management of nutrients can result in significant losses other than removal in cash crop and negative economic consequences for the farmer; therefore, the cost of practices that reduce nutrient losses on a cash-crop farm can be at least partially offset by decreased costs in purchased fertilizer.

On farms with livestock (e.g., a dairy), a large proportion of the plant nutrients that were in the crops produced as feed for the animals are returned to the fields in manure from the animals (Figure 1b). Supplementing on-farm crop production with fertilizer, off-farm feeds or other animal inputs is more likely on a modern crop and livestock farm with ruminant animals than on traditional self sufficient crop and livestock farms. Thus, the manure produced by the animals is no longer spread on the fields where the crops were produced. The plant nutrients in the feed inputs can offset the nutrients removed from the farm as sold animal products.

Feed inputs enable farms to have more animals on fewer acres. Sometimes, these off-farm feed nutrients can exceed what is needed for crops grown on-farm and result in excessive manure nutrients that can be potential sources of water contamination. All sources of plant nutrients being applied to fields must be determined to protect the environment from negative impacts associated with the over-application of nutrients to crop fields.

Trends in animal housing and the success of crop production on cash-crop farms in specialized geographic regions have made it possible to concentrate large numbers of animals, such as poultry and swine, on small land areas. Most, if not all, of the feed necessary for these animals can be economically transported to the farm where the animals are housed (Figure 1c). Although poultry and swine farms may produce crops for off-farm sale, the land areas involved can be quite limited because the focus of the management activity is on animal production. The cash-crop farm and the intensive, modern livestock farm are connected by the flow of feed; however, nutrients in this flow often do not cycle back to their original locations. The application of nutrients to the fields on these farms is not closely related to the major production activity of the farm (i.e., selling animals or animal products). This will usually result in levels of nutrients in excess of the crop needs on the farm and a high potential for environmental problems.

Field-based agronomic practices may be of limited effectiveness in assimilating the total quantity of nutrients on intensive livestock farms because of the small land area on the farm. It is unlikely that environmental quality can be protected on poultry and swine farms solely by recycling nutrients for crop production. Successful management of nutrients to protect the environment will depend on support from off-farm people and organizations.

Animal density and nutrient balance

Animal density and the proportion of feed coming from off the farm are important features in determining the nutrient status of a farm. On low animal density farms (<1.25 animal equivalent units [AEU's] per acre) or those where little feed (<50%) comes from off the farm, manure nutrients produced on the farm will not meet total crop nutrient needs. In this group an appropriate management objective would be to maximize nutrient use efficiency on the farm. The environmental impact of these operations can be minimal if sound nutrient management principles are applied. Management decisions should be made based on expected crop response to nutrients (i.e., increasing yields or decreasing purchased inputs). Plans should utilize soil tests and manure analysis to assure distribution and timing of manure applications to maximize nutrient availability from the manure and minimize purchase of commercial fertilizer. Examples of practices that would be appropriate on this group of farms include: spring application of manure, immediate incorporation of manure, use of cover crops to scavenge nutrients, no manure spread on legumes, and efficient manure storage.

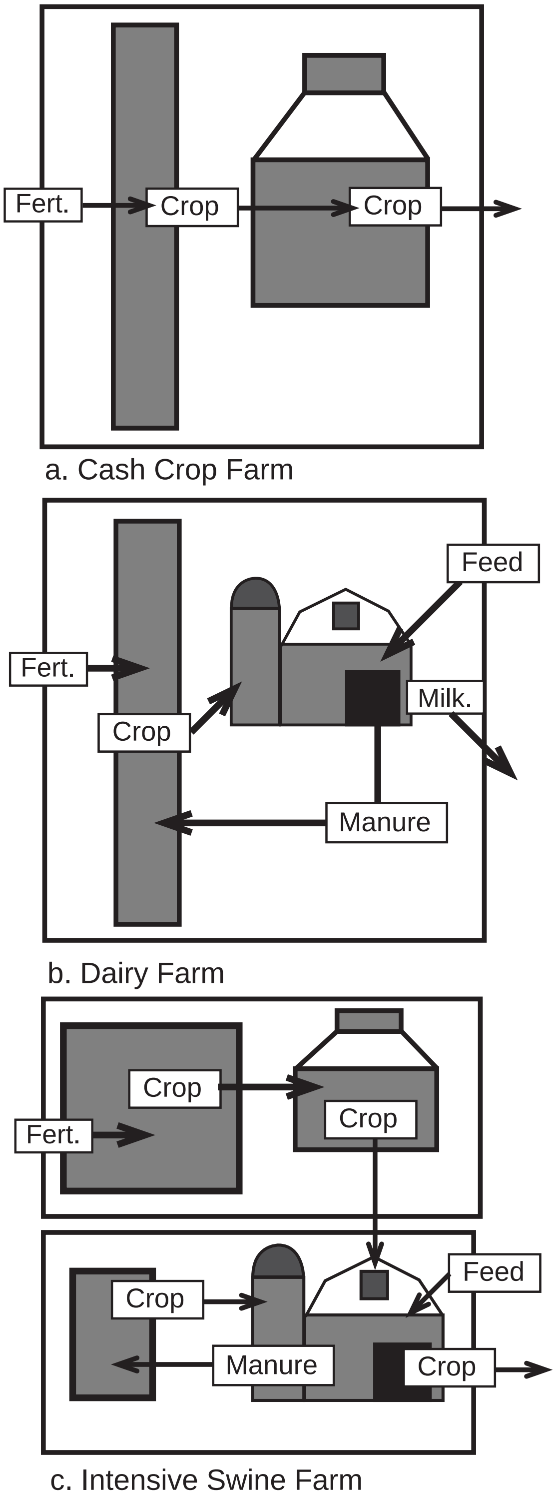

Figure 1. Nutrient Cycles on Different Types of Farms

Farms with medium animal density (1.25 - 2.25 AEU's/acre; 50-80% feed from off farm) supply manure nitrogen roughly equivalent to total crop needs, but excessive phosphorus supply is likely. An appropriate management objective for these farms would be to maximize environmentally safe nutrient use on the farm. Nutrient use efficiency will likely be a secondary concern if there is enough or more than enough nutrients on the farm to meet crop requirements. The major concern will be safely using all of the manure produced. There is good potential for environmental benefits from improved management on these farms. Changes in the overall farm management, such as altering the cropping system, may be necessary on this group of farms. A detailed manure management plan, based on nutrient balance rather than crop response, will probably be necessary on these farms.

On high intensity farms (>2.25 AEU's/acre; >80% feed from off farm), livestock manure production often significantly exceeds total crop nutrient needs. On these farms, the management objective will be to use every available means to remove excess manure not needed for crop production. Alternative off-farm uses for the manure will need to be explored. Often, this will mean locating a market for the manure and arranging the logistics of transportation and appropriate application. The on-farm plans for this group of farms will involve determining the maximum amount of manure that can be safely applied on the farm and the appropriate timing of application to minimize environmental impact. High intensity farms have the highest potential to negatively impact the environment. In many cases, unless a favorable marketing arrangement can be developed, implementing improved nutrient management on this group of farms will have a negative economic impact on the farm.

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PART XI
Utilization of Organic Wastes as Nutrient Sources and Soil Amendments

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Introduction

Waste products such as manure, biosolids (municipal wastewater sewage sludge), and industrial sludges supply organic matter and nutrients when used as soil amendments. The organic matter in these materials can improve soil tilth and aeration, increase water infiltration into soil and soil moisture holding capacity, decrease soil erosion potential, increase soil cation exchange capacity, buffer soil pH, and promote the growth of beneficial soil organisms. Some of all of the essential plant elements are contained in these materials, but they rarely occur in the proportion required for balanced plant nutrition.

The nutrient and heavy metal contents of organic wastes are highly variable, and analysis of individual wastes must be performed to certify quality and to ensure appropriate application rates. The major environmental concerns associated with the land application of organic wastes are the direct runoff of the organic material and any soluble constituents (e.g., phosphorus) into surface waters and the leaching of nitrate (NO_3^-) to groundwater. Bioavailability of heavy metals and transport of microbial pathogens can pose additional risks if waste material quality and proper management is not assured.

Sources of organic wastes

Processes that generate wastes

Manure

Livestock (beef and dairy cattle, swine) and poultry (broilers, layers, turkeys) operations generate animal waste (feces and urine) that must be collected and stored prior to land application. Some animal waste handling systems (e.g., composting, anaerobic lagoons) are designed to treat the waste by reducing pathogens, odors, and nitrogen content and increasing organic matter stability, but most systems are simply collection and storage facilities. Descriptions of manure types associated with beef and dairy cattle, swine, and poultry are presented in Table 1.

Table 1. Manure Collection Systems (Source: Evanylo, 1994)

Type	Description	Animal Type
Solid without bedding	Feedlot, scraped	Beef and dairy cattle, swine
Solid with bedding	Tramp shed	Beef and dairy cattle
Anaerobic lagoon	Solids settled on bottom	Beef and dairy cattle, swine
Anaerobic lagoon sludge	Supernatant of a non-agitated waste lagoon	Beef and dairy cattle, swine, poultry
Compost	Controlled aerobic decomposition	Beef and dairy cattle, swine, poultry
Liquid manure slurry	Pit storage of wash waters	Beef and dairy cattle, swine, poultry
Deep pit	Two-story poultry house; manure falls through the caged 2nd floors to 1st	Poultry
Solid without litter	Manure collection gutters under poultry are scraped each week	Poultry
House litter	Manure falls onto bedding and is removed after one or more flocks	Poultry
Stockpiled litter	Same as house litter, but stockpiled until needed	Poultry

Biosolids

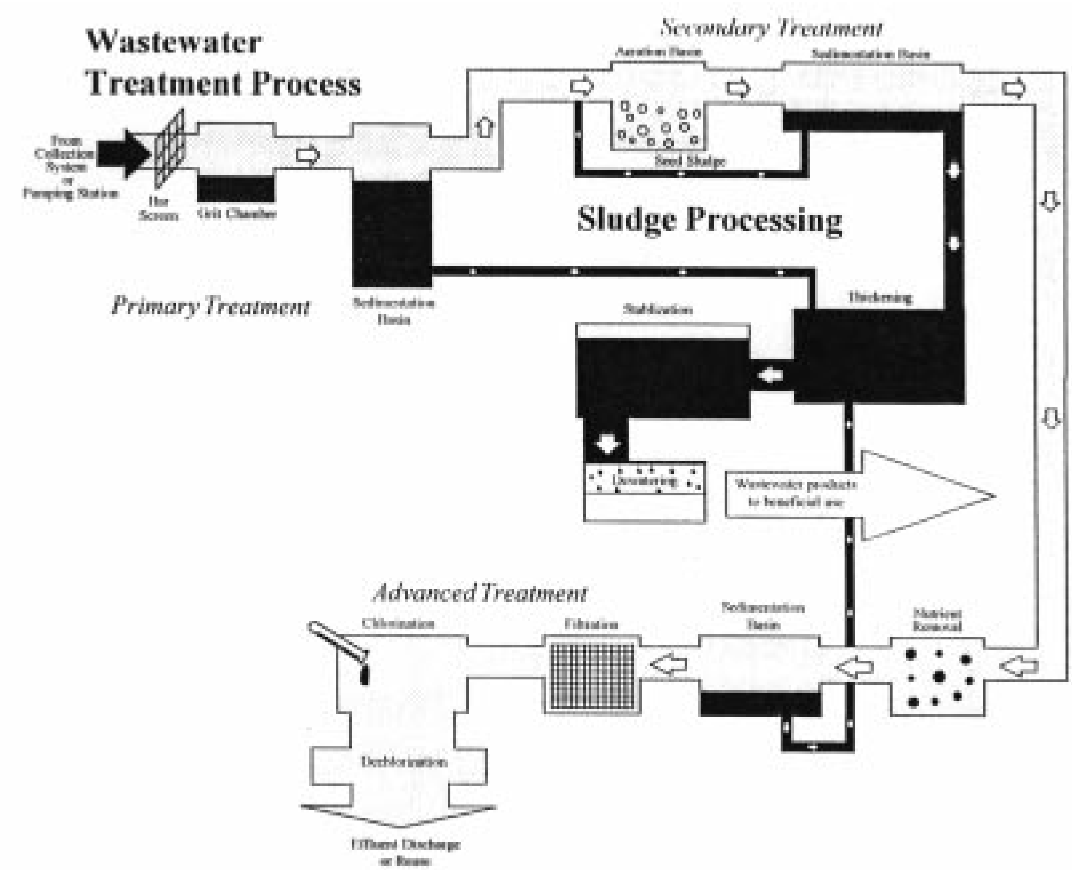
Biosolids are municipal wastewater sewage sludges that have been treated to permit their safe and beneficial application to soil for agricultural purposes. Biosolids are the materials remaining after treatment facilities purify wastewater from homes, businesses and industries. In some communities, runoff from roads, lawns and fields is also included. Biosolids are composed of inorganic constituents, such as macro- and micro-nutrients and non-nutrient trace elements, organic compounds, and microorganisms, including pathogens and parasites.

With minor exceptions, such as pretreatment required by industrial wastewater and sewer ordinances, treatment plants have little control over the material they process. They must accept all incoming wastewater and purify it before discharging the effluent back into the environment. The wide variety of incoming wastewater and available treatment technologies determines the volume and composition of wastewater treatment plant biosolids.

Figure 1 illustrates a generalized wastewater treatment process used to produce biosolids. As wastewater enters the plant, a screen removes large objects and a settling chamber removes grit. The wastewater then travels through the primary sedimentation basin where much of the solid matter is separated from the liquid. The secondary treatment process removes additional solids and some dissolved nutrients from the liquid. Advanced treatment further removes dissolved nutrients, then filters and disinfects the wastewater. Solids are combined, thickened, and stabilized. The stabilization process reduces pathogen numbers and the properties that attract vectors (i.e., disease-spreading animals) and readies the biosolids for dewatering. Once dewatered, the biosolids are ready to be land applied.

The State Department of Health is responsible for administering and enforcing the Biosolids Use Regulations (12 VAC 5-585, 32.1-164.5 of the Code of Virginia), under which most land application programs operate in Virginia. Further details regarding wastewater and biosolids treatment processes, regulations, and agricultural land application practices can be found in the Virginia Cooperative Extension Publication 452-301 through 452-304, a series on agricultural land application of biosolids in Virginia (Evanylo, 1999).

Figure 1. Schematic of Typical Wastewater Treatment Process.



Industrial sludge

Many industries produce wastewater that is processed in the same manner as municipal wastewater. The solids removed from these industrial wastewaters can be land applied if they meet the same stringent standards for biosolids. Some of the industries whose solids are often beneficially recycled onto land include textile mills (textile scrubber wastes), fermentation (brewery wastes containing yeast), and wood processing (paper mill sludge). The Virginia Department of Environmental Quality issues permits to applicators of industrial wastes.

Waste characteristics

Manure

Animal manure is a mixture of metabolic products such as urea and uric acid, living and dead organisms, and partially decomposed residues from the original feed. Nutrient content of manure varies with: (1) animal type and age, (2) composition of the feed, (3) amount of bedding and water added or lost, (4) method of manure collection and storage, and (5) length of time the manure is stored before field application. On a typical livestock farm about 75% of the nitrogen (N), 60-70% of the phosphorus (P), and 80-85% of the potassium (K) fed to animals are excreted in the manure. Examples of nutrient contents in fresh manures are presented in Table 2. The average concentrations of N, P, and K in poultry manures are higher than in other livestock wastes. The relative proportion of N:P in all fresh manures is generally about 3:1 to 4:1.

Table 2. Manure Production and Nutrient Content (Source: Barker, 1980)

Animal	Animal Weight Lbs	Fresh Manure lbs/yr	Nutrients in Fresh Manure N	P	K
			lbs/ton		
Dairy	640	37,400	12	3	12
Beef	440	24,200	12	3	8
Swine	45	3,080	12	3	5
Caged layer	2	100	28	9	10
Dry litter:					
Broiler	1	15	52	18	28
Turkey	7	48	36	14	12

The greatest impact on nitrogen content of manures is loss of ammonia (NH_3) through volatilization during handling and storage. As much as 50-60% of the original nitrogen may be lost during handling and storage (Table 3). Generally, more atmospheric nitrogen loss will occur the longer the manure is stored. Nitrogen loss from manure reduces the ratio of N:P in manure to be applied to land to about 1:1 to 1.5:1 because phosphorus is conserved in manure during collection and storage. The consequence of this is that higher amounts of phosphorus than required by crops are supplied when manures are applied at rates that supply the necessary amounts of nitrogen.

Table 3. Nitrogen Loss and Retention From Manure Storage and Handling Systems (not including loss from field application) (Vanderholm, 1975)

Storage and handling system	Amount Lost (%)	Amount Remaining (%)
1. Manure liquids and solids hauled daily	15-25	75-85
2. Manure liquids and solids held in a covered, essentially watertight structure	20-30	70-80
3. Manure liquids and solids held in an uncovered, essentially watertight structure	30-40	60-70
4. Manure liquids and solids held in a storage pond; contents are agitated before spreading	30-40	60-70
5. Manure and bedding held in roofed storage	30-40	60-70
6. Manure without bedding held in unroofed storage; leachate is lost; solids are spread	45-55	45-55
7. Manure stored on open feedlot surface; only the solids are spread	50-60	40-50
8. Poultry layer manure stored in roofed shallow pit cleaned every 3 to 6 months	30-40	60-70
9. Broiler manure on sawdust or shavings in warm, humid climate; house cleaned every 4 months	45-55	45-55
10. Poultry layer manure in cool humid climate; stored in roofed, fan-ventilated pits cleaned yearly	50-60	40-50

Table 4 shows the wide range in nutrient composition of manures sampled from numerous farms in Virginia following the effects of considerable collection and storage losses of nitrogen. It is not advisable to use average nutrient contents when determining manure application rates because of the great variability in the values. The most accurate way to determine nutrient content of manure is by laboratory analysis. The minimum analysis should include: percent dry matter, ammonium nitrogen (NH_4-N), total Kjeldahl nitrogen (TKN), phosphorus (as P or P_2O_5) and potassium (as K or K_2O). Organic nitrogen can be calculated as the difference between total Kjeldahl nitrogen and ammonium nitrogen (i.e., TKN - NH_4-N). Nitrate nitrogen is normally so low in manure that its concentration is not determined.

<u>Biosolids</u>

Biosolids vary widely in their chemical, biological, and physical properties. The determining factors include the source and composition of the sewage, the treatment system, the extent to which the material is digested and stabilized, and the handling method between processing and application to the soil.

Nineteen studies of municipal biosolids from 45 sites in seven southern states demonstrated enormous variability in composition (Table 5). Because composition varies greatly, each type of biosolid intended for use on agricultural land must be analyzed separately. The concentrations of nitrogen and phosphorus in biosolids are similar to those in animal manures, while potassium in biosolids is much lower than those in most animal wastes.

Although the source of the biosolids affects its nitrogen content, the type of biosolids treatment may be just as important a determining factor. Median total nitrogen concentrations in biosolids subject to various types of treatment were 4.8% for aerobic digestion, 4.2% for anaerobic digestion, and 1.8% for combined lagooned, primary, tertiary, and other unspecified processes (Sommers et al., 1977).

Most biosolids contain both organic and inorganic forms of nitrogen. Inorganic nitrogen is normally present as either ammonium (NH_4^+) or nitrate (NO_3^-), with the proportion of each being dependent on the waste treatment process employed. Aerobic digestion results in mineralization of organic N to NH_4^+ and nitrification of NH_4^+ to NO_3^-. In contrast, only NH_4^+ is present in anaerobically digested biosolids. In anaerobically digested biosolids, about 20 to 50% or more of the N is NH_4-N, with very little NO_3-N. If wastes are stored in a lagoon before application, inorganic N can be lost through ammonia (NH_3) volatilization and denitrification.

In contrast to nitrogen, most of the phosphorus in biosolids is in the inorganic form. The inorganic phosphorus content of eight biosolids analyzed by Sommers et al. (1976) averaged 73% of the total P content. Biosolids are generally considered poor sources of plant available potassium, primarily due to the low concentrations of potassium in biosolids. Potassium is a soluble constituent in wastewater sewage and is largely lost in the treated and discharged effluent.

Table 4. Mean, Minimum and Maximum Amounts of NITROGEN, PHOSPHORUS, AND POTASSIUM in Manure from Various Animal Types and Handling Systems Tested by the Virginia Tech Water Quality Laboratory, January 1989 to November 1992. (Source: E.R. Collins)

Manure Type	TKN		NH_4-N		P_2O_5		K_2O	
(No. of samples)	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Liquid:								
Dairy (434)[a]	22.6	1.0-52.5	9.6	0.0-44.6	12.1	0.0-37.2	18.9	0.0-48.8
Swine (109)[a]	10.0	0.6-58.5	5.3	0.3-25.8	5.7	0.4-61.5	5.7	0.1-23.5
Poultry (14)[a]	51.1	4.5-89.1	33.0	0.6-66.3	41.0	0.6-100.3	30.5	2.0-53.4
Semi-solid:								
Dairy (46)	10.5	3.4-23.6	3.2	0.1-7.8	6.1	2.2-19.1	8.7	2.0-16.0
Beef (18)	12.8	7.8-23.9	2.6	0.2-15.5	6.7	2.5-14.6	11.8	4.4-30.9
Dry:								
Broiler Litter (254)	62.6	5.7-99.5	11.8	0.2-25.8	62.1	22.7-119.4	28.6	3.3-53.3
Layer/breeder (54)	36.5	9.1-110.6	9.0	0.2-29.6	65.1	9.8-149.7	24.2	4.8-50.2

[a] Values presented in lbs/1000 gals. All other values in lbs/ton.

Table 5. Properties of Municipal Biosolids from Several Southern States (King et al., 1986)

	Number of samples	Range	Mean	Median[a]
Solids content of liquid biosolids (%)	13	0.6-7.1	3.8	4.4
Ash (% of solids)	16	19-59	43.0	47.0
pH	8	5.4-7.0	6.1	5.9
Total N of solids (%)	21	0.6-7.5	3.0	2.6
Total N[a] of liquid fraction (mg/L)	13	7-730	280	290
Total P of solids (%)	40	0.4-5.3	1.8	1.6
Total K of solids (%)	40	< 0.1-1.0	0.2	0.2
Total Ca of solids (%)	39	< 0.1-6.0	1.5	1.3
Total Mg of solids (%)	39	0.1-0.5	0.2	0.2

[a] Predominantly NH_4-N.

<u>Industrial sludge</u>

Data on solids, ash, and macronutrients in sludges generated by textile mills, fermentation processing, and wood processing are summarized in Table 6. The nitrogen content of textile and fermentation wastes is generally comparable to that of municipal biosolids, but the nitrogen content of wood processing wastes is usually much lower. The concentrations of other macronutrients are generally low compared to manures and biosolids.

Factors that affect nutrient availability

The availabilities of nutrients in organic wastes are due to differences in composition and form of nutrients. The following sections on specific nutrients are generally true for all organic wastes.

<u>Nitrogen</u>

Nitrogen occurs primarily in two forms in organic wastes - inorganic N, largely as ammonium (NH_4^+), and organic N. The ammonium nitrogen is immediately available to crops, but it can readily be converted to ammonia (NH_3), which is easily lost to the atmosphere. Organic nitrogen must be mineralized to ammonium by soil microorganisms before it can become available for uptake by plants.

Table 6. Properties of Industrial Wastes from Several Southern States (King et al, 1986)

	Textile mill sludge		Fermentation sludge		Paper mill sludge	
	Median	Range	Median	Range	Median	Range
Solids content of liquid wastes (%)	6.9	0.6-13.5	19	13-54	12.4	——
Ash (% of solids)	43	14-76	49	37-66	45	6-67
Total N of solids (%)	2.8	1.0-7.9	3.5	2.0-7.0	0.4	0.3-2.3
Total N[a] of liquid fraction (mg/L)	22	16-112	340	19-680	——	——
Total P of solids (%)	0.9	0.3-2.0	0.2	0.1-0.7	0.1	<0.1-0.30
Total K of solids (%)	0.2	0.1-0.3	0.1	<0.1-0.2	0.1	<0.1-9.3
Total Ca of solids (%)	0.5	0.1-0.8	5.2	<0.1-9.8	0.8	0.3-9.8
Total Mg of solids (%)	0.2	0.1-0.4	<0.1	<0.1-0.2	0.1	<0.1-0.7

[a] Predominantly NH_4^+-N

Nitrate (NO_3^-) concentrations in manure and biosolids are usually low and contribute little to the immediately available plant nitrogen pool; however, nitrate-N is rapidly produced by the microbial process of nitrification from ammonium either added directly to the soil or mineralized from organic nitrogen. The resulting inorganic nitrogen is available to the crop as ammonium and nitrate.

In summary, factors that determine the rate and timing of nitrogen availability to crops from organic wastes include:
1. Amount of NH_4-N in the manure;
2. Application method and resulting atmospheric loss of NH_3; and
3. Rate of mineralization of organic N to plant available forms.

Organic wastes should not be applied in excess of the agronomic N rate, which is the rate required to supply the nitrogen needs of the target crop. Therefore, the application rate should be based on the amount of plant available N in the waste unless another constituent (e.g., P, lime equivalent) limits the application rate to a greater extent.

Ammonia (NH_3) is extremely volatile. Its loss during storage and from the soil surface after application may be as great as 70% of the total amount of manure or biosolids nitrogen. All of the ammonium is immediately available for plant utilization. The value and amount of nitrogen utilized by the crop will depend on how much ammonia had been conserved during handling. The values in Table 7 and 8 provide estimates on what fractions of ammonium in organic wastes are available for plant uptake under different incorporation timing schemes.

Table 7. Fraction of Ammonium Nitrogen in Animal Manure Considered to be Available for Plant Uptake (Source: Virginia Department of Conservation and Recreation, 1995)

Method of application	Semi-solid manure	Liquid Manure slurry	Lagoon liquid	Dry litter
		Fraction of available N		
Injection	——-	0.95	0.95	——-
Broadcast with immediate incorporation	0.75	0.75	0.90	0.90
Incorporated after 2 days	0.65	0.65	0.80	0.80
Incorporated after 4 days	0.40	0.40	0.60	0.65
Incorporated after 7 days	0.25	0.25	0.45	0.50
Irrigation without incorporation	——-	0.20	0.50	——

Table 8. Fraction of Ammonium Nitrogen (NH_4-N) in Biosolids Considered to be Available for Plant Uptake (Source: Virginia Department of Health, 1997)

Management practice	Biosolids pH<10	Biosolids pH>10
	Fraction of available N	
Injection below surface	1.00	1.00
Surface application with:		
Incorporation within 24 hours	0.85	0.75
Incorporation within 1-7 days	0.70	0.50
Incorporation after 7 days	0.50	0.25

Mineralization of organic nitrogen to a plant-available form occurs in two phases. The first phase includes the less resistant organic nitrogen, which mineralizes during the first year of application. The second phase includes the more resistant residual organic nitrogen, which mineralizes very slowly in future years. Repeated yearly applications to the same field result in an accumulation of a slow-release (residual) manure or biosolids nitrogen source from present and past applications.

Available nitrogen from mineralization of organic nitrogen can be estimated using coefficients determined from experimentally-derived decay series. The fractions listed in Tables 9 and 10 are for the mineralization of manures and biosolids. As an example, the decay series of 0.35-0.12-0.05 for dairy manure means that 35 percent of the organic nitrogen is mineralized during the year applied, 12 percent of the initial organic nitrogen remaining after the first year is mineralized during the second year, and 5 percent of the initial organic nitrogen remaining after the second year is mineralized during the third. The nitrogen remaining after the first year that will become available for plant use in subsequent years is called residual nitrogen.

There are no universal decay series across the United States because the rate of microbial breakdown depends primarily upon soil characteristics and climatic conditions. The decay series is for the stable organic nitrogen only and does not include ammonium, which is 100% available.

Table 9. Available Fractions of Remaining Organic Nitrogen During the Three Years after Application of Various Animal Manures (Source: Virginia Department of Conservation and Recreation, 1995)

Animal Type	Year One	Year Two	Year Three
	Fraction of Available N		
Dairy & Beef	0.35	0.12	0.05
Swine	0.50	0.12	0.05
Poultry	0.60	0.12	0.05

Table 10. Available Fractions of Remaining Organic N During the Three Years After Application of Variously Treated Biosolids (Source: Virginia Department of Health, 1997)

	Year One	Year Two	Year Three
	Fraction of Available N		
Primary	0.30	0.15	0.07
Waste activated	0.40	0.20	0.10
Aerobically digested	0.30	0.15	0.08
Anaerobically digested	0.20	0.10	0.05
Lime stabilized	0.30	0.15	0.08
Composted	0.10	0.05	0.03

Calculations of plant available nitrogen (PAN) from organic waste will include the portion of the ammonium that is not lost by volatilization and a portion of the stable organic nitrogen. The amount of PAN in organic wastes can be estimated by:

$$\text{PAN} = NO_3\text{-N} + x\,(NH_4\text{-N}) + y\,(\text{Organic N}).$$

Where x is the fraction of NH_4-N that does not volatilize (values found in Tables 7 and 8) and y is the fraction of organic N expected to mineralize (values found in Tables 9 and 10).

Phosphorus and potassium

Manure and biosolids are excellent sources of phosphorus (P). Much of the phosphorus in manure may be organically-complexed and, like organic nitrogen, must mineralize before it is available for utilization by plants. Organic phosphorus in wastes mineralizes rapidly and is readily plant-available. The phosphorus in biosolids, which exists largely in inorganic forms complexed by iron compounds, may be somewhat less plant-available than the phosphorus in manures. Ultimately, the plant availability of phosphorus from organic wastes is controlled by soil chemical reactions in the same way that soil chemistry controls the availability of phosphorus from inorganic fertilizer. The availabilities of phosphorus in manure and biosolids are estimated as 90 to 95% and 50 to 95% of fertilizer phosphorus, respectively.

Manure potassium (K), chiefly present in the urine as inorganic potassium, is chemically equivalent to fertilizer potassium (i.e., it is available for plant growth in the year it is applied). Biosolids are generally poor sources of plant available potassium due to its presence in low concentrations; however, potassium in biosolids is normally assumed to be 100% plant available.

Essentially all of the potassium and most of the phosphorus supplied in organic wastes is plant-available. The amount of manure required to meet crop phosphorus and potassium requirements can be calculated by using a combination of soil testing and manure analysis.

Secondary and micronutrients

Manures and biosolids contain secondary macronutrients (i.e., calcium, magnesium and sulfur) and micronutrients (i.e., manganese, iron, copper, zinc, boron, molybdenum) which are not commonly applied in commercial fertilizer unless specifically recommended. Organic wastes provide some insurance against yield reductions due to insufficient secondary and trace nutrients when the cost of applying such nutrients in commercial fertilizer cannot be justified because of the lack of evidence of a consistent yield response.

Some trace elements may accumulate to concentrations in the soil that are phytotoxic (e.g., zinc, copper, nickel) or in plants that are toxic to livestock (e.g., molybdenum) or humans (e.g., arsenic, cadmium) if organic wastes containing high concentrations of these trace elements are applied. The permissable concentrations of these trace elements in biosolids and industrial sludges are strictly regulated. Concentrations of these elements in manure do not normally pose health, environmental, or agronomic risks, but their soil accumulation and bioavailability should be monitored where continuous applications of some types of manure have been made.

Lime

The addition of lime in some biosolids stabilization treatment processes can provide calcium carbonate equivalencies of 10-50 percent. It is possible that the lime potential of these biosolids can limit waste application rates on poorly-buffered, coarse-textured (i.e., sandy) soils having a high soil pH. Preventing the pH of these soils from rising above about 6.8 is necessary to eliminate the risk of inducing micronutrient (e.g., manganese in small grains and soybean, zinc in corn) deficiencies.

Best management practices

Wastes must be well managed to reap agronomic benefits and to reduce environmental and health risks. Overall, the most important factors in preventing nutrient loss include field application methods, timing of application, and application rate.

Application rate

Waste application rates should balance nutrient content in the waste with crop nutrient demands based on realistic yield goals. The ratio of $N:P_2O_5:K_2O$ in organic wastes usually does not match the ratio of the nutrients needed by the crop; however, an appropriate rate can be calculated by basing it on the nutrient that is the most limiting to crop growth. Generally, the nutrient that determines the overall application rate is nitrogen.

The total phosphorus application rates are generally much higher than crop needs when a waste application rate is based on plant available nitrogen (PAN). For example, biosolids having 1.3% PAN and 1.0% total P (2.3% P as P_2O_5) applied to supply 150 lbs PAN per acre would also apply 115 lbs P or 265 lbs P_2O_5 per acre. Crop nitrogen removal is normally two to four times higher than phosphorus removal. Therefore, continuous application of wastes based on agronomic nitrogen rates will build soil phosphorus concentrations many-fold higher than required. (See Nutrient Removal by Crops table, Part VII Soil Testing & Plant Analysis) Phosphorus runoff from soils where continuous applications of organic wastes have built soil phosphorus to excessive levels poses an environmental threat to the health of surface waters. It is advisable to apply wastes at rates recommended by the most limiting of soil test P/crop P removal or agronomic N rate.

Application method

Soil incorporation captures more of the NH_4-N than surface application of waste. Research has shown that 20% of the nitrogen may be lost to the atmosphere in the first six hours after spreading manure on the soil surface, and nearly 50% can be lost after four days (Table 11). Plowing or disking of manure, biosolids, and other sludges into the soil shortly after application, or injecting the waste into the soil reduces such losses.

Table 11. Relative Effectiveness of Manure in Increasing Crop Yields as Influenced by Time Between Spreading and Plowing Under (Salter and Schollenberger, 1939)

Treatment	Relative value in increasing crop yield (Average of 34 experiments)
Manure plowed under immediately	100
Manure plowed under 6 hr after spreading	85
Manure plowed under 24 hr after spreading	73
Manure plowed under 4 days after spreading	56

Application timing

Wastes should be applied as closely as possible to the time of maximum crop nutrient uptake to ensure that the nitrogen will be available to crops rather than lost to surface water, groundwater, or the atmosphere. Fall and winter applications of biosolids and manures should be avoided unless actively growing winter cover crops are present. Without an actively growing crop, nitrate nitrogen may leach to groundwater or be transported to surface water. Surface applications of biosolids and manures containing high concentrations of ammonium nitrogen during hot dry periods can result in large losses of ammonia.

Cropping systems

The most appropriate crops for the use of manure and biosolids are those that have relatively high nitrogen requirements (i.e., corn, small grains, pasture grasses). Application of manure and biosolids to legumes such as soybean or alfalfa is generally not an efficient use of nitrogen, since rhizobial bacteria associated with the roots of legumes fix N from the atmosphere; however, if no other appropriate crop is available, soybean and alfalfa will effectively use manure nitrogen.

Biosolids and industrial sludges are particularly useful in the reclamation of surface-mined areas, sand tailings piles, borrow pits, and other disturbed land areas. Soils on these sites lack organic matter and nitrogen, they are usually acid (low pH) and low in available phosphorus and potassium, and have poor physical structure. The potential for groundwater pollution from biosolids application may be greater on surface-mined sites than on undisturbed sites, unless a vegetative cover is established, because the soil strata may be disturbed well below the surface.

Site management

Protection of water resources from nutrients, especially nitrogen and phosphorus, and pathogens must be considered when handling and utilizing manures and biosolids. Drainage from feedlots and storage lagoons should not be permitted to flow into streams and reservoirs. Proper field management must begin at the unloading site. Soil compaction may occur due to the weight of the wastes and vehicles transporting the material if soil moisture is high.

Steps should be taken to prevent soil erosion as a direct result of land application practices. Detrimental water quality impacts from manures and biosolids can be avoided by employing conservation tillage practices that reduce erosion and prevent the movement of sediment and waste constituents to surface water. Water pollution problems caused by movement of waste constituents in runoff water can be minimized by use of grassed buffer strips along waterways adjacent to application sites.

Liquid waste injection practices can affect the amount of soil erosion that occurs. Driving the applicator vehicle across the slope instead of up and down reduces erosion. Injecting the liquid wastes up and down the slope provides channels for water and intensifies erosion potential in the same way as plowing or cultivating up and down the slope. Using injectors in muddy soils results in much the same type of soil structural damage as plowing when the soil is too wet. Clay soils, in particular, become cloddy and adequate seedbed preparation is very difficult if stirred when wet. Applicator vehicles with high flotation tires reduce compaction damage in the upper zone of wet soils; however, compaction in the 12 to 24 inch depth is a function of total axle weight.

The environment must not be degraded by allowing waste constituents to leave the site by overland flow. Manure or biosolids should not be spread on frozen ground, near sinkholes or rock outcrops, or on steep slopes where nutrients can leach or runoff into ground- or surface water. Even sites with a very slight slope can cause severe runoff problems from rain or melting snow on top of frozen ground.

In summary, the relative risks of all waste application options must be considered in arriving at policies and practices to manage their use on land effectively. Awareness of the agricultural, health, and environmental benefits, costs, and impacts are critical to developing publicly acceptable management programs.

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PART XII
Herbicide Considerations

E. Scott Hagood, Extension Weed Specialist

Management of herbicide resistant weeds

Since the initial development of selective herbicides in the late 1940's, farmers have relied heavily on these materials to provide effective and economical control of weeds. Herbicide use has allowed tremendous advances in our agricultural productivity. The relatively recent development of resistance in various weed species to commonly used herbicides represents one of the most serious threats to profitable agronomic crop production. Many factors involving the characteristics of both the target weed and the herbicide determine whether resistance will occur, and the rate at which resistant species develop. The following is a brief discussion of the factors involved in the development of herbicide resistance, and appropriate methods for management of resistant weeds.

Resistance, as defined by the Weed Science Society of America, is the naturally occurring inheritable ability of some weed biotypes within a population to survive a herbicide treatment that would, under normal conditions of use, effectively control that weed population. The genetic change which confers resistance to certain members or biotypes within a given weed species is naturally occurring, and can allow those weeds to survive a herbicide application in a number of distinct ways. The most common mechanism for resistance is alteration of the target enzyme site of herbicide binding. In the susceptible species, the herbicide would bind to an enzyme in such a manner as to prevent its catalyzation of a necessary metabolic reaction, thereby causing death of the plant. In weeds with the altered binding site, however, the herbicide cannot bind, and the reaction proceeds without deleterious effect on the plant. Increased herbicide metabolism also accounts for herbicide resistance in some weeds, in which the herbicide is rapidly degraded to nontoxic forms in the resistant biotype but is retained primarily in its toxic form in the susceptible biotype. A third resistance mechanism involves enzyme amplification or overproduction in the resistant biotype, wherein increased levels of the enzyme allow a requisite reaction to proceed at a normal rate despite the presence of the herbicide.

Many factors determine the likelihood of the development of resistance in a weed species to a specific herbicide. Herbicides with high specificity in mode of action provide a much greater potential for resistance. Where alteration of the target site is the mechanism for resistance, and the herbicide is specific to inhibition of a single enzyme, simple single gene mutations can result in resistant individuals. Conversely, herbicides with broader effects on multiple sites or functions provide relatively little potential for the development of resistance. Herbicide persistence also affects the potential for the development of resistance, because the length of time that the selection pressure is present directly influences the likelihood that resistant individuals will be identified. Continued use of the same herbicide, or herbicides with the same mode of action, also dramatically increases the potential for resistance.

The potential for resistance is also determined by characteristics of the weed species. Species with high seed production and rapid turn over of the weed seed bank in the soil are most likely to develop resistance. The rate of resistance development is also determined by the extent to which a mutation which confers resistance is distributed throughout the population prior to initiation of the selection pressure via the herbicide. Fitness of the resistant individuals also determines the extent to which this biotype will become a constraint to production, where a less fit resistant biotype will pose a lesser threat to production than a resistant biotype with fitness similar to or exceeding that of the susceptible biotype.

In Virginia, triazine resistant pigweed is currently the most prevalent herbicide resistant weed species. This problem arose due to an altered target site and reduced susceptibility of this pigweed biotype to triazine herbicides including atrazine, simazine (Princep), and cyanazine (Bladex). The resistant pigweed biotype spread rapidly in western and southwestern Virginia due to continuous no-till corn production and continuous use of atrazine plus simazine. The resistant biotype has subsequently spread across Virginia, but this eastward movement was slowed by the fact that the corn/soybean rotation common in eastern Virginia introduced alternative rotational herbicides. Other resistant weed species confirmed in Virginia include triazine resistant common lambsquarters, imazethapyr

(Pursuit) resistant pigweed, diclofop (Hoelon) resistant annual ryegrass, and sethoxydim (Poast Plus) resistant johnsongrass. It is important to note that these weeds may also exhibit resistance to other herbicides in the same chemical family or in the same mode of action group.

Herbicide resistant weed species must be managed with a combination of herbicidal, cultural, and mechanical weed control techniques. Crop rotation, where appropriate, is critical to successful resistant weed management, as it may allow the use of a more competitive crop or a crop whose life cycle and associated management and harvest procedures disrupt the life cycle of the resistant species. Most critical to resistant weed management, however, is herbicide rotation. Whether in a continuous crop, or in a crop rotation, herbicide rotation must be employed to prevent the development of new herbicide resistant weed species or to manage existing weed species. Rotation of herbicides with differing modes of action and with high efficacy on the target species will prevent a resistant biotype from developing to the point that it constrains production. Combination of herbicides within an application or within a growing season is also effective for resistant weed management, where combinations of differing modes of actions will control an existing resistant biotype as well as prevent the development of new resistant species. As stated, the use of herbicides with high specificity in terms of mode of action increases the likelihood of the development of resistance. Herbicide rotations or combinations involving two herbicides with modes of action with this degree of specificity should be avoided if possible due to the possibility of the development of resistance to both compounds (multiple resistance).

Chemical combinations or rotations employed without knowledge of the mode of action of the herbicides being used cannot constitute meaningful resistance management. The Pest Management Guide for Field Crops, VCE Publication 456-016, contains tables which relate the active ingredients in all recommended single ingredient and prepack herbicides for agronomic crops, as well as tables relating the mode of action of each herbicide and its effectiveness on individual weed species. Taken in total this information can easily be used to formulate effective programs for the management of resistant weed species.

Rainfree Periods for Post Emergence Herbicides

Information as a guide to pre-pack herbicide mixes, guide to single active ingredient herbicides, and herbicide recommendations are available in The Pest Management Guide for Field Crops, VCE Publication 456-016 which is revised annually.

The table below is included in this reference publication because rainfall is difficult to predict in our environment, especially in the summer. The table shows the critical time between application and rainfall varies from only 30 minutes to eight hours.

Rainfree Periods for Postemergence Herbicides

Herbicide	Hours	Herbicide	Hours
Accent	4	Harmony Extra	3
Aim	1	Hoelon	Not specific
Assure II	1	Hornet	4
Ally	4	Laddok S-12	8
Atrazine	1-2	Liberty	4
Banvel	4	Liberty ATZ	4
Basagran	8	Lightning	1
Basis	4	Marksman	6
Basis Gold	4	Northstar	4
Beacon	4	Peak	4
Bladex	1-2	Permit	4
Blazer	6	Pinnacle	1
Buctril	1	Poast Plus/Poast	1

Rainfree Periods for Postemergence Herbicides (cont)

Herbicide	Hours	Herbicide	Hours
Bugle	1	Pursuit	1
Celebrity Plus	4	Raptor	1
Clarity	4	Reflex	1
Classic	1	Resource	1
Cobra	30 minutes	Roundup Ultra	1-6
Concert	1	Scepter	
2,4-D Amine	6-8	Scorpion III	6
2,4-DEster	1-2	Select	1
2,4DB	6	Shotgun	4
Distinct	4	Stellar	1
Exceed	4	Stinger	6-8
Extrazine II	1-2	Storm	8
Flexstar	1	Synchrony	1
Fusilade	1	Touchdown	4
Fusion	1	Tough	1-2
Gramoxone Extra	30 minutes		

PART XIII
Composition of Feeds

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Feed composition varies greatly by plant species, stage of growth and environmental conditions. The following table was modified from Nutrient Requirements of Beef Cattle, National Research Council, 7th revised ed., 1996. Terms used in the heading of the table are defined below:

Definition of Terms

b	DM % AF:	percent dry matter as fed
c	NDF % DM:	neutral detergent fiber concentration as a percentage of dry matter
d	Lignin % NDF:	lignin concentration as a percentage of neutral detergent fiber content
e	TDN % DM:	total digestible nutrient concentration as a percentage of dry matter
f	ME Mcal/kg:	metabolizable energy content
g	NEma Mcal/kg:	net energy content of feed for maintenance
h	NEga Mcal/kg:	net energy content of feed for gain
i	CP % DM:	crude protein concentration as a percentage of dry matter
j	CIP % CP:	degraded intake protain concentration as a percentage of crude protein content
k	UIP % CP:	ungraded intake protein concentration as a percentage of crude protein content
l	SolP % CP:	soluble protein concentration as a percentage of crude protein centent
m	NPN % SolP:	nonprotein nitrogen concentration as a percentage of soluble protein content
n	ADFIP % CP:	acid detergent insoluble protein concentration as a percentage of crude protein content
o	Starch % NSC:	starch concentration as a percentage of nonstructural carbohydrate content
p	Fat % DM:	fat concentration as a percentage of dry matter
q	Ash % DM:	ash concentration as a percentage of dry matter

Part XIII General Compositions of Feeds[a]

Grains and by-product feeds Common Name	DM %AF[b]	NDF %DM[c]	Lignin %NDF[d]	TDN %DM[e]	ME Mcal/kg[f]	NE_{ma} Mcal/kg[g]	NE_{ga} Mcal/kg[h]	CP %DM[i]	DIP %CP[j]	UIP %CP[k]	SolP %CP[l]	NPN %SolP[m]	ADFIP %CP[n]	Starch %NSC[o]	Fat %DM[p]	Ash %DM[q]
Bahiagrass Hay	90.00	72.00	11.11	51.00	1.84	1.00	0.45	8.20	63.00	37.00	25.00	96.00	6.50	6.00	1.60	11.00
Bermudagrass Late Vegetative	91.00	76.60	8.57	49.00	1.77	0.93	0.39	7.80	85.00	15.00	25.90	25.40	8.90	6.00	2.70	8.00
Brome Hay Pre-bloom	88.00	55.00	7.69	60.00	2.17	1.31	0.74	16.00	79.00	21.00	25.00	96.00	6.50	6.00	2.60	10.00
Brome Hay Late-bloom	91.00	68.00	11.11	55.00	1.99	1.14	0.58	10.00	59.00	41.00	25.00	96.00	6.50	6.00	2.30	9.00
Fescue K31 Hay	91.00	62.20	6.35	61.00	2.21	1.34	0.77	15.00	82.00	18.00	25.90	25.40	8.90	6.00	5.50	9.00
Fescue K31 Hay Full-bloom	91.00	67.00	7.46	58.00	2.10	1.24	0.68	12.90	77.00	23.00	25.90	25.40	8.90	6.00	5.30	8.00
Fescue K31 Hay Mature	91.00	70.00	10.00	44.00	1.59	0.75	0.22	10.80	86.00	14.00	25.90	25.40	8.90	6.00	4.70	6.80
Orchardgrass Hay, Early-bloom	89.00	59.60	7.70	65.00	2.35	1.47	0.88	12.80	77.00	23.00	25.00	96.00	5.70	6.00	2.90	8.50
Orchardgrass Hay, Late-bloom	90.60	65.00	11.40	54.00	1.95	1.11	0.55	8.40	64.00	36.00	25.00	96.00	6.10	6.00	3.40	10.10
Reed Canarygrass Hay	89.00	64.00	6.25	55.00	1.99	1.14	0.58	10.30	71.00	29.00	25.00	96.00	6.10	6.00	3.10	10.00
Ryegrass Hay	88.00	41.00	4.88	64.00	2.31	1.44	0.86	8.60	65.00	35.00	25.00	96.00	5.70	6.00	2.20	10.00
Sorghum Sudan Hay	91.00	66.00	6.06	56.10	2.03	1.18	0.62	11.30	69.00	31.00	20.00	95.00	11.00	10.00	1.80	9.60
Sorghum Sudan Pasture	18.00	55.00	5.45	65.00	2.35	1.47	0.88	16.80	88.00	12.00	45.00	11.11	5.00	90.00	3.90	9.00
Sorghum Sudan Silage	28.00	68.00	7.04	55.00	1.99	1.14	0.58	10.80	72.00	28.00	50.00	90.00	11.00	100.00	2.80	9.80
Timothy Hay Mid-bloom	89.00	63.70	7.46	57.00	2.06	1.21	0.64	9.70	69.00	31.00	25.00	96.00	6.10	6.00	2.70	7.00
Timothy Hay Full-bloom	89.00	64.20	8.82	56.00	2.02	1.18	0.61	8.10	62.00	38.00	25.00	96.00	6.10	6.00	2.90	5.20
Timothy Hay Seed Stage	89.00	72.00	12.50	47.00	1.70	0.86	0.32	6.00	50.00	50.00	25.00	96.00	6.50	6.00	2.00	6.00
Alfalfa Hay Early-Vegetative	91.00	33.00	18.18	66.00	2.39	1.51	0.91	30.00	90.00	10.00	30.00	96.00	10.00	10.00	4.00	10.00
Alfalfa Hay Late-Vegetative	91.00	37.00	18.92	63.00	2.28	1.41	0.83	27.00	89.00	11.00	30.00	93.00	10.00	10.00	3.80	9.00
Alfalfa Hay Early-Bloom	91.00	39.30	20.00	60.00	2.17	1.31	0.74	25.00	88.00	12.00	29.00	93.00	11.00	10.00	2.90	9.20
Alfalfa Hay Mid-Bloom	91.00	47.10	22.73	58.00	2.10	1.24	0.68	22.00	84.00	16.00	28.00	93.00	14.00	10.00	2.60	8.50
Alfalfa Hay Late-Bloom	91.00	53.00	23.02	52.00	1.88	1.04	0.49	17.00	82.00	18.00	26.00	92.00	18.00	10.00	1.50	8.00
Alfalfa Silage Early-Bloom	35.00	43.00	23.26	63.00	2.28	1.41	0.83	19.50	92.00	8.00	50.00	100.00	15.00	10.00	3.70	9.50
Alfalfa Silage Full-Bloom	40.00	51.00	23.53	55.00	1.99	1.14	0.58	16.00	91.00	9.00	40.00	100.00	21.00	10.00	2.70	8.00
Birdsfoot Trefoil, Hay	91.00	47.50	19.15	59.00	2.13	1.28	0.71	15.90	82.00	18.00	28.00	96.00	14.00	10.00	2.10	7.40
Clover Ladino, Hay	89.00	36.00	19.44	60.00	2.17	1.31	0.74	22.40	86.00	14.00	30.00	96.00	10.00	10.00	2.70	9.40
Clover Red Hay	88.00	46.90	17.86	55.00	1.99	1.14	0.58	15.00	80.00	20.00	25.00	92.00	20.00	10.00	2.80	7.50
Vetch Hay	89.00	48.00	16.67	57.00	2.06	1.21	0.64	20.80	86.00	14.00	28.00	96.00	14.00	10.00	3.00	7.00
Barley Silage	39.00	56.80	5.44	60.00	2.17	1.31	0.74	1.90	86.00	14.00	70.00	100.00	6.10	100.00	2.92	8.30
Barley Straw	91.00	72.50	13.75	40.00	1.45	0.60	0.08	4.40	30.00	70.00	20.00	95.00	65.00	100.00	1.90	7.50
Corn Cobs Ground	90.00	87.00	7.78	50.00	1.81	0.97	0.42	2.80	22.00	78.00	25.00	10.00	10.00	90.00	0.60	1.80

Grains and by-product feeds Common Name	DM %AF	NDF %DM	Lignin %NDF	TDN %DM	ME Mcal/kg	NE_{ma} Mcal/kg	NE_{ga} Mcal/kg	CP %DM	DIP %CP	UIP %CP	SolP %CP	NPN %SolP	ADFIP %CP	Starch %NSC	Fat %DM	Ash %DM
Corn Silage 25% Grain	29.00	52.00	9.62	68.00	2.46	1.57	0.97	8.30	76.00	24.00	55.00	100.00	9.00	100.00	2.10	8.00
Corn Silage 35% Grain	33.00	46.00	8.70	69.00	2.49	1.60	1.00	8.60	77.00	23.00	50.00	100.00	9.00	100.00	2.60	7.00
Corn Silage 50% Grain	35.00	41.00	7.00	75.00	2.71	1.79	1.16	8.00	75.00	25.00	45.00	100.00	7.88	100.00	3.50	4.20
Corn Silage Immature *(no ears)*	25.00	60.00	5.00	65.00	2.35	1.47	0.88	9.00	78.00	22.00	45.00	100.00	4.50	100.00	3.10	11.00
Corn Silage Stalklage	30.00	68.00	10.29	55.00	1.99	1.14	0.58	6.30	68.00	32.00	45.00	100.00	4.50	100.00	2.10	9.00
Corn Stalks Grazing	50.00	65.00	10.00	65.85	2.38	1.50	0.91	6.50	69.00	31.00	20.00	95.00	13.57	10.00	2.10	7.20
Oat Silage Dough	36.40	58.10	16.07	59.00	2.13	1.28	0.71	12.70	85.00	15.00	50.00	100.00	10.00	100.00	3.12	10.10
Oat Straw	92.20	74.40	20.00	45.00	1.63	0.79	0.25	4.40	55.00	45.00	20.00	95.00	65.00	5.00	2.22	7.80
Oat Hay	91.00	63.00	9.09	53.00	1.92	1.07	0.52	9.50	68.00	32.00	30.00	93.00	10.00	90.00	2.40	7.90
Grain Sorghum Silage	30.00	60.80	9.38	60.00	2.17	1.31	0.74	9.39	73.00	27.00	45.00	100.00	5.00	100.00	2.64	5.00
Wheat Silage Dough	35.00	60.70	14.81	57.00	2.06	1.21	0.64	12.50	81.00	19.00	45.00	100.00	8.00	100.00	2.50	7.50
Wheat Straw	89.00	78.90	16.47	41.00	1.48	0.64	0.11	3.50	31.00	69.00	0.00	95.00	65.00	100.00	2.00	7.50
Barley Grain Heavy	88.00	18.10	10.53	84.00	3.04	2.06	1.40	13.20	66.93	33.07	17.00	29.00	5.00	90.00	2.20	2.40
Barley Grain Light	88.00	28.00	10.36	77.00	2.78	1.85	1.22	14.00	66.93	33.07	17.00	29.00	5.00	90.00	2.30	4.00
Corn Hominy	90.00	23.00	3.64	91.00	3.29	2.27	1.57	11.50	47.49	52.51	18.00	78.00	5.00	90.00	7.30	1.00
Corn Grain Cracked	88.00	10.80	2.22	90.00	3.25	2.24	1.55	9.80	44.67	55.33	11.00	73.00	5.00	90.00	4.06	1.46
Corn Dry Ear 56 lb/bu	87.00	28.00	7.10	82.00	2.96	2.00	1.35	9.00	46.03	53.97	16.00	69.00	3.00	90.00	3.70	1.90
Corn Ground Grain 56 lb/bu	88.00	9.00	2.22	88.00	3.18	2.18	1.50	9.80	57.37	42.63	11.00	73.00	5.00	90.00	4.30	1.60
Corn Grain Flaked	86.00	9.00	2.22	93.00	3.36	2.33	1.62	9.80	43.04	56.96	8.00	73.00	5.00	90.00	4.30	2.00
Corn HM Ear 56 lb/bu	72.00	28.00	7.10	85.00	3.07	2.09	1.42	9.00	62.05	37.95	30.00	80.00	8.28	100.00	3.70	1.90
Corn HM Grain 56 lb/bu	72.00	9.00	2.22	93.00	3.36	2.33	1.62	9.80	67.82	32.18	40.00	100.00	5.30	100.00	4.30	1.60
Cottonseed Black Whole	92.00	40.00	37.50	95.00	3.43	2.38	1.67	23.00	69.56	30.44	40.00	2.50	6.00	90.00	17.50	5.00
Cottonseed High Lint	92.00	51.60	34.04	90.00	3.25	2.24	1.55	24.00	69.56	30.44	40.00	2.50	6.00	90.00	17.50	4.16
Cottonseed Meal-mech	92.00	28.00	21.43	78.00	2.82	1.88	1.24	44.00	57.00	43.00	20.00	40.00	8.00	90.00	5.00	7.00
Cottonseed Meal-Sol 41% CP	92.00	28.90	23.08	75.00	2.71	1.79	1.16	46.10	57.00	43.00	20.00	40.00	8.00	90.00	3.15	7.00
Cottonseed Meal-Sol 43% CP	92.00	28.00	25.00	75.00	2.71	1.79	1.16	48.90	57.00	43.00	20.00	40.00	8.00	90.00	1.70	7.00
Molasses Beet	77.90	0.00	0.00	75.00	2.71	1.79	1.16	8.50	100.00	0.00	100.00	100.00	0.00	0.00	0.00	11.40
Molasses Cain	74.30	0.00	0.00	72.00	2.60	1.70	1.08	5.80	100.00	0.00	100.00	100.00	0.00	0.00	0.00	13.30
Oats 32 lb/bu	91.00	42.00	9.52	73.00	2.64	1.73	1.11	13.60	76.55	23.45	53.00	19.00	5.00	90.00	4.90	5.00
Oats 38 lb/bu	89.00	29.30	9.38	77.00	2.78	1.85	1.22	13.60	83.00	17.00	53.00	19.00	5.00	90.00	5.20	3.30
Rice Grain Ground	89.00	16.00	13.00	79.00	2.86	1.91	1.27	8.90	69.85	30.15	40.00	50.00	2.70	90.00	1.90	5.00
Rye Grain	88.00	19.00	5.30	84.00	3.04	2.06	1.40	13.80	78.99	21.01	53.00	19.00	4.00	90.00	1.70	2.00

Grains and by-product feeds Common Name	DM %AF	NDF %DM	Lignin %NDF	TDN %DM	ME Mcal/kg	NE_{ma} Mcal/kg	NE_{ga} Mcal/kg	CP %DM	DIP %CP	UIP %CP	SolP %CP	NPN %SolP	ADFIP %CP	Starch %NSC	Fat %DM	Ash %DM
Sorghum, Dry Grain	89.00	13.30	6.09	76.00	2.75	1.82	1.19	11.60	50.76	49.24	12.00	33.00	5.00	90.00	3.10	2.00
Sorghum, Rolled Grain	90.00	16.10	6.09	82.00	2.96	2.00	1.35	12.60	43.00	57.00	12.00	33.00	5.00	90.00	3.03	1.87
Sorghum, Steam Flaked	70.00	23.00	6.09	88.00	3.18	2.18	1.50	12.00	56.40	43.60	12.00	33.00	5.00	100.00	3.10	2.00
Wheat Ground	89.00	11.80	6.25	88.00	3.18	2.18	1.50	14.20	77.00	23.00	30.00	25.00	2.00	90.00	2.34	2.01
Wheat Middlings	89.00	35.00	5.95	83.00	3.00	2.03	1.37	18.40	77.15	22.85	40.00	75.00	3.00	90.00	3.20	2.40
Wheat Grain Hard red spring	88.00	11.70	6.25	84.00	3.04	2.06	1.40	14.20	73.95	26.05	30.00	73.00	2.00	90.00	2.00	2.00
Wheat Grain Soft white	90.00	9.70	4.29	85.00	3.07	2.09	1.49	11.30	73.95	26.05	30.00	73.00	2.00	90.00	1.90	2.00
Brewers Grain 21% Dry Matter	21.00	42.00	9.52	70.00	2.53	1.63	1.03	26.00	40.86	59.14	8.00	50.00	10.00	100.00	6.50	10.00
Brewers Grain Dehydrated	92.00	48.70	13.04	66.00	2.39	1.51	0.91	29.20	34.12	65.88	4.00	75.00	12.00	100.00	10.80	4.00
Canola Meal	92.00	27.20	12.76	69.00	2.49	1.60	1.00	40.90	67.85	32.15	32.40	65.00	6.38	90.00	3.47	7.10
Corn Gluten Feed	90.00	36.20	2.22	80.00	2.89	1.94	1.30	23.80	75.00	25.00	49.00	100.00	2.00	100.00	3.91	6.90
Corn Gluten Meal	91.00	37.00	2.70	84.00	3.04	2.06	1.40	46.80	38.08	61.92	4.00	75.00	2.00	100.00	2.40	3.00
Corn Gluten Meal 60% CP	91.00	8.90	7.14	89.00	3.22	2.21	1.52	66.30	41.00	59.00	4.00	75.00	2.00	100.00	2.56	2.86
Distillers Gr.+ solubles	25.00	46.00	9.09	88.00	3.18	2.18	1.50	29.50	27.19	72.81	19.00	89.00	21.00	100.00	10.30	5.00
Distillers Gr. Dehy.—Light	91.00	46.00	10.00	88.00	3.18	2.18	1.50	30.40	27.97	72.03	6.00	67.00	13.00	100.00	9.80	4.00
Distillers Gr. Dehy.—Inter.	91.00	46.00	10.00	88.00	3.18	2.18	1.50	30.40	26.35	73.65	6.00	67.00	18.00	100.00	10.70	4.60
Distillers Gr. Dehy.—Dark	91.00	46.00	10.00	88.00	3.18	2.18	1.50	30.40	25.92	74.08	6.00	67.00	21.00	100.00	9.80	4.00
Distillers Gr. solubles dehy.	91.00	23.00	4.35	88.00	3.18	2.18	1.50									
Distillers Gr. Wet	25.00	40.00	10.00	90.00	3.25	2.24	1.55	29.70	45.09	54.91	44.00	100.00	13.00	100.00	9.20	8.00
Lupins	90.00	33.00	10.00	78.00	2.82	1.88	1.24	26.00	33.40	66.60	25.00	68.00	12.00	100.00	9.90	4.00
Peanut Meal	92.40	14.00	10.00	77.00	2.78	1.85	1.22	34.20	69.20	30.80	26.00	23.00	3.00	90.00	5.50	5.10
Soybean Meal—44	89.00	14.90	2.14	84.00	3.04	2.06	1.40	52.90	80.00	20.00	33.00	27.00	1.00	90.00	2.30	6.30
Soybean Meal—49	90.00	7.79	2.50	87.00	3.15	2.15	1.47	49.90	65.00	35.00	20.00	55.00	2.00	90.00	1.60	7.20
Soybean Whole	90.00	14.90	1.54	94.00	3.40	2.35	1.65	54.00	65.00	35.00	20.00	55.00	2.00	90.00	1.10	6.70
Soybean Whole Roasted	90.00	13.40	10.00	94.00	3.40	2.35	1.65	40.34	75.00	25.00	44.00	22.73	3.00	90.00	18.20	4.56
Sunflower Seed Meal	90.00	40.00	30.00	65.00	2.35	1.47	0.88	42.80	38.31	61.69	5.70	100.00	7.29	90.00	18.80	5.80
Urea	99.00	0.00	0.00	0.00	0.00	0.00	0.00	25.90	80.00	20.00	30.00	18.20	300.00	30.00	5.00	200.00
Apple Pomace	22.00	41.00	2.00	68.90	2.49	1.60	1.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	100.00
Bakery Waste	92.00	18.00	5.56	89.00	3.22	2.21	1.52	5.40	48.21	51.79	11.00	100.00	31.50	100.00	4.70	5.00
Soybean Hulls	91.00	66.30	2.99	80.00	2.89	1.94	1.30	0.00	100.00	0.00	0.00	0.00	0.00	100.00	7.90	10.00

[a] Nutrient Requirements of Beef Cattle, National Research Council, Seventh Revised Edition 1996.

PART XIV
Diagnostic Laboratory Services

Steven H. Umberger, Associate Director, Virginia Cooperative Extension, Agriculture and Natural Resources

NOTE: Access to the following laboratory services may be obtained through your local Virginia Cooperative Extension Office.

Manure testing

Funded through the Virginia Department of Conservation and Recreation (DCR), manure samples are sent to a laboratory at the University of Maryland for testing. Samples are analyzed for ammonia, copper, manganese, nitrogen, phosphate, potash, sulfur, zinc, and moisture content. Containers, sample forms, and instructions for mailing can be obtained from a local Extension office. An agricultural Extension Agent or DCR nutrient management specialist should be consulted for interpretation of the results.

Charge – none

Pre-sidedress nitrate soil test for corn

Funded through the Virginia Department of Conservation and Recreation (DCR), field test kits are available for measuring soil nitrate concentrations. These tests should be conducted on corn fields with a history of manure or biosolids application within the previous three years, or on fields that received applications of commercial fertilizer nitrogen of 30 pounds or less in a starter band, or less than 40 pounds broadcast at planting. Test results are used to determine the most appropriate level of nitrogen to be applied as a sidedress on corn. An Extension Agent or DCR nutrient management specialist should be contacted to assist with the test.

Charge - none

Soil testing

Soil samples are analyzed for specific soil nutrients to determine proper application rates of fertilizer and lime for optimum plant growth. Routine analysis includes soil pH, P, K, Ca, Mg, Zn, Mn, Cu, Fe, and B. Soluble Salts and Organic Matter tests are also available. Completed soil test results, along with a recommendation on fertilization and liming, are mailed to the client. Sampling and mailing instructions are found on the sample boxes and forms, which should be sent directly to the lab with the soil sample and payment.

Charges per sample:	**In-State**	**Out-of-State**
Routine analysis (**No charge for commercial farm samples**)	$7.00	$10.50
Soluble salts	$3.00	$ 4.50
Organic matter	$3.00	$ 4.50
FAX results	$1.00	$ 1.50

Insect identification

Insect samples and insect damaged plant material are handled and processed through the insect identification laboratory. Insects from any structural, plant, or animal hosts are accepted. Insects are identified to the lowest taxonomic level needed for control decisions. Control recommendations accompany insect identification results, which are sent back electronically to each Virginia Cooperative Extension office. Virginia Cooperative Extension offices are supplied with alcohol vials and mailing tubes for specimen shipment. Samples should not be submitted before reviewing instructions on the back of the insect identification submission form 444-113.

Charge – none

Plant disease and plant identification

The Plant Disease Clinic offers plant diagnostic services for diseases caused by fungi, bacteria, viruses, and nematodes, in addition to abiotic problems, such as environmental stress, herbicide injury, and air pollution injury. Both predictive and diagnostic nematode assay services are offered. Predictive assays monitor nematode populations in soil where no plant problem has been observed, whereas diagnostic assays determine whether nematode feeding is the cause of observed plant damage. The Clinic also performs plant and mushroom identifications, although weed identifications are done by the Weed Clinic. The local Extension office should be contacted for information on proper sampling technique and submission of samples. Submit plant samples for disease diagnosis with submission form 450-097. Refer to the back of the form for information on proper sampling techniques. Submit soil samples for predictive nematode assays with submission form 450-098 and soil samples for diagnostic assays with submission form 450-901. Samples should be submitted early in the week to avoid weekend mail.

Charges -No charge for routine plant disease diagnosis, plant or mushroom identification, or diagnostic nematode assays. A fee is charged for plants requiring virus detection. Charges vary, depending upon the number of antibody tests conducted for virus identification.

The fee for predictive nematode assays is $11.00 for each soil sample submitted for routine analysis, and $19.00 per soil sample submitted for routine analysis plus cyst counts.

Also see: http://www.ppws.vt.edu/~clinic

Weed identification

Weed samples submitted to the Plant Disease Clinic are processed and transferred to the Weed Identification Clinic for identification and control recommendations. If possible, weed samples should include leaves, stems, roots, flowers, and seed. Samples should be accompanied by the Weed Identification submission form 450-138.

Charge –none

Also see: http://www.ppws.vt.edu/~clinic/weedid.html

Forage testing

Basic analysis results for forage, silage, and complete feed samples submitted to the Forage Testing Laboratory include dry matter, crude protein, acid detergent fiber (ADF), and estimates of total digestible nutrients, net energy, and digestible protein. In addition to the basic analysis, other analyses that may be conducted, include macro minerals, trace minerals, nitrates, fat (ether extract), soluble protein, lignin, and neutral detergent fiber (NDF). Whole corn stalks or cobs must be pre-chopped before shipping.

	Charges Per Sample
Basic Analysis	$10.00
Macro minerals (Ca, P, Mg, K, Na, and S)	$ 7.00
Macro + trace minerals (Ca, P, Mg, K, Na, S, Zn, Cu, Mn, and Fe)	$10.00
Nitrates	$ 5.00
Fat	$ 7.00
Soluble protein	$ 4.00
Lignin	$ 7.00
Neutral detergent Fiber (NDF)	$ 4.00

Toxicology

The Toxicology Laboratory has the capability to conduct analyses for heavy metals, minerals (deficiencies and poisonings), Vitamins A and E, pesticides, rodenticides, mycotoxins, nitrate, and cyanide. The majority of samples submitted to the laboratory deal with forage and feed analyses for mycotoxins, nitrate, and cyanide.

Mycotoxins are typically not a problem in hay or haylage. Individuals unsure of the appropriateness of a sample should contact the toxicologist before sending the sample. A representative sample of at least one pound is adequate for feed and forage tests. A history, including feed type, type of animal, and clinical sign, should be submitted with each sample.

	Charge per sample
Aflatoxin (semi-quantitative)	$20.00
Zearalenone (semi-quantitative)	$20.00
Vomitoxin (semi-quantitative)	$20.00
Mycotoxin Screen for aflatoxin, zearalenone, and vomitoxin (semi-quantitative)	$30.00
Fumonisin – moldy corn poisoning of horses (semi-quantitative)	$25.00
Nitrate	$14.00
Cyanide – prussic acid (sample must be frozen)	$15.00

Pesticide residues

The Pesticide Residue Laboratory conducts analyses of pesticides in soil, water, animal, and plant tissue samples referred through Virginia Cooperative Extension. Multi-residue pesticide analyses and pesticide-specific analyses assist in evaluating existing, or potential problems with field or ornamental crops, household water supplies, pesticide spills, and fish and wildlife poisonings. Analysis is dependent upon obtaining proper analytical method, having a standard of the pesticide in question, and having the instrumentation required for the analysis. The laboratory should be contacted before samples are collected and sent. A cover letter should accompany samples. The letter should contain the following information: sample identification, tests requested, and any other information that may add to optimizing the laboratory analysis.

	Charge per sample:
Water scan	minimum of $35.00
Soil scan	minimum of $45.00
Plant scan	minimum of $45.00
Animal scan	minimum of $45.00
Individual pesticide analysis	minimum of $25.00

Virginia Tech does not run plant tissue samples.

Row Length/Acre

Row Spacing	Total Length
12 inches	14,520 yards = 43,560 feet
20 inches	8,712 yards = 26,136 feet
24 inches	7,260 yards = 21,780 feet
30 inches	5,808 yards = 17,424 feet
36 inches	4,840 yards = 14,520 feet
40 inches	4,356 yards = 13,069 feet
42 inches	4,149 yards = 12,446 feet

Mass and Weight

Unit	Number of Grams	Approximate U.S. Equivalent	
Metric ton	1,000,000	1.1	tons
Quintal	100,000	220.46	pounds
Kilogram	1,000	2.2046	pounds
Hectogram	100	3.527	ounces
Decagram	10	0.353	ounce
Gram	1	0.035	ounce
Decigram	0.10	1.543	grains
Centigram	0.01	0.154	grain
Milligram	0.001	0.015	grain

Metric System - Length

Unit	Number of Meters	Approximate U.S. Equivalent
Myriameter	10,000	6.2 miles
Kilometer	1,000	0.62 miles
Hectometer	100	109.36 yards
Decameter	10	32.81 feet
Meter	1	39.37 inches
Decimeter	0.1	3.94 inches
Centimeter	0.01	0.39 inch
Millimeter	0.001	0.04 inch

Metric system - Area

Unit	Number of Square Meters	Approximate U.S.Equivalent
Square kilometer	1,000,000	0.3861 square mile
Hectare	10,000	2.4700 acres
Are	100	119.6000 square yards
Centare	1	10.7600 square feet
Square centimeter	0.0001	0.15500 square inch

Metric System - Volume

Unit	Number of Cubic Meters	Approximate U.S.Equivalent
Decastere	10	13.100 cubic yards
Stere	1	1.310 cubic yards
Decistere	0.10	3.530 cubic feet
Cubic centimeter	0.000001	0.061 cubic inch

Metric System - Capacity

Unit	Number of Liters	Approximate U.S. Equivalent		
		Cubic	Dry	Liquid
Kiloliter	1,000	1.31 cubic yards		
Hectoliter	100	3.53 cubic feet	2.84 bushels	
Decaliter	10	0.35 cubic feet	1.14 pecks	2.64 gallons
Liter	1	61.02 cubic inches	0.908 quart	1.057 quarts
Deciliter	0.10	6.10 cubic inches	0.18 pint	0.210 pint
Centiliter	0.01	0.60 cubic inches		0.338 fluid ounce
Milliliter	0.001	0.06 cubic inch		0.27 fluid dram

Energy Values

One horse power = 746 watts	=	force required to raise 33,000 lbs one ft per min
British thermal unit (BTU)	=	252 calories
Calorie	=	the amount of heat needed to raise the temperature of one gram of water, one degree centigrade
One watt	=	the power developed in a circuit by a current one ampere flowing through a potential difference of one volt - 1/746 horse power

PART XVI
Calibration of Sprayers

Daniel E. Brann, Extension Grains Specialist

Be sure to calibrate your sprayer properly. Using too much pesticide may injure your crop; using too little may result in little or no pest control. Apply all pesticides at the recommended rate. Never exceed the labeled rate. Pressure, nozzle size, spacing of nozzles, and speed of the application all affect the application rate.

Large-Area Method of Calibration

1. Adjust tractor speed, pressure, and oriface size according to manufacturer's directions.
2. Measure and stake off one acre (43,560 sq ft) in the field to be treated.
3. Fill tank on sprayer with water.
4. Maintain constant pressure and speed in spraying the acre. Mark pressure, throttle, and gear settings.
5. Remember -- the amount of water necessary to refill the tank is equal to gallons per acre.
6. Make up the spray solution with the correct amount of chemical in the amount of water applied per acre.
7. Make the application at pressure, throttle, and gear settings used in calibrating.

Short-Course Method of Calibration

1. Measure off a course of 163 1/3 feet in the field to be treated.
2. Adjust tractor speed, pressure, and orifice size according to manufacturer's directions.
3. Spray over the measured course, catching the discharge from one nozzle.
4. Measure discharge with a standard measuring cup.
5. $\frac{\text{Number of cups x 200}}{\text{Nozzle spacing in inches}} = \text{gallons/A}$
6. Make up spray solution with the correct amount of chemical in the amount of water that will be applied to each acre.
7. This procedure may also be used in calibrating for band treatments. For band applications, substitute band width for nozzle spraying.

Calibration Tables and Information
Travel Speed Chart
Time Required in Seconds to Travel

Miles per Hour	100 ft	200 ft	300 ft
1	68	136	205
2	34	68	102
3	23	46	68
4	17	34	51
5	14	27	41
6	11	23	34
7	10	20	29
8	9	17	26
9	8	15	23
10	7	14	21

1 mph = 88 feet per minute
1 mph = 1.466 feet per second
Speed in mph = No. 35 inch steps per minute/30

www.ext.vt.edu

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