

Cornell Field Crops and Soils Handbook

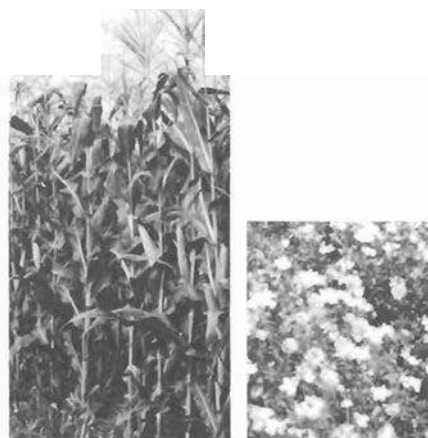


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EXTENSION PUBLICATION

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Cornell Field Crops and Soils Handbook



SECOND EDITION

New York State College of Agriculture and Life Sciences
Ithaca, New York

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Cornell Field Crops and Soils Handbook

(second edition, 1987)



For the past 38 years, *Cornell Recommends for Field Crops* has provided New York farmers with a single, easily obtained compilation of information about producing field crops. The new edition each year has also presented the latest recommendations based upon Cornell's experimental research. This has helped producers and business people associated with agriculture to keep abreast of the rapid changes in crop production technology.

Cornell Recommends has served its purpose well and will continue to provide up-to-date information to growers in the future. Because of advances in agricultural research, however, there is a need to provide more information than can be published in *Cornell Recommends for Field Crops*. The *Field Crops and Soils Handbook* was created to serve as a resource reference and contains expanded background information, recent research findings, and the reasoning behind the recommendations in *Cornell Recommends*.

As with the earlier edition, the *Field Crops and Soils Handbook* is designed to serve as a companion publication to *Cornell Recommends*. The handbook will be revised periodically, depending on the amount of additional information that needs to be included. *Cornell Recommends* will continue to be produced each year. We hope the two publications will have an even larger impact on improving New York crop-production efficiency than what *Cornell Recommends* alone has had over the past third of a century.

The following persons prepared the various sections of the *Cornell Field Crops and Soils Handbook*, second edition, revised 1987:

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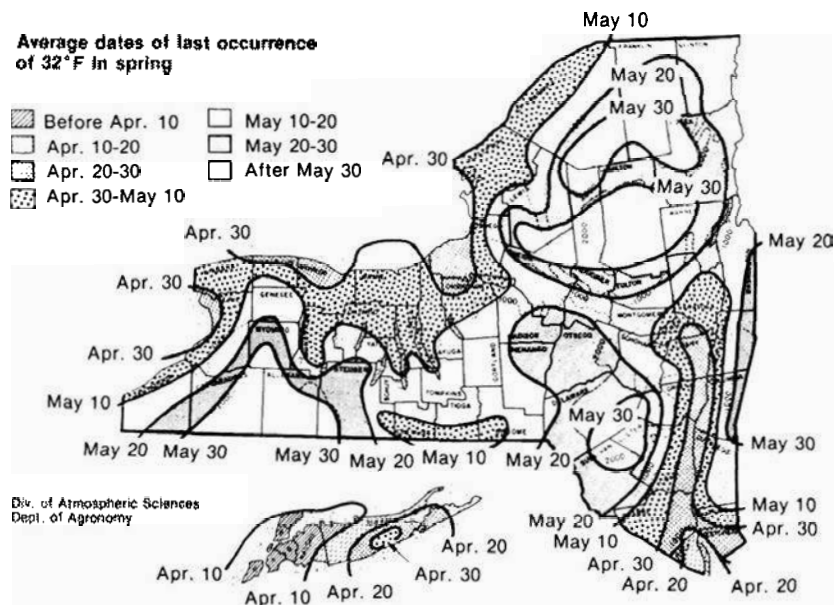
Appreciation is expressed to Susan Clark and Pamela Kline for their help in preparing this handbook.

General Information for Crop Production

NEW YORK STATE'S CLIMATE

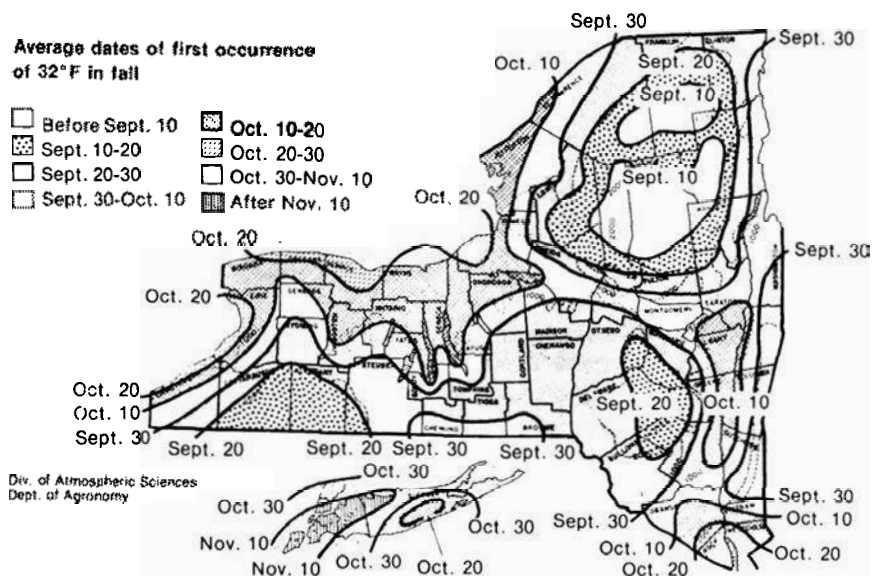
AVERAGE DATES OF LAST SPRING AND FIRST FALL OCCURRENCE OF 32°F

Average dates of last occurrence of 32°F in spring



Average dates of last occurrence of 32°F in spring

Average dates of first occurrence of 32°F in fall



Average dates of first occurrence of 32°F in fall

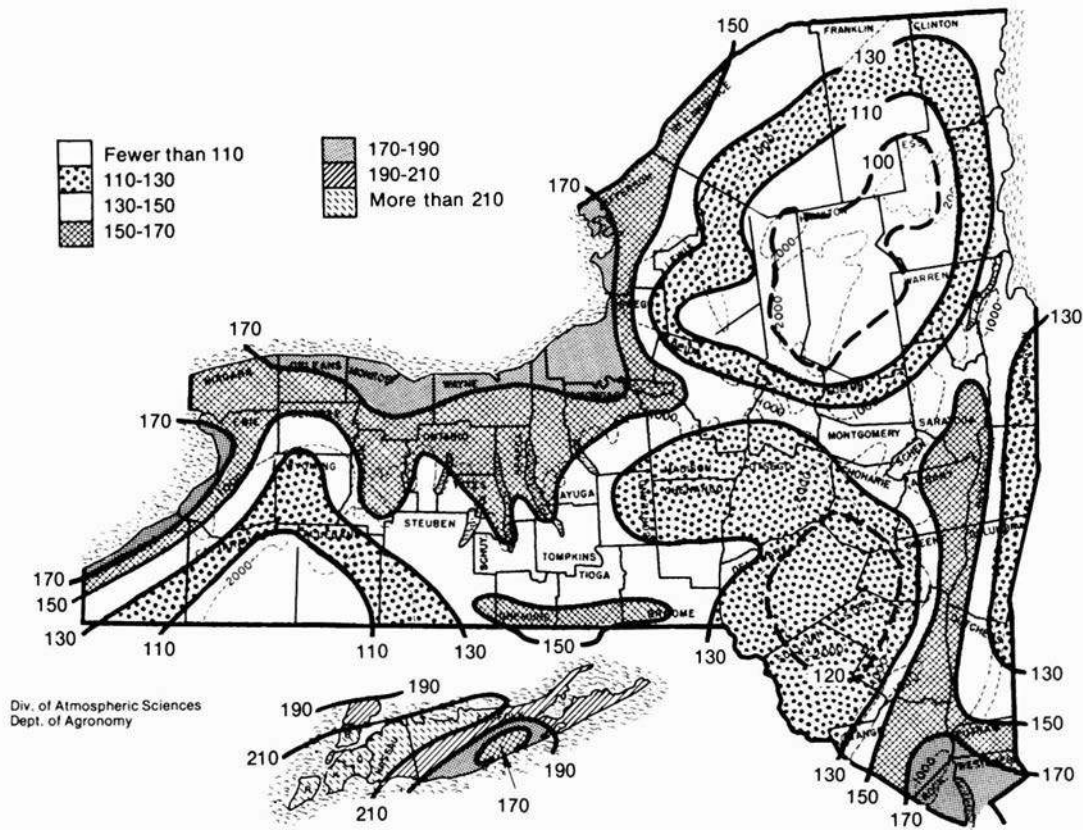
These two maps show the average last date in spring and average first date in fall on which a temperature of 32°F or cooler will occur. Such factors as higher elevation, more northerly latitude, and increased distance from the Great Lakes or Atlantic Ocean will tend to cause freezing

temperatures (32°F or cooler) to occur later in the spring and earlier in the fall.

Topography and terrain features have an important influence on the occurrence of freeze temperatures in the spring and fall. Changes in degree and aspect (direction) of slope

as well as in elevation can cause significant differences in temperature conditions within a relatively short distance. Caution, therefore, should be exercised in using these maps in areas of hilly terrain, such as the Southern Tier, the Catskill Region, and the Northern Plateau.

AVERAGE LENGTH (DAYS) OF THE FREEZE-FREE SEASON



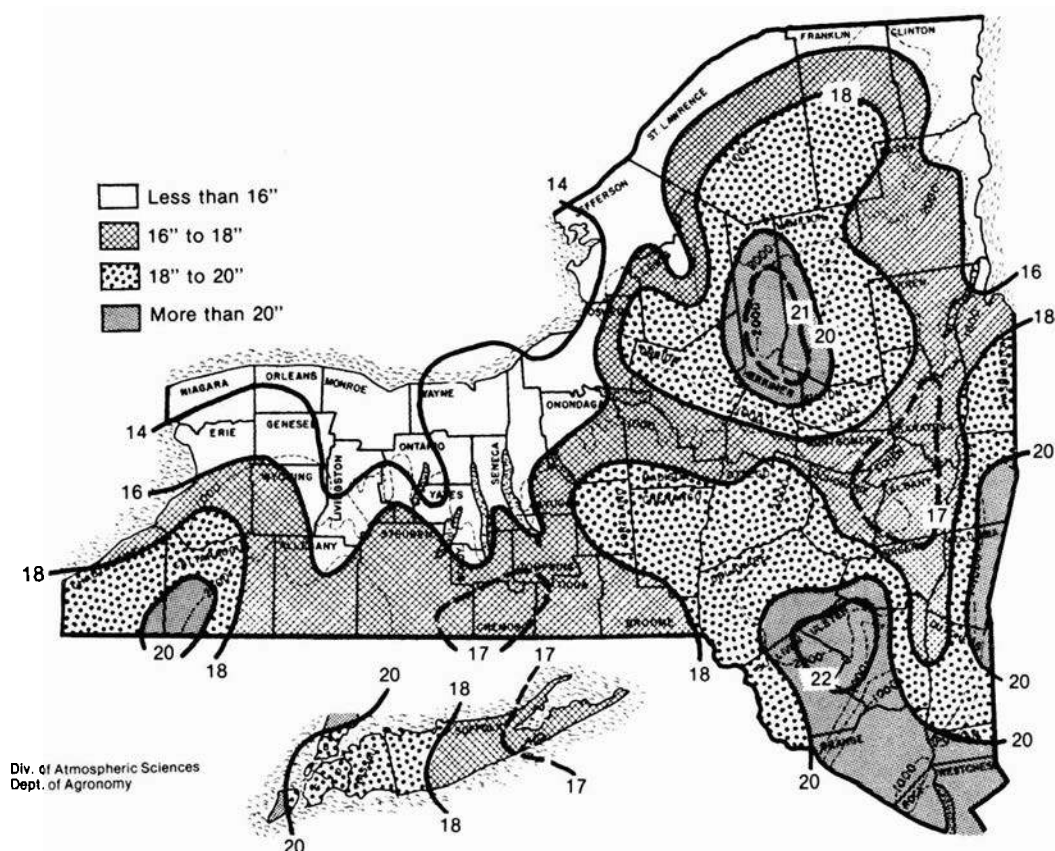
Average length (days) freeze-free season

The map depicts the average number of consecutive days during which the temperature continues warmer than 32°F. The frost-free season for the production of crops thus extends from the average date of the last spring freeze to the average date of the first fall freeze. Near Lake Ontario, for example, the last spring freeze occurs on the average about April 30, and the first fall freeze, around October 20. This results in a frost-free season with an average length of about 170 days. This section would be considered to be a reasonably safe one for the production of a crop that matures in less than 170 days; but on the other hand, it might

be regarded as too risky for the growing of another kind of crop that requires 200 frost-free days for maturity.

Because topography, terrain features, and elevation are important factors in the occurrence of freezing temperatures, caution is recommended in the use of this map in hilly areas of New York State. Higher elevations, northerly facing slopes, deep valleys, and areas of poor air drainage are subject to late spring and early fall frosts and, hence, will have a shorter freeze-free season.

AVERAGE TOTAL PRECIPITATION—MAY TO SEPTEMBER

Average total precipitation (inches)
May–September

The average total precipitation (inches) for the period of May 1 through September 30 is presented in this map.

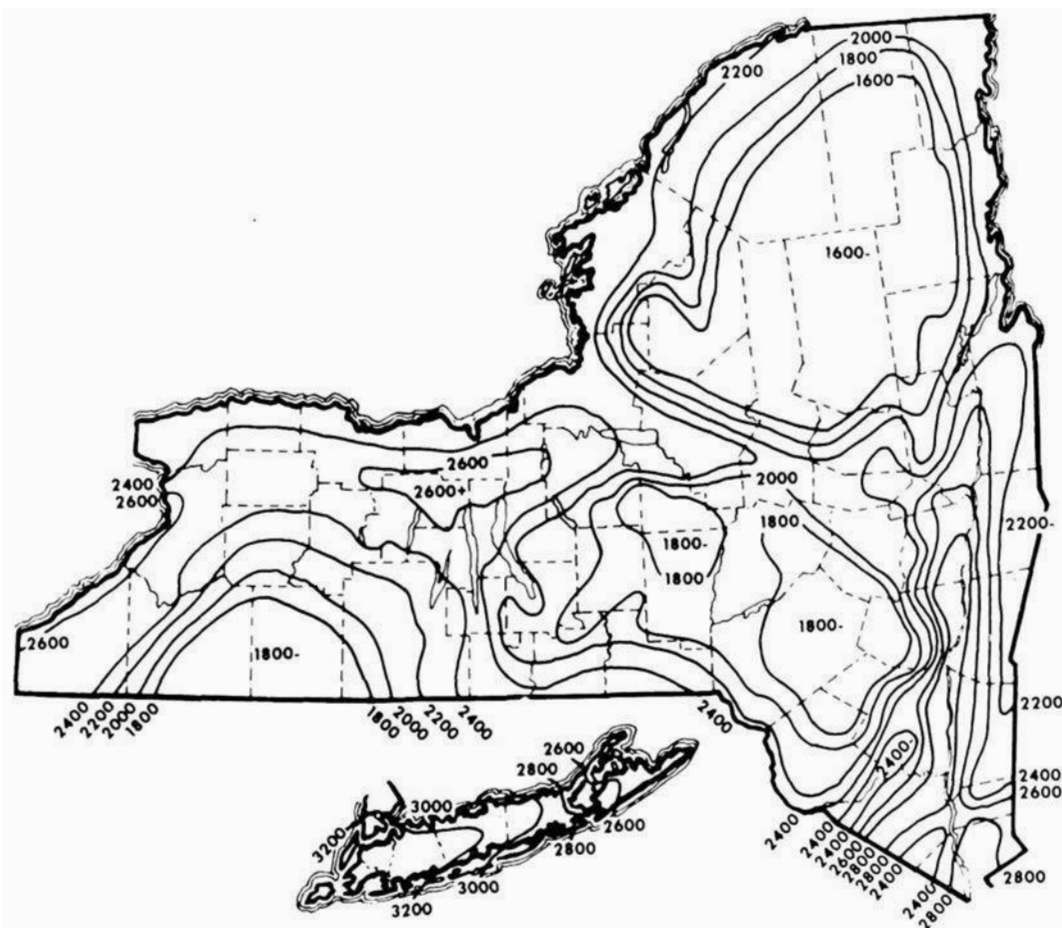
For the principal farming areas of New York State the total May–September rainfall varies on the average from about 14 inches near Lake Ontario up to slightly more than 20 inches in the lower Hudson River valley.

In any given year the total May–September precipitation may deviate by as much as several inches either above or below the average value shown on the map. Much of New York's warm season rainfall is produced by intermittent or rela-

tively brief showers and thunder-showers. In occasional years southeastern parts of the state are exposed to very heavy rainfall from off-shore hurricanes and tropical storms in late summer or early autumn.

Localized showers and thunderstorms often produce rather wide differences in amounts of precipitation within areas the size of one or two counties. In any given growing season there may be rather considerable differences among regions of the state in the total May–September rainfall.

ACCUMULATIVE GROWING DEGREE DAYS



Accumulative growing degree days freeze-free season, base 50°F. Growing degree days relate plant growth to air temperature. This map is for use with warm season crops such as corn and soybeans.

The use of growing degree days is a means by which plant growth can be related to air temperature. In general the rate of plant growth increases as seasonal temperatures increase or warm.

On each day of the growing season the air temperature normally increases during the daylight hours to a maximum in the afternoon and cools during the night hours to a minimum value near sunrise. For each 24-hour day, there is a maximum (high) and a minimum (low) temperature. The arithmetical average of these two values is designated as the mean temperature for the day, or the daily mean temperature.

It has been observed that so-called cool-season crops grow when the daily mean temperature in the spring has warmed to a level of 40° F. On the other hand, warm-season crops, such as corn and soybeans, require a daily mean temperature of at least 50° F before growth will occur. Such temperature levels are referred to as a *base* or *threshold* temperature.

The concept of the growing degree day involves determination of the number of degrees F by which the daily mean temperatures on a given day exceeds an appropriate base temperature. Each degree in excess is called a growing degree day. The greater the daily excess, or number of growing degree days, the

warmer was the day's weather; and presumably, the greater was the rate of crop growth. The growing degree days are determined in this manner for each day and accumulated from the beginning to the conclusion of the growing period of a given crop. The result is the accumulative growing degree days for a specific growing season. Such data for a large number of growing seasons are summarized to obtain the average accumulative growing degree days that may be expected.

In New York State growing degree days have been applied mostly to the production of warm-season crops, such as corn and soybeans. Hence, a daily mean temperature of 50° F is used as the base for calculating the daily quota of growing degree days. The calculation is made as follows: First, note the maximum (high) and minimum (low) temperatures for the 24-hour calendar day; then average the two numbers to obtain the daily mean temperature. For instance, a maximum of 80° F and a minimum of 62° F would yield an average (daily mean) temperature of 71° F. Finally, subtract the base temperature of 50° F to get an excess of 21 degrees, or 21 growing degree days for that day.

$$\frac{[\text{Daily max. temp. (°F)} + \text{Daily min. temp. (°F)}]}{2} - 50$$

= Daily growing degree days (GDD).

The temperature extremes (high and low) are recorded for each day of the growing season from the initial date after the last 32° in the spring to the date before the first 32° in the fall. By adding together the growing degree days for each day in this period

the accumulative, or total, for the frost-free growing season is obtained. On days when the daily mean temperature is 50° F or colder, there is no excess of degrees, and the number of growing degree days is taken as zero or none.

The average accumulative growing degree days, determined in this manner for a base temperature of 50° F, are shown on the map. A similar procedure is followed for calculating and mapping growing degree days when a base temperature of 40° F (or any other base temperature) is adopted.

The midwestern states, embracing the Corn Belt, have adopted a slightly different procedure for calculating growing degree days on a daily basis. This procedure considers the fact that plants develop, grow, and produce best within a certain range of temperature. For corn the range is apparently from 50° to 86° F. Each degree of temperature within this range is assumed to contribute to crop development in the amount of 1 growing degree day.

In this so-called Corn Belt method, the daily maximum and minimum temperatures are averaged and the base temperature of 50° F subtracted to obtain the daily growing degree days, the same procedure as that used in the method for New York State. The difference, however, is that the Corn Belt method mathematically counts any daily minimum temperature below 50° F as equal to 50° and any daily maximum temperature greater than 86° F as equal to 86°. Thus, a daily minimum of 42° F, for example, is transposed to the formula as 50°, and a maximum temperature of 90° F is transposed as 86°.



To further illustrate, let us compare the daily growing degree days obtained from a daily set of temperature extremes by (1) the Corn Belt method and (2) the straight average

method used in New York State. We assume a daily minimum temperature of 40° and a daily maximum of 70°. The latter method uses a straight arithmetical average of 55, subtracts the base of 50, and gives 5 growing degree days for the day in question. In the Corn Belt method, the 40 minimum is immediately transposed to a value of 50; then the arithmetical average is determined to be 60° (70° plus 50° divided by 2); and finally, the subtraction of the 50° base temperature yields 10 growing degree days, or 5 more than obtained by the other method for the same day. As this example illustrates, computation by the Corn Belt method will normally yield not only a greater daily total (from the same temperature data) but also a greater accumulative total of growing degree days on a seasonal basis in New York.




The foregoing discussion may help to explain why a certain corn hybrid from an agronomist in the Corn Belt may be listed as having a growing degree day rating of say 3000, whereas the very same corn hybrid is cited by a New York State agronomist as having a rating of 2700. The reason for the discrepancy is that the growing degree day total has been determined by two different methods.

SOILS AND SOIL MANAGEMENT GROUPS OF NEW YORK



GROUP I SOILS

-  Fine-textured soils developed from clayey lake sediments. Examples: Vergennes, Kingsbury, Livingston.
-  Medium- to fine-textured soils developed from lake sediments. Examples: Hudson, Odessa, Rhinebeck, and Schoharie.


GROUP II SOILS

-  Medium- to fine-textured soils developed from calcareous glacial till. Examples: Cazenovia, Hilton, Honeoye, Lima, Ontario.
-  Medium- to moderately fine textured soils developed from slightly calcareous glacial till mixed with shale. Examples: Burdett, Conesus, Darien, Manheim, Mohawk, and Nunda.
-  Medium-textured soils developed in recent alluvium. Examples: Chagrin, Teet, and Wayland.


GROUP III SOILS

-  Moderately coarse textured soils developed from recent alluvium. Examples: Barbour, Chenango, Howard, Tioga, and Tunkhannock.
-  Medium-textured acid soils usually with fragipans developed on glacial till. Examples: Camroden, Erie, Langford, Lordstown, Marcy, Mardin, Oquaga, Valois, and Volusia.



GROUP IV SOILS

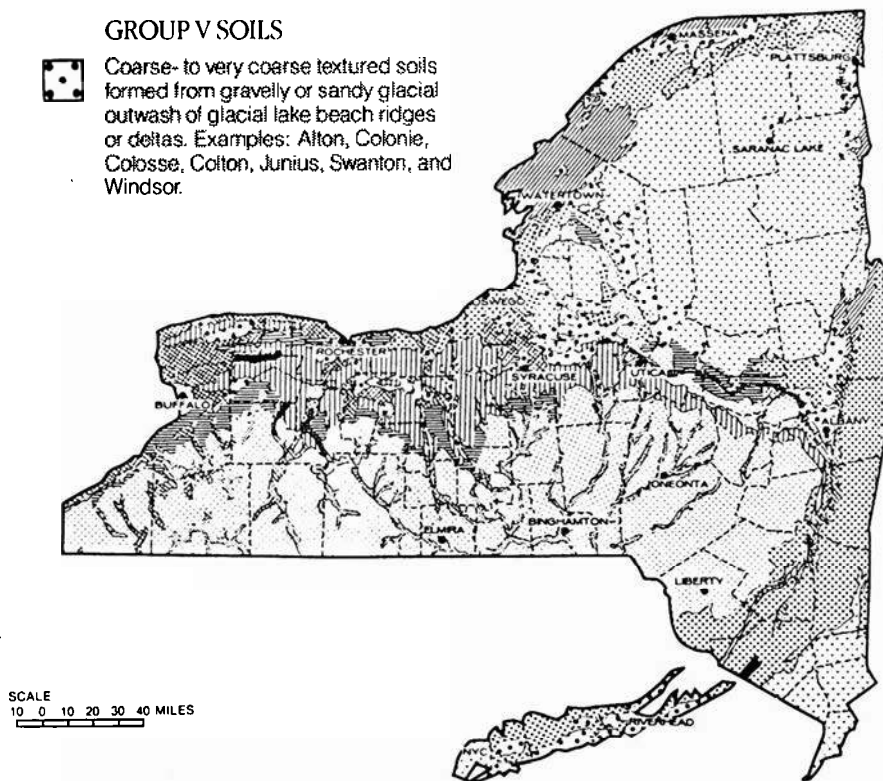
-  Coarse- to medium-textured soils formed from glacial till or glacial outwash. Examples: Broadalbin, Bombay, Copake, Grenville, Hoosic, Madrid, Moira, Parishville, Sodus, and Worth.

GROUP V SOILS

-  Coarse- to very coarse textured soils formed from gravelly or sandy glacial outwash of glacial lake beach ridges or deltas. Examples: Alton, Colonie, Colosse, Colton, Junius, Swanton, and Windsor.

OTHER AREAS

-  Organic or muck lands.
-  Urban areas, Adirondack Mountains, Tug Hill, and primarily rock land.



Five soil management groups are presently being used for fertility and management recommendations in New York. The five groups are classified according to the texture of the surface and the subsoil. The groups are then subdivided on the basis of the parent material. See the map for the general locations of the groups.

Soil Management Group I

The soils of management group I are medium- to fine-textured and were developed from lake sediments. They are heavy-textured, generally wet soils formed from lake or marine sediments deposited in glacial lakes. They are characterized by a very slowly permeable subsurface of silty clay to clay. This group is divided into two subgroups:

Subgroup IA. *Fine-textured soils developed from clayey lake sediments.* These are the heavy, generally

wet soils formed from lake or marine sediments with silty clay loam to clay surfaces over heavier silty clay to clay subsoils. They contain little or no sand or gravel. The slope is generally level or nearly level, and the topography is level to undulating. The very slowly permeable profile and nearly level slopes make soil drainage and water management difficult, but very important. Land smoothing and open ditches with good outlets are recommended. Rotations containing sod crops, cultural practices such as fall plowing, the incorporation of organic

The soil pH ranges from 5.4 to 7.0; thus lime may or may not be needed. If the pH is low, large quantities of lime are required.

Magnesium on these soils is usually adequate to high.

The organic matter contents are generally high, but the release of nitrogen is slow, especially in the spring because of the cold, wet nature of these soils.

The nitrogen-supplying power of these soils usually exceeds 80 pounds per acre per year. The efficiency of applied nitrogen is often

The potassium-supplying power is high, but restricted root growth decreases the ability of the plant to extract the potassium; therefore, some potassium-containing fertilizers are needed.

The corn yields of this subgroup are generally below 100 bushels per acre (17 tons per acre of silage), except for the moderately well drained Vergennes and Wilpoint soils. The yield potential for perennial forages ranges from 2.5 to 4.5 tons per acre. Birdsfoot trefoil and grass are usually the most appropriate species to grow.

Examples of group IA clayey soils are the moderately well drained Vergennes, the somewhat poorly drained Kingsbury, and the poorly drained Livingston soils. Large acreages of group IA soils occur in northern New York with limited acres (not shown on map) in eastern New York and the Hudson Valley.

Subgroup IB. *Medium- to fine-textured soils developed from lake sediments.* These soils are formed from glacial lake or marine deposits and have a permeable, very fine sandy loam, silt loam, or silty clay loam surface over a more slowly permeable, heavier silty clay loam to clay subsurface. They differ from subgroup IA because of the more sandy surface and usually a more permeable subsoil. They generally occur on nearly level to gently sloping or rolling landscapes of the lower elevations near the lakes and along the Hudson River. The more rolling landscape makes surface water control and drainage easier than on the nearly level areas, but it increases the erosion hazard. Water and erosion control are important in managing these soils for crop production.

The pH of these soils ranges from 5.2 to 7.4, but most often the pH is 5.8 or above. Most subgroup IB soils



New York's variable topography and numerous soil types call for specific management to fit each field.

residues, and timely fitting operations at proper moisture conditions should be used to maintain good soil tilth and to obtain near-optimum crop yields.

The water-holding capacity of these soils is high; but because of limited rooting in the clayey subsoils, crops suffer from drought more frequently than when grown on group II or III soils.

low, especially if applied preplant. These heavy-textured soils are often waterlogged, and the nitrogen is lost by denitrification. Side-dressing the nitrogen increases the efficiency of the applied nitrogen.

Phosphorus is usually low, and the placement of phosphorus in the band near the seed at planting is critical. The heavy soil texture and wet and cold spring conditions slow root growth. Thus the roots cannot extract nutrients from a large volume of soil. This reduces phosphorus uptake and increases the probability of a response from phosphorus placed in the fertilizer band.

need some lime for alfalfa production. The magnesium supply is usually adequate.

The organic matter content is generally medium, and the nitrogen release is good on the well-drained to moderately well drained soils. The nitrogen-supplying power generally

exceeds 80 pounds per acre per year, but nitrogen loss is a problem as with the subgroup IA soils.

Original phosphorus levels are low, but the addition of fertilizer phosphorus to cultivated areas has increased phosphorus contents to high levels. Band placement of phos-

phorus is important for establishment of all crops.

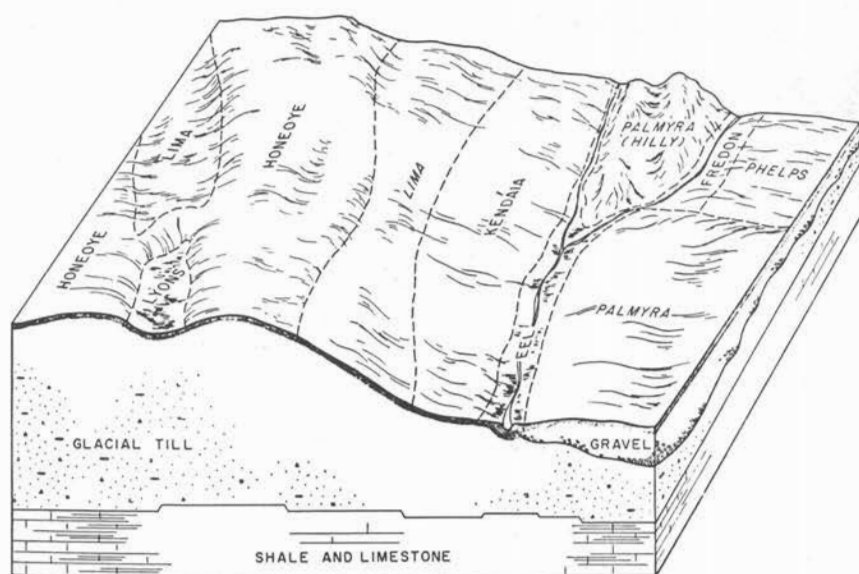
The potash-supplying power is high, but continuous cropping without adequate fertilizer can reduce the potassium levels.

The yield potentials for these soils vary from 75 to 120 bushels of corn per acre (13 to 20 tons of silage) depending on the soil drainage. The potential yields of perennial forage range from 2.5 to 5.5 tons per acre, but only the well-drained and moderately well drained soils are suited for alfalfa production.

The Hudson, Odessa, and Schoharie series are examples of the well-drained and moderately well drained soils of the subgroup IB. Other examples are the somewhat poorly and poorly drained Caneadea, Canadice, and Rhinebeck soils and the very poorly drained Lakemont soils.



The silty clay loam soils such as Rhinebeck of group IB often need surface water control to improve the crop production potential.



Typical landscape cross section of Honeoye-Lima soil association (group IIA) formed on gently sloping or rolling high-lime glacial till.

Soil Management Group II

The soils of group II are medium-textured to moderately fine textured soils developed from calcareous glacial till, calcareous glacial till mixed with shale, or recent alluvium. There are three subgroups, separated according to the parent material. The yield potentials of these soils vary from 75 to 150 bushels per acre of corn (13 to 26 tons per acre of corn silage) and from 2.5 to 6 tons per acre of forage, depending primarily upon the soil drainage characteristics.

Subgroup IIA. *Medium- to fine-textured soils developed from calcareous glacial till.* These soils are found in areas of undulating to gently rolling topography in the central plains of New York. They are formed from strongly calcareous glacial till. The soil profile is slightly acid to slightly alkaline in the surface and slightly alkaline or strongly alkaline in the subsoil.

The surface texture may be a very fine sandy loam, loam, or silt loam with silt loam to silty clay loam subsoils. The water-holding capacity of these soils is high. Lime is usually not required, but surface soil pH's are occasionally low. The nitrogen and potassium supplies are generally high, but the native phosphorus supply is low. Additions of fertilizer phosphorus have increased the phosphorus content to high levels in some soils.

Soil water management is a problem on most of these soils. Erosion control and adequate soil drainage are critical problems. Subsurface drainage is effective in removing excess soil water. Strip-cropping, diversion ditches, sod waterways, and subdrain outlet terraces have successfully provided both erosion control and drainage. Once the water management problems have been solved, these are among the most productive soils of the state.

Some examples are the well-drained to moderately well drained Cazenovia, Hilton, Honeoye, Lima, and Ontario series; the somewhat poorly drained Appleton, Kendaia, and Ovid series; and the poorly drained Lyons and Romulus series.

Subgroup IIB. *Medium-textured to moderately fine textured soils developed from slightly calcareous glacial till mixed with shale.* These soils generally have a very fine sandy loam or silt loam surface over a heavy silt loam or silty clay loam subsurface. These soils occur on nearly level or slightly undulating to rolling landscapes and are generally located in the transition zone to the higher lime soils. The sloping landscapes often show signs of erosion, and erosion control practices are generally necessary. On the more level or concave topography and finer-textured soils, drainage is a problem.

The better-drained soils of this group are well suited for the production of almost all field crops and vegetables. Almost all soils of this group require lime for legumes, and many must be limed for optimum production of other field crops. In general, the organic matter and nitrogen in

level, first bottomlands and are subject to spring floods. The better-drained soils are intensively used and highly productive for a wide variety of crops. They have a water-holding capacity of 5 to 9 inches of available water. These are among the most fertile soils in New York. Crops



Typical drumlin landscape of the Ontario-Hilton soil association (group IIA). This landscape scene shows soils ranging from the well-drained Ontario in the area containing the strip crops on the drumlin to the very black organic soils formed in the very poorly drained lowland area between drumlins.

these soils are medium. The original phosphorus supply was low, but phosphorus additions have increased it to high levels in some soils. The potassium supply in these soils is high.

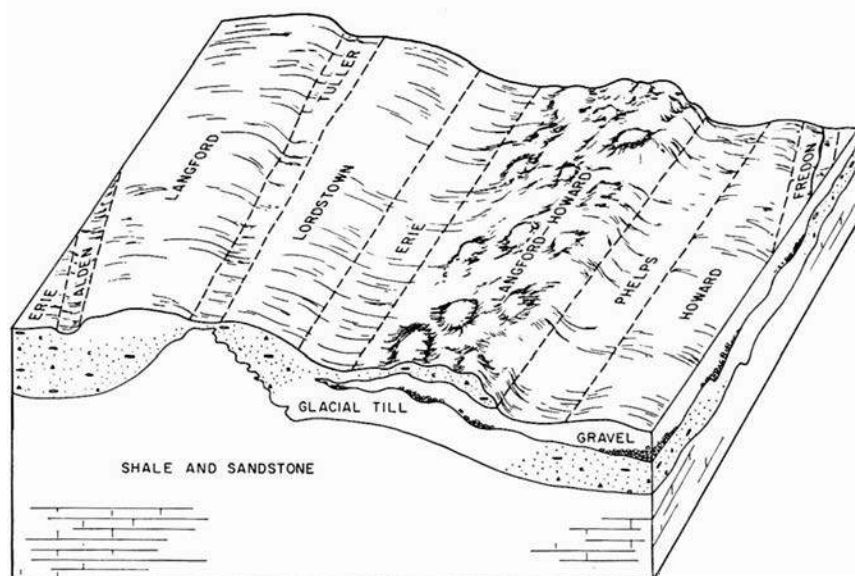
Some examples are the well-drained to moderately well drained Conesus, Lansing, Mohawk, and Nunda series. The somewhat poorly or poorly drained members include the generally finer textured Burdett, Darien, Kendaia, and Manheim series.

Subgroup IIC. *Medium-textured soils developed in recent alluvium.* These soils have developed on nearly

grown on these soils respond to practices that improve soil tilth and minimize soil compaction. Examples are the well-drained Hamblin or Genesee, moderately well drained Teel, and somewhat poorly drained Wayland.

Soil Management Group III

Soil management group III has two subdivisions. They are similar in most of their management requirements, but can differ in parent material, slope, tillage, and erosion control practices. The soil management



Hill—valley landscape cross section of the southern tier with the low-lime Langford—Erie soil association (group IIIB) and the Howard—Phelps outwash soils (group IIIA).

group III soils are medium in potassium-supplying power and are a medium-textured silt loam in both the surface and the subsoil (see map and key for general locations).

Subgroup IIIA. *Moderately coarse textured soil developed from the recent alluvium.* These soils generally have a sandy loam, gravelly loam, or gravelly silt loam surface and gravelly loam, loam, sand, or gravel subsurfaces. They occur on gravelly outwash plains in the valleys or on glacial kames or eskers. The majority are level to nearly level and are well suited to a variety of crops. Erosion and soil structure are generally not problems. These soils contain about 4 to 7 inches of available water in the soil profile. Irrigation may be required for vegetable production or during dry years for field crops.

The soils located near the high-lime glacial tills are usually higher in pH than the soils in the southern part of the state, but lime must be added to most of these soils for optimum

crop production. Nitrogen, phosphorus, and potassium are needed under intensive cropping. Yield potentials for this group are very high with corn yields generally between 110 and 130 bushels per acre on the well-drained and moderately well drained areas. Perennial forage yields range from 2.5 to 5.8 tons per acre depending on soil drainage.

Examples are the well-drained to moderately well drained Barbour, Braceville, Chenango, Howard, Kars, Palmyra, Phelps, and Tioga series. The somewhat poorly drained soils include the Fredon, Holly, and Red Hook series.

Subgroup IIIB. *Medium-textured acid soils with fragipans developed on glacial till.* These soils contain shale, sandstone, slate, or schist-type rocks with little or no lime. They have a silt loam surface and a more dense or compacted silt loam subsoil with fragipan or hardpan at various depths below the surface. The depth to the fragipan determines the soil drainage characteristics—the

deeper the pan, the better drained the soil. The entire profile contains few to many angular and (or) flat stones of various sizes.

The well-drained and moderately well drained soils usually contain 4 to 7 inches of available water; the somewhat poorly drained soils contain 3 to 4 inches. Erosion is a problem on all soils within this group. These sloping soils must be protected to reduce erosion by using combinations of cover crops, strip-cropping, crop rotations, and diversion ditches.

The pattern of soils within a field is usually complex because of the variable slopes. Most fields will contain two or more soils with different drainage characteristics; that is, the majority of a field may be moderately well drained soil such as Mardin, but in the low places a poorly drained soil such as Chippewa will occur. This type of soil pattern requires diversion terraces to intercept runoff from higher elevations and random subdrainage to eliminate wet spots. Such practices permit more timely, efficient farm operations.

Yield potentials for the subgroup IIIB soils are generally lower than for subgroup IIIA because water is often a problem.

The well-drained and moderately well drained soils generally occur on the convex slopes near the top of the hills, on the knolls, or on sloping areas where there is no water seepage. These include the Mardin, Valois, Langford, and Tunkhannock soils. The well-drained Lordstown and Oquaga soils occur on steeper slopes and are shallow to bedrock. The somewhat poorly and poorly drained soils such as Camroden, Elbery, Erie, Marcy, Morris, and Volusia occur on the longer slopes of the hill-sides, on concave slopes, and near the bases of hills where water tends to collect or seep from above.

Soil Management Group IV

There is no subdivision of the soil management group IV. The soil management group IV soils are low in potassium-supplying power, and are coarse-textured to moderately coarse textured soils (see map and key for general locations).

Coarse- to medium-textured soils formed from glacial till or glacial outwash. The soil texture is sandy loam or silt loam in the surface, with or without gravel. The subsurface ranges from gravelly loams to clays. The slopes vary from level to strongly undulating. The somewhat poorly to poorly drained soils of this group can usually be drained effectively with widely spaced tile lines.

These soil profiles usually have an available water capacity of 3 to 5 inches. Crops grown on these soils suffer from insufficient water during extended dry periods, especially if the water table is more than 2 to 3 feet in depth.

The soil tilth is excellent, and the soils can be worked over a wide range of moisture conditions without injury. Erosion from wind and water may be a problem in some areas.

Most of these soils require regular additions of lime for crop growth. Crops respond well to fertilizers when moisture is adequate.

Examples of the well-drained to moderately well drained soils of this group are Bombay, Broadalbin, Copake, Empeyville, Gloucester, Grenville, Hogansburg, Hoosic, Ira, Madrid, Moira, Parishville, Sodus, and Worth.

Some somewhat poorly to poorly drained examples are Brayton, Fredon, Massena, Scriba, and Westbury.

Soil Management Group V

Coarse-textured to very coarse textured soils formed from gravelly or sandy glacial outwash or glacial



Typical hill-valley landscape of the southern tier showing the outwash soils (group IIIA) in the valley and the low-lime glacial till soils (group IIIB), many containing fragipans on the hillsides.



Sandy soils (group V) on old beach ridges, sand dunes, and the like occur around the edges of old glacial lakes. These soils have a very low native-fertility status and very low water-holding capacities.

lake beach ridges or deltas. The parent material for these soils has been reworked by wind or water either as glacial outwash or by wave action from the glacial lakes, removing almost all the silt and clay and leaving usually deep deposits of sand and (or) gravel. The soils that form have coarse textures usually with little organic matter. The topography is nearly level to undulating.

Most of these soils are excessively drained. The available water capacity is very low, 2 to 3 inches. Supplemental irrigation is essential for consistent crop production. The tilth of these soils is generally good to loose. They can be worked at almost any time following a rain and are commonly used for producing fresh market vegetable crops.

They require small, but regular, additions of lime. The fertility needs are great. The soils usually supply less than 50 pounds per acre of available nitrogen or potassium. Leaching of fertilizer nitrogen and potassium is a problem, and additional fertilizer nitrogen and potash should be added to the irrigated soils. The nitrogen

should be applied as sidedress applications and potassium as spring or summer applications to reduce leaching losses.

Without irrigation these soils have low yields, generally less than 90 bushels per acre of corn and 4.5 tons of alfalfa.

Examples of the excessively drained to well-drained soils include Alton, Colosse, Colton, Hinckley, and Windsor.

The somewhat poorly and poorly drained soils include Claverack, Colonie, Elmwood, Granby, Junius, and Swanton.

Other Areas

1. Organic or muck lands. Muck lands are formed by deposits of decaying organic matter in bogs. They must be drained before they can be used for agriculture. Water management is very important, not only for drainage for crop production, but also for irrigation and control of the rate of decay of the organic matter.

Muck soils are usually high in nitrogen, but low in phosphorus, po-

tassium, copper, and magnesium. The deep mucks may be very acid, but shallow mucks may have marl mixed with, or very close to, the surface. This complicates the fertility program, especially for zinc and manganese.

The muck soils are generally used for the production of vegetable crops, but field crops are sometimes grown. When used for field crops, they should be fertilized with phosphorus and potassium as indicated in the section for soil management group V; but nitrogen application rates should be *reduced* to one-third to one-half of the rates recommended for mineral soils.

2. Nonagricultural land. These areas include the urban areas, lakes, Adirondack Mountains, rock land, and Tug Hill. A small percentage of agricultural lands are located within these areas. Such lands are too small and too diverse to make general recommendations. Persons desiring information for agricultural operations in these areas should contact their local Cooperative Extension or Soil Conservation office.

SOIL CHARACTERISTICS AND YIELDS

Field-grown crops depend upon the soil to provide water, nutrients, and support to the plant and to permit air to freely move to the roots. The ability to provide these plant-growth factors, along with ease of tillage, erosion potential, and the land topography, determines a good agricultural soil. Some physical properties of soils are important in determining a good agricultural soil.

Soil Drainage

The relative ability of a soil to permit drainage of excess water from the entire soil profile is known as soil

drainage. Soils are classified into drainage groups by their moisture status during the growing season. The moisture status during the growing season is determined either by observing the soil moisture conditions over a period of years or by measuring the soil depth to soil color mottling. Mottling is the soil color change in response to soil drainage. Soils that are well drained have uniformly bright colors such as brown, yellow, red, or combinations of these colors. The surface soils may have these bright colors, yet be darkened by organic matter. Surface and sub-surface soils may also inherit darker colors from gray black or black shales present in the parent material. Uni-

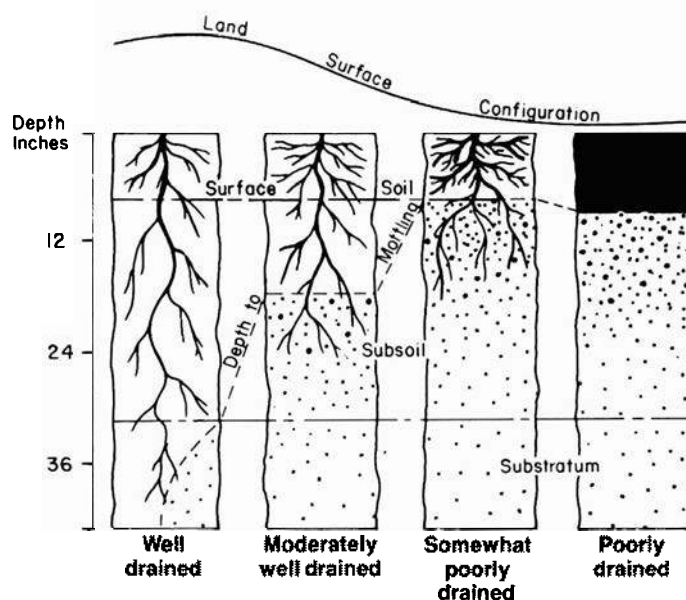
form light gray colors in the profile indicate prolonged saturation with water. If the surface soil is light gray, water stands on or near the surface for prolonged periods during the summer. If there are alternating periods when the soil is saturated and not saturated with water at a particular depth, some of the bright brown or yellow colors change to gray spots or mottles. The depth to this color change determines the soil drainage group or class. The classes and some of their characteristics are illustrated and described as follows:

Excessively drained. These soils are dry after only moderate periods of dry weather during the summer. They are usually sandy or shallow to

bedrock with a low water-holding capacity (less than 3 in. of plant-available water). The soil colors are bright throughout the profile. In New York these soils are often used for irrigated fruit and vegetable crops, especially early short-season fresh-market vegetable crops. Corn grown on these soils often suffers from lack of water, and without irrigation the crop may fail.

Well-drained soils. These soils have the least problems associated with wetness and dryness. The excess water drains from the profile rapidly enough to prevent extended periods of saturation. After heavy midsummer rains the water will not remain on the surface of the usually moist soils longer than 1 or 2 days, and they will remain wet for only 3 to 5 days. Even though the excess water drains rapidly, these soils hold sufficient water for normal plant growth during moderately dry periods. Normal rooting depth in these soils is beyond 24 inches. Color mottling does not occur closer than about 24 inches (usually at least 30 in.) to the surface. The well-drained soils generally occur on the concave land surfaces such as knolls, hilltops, and upper hillsides, but may also occur on level areas. These land surfaces do not receive surface-water runoff or subsurface water seepage from surrounding areas and have sufficient slope or sufficiently rapid soil permeability to prevent surface-water accumulation. On most farms well-drained soils are the most valued fields because they can be tilled first in the spring and have a high-yield capacity.

Moderately well drained soils. These soils remain wet several days longer in the spring than the well-drained soils. After heavy midsummer rains, water may remain on the surface for 2 or more days. Likewise, they will remain wet for several days.



The pattern of soil water drainage affects rooting of upland plants.

Mottling of colors will occur to within 18 to 24 inches of the soil surface. Plants will not normally root deeper than 18 to 24 inches.

The moderately well drained soils usually occur on areas either with less slope for surface runoff or down the slope from well-drained soils where they receive some surface runoff and subsurface water seepage. The moderately well drained soils usually have a heavier-textured subsurface horizon or a moderately dense fragipan to restrict water drainage through the soil profile. Crops such as corn that are more tolerant to short periods of excess water produce very good yields when grown on these soils. Crops such as alfalfa with less tolerance to excess water, even for short periods, are slightly to moderately injured when grown on the moderately well drained soils, and the yields or stands are reduced.

Somewhat poorly drained soils. Wetness is a serious problem for most uses of these soils. They remain wet until late in the spring and often can-

not be tilled until mid-June or early July. They remain wet long enough to severely damage crops after heavy midsummer rains. Surface water on the somewhat poorly drained soils is also a problem. These soils may occur either on very flat areas where surface drainage is slow or down the slope where they receive the surface water runoff from other areas. These soils often occur as small to large wet areas within well-drained to moderately well drained soil areas, their presence hindering spring plowing operations. Many of the wetter soils have fragipans or other dense layers, at 12 to 18 inches below the soil surface, which restrict water drainage and root growth. Mottling of the soil colors occurs within 8 to 18 inches of the surface. Rooting depth is limited to 18 inches or less; therefore, crops may suffer not only from excess water after heavy rains but also from drought during moderately dry summer periods.

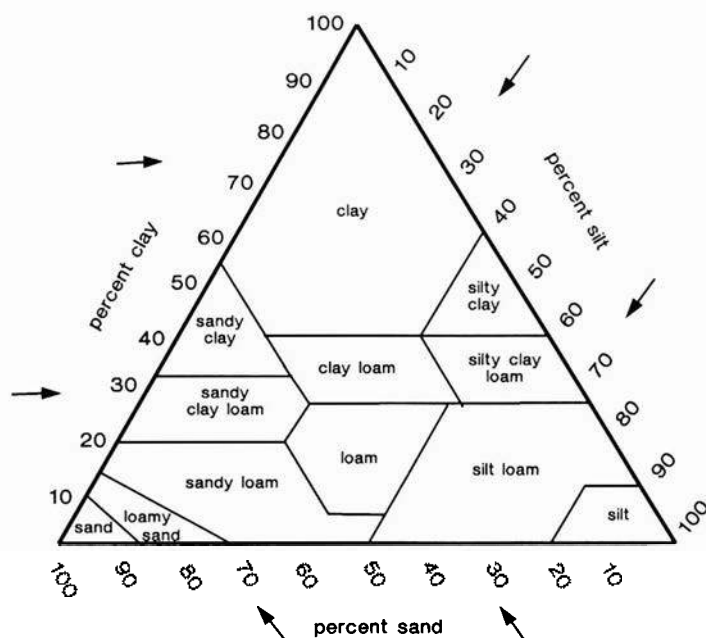
Poorly drained soils. Without artificial drainage these soils remain wet and may have water standing on

or near the soil surface until mid-summer. They usually remain wet for extended periods after heavy mid-summer rains. The usually wet soils occur as depressions within areas of better drained soils or as seep spots near the base of long slopes. Large areas of poorly drained soils are not normally tilled without extensive artificial drainage systems. Small areas within a better drained field are usually tilled to improve the drainage. The color of the usually wet soils is gray even in the soil surface, but the surface may be very dark gray to black because of organic matter accumulations. A dark surface with an abrupt change to a uniformly gray subsurface is a good indication of a usually wet soil.

Very poorly drained soils. These are the soils of swamps and marshes that have water standing at or near the soil surface at all times except during very long dry periods. Except for the muck soils, these soils are not commonly used for agricultural purposes.

Soil Texture

Soil texture refers to relative quantities of the individual particles of different sizes within the soil. The particles larger than 2 mm, rock fragments, gravel, and stones, are not considered in the soil textural classification. The larger than 2-mm size are included as modifiers to the textural class, for example, Chenango *gravelly* silt loam. The sand fraction is the coarsest particles considered in soil texture. Sand can be seen with the naked eye and feels gritty. Sand particles will settle out of water very rapidly. Silt is the intermediate size of particles. Individual fine silt particles cannot be seen with the naked eye, but can be seen with the aid of a microscope. The feel of pure silt is smooth like cornstarch. Silt particles



Soil textural triangle is used to determine soil textural class from the percentages of sand, silt, or clay in the soil.

settle out of water slowly. Clay, the smallest of the particles, are too small to be seen even with an ordinary microscope. Individual clay particles can be obtained only by dispersing the clay in water because of their tendency to stick together. Once the clay is suspended in water, the individual clay particles will stay suspended until the particles join together to make larger particles. Then they will settle out. The fine clay particles are responsible for muddy ponds several days or weeks after a rain.

Soil textural class is the range in soil-particle-size distributions with similar physical properties. These are defined according to the soil textural triangle shown. The textural chart is read by finding where two lines representing the percentages by weight of sand, silt, and/or clay intersect (cross) by reading the percentage of sand, silt, or clay across the triangle in the directions shown by the arrows for each textural component. Notice for example that a clay

loam can have a clay content that ranges from 27 to 40%, silt content from 21 to 53%, and sand content from 20 to 45%. A corresponding increase in one component must result in a decrease in one or both of the other two components. If the soil texture is to remain a clay loam, the resulting values for the other two components must fall in the area representing a clay loam, or the soil textural class must change.

In gardening discussions the most commonly referred to soil class is loam. As shown in the textural triangle, loam is not in the center of the triangle, as one might expect. Thus clay has more influence on the textural classes and soil physical properties than does sand or silt. This is because of the very small particle size. The clay also contributes more to soil properties of water-holding capacity, cation exchange capacity, lime requirement, and potassium-supplying power than does the silt or sand-sized particles.

Organic matter content is not considered when making a textural class determination. The organic matter content has an extremely large influence on soil tilth—the ease with which a soil tills.

Texture is an important property of soils because it influences, either directly or indirectly, many of the other attributes such as water-holding capacity, nutrient-holding capacity (cation exchange), organic matter content, and soil tilth. These attributes along with climate and management determine yields.

Soil texture is among the properties needed in the soil test program for the estimation of soil type when the soil name is not known. The general textural classes used within the soil test program are sandy, loamy, silty, and clayey soils. These textures can be determined in the field by physical inspection as follows:

Sandy soil. A sandy soil is loose and single grained (several individual particles are not joined together in an aggregate). The individual grains can readily be seen or felt. If squeezed in the hand when dry, it will fall apart when the pressure is released. If squeezed when moist, it will form a fragile ball or cast that will crumble when touched.

Loamy soil. A loamy soil has a relatively even mixture of sand, silt, and clay. When dry, it is mellow with a somewhat gritty feel. When moist, it is fairly smooth and somewhat plastic. If squeezed when dry, it will form a cast or ball that, when handled carefully, will not break. If squeezed when wet, the cast or ball can be handled freely without breaking, but is still easy to destroy by pressing on the cast.

Silty soil. A silty soil has a small to moderate amount of sand and clay. Most of the particles are silt. When dry, it may appear cloddy, but the lumps can be readily broken. When the lumps are pulverized, it feels soft and floury. When wet, the soil readily runs together and puddles. If worked when wet, these soils readily form clods, especially if the soil is low in organic matter. A silty soil low in organic matter is often mistaken for a clayey soil. Either moist or dry, it will form casts or balls that can be freely handled without breaking. When moistened and squeezed between the thumb and finger, it will not ribbon, but will give a broken appearance.

Clayey soil. A clayey soil is very fine textured and contains a large amount of clay. It usually forms hard lumps or clods as it dries. These dry clods are difficult to crush. When wet, it is plastic and usually sticky. If a clayey soil is worked when wet, it forms many clods, which are difficult to eliminate. Repeated disking or harrowing usually only breaks the clods to more smaller ones. A single rain may or may not soften the clods.

When dry, these soils require a large amount of tractor power to plow. Upon drying, they often produce cracks of 2 inches or more in width. When the moist soil is pinched between the thumb and fingers, it will form a long, flexible ribbon. Clayey soils are commonly found on relatively flat to slightly rolling topography in northern New York and the Hudson Valley. They also may occur in central New York, but seldom are found in the southern tier.

Soil Topography

A specific soil is usually associated with a certain type of landscape. Thus, the topography, or the landscape, is used along with the soil

drainage and texture within the soil testing system to determine an estimated soil type. The landscapes given are the hilltop, hillside, valley floor, and the plains. These landscapes refer to the total land surface and not to the minor variations of a small wet spot or mound.

The hilltop is to be considered as all of the area above the crest of the hill. It would, in general, have a gentle concave slope where water would drain from the surface. The hillside would refer to the land surface from the base of the hill to the hill top. If there is a small mound located on the side of the larger hill, it would still be considered as part of the hillside.

The valley floor is the flatter areas between two hills and is generally composed of soils vastly different from those on the hillsides or hilltops. In somewhat hilly areas it is fairly easy to distinguish the valley floor. When the valley floor is large, such as the Genesee Valley, one must think about the total landscape.

The plains refers to all areas within the central plains of New York, whether on top of a drumlin or mound or between the mounds. Only areas within the central New York area are designated as plains, but valley floors can occur within the plains.

Soil Water

Water is retained within the soil pore spaces (voids between the soil particles) with varying degrees of energy. Shortly after a large rain the soil is often referred to as saturated, that is, all the pore spaces are filled with water. Part of this water will drain with time from the soil through the large soil pores that are continuous in some

fashion through the soil profile. The water content of the soil after this water has drained is called *field capacity*.

The rate at which water enters the soil surface is called *soil permeability*. Some of the water is held within the soil so tightly that the plant roots cannot remove it. When the soil dries to this moisture content, the plants wilt. This moisture content is referred to as the *wilting point*. *Plant-available water* is that water held by the soil between the wilting point and field capacity.

The plant-available water can be expressed either as a percentage of the dry weight of the soil or on a volume basis such as fraction of inch of water per inch of soil depth, inches of water per foot of soil depth, or inches of soil water in the soil rooting zone.



This kind of situation can often be avoided by installing a drainage system. One incident like this can cost more in time loss, crop loss, labor, and replacement parts than the cost of a subsurface drain, which should continue to function, at little or no additional cost, for 40 years or more.

Sandy soils have the lowest plant-available water; and available water generally increases with soil texture up to clay loam, then decreases as the

clay content is increased. The reason for the decrease for clay soils is that the water content of the wilting point is usually increased more than is the field capacity. Increasing the organic matter content usually increases plant-available water.

The higher the soil water content, the slower the soil will warm up in the spring. The higher the plant-available water content of the soil in the rooting zone, the less likely the crop will suffer from drought. The best balance between these two conditions is usually obtained in a well-drained loamy soil that is high in organic matter. Under these conditions the soil would likely contain 2.0-2.5 inches of water per foot of rooting depth or approximately 4-6 inches of plant available water in the rooting zone.

LAND DRAINAGE

Benefits of Drainage

- Removes excess water from the soil.
- Permits more-efficient machine operations.
- Improves "earliness" of fields.
- Increases soil air supply for good root growth.
- Increases the uptake of nutrients by crop plants.
- Permits use of heavy harvesting equipment.
- Promotes more-uniform crops within a field.
- Reduces root damage from soil heaving.
- Allows use of more-profitable crops.
- Increases production at relatively low cost.
- Increases the farm property value.

Drainage techniques are used to remove excess water from the soil.

Precipitation in New York ranges generally between 35 and 40 inches per year and is uniformly distributed among the seasons. In most years, summer rainfall is about equalled by the combined effects of evaporation from the soil and plant use so that summer wetness is not a common problem on many soils. During the fall, the soil is rewetted by the precipitation, and less evaporation and plant use occur. During the winter, precipitation collects on the surface of the wetted soil as variable amounts of snow. In late winter and early spring, the combined effect of melting snow and normal rainfall results in an excess of water in the soil. As the season progresses, the increasing temperatures and plant growth begin again to evaporate and extract the soil water.

The critical times to remove excess water from the soil are in the spring, to facilitate tillage and planting, and in the fall, to facilitate harvesting. In

some years drainage may remove some excess water during the summer, and better plant growth results. A properly designed drainage system removes only excess water, which is detrimental to plant growth. It will not result in increased soil susceptibility to drought.

Causes of Soil Wetness

There are three causes of soil wetness: too much precipitation (a wet year); the accumulation of runoff water in low-lying areas of the field; and the lack of an outlet for the excess water, due to topography or internal soil properties. Little can be done about the first cause; the second can be corrected by installing cutoff ditches (diversion ditches) to keep the runoff from accumulating in low-lying areas. Drainage practices can be used to alleviate the problems caused by topography or unfavorable soil properties.

Drainage Systems

The most efficient and economical way to perform land drainage is in a systematic manner. A drainage system requires planning. Such planning and systematic installation will save time and money in the long run. Drainage systems are often part of the soil and water conservation plan (see p. 26). Information about installing drainage systems can be obtained from your county Soil and Water Conservation District or your local professional land improvement contractor.

Kinds of Drainage

Surface drainage removes surface water. This is accomplished by digging shallow (surface) ditches that carry the surface water from the field. The soil removed to form the ditches is used to fill low spots in the field. The areas between the ditches are then smoothed to remove the remaining low areas where water might accumulate. Surface drainage is used on soils that are too fine textured ("tight") for water to move through the soil or where the available outlets are not deep enough to use tile drainage.

Subsurface drainage (tile drainage) consists of placing a line of tile (or plastic tubing) beneath the surface. This subsurface channel is constructed to provide a continuous grade from the upper end to the outlet. Excess soil water seeps into the

drain and flows to the outlet.

Open ditches are not usually real drainage systems. They often act only as outlets for other types of systems. They waste land, interfere with machinery, encourage weed growth, and are difficult to maintain. They are often necessary and are the most economical way to move large volumes of water.

Outlet Development

Though it is commonly recognized that surface water flows downhill only, this fact is sometimes obscured in drainage installations. To be effective, the drainage system must have an adequate outlet. Because a tile drainage system is usually installed 24 to 30 inches below the land surface, it must discharge into an outlet where the water level is even lower. If the end of the tile drain is submerged, it cannot function efficiently. A drainage system is never better than its outlet.

Crop Yields

Improved soil drainage, combined with good management, will result

in better crop yields. Studies in Quebec indicate that tile-drained fields are ready for spring seedbed preparation 8 to 21 days earlier than non-drained fields. Recent studies have shown that late planting of corn can reduce yields by 1 bushel per day and an equivalent tonnage of silage. Adding 8 to 21 days to the growing season can improve yields.

Assistance

Information about installing drainage systems can be obtained from the local Soil and Water Conservation District, Cooperative Extension office, or professional, land-improving contractor. Such local sources can provide current information about drainage materials, systems, and cost.

Corn yields—Ohio

Drainage	Yield bu/acre
Nondrained	62
Surface drained	81
Tile drained	104
Tile & surface drained	110

Crop yields—Miner Institute, Chazy, N. Y.

Crop	Well drained	Poorly drained	
		Without tile drainage	With tile drainage
Sudangrass, lb/acre, dry matter	6,400	1,400	6,700
Corn, bu/acre	130	55	140
Corn silage, tons/acre	24	8	22

SOIL AND WATER MANAGEMENT

Soil Erosion

Soil erosion is the movement of soil particles by wind, ice, water, gravity, or combinations of these. Most soil erosion in New York is caused by wa-

ter falling as rain or flowing over the land surface.

Erosion consists of three processes: *detachment*, *transportation*, and *deposition*. In a typical situation raindrops falling on bare or thinly vegetated soils detach soil particles from the soil mass. These detached soil particles are transported by wa-

ter flowing over the soil surface. As the runoff water accumulates, both the depth of flow and its speed increase. As the speed and volume of flow increase, more soil particles are detached from the soil mass, both by the impact of the raindrops and by the abrasive action of the detached particles carried in the runoff flow.



Soil erosion results in the loss of topsoil, which is often high in fertility. This material is too valuable to be used for filling roadside ditches. Conservation practices will help to keep this limited resource in the crop field, where it is most useful.

Table 1. Estimated annual erosion in New York

Land use	Extent	Annual erosion	Total erosion
	acres	tons/acre	million tons
Woodland	17 million	0.4	7
Cropland, adequately treated	3 million	1.3	4
Cropland, inadequately treated	2 million	7.5	15
Pasture	1.5 million	0.7	1
Urban	1.5 million	0.7	1
Construction	50 thousand	20	1
	miles	tons/mile	million tons
Roadbanks	154 thousand	29	5
Streambanks	132 thousand	73	10

Source: SCS data.

Because the soil surface is practically never uniform in slope, the runoff water accumulates in the relatively lower areas; there the depth of flow and its erosive action are increased. This increased erosive action detaches more soil particles, and rills or gullies in the soil surface are formed. The detached soil particles are transported by the flowing runoff water. When the speed of the runoff water is slowed, the eroded soil particles are deposited in fields, roadside ditches, streams, or lakes.

Types of erosion. *Raindrop erosion* is the detachment of soil particles by the impact of raindrops.

Sheet erosion is the uniform removal of a thin layer of soil particles by raindrop impact and the flow of a thin sheet of water across the surface.

Rill erosion is the removal of soil material from areas of water accumulation. These small channels are visual evidence of erosion. They are relatively shallow (less than 12 in. deep) and can be filled in with tillage implements.

Gully erosion. Gullies are deep rills—usually deeper than 12 inches. They may be deep enough to interfere with the use of farm machinery.

Streambank erosion. Streams are agents of erosion. The abrasive action of the water and eroded materials can remove large quantities of soil from streambanks. This is especially true when the stream flow is high and the banks are saturated with water.

Erosion in New York

The Soil Conservation Service (USDA) has published the results of its Erosion and Sediment Inventory, which gives *estimates* of the erosion problem in the state. These estimates are shown in table 1.

An estimated 45 million tons of soil are eroded in the state each year.

About 10% of this amount (4 ½ million tons) is estimated to reach, and be transported by, identifiable streams. This erosion results in the loss of topsoil and plant nutrients to the landowner. The deposited material may cause additional problems for individual landowners or for the public.

The inventory estimated that cropland that needs better conservation treatment ("cropland inadequately treated" in table 1) accounts for 15 million tons—one-third of the total estimated annual soil erosion.

Erosion on New York's farms. The largest source of soil erosion is cropland that needs better conservation treatment. Two million acres of such cropland are losing an estimated 7 ½ tons of soil per acre per year—a total of 15 million tons per year! Adequately treated cropland loses about 1 ¼ tons of soil per acre annually; pastures are estimated to lose less than 1 ton per acre annually.

Can erosion be eliminated? NO! Erosion is a natural process and cannot be completely eliminated. Even woodlands produce some erosion, estimated to be about ½ ton per acre annually. But it can be reduced. Note (table 1) that adequate conservation treatments can reduce the average annual soil erosion from cropland by about 6 ¼ tons per acre (from 7 ½ down to 1 ¼ tons per acre).

Why is soil erosion important? Since the plowed layer of an acre of cropland weighs 1,000 tons, it is obvious that even at the rate of 7 ½ tons per year, it would take a long time to erode away all the topsoil.

But soil erosion on cropland in New York is seldom confined to sheet erosion. And if the 6 ¼ or 7 ½ tons per acre come from smaller areas, it may not take long to affect the productive capacity of some part of the field.

Soil erosion is a selective process: the finer soil particles (silt and clay particles) are eroded readily; the coarser particles (sand and stones) are less likely to erode. The silt and clay-sized particles are the ones that usually contain plant nutrients, organic matter, and pesticides. Keeping these particles in place on the cropland helps to maintain soil productivity.

Eroded soil materials are eventually deposited somewhere: in the field, a roadside ditch, a stream, or a lake (see illustration p. 22). Though there is no general agreement about how much of the eroded soil ends up in a stream, it is generally agreed that reducing soil erosion from cropland should reduce the amount of eroded soil reaching the streams and lakes.

What is adequate conservation treatment? As defined by the Soil Conservation Service, cropland is adequately treated when the calculated average annual erosion rate is less than a specified value (usually 2 to 4 tons per acre, depending upon the soil type). Adequate treatment may consist of changed management practices, the installation of conservation devices, or both. Information and assistance in planning can be obtained from your county Soil and Water Conservation District.

Conservation Practices

Soil conservation practices are designed (a) to protect the soil surface from the erosive force of raindrops, (b) to slow down the rate of runoff, (c) to grow crops that hold the soil particles in place, and (d) to provide areas where eroded particles can be deposited.

Surface protection. To protect the soil from raindrop impact, close growing crops (small grain or hay) should be grown. The dense canopy of vegetation protects the soil surface

from raindrops; the dense growth of roots holds soil particles against erosive forces. Sod crops also improve soil structure.

Soil fertility. Proper soil fertility practices will help to ensure the establishment of healthy and profitable crops, which will also protect the soil surface. Soil fertility information is on pages 27 to 50.

Soil pH control. The adjustment and maintenance of soil pH by the addition of ground limestone are important to the establishment and growth of good crops and to efficient use of fertilizer nutrients. Information about pH control can be found on pages 27 to 43.

Cross-slope culture. Tillage and planting across the slope of the land reduces runoff and erosion. Cross-slope culture, with proper management, has resulted in crop yields 20% higher than those from up-and-down-hill methods in New York. Many fields still require the removal of hedgerows or fences to facilitate cross-slope culture. Water control measures are an essential part of such a soil management system.

Strip-cropping. If all sloping land could be kept permanently in close-growing crops, the rate of soil erosion could be greatly reduced. Because it is often impractical to produce only close-growing crops, a compromise solution is the use of strip-cropping. The alternating strips of cultivated crop and close-growing crop allow the production of cultivated crops on sloping land; the close-growing strips provide surface protection, slow down any runoff water, and filter out some of the eroded soil particles.

Field strip-cropping. Parallel, even-width, alternate strips planted to row crops and close-growing crops can be installed across the general slope of the land. This is an effective and easily applied conservation practice.

Contour strip-cropping. Contour strips resemble field strips, but both the upper and lower boundaries of each strip are kept on the contour. They are best adapted to smooth, single slopes, which allow the strips to be uniform in width.

Graded strips are designed with a 1% or 2% slope. They are often used on sloping soils that are moderately to somewhat poorly drained. Graded strips are often used with diversion terraces to provide erosion control and safe removal of excess water.

Crop rotations. A planned sequence of crops provides several advantages: it permits the development of a long-term pesticide plan; it results in improved soil structure; and it may lessen the need for some pesticides. A planned program of pesticide application is important with some of the residual-acting herbicides. The production of sod crops in a planned rotation will improve soil structure and result in reduced runoff and erosion and improved soil tilth for growing other crops. Rotations commonly consist of corn, small grains, and hay and must be planned to meet your production goals.

Cover crops. After a cultivated crop is harvested, a cover crop can be planted to protect the soil from erosion during the nongrowing season. A cover crop can also provide some organic matter when it is incorporated into the soil in preparation for the succeeding crop.

Rye is often used as a cover crop and would be especially helpful after a crop of corn silage is removed. Rye will continue to grow through the fall months and thus increase the amount of overwinter soil protection.

Oats can be used as a cover crop. Because oats will winter-kill, there is no danger that they will be too tall to handle the next spring. But a cover crop of oats should be planted early

enough to adequately cover the soil before the oats are killed by freezing. Information on cover crop seeding is given in table 21.

Cropland terraces are broad, shallow channels constructed across the slope of the field. They are effective on long, smooth, single slopes of up to 8%. Cropland terraces reduce soil losses and conserve rainfall for higher yields of row crops. They offer minimal interference to farm machinery. They can be constructed with tile outlets and made parallel to reduce the problems of uneven strip widths and point rows in the field. Thus, a method of controlling runoff and erosion and of disposing of the water without using sod waterways is provided. The outlet tile can also help to drain troublesome wet spots.

Diversion terraces. These are often called "diversion ditches" in New York. There are about 3,000 miles of these terraces in New York. Construction is proceeding at about 30 miles per year. They have a slight grade in the channel and can be used on slopes up to 12%. They should be kept in permanent grass-legume sod. Because they often have high dikes, deep channels, and steep cross sections, they should be located to minimize interference with machinery operations. Tile outlets can sometimes be used with diversion terraces to eliminate the usual problems of maintaining adequate, noneroding outlets. If several terraces are needed in a system, they can sometimes be constructed parallel to one another to eliminate the problems of point rows.

Subsurface drainage. Either random lines or complete systems for subsurface drainage can be installed to increase the efficiency of crop production. Subdrained soils often out-yield adjacent nondrained soils and can be cropped intensively. Subsurface drainage enables the farmer to

keep sloping areas in long-term sod crops or in conservative crop rotations.

Surface drainage or "land smoothing" is useful for farmers who have nearly level, wet, fine-textured (clayey) soils. This kind of drainage system involves farming wide, smoothed lands with wide, shallow, open ditches. It facilitates high yields of corn and forages on formerly unproductive soils.

No-till systems. Establishing crops without plowing or otherwise disturbing the soil surface greatly reduces soil erosion on sloping soils. Planting directly into a killed sod or cover crop retains the soil protection features of the surface cover. No-till corn planters can also be used in conventional seedbeds and offer a greater degree of flexibility in corn production.

Tillage Systems

Soil resource. The soil resource is one of the most important considerations in choosing a tillage system. Conventional tillage systems may be adapted to a wide range of soil conditions. No-till systems are generally most successful on the better-drained, coarse- to medium-textured soils. Other tillage systems are between these two extremes, depending upon the amount of tillage performed.

Soil drainage. Conventional tillage is adapted to a wide range of drainage conditions because the air-water relations are usually improved with tillage. No-till systems should usually be restricted to the well-drained and moderately well drained soils. Improving the drainage of imperfectly drained soils improves the yields with both systems, but is essential if no-till systems are to be used. The amount of improvement is soil and slope dependent.

Texture. Coarser soils are suited for a diversity of tillage methods, whereas finer-textured soils usually benefit from tilling and aerating the root zone. No-till systems are better adapted to the coarser-textured soils and are well suited to the silty clay loams to clayey soils.

Erosion. The increase in crop residue on the soil surface, associated with reduced tillage, significantly decreases soil erosion. Large amounts of soil cover, however, reduce soil temperature and, as a result, delay emergence and early crop growth. Where soil erosion is a problem, the tillage system and other management factors should be modified to reduce erosion.

Topography. Conservation tillage often improves both erosion control and soil management of a complex topography. Care must be taken to maintain proper seed and fertilizer placement in a conservation-tillage system on a complex topography.

Stones. No-till systems help keep stone movement to the surface to a minimum. Excessive stoniness, however, makes it more difficult to maintain proper seed and fertilizer placement in a no-till system.

Nutrients. Areas with low lime and fertility levels will benefit from conventional tillage methods that incorporate soil amendments. Manure management and nutrient conservation become more difficult as tillage is reduced.

Equipment. Reduced tillage reduces the amount of equipment and fuel required to produce a crop, but the equipment must be well fitted and calibrated. With a no-till system particularly, planters and sprayers must be properly equipped, adjusted, and operated if the planting is to be successful.

Energy. Reduced tillage, particularly a no-till system, decreases farm consumption of gasoline or diesel

fuel. The greater reliance on chemical pesticides with no-till causes total energy requirements to be very similar for all tillage systems.

Labor and labor distribution. Reduced tillage results in less labor and more timely field operations in the spring because fewer field operations are required. Reduced tillage can also improve field trafficability so that fall harvests are less affected by wet weather. On the other hand, a no-till system requires more time expended during the growing season to monitor the crop for potential problems. Weeds, for example, can be more prevalent in no-till fields. Consequently, no-till fields should be more closely monitored because of a greater potential for weeds and other pest problems.

Insects and diseases. Reduced tillage does not appear to greatly alter most pest problems. Because tillage is a fundamental pest control method, however, existing pest problems can become more troublesome under reduced tillage. For example, no-till planting of corn into residue infected with diseases such as anthracnose or eyespot can intensify those diseases. Slugs are also a much greater problem in reduced tillage fields, particularly where plant residue is heavy.

Weed control. No-till cropping systems preclude the use of mechanical weed control measures such as tillage and cultivation for the preparation and maintenance of a weed-free seedbed. No-till planting can also limit the use of herbicides that can be applied preplant incorporated as well as those chemical control programs that benefit from mechanically mixing the herbicide in the soil. These limitations place an added burden on cultural (managerial) and chemical control measures and, in some situations, may mean that additional herbicides are

needed. Growers who opt for no-till crop production should avoid weed situations that require tillage or the use of preplant-incorporated herbicides. In addition, they must manage the crop to the very best of their ability in every way, including proper herbicide choice and application.

Yields. Various tillage systems have about equal potential yields if they are properly managed on soil types adapted for the respective tillage system. On marginal field conditions or if overall crop management is variable, conventional tillage offers the greatest potential for successful results. To be successful in a reduced- or no-till system, good crop management on recommended soil types is essential.

Economics. Which tillage system to use will depend on the yields obtained as well as the soil, climate, labor, and management resources on a particular farm. Eliminating some of the tillage operations will reduce machinery operating costs for fuel, oil, repairs, and spring labor. It may also reduce long-term machinery costs if some machinery can be eliminated. For some types of tillage systems the maximum tractor size may also be reduced.

Offsetting these reduced costs are higher fertilizer, insecticide, herbicide, and seed costs. The added chemical and seed costs usually offset the decreases in costs for fuel and machinery. If the yields are equal on two comparable tillage systems, the economics of the two systems are also about the same. Reduced tillage can reduce soil erosion, allow for more acres of tilled crops, and provide for more-timely operations and better maintenance of soil productivity than would otherwise be possible. If a reduced-tillage system will provide one or more of these advantages with similar yields and economics, it should be given close consideration.

Soil and Water Conservation Plans

New York State laws. The Soil and Water Conservation District Law, which provides for the formation and direction of SWCDs, emphasizes the importance of soil and water conservation plans as does the 1985 farm bill. The law requires that (a) every owner or occupier of agricultural land shall apply to the SWCD for a soil and water conservation plan; (b) the SWCD shall provide a soil and water conservation plan; (c) all soil and water conservation plans made for owners or occupiers of agricultural land shall be reviewed at least once in every 5 years.

"Agricultural land" is any land holding larger than 25 acres used for the raising of any agricultural or forestry products. This includes concentrated agricultural operations on land holdings less than 25 acres. "Concentrated agricultural operations" are any form of agricultural operation that produces large amounts of animal and related wastes in a limited area (feedlots, poultry operations, etc.).

Conservation plans. A soil and water conservation plan begins with an analysis of your farming operation, particularly with regard to the prevention of soil erosion. Such a plan must be a comprehensive one, because the decisions made about any field or group of fields normally affect the management of most of the other fields in the farming operation.

A farm plan considers your management goals and incorporates these, as much as possible, into a long-range plan for your farm. The plan consists of a number of useful items: a soils and land capability map; a farm plan, drawn on an aerial photograph; a field numbering system; and recommendations for soil and water conservation practices. In addition, farm plans usually specify

appropriate rotations for each field and suggestions for implementing the plan.

How to obtain a plan. Apply to your local SWCD for a plan. To apply, you fill out a standard request form, available from the local SWCD.

Cost of plan. There is no charge for the preparation of a conservation plan. But you should plan to spend some time with the SWCD representative who prepares the plan to indicate your goals and to help locate the farm on an aerial photograph.

Required practices. A soil and water conservation plan is not a contract. Landowners are not required by the New York law to install conservation practices. The plan is a service to assist you in reducing soil erosion on your farm. The 1985 National Food and Security Act changes the requirements for using the farm plan, especially for highly erodible farm land (see next section).

CONSERVATION PROVISIONS IN THE 1985 FARM BILL

The Food and Security Act of 1985 (signed into law December 23, 1985) contained more "necessary" soil conservation measures than any previous national legislation. There are four major provisions of the 1985 farm bill that may apply to a land user:

1. The Conservation Reserve Program—to remove highly erodible crop lands from agricultural production under a 10-year annual rental contract and thus reduce erosion.
2. Sodbuster—to discourage conversion of highly erodible grasslands or woodlands to agricultural production and thus prevent erosion.
3. Swampbuster—to discourage conversion of wetlands to agricultural production and thus save environmentally important wetlands.

4. Conservation compliance—to discourage production of annual tilled crops on lands not adequately protected from soil erosion and thus reduce and prevent soil erosion.

The bill gives the Agricultural Stabilization and Conservation Service (ASCS) the major administrative responsibilities for the programs, the Soil Conservation Service (SCS) the major technical responsibilities (i.e., determining highly erodible fields, identification of wetlands, etc.), the local Soil and Water Conservation Districts (SWCD) the responsibility for approving Conservation Plans, and Cooperative Extension (CE) the requirement to assist with the educational programs.

If a land user does not comply with the provisions of the 1985 farm bill, the land user and landowner become ineligible for certain USDA farm programs—namely price and income supports, crop insurance, Farmers Home Administration (FHA) loans, Commodity Credit Corporation storage payments, Farm Storage Facility loans, Conservation Reserve Program annual payments, and other USDA commodity-related payments. Generally, the land user must certify that he/she is in compliance with the regulations at the time of application for one of the USDA programs. Thus, the land user should not wait until application time to contact ASCS and/or SCS about eligibility and/or compliance.

Conservation Reserve Program (CRP). To place highly erodible crop land under a 10-year contract for the conservation reserve, the land user or owner must (1) determine if the field is eligible (contact SCS), (2) submit a bid for the annual rental agreement to ASCS during one of the sign-up periods, (3) sign the contract, and (4) have an acceptable bid price as determined by ASCS. The terms of

the contract include establishing (if necessary) and maintaining a permanent vegetative cover of grasses, legumes, trees, windbreaks, or wildlife plantings on the highly erodible cropland. A 50% USDA cost share is available to establish the vegetative cover. A current Cornell soil test is required. The vegetation may not be harvested or grazed or planted to Christmas trees during the period of the contract. Acreage going into the conservation reserve reduces the crop acreage base for the farm. Annual payment may be either in commodity certificates or by check as determined by USDA.

Sodbuster. Any land that was *not* in an annual crop at least 2 years during the period 1981–1985 and is classified as highly erodible land (a potential to erode at 8 times, 8T) must be tilled and/or planted to an agricultural commodity under a locally approved conservation plan. If the highly erodible area is planted to an agricultural commodity and not under a conservation plan, the entire farm becomes ineligible for USDA program benefits. To regain eligibil-

ity the next crop must be planted under an approved plan. For those who are not sure if the land is in the sodbuster category, contact ASCS or SCS. For a field to be considered as highly erodible, one-third or more of it must be highly erodible or the highly erodible area must be 50 acres or more.

Swampbuster. Conversion of wetlands for agricultural production may result in loss of eligibility for certain USDA program benefits as discussed previously. Wetlands consist of soils that are covered with standing water or are saturated most of the year and that support mostly water-loving plants. The Soil Conservation Service maintains lists of the kinds and combinations of soils and plants that define wetlands. Likewise, SCS employees can determine if lands you plan to drain are wetlands by either consulting maps or visiting the site. Wetlands drained before December 23, 1985, do not result in loss of program eligibility.

Conservation compliance. The conservation compliance provision of the 1985 farm bill currently applies

to land where annually tilled crops were grown at least once during the period 1981–85. It will apply to *all* highly erodible land in annual crop production by 1990. If you produce crops on highly erodible land without an approved conservation system, you may lose your eligibility for certain USDA benefits as previously described. Highly erodible land has the potential to erode at 8 times (8T) the rate at which the soil can maintain continued productivity. For a field to be highly erodible, one-third of the area must be highly erodible or the highly erodible area must be 50 acres or more. SCS employees determine if the field is highly erodible by consulting maps or by visiting the site.

You have until January 1, 1990, to develop and begin actively applying a conservation plan on highly erodible cropland and until January 1, 1995, to have the conservation plan fully operational. If soil maps of the farm are not available, you have until 2 years after the soil mapping to develop and begin actively applying a locally approved conservation plan.

SOIL FERTILITY MANAGEMENT

Cornell Soil Testing Program

The New York State College of Agriculture and Life Sciences at Cornell University provides a research-based soil testing service. This program is designed as a soil management tool for New York State farmers. The standard analyses package for the soil sample is pH (acidity), lime requirement, and available phosphorus, potassium, calcium, magnesium, zinc, manganese, iron, aluminum, nitrate-nitrogen, and organic matter. Many additional tests are also available. The laboratory results and the information provided by the grower on

the soils and crops are subjected to computer analysis, and recommendations are prepared. The final report includes, in addition to the soil chemical analysis, lime and fertilizer recommendations to meet the needs of your particular crops/rotation, usually for a 3-year period.

Soil testing provides a means to predict the soil nutrient status even before a crop is planted, thereby permitting more-efficient use of fertilizer, lime, and manures. A complete soil test, with the appropriate interpretation of the results, is the best method of determining adequate lime and fertilizer requirements

without excessive use. Adding lime and fertilizer for crop production without a current soil test is economically and environmentally irresponsible.

The Cornell Soil Testing Program has five distinct parts: (1) sample collection, (2) gathering sample background information, (3) chemical analysis of the sample, (4) interpretation of the chemical test results and sample background information provided, and (5) lime and fertilizer recommendations for the crops to be grown.

SOIL SAMPLING

A good soil sample is the first criterion for a reliable soil test. Unfortunately, many poor soil samples are taken because of ignorance, failure to follow instructions, lack of time, or laziness. The cost of labor makes collecting samples expensive; hence, there is a tendency to shortcut accepted sampling procedures. The following eight steps are for correctly collecting and submitting a soil sample. When obtaining a sample, keep in mind that accurate fertilizer recommendations interpreted from the analysis depend on a representative soil sample.

1. Get a soil mail kit and full information.

Cornell soil sampling kits can be obtained from local county offices of Cooperative Extension, from some commercial firms that stock the kits for the convenience of their customers, or by contacting the Cornell Nutrient Analysis Laboratory, 804 Bradford Hall, Cornell University, Ithaca, NY 14853, (607)255-4540. Each kit includes a sample background information sheet to be completed by the grower, a mailing bag with a plastic liner and an attached envelope for sending in the soil sample, and an instructions sheet.

2. Use the proper sampling tools.

There are two important requirements of a sampling tool: first, a uniform slice must be taken from the surface to the depth of insertion of the tool (usually the plow layer), and second, the same depth and volume of soil should be taken from each spot sampled. A soil probe or auger is best; if not available, use a garden spade or shovel. The technique for using a spade is to imitate the action of a core tube by digging a V-shaped hole to plow depth, cutting a 1/2-inch-thick slice of soil from the face of the

hole, and trimming both vertical sides of the slice so as to leave a strip of soil about 1 inch wide in the middle of the spade.

3. Sample uniform areas.

Each sample should be from a relatively homogeneous unit of soil, to minimize any large-scale geographic variation. It is unrealistic to assume that a field enclosed by a fence makes a homogeneous unit. Areas that differ in soil series type, appearance, slope, crop growth, soil color, or past management (liming, manuring, fertilizing, or cropping) should be sampled separately. The size of the area represented by a sample should not exceed about 15 acres.

4. Take subsamples from many spots in each area, and send a composite of these subsamples to the laboratory for analysis.

Each soil sample sent to the laboratory should be a composite consisting of the soil from cores taken randomly at several places across the field. The purpose of this sampling procedure is to minimize the effects of any local nonuniformity in the soil. Subsamples at about 15 to 20 locations over the area should be taken for each composite sample. The soil subsamples should be mixed well in a plastic bag or plastic bucket. Metal containers, especially galvanized metal, will contaminate the sample. About 1 pint of the composite sample is placed within the plastic bag; the bag is tied, and enclosed in the cloth bag to be sent to the laboratory for analysis.

5. Keep out of unusual areas or sample separately.

For row crops where fertilizer has been banded, the subsamples should be taken between the visible rows to avoid sampling residual fertilizer. Additionally, sampling immediately after broadcast application of fertilizer

is not recommended, unless the soil has since been tilled.

Small or unusual areas should be avoided when the intent is to estimate the mean fertility level of the area. Areas that should be avoided include dead furrows, back furrows, windbreaks, snow fences, old fence lines, sites of old manure and lime pits, wet spots, and areas near lime rock roads, trees, or the boundary between slopes and bottomland. On the other hand, if the intent is to troubleshoot a small spot in the field where there has been poor crop growth, a separate sample of the unusual area is usually necessary.

6. Sample to the proper depth.

Cultivated agronomic crops. Soil samples are ordinarily taken to the tillage depth. This depth is usually 6 to 9 inches, but may be deeper. The operations of land preparation tend to mix previous applications of lime and fertilizer through the entire tilled layer; hence, the lime and fertilizer recommendations must consider the tillage depth.

No-till or minimum till. With no-till or minimum till it is best to take a small sample from the surface 1 inch in depth and another sample from 1 to 6 inches in depth. The surface and the normal-depth samples should be placed in separate labeled plastic bags and sent to the laboratory in the same outer cloth bag with one information sheet. The plastic bags should be labeled clearly as Surface 0–1 inch and Normal Depth 1–6 inches.

7. Establish a regular sampling time.

For most field crops, the soil should be sampled every 2 to 3 years. For soils under intensive use, as in high-value-per-acre vegetable crops, soil should be tested before planting each crop.

Soil samples may be taken at any time during the year when the soil is not frozen and moisture conditions

permit. Soil should not be sampled when extremely wet unless absolutely necessary. It is suggested that any given field be sampled at about the same time of the year.

8. Prepare the sample for submission to the laboratory.

Avoid sampling when it is very wet. If it should become necessary to sample wet soil, spread the sample in a thin layer on a clean sheet of wrapping paper or waxed paper and allow to dry out at room temperature before sending it to the laboratory. Do not use heat to hasten drying. Do not send wet samples to the laboratory. They may leak in the mail and will be delayed in the lab until they dry. But more important, rapid biological transformations of the amounts and forms of soil nutrients (particularly forms of inorganic nitrogen) can occur in a wet sample. Drying is an effective means of preserving the field chemical characteristics of the soil sample.

Place the plastic bag in the cloth outer bag. The plastic bag should contain sufficient soil to fill the cloth bag to the line. Tie the cloth bag securely with the drawstring. Include only one sample in each bag (except no-till samples; see 6).

BACKGROUND INFORMATION

The information sheet (see p. 31) is designed to gather data necessary to make specific recommendations based on the grower's field history and cropping patterns. The more complete the information provided, the better will be the fertilizer recommendation interpreted from the soil analysis. Incomplete or inaccurate information may lead to delays or inaccurate recommendations. Important parts of the information sheet follow:

- **Identification.** Proper identification allows keying the laboratory

results to the area sampled. Make the test results part of your permanent field records. Then you'll know when soil fertility levels rise and fall.

- **Soil.** Soil properties influence yield and crop fertilizer needs; hence, specific recommendations can be made only if the name of the major soil in the field being sampled is provided. The soil name, in conjunction with soil survey information, can be used to determine the soil's management properties, surface and subsurface texture, drainage characteristics, nitrogen-supplying power, fertilizer-nitrogen-use efficiency, and potassium-supplying power. The soil name and experimental yield data from across the state are used collectively to estimate the crop yield potential.
- **Soil estimation.** If the soil name is unknown, the soil association symbol, which can be obtained from the local extension office, can be used for making an estimate of the soil type. The questions relating to soil drainage, texture, and topography assist in making an estimate of the soil type from the soil association code.
- **Crops.** The principal objective of any cropping practice or soil management program is sustained crop production. It is not surprising that the entire crop rotation must be considered to make the most economical and efficient use of lime and fertilizer. Recommendations are made for 3 years of the rotation if crops to be grown during the next 3 years are provided. If an extended recommendation is not desired, omit crop codes for the second and third crop years.
- **Manures.** The value of animal and green manures is determined not only by the organic matter they fur-

nish but especially in the quantity of nitrogen they supply to the crop. Unfortunately, we do not have a soil test that can reliably measure crop-available nitrogen in soil. Manure source, rate of application, time of application, soil type, and cropping system data, however, allow estimating rates of decay and recycling of nitrogen contained in animal wastes and green manures.

CHEMICAL ANALYSIS OF THE SAMPLE

A chemical soil test is a method for estimating the ability of a soil to supply nutrients to crops. This is accomplished by treating a soil sample with a mixture of chemicals in a controlled manner for a fixed period of time and determining the nutrients extracted by using various chemical and instrumental procedures. The quantity of nutrient extracted is an index of the plant availability of that nutrient. The quantity of the nutrient extracted is of little value until the soil test has been calibrated with plant growth and production under field conditions.

There is no universal soil test, and considerable variation in methodology exists. The variance in fertility test methodology introduces differences in test results, which give rise to confusion. There are even various ways of expressing results. Moreover, soil tests that work in one state or region may be completely useless in another, depending on soil, climate, crop, and economic factors. Causes for success or failure of soil tests are generally related to the amount and quality of research data available to define the relationship between the quantity of nutrient extracted from soil by a particular solvent and the yield of the crop in the field.

INTERPRETATION OF THE CHEMICAL SOIL TEST

The Cornell laboratory is the only organization that offers a correlated soil test based on field and laboratory research data for New York State conditions. The recommendation concept employed in interpreting the test results and supplied background information is sufficiency levels of available nutrients (SLAN). The SLAN concept is based on a mathematical expression of the law of diminishing returns whereby increases in yield of a crop per unit of available nutrient decrease as the level of available nutrient approaches sufficiency.

Although nearly all university laboratories use the SLAN concept, essentially all commercial and industrial laboratories use other recommendation methods. The reason for the split is simple. Proper application of the SLAN concept requires an enormous amount of background research, which is prohibitively expensive for commercial and industrial laboratories to conduct. The background research must determine, among other things, the significant chemical forms of available nutrients in the soils of the area, the extractants most suitable for accurately measuring the available forms, the relative productive capacity for the soils for the various crops, the differential response of the various rates and methods of fertilizer application for the different crops, field-sampling techniques, test procedures, methodology, and local economic conditions. The soundness of the required interpretive judgments depends almost entirely on the thoroughness and quality of these background studies. It is perhaps no exaggeration to say that the success of a soil testing program is directly proportional to its research backing.

Without local field calibration of the soil test, the rationale often used

is to apply fertilizers at a rate to ensure maximum yield with little regard for the costs or possibilities of economic return. Research has shown the SLAN concept to be superior to other concepts as a practical basis for applying fertilizer. In one experiment conducted at five locations for 3 years, it was found that the average cost of fertilizers recommended by a laboratory using the SLAN concept was \$25.71 per acre, whereas the average cost of fertilizers recommended by laboratories using other concepts was \$57.35 per acre. Yet the yields were the same for all fertilizer treatments at each location and in each year. In an independent 5-year study, the advice of several laboratories using fertilizer recommendation rationales other than the SLAN concept was followed, and the crops did manage to turn a profit. But the returns were as much as \$178 per acre greater when SLAN based recommendations were followed.

LIME AND FERTILIZER RECOMMENDATIONS

The results of the soil test as well as the lime and fertilizer recommendations are printed on a multipart form. A copy will be sent to (1) the grower, (2) the industry representative if the name and address are given, (3) the Cooperative Extension agent for the designated county, and (4) the local ASCS office if the sample was taken for a conservation practice supported by ASCS.

An example of the results and recommendations for a soil sample are shown on page 33. For ease of interpretation, a section of the results sheet is reserved for an abbreviated listing of the pertinent information given when the sample was submitted. This area covers such items as field location and identification, soil

type, soil characteristics, yield of last crop in bushels or in hundredweight, and crop management practices. If the soil association symbol was used to estimate the soil name, the estimated soil type will be printed.

The section dealing with the laboratory results of the soil sample lists the values for pH, phosphorus, potassium, magnesium, and calcium. The horizontal bar graph gives a visual assessment of the pH and nutrient levels in the soil. The nutrient levels are based on the particular soil in question and are for the first crop to be grown. For pH, the entire rotational sequence is considered. Micronutrient soil tests are recorded on the next line with the indicated units of measure.

The last half of the soil test report is partitioned into two sections. The first deals with the lime and fertilizer recommendations for up to three crops that appear on the information sheet. A range is usually given for the nitrogen recommendation. The second section includes comments relative to lime and fertilizer management. Where micronutrients or other tests are made, specific recommendations for these tests are printed only if a potential problem exists. No comments are made when additional tests are in the normal or adequate range.

If the information sheet is filled out properly, your recommendations will be returned from the Cornell Nutrient Analysis Laboratory, 804 Bradford Hall, Cornell University, Ithaca, New York 14853. If several samples are submitted at one time, they will usually, but not necessarily, be returned together. When insufficient information is given, such as missing soil information or omission of the crop to be grown, the soil test results will be returned to the local Cooperative Extension agent for recommen-



Cornell Nutrient Analysis Laboratories

G01 Bradfield Hall, Cornell University, Ithaca, NY. 14853

(607) 255-4540

CLIENT		COMMERCIAL REPRESENTATIVE		LOCATION OF OPERATION	
John Doe NAME		Joe Smith NAME		DUTCHESS COUNTY	
RD		Ag Industry ORGANIZATION		TOWNSHIP	
Anytown NY 12485 CITY STATE ZIP		RD			
(607) 255-4540 TELEPHONE		Anytown NY 10940 CITY STATE ZIP		COUNTY TO RECEIVE RESULTS IF DIFFERENT FROM ABOVE	

ID	SAMPLE BAG NUMBER	SAMPLE IDENTIFICATION		FIELD ACRES	DATE SAMPLED	
	112121414 (COPY FROM BAG)	219111111111 (NO MORE THAN 10 CHARACTERS)		1.0	06	02 87 MONTH DAY YEAR
SOIL	For recommendations, provide the soil name or estimate the soil type. Soil properties influence yield and crop fertilizer needs.	SOIL NAME AND MAP UNIT SYMBOL		TILLAGE DEPTH	ARTIFICIAL DRAINAGE	
		Pittsfield 165A SOIL NAME AND MAP SYMBOL (e.g. Maf)		() NO TILL () 1-7 INCHES (X) 7-9 INCHES () 9+ INCHES	(X) NONE () INADEQUATE () ADEQUATE () EXCELLENT	
SOIL ESTIMATION	Complete only if the soil name was not provided above. If the soil name is unknown, completing this section will allow us to estimate the soil type and make recommendations.	SOIL ASSOCIATION SYMBOL		SOIL DRAINAGE	TEXTURE	TOPOGRAPHY
			() EXCELLENT () GOOD () FAIR () POOR	() SANDY () LOAMY () SILTY () CLAYEY	() HILLTOP () HILLSIDE () VALLEY FLOOR () PLAIN	
CROPS	For recommendations, indicate the crops grown. The fertilizer recommendations are based on crops in the rotation for the next three years. Past crop history is also important.	CROPS GROWN		COVER CROPS		
		PLACE CROP CODES FROM BACK OF SHEET BELOW	THIS CROP	When will a cover crop be planted?		
		PAST CROPS	FUTURE CROPS	CROP NAME OR VARIETY		
		LAST YEAR C101S	THIS YEAR C101S	Indicate crop if not on the code list		
		2 YEARS AGO C101S	NEXT YEAR A11E	19 87 Establishment Year		
		3 YEARS AGO C101S	3rd YEAR A11T			
SPECIAL CROPS	FRUIT CROPS AND TREES		POTATOES			
	Recommend for: () PRE-PLANT PREPARATION () ESTABLISHED CROP	Ground cover: () GRASS () HERBICIDE STRIP () MULCH () CULTIVATED	This sample taken from: () SURFACE SOIL () SUB-SURFACE SOIL Give bag number of sample to match with this sample if separate surface and sub-surface soil samples were taken 1111	How severe is scab? () NONE () MINOR () MODERATE () SEVERE	Will the variety grown be scab resistant? () YES () NO	
MANURE	ANIMAL MANURES		GREEN MANURES			
	Proper management of nutrient in animal or green manures can reduce the cost of fertilizer. Complete the following if a recent sod crop was grown, or if manure applied last year or will be applied in the next three years.	MANURE FROM (X) CATTLE () POULTRY () SWINE () HORSE () SHEEP () OTHER	MANAGEMENT () DAILY SPREAD () STORAGE	RATE OF MANURE APPLICATION		Estimate the percent legume in a current, or recent hay or pasture sod
			Solid (T/A) LAST YEAR 215 THIS YEAR 215 2nd YEAR 11 3rd YEAR 11	OR Liquid (GAL/A) LAST YEAR 1111 THIS YEAR 1111 2nd YEAR 1111 3rd YEAR 1111	(X) 0-100% grass () 1-25% () 25-50% () 50-100% 19 83 If sod was plowed or killed, give year	
TESTS	SOIL TESTS		TISSUE, WATER OR NUTRIENT SOLUTION TESTS			
	Send no money. The costs for performing the soil tests are included in the purchase price of the soil mailer. Standard soil tests include: phosphorus, potassium, calcium, magnesium, aluminum, iron, manganese, zinc, nitrate, pH lime requirement, organic matter, and soluble salts. () Substitute pH in CaCl2 for pH in water. () No 0-1 inch sample enclosed.		If a plant tissue sample was recently submitted and if the sample is relevant to this field or site, identify sample: PLANT SAMPLE ID #			
COMMENTS	SAMPLE BACKGROUND INFORMATION SHEET					
Please read material on back of sheet.						

INFORMATION SHEET FOR AGRONOMIC, COMMERCIAL FRUIT, AND COMMERCIAL VEGETABLE CROPS

AGRONOMY SOIL TESTING SERVICE REPORT

BACKGROUND INFORMATION

LA# NO. 999-1

29		10	12244		DUTC	DUTC	2	6-8-87	N	N	N	COS	COS	COS	
FIELD NAME OR NO.		ACRE	SAMPLE BAG NO.	ASCS	COUNTY	SENT TO COUNTY	REC'D LAB DAYS	MO/DAY/YR COMPLETED	1ST	2ND	3RD	COVER CROPS	LAST	2ND	3RD
PITTSFIELD 4						N	7-9	NONE	83	25			COW		
SOIL NAME		MAP SYMBOL	DRAINAGE	TEXTURE	TOPOGRAPHY	AREA DRAIN	FLOW/DEPTH	% URGAIN	SOD PLOWED	1ST MANURE RATE (T/A)	2ND	3RD	KIND OF MANURE	DEGREE VAL POT. SCAR	
SOIL TEST FOR: GROWER		INDUSTRY REPRESENTATIVE						COUNTY AGENT							
DOE, JOHN RD ANYTOWN		JOE SMITH AG. INDUSTRY RD ANYTOWN						COOPERATIVE EXTENSION FARM AND HOME CENTER RT ANYTOWN							
NY 12485		NY 10940						NY 12545							

SOIL TEST RESULTS

NUTRIENT LEVEL

		VERY LOW	LOW	MEDIUM	HIGH	EXCESS
PH		5.8				
PHOSPHORUS (P)	LBS/A	7				
POTASSIUM (K)	LBS/A	120				
MAGNESIUM (Mg)	LBS/A	200				
CALCIUM (Ca)	LBS/A	1800				

12																			
EXC. ACIDITY ME/100 g.	Fe	Al	Mn	Zn	B	NO ₃ -N	NH ₄ -N	% O. M.	SOL. SALT K x 10 ⁵										
	POUNDS PER ACRE																		

LIME AND FERTILIZER RECOMMENDATIONS

CROP-1987 (COS)
CORN SILAGE

CROP-1988 (ALE)
ESTAB. ALFALFA

CROP-1989 (ALT)
TOPDR. ALFALFA

T/A	LBS/A	LBS/A	LBS/A	LBS/A	LBS/A

GROWER'S COMMENT:

SAMPLE BACKGROUND INFORMATION SHEET.

CROP 1987 - CORN SILAGE

1. LIME RATE IS FOR 100% EFFECTIVE NEUTRALIZING VALUE-INCREASE RATE BY E.N.V. SCORE OF LIMESTONE TO BE USED.
2. SPLIT LIME RATE-PLOW IN HALF, WORK REST IN SEED ZONE BEFORE PLANTING.
3. BAND MOST IF NOT ALL PHOSPHORUS AT PLANTING.
4. DO NOT BAND MORE THAN 80-100 LBS OF NITROGEN + POTASSIUM AT PLANTING.

CROP 1988 - ESTAB. ALFALFA

- 5, ALSO SEE COMMENT NUMBER(S), 3.

PLEASE READ MATERIAL PRINTED ON BACK OF SHEET



Cornell University
State University of New York
U.S. Department of Agriculture

G01 Bradfield Hall
Department of Agronomy
Ithaca, New York 14853

SOIL TESTING SERVICE
Phone: 607-256-4540

INTERPRETATION OF THE SOIL TEST REPORT

BACKGROUND INFORMATION

This section includes the information given at the time the soil sample was submitted. A review of your receipt copy will assist you in making interpretations. If difficulty arises, contact your Cooperative Extension Agent at the address listed on previous page.

SOIL TEST RESULTS

The soil test results for plant nutrients are given in the boxed areas as pounds per acre. The standard tests are also shown graphically. The pH, nutrient levels and soils information submitted with the sample are used to calculate the lime and fertilizer recommendations.

NUTRIENT STATUS — General explanation of the nutrient levels are as follows:

VERY LOW — The nutrient level or pH is sufficiently low to require extra inputs of lime or fertilizer. This is shown by a higher than normal lime and fertilizer rate in the recommendation section. For example, if the pH is in the very low range lime should be added at least 1 year before alfalfa is seeded. If soil test phosphorus (P) is very low the fertilizer must contain a higher than normal amount of phosphorus (P_2O_5) to supply the phosphorus needs. Most of the phosphorus should be applied in a band at seeding. If soil test potassium (K) is very low fairly large quantities of potassium (K_2O) should be applied. This is usually best applied as a broadcast application before seeding. These additional inputs are included in the recommendation section. Soil samples should be taken yearly and recommendations followed carefully.

LOW — The nutrient level or pH is below normal. Higher than normal fertilizer rates are required for maximum economic yields. A low pH should be corrected with split applications of lime at least 6 months before seeding a legume. When soil test P is low most, if not all, of the phosphorus (P_2O_5) should be applied near the seed in a fertilizer band. Soil samples should be taken yearly for annual crops and every two years for hay crops.

MEDIUM — The nutrient level or pH is sufficient for normal fertilizer and lime rates to produce maximum economic yields. Most soil tests will probably occur within the medium or the high range if a well managed cropping program has been followed in previous years. Soil samples should be taken every two or three years.

HIGH — The nutrient level or pH is adequate for maximum economic yields. Only a low rate of starter fertilizer at seeding is needed. Soil samples should be taken every three years.

EXCESS — Usually the nutrient level or pH is too high and may either cause plant injury or interfere with the availability or uptake of other nutrients. For some nutrients an excess will increase the probability that the nutrient will contribute unnecessarily to pollution.

The exchange acidity and pH are used to calculate the lime recommendations. Iron (Fe), Aluminum (Al) and Manganese (Mn) are seldom deficient for crop growth in New York soils. Excesses of these elements can cause poor plant growth, reduced phosphorus availability and a high lime requirement on acid soils. Zinc (Zn) is considered adequate at a (high) level of 1.0 pound per acre or greater. Boron (B) is adequate when soil test reading is greater than 0.75 and low when the reading is below 0.35 pounds per acre. Soluble salts are usually no problem when the reading is 100 or less but crop injury may result when the value is greater than 200.

LIME AND FERTILIZER RECOMMENDATIONS

The recommended quantities of lime in tons/acre and N, P_2O_5 and K_2O in pounds per acre are shown in the boxed areas for the crop to be grown. If second and/or third year crop codes were submitted, a recommendation for these crops is also given. For custom blended fertilizer, use the actual recommended quantities of N, P_2O_5 and K_2O . Additional information about soil testing, lime and fertilizers can be found in the Cornell Recommends for Field Crops and in the Cornell Field Crops Handbook.

COMMENTS

The comment section includes suggested quantities of the more common fertilizer grades that may be used. In addition, timing of applications necessary to maximize both nutrient utilization and profit are given. Where micronutrients or other tests were made, specific recommendations for these nutrients are printed only if a potential problem exists. No comments are made when the micronutrient levels are in the normal or adequate range.

The fertilizer recommendations made for the first year may differ from the second and third years for the same crop. This is because of expected changes in the soil nutrient levels from the recommended fertilizer applications. For example, a broadcast application of K_2O may be recommended in the first year to reduce the K_2O needed in following years. Unless specifically stated this broadcast recommendation will not be needed in the following two crop years. Other crop management information may from time to time also be given as part of the comments section.

For additional information contact Cooperative Extension Agent listed on previous page.

W. Shaw Reid
W. SHAW REID
ASSOCIATE PROFESSOR
SOIL SCIENCE EXTENSION

Stuart Klausner
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EXTENSION ASSOCIATE
SOIL SCIENCE EXTENSION

Cooperative Extension in New York State provides Equal Program and Employment Opportunities. New York State College of Agriculture and Life Sciences, New York State College of Human Ecology, and New York State College of Veterinary Medicine at Cornell University. Cooperative Extension Associations, County Governing Bodies, and United States Department of Agriculture, cooperating.

dations. This delays the return of the results.

Initially, all inquiries about soil test samples and recommendations should be addressed to your local Cooperative Extension agent. Further inquiries concerning the laboratory methods, analyses, and projected completion date of samples should be directed to the Cornell Nutrient Analysis Laboratory, 607-255-4540. Inquiries about fertilizer recommendations for field crops are directed to Agronomy Extension, 155 Emerson Hall, Ithaca, NY 14853, 607-255-2177. Please indicate grower's name, address, and county, sample bag number, and date mailed. If inquiring about recommendations from a soil test report, include the lab number.

Evaluation of Agricultural Limestones

Limestones differ in their ability to neutralize soil acidity, in the time required to react with soil acidity, in their magnesium content, and in their cost per ton. The effective neutralizing value (ENV) method described here is one means of comparing the effectiveness of different sources of limestone for increasing the soil pH. It does not provide an economic evaluation for supplying magnesium beyond the pH effects. The magnesium requirement, as determined by soil test, must be evaluated from the percentage of magnesium (% Mg) expressed in the guarantee shown on the label or order slip. The information on the lime label may differ slightly from company to company throughout 1990, but should contain most of the information discussed in this section. A new uniform lime label is being proposed for several northeastern states; therefore, the material within this publication assumes that a new label will be adopted in New York by 1990.

Even if it is not adopted, there isn't much difference in the requirements of the current law, and the principles discussed still apply.

The information necessary to evaluate the limestone is required by law to be on the label for bagged material or on the delivery slips that must accompany bulk-spread materials. Lime distributors should supply the necessary information on the materials they sell. In the future the seller of limestone will be required to supply at least the following information to the buyer:

1. The name and address of the company registering the material with the state.
2. The brand name of the product.
3. The type of material being used (limestone, marl, hydrate, oxide, shells, industrial by-product).
4. The class of fineness of the particles (fine, medium, coarse) if the material is limestone or shells.
5. Total neutralizing value is the percentage of the total material that is capable of neutralizing an acid, expressed as if all the neutralizing material were equivalent to calcium carbonate (CCE).
6. The particle sizes of the material based on dry weight for ground limestones or shells expressed as (a) the percentage passing a 100-mesh screen (openings 0.0058 in., or 0.15 mm), (b) the percentage passing a 60-mesh screen (openings 0.0097 in., or 0.25 mm), and (c) the percentage passing a 20-mesh screen (openings 0.0328 in., or 0.84 mm).
7. The calcium and magnesium content expressed in elemental form as a percentage of the total dry weight (% Ca and % Mg).
8. The effective neutralizing value of the material and the relative amounts of the lime required to be equal to 100% ENV.
9. The moisture content of the material if it exceeds 5.0%.
10. The net weight of the product being sold.

The seller may supply additional information. The information that might be given on the delivery slip of two limestones is illustrated on the following page.

Total neutralizing value. The first component of limestone evaluation is the total neutralizing value expressed as the calcium carbonate equivalence as shown. The calcium carbonate equivalence, or total neutralizing value, varies considerably among limestones and liming materials because of the following factors:

- Most limes contain some inert impurities that do not react with acid and, hence, reduce the total neutralizing value.
- Some limestones may contain appreciable amounts of $MgCO_3$. Per unit weight, $MgCO_3$ neutralizes 1.2 times more acidity than $CaCO_3$; and hence, limestones with large amounts of $MgCO_3$ are likely to have higher neutralizing values than those with low amounts of $MgCO_3$.
- Hydrated lime and slaked lime have been heated to high temperatures to drive off CO_2 and, per unit weight, may neutralize more acidity than $CaCO_3$ or $MgCO_3$. Thus their CCE often exceeds 100%.

The total neutralizing value is the relative ability of the lime to neutralize strong acid in terms of an equivalent amount of pure calcium carbonate (CCE); that is, it is the percentage of pure calcium carbonate that the limestone can replace, expressed as a percentage of the total dry weight.

Limestone #1

Calcium Carbonate Equivalence (CCE).....	78.8%
Calcium (% Ca)	20.8%
Magnesium (% Mg)	8.0%

Particle Sizes

98% passing 20-mesh sieve
90% passing 60-mesh sieve
70% passing 100-mesh sieve

Effective Neutralizing Value (ENV)—70.3

Weight required for 100% effectiveness—1.4

Limestone #2

Calcium Carbonate Equivalence (CCE).....	104.3%
Calcium (% Ca)	20.8%
Magnesium (% Mg)	12.5%

Particle Sizes

98% passing 20-mesh sieve
80% passing 60-mesh sieve
75% passing 100-mesh sieve

Effective Neutralizing Value (ENV)—89.9

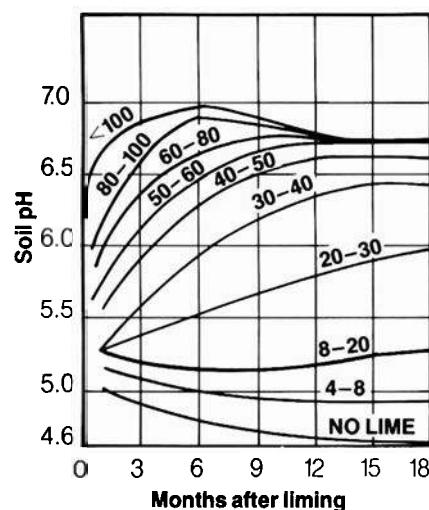
Weight required for 100% effectiveness—1.2

For example, 78% calcium carbonate equivalence means that 100 pounds of the limestone will neutralize the same amount of acidity as 78 pounds of pure calcium carbonate; 110% calcium carbonate equivalence means that 100 pounds of the limestone will neutralize the same amount of acidity as 110 pounds of pure calcium carbonate (the latter example would be typical of a nearly pure dolomitic-type limestone containing large amounts of $MgCO_3$). Currently, the lime is required to have a 60% calcium carbonate equivalence to be registered for sale in New York.

Fineness or particle size. The total neutralizing value of a limestone is determined by reaction with a strong acid in a well-stirred solution. Conditions in the soil are very different; soils contain weak acids, and the lime is often not well mixed with the soil. Agricultural limestones must first dissolve into the soil water before neutralization of the soil acidity can occur. The rate of the limestone dissolution is controlled by the surface area exposed to the soil solution, and the surface area per unit weight increases as the particle size decreases. Thus, one can evaluate the rate at which a limestone will react with an acid soil from the amount of various particle sizes in the limestone.

The particle size is measured by determining the relative percentages of the limestone that will pass through standard sieves of various sizes. The proposed uniform lime label will require the fineness to be expressed in terms of 3 sieves: 20-mesh, 60-mesh, and 100-mesh. The New York lime law required at least 80% of the lime to pass a 20-mesh sieve and at least 30% to pass a 100-mesh sieve for the lime to be registered for sale. These minimum values are likely to remain about the same under the uniform label.

The smaller limestone particles that pass a 100-mesh sieve react with an acid soil within a relatively short period of time, usually less than 6 months after application. Soil pH reaches the maximum pH in about 6 months after the 100-mesh limestone has been added (see illustration). The coarser particles react more slowly as evidenced in the graph by a lower soil pH at any given time. At the end of a 12-month period, particles smaller than 60 mesh have reacted to give a pH about as high as that obtained from the 100-mesh size. The larger than 40-mesh particles have not completely reacted at the end of 18 months. The 20-30-mesh and larger material is definitely inferior to the smaller particle sizes. The ma-



Influence of particle size and time after application of liming materials on soil pH. Values are the average of a dolomitic and a calcitic limestone applied at 3 tons per acre to a Canfield silt loam. T. A. Meyer and G. L. Volk, 1952, *Soil Sci.*, 73: 37-52.

terial larger than 20-mesh has not reacted rapidly enough to maintain the initial soil pH.

In evaluating the reaction of the limestones by particle sizes, one concludes that the material larger than 20-mesh is of little or no value; the materials smaller than 100-mesh react quickly. About 80% of the lime in particles between 60- and 100-mesh sizes have reacted, whereas

Table 2. Conversion of 100% effective neutralizing values of limes recommended by soil test to rates of limestone to be applied for various lime scores

Lime Score (ENV) %	Recommended rates of 100% effective neutralizing value limes											
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
	Lime rates to be applied to obtain 100% ENV (tons/acre)											
50	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
55	.9	1.8	2.7	3.6	4.5	5.5	6.4	7.3	8.2	9.1	10.0	10.9
60	.8	1.7	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.3	9.2	10.0
65	.8	1.5	2.3	3.1	3.8	4.6	5.4	6.2	6.9	7.7	8.5	9.2
70	.7	1.4	2.1	2.9	3.6	4.3	5.0	5.7	6.4	7.1	7.9	8.6
75	.7	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0
80	.6	1.2	1.9	2.5	3.1	3.7	4.4	5.0	5.6	6.2	6.9	7.5
85	.6	1.2	1.8	2.4	2.9	3.5	4.1	4.7	5.3	5.9	6.5	7.1
90	.6	1.1	1.7	2.2	2.8	3.3	3.9	4.4	5.0	5.6	6.1	6.7
95	.5	1.1	1.6	2.1	2.5	3.2	3.7	4.2	4.7	5.3	5.8	6.3
100	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0

only about 40% of the material in particles between 20- and 60-mesh sizes have reacted with the soil within the first year after application.

Calculation of effective neutralizing value (ENV). The effective neutralizing value is a combination of the total neutralizing value and the rate of reaction of the various particle sizes to obtain an estimate of the quantity of limestone that is likely to react with an acid soil within the first year after application. This estimate assumes that all the limestone particles finer than 100-mesh, 80% of the particles between 60- and 100-mesh, and 40% of the particles between 20- and 60-mesh sieve size will react with an acid soil within the first year after application. The coarser than 20-mesh material requires much longer periods of time to react as shown in the graph and is given no effective value in this calculation. Some long-term value is probably associated with these coarser particles, but their long reaction time makes them uneconomical, because the interest accumulates on their costs faster than they react with the soil.

The effective neutralizing values (ENV) of the two limestones given on

page 36 are on the effective neutralizing value score card. These two materials have similar fineness values, but limestone #1 has a much lower total neutralizing value (78.75% vs. 104.3% CaCO_3) and thus a considerably lower percentage for effective neutralizing value (70% vs. 90%). The lowest effective neutralizing value obtained for a limestone that meets the minimum specifications of the New York State lime law would be about 37%, whereas the highest possible for a dolomitic limestone would be 110%, and for a calcitic limestone, 100%. The usual range of effective neutralizing values for limestones being sold in New York is 50% to 95%. The high calcium limestones have values usually slightly lower than do the high magnesium limestones as a result of the higher neutralizing value of magnesium carbonates.

Lime recommendations using ENV. The effective neutralizing value is the fraction of the limestone, expressed as pure calcium carbonate, that is expected to react within the first year after application. It is useful for calculating the quantity of lime required to increase the soil pH to a

desired level. When the Cornell soil test recommendations report 4 tons per acre of lime required to increase the soil pH to a desired level, this means 4 tons per acre of 100% effective neutralizing value material. To calculate the actual rate of limestone required to increase the pH to the desired level, the recommended 4-ton-per-acre rate is divided by the effective neutralizing value of the limestone to be used. For the two limestones given in the example, limestone #1 would require (4 tons lime divided by 0.70 ENV) 5.7 tons per acre of limestone. Limestone #2 would require (4 tons lime divided by 0.9) 4.4 tons per acre.

The conversion for the weight of the lime required to equal 100% ENV is also furnished on the label or in table 2. This value is calculated as $1 \div \text{ENV}$. Thus the lime recommendation for 4 tons of 100% ENV can be obtained by multiplying the recommended lime rate by this value; that is, for limestone #1 this would be 4 tons $\times 1.4 = 5.6$ tons or the same within rounding errors as that obtained before.

To read this table, determine the effective neutralizing value of the

Instructions

Line 1. Enter % limestone passing 100-mesh.

Line 2a. Enter % passing 20-mesh sieve.

b. Enter % passing 60-mesh sieve.

c. Subtract values on line 2b from 2a and enter here.

d. Multiply value on line 2c by 0.40 and enter result.

Line 3a. Enter % passing 60-mesh sieve (same as line 2b).

b. Enter % passing 100-mesh sieve (same as line 1).

c. Subtract 3b from 3a and enter here.

d. Multiply value on line 3c by 0.80 and enter here.

Line 4. Sum lines 1, 2d and 3d and enter on line 4.

Line 5. Enter calcium carbonate equivalence (CCE) in decimal form, i.e., $CCE \div 100$.

Line 6. Multiply line 4 by line 5 and enter on line 6. This is the effective neutralizing value.

Line 7. Divide 100 by the ENV (line 6) and enter on line 7. This is the quantity of this lime required to equal 1 unit (i.e., 1 ton or 1 pound) of 100% ENV.

Line 8. Enter the cost of 1 ton of lime on line 8.

Line 9. Multiply amount on line 8 by line 7. This is the cost of 1 ton of 100% ENV lime and provides the cost comparison of each material for the quantity of material that will react with the soil within the first year after application.

Limestone effectiveness value score card

The information needed for the calculations of the limestone effectiveness value (ENV) is shown on the label or on the delivery sheet. Two examples of the calculations for the limestones listed on page 36 follow:

Score Card

	Limestone #1	Limestone #2
1. Passing 100-mesh	<u>70</u>	<u>75</u>
2a. Passing 20-mesh	<u>98</u>	<u>98</u>
b. Passing 60-mesh	<u>90</u>	<u>80</u>
c. 20- to 60-mesh	<u>8</u>	<u>18</u>
d. 20- to 60-mesh reaction value	$\times 0.40$ <u>3.2</u>	$\times 0.40$ <u>7.2</u>
3a. Passing 60-mesh	<u>90</u>	<u>80</u>
b. Passing 100-mesh	<u>70</u>	<u>75</u>
c. 60- to 100-mesh	<u>20</u>	<u>5</u>
d. 60- to 100-mesh reaction value	$\times 0.80$ <u>16.0</u>	$\times 0.80$ <u>4.0</u>
4. Fineness score	<u>89.2</u>	<u>86.2</u>
5. % Calcium Carbonate Equivalence $\div 100$	<u>.788</u>	<u>.1043</u>
6. Effective Neutralizing Value	<u>70.3</u>	<u>89.9</u>
7. Weight equivalent to 100% ENV	<u>1.42</u>	<u>1.11</u>
Cost Effectiveness		
8. Cost per ton	<u>25.00</u>	<u>30.00</u>
9. Cost per ton of 100% Effective Neutralizing Value	<u>35.50</u>	<u>33.50</u>

limestone to be used (example of 0.90) and locate the value on the left side of the chart. At the top of the table, locate the recommended lime rate given by soil test or from the pH tables. Move down the column until you come to the line containing the effective neutralizing value of the lime to be used. The value of the limestone rate to be used is given at the intersection of your desired rate and effective neutralizing value of lime.

For lime scores not included within the table, divide the lime rate by the effective neutralizing value of the limestone; for example, 2 tons per acre lime recommended divided by 1.50 score equals 1.3 tons per acre to be used.

Cost effectiveness of limestones. Cost per ton of effective neutralizing value limestone can also be determined by dividing the cost per ton of the limestone by the effective neutralizing value. For example, if limestone #1 from page 36 sells for \$25.00 per ton with an ENV of 70 and limestone #2 sells for \$30.00 per ton with an ENV of 90, then costs of effective neutralizing material would be \$35.71 and \$33.33 per ton, respectively. To supply a 4-ton ENV lime requirement, it would require \$142.76 to purchase limestone #1 and \$133.33 to purchase limestone #2. The relative cost effectiveness considers only the ENV and not other factors such as the magnesium content of the limestone, the soil magnesium needs, the availability of the materials at the time when the lime can be spread, and other costs. There may be other reasons to purchase a particular limestone even though the relative cost effectiveness may be slightly higher.

Comparing other sources. The sources of limes such as quick lime (CaO), slack lime [Ca(OH)_2], and marl usually react with the soil rapidly

enough for the particle sizes not to be as critical as with agricultural limestones. When these sources are used, the evaluation of the limestone is calculated by using only the calcium carbonate equivalence (CCE) value as if it were the ENV.

Other sources of lime such as oyster shells should be compared for their effective neutralizing values by using the particle sizes as with limestones. Industrial by-products are an extremely variable group of chemical possibilities. Some can be useful as liming materials, but care should be exercised before purchase to ensure that they are properly evaluated.

Calcium and magnesium content of limestones. The limestones sold in New York vary from less than 0.2% to over 12% magnesium content. Limestone is the most economical method for providing magnesium to acid soils needing additional magnesium.

For all field crops except birdsfoot trefoil and soybeans, the limestone should contain at least 5.0% magnesium when the soil test magnesium is below 50 pounds per acre. The lime content should be 1 to 2.5% or more when the soil test magnesium is between 50 and 100 pounds per acre.

Likewise, the magnesium content should be greater than 0.5% when the soil test magnesium is between 100 and 200 pounds per acre.

Birdsfoot trefoil and soybeans require higher quantities of soil magnesium than other field crops do. For birdsfoot trefoil and soybeans, the magnesium content should be greater than 2.5% when the soil test magnesium is below 100 pounds per acre. The content should be 1% to 2.5% or more when the soil test is 100 to 200 pounds per acre and should be greater than 0.5% for between 200 and 400 pounds per acre of soil test magnesium.

These recommendations are based upon adding major quantities, greater than 2 tons per acre, of lime to acid soils. If the pH is near 7.0 and the magnesium is low, smaller quantities of lime containing 10% or more magnesium can also be used to correct low magnesium levels.

If the pH is 6.0 or above for corn or 6.5 or above for trefoil and the magnesium is low, a limestone high (about 10% Mg) in magnesium is still the most economical method for correcting low soil magnesium levels. It will require some time for the lime to react when the soil pH is near or



Lime is required on about two-thirds of the crop acres in New York. Fortunately, adequate supplies of agricultural limestone and spreading services are available in all areas of the state.

slightly above 7.0; therefore, for very low magnesium values (50 lb/A), some magnesium in the fertilizer may be desirable.

Research on the Mg in New York soils indicates that for most crops Ca/Mg ratios between 1:2 and 100:1 produce no more than a 10% yield variation for field crops; therefore, extreme cost measures to correct a Ca/Mg ratio problem are not economical, but some modification can be made at a low cost as part of the usual liming program.

The research information available indicates that there is no problem with excess magnesium until soil magnesium exceeds soil calcium. Magnesium can only exceed calcium in New York soils when large quantities of magnesium from other than limestone sources have been used. One cannot obtain a magnesium level higher than the calcium level by

adding limestone because the highest-magnesium limestones contain less magnesium than calcium. There is no advantage to applying a high-calcium limestone just to lower the magnesium values. If the soil test

magnesium level is high and a high-calcium limestone is the most economical source of lime, then the high-calcium lime should be used because of the cost, not because of the high soil magnesium levels.

Table 3. Range and recommended soil pH for optimum growth of various species of field crops

Crop species	Normal growth pH range	Recommended pH value
Alfalfa	6.5 to 7.5	6.6 to 7.0
Barley	6.3 to 7.0	6.3 to 6.5
Birdsfoot trefoil	6.0 to 7.0	6.3 to 6.5
Clovers	5.8 to 7.0	5.8 to 6.2
Corn	5.8 to 7.0	5.8 to 6.2
Grasses	5.8 to 7.0	5.8 to 6.2
Oats	5.8 to 7.0	5.8 to 6.2
Soybeans	6.5 to 7.5	6.6 to 7.0
Wheat	6.3 to 7.0	6.3 to 6.5

Lime Recommendations

For optimum crop production on the acid soils of New York State, soil pH must be adjusted with lime to match the crop needs. The lime needs are as critical as commercial fertilizer or proper varieties. As a matter of fact, one cannot make use of the increased yield potential in the newer varieties or more than minimum quantities of fertilizer if the desirable pH is not maintained.

The critical nature of maintaining the proper pH and the increased cost of limestone over the past few years mean greater care is needed in making lime recommendations. Thus, the

Table 4. Lime recommendations to increase the soil pH to 7.0 for alfalfa and soybeans

Exchange acidity (me/100 grams soil)																									
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25																									
pH	Tons of 100% ENV limestone per acre*																								
4.4	2.7	3.2	3.8	4.3	4.8	5.4	5.9	6.4	7.0	7.5	8.0	8.6	9.1	9.6	10.2	10.7	11.2	11.8	12.3	12.8	13.4				
4.5	2.7	3.2	3.8	4.3	4.8	5.4	5.9	6.4	6.9	7.5	8.0	8.5	9.1	9.6	10.1	10.7	11.2	11.7	12.3	12.8	13.3				
4.6	2.7	3.2	3.7	4.3	4.8	5.3	5.9	6.4	6.9	7.4	8.0	8.5	9.0	9.6	10.1	10.6	11.1	11.7	12.2	12.7	13.3				
4.7	2.7	3.2	3.7	4.3	4.8	5.3	5.8	6.4	6.9	7.4	7.9	8.5	9.0	9.5	10.0	10.6	11.1	11.6	12.2	12.7	13.2				
4.8	2.7	3.2	3.7	4.2	4.8	5.3	5.8	6.3	6.8	7.4	7.9	8.4	8.9	9.5	10.0	10.5	11.0	11.6	12.1	12.6	13.1				
4.9	2.6	3.2	3.7	4.2	4.7	5.2	5.8	6.3	6.8	7.3	7.8	8.3	8.9	9.4	9.9	10.4	10.9	11.5	12.0	12.5	13.0				
5.0	2.6	3.1	3.6	4.2	4.7	5.2	5.7	6.2	6.7	7.2	7.7	8.3	8.8	9.3	9.8	10.3	10.8	11.3	11.8	12.4	12.9				
5.1	2.6	3.1	3.6	4.1	4.6	5.1	5.6	6.1	6.6	7.1	7.6	8.1	8.6	9.2	9.7	10.2	10.7	11.2	11.7	12.2	12.7				
5.2	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.4	8.9	9.4	9.9	10.4	10.9	11.4	11.9	12.4				
5.3	2.4	2.9	3.3	3.8	4.3	4.8	5.2	5.7	6.2	6.6	7.1	7.6	8.0	8.5	9.0	9.5	9.9	10.4	10.9	11.3	11.8				
5.4	2.2	2.7	3.1	3.5	4.0	4.4	4.9	5.3	5.7	6.2	6.6	7.0	7.5	7.9	8.3	8.8	9.2	9.7	10.1	10.5	11.0				
5.5	2.1	2.5	2.9	3.3	3.7	4.2	4.6	5.0	5.4	5.8	6.2	6.6	7.0	7.4	7.8	8.3	8.7	9.1	9.5	9.9	10.3				
5.6	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.1	5.5	5.9	6.3	6.7	7.1	7.5	7.9	8.3	8.7	9.1	9.5	9.8				
5.7	1.9	2.3	2.7	3.1	3.4	3.8	4.2	4.6	4.9	5.3	5.7	6.1	6.5	6.8	7.2	7.6	8.0	8.3	8.7	9.1	9.5				
5.8	1.8	2.2	2.5	2.9	3.3	3.6	4.0	4.3	4.7	5.0	5.4	5.8	6.1	6.5	6.8	7.2	7.5	7.9	8.3	8.6	9.0				
5.9	1.7	2.0	2.4	2.7	3.0	3.4	3.7	4.0	4.4	4.7	5.0	5.4	5.7	6.0	6.4	6.7	7.0	7.4	7.7	8.0	8.4				
6.0	1.6	1.9	2.3	2.6	2.9	3.2	3.5	3.8	4.2	4.5	4.8	5.1	5.4	5.7	6.0	6.4	6.7	7.0	7.3	7.6	7.9				

NOTE: Lime recommendations are based on plow depth of 8.0 inches. Correct rate if plowing a different depth.
*The recommendations are for 100% effective neutralizing value (ENV) limestone and should be corrected for the ENV score (see limestone score card) for the brand of lime to be used. Once they are corrected for the lime score, the final application rate should usually be rounded to the nearest 0.5 ton.

lime recommendations are based upon the effective neutralizing value (see previous discussion).

It requires about 500 pounds of lime per acre per year to maintain the soil pH between 6.0 and 7.0 in a corn-alfalfa rotation. The higher the yield potential of the soil, the more lime that is required.

Lime rate tables. The soil pH range required for normal growth of crops and the pH range used for the liming recommendations are shown in table 3. Lime is to be added when the pH is below the recommended value. The rate added is sufficient to increase the soil pH to the higher pH value.

The lime recommendations are made for the crop requiring the highest pH within the rotation. When alfalfa or soybeans are in the rotation, the minimum pH should be 6.7; and after liming, the soil pH should be in-

creased to 7.0 by using the lime recommendations from table 4. For barley, birdsfoot trefoil, and wheat the minimum soil pH should be 6.3, and the soil is to be limed to pH 6.5 or above by using the lime recommendations from table 5. Other crops such as grasses, corn, sorghum, and oats grow best when the soil pH is 6.0 or above. The liming recommendations for these crops are sufficient to increase the soil pH to 6.2 by using the lime recommendations from table 6. For soil tests the lime recommendations are made by determining the maximum lime requirements for the 6 crop years shown on the soil test information sheet.

The general lime recommendations in table 7 are to increase the soil pH for an 8-inch-deep plow layer to 7.0. They are to be used only when complete soil tests are not available or when the soil pH is above 6.0. Ex-

change acidity is not normally determined by soil test when the soil pH is above 6.0.

The lime rates given in these tables are based upon an 8-inch plow depth. If the plow depth is greater than 8 inches, increase the lime rate by multiplying the rate given by 12% for each inch of depth greater than 8 inches. If the plow depth is less than 8 inches, decrease the rate given by 12% for each inch of depth less than 8 inches. For example, a plow depth of 10 inches and a lime rate of 4 tons would require 24% more lime than given in the table, or 4 tons x 0.24 = 0.96 ton more lime than given in the table. Thus, the lime rate to be applied would be approximately 5 tons.

The soil test system currently uses plow depths of 6, 8, and 10 inches for the 1-7, 7-9, and 9+ -inch boxes checked on the soil test information sheet. The depth used for no-till is 0-

Table 5. Lime recommendations to increase the soil pH to 6.5 for barley, birdsfoot trefoil, and wheat

	Exchange acidity (me/100 grams soil)																				
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
pH	Tons of 100% ENV limestone per acre*																				
4.4	2.4	2.9	3.4	3.8	4.3	4.8	5.2	5.7	6.2	6.7	7.1	7.6	8.1	8.5	9.0	9.5	10.0	10.4	10.9	11.4	11.8
4.5	2.4	2.9	3.3	3.8	4.3	4.7	5.2	5.7	6.1	6.6	7.1	7.6	8.0	8.5	9.0	9.4	9.9	10.4	10.8	11.3	11.8
4.6	2.4	2.8	3.3	3.8	4.2	4.7	5.2	5.6	6.1	6.6	7.0	7.5	8.0	8.4	8.9	9.4	9.8	10.3	10.8	11.2	11.7
4.7	2.4	2.8	3.3	3.8	4.2	4.7	5.1	5.6	6.1	6.5	7.0	7.5	7.9	8.4	8.8	9.3	9.8	10.2	10.7	11.2	11.6
4.8	2.3	2.8	3.3	3.7	4.2	4.6	5.1	5.5	6.0	6.5	6.9	7.4	7.8	8.3	8.8	9.2	9.7	10.1	10.6	11.0	11.5
4.9	2.3	2.8	3.2	3.7	4.1	4.6	5.0	5.5	5.9	6.4	6.8	7.3	7.7	8.2	8.6	9.1	9.5	10.0	10.4	10.9	11.3
5.0	2.3	2.7	3.2	3.6	4.0	4.5	4.9	5.4	5.8	6.3	6.7	7.1	7.6	8.0	8.5	8.9	9.4	9.8	10.2	10.7	11.1
5.1	2.2	2.7	3.1	3.5	4.0	4.4	4.8	5.3	5.7	6.1	6.6	7.0	7.4	7.9	8.3	8.7	9.2	9.6	10.0	10.5	10.9
5.2	2.1	2.5	3.0	3.4	3.8	4.2	4.6	5.0	5.5	5.9	6.3	6.7	7.1	7.5	8.0	8.4	8.8	9.2	9.6	10.0	10.5
5.3	2.0	2.3	2.7	3.1	3.5	3.9	4.3	4.6	5.0	5.4	5.8	6.2	6.5	6.9	7.3	7.7	8.1	8.5	8.8	9.2	9.6
5.4	1.7	2.0	2.4	2.7	3.0	3.4	3.7	4.0	4.4	4.7	5.0	5.4	5.7	6.0	6.4	6.7	7.0	7.4	7.7	8.0	8.4
5.5	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.7	5.9	6.2	6.5	6.8	7.1	7.4
5.6	1.4	1.7	1.9	2.2	2.5	2.7	3.0	3.3	3.5	3.8	4.1	4.3	4.6	4.9	5.1	5.4	5.7	5.9	6.2	6.5	6.8
5.7	1.3	1.5	1.8	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.7	4.0	4.2	4.5	4.7	5.0	5.2	5.5	6.0	6.2	6.2
5.8	1.1	1.4	1.6	1.8	2.0	2.2	2.4	2.7	2.9	3.1	3.3	3.5	3.7	4.0	4.2	4.4	4.6	4.8	5.0	5.3	5.5
5.9	1.0	1.1	1.3	1.5	1.7	1.9	2.1	2.2	2.4	2.6	2.8	3.0	3.2	3.3	3.5	3.7	3.9	4.1	4.3	4.4	4.6
6.0	0.8	1.0	1.2	1.3	1.5	1.6	1.8	1.9	2.1	2.3	2.4	2.6	2.7	2.9	3.0	3.2	3.4	3.5	3.7	3.8	4.0

NOTE: Lime recommendations are based on plow depth of 8.0 inches. Correct rate if plowing a different depth.

*The recommendations are for 100% effective neutralizing value (ENV) limestone and should be corrected for the ENV score (see limestone score card) for the brand of lime to be used. Once they are corrected for the lime score, the final application rate should usually be rounded to the nearest 0.5 ton.

Table 6. Lime recommendations to increase the soil pH to 6.2 for clover, corn, grasses, and oats

pH	Exchange acidity (me/100 grams soil)																				
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Tons of 100% ENV limestone per acre*																				
4.4	2.2	2.7	3.1	3.6	4.0	4.4	4.9	5.3	5.7	6.2	6.6	7.1	7.5	7.9	8.4	8.8	9.2	9.7	10.1	10.6	11.0
4.5	2.2	2.7	3.1	3.5	4.0	4.4	4.8	5.3	5.7	6.1	6.6	7.0	7.4	7.9	8.3	8.8	9.2	9.6	10.1	10.5	10.9
4.6	2.2	2.6	3.1	3.5	3.9	4.4	4.8	5.2	5.7	6.1	6.5	7.0	7.4	7.8	8.3	8.7	9.1	9.5	10.0	10.4	10.8
4.7	2.2	2.6	3.0	3.5	3.9	4.3	4.8	5.2	5.6	6.0	6.5	6.9	7.3	7.8	8.2	8.6	9.0	9.5	9.9	10.3	10.8
4.8	2.2	2.6	3.0	3.4	3.8	4.3	4.7	5.1	5.5	6.0	6.4	6.8	7.2	7.6	8.1	8.5	8.9	9.3	9.8	10.2	10.6
4.9	2.1	2.5	2.9	3.4	3.8	4.2	4.6	5.0	5.4	5.8	6.3	6.7	7.1	7.5	7.9	8.3	8.7	9.2	9.6	10.0	10.4
5.0	2.1	2.5	2.9	3.3	3.7	4.1	4.5	4.9	5.3	5.7	6.1	6.5	6.9	7.3	7.7	8.1	8.5	9.0	9.4	9.8	10.2
5.1	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	5.9	6.3	6.7	7.1	7.5	7.9	8.3	8.7	9.1	9.5	9.9
5.2	1.9	2.3	2.7	3.0	3.4	3.8	4.2	4.5	4.9	5.3	5.6	6.0	6.4	6.8	7.1	7.5	7.9	8.3	8.6	9.0	9.4
5.3	1.7	2.0	2.4	2.7	3.0	3.4	3.7	4.0	4.4	4.7	5.0	5.4	5.7	6.0	6.4	6.7	7.0	7.4	7.7	8.0	8.4
5.4	1.4	1.7	2.0	2.3	2.5	2.8	3.1	3.4	3.6	3.9	4.2	4.5	4.7	5.0	5.3	5.6	5.8	6.1	6.4	6.7	6.9
5.5	1.2	1.4	1.7	1.9	2.1	2.4	2.6	2.8	3.0	3.3	3.5	3.7	4.0	4.2	4.4	4.7	4.9	5.1	5.4	5.6	5.8
5.6	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0
5.7	0.9	1.1	1.3	1.4	1.6	1.8	2.0	2.1	2.3	2.5	2.7	2.8	3.0	3.2	3.4	3.5	3.7	3.9	4.0	4.2	4.4
5.8	0.7	0.9	1.0	1.2	1.3	1.4	1.6	1.7	1.9	2.0	2.1	2.3	2.4	2.6	2.7	2.8	3.0	3.1	3.3	3.4	3.5
5.9	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5
6.0	0.4	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.4	1.5	1.5	1.6	1.7	1.7	1.8

NOTE: Lime recommendations are based on plow depth of 8.0 inches. Correct rate if plowing a different depth.
 *The recommendations are for 100% effective neutralizing value (ENV) limestone and should be corrected for the ENV score (limestone score card) for the brand of lime to be used. Once they are corrected for the lime score, the final application rate should usually be rounded to the nearest 0.5 ton.

Table 7. General lime recommendations

Initial soil pH	Loams Silty Sandy & silt clay Sands loams loams loams			
	tons/acre			
4.5	4.0	7.0	11.0	15.0
4.6 to 4.7	3.5	6.5	10.0	13.0
4.8 to 4.9	3.0	6.0	9.0	12.5
5.0 to 5.1	2.5	5.5	8.5	12.0
5.2 to 5.3	2.0	4.5	6.5	8.0
5.4 to 5.5	1.5	3.0	4.0	6.0
5.6 to 5.7	1.0	2.0	3.0	5.5
5.8 to 5.9	0.8	1.8	2.5	3.5
6.0 to 6.1	0.6	1.5	2.0	3.0
6.2 to 6.3	0.5	1.0	1.5	2.5
6.4 to 6.5	0.3	0.8	1.3	2.0
6.6 to 6.7	0.2	0.7	1.0	1.5

1 inch for the surface and 1-6 inches for the primary nutrient supply zone.

Points to remember when using lime recommendations

1. If the original pH is greater than 6.0 or a complete soil test is not available, use table 7.
2. Rates are based on an 8-inch plow depth. Reduce or increase recommendations by 12% for each inch that differs from 8 inches. Decrease the lime rate by one-third if the soil is quite gravelly.
3. The lime rates in the tables assume 100% effective neutralizing value. The rate must be changed to account for the difference in ENV of the limestone to be used. For example, a 4-ton rate of a lime with an .80 ENV would require $4 \div 0.80 = 5$ tons/acre.

Lime applications. If the soil pH is below 6.0, the lime should be applied long enough before a legume seeding for the lime to react with the entire plow layer. If there is insufficient time for an adequate reaction with the entire plow layer (at least 2 plowings), at least one-half of the recommended lime rate should be added to the surface and disked in before the seeding to provide a favorable pH in the soil zone near the seed to encourage good establishment.

Split the lime application on soils that require more than 4 tons per acre by plowing one-half down and disk the remainder into the surface. Smaller lime applications that are necessary to maintain the pH above 6.5 can be made at any time before seeding and can be either applied to the surface or plowed down.



The Cornell pH kit can be used to determine the soil pH and whether lime is needed. It does not determine the amount of lime needed. A complete soil test should be used to determine the quantity of lime to be applied.

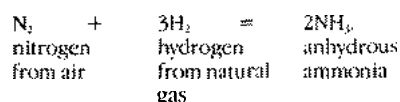
If the pH is 5.5 or below, lime should be applied at least a year before a pH-sensitive crop such as alfalfa or barley is planted. It is usually recommended that a split application of lime be applied and a less-sensitive crop such as corn or clover be planted for at least 1 year before planting alfalfa.

The last summer or fall that a field is in sod is a good time to apply small maintenance additions of lime. At that time the soil is firm, and lime can be applied with less likelihood that the spreader trucks will get stuck, rut the fields, or compact the soil.

Manufacture of Fertilizers

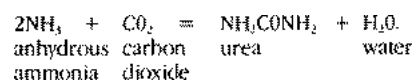
The manufacture of fertilizer uses large quantities of energy as well as raw materials. Likewise, it requires energy to transport these materials to the point of use. A combination of availability of raw materials, energy, and transportation facilities and quantity of fertilizer used determines the location of the fertilizer plants.

Nitrogen. *Anhydrous ammonia* (NH_3). Anhydrous ammonia is made by reducing natural gas (methane) to carbon dioxide and hydrogen. The hydrogen is reacted with nitrogen from the air to produce anhydrous ammonia.



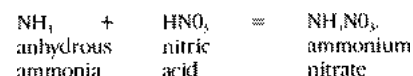
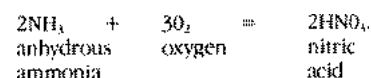
The combination of hydrogen and nitrogen will only occur at very high temperatures and pressures and thus uses energy. Approximately 40,000 cubic feet of natural gas are required to produce 1 ton of anhydrous ammonia. As much natural gas is required to make 3 to 4 tons of anhydrous ammonia as to heat an average insulated house for a year. To conserve nitrogen (use only that quantity necessary for maximum economic yields) is as important as to conserve energy. The other sources of commercial nitrogen fertilizers, except some industrial by-product ammonium sulfate, are made from anhydrous ammonia (NH_3).

Urea (NH_2CONH_2). To manufacture urea either for feed or fertilizer, anhydrous ammonia is reacted with the carbon dioxide obtained from natural gas in the presence of a catalyst to produce urea and water.



The urea is granulated and dried. This also requires energy. Thus, urea NH_2CONH_2 , costs more to produce than anhydrous ammonia.

Ammonium nitrate (NH_4NO_3). Ammonium nitrate is made by oxidizing (burning) anhydrous ammonia in the presence of a platinum screen and other catalysts to form nitrous oxide. The nitrous oxide is reacted with water to produce nitric acid. The nitric acid is neutralized by using more anhydrous ammonia, and ammonium nitrate is formed.



When either urea or ammonium nitrate is first produced, it is a hot molten liquid. The granules commonly used in dry fertilizer materials are prepared by spraying this hot liquid into a large revolving drum, coating the prills with clay to help prevent moisture absorption, and allowing them to cool. The purpose of the clay coating is to prevent the prills from sticking together and to help prevent moisture absorption by the fertilizer.

Ammonium sulfate [$(\text{NH}_4)_2\text{SO}_4$]. Ammonium sulfate is produced by reacting ammonia with sulfuric acid. It is generally produced as a by-product of the removal of ammonia or sulfur from manufacturing processes. Very little ammonium sulfate is made specifically for fertilizer consumption.

Nitrogen solutions—urea + ammonium nitrate ($\text{NH}_4\text{NO}_3 + \text{NH}_2\text{CONH}_2$). Nitrogen solutions are made by dissolving ammonium nitrate and urea in water. The ammonium nitrate and urea are transferred directly from the production plant to the water, thus saving the drying and the clay coating. The 28 to

32% nitrogen solutions usually contain about 50% of the nitrogen as urea and about 50% as ammonium nitrate. Other than 28 to 32% solutions can be and are produced. A gallon of 32% nitrogen solution weighs 11.06 pounds and contains 3.54 pounds of nitrogen.

Aqua ammonia and low-pressure solutions. Aqua ammonia (ammonia in a water solution) and other low-pressure nitrogen solutions are made by adding anhydrous ammonia to water under controlled conditions. The concentration of nitrogen within the water is determined by the amount of anhydrous ammonia added. Pressure is developed over the solution by the ammonia. Most aqua solutions are produced to contain 20 to 30% nitrogen.

Anhydrous ammonia can be added to ammonium nitrate and (or) urea solutions to produce more-concentrated products varying in concentration from about 30 to 42% nitrogen. These are commonly referred to as low-pressure solutions, their advantages being that they produce less pressure than anhydrous ammonia and still contain a fairly concentrated nitrogen solution for shipment and application.

The disadvantages of low-pressure solutions are that they must be handled as a material under pressure and must be soil injected the same as anhydrous ammonia to prevent ammonia loss. Both these disadvantages mean a higher equipment and application cost.

These products are not commonly sold in New York, but there has been some interest in them for certain locations.

Ammonium phosphates. The ammonium phosphates are commonly used to supply nitrogen and phosphorus. Generally, they contain smaller amounts of nitrogen than phosphate (P_2O_5). The more-common

ammonium phosphates are monoammonium phosphate ($NH_4H_2PO_4$), 13-52-0 or 11-48-0; diammonium phosphate $[(NH_4)_2HPO_4]$, 18-46-0; and ammonium polyphosphate, 12-64-0. These compounds are essentially 100% water soluble and are concentrated sources of fertilizers. They are made by reacting phosphoric acid with ammonia. The quantity of ammonia added and the heat determine whether one makes monoammonium, diammonium, or ammonium polyphosphate. The ammonium phosphates are commonly used for direct application or in bulk-blended fertilizers.

Ammoniated superphosphates. Ammoniated superphosphates are made by introducing anhydrous ammonia into superphosphate or concentrated (triple) superphosphate. The result is a fertilizer containing both nitrogen and phosphorus similar to the ammonium phosphates. The chemical difference between the ammoniated and the ammonium phosphates is the presence of extra calcium in the material. Ammoniated superphosphates have the chemical formula of mono-calcium-ammonium phosphate $[Ca(NH_4HPO_4)_2]$. This compound is nearly 100% water soluble and plant available; but if too much nitrogen is added, some of the phosphorus is converted to non-water-soluble compounds. Further addition of ammonia converts some of the phosphorus to forms that are not plant available. Most producers today maintain about 60% water solubility and essentially 100% plant availability in their ammoniated superphosphates.

Both ammoniated superphosphates and monoammonium phosphates make excellent sources of nitrogen and phosphorus for band application. There appears to be little difference in plant response between these sources as long as at least

60% water solubility is maintained in the ammoniated superphosphates.

Phosphorus. Superphosphates. Ordinary superphosphate and concentrated (triple) superphosphate fertilizers are made by reacting a phosphorus-containing ore, usually apatite, with sulfuric acid. Ordinary superphosphate (0-20-0) contains monocalcium phosphate and calcium sulfate (gypsum). If during production the calcium sulfate is separated from the monocalcium phosphate fertilizer, concentrated superphosphate (0-46-0) is obtained. Recently, because of lower-grade phosphorus ores, the analysis of concentrated superphosphate has varied from 44% to 46% P_2O_5 . Both these superphosphates contain the same chemical phosphorus compound, monocalcium phosphate $[Ca(H_2PO_4)_2]$, but ordinary superphosphate contains another major component, calcium sulfate or gypsum. Thus, ordinary superphosphate contains a major quantity of sulfur. Concentrated superphosphate may contain some sulfur—usually less than about 3%.

Phosphoric acid. Phosphoric acid is used as the phosphorus source for manufacture of the ammonium phosphates, ammonium polyphosphates, and liquid or slurry fertilizers. Phosphoric acid for most fertilizers is produced by reacting rock phosphate (apatite) with excess sulfuric acid (made from sulfur), then purifying and concentrating the resulting phosphoric acid. The amount and method of concentrating the acid determine the P_2O_5 content and, therefore, whether it is considered as the more concentrated form, polyphosphate. The phosphoric acid is then used in the manufacture of other fertilizer materials.

Ammonium phosphates. The P_2O_5 content of the phosphoric acid determines whether, when reacted with

anhydrous ammonia, an ammonium phosphate or ammonium polyphosphate is produced. The ammonium polyphosphates are made from phosphoric acids containing about 70% P_2O_5 .

When the phosphoric acid is reacted with ammonia, the resulting ammonium phosphate can be dried and granulated for the production of dry fertilizer or can be maintained as a liquid. Essentially the same chemical forms can exist as a liquid or as a dry material.

The common liquid ammonium phosphates are the 10-34-0 and 11-37-0 grades. These materials are usually stored at a blend plant and can be mixed with muriate of potash to form a liquid containing N-P-K. A disadvantage of these liquids is their low analyses. They must contain some nitrogen.

Potassium. Potassium fertilizers are primarily mined from deposits of potassium chloride, potassium sulfate, and potassium and magnesium sulfates. United States' production of potassium fertilizer has declined within recent years. We import essentially all our potassium fertilizers, mostly from Canada. Over 90% of the potassium fertilizers used in the Northeast come from Canada. Thus, we are dependent upon the supply and pricing structure of the Canadian potash for our potassium.

Some Important Reactions of Nitrogen

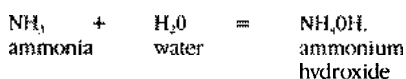
Nitrogen can be supplied to crops from several fertilizer sources. These sources can contain nitrogen in several different chemical forms. The plant may not be able to use the nitrogen in the form supplied, and some forms of nitrogen may even be toxic to plants. Under soil conditions adequate for normal growth of plants, the various forms of nitrogen are ul-

timately (usually rapidly) converted to ammonia and subsequently to nitrate. Nitrate is the form of nitrogen most often used by plants. In this section we will discuss several forms of nitrogen and the changes they undergo in the soil.

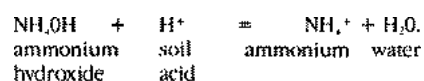
First, a general description of the changes in nitrogen that occur in soils follows.

Nitrogen transformations. *Organic nitrogen* ($-CNH_2$). The change from organic nitrogen (nitrogen contained in organic matter) to inorganic ammonia occurs over a wide range of soil conditions. Different types of microbes use the organic matter as a source of energy. When the content of nitrogen in the organic matter is sufficient (i.e., C to N ratio of 15 to 1), inorganic nitrogen is released as ammonia or the ammonium ion. Once the ammonia is released, it undergoes the same reaction as other ammonium fertilizer sources. This release of inorganic nitrogen is called *mineralization*. Nitrogen is generally released when any green plant, sod crop, or manure is incorporated into the soil. When sawdust, bark, or other material very low in nitrogen as compared with carbon is incorporated, nitrogen may be removed from the soil by the growing microbes and incorporated into their bodies. This process is called *immobilization*. For some materials there is no major change in the soil nitrogen status with decomposition. These crop residues include small grain straws, corn stalks, and the like.

Ammonia (NH_3 , a gas). The ammonia reacts instantly with any water present in the soil to form ammonium hydroxide, a high-pH base.



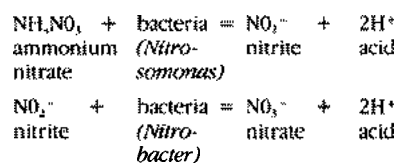
Ammonium hydroxide is the ingredient in smelling salts and, if exposed to the air, will revert to ammonia (gas) and water. Ammonium hydroxide will also react with soil acids to form the ammonium ion and water.



Thus, the initial reaction for ammonium formation from organic materials, urea, or anhydrous ammonia is a very high pH, especially if the application is concentrated in a small area such as a fertilizer band. This high pH is often harmful to germinating seeds, seedling plants, and roots.

Ammonium (NH_4^+). The ammonium form of nitrogen (NH_4^+) has a positive charge and will be attracted to, and held on, the negatively charged clay particles in the soil. This is why ammonium nitrogen is often classified as a nonleachable nitrogen source. The nonleachable characteristic of the ammonium ion has minimum significance in maintaining the nitrogen in warm soils because it is soon converted to the leachable nitrate ion (NO_3^-). The nitrate ion is negatively charged and, hence, is not attracted and held by the clay particles in the soil.

Nitrate (NO_3^-). Once the organic nitrogen becomes ammonium or when commercial fertilizers containing ammonia are added to the soil, a two-step conversion occurs.



The ammonium nitrogen is converted to nitrite by the actions of bacteria of the genus *Nitrosomonas*. *Nitrosomonas* bacteria will convert ammonium nitrogen to nitrite in a

pH range from below 5.6 to above 8.5. When the ammonium ion is converted to nitrite, acid (H^+ ion) is also produced, and thus the pH is lowered.

Bacteria of the genus *Nitrobacter* will convert nitrite to nitrate nitrogen. The conversion of ammonia or ammonium to nitrite and nitrate can and usually does occur rapidly. The conversion of 50 pounds per acre of ammonium nitrogen from ammonium sulfate or ammonium nitrate can occur in less than a week under favorable conditions. Conversion of urea and anhydrous ammonia requires up to 3 weeks because of the high pH produced. Once the nitrogen is converted to nitrate, it is readily leachable. Because these conversions occur readily in soils, there is no completely nonleachable source of nitrogen, although the nitrification process can be slowed by adding a nitrification inhibitor.

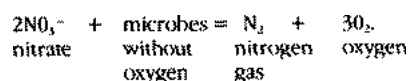
Acid is also released upon the conversion of ammonia to nitrate, further reducing the soil pH. The release of these acids is the reason most nitrogen-containing fertilizers are called acid-forming fertilizers. In general, it requires about 4 pounds of lime to counteract the acidity produced from 1 pound of ammonium nitrogen. Even on acid soils it is more economical to counteract the acidity produced by the fertilizer with lime rather than try to purchase fertilizers that are labeled as nonacid forming.

Nitrobacter bacteria convert nitrite to nitrate in a more-restricted pH range than that in which *Nitrosomonas* bacteria convert ammonium to nitrite. The pH range for *Nitrobacter* bacteria is from below 6.0 to about 8.0. Under certain conditions when there is a very high pH, nitrite will accumulate. In excessive quantities (probably about 1 lb/acre), nitrite is very harmful to plants. An excess of nitrite may occur when high concen-

trations of urea, anhydrous ammonia, and (or) diammonium phosphate are used in the fertilizer band close to the seed or seedling plants. Thus, care must be exercised in using these materials for band fertilizers.

Large concentrations of free ammonia may exist from the application of anhydrous ammonia, urea, or diammonium phosphate. Ammonia in high concentrations is also harmful to plants. It is difficult to separate the conditions of nitrite injury and ammonia injury to plants because neither produces visible symptoms. In a concentrated band these fertilizers may produce both conditions of free ammonia and excess nitrite. Reduced plant stands or lower yields may result.

Denitrification. The conversion of ammonia to nitrate occurs only when adequate oxygen is present in the soil. When the soils are wet and air movement within the soil is restricted, oxygen becomes limiting and another type of nitrogen conversion (denitrification) occurs.



The nitrate nitrogen is converted to nitrogen gas (the same nitrogen gas that makes up 78% of the air) and is lost from the soil and plant use. This process is called denitrification.

Data from New York indicate that on the average 75 to 90% of fall-applied nitrogen and about 35% of spring preplant nitrogen for corn are lost by July. Probably most of the nitrogen is lost by denitrification under most New York soil conditions. Side-dress nitrogen recommendations help to prevent loss in two ways: (1) The nitrogen is applied after the wet spring period has passed, and denitrification or leaching is minimized. (2) The nitrogen is applied just be-

fore maximum nitrogen uptake by the corn, and there is less time for loss to occur.

Characteristics of Nitrogen Fertilizers

It is often quoted that a pound of nitrogen fertilizer is equivalent to any other pound of nitrogen fertilizer regardless of the source. This is true only when the materials are applied under conditions suitable for each source. Several characteristics of the fertilizer material influence the time and method of application needed for maximum efficiency.

Anhydrous ammonia (NH_3). Anhydrous ammonia is a liquid under pressure, contains 82% nitrogen, and weighs about 5 pounds per gallon. It becomes a gas upon application when the pressure is released. Because ammonia reacts rapidly with water to form a strong base, it is extremely caustic to the eyes, skin, and lungs, and, therefore, must be handled with care. When handled and applied properly with good equipment, it is an excellent source of nitrogen for many crops.

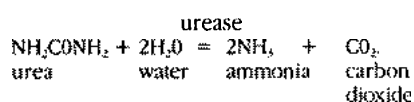
To prevent application losses, anhydrous ammonia must be placed into the soil 6 to 8 inches deep, so that the ammonia can react completely with the soil before the gas can escape. The most common application method is to knife the anhydrous ammonia into the soil as a side-dress application for corn.

Anhydrous ammonia causes a high soil pH around the point of release. Because this is harmful to young germinating seedlings, anhydrous ammonia should not be applied near the seed, but rather at midrow. When seeds are placed in or near a preplant anhydrous ammonia band, loss of stand and yield may result. It is difficult to apply preplant bands without this problem. One possible solution

is to dilute the bands as much as possible by using more, closer-spaced knives so that the rate per knife is lower or by using plow sole applications.

Anhydrous ammonia is usually one of the cheapest sources per pound of nitrogen, especially when it is purchased in large quantities; but the equipment for transportation and application is expensive. About 200 acres of corn are required for the use of anhydrous ammonia with farm-owned equipment to be economically feasible. Likewise, a retail supply of anhydrous ammonia must be nearby. Using anhydrous ammonia as an additive to corn silage would spread the investment and reduce the amount of corn required for its use as a fertilizer to be economical. The total N needed on dairy farms may make such anhydrous ammonia additions for corn unnecessary.

Urea (NH_2CONH_2). Urea is a dry, white prill containing 45 to 46% nitrogen. It is the most concentrated dry source of N available and is generally the least expensive of the more commonly used dry sources. Urea has several characteristics that influence the time and method for efficient applications. For urea to be used by plants, it must change from urea to ammonia. This change occurs by the action of the enzyme called urease on the urea. Urease is a naturally occurring enzyme that is produced as a by-product of plant decomposition and microbial growth. The urea molecule breaks down into ammonia, carbon dioxide, and water, the same components used in its production.



This breakdown of the urea to ammonia occurs rapidly under moist soil conditions. It is usually complete within a few hours after application. If the urea is placed on the soil surface, some of the ammonia is lost to the air. Under soil-drying conditions, the nitrogen loss can approach 40% of the applied nitrogen. When applied just before a rain, the urea can dissolve and enter the soil with the water before breakdown to ammonia occurs. The ammonia released from the urea can then react with the soil, and ammonia loss is prevented. If excess rain occurs, the urea can leach through the soil. An average loss for summer-applied topdressed urea is likely to be 15 to 20% of the applied nitrogen. Thus, when urea is applied, it should be mixed or covered with the soil in some manner to prevent this loss. This loss limits the usefulness of urea for topdressing pastures, meadows, and small grains as well as other crops when the material is not incorporated into the soil.

When the urea is applied in a band at planting, the ammonia released from the urea causes a high pH in the fertilizer band. This can result in seedling damage as described in the preceding section. Thus, urea should not be banded at rates greater than 20 to 30 pounds per acre at planting.

Urea can be banded as a sidedressing for corn by using disk openers and placing the urea about 2 inches below the soil surface. Likewise, it can be applied preplant incorporated without ammonia loss, but the other losses common to preplant applications of nitrogen may occur.

Ammonium nitrate (NH_4NO_3). Ammonium nitrate is a dry prill containing 33 to 34% nitrogen. It was once the primary source of fertilizer nitrogen, but urea production now exceeds ammonium nitrate production.

On most soils the losses from topdressed ammonium nitrate are less than for urea; therefore, it often is a better nitrogen source for topdressings. On high pH soils, however, some nitrogen may be lost by volatilization from ammonium nitrate, because the ammonium reacts with the carbonate from lime to form ammonium carbonate. The ammonium carbonate breaks down to ammonia, water, and carbon dioxide. The ammonia may then be lost by volatilization from the soil surface. This loss does not often exceed 10% of the applied nitrogen, even on high pH soils.

Areas for storage of ammonium nitrate should be dry and free from all petroleum products such as oils and fuels. Ammonium nitrate mixed with these products is extremely explosive. It should also be kept away from heat and explosives.

Ammonium sulfate [$(\text{NH}_4)_2\text{SO}_4$]. Ammonium sulfate is a dry, usually crystalline source containing 20% nitrogen. It is a by-product of several industries, especially steel production. Most of the ammonium sulfate is used in bulk-blended or mixed fertilizers because it is compatible with both urea and ammonium nitrate. It undergoes the same reactions and can be used in the same way as ammonium nitrate.

Nitrogen solutions (NH_4NO_3 and NH_2CONH_2 in water). Nitrogen solutions will quickly dehydrate any portion of the plant they touch. If used at high rates, the solutions may almost completely defoliate the plant; therefore, nitrogen solutions should not be used as a postemergence spray unless directed below most of the plant leaves.

Because nitrogen solutions contain about 50% of the nitrogen as urea, some nitrogen volatilization losses can be expected when nitrogen solutions are used as a topdress-



Liquid fertilizer storage facilities consist of large tanks of metal or plastic. The basic materials are usually mixed to the desired analysis just before application.



Liquid fertilizers are transported and often applied with tank trucks or trailers. The transfer of liquids by pump makes them easier and faster to handle.

ing. For sidedressing corn, the solutions should be knifed about 2 inches into the soil in a manner similar to that for anhydrous ammonia.

Nitrogen solutions are readily available, convenient, and a safe and easy nitrogen source to use. Solutions require a moderate financial investment for equipment. Likewise, more attention than that normally exercised in the past should be given to proper placement.

Solution versus Dry Fertilizers

As shown in the "Manufacture of Fertilizers" section, the same basic chemical compounds are present in the liquid fertilizers as in many of the dry fertilizers. There is no difference in the plant response obtained from liquid or dry fertilizers if they are applied to the soil in similar positions, that is, banded or broadcast. The differences between these materials, therefore, is in the methods for transporting, storing, and handling. Liquids have some advantages because they can be transferred from tanks to other equipment and applied using

liquid pumps. Pumping is usually faster and is easier than handling most dry materials. Liquid materials require a higher initial equipment investment. Dry materials would be much easier to handle if similar quantities of money were invested in dry-handling facilities.

The disadvantages of liquid fertilizers are more weight must be transported and lower fertilizer analyses are often used. This may not be the case with some of the newer "slurry"-type liquids being developed. Slurries are solid particles of fertilizer suspended in a clay-water mixture that prevents the solid particles from settling to the bottom of the tank. Slurries are not commonly used in New York, but their use in other parts of the United States is increasing. The disadvantage of slurries is they can only be used as a broadcast application.

Calculations for liquid fertilizers. The analyses for liquids are expressed in exactly the same terms as for dry materials—as percentages by weight of the nutrients contained in

the total weight of the material, that is, 9-18-9 refers to 9% of nitrogen, 18% of P_2O_5 , and 9% of K_2O . This means 9, 18, and 9 pounds of N, P_2O_5 , and K_2O per 100 pounds of total liquid material. We are accustomed to thinking of liquids in gallons; to make the conversion from gallons to pounds, we must know the total weight of the product per gallon and its analyses. Most liquids have a weight of 11 to 12 pounds per gallon.

For example: How much N, P_2O_5 , and K_2O are in a gallon of 9-18-9? Assume a weight of 12 pounds per gallon. Thus, when we multiply the weight (in pounds per gallon) by the analysis of each nutrient in the fertilizer (percentage must be converted to decimal as $9\% = 0.09$), we obtain 1.08 pounds of N, 2.16 pounds of P_2O_5 , and 1.08 pounds of K_2O .

Cost comparisons for liquid fertilizers. The cost of similar fertilizer materials can and should be compared on a cost per pound of plant nutrient basis. When fertilizers are sold by the gallon, the cost per pound of plant nutrient is obtained



With the proper equipment, application of bulk dry fertilizers can be very efficient.

by dividing the selling price per gallon by the number of pounds of plant nutrients supplied per gallon. For the above example, if the selling price of a 9-18-9 fertilizer is \$3.00 per gallon, the cost per pound of plant nutrient would be \$0.69 [$\$3.00 \text{ per gallon} / (1.08 + 2.16 + 1.08)$ or (4.32 lb plant nutrient)]. A comparable value for most commercial liquid fertilizers normally sold by weight and analysis would be about \$0.25, whereas dry materials might be about \$0.22 per pound of plant food. These prices vary with distribution, time of year, and conditions of sale; therefore, they should only be used as an illustration and not for direct comparison of materials. For a direct cost comparison, determine prices from your local dealers. The calculation does illustrate that the price per pound of plant nutrient should be a primary factor in purchasing any fertilizer material.

Fertilizer Injury

Fertilizer injury to small seedlings can occur when too much fertilizer is applied in the fertilizer band. The fertilizer salts dissolve in the soil water and are taken up by the plant too rapidly; as a result the plant dehydrates. This injury is commonly referred to as fertilizer salt injury. It can be observed, especially on windy days when the plants are small, as wilted leaves and scorched leaf tips and edges. The injury can be reduced or prevented by limiting the quantity of nitrogen plus potash used in the fertilizer band. No more than 80 pounds per acre of $N + K_2O$ should be used in the fertilizer band. The phosphorus is not included in the calculation, that is, 400 pounds per acre of 10-10-10 would be 80 pounds per acre of $N + K_2O$.

A second type of seedling injury involves the use of urea and diammonium phosphates within the fertilizer band. A discussion of the injury is included under properties of fertilizers. It is recommended that (1) no more than 20 pounds per acre

of N as urea be used in the fertilizer band; (2) no more than 30 pounds of P_2O_5 from diammonium phosphate be used in the fertilizer band; (3) no more than 20 to 30 pounds of urea nitrogen plus N from diammonium phosphate be used in the fertilizer band; and (4) no more than 30 to 40 pounds of ammonium nitrogen from all sources be used in the band with diammonium phosphate.

Determining the fertilizer ratio and grade. The fertilizer ratio is given by the smallest whole numbers that describe the ratio of N to P_2O_5 to K_2O present in the fertilizer; that is, a 1-4-4 ratio means that there are 4 pounds of P_2O_5 and K_2O to a pound of N. Recommendations are often made to apply a fertilizer of a particular ratio that will give a certain rate of one or more of the nutrients; for example, the recommendation to apply sufficient quantities of a 1-2-2 ratio fertilizer to provide 20 pounds of nitrogen would mean to apply a material such as 10-20-20 to provide 20 pounds of nitrogen. The 20 pounds of nitrogen would then be provided by adding (20 divided by 0.10) 200 pounds per acre of 10-20-20.

The fertilizer grade gives the percentages of N, P_2O_5 , and K_2O present in the fertilizer and is the basis for the sale of most fertilizers. There can be several different fertilizer grades that will fit a particular fertilizer ratio, for example a 1-1-1 ratio can be obtained with 10-10-10, 12-12-12, 15-15-15, and so forth. An individual dealer may stock only one fertilizer grade for a particular ratio.

Band Rates

The rate and ratio of fertilizer to be used in the band must be determined after the rates of individual nutrients are obtained. For example, if more than 40 pounds of nitrogen are required, the rate of nitrogen to be applied in the band rate should be



When too much fertilizer is placed close to the seed, seedling and root damage can occur. Here, 60 pounds of nitrogen and phosphorus were placed 2 inches below and 2 inches to the side (*left*), 2 inches directly below (*center*), and 3 inches to the side (*right*) of the seed. Notice the root damage to the plants when the fertilizer was placed directly below the seed.

reduced to 10 to 20 pounds per acre and the remaining nitrogen applied as a sidedress application. When more than 80 pounds each of nitrogen and potash are required, reduce the band rate to contain less than 80 pounds and apply the remaining as a preplant or sidedress application. If more than 40 to 50 pounds per acre of phosphorus are required, reduce the rate of potash to equal the phosphorus and apply the remaining potash preplant. When relatively small quantities of fertilizers are recommended, a higher rate can usually be applied in the first year and applications omitted the following year or years. When the rate of potash is

smaller than the phosphorus rate and standard grades are to be used, the potash rate is normally increased to equal the phosphorus rate; for example, if 40 pounds of N and P_2O_5 , and only 30 pounds of K_2O are needed, a 1-1-1 ratio is used.

When these adjustments are made, standard grades can be used for most band fertilizer applications. When bulk blends are used in the fertilizer band, the blends can be custom mixed to fit the ratio needed, but no more than 80 pounds per acre of N + K_2O should be applied. Care should be taken to avoid most of the urea and diammonium phosphates in making these bulk blends for band applications. Likewise, make sure



When banded at planting, urea and (or) diammonium phosphate (DAP) fertilizers often cause injury to seedling plants. Note smaller plants and absence of roots (*right and center*) where urea and (or) diammonium phosphate (18-46-0) were used. The white spot in the soil is sand used to mark placement of fertilizer.

that uniform particle sizes are used to prevent separation of the individual fertilizer components, especially for band applications. Transfer bulk blends in a manner to prevent the formation of cones under the transfer point to avoid nutrient separation. When properly mixed from recommended sources and properly handled, bulk blends are adequate sources for band placement. If you are not sure these precautions have been taken, do not use the blends for band applications.

MANAGING ANIMAL MANURES

For centuries farmers have spread animal manures on the land as a way to increase soil productivity. Once applied to the soil, manure is decomposed by microorganisms, forming humus and releasing essential elements for plant growth. The economic value of manure is related to its fertilizer replacement value, its organic matter content, and probably some unknown factors that enhance crop production.

Management is the key to efficient use of nutrients by a crop. Proper management will increase economic crop returns and reduce the potential for polluting surface and ground waters. This chapter discusses the basic principles regarding the use of manure in a soil fertility program and presents general guidelines for managing manure for optimum crop production.

Nutrient Content

Depending on the species, approximately 70–80% of the nitrogen, 60–85% of the phosphorus, and 80–90% of the potassium fed to animals are excreted in the manure. The high nutrient return in manure permits a recycling of plant nutrients from crop to animal and back to the crop again.

The amount of nutrients contained in manure and their eventual uptake by plants will vary considerably from farm to farm. The major factors determining nutrient content and availability are (1) composition of the feed ration, (2) amount of bedding and water added or lost, (3) method of manure collection and storage, (4) method and timing of land application, (5) characteristics of the soil and the crop to which manure is applied, and (6) the climate.

Table 8 shows the wide range in nutrient composition of manures sampled from numerous farms. Because

Table 8. Range in nutrient analysis of manure for various handling systems

Type	Nonliquid systems			Liquid systems		
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
	lb/ton			lb/1000 gal		
Dairy	5–16	2–16	2–31	3–51	2–21	2–58
Beef	4–20	1–13	3–29	6–37	1–29	5–30
Swine	3–27	1–62	2–18	1–65	1–63	1–49
Poultry	4–111	1–96	2–55	35–75	13–91	13–39

Source: Adapted from T. Bates and E. Gagnon, 1981, *Nutrient content of manure*, University of Guelph, Guelph, Ontario, Canada.

of the large amount of variation, it is not advisable to use the average nutrient contents often seen in publications. Average values are very misleading. The best way to determine the nutrient content of manure is by laboratory analysis. The minimum analysis should include the percentage of dry matter, ammonium nitrogen (NH₄), total nitrogen (ammonium N + organic N), phosphorus (P or P₂O₅), and potassium (K or K₂O).

The key to an accurate manure analysis is proper sampling. Samples should be taken just before spreading to account for losses during handling. Storages should be sampled each time they are emptied, and daily spread operations should be sampled several times throughout the year to obtain a good average nutrient value. When the results become reasonably consistent, sampling can be done less frequently. Samples should be taken from representative loads to give the nutrient content at the time of application. Be sure liquid storages are agitated thoroughly before unloading. Place a composite sample in a plastic bottle, seal tightly, and freeze immediately. Freezing is to preserve the sample, because a considerable amount of nitrogen can be lost by improper handling.

Nutrient Availability

The nutrients in manure cannot be substituted for the nutrients in commercial fertilizer on a pound-for-pound basis. A portion of the nutrients are not as readily available, nor can they be as accurately applied as those in fertilizer. How efficiently they are used by a crop depends on management of the land application program, as well as the rate of biological breakdown of the organic material and release of plant-available nutrients. The following sections describe how nutrient availability can be estimated.

NITROGEN

There is no quick soil test procedure to determine the N supply from organic matter. Therefore, the N supply from manure in the soil must be estimated from research studies and applied to individual farm conditions.

Because of its chemical nature, manure N is more difficult to manage than other nutrients. There are two forms of N in manure, namely the unstable and stable organic N (fig. A). In either form, the organic N must be decomposed by microorganisms to an inorganic N form before it can be used by plants. The resulting inorganic N is available for crop growth

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	lb/ton			lb/1000 gal		
Dairy	5–16	2–16	2–31	3–51	2–21	2–58
Beef	4–20	1–13	3–29	6–37	1–29	5–30
Swine	3–27	1–62	2–18	1–65	1–63	1–49
Poultry	4–111	1–96	2–55	35–75	13–91	13–39

Source: Adapted from T. Bates and E. Gagnon, 1981, *Nutrient content of manure*, University of Guelph, Guelph, Ontario, Canada.

of the large amount of variation, it is not advisable to use the average nutrient contents often seen in publications. Average values are very misleading. The best way to determine the nutrient content of manure is by laboratory analysis. The minimum analysis should include the percentage of dry matter, ammonium nitrogen (NH₄), total nitrogen (ammonium N + organic N), phosphorus (P or P₂O₅), and potassium (K or K₂O).

The key to an accurate manure analysis is proper sampling. Samples should be taken just before spreading to account for losses during handling. Storages should be sampled each time they are emptied, and daily spread operations should be sampled several times throughout the year to obtain a good average nutrient value. When the results become reasonably consistent, sampling can be done less frequently. Samples should be taken from representative loads to give the nutrient content at the time of application. Be sure liquid storages are agitated thoroughly before unloading. Place a composite sample in a plastic bottle, seal tightly, and freeze immediately. Freezing is to preserve the sample, because a considerable amount of nitrogen can be lost by improper handling.

Nutrient Availability

The nutrients in manure cannot be substituted for the nutrients in commercial fertilizer on a pound-for-pound basis. A portion of the nutrients are not as readily available, nor can they be as accurately applied as those in fertilizer. How efficiently they are used by a crop depends on management of the land application program, as well as the rate of biological breakdown of the organic material and release of plant-available nutrients. The following sections describe how nutrient availability can be estimated.

NITROGEN

There is no quick soil test procedure to determine the N supply from organic matter. Therefore, the N supply from manure in the soil must be estimated from research studies and applied to individual farm conditions.

Because of its chemical nature, manure N is more difficult to manage than other nutrients. There are two forms of N in manure, namely the unstable and stable organic N (fig. A). In either form, the organic N must be decomposed by microorganisms to an inorganic N form before it can be used by plants. The resulting inorganic N is available for crop growth

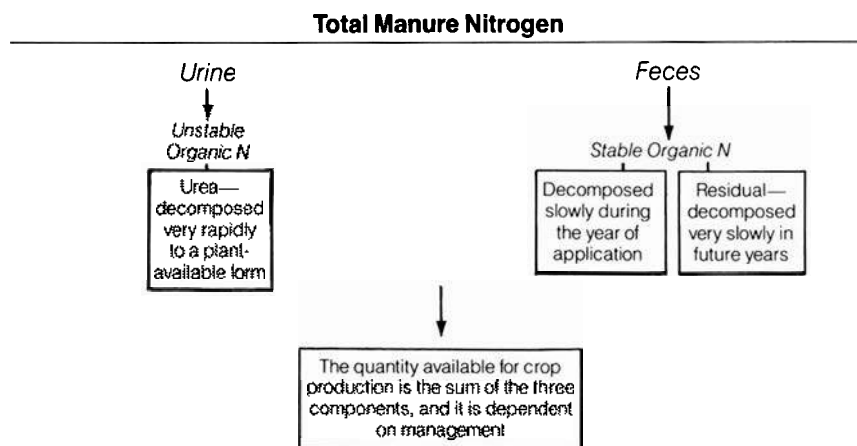


Figure A. Form and degree of nitrogen availability in manure.

as nitrate (NO_3) and ammonium (NH_4).

The unstable organic N is present in urine as urea or uric acid and may account for more than 50% of the total N. Urea in manure is no different from urea in commercial fertilizer. It decomposes very rapidly to ammonium (NH_4) and, in turn, converts very quickly to ammonia (NH_3) as the pH increases and the manure begins to dry.

All the ammonium in manure is immediately available for plant growth. Ammonia is extremely volatile, however, so exposure of manure on the barn floor, in the feedlot, in storage, or after spreading increases the N loss. At every step between production and its use by the crop, ammonia is the most valuable and most easily lost component. It is also the most variable component between management systems, and therefore, an analysis of the manure is useful to determine how much ammonia has been conserved before spreading. Table 9 shows a typical field loss of ammonia after spreading.

The more stable organic N is present in the feces and is a more slowly released form of organic N than urea. The decomposition of stable organic N to a plant-available form occurs at two rates. The less-resistant organic

N decomposes during the year of application, whereas the more-resistant organic N decomposes very slowly in future years. Repeated application to the same field results in an accumulation of a slow-release manure N source.

A decay, or decomposition, series is commonly used to estimate the rate of N availability from stable organic N. A decay series of .35-.12-.05-.02 is used to estimate the rate of decomposition of organic N in fresh manure in New York. The sequence of numbers means that 35% of the organic N is decomposed during the year applied, 12% of the initial organic N application is decomposed during the second year, 5% is decomposed the third year, and 2% the fourth year. The last three numbers in the decay series are the annual rates of decomposition of the residual organic N from past applications.

There is some evidence that manure containing large amounts of bedding may decompose at a slower rate than fresh manure. Therefore, the estimated availability of N during the year applied is reduced from 35 to 25% when the dry matter content exceeds 18%.

The amount of N available during the growing season is equal to the ammonium N + decomposed or-

Table 9. Loss of ammonia by volatilization after a surface application of dairy manure

Days after application	Ammonia N loss, %
1	20
2	40
3	50
4	60
10	75
15	90

ganic N from the present application + decomposed organic N from past applications. An estimate of N availability in New York is shown in figure B. The quantity that is available can vary from year to year and from farm to farm because the rate of microbiological breakdown depends upon soil characteristics and climatic conditions. Other factors affecting availability are animal species, moisture content, bedding, and method of manure storage. However, the guidelines in figure B are reasonable estimates.

At the present time, there is not enough research data to determine N availability from manure when left on the surface throughout the growing season. The value of N in manure spread for no-till crops or for top-dressings on hayfields or pastures will have to be based on your past experiences.

A work sheet is provided to make it easier for you to estimate N availability from present and past applications. Transfer the values in figure B to work sheet I to determine availability based on your management practice. The example in work sheet 1 shows that the amount of available N will be low when manure is spread during the fall of the year. The nitrogen value increases considerably by

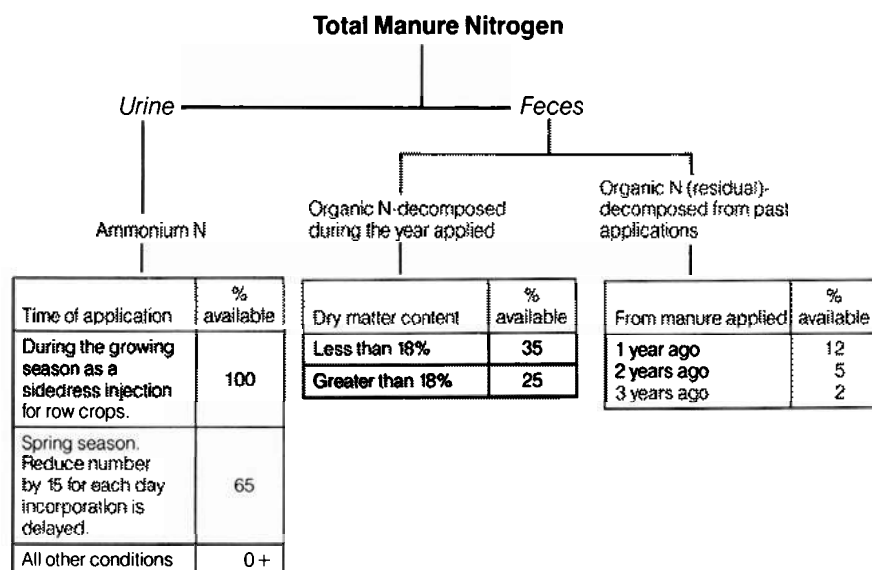


Figure B. Estimated availability of the different forms of nitrogen in manure.

applying and immediately incorporating manure in the spring.

Work sheet 1 is also available in computer program form at your Co-operative Extension office. If you do not have a manure analysis, the work sheet or computer program will not be very helpful.

PHOSPHORUS AND POTASSIUM

Manure is an excellent source of P and K. When manure is applied at a rate to supply the N needed, P and K will most likely be applied in excess of crop needs.

Not all the P in manure is immediately available for plant use. Some of the P is in an organic form that has to decompose before it is available. P is not very mobile in the soil. Therefore, broadcasted manure is not an efficient method of applying P when establishing a crop. Some P will be recommended in a band-placed starter fertilizer except when the soil test level is extremely high. For top-dressing hayfields, the P in broadcasted manure is probably as effi-

ciently used as P in broadcasted fertilizer.

Essentially all the K in manure is available for plant growth during the year applied. K can be used efficiently by a crop as either a band or broadcast application.

The fertilizer requirements for P and K on manured fields can be determined by soil testing. The soil test levels are a reflection of how much P and K have been applied from past manuring; and these values should be used to determine the amount of fertilizer needed.

If manure was applied before the soil test was taken, follow Cornell's P_2O_5 and K_2O fertilizer recommendations. The P and K applied will be reflected in the soil test values. If manure will be applied after the soil test is taken, the following guidelines are offered.

Phosphorus

For crop establishment or topdressing:

a. If the fertilizer recommendation is less than 40 lb/acre, apply the entire

amount as fertilizer.

b. If the fertilizer recommendation exceeds 40 lb/acre, apply 40 lb and use the P in manure to supply the rest.

Potassium

For crop establishment:

a. If the fertilizer recommendation is less than 20 lb/acre, apply the entire amount as fertilizer.

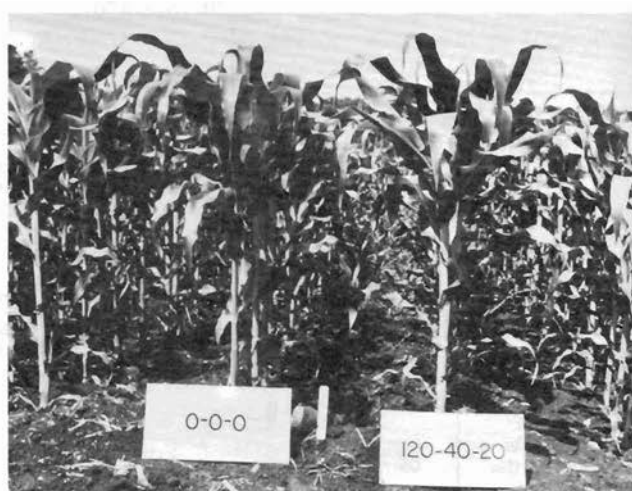
b. If the fertilizer recommendation exceeds 20 lb/acre, apply 20 lb and use the potassium in manure to supply the rest.

For topdressing:

The potassium in manure can be used to supply the entire amount.

MICRONUTRIENTS

Manure contains small quantities of micronutrients; hence, micronutrient deficiencies on manured fields are not very common. Because of the slow availability of micronutrients in manure, a micronutrient deficiency should be corrected with a commercial fertilizer source.



Manure is an excellent source of plant nutrients. Yields are shown in table 10.

Economics

The effectiveness of manure as a fertilizer is based on the nutrients it contains that are not supplied in adequate amounts by the soil. Thus, the fertilizer dollar value of manure is equal to the cost of the fertilizer that has to be purchased if manure is not applied. In fields where the soil test levels for P and K indicate these nutrients are in adequate supply, only the fertilizer nitrogen value of the manure should be considered.

When contemplating capital investments for manure handling, make a careful economic analysis of the change in your management. For instance, an expenditure that produces nutrient surpluses is not economical unless the surplus can be sold; on the other hand, an expenditure that markedly improves nutrient recycling, environmental quality, or your management ability is a good investment.

The results of several field trials (tables 10 and 11) illustrate the effectiveness of manure as a fertilizer. The corn yields shown in table 10 are typical of those found on farms where manure has been applied uniformly

Table 10. Corn yields on a manured field with various rates of fertilizer

Manure input, lb/A		Cornell soil test	
N = 149	P ₂ O ₅ = 59	pH = 6.4	K = 375 (H)
K ₂ O = 149		P = 16 (H)	Mg = 320 (H)
Fertilizer applied N-P ₂ O ₅ -K ₂ O, lb/A		Corn silage, T/A	
0- 0- 0		19.3	
20-40-20		19.0	
40-40-20		20.7	
80-40-20		19.3	
120-40-20		19.3	
120-40-80		20.1	

NOTE: Manure was spring applied at 4500 gal/A and plowed down within 8 hr.

at a high rate for many years. Under these conditions, nutrients accumulate in the soil, the soil test levels increase, and the need for commercial fertilizer decreases. When corn is in rotation with hay, some additional N will be supplied by the previous sod crop. On this farm there was no economic advantage to applying fertilizer.

The yields shown in table 11 were on a field in continuous corn that did not receive much manure in the past;

therefore, N availability may be low because of little or no supply from previous application. Although this year's manure application supplied plenty of P and K, it was economical to add a starter fertilizer containing up to 40 pounds of N. Even at high rates of manure there is an advantage to using a band-placed starter fertilizer with the planter, especially with the cold, wet springs experienced in New York.

Work Sheet 1. Estimating the amount of nitrogen available for crop production

Example: A dairy manure sample was taken from a nonliquid storage facility and analyzed. The following calculations show how to estimate the amount of nitrogen that will be available during the growing season from the current manure application and from previous applications. Assume that 25 tons/acre, having an organic N content of 6 lb/ton, were applied in each of the past 3 years.

Calculations

- A.** Insert the percentage of dry matter and the nitrogen value of the manure from the analysis in lb per ton for a nonliquid system or lb per 1000 gal for a liquid system. $\text{Organic N} = \text{Total N} - \text{Ammonium N}$.

	Example	Your Farm
Dry matter	15%	
Total N*	10 lb/ton	
Ammonium N	4 lb/ton	
Organic N*	6 lb/ton	

- B.** Determine the availability of nitrogen during the first year. $\text{Available N} = \text{lb of ammonium N or organic N in item A} \times \text{the percentage of availability from figure B}$.

	Time of application	Quantity available from:		Available N
		Ammonium N (lb \times %)	Organic N (lb \times %)	
Examples:	Fall	4 \times 0	+ 6 \times .35	= 2.1 lb/ton
	Spring Incorp. delayed 2 days	4 \times .35	+ 6 \times .55	= 3.5 lb/ton
	Spring Immed. incorp.	4 \times .65	+ 6 \times .55	= 4.7 lb/ton

Your Farm: _____ + _____ = _____

- C.** Determine the availability of nitrogen from previous applications. Omit those years when manure was not applied. $\text{Available N per acre} = \text{application rate from previous records in tons or 1000s of gal} \times \text{lb of organic N per ton or per 1000 gal} \times \text{percentage of availability from figure B}$.

Quantity available from residual organic N from:

	1 year ago (rate \times N \times %)	2 years ago (rate \times N \times %)	3 years ago (rate \times N \times %)	Residual N availability
Example:	25 \times 6 \times .12	+ 25 \times 6 \times .05	+ 25 \times 6 \times .02	= 28.5 lb/A
Your Farm:	_____	+ _____	+ _____	= _____

*Some laboratories may report their nitrogen results under the heading "nitrogen" and "ammonium or ammonia N." The larger of the two numbers is total N. Many laboratories do not report organic N simply because it is the difference between total N and ammonium N.

Land Application

The goal of a well-managed land application program is to develop a soil fertility program that uses manure to supply as much of the needed plant nutrients as possible, with commercial fertilizer providing only what is additionally needed.

A particular kind of manure-handling system does not, in itself, increase or decrease nutrient use by a crop; management does! The first step in developing a land application program is to determine the amount of nutrients collected in manure; the second is to soil test to determine nutrient requirements of the crop rotation; the third is to estimate nutrient availability in manure; and the fourth is to calculate a compatible rate of application.

The quantity of nutrients produced should be compared with the total nutrient requirement of your crop rotation. Table 12 shows a typical nutrient balance for a 75-cow dairy in New York. With similar information for your farm, a management program can be developed to ensure that manure will supply a major portion of the nutrient requirement.

If your crops require more nutrients than are available in manure, you should consider changing your management practices to conserve more. On the other hand, if the availability of nutrients in manure exceeds crop requirements, there is no advantage in changing management to conserve more unless (a) you can sell the excess, (b) the convenience or environmental concerns outweigh the economic returns, and (c) the change enables you to manage other areas more effectively.

RATE OF APPLICATION

Usually, the ratio of N to P to K in manure does not match the ratio of the amount of these nutrients needed by

Table 11. Corn yields on a manured field with various rates of fertilizer

Manure input, lb/A		Cornell soil test	
N = 342	P ₂ O ₅ = 156	pH = 6.3	K = 320 (H)
K ₂ O = 294		P = 11 (H)	Mg = 360 (H)
Fertilizer applied N-P ₂ O ₅ -K ₂ O, lb/A		Corn silage, T/A	
0- 0- 0		20.8	
20-40-40		22.5	
40-40-40		23.4	
80-40-40		23.0	
120-40-40		23.3	
120-80-80		23.7	

NOTE: Manure was spring applied at 30 T/A and plowed down within 6 hr.

Table 12. A nutrient balance on a typical dairy farm in New York

Nutrients produced in manure	Nutrient requirements from soil testing
75 cows + 53 heifers Manure, T = 1,830 Analysis, lb/T = 10-5-9	Soil = silt loam, 228 A Soil test = medium Rotation = 4 yr corn 4 yr alfalfa
N = 18,300 lb P ₂ O ₅ = 9,100 lb K ₂ O = 16,400 lb	N = 11,800 lb P ₂ O ₅ = 7,300 lb K ₂ O = 11,100 lb

the crop; therefore, complete utilization is rarely accomplished. When manure is applied to meet the N requirement of a crop, P and K will usually be applied in excess. Further accumulations will occur from overapplying fertilizer.

It takes some planning and pencil pushing to arrive at an application rate that fits a particular cropping pattern. Work sheet 2 is provided to help you determine for each field (1) the nutrient requirement, (2) the manure application rate needed to supply the nutrient that has the highest priority, and (3) the quantity of commercial fertilizer needed in addition to the manure.

The example in work sheet 2 showed that a 120-pound-per-acre N requirement for corn could be met by a combination of residual N from past applications, applying 30 tons of manure, and adding 30 pounds of N in the starter fertilizer at planting. Thirty tons per acre will also contain 150 pounds of P₂O₅ and 270 pounds of K₂O. For the spreader being used, it took 44 loads to apply 30 tons per acre to a 15-acre field.

The amount of liquid manure applied by irrigation can be measured by placing cans in the field to record the depth of water applied. There are 27,150 gallons in 1 acre-inch.

Work Sheet 2. Estimating a Rate of Application

Example: A dairy operator will apply manure to a 15-acre cornfield in the early spring and incorporation will be delayed for 1 week. From the manure analysis and available N calculations in work sheet 1, determine the rate of application to meet the N requirement, the amount of P_2O_5 and K_2O added, the amount of commercial fertilizer needed, and the number of spreader loads needed to apply the desired application rate.

Calculations	Example	Your Farm
A. Determine the nutrient needs of the crop.		
1. Crop to be grown	<u>Corn</u>	_____
2. Nutrient requirements from the Cornell soil test	N = <u>120 lb/A</u>	_____
	P_2O_5 = <u>30 lb/A</u>	_____
Soil Test P = <u>8(med)</u> , K = <u>150(high)</u>	K_2O = <u>20 lb/A</u>	_____
B. Determine the nutrient value of manure. Express as pounds per ton for a nonliquid system or pounds per 1000 gallons for a liquid system.		
1. Available N from item B in work sheet 1	N = <u>2.1 lb/A</u>	_____
2. P_2O_5 from recent analysis	P_2O_5 = <u>5 lb/A</u>	_____
3. K_2O from recent analysis	K_2O = <u>9 lb/A</u>	_____
C. Determine the rate of application.		
1. Nutrient having the highest priority.	= <u>N</u>	_____
a. Amount to be supplied by manure. Express as pounds needed in item A.2 minus amount of fertilizer applied. <u>120 lb - 30 lb at planting</u>	= <u>90 lb/A</u>	_____
b. If nitrogen, subtract residual N availability from item C in work sheet 1. <u>90 lb - 28 lb/A residual</u>	= <u>62 lb/A</u>	_____
2. Rate of manure needed to supply highest priority nutrient (item C.1 ÷ item B). Express in tons per acre for a nonliquid system or as 1000s of gallons per acre for a liquid system. <u>62 lb/A ÷ 2.1 lb/ton</u>	= <u>30 tons/A</u>	_____
3. Pounds of N, P_2O_5 , and K_2O applied per acre with manure.		
a. N value from item B.1 times manure rate from item C.2 plus residual N availability from item C in work sheet 1. <u>(2.1 lb/ton × 30 tons) + 28 lb</u>	N = <u>90 lb/A</u>	_____
b. P_2O_5 value from item B.2 times manure rate from item C.2. <u>5 × 30</u>	P_2O_5 = <u>150 lb/A</u>	_____
c. K_2O value from item B.3 times manure rate from item C.2. <u>9 × 30</u>	K_2O = <u>270 lb/A</u>	_____

(continued on next page)

(continued)

D. Determine the amount of commercial fertilizer needed.

-30 lb N based on 90 lb from manure

-P₂O₅ and K₂O based on soil test recommendation

N = $\frac{30 \text{ lb}}{A}$

P₂O₅ = $\frac{30 \text{ lb}}{A}$

K₂O = $\frac{20 \text{ lb}}{A}$

E. Determine the number of manure spreader loads required to apply the application rate in C.2.

1. Spreader capacity (use equations from table 13).

a. Liquid system:

(Express in units of 1000s of gal per load.)

= _____

b. Nonliquid system:

cu ft of spreader = $16.9' \times 6.3' \times 3.2'$

= 340 ft^3

tons per load = $340 \text{ ft}^3 \times 62 \text{ lb/ft}^3 \div 2000$

= 10.5 tons/load

2. Number of loads needed.

a. Loads per acre = manure rate in C.2 \div spreader capacity from E.1.

$30 \div 10.5$

= 2.9 loads/A

b. Loads per field = loads per acre \times acres.

2.9×15

= 44 loads

To save a lot of tedious calculations, contact your extension office. It has a computer program that will calculate annual manure production on your farm, the amount of nutrients (from a manure analysis) collected, the nutrient requirements of your crop rotation, and estimates of N availability for various management practices. From the computer print-out a compatible rate of application can be determined.

After determining the rate for each field, add the total amount of manure needed and compare this to the amount collected. If there is an excess, divide it among those fields having the highest nutrient demand.

Excessive rates of manure will oversupply nutrients that may affect plant growth and animal nutrition. Excessive rates of application as well

as accumulations of manure around barn lots will eventually cause water pollution. Examples include aquatic growth in lakes and high nitrate levels in groundwater. Preventing such problems calls for a combination of appropriate soil and water conservation practices and proper management of the rate, timing, and method of manure application. In extreme cases additional land must be used to lower the application rate.

MAXIMIZING THE VALUE OF MANURE

The timing and method of manure application determine the efficiency of nutrient recycling. Some important points follow:

- Incorporating manure immediately minimizes odors and ammonia

loss. If manure supplies more N than is needed, some ammonia loss is unimportant as far as the crop is concerned. Ideally, ammonia should be conserved so that N can be applied to a larger number of acres. Incorporation of manure too far in advance of crop needs will result in N losses. Spring or early summer incorporations are best.

- Surface runoff and erosion must be controlled. Using tillage to incorporate manure on erosive soils in the fall may result in unacceptable soil losses. Applying manure as close to planting as feasible reduces the potential for nutrient loss.

- As is the case with commercial fertilizer, manure must be spread uniformly to get consistent results.



wrong



right

Manure must be spread uniformly to obtain consistent results.

- Amounts of commercial fertilizer should be reduced according to the nutrient value of the manure and the accumulation of nutrients in the soil from past manuring. Avoid overapplications.

The recommendations from Co-operative Extension should be followed to ensure a proper balance of plant nutrients. Keep a record of nutrient levels in fields and use this information as the basis for adjusting your manure management and soil fertility program.

Table 13. Approximate manure spreader capacities

Nonliquid system

Spreader volume (Measure all dimensions in feet and tenths of feet.)

Box spreader: cubic feet = length × width × average depth.

Barrel spreader: cubic feet = $0.393 \times d^2(\text{diameter squared}) \times \text{length}$.

Irregular shapes: Use manufacturer's rated capacity. Estimate the percentage of a full load.

Spreader capacity

$$\text{Tons per load} = \frac{\text{cubic feet} \times 62 \text{ lb per ft}^3}{2000 \text{ lb per ton}} \quad \left(\text{Use } 55 \text{ lb per ft}^3 \text{ for extremely dry manure.} \right)$$

Liquid system

Tank spreader: Use manufacturer's data to determine gallon capacity. Estimate the percentage of a full load. There are approximately 8300 lb in 1000 gal.

INTEGRATED PEST MANAGEMENT

Economical crop production is one of the many challenges facing farmers today. The use of integrated pest management techniques helps producers to optimize the net profitability of crop production by increasing the quantity, quality, and timeliness of field information available for mak-

ing management decisions. Many farmers are using this systematic approach to improve crop management decisions on their farms. Integrated pest management, or IPM, is a system that uses all suitable pest control techniques to keep pest populations below economically injurious levels. The key to using this approach successfully lies in the collection of pest and crop information from individ-

ual fields on a regular schedule. Crops are monitored for insects, diseases, weeds, nutritional deficiencies, and other factors known to adversely affect crop health, yield, or value. Once problems have been detected and correctly identified, the information is then evaluated with sensitivity for economic and environmental factors to select short- and long-term crop-production strategies

for minimizing losses caused by pests, with as little cost to the producer and disruption of the environment as possible. Applying this action-as-needed management philosophy is the basis of integrated pest management.

IPM helps improve economic efficiency of crop production as well as optimize environmental quality. Regular crop monitoring (crop scouting) is beneficial in several ways. Crop scouting acts as an "early warning system" enabling growers to detect and identify potential yield- and (or) quality-reducing problems and to correct or avoid these situations before economic losses occur. Timely crop monitoring also identifies situations where pests are absent or at levels well below those necessary to cause economic loss, thus helping to minimize crop input expenses by avoiding unnecessary pesticide applications and expenditures. Information obtained through crop scouting can also help optimize management decisions that affect environmental quality, such as judicious use of pesticides and fertilizer on an as-needed basis, proper chemical-application practices, use of selective chemicals where possible, and protection of naturally occurring beneficial control organisms.

An IPM approach makes use of the concept of pest thresholds to identify situations requiring economically justifiable control measures. A pest population must reach a particular size before expected losses in crop yield or quality will equal costs of pest control. An action threshold is the pest density (number of pest insects, weed density, % of diseased plants, etc.) at which management options should be employed to minimize or prevent economic loss. Ideally, the action threshold, also referred to as an economic threshold,



Monitoring field crops on a regular schedule provides timely information to optimize pest control decisions that are cost-effective and environmentally sound. Alfalfa can easily be checked for numbers of potato leafhoppers by using an insect sweep net.

takes into consideration many factors, including the life stage of the particular pest, growth stage of the crop, market value of the crop, and all relevant short- and long-term ecological, economic, and social ramifications of IPM actions. The action threshold is used as a decision-making guide in IPM and is the basis for the action-as-needed philosophy.

At the present time thresholds have been determined for some, but not all, field crop insect pests. Some thresholds that are available today may be modified, and additional thresholds may be established for other pests and pest combinations as new research information becomes available.

Thresholds have not been established for many weeds and diseases found in field crops. Scouting information on these pests is however,

very useful for fine tuning management decisions. The primary benefit of weed scouting is the establishment of improved weed inventory records for individual fields. Early identification of predominant weed species in fields enables producers to select herbicides intelligently for use in combination with cultural and mechanical control methods. Weed scouting can also provide important information for decisions regarding crop rotation.

Scouting for diseases identifies important diseases that are prevalent on the farm. This information is particularly useful for selecting crop varieties and for determining site selection, tillage practices, crop rotations, and other cultural procedures to minimize disease incidence in subsequent growing seasons. Following detection, producers are able to initiate sanitation procedures to reduce possible disease spread to other locations.

NOTE: Thresholds should be used as *guides* to indicate that some pest management action may be useful. Thresholds may change with time, and some pest management strategies may be more appropriate under some circumstances than under others. Consult the most recent *Cornell Recommends for Field Crops* or your Cooperative Extension agent for the latest threshold information available for a particular pest.

Pest management options that may be employed once detection and identification of a pest have been accomplished and thresholds reached include early harvest, sanitation procedures, use of biological control agents, and selection and use of pesticides. Early pest detection often allows producers to reduce the acreage on which pesticides are necessary, to employ pesticides that are specific for controlling a given pest or have a lower residual effect, and

(or) to use practices that help conserve naturally occurring beneficial control organisms. Factors that affect the choice of these management options include general crop condition, crop growth stage, pest growth stage, number of days until crop harvest, expected yield or quality, anticipated use of crop, value of crop, and equipment available.

Who Can Scout Crops?

Anyone can learn to monitor crops for pest problems. Scouting techniques have been developed for many pests, particularly insect pests. Helpful fact sheets and other educational materials are available to assist in identification and diagnosis of pest problems and selection of management options. Combining pest scouting with other activities, such as determination of crop population density, soil and forage quality sampling, and determination of grain maturity, can increase the efficiency of scouting time and provides opportunities for collecting additional information to optimize management efficiency.

Many producers using integrated pest management scout their own crops, whereas others hire field scouts or professional agricultural consultants or participate in grower IPM programs to obtain scouting information. Whatever method is employed to obtain timely crop and pest reports, having this information is extremely useful in the selection of cost-effective crop management strategies.

IPM Summary

Integrated pest management (IPM) helps reduce management risks and optimize the economic efficiency of pest control decisions through (1) early detection of pests, (2) proper identification of pests, (3) accurate

assessment of potential for economic impact, and (4) timely employment of appropriate, economically efficient, and environmentally sound management strategies.

Basic Crop-Scouting Techniques

Integrated pest management techniques benefit growers through improved management decisions based on timely crop information. The quality of management decisions, however, is greatly influenced by the quality of scouting information. The most important principle of crop scouting is to collect pertinent information representative of conditions found throughout the field. Fields should be scouted using an M- or K-shaped zig-zag pattern to increase the probability of finding problems. In general, samples should be taken at least 150 feet or 50 rows from the margin of the field. Different locations within the field should be sampled with each visit. Borders, ditch banks, fence rows, and other similar field areas should not be sampled unless there are specific reasons for doing so. Information collected on the edges of fields may provide misleading information about the field as a whole. While walking through the field border areas, keep alert for signs of any problems. Pests found in these areas might necessitate spot treatment or might indicate potential trouble for the whole field; for example, common stalk borers or armyworms often move from weedy fence rows or ditch banks and may be expected along border areas first.

Scouting experience has shown that most specific sampling procedures can provide accurate information for an area up to 40 acres. If fields are larger than 40 acres, divide the field into smaller units for sampling, and sample each unit separately. At least five (5) areas within

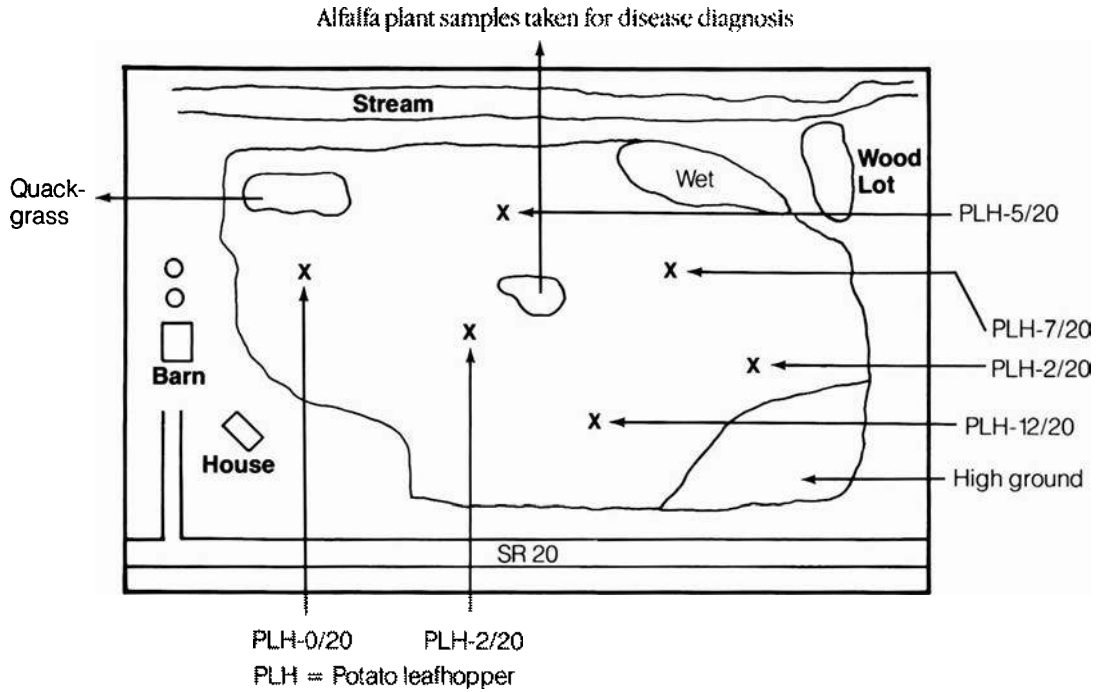
the field should be sampled. Plan on spending at least 20-30 minutes scouting each field.

Before entering the field. (1) Make certain you are properly equipped with the tools you will need while in the field. (2) Draw a simple map of the field, indicating prominent features and landmarks. During the scouting procedure, mark the map with sample-site locations, areas of pest infestation, and number of pests found or amount of damage observed in each area sampled. An example of a useful field map is given. (3) Identify the field on the scouting form containing the field map. (4) Record the date and time of day. (5) Record the stage of growth of the crop. (6) Record general soil and crop conditions. (7) Sample the field in the pattern prescribed for the particular pest(s). (8) Record the results of any scouting procedure performed. (9) If there is a doubt as to correct identification of a pest or problem, collect samples of the pest and (or) their damage for later identification.

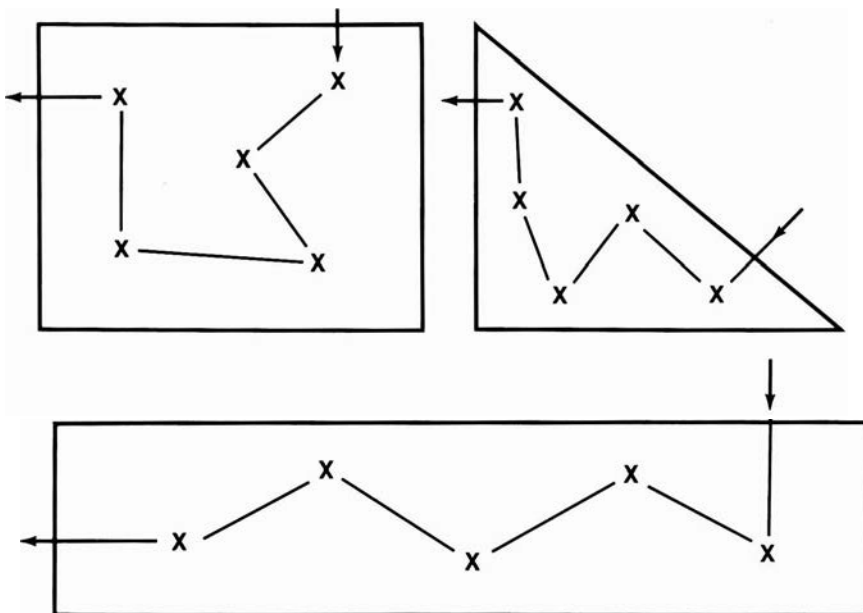
Sampling Procedures

The following information is presented as an overview of sampling patterns useful in detection of pests in the field. Sampling for specific pests will often require use of special techniques. To obtain the latest information on sampling techniques for a specific field crop pest, consult your local Cooperative Extension agent or current *Cornell Field Crop Recommendations*.

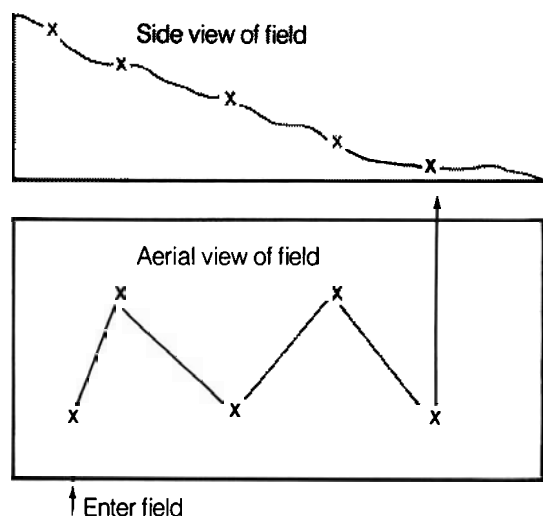
Correct sampling is the key for obtaining useful field information. It is important to randomly select plants for sampling. Do not examine only the "best" and "worst" plants. A random sample is taken by walking to the general area to be sampled, and looking up to the sky, walk forward five paces. Begin the inspection pro-



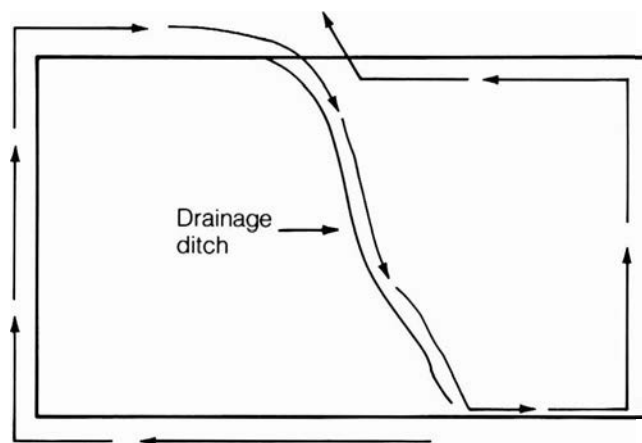
Field map example. Field maps used in crop scouting should be informative and descriptive. Included should be prominent landmarks and field notes such as location of sampling areas, location of particular problems, number or severity of particular pests, and other useful pest or crop information.



Pattern I example. Sampling pattern for pests expected to have uniform distribution in the field. X = sample area.



Pattern II example. Sampling pattern for pests expected to be concentrated in areas of the field with unique characteristics.



Pattern III example. Sampling pattern for pests expected to be concentrated along field margins or ditches.

cedure with the plant nearest the toe of your right foot.

Selecting an appropriate subsample method will depend on the mobility of the pest being scouted. Two subsample methods are recommended:

Consecutive plants are examined when the pest will not be disturbed by sampling procedures on adjacent plants. This method is appropriate for scouting pests such as cutworms, stalk-boring insects, weeds, and diseases.

Random plants are examined when mobile insects are being surveyed. In this case, the next plant examined should be some distance away to remove any possibility of re-counting insects that may have moved from plants sampled earlier. Random sampling is the preferred sampling method for insects such as corn rootworm adults.

Sampling Patterns

Pests may be expected to be found in one of three general distribution patterns in a field. Scouting efforts for particular pests should be selected accordingly.

Pattern I. Pests are expected to be uniformly spread over the field. In scouting for a pest with this distribution pattern, sample sites are chosen so as to be evenly distributed over the field, obvious influencing factors such as field borders being excluded. Pests fitting this pattern would include European corn borer, corn rootworm adults, potato leafhopper, and foliar diseases.

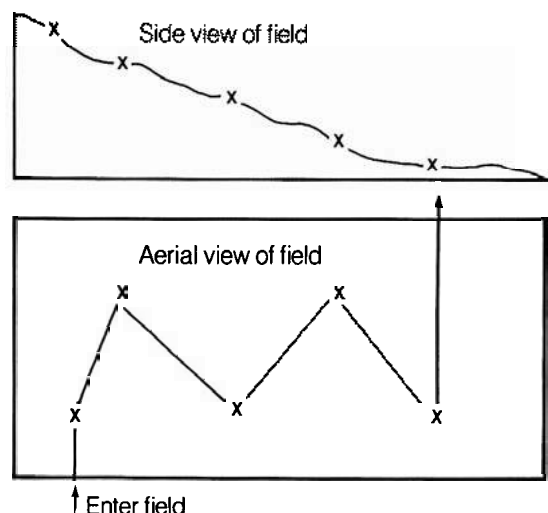
Pattern II. Pests are expected to be concentrated in particular areas of the field. Pests fitting this pattern would include black cutworm, white grubs, Phytophthora root rot, or other diseases that may be associated with wet areas within the field or with areas with different soil texture, drainage, pH, fertility, or cropping history. If pests are detected in one

area and not in another, efforts should be made to subsample that region to determine the extent and severity of the pest infestation more accurately.

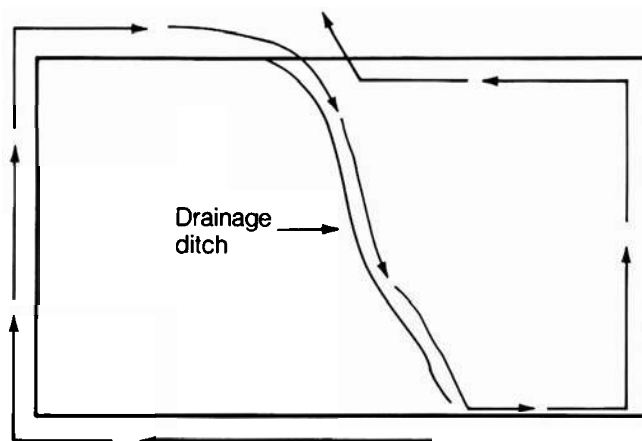
Pattern III. Pests are expected to appear at field edges first. Pests fitting this pattern would include common stalk borer in conventionally tilled corn, armyworm, grasshoppers, and alfalfa snout beetle. Sample for these pests by walking fence rows, ditch banks, and field borders.

NOTE: More than one pest may be present in fields at the same time. For this reason, combinations of the sampling procedures described may be necessary to accurately detect presence of all pests.

Additional information on integrated pest management field-crop-scouting techniques is available through your local county Cooperative Extension agent and Cornell University personnel in plant protection, plant production, and dairy/field crops integrated pest management.



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WEEDS AND WEED CONTROL

Weed Identification

Weed identification is the key to a successful weed control program. Incorrect identification of a problem weed can mean the difference between profit or loss. Knowing a weed's life cycle, including the methods of reproduction, is the most important identifying characteristic. In addition, it is sometimes necessary to know the exact species before selecting weed control measures.

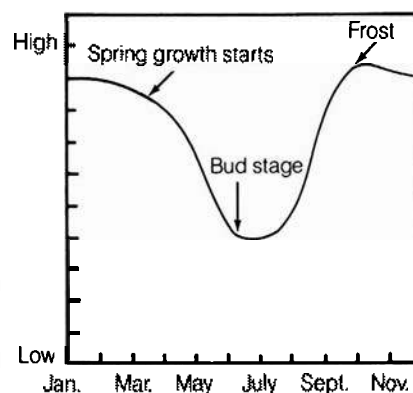
Life cycles. Plants, including weeds, can be classified as annuals (summer annuals or winter annuals), biennials, or perennials. In some cases a weed may exhibit two or more different life cycles. Annual weeds complete their life cycle within a year. Summer annuals such as large crabgrass germinate from seed in the spring or early summer and produce seed before the end of the growing season. Winter annuals germinate from seed in late summer or autumn and overwinter in a vegetative stage. They flower and set seed early in the next growing season. Shepherdspurse generally exhibits this life cycle. Biennial weeds take 2 years to complete their life cycle. They germinate from seed in the spring or early summer of the first year and then flower and set seed during the second year. Examples are bull thistle and wild carrot. Finally, perennial weeds are those that live for more than 2 years like quackgrass. Most problem weeds in tilled fields are either annuals or perennials. Biennial weeds will not persist in fields that are plowed and fitted, but are commonly found in pastures, hayfields, and waste areas. Biennial weeds may increase in other crops as no-till planting is adopted for these crops. This would most likely occur with continuous no-till cropping systems.

Whereas annual and biennial weeds reproduce and spread by seeds only, many perennial weeds reproduce by seeds and vegetative reproductive structures such as rhizomes (underground stems) or bulbs. As a result, perennial weeds can be grouped in the following manner:

PERENNIAL FORMS	EXAMPLES
Simple	Dandelion
Bulbous	Wild garlic
Tuberous	Yellow nutsedge
Creeping	
<i>Shallow-rooted</i>	Quackgrass
<i>Deep-rooted</i>	Common milkweed

With the exception of the simple perennials, each of the other types reproduces by seed and by some other means. In the case of wild garlic, underground bulbs serve as a means of spread; for yellow nutsedge, the nutlike tubers are the major means of reproduction; and for some creeping perennials, the rhizomes or underground stems allow these weeds to spread. Each of these underground reproductive structures serves as a storehouse for food materials, and it is this food reserve that allows these weeds to survive the winter. During late summer and autumn, these perennials are pumping a supply of carbohydrates from the leaves (the manufacturing site) down into these storage organs as illustrated. Perennial weed control requires the destruction of the above-ground and the underground plant parts.

Differentiating broadleaf weeds, grasses, and sedges. Along with knowing the life cycle of a weed and how it reproduces, it is important to recognize differences be-



Food reserves of a perennial plant.

tween broadleaf weeds, grasses, and grasslike weeds. Broadleaf weeds are easily recognized, but there are occasions when grasses may be confused with grasslike plants. The plants most easily confused with grasses are sedges and rushes; however, close examination of the stems will usually distinguish between these groups. Grasses have round or flattened stems that are usually hollow. Sedges have three-sided or triangular stems that are usually solid, whereas rushes have round, solid stems. Cross sections of these stems are shown here. Few, if any, rushes present problems in field crops, and only one sedge is a common field crop weed in the Northeast. This problem sedge is yellow nutsedge. Recognizing this weed is important because it is a perennial that requires special control measures.



Cross sections of stems. Sedge stem is triangular.

Weed competition. Weeds compete with crops for limited supplies of soil water, soil nutrients, sunlight, and other natural resources. This competition results in reduced crop yields and quality. Knowing which weeds are most competitive or cause the greatest losses will help in the selection of cost-effective weed control measures. General guidelines on the relative competitiveness of different weeds follow.

- Perennial weeds are generally more competitive than annual weeds.
- Broadleaf weeds tend to be more competitive than grasses.
- Weeds with life cycles similar to that of the crop tend to be more competitive than weeds with different life cycles.
- Losses due to weeds are greater when resources such as soil moisture are limited than when resources are adequate for both the crop and the weeds.

Along with knowing the types of weeds present in a field, it is helpful to know the relative numbers of each so that a priority listing of the problem weeds can be made. Although quackgrass is more competitive than crabgrass, it should be obvious that a few scattered patches of quackgrass will cause less damage than an extremely heavy infestation of crabgrass.

Weed inventory. Field crop producers can and should use a weed inventory to assist in the selection of weed control programs for their fields. By tailoring weed control programs to fit the problems in each field, growers can minimize weed control costs while maximizing yields and profits. An inventory can be made by making careful observations or scouting each field two or three times during the year. A record of these observations can be made by

Table 14. Summary of common field crop weeds in New York

<i>Life cycle & growth form</i>	<i>Problem weeds</i>
<i>Summer annual</i>	
Broadleaf weeds	Common lambsquarters Common ragweed Redroot pigweed Velvetleaf Wild mustard
Grasses	Barnyardgrass Fall panicum Green foxtail Large crabgrass Smooth crabgrass Witchgrass Yellow foxtail
<i>Winter annual</i>	
Broadleaf weed	Shepherdspurse
<i>Biennial</i>	
Broadleaf weeds	Bull thistle Wild carrot
<i>Perennial</i>	
Broadleaf weeds	Canada thistle Common milkweed Field bindweed Hedge bindweed Horsenettle
Grasses	Quackgrass
Sedge	Yellow nutsedge

numbering or naming each field and then recording the types (broadleaf annuals, annual grasses, etc.) of weeds present in each field.

In scouting for weeds, care should be taken to observe representative areas of the field. Observations should be made randomly in at least five locations in a 40-acre field. Larger fields should be divided into 40- to 50-acre units for scouting purposes. These divisions can be based on soil type, topography, field history, or other factors that may affect weed populations.

In a summer annual crop like corn, the first observations should be made by the time the corn is 3 or 4 inches tall. Early season observations can tell the grower how effective pre-

plant-incorporated or preemergence herbicide applications have been and can suggest the possible need for cultivation or postemergence herbicide applications. It is also a good time to complete records on the kinds and rates of herbicides used, as well as the dates of application.

A second look at the fields in mid-summer (before the corn is waist-high) can provide information on the overall effectiveness of the weed control practices and can provide clues on how the program might be adjusted in future years. This would be a good time to record the types and numbers of weeds present and to map the location of special problem areas in the field. Mapping the location of perennial broadleaf weeds



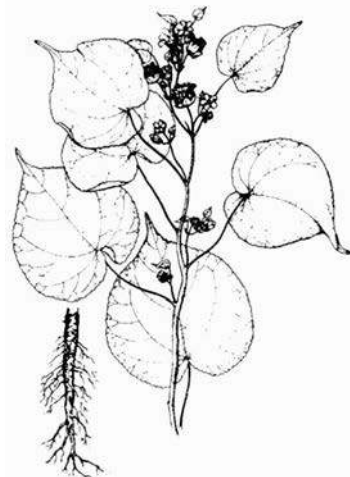
Common lambsquarters



Common ragweed



Redroot pigweed



Velvetleaf

can be especially useful, for they often grow in patches and can be controlled with spot treatments between crops. The scout should make special note of the weeds in unsprayed areas because these areas provide the most accurate picture of the weed population. Additional notes on weed types and numbers can be taken by the grower at harvest to complete the weed inventory.

Scouting new legume seedlings for weeds must be done shortly after the seedling emerges, because weed control measures for annual broadleaf weeds must be applied when the legume is 1 to 3 inches tall and weeds have 2 to 4 true leaves. In established hayfields the inventory can be made at the time of each harvest. This should provide adequate information for decisions on dormant or between-cuttings herbicide applications.

Finally, small grain fields should be checked for weeds before stem elongation, for most herbicide applications should be made no later than the fully tillered stage (usually 4 to 8 in. tall with 12 or more leaves).

Table 14 provides a summary of common field crop weeds in New York and groups them according to their life cycle and growth form. The information obtained during a weed inventory should be organized in a similar manner so that it can be used in selecting weed control measures and in planning crop rotations.

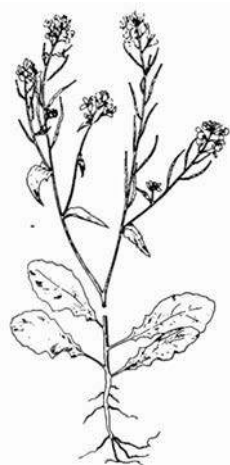
Common lambsquarters is a broadleaf summer annual, which reproduces by seed. Stems are 3 to 4 feet tall, smooth, grooved, often have red or light green streaks, and may show considerable branching. Leaves are alternate, smooth, and usually have a white mealy coating on the lower surface. Flowers are small, green, without petals, and are borne in irregular clusters at the ends of branches and in the axils of leaves.

Common ragweed is a broadleaf summer annual, which has a shallow root system. Stems are smooth or hairy and may be 1 to 4 feet tall. Leaves are nearly smooth and deeply cut into a number of lobes. Male flowers are borne in small inverted clusters at the tips of branches; female flowers are borne at the base of leaves in forks of the upper branches.

Redroot pigweed is a broadleaf summer annual, which reproduces by seed. Plants have a shallow red taproot and rough stems, which branch freely and grow up to 6 feet tall. Leaves are egg shaped and rather dull green. Flowers are green, small, and in dense clusters at the ends of branches and in the axils of leaves.

Velvetleaf is a broadleaf summer annual, which often grows 6 to 8 feet tall. Stems and large, heart-shaped leaves are covered with soft, velvety hairs. Flowers are about $\frac{3}{4}$ inch across, have 5 yellow petals, and are borne in the axils of the upper leaves. Seed pods are cup shaped with a ring of prickles around the upper edge.

Wild mustard is a broadleaf annual or winter annual, which reproduces by seed. Stems are erect, branched near the top, and have a few bristly hairs. Lower leaves are irregularly lobed, toothed, and have bristly hairs, whereas upper leaves are smaller, often not lobed, and often borne directly on the stem. Conspicuous yellow flowers with 4 petals are borne in clusters at the ends of branches. Slender seed pods are



Wild mustard



Barnyardgrass



Fall panicum



Green foxtail

formed on a spreading stalk.

Barnyardgrass is a summer annual with rather shallow roots and reproduces by seed. Stems are thick, coarse, mostly erect, branching at the base, and 1 to 4 feet tall. Leaf blades and sheaths are smooth and light green. Seed heads bear several rather compact side branches, which are green or purplish.

Fall panicum is a summer annual, which reproduces by seed. Stems are 2 to 4 feet long, smooth, and spreading so that they are partly flat on the ground. Leaves are smooth or sparsely hairy, rough to touch, and have a prominent white midrib. Leaf sheaths are smooth and often purplish. Seed heads are branching and open, but are more compact and shorter than those of witchgrass.

Green foxtail is a summer annual, which reproduces by seed. Stems are branched from the base, somewhat spreading, and 1 to 3 feet tall. Leaves are hairless; seed heads are erect or somewhat nodding, rather dense, green or purple, and cylindric but tapering a little at the summit.

Large crabgrass is a summer annual, which reproduces by seed.

Stems are stout, smooth, up to 3 feet long, and, when prostrate, root at the nodes with flowering shoots ascending. Leaf blades are usually somewhat hairy, and the sheaths have dense, long hairs. Seed heads with 3 to 10 fingerlike segments are formed at the top of the stem.

Smooth crabgrass is a summer annual, which reproduces by seed. Stems are usually prostrate, spreading, and hairless. Leaves are bluish or purplish and hairless. Seed heads are similar to those of large crabgrass, purple, with 2 to 6 segments.

Witchgrass is a summer annual, which reproduces by seed. Stems are 1 to 3 feet tall, often spreading, and branched. Leaves and leaf sheaths are covered with dense, soft hairs. Seed heads are branched and become spreading at maturity, often breaking from the stem and blown about by the wind.

Yellow foxtail is a summer annual, which reproduces by seed. Stems are flattened, branch at the base, and 1 to 2 feet tall. Leaves have many long hairs on the upper surface near the base. Seed heads are erect, evenly cylindric, and yellow at maturity.

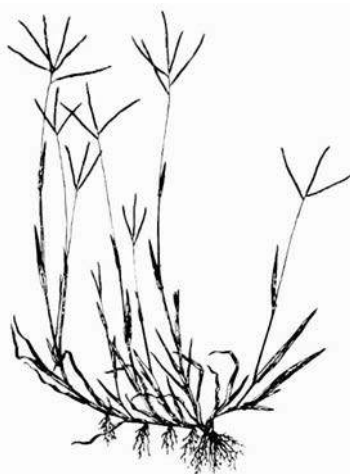
Shepherdspurse is a broadleaf summer or winter annual, which reproduces by seed. Plants have branched taproots and stems that are 1 to 1½ feet tall and covered with gray hairs. Lower leaves form a rosette at the base, are coarsely lobed, and clasp the stem with pointed lobes. Upper leaves are smaller and arrow shaped. Flowers are small, white, and 4 petaled. They are borne in elongated clusters at the ends of branches and form flat, triangular seed pods.

Bull thistle is a biennial, which reproduces by seed. In the first year it forms a rosette of coarsely toothed leaves and a large, fleshy taproot. During the second year, a hairy, branched stem grows 3 to 6 feet tall. Leaves are deeply cut and run down the stem. They are rough and spiny on the upper surface and are lighter colored and hairy beneath. Flower heads are 1 to 2 inches across, deep purple or rose, and surrounded by many spiny bracts. Seeds are straw colored with darker stripes and are tipped with down.

Wild carrot is a biennial, which reproduces by seed. In the first year it



Large crabgrass



Smooth crabgrass



Witchgrass



Yellow foxtail

produces a rosette of finely divided leaves and a fleshy taproot. During the second growing season, it produces a stem, 1 to 3 feet tall, somewhat hairy and branched at the top. Leaves are alternate, finely divided, hairy, and have a distinct carrotlike odor. Small white flowers are borne in flat-topped clusters at the ends of the branches.

Canada thistle is a deep-rooted perennial, which reproduces by seed and creeping rhizomes extending to a depth of several feet. Stems are 2 to 5 feet tall, grooved, branching only at the top, and becoming hairy as they mature. Leaves are lobed with crinkled edges and spiny margins. Numerous flower heads (about $\frac{3}{4}$ in. in diameter) are borne in clusters at the top and on side branches. Flowers are white to lavender, and seed is brown and is attached to tannish down.

Common milkweed is a deep-rooted perennial, which reproduces by seed and long, spreading rhizomes. Stems grow from 2 to 5 feet tall, are covered with short downy hairs, and are filled with a milky juice. Leaves are opposite, oblong,

rounded, and 4 to 8 inches long. Flowers are pink to white and are borne in many-flowered, ball-like clusters. They form grayish seed pods, which are hairy and covered with soft, spiny projections. Seed are flat, oval, with a tuft of silky white hairs at the tip.

Field bindweed is a deep-rooted perennial, reproducing by seed and creeping rhizomes, which may go as deep as 20 feet. Stems are smooth, slender, 2 to 7 feet long and twine or spread over the soil surface. Leaves are alternate, variable, and somewhat arrow shaped. Flowers are funnel shaped, about 1 inch across, and white or pink.

Hedge bindweed is a perennial, which reproduces by seed and extensive, fleshy, but relatively shallow, creeping rhizomes. Stems are smooth, 3 to 10 feet long and twine or spread over the soil surface. Leaves are large, alternate, and usually sharp pointed at the tip with large basal lobes. Flowers are $1\frac{1}{2}$ to 2 inches across and are white or pinkish. The lower part of the flower and seed pod are enclosed in two leafy bracts.

Horsenettle is a deep-rooted per-

ennial, which reproduces by seed and creeping rhizomes. Stems are 1 to 4 feet tall and covered with hairs and short yellow spines. Leaves are alternate and wavy edged with yellow spines on the midrib and veins. White or bluish flowers are about an inch across and are borne in clusters. When mature, they bear a yellow, juicy berry, containing many seeds.

Quackgrass is a shallow-rooted creeping perennial, which reproduces by seed and extensive rhizomes, varying in depth from 2 to 8 inches. Roots arise only at the nodes of these underground stems. The aboveground stems are from $1\frac{1}{2}$ to 3 feet tall and bear a compact seed head.

Yellow nutsedge is a perennial species, which reproduces by seed and tubers on the root tips. Stems are erect and triangular, and the stems and grasslike leaves are yellow green. Yellowish brown seed heads are borne at the top of the plant.

Weed Control

There are three ways of dealing with weeds: prevention, eradication, and control. Prevention can be a very use-



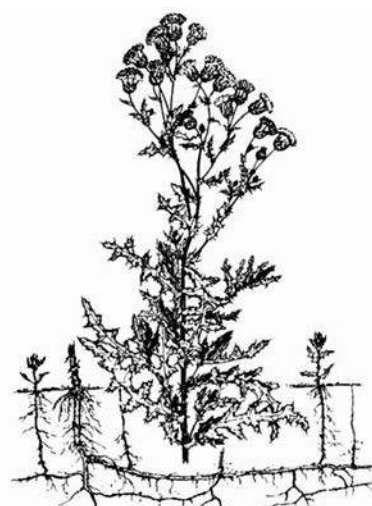
Shepherdspurse



Bull thistle



Wild carrot



Canada thistle

ful way of avoiding problems, but is an approach that will work only on those weeds not present in a given situation. It is estimated that 60% of the weeds in North America have been introduced from other parts of the world. Johnsongrass was originally introduced as a forage species in the South and is now a serious weed problem in many parts of the country. Another weed, wild carrot, was brought to this country as an ornamental. Think how simple weed control would be if our ancestors had been more careful. Unfortunately, weed introduction is still taking place. Every year many exotic and (or) ornamental plants are brought into this country. Some will become serious weed problems.

Although reference has been made to the country as a whole, the same principles apply to individual farms. It is difficult to prevent seeds that are readily moved by wind or water from landing on a particular farm, but many weeds depend on people for transportation. These weeds can be kept out of certain fields. One of the principal ways weeds are spread is through the movement and use of

crop seed contaminated with weed seed. Most weed seeds can be removed from crop seed, and the investment in certified seed or in cleaning seed will certainly pay. The movement of farm equipment from field to field is another means of spreading certain weeds. Tubers and rhizomes such as those of yellow nutsedge and quackgrass can be dragged from one place to another on tillage implements, and seeds of others can easily be transported on harvesting equipment. In either case, a thorough cleaning of the machinery will prevent these weeds from spreading. Manure movement can also be responsible for spreading weeds. Velvetleaf seed is known to remain viable in a manure pile for up to 1 month. It is estimated that stacking manure for 4 months will destroy all weed seeds. Unless stacking can be done, manure contaminated with a weed like velvetleaf should not be spread on fields that do not have this particular weed problem.

The second means of attacking the weed problem is to eradicate them. Eradication involves the complete elimination of all live plants, plant

parts, and seeds from a given area. This is not an easy task and is seldom, *if ever*, successful. It should only be considered when dealing with new infestations that are limited in area. Eradication of a weed species requires extreme diligence over a number of years to ensure that every dormant seed and vegetative reproductive organ, such as rhizomes and tubers, has germinated and subsequently been killed.

Because both prevention and eradication have limited application, field crop producers usually resort to control measures for weeds that are both persistent and widespread. Weed control is the process of limiting weed infestations so that crops can be grown profitably or other operations can be conducted efficiently. In other words, control measures are geared to manage the infestation so that it is not economically damaging or that the weeds do not interfere with normal operations. Control measures are usually classified into one of four types: (1) mechanical or physical, (2) cultural or managerial, (3) biological, or (4) chemical.



Milkweed



Field bindweed



Hedge bindweed

Mechanical weed control. Some of the oldest weed control measures are of a physical nature. Hand pulling and hoeing certainly fit into this category. Other mechanical means include tillage, mowing, flooding, burning, and mulching (smothering). Of these, tillage and mowing have more application to field crops than the others. All primary and secondary tillage operations done on New York farms help provide a weed-free seedbed. Although not as popular now as in the past, cultivation of row crops is an effective way of controlling weeds. Annual and biennial weeds are easily killed by tillage, because they reproduce only by seed. Annual weeds controlled by cultivation would include redroot pigweed and fall panicum. Biennial weeds like bull thistle and wild carrot do not persist in fields that are tilled and so are not a problem in conventionally planted row crops. A single cultivation will not control perennial species like common milkweed or quackgrass. These weeds regrow from their underground reproductive organs following cultivation. In the process, they use part of their

stored foods and are weakened. Perennial weeds can be controlled by tillage if the operations are repeated over a long period of time. This technique is known as "root starvation" and usually takes two or three growing seasons. Each time the topgrowth of a perennial weed is destroyed by tillage, the plant will regrow by using some of its underground food reserves. If successive tillage operations are timed so that each will further deplete these reserves, a perennial weed can eventually be starved to death. With most perennial species, these repeated tillage operations should be done at the time of bud formation.

Cultural weed control. Cultural or managerial methods of weed control include all practices that make the crop more competitive than the weeds. The choice of crop is perhaps the most important management decision that must be made. The crop grown should be one that will compete with the weeds found in a given field. In addition, the variety or hybrid should be one that is well adapted to local growing conditions. If not, the crop will be at a disadvan-

tage from the start. Other management practices that favor the crop over the weeds include the use of crop rotation, proper soil water management, proper use of fertilizer, adjustment of soil pH, correct date and rate of planting, correct row spacing, use of weed-free seed, and many more. In general, all efforts should be made to make the growing conditions for the crop as favorable as possible. By doing so, the crop can compete most effectively with the weeds, and the losses due to weeds will be kept to a minimum.

Biological weed control. Biological methods of weed control involve the use of natural enemies such as insects, diseases, animals, and other plants. Of these, insects have proved to be the most effective weed control organisms. This type of control is not practical on a small scale, and programs of this type are generally handled by governmental agencies.

Chemical weed control. Chemical methods of weed control involve the use of herbicides. Herbicides are one of a group of chemicals referred to as pesticides. Pesticides include all substances used for controlling in-



Horsenettle



Quackgrass



Yellow nutsedge

sects, rodents, disease organisms, weeds, and other forms of plant or animal life that are considered pests. Herbicides, then, are chemicals used for killing or inhibiting the growth of plants. The widespread use of herbicides has led growers to think they are a cure-all for their weed problems, but they are not! In reality, herbicides can be a two-edged sword and should be used as a supplement to, rather than a substitute for, other weed control methods.

Combinations of control measures. A successful weed control program for field crops will involve two or more types of control, for relying on one often results in failure. The growers who drain and lime their fields to favor crop growth and then use good judgment in selecting varieties, fertility levels, populations, and planting dates and in seedbed preparation are well on their way to winning the battle with weeds. Herbicides do play an important role in modern crop production, but should not be relied on to do the entire job of weed control. In addition to using herbicides, growers should employ every cultural practice known to in-

crease the competitiveness of the crops and then supplement the herbicides with cultivation or mechanical controls where possible.

Principles of Herbicide Use

Herbicides can be a handy tool for controlling weeds. Only by knowing the properties of herbicides and their proper usage, however, can maximum benefit be gained from them. If their properties are misunderstood or they are improperly used, herbicides may cause losses through crop injury and (or) inadequate weed control.

Herbicide classification. Herbicides can be classified as selective or nonselective in their action. A selective herbicide such as atrazine kills certain plants in a mixed population without serious injury to other plants. Nonselective herbicides like paraquat (Gramoxone Super) affect all plant species. Obviously, selective herbicides are more widely used than nonselective herbicides in field crops production. However, some nonselective compounds can be used to advantage before crop emer-

gence. Within each of these broad categories, herbicides can be grouped in the following manner:

A. Foliar-applied compounds

1. *Contact herbicides* kill mainly by touching the plant surface rather than by being taken into the plant. Only that portion of the plant sprayed is affected.
2. *Translocated herbicides* move within the plant from the point of entry. They may produce a toxic effect a considerable distance from the point of application.

B. Soil-applied compounds

Some herbicides have both foliar and soil activity and so appear twice in this classification scheme. Table 15 provides examples of these various categories.

Time of application. In addition to classifying herbicides according to the way they are applied, grouping them according to when they are applied is also important. Some herbicides must be applied before planting the crop and mechanically mixed with the soil, because they will evaporate or be degraded by sunlight if left on the soil surface. Others are ap-

Table 15. Herbicide classification scheme with examples

	<i>Selective</i>	<i>Nonselective</i>
Foliar applied		
Contact herbicides	atrazine bromoxynil (Buctril)	paraquat (Gramoxone Super)
Translocated herbicides	2,4-DB (Butoxone) dicamba (Banvel)	glyphosate (Roundup)
Soil applied		
	atrazine metolachlor (Dual)	bromacil (Hyvar-X)

plied this way to improve performance. These are *preplant-incorporated* applications and are generally made just before planting. For many of these compounds, applying them to a dry soil is also important, because they evaporate faster from a wet surface than from a dry one. Although herbicide incorporation is most often done with a tandem disk, other secondary tillage implements such as field cultivators can be used effectively. A second, shallow-tillage operation in the opposite direction ensures proper herbicide distribution.

Preemergence applications are made to the soil surface after planting but before crop and weed emergence. To be effective, preemergence herbicides must be dissolved or suspended in the soil solution so that they can be absorbed by germinating weeds. As a result, they depend on rainfall for incorporation and activation. The amount of herbicide in the soil water is also affected by the adsorptive capacity of the soil for the herbicide and the solubility of the chemical. Water solubility of herbicides varies greatly depending on the chemical structure. Some preemergence herbicides like metolachlor

(Dual) are quite water soluble and move into the soil with only a light shower. Others, such as simazine (Princep) are relatively insoluble and require a good rain to be incorporated. Generally, from 1/2 to 1 inch of rainfall within a week to 10 days of application will incorporate most preemergence herbicides. Because most annual weeds germinate in the top inch of soil, it is desirable to have a concentrated layer of herbicide in this zone so that annual weeds are killed as they germinate. Excessive rainfall may move soluble herbicides below this germination zone and result in poor weed control and (or) crop injury. If rainfall does not occur within 10 days, it may be helpful to give the fields a shallow cultivation. This will kill emerging weeds and incorporate the herbicide for those yet to germinate.

Soil properties that affect the availability of soil-applied herbicides include soil texture, organic matter level, and pH. Soil texture is determined by the relative amounts of sand, silt, and clay in a soil. Textural names such as loamy sand and clay loam are assigned to soils depending on the amount of sand, silt, and clay in a soil. Clay particles are negatively

charged and have a large surface area. As a result, soils high in clay content (heavy soils) have the capacity to adsorb, or tie-up, herbicides and generally require higher application rates than coarse-textured (light) soils.

Soil organic matter level also affects the adsorptive capacity of the soil. Although undecomposed plant and animal residues can influence herbicide performance, the well-decayed, fine, organic matter particles known as humus are of greatest importance. Like clay particles, these humus particles are negatively charged and exhibit an even greater capacity than clay to adsorb herbicides. Consequently, herbicide application rates also have to be adjusted for soil organic matter level.

Recommendations for soil-applied herbicides in *Cornell Recommends for Field Crops* are for medium-textured soils with organic matter levels of 3 to 4%. They should be used as guidelines in determining herbicide rates. Fine tuning of rates can be done by consulting the herbicide label.

Soil pH can also affect the availability of soil-applied herbicides. This is especially important for the triazine herbicides (atrazine, Bladex, and Princep). These herbicides are most strongly adsorbed on clay and organic matter particles at low pH's. Although the amount of triazine adsorption increases at all pH levels below 7.0, it is most dramatic at pH's of 6.0 and below.

Postemergence applications are made after emergence of the crop and (or) weeds. Whereas the other treatments depend on herbicidal activity through the soil, postemergence treatments have to be active through the foliage of weeds and, at the same time, must not injure the crop. Postemergence applications are greatly affected by the age of the

weeds and the growing conditions. In general, postemergence applications should be made when weeds are young and (or) actively growing because they are easiest to kill then. Adverse environmental conditions, such as hot, dry weather before spraying, make postemergence applications less effective; warm, moist weather provides more favorable conditions. Crops are also sensitive to injury by postemergence herbicides during periods that favor rapid growth. Rainfall after postemergence applications can reduce their effectiveness.

For control of summer or winter annual weeds such as velvetleaf and shepherdspurse, postemergence herbicides should be applied during the seedling stage. Postemergence applications for biennials such as bull thistle and simple perennials such as dandelion should be made in the fall or early spring. Foliar treatments for creeping perennial weeds such as common milkweed should be made during the bud stage in the spring or summer or during vigorous fall growth. With perennial weeds, it is important that they be actively growing and have a large leaf area so that the spray will be absorbed by the leaves and translocated into the underground reproductive and food storage organs.

Plants have a waxy layer on the leaves that can cause postemergence sprays to bead up on the surface and limit the amount of herbicide absorbed by the plants. As a result, surfactants or wetting agents are recommended for use with many postemergence herbicides. These adjuvants are added to the spray solution to reduce the surface tension of water or other carriers so that the spray droplets will flatten out and increase the leaf area covered with the spray. Surfactants are especially important in the use of contact herbi-

cides like paraquat (Gramoxone Super), because only those parts covered by the spray are affected. With other postemergence applications, it is important that the herbicide be taken into the plants where it can act on the weeds. A blend of crop oil and surfactant is often added to the spray solution to help move the herbicide through the waxy layer on the leaves. An example would be the use of a crop oil concentrate-surfactant blend with atrazine for postemergence weed control.

Herbicides such as atrazine and cyanazine (Bladex) affect annual weeds through the soil and through the foliage. As a result, they can be applied either preemergence or early postemergence; however, preemergence applications are usually the preferred choice, especially if some of the target weeds are annual grasses. Most herbicides enter more easily through plant roots than through the leaves and translocate upward more readily than downward. Postemergence herbicides that are not readily translocated downward may not control annual grasses, for the growing point of grasses is at the base of the plant during early stages of development. On the other hand, preemergence herbicides in the soil are readily absorbed and translocated up to the growing point. In addition, germinating weeds are easier to kill than are established weeds. With broadleaf annuals, the growing point is at the top of the plant; so early postemergence applications can be very effective, especially on hard-to-kill species like velvetleaf.

Herbicide persistence. Persistence, or the length of time that a herbicide remains active, is one of the factors that determines the effectiveness of soil-active herbicides. Ideally, soil-active herbicides should persist long enough to control weeds that

might interfere with crop production, yet not carry over to injure subsequent rotational crops. Although this sounds simple, various climatic, edaphic (soil-related), biotic, and cultural factors, along with the chemical properties of the herbicide, determine the degradation rate of a herbicide. Understanding the interactions among these factors is essential to the proper and safe use of these chemicals.

Herbicides can be degraded by soil microorganisms, by chemical reactions in the soil solution, by sunlight, and by chemical reactions within plants. In addition, their availability for degradation is affected by the amount of adsorption on soil particles, evaporation from the soil surface, plant uptake, and leaching into the soil profile with excess soil moisture.

When a herbicide is applied to, or is moved into, the soil, microorganisms attack it as a new food supply. Organisms that can effectively use this new energy source increase in number. This, in turn, speeds the degradation of the herbicide. Other factors that affect microbial activity are soil temperature, water, oxygen, the availability of mineral nutrients, and soil pH. Soil temperatures in the range of 75°–90° F favor microbial activity, whereas at temperatures below 40° F most activity ceases. Generally, environmental factors that favor microbial activity will also speed herbicide degradation. Warm, moist, well-drained (aerated) soils with high fertility and optimum pH will favor rapid herbicide degradation. Other factors remaining constant, warm, moist soil conditions will degrade herbicides faster than cool, dry conditions. Along with microbial degradation, oxidation, reduction, hydrolysis, and other reactions may result in the chemical degradation of herbicides. Chemical degradation is

difficult to separate from microbial degradation because these chemical reactions are controlled by some of the same factors.

Herbicides that remain on the soil surface for an extended period of time may be subject to photodecomposition or light degradation. When herbicide molecules absorb light energy, the electrons become excited and chemical bonds may be broken or formed. The resulting compounds are similar to those from microbial or chemical degradation. Soil-active herbicides may be absorbed by plants and, if not metabolized, may be removed when the crop is harvested. In other instances, herbicides are metabolized or inactivated inside the plant. The absorption and metabolism of triazine herbicides by corn furnishes an excellent example of herbicide inactivation. Because of this rapid inactivation, corn is not injured by these herbicides, whereas other species, not able to metabolize triazines, are killed.

Because so many factors—herbicide chemistry, soil characteristics, weather, and plant interactions—influence herbicide degradation and persistence, it is difficult to predict the length of time a herbicide will remain effective. There is little doubt that herbicide persistence is a relative term. Herbicides that are very short-lived may fail before the end of the growing season, remedial weed control being required or a loss in crop yield or quality resulting. On the other hand, certain field crop herbicides can carry over and cause injury to subsequent crops. They include atrazine, simazine (Princep), and trifluralin (Treflan). In general, problems with carryover can be minimized by

- reading and following label instructions,
- using the minimum dosage required,

- calibrating equipment and making careful application,
- using herbicide rotation as well as crop rotation,
- selecting herbicides that are not persistent,
- keeping accurate records of herbicide use, and
- using herbicides in combination with other weed control practices.

Once a residue problem exists, tolerant crops must be grown unless the herbicide can be diluted by plowing and incorporating large quantities of organic matter such as manure.

Herbicide formulation. Herbicides are available in several different forms including wettable powder, dry flowable, flowable liquid, granule, and either water-soluble or emulsifiable-concentrate liquid formulations. Some herbicides are formulated in only one form, but others may appear in two or three of these forms. Each has its advantages and disadvantages.

Wettable powder and *dry flowable* formulations are dry preparations that are mixed with water or liquid fertilizer to form a suspension at the time of spraying. The dry flowable formulations are composed of small pourable aggregates of the dry material. They are easier to handle and mix than are the wettable powders. Both require constant agitation to keep the particles from settling out in the spray tank. Agitation can be provided by mechanical mixing or by using a bypass line from the pump. These formulations are abrasive and can cause considerable wear of roller pumps (centrifugal pumps are less subject to wear) and nozzle tips. All screens in the sprayer should be 50-mesh to avoid clogging when spraying wettable powders or dry flowables.

Flowable liquids are very finely ground preparations of herbicide that are suspended in liquid. Compared with dry formulations, they are easier to get into a water or liquid-fertilizer suspension, require less agitation, and create less problems with clogged screens and nozzles.

Certain preplant and preemergence herbicides are available as *granules* for dry application. They are almost always more costly than other forms, but are easily applied. In these formulations, the active ingredient is adsorbed onto some inert material of uniform size to facilitate spreading in a band or using in broadcast applications. The activation of herbicide granules may be slower than it is for herbicide sprays, particularly during periods of low rainfall. The slow release of active ingredient from granules may also create more carryover problems than occur with other formulations.

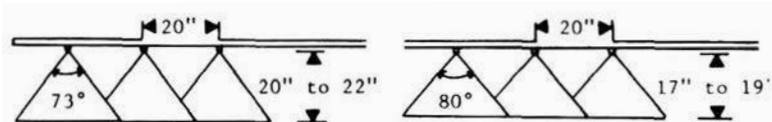
Liquid formulations are either water-soluble or emulsifiable-concentrate formulations. The latter have emulsifying agents that impart a milky appearance to the spray mixture and keep them in suspension during spraying. Liquid formulations are easily mixed with the carrier and require little agitation to keep them mixed. Some herbicides, like 2,4-D, have several different liquid formulations, and these forms may perform quite differently. There are salt, amine, and ester formulations of this herbicide. They vary in their herbicidal activity and in volatility (their tendency to evaporate). The salt formulations are the least likely to vaporize, whereas the ester forms vaporize easily. Some esters are formulated with long ester side chains attached to the 2,4-D molecule. They are called low-vol esters and are less volatile than other ester formulations. The ester forms are also more active

than the other forms. This means that lower rates of the ester formulations than of the amine and salt formulations can be used.

Application equipment. Herbicide application requires an implement that will distribute the material evenly over a given area and is easily calibrated to apply the desired amount. Equipment for herbicide application usually takes the form of a sprayer or some type of granule applicator. Sprayers are made up of a tank, pump, pressure regulator, boom, nondrip nozzles, and strainers between the tank and pump and between the pump and nozzles.

Although there are many types of nozzles or spray tips, the flat spray (fan) tips are best for herbicide application. Other types include hollow-cone tips and flood-type nozzles. The hollow-cone tips are sometimes used for herbicides that require soil incorporation. Flood-type nozzles designed for liquid fertilizer can be used for herbicides, but do not give as uniform distribution as the flat spray tips. For broadcast applications, the flat spray tips with tapered-pattern edges are most desirable, for they can be arranged along a boom to overlap enough to get even coverage. Flat spray tips with tapered-pattern edges should be rotated about 12° to 15° so that the individual spray patterns are slightly offset. Other flat spray tips have even-pattern edges and are used for applying a band of 5 to 7 inches over the planted crop row. Banding herbicides over the row can reduce herbicide costs and carryover, but this method of application must be used in conjunction with at least one cultivation to remove weeds between the rows.

Nozzle tips are marked with a series of numbers or a combination of numbers and letters that give the specifications. The specifications for a flat spray tip with tapered-pattern



Spray patterns of 73° and 80° nozzle tips.

edges could be 8002. In this case, the first two numbers indicate that the angle of the spray pattern is 80° . The angle of the pattern influences the height the nozzles should be above the target. The 80° series should be 17 to 19 inches above the target, whereas the 73° series should be 20 to 22 inches above the target as shown. The last two numbers tell the relative size of the orifice or opening. An 8004 tip would deliver twice the spray volume with similar sprayer speed and pressure as an 8002 tip. Spraying wettable powder formulations requires that 8003 or 8004 tips be used, because 8002 tips will clog. If these numbers are preceded and (or) followed by letters such as HSS8003E, it would indicate that the tip is made of *hardened stainless steel* and that it has an *even* pattern for band spraying.

Nozzle tips may be made of brass, plastic, stainless steel, or hardened stainless steel. Brass tips are the least durable. Plastic tips are corrosion resistant, but stainless steel and hardened stainless steel tips are both corrosion resistant and durable. As such, they will last longer than the other types and are well worth the added cost. Tip wear is limited when spraying liquid formulations and most rapid when using wettable powders. As a result, the sprayer should be recalibrated frequently if wettable powders are used. If recalibration shows that tips are delivering 10% more than they did when they were new, they should be replaced. Worn

tips not only deliver more spray than they should, but give uneven distribution, which leaves streaks across the field. If tips become clogged, a toothpick or straw should be used to unblock the tip, *not* a piece of wire, because this may enlarge the opening or distort the spray pattern.

Sprayer calibration. Sprayer calibration is done to determine the application rate in gallons per acre (gpa). The desired volume depends on the type of application being made. Soil-applied herbicides must be distributed evenly over the soil; as long as this objective is achieved, the spray volume is not important. Volumes of 10 to 20 gpa are usually satisfactory. Translocated foliar herbicides are usually applied with similar volumes, but contact herbicides like paraquat (Gramoxone Super) do not work well unless the foliage is thoroughly wetted. This requires a minimum of 20 gpa.

Calibration should be done at the beginning of the season and whenever a different application rate is used. Before calibrating a sprayer, clean it, and check to see that all nozzles and other parts are working. The spray volume delivered depends on ground speed, operating pressure, nozzle spacing, and the size of the nozzle openings. There are many ways to calibrate a sprayer, but the steps outlined here are the most straightforward.

1. Measure the distance between the two end nozzles on the boom in feet. This is the effective boom *width*.

2. Divide the width of the boom into 43,560 to get the number of feet of travel necessary to cover an acre.
3. Measure and stake off the number of feet needed to cover an acre.
4. Fill supply tank *and* boom full of water at starting point.
5. Spray the area exactly as one would spray the field, using the same speed and pressure (usually 3 to 5 mph and 30 to 40 psi).
6. Shut off the sprayer immediately when you get to the end.
7. Measure carefully the number of gallons required to refill the spray tank. This is the volume of water the sprayer will deliver per acre.
8. Use this calibration information to determine the amount of herbicide to add to a given volume of water in the spray tank.

Calculating the amount of herbicide. Weed control recommendations in *Cornell Recommends for Field Crops* are given as the amount of commercial product per acre. This eliminates the need to convert from the amount of active ingredient to commercial product. The only calculation left, then, is to multiply the recommended amount per acre by the number of acres the sprayer will cover as determined by calibration.

Mixing the spray solution. Fill the spray tank $\frac{1}{4}$ to $\frac{1}{2}$ full with clean water or fertilizer solution and start agitation before adding herbicides or spray additives. If liquid or dry flowable formulations are used, they can be added directly into the partly filled spray tank. Wettable powders, however, should be mixed with a small amount of water in a bucket to form a slurry. This will ensure complete wetting, and the slurry then readily mixes with the water in the tank. If a wettable powder is to be used with other formulation types

and (or) with a crop oil concentrate-surfactant blend, the wettable powder should be treated as stated. Then after 2 or 3 minutes of agitation in the spray system, the other herbicides and (or) crop oil concentrate-surfactant blend can be added to the tank. Finish filling the tank with water or fertilizer.

Cleaning the sprayer. A sprayer should be cleaned immediately after spraying to prevent corrosion and deterioration of the spray equipment. Proper cleaning is also important to prevent herbicide residues left in the tank from injuring sensitive crops sprayed later in the season. For example, it would not be wise to have atrazine residue in the spray system when postemergence applications are made on legume seedlings.

For wettable powder, dry flowable, and flowable liquid formulations, the key is to physically flush all the material from the tank and system with plenty of water. Nozzles and screens should be removed before flushing the spray tank and cleaned thoroughly to dislodge any of the herbicide particles. Most water-soluble and emulsifiable-concentrate formulations can be cleaned from a sprayer by circulating a detergent solution through the system for several minutes and following with several clean water rinses.

Cleaning hormone-type herbicides like 2,4-D or dicamba (Banvel) from spray equipment requires extra effort. Ester formulations of 2,4-D are oil soluble and are difficult to clean from a sprayer. To clean 2,4-D ester from a sprayer, the first rinse should be made with kerosene or diesel fuel, because it will carry away these herbicides. After the first rinse, washing with warm, detergent water will help remove the oil. Further decontamination of the sprayer can be accomplished by filling the cleaned tank and lines with a mixture of wa-

ter and ammonia (use 1 qt household ammonia per 25 gal water). This mixture should be circulated through the sprayer and then allowed to stand in the closed system for 24 hours before rinsing thoroughly with water. Salt formulations of 2,4-D or dicamba are water soluble and can be cleaned from equipment by following this procedure without the kerosene or diesel prerinse.

Safety precautions. Before using any pesticide, herbicides included, a few simple rules should be reviewed to protect yourself and others from accidental poisoning and to avoid harming the environment.

- Use herbicides only when necessary.
- Read the label before each use. Follow all precautions on the label and apply only as directed.
- Store herbicides in the original labeled containers in a locked store-room marked PESTICIDES—KEEP OUT.
- Dispose of empty containers safely. Burn paper bags and fiber drums daily. Triple rinse empties that contained liquids and crush them so that they cannot be reused. Bury crushed containers.
- Do not eat or smoke when working with herbicides.
- In case of accidental poisoning with herbicides due to exposure by swallowing, inhalation, or contact with skin or eyes, contact a physician or one of the New York State Poison Control Centers for complete information as to treatment.

DIAGNOSIS OF CROP DISEASE PROBLEMS

Diagnosis of plant health problems is an essential step in problem remediation within a crop cycle or in problem prevention in future crops. Infectious diseases, caused by pathogenic microorganisms (fungi, bacteria, viruses, and nematodes), contribute annually to losses of yield and quality in New York field crops. Environmental stresses, genetic and nutritional disorders, and insect and abiotic injuries can induce symptoms that closely mimic those of infectious diseases. Practical disease diagnosis involves careful observation of the pattern and nature of symptoms in the field and the collection of extensive background information. Cooperative Extension agents and crop protection consultants can be of considerable assistance in helping to detect diagnostic clues in the field. In many instances, however, even the best field detective needs to rely on laboratory methods (e.g., pathogen isolation, microscopic examination, serological tests) to confirm a diagnosis.

Cornell University provides field crop disease diagnostic services as an educational function. Plant samples are submitted to the Insect and Plant Disease Diagnostic Laboratory, Department of Plant Pathology, 317 Plant Science Building, Cornell University, Ithaca, NY 14853. Each sample must be accompanied by a completed diagnostic checklist, which can be purchased from any County Cooperative Extension office in New York State. The value of a laboratory diagnosis depends on the condition of the



Diagnosis of crop diseases often involves laboratory analyses.

specimen when it arrives at the lab, the degree to which the sample is representative of the problem in the field, and the accuracy and completeness of the accompanying information. Your Cooperative Extension agent can provide you with guidelines for collecting plant specimens and for packaging and sending plant material to the diagnostic laboratory.

If you suspect that nematode damage is the cause of a plant problem, you may want to have a root and soil sample analyzed at the Cornell Nematode Diagnostic Laboratory. Information about proper sampling methods and how and where to send samples may be obtained from the Nematode Diagnostic Laboratory, Department of Plant Pathology, Cornell University, Ithaca, NY 14853.

CERTIFIED SEED

The blue tag of certified seed can be a helpful guide when you are choosing your grain and forage seeds. This tag assures you that the seed in the bag has passed rigorous inspections for genetic identity and for freedom from seedborne diseases and weed seeds. Seed certification is a program sponsored by state departments of agriculture and agricultural colleges to help farmers identify high quality seed. It has been in operation for over 50 years and is still going strong.

The close checks on certified seed start with its parent generation, the foundation seed, which serves as planting stocks for certified seed production. In New York, foundation seed is grown by the New York Seed Improvement Cooperative. This organization works with skilled seed growers in the planting, production, and harvest of each foundation seed crop. Trained personnel from the cooperative literally check seed fields plant by plant to eliminate offtypes, mixtures, or other contaminants. Freshly cleaned combines serve to avoid mixtures during harvest, and the seed is carefully cleaned by the cooperative's skilled seed plant operators. The final output is checked in the state seed laboratory at Geneva to assure that high quality has been maintained throughout.

Certified seed growers must plant foundation seed to produce their certified seed crop. Here the cycle begins again. Certification inspectors check seed fields for offtypes, potential seedborne disease, and objectionable and noxious weeds. Cross-pollinated crops like corn must be isolated from other fields of the same crop. Fields that do not meet standards are rejected. And again, the final product, the seed, is checked to be sure that no contami-

nation has crept in and that the final seed meets the high standards of certification.

In purchasing seed, you may find certified seed coming from states other than New York, even from Canada. Certified seed from other states normally meets the same quality standards that we apply in New York. Seed growers in other states take pride in their seed, and we have seen no certified seed coming into New York that was not first-rate in quality. For practical purposes, you can expect all certified seed to be high in quality.

CROPS FOR LATE PLANTING

New York farmers often are faced with wet, cold spring conditions that delay planting. When planting is delayed past early June, questions come up as to what crops are the best choices.

Grain corn. In areas of the state where the first killing frost can be expected around the first of October, corn for grain should probably not be planted later than June 15. After this, the risk that the grain will not be physiologically mature before the first frost becomes great. In regions where the average date of the first killing frost is later in October, the planting date can be moved after June 15 about the same number of days that the first frost occurs after the first of October.

However, in all areas of the state, it is not advisable to plant grain corn after July 1. Whenever corn to be used for grain is planted after approximately June 1, it is important that short-season hybrids be used. These early hybrids have more chance of maturing before frost and also dry down more rapidly in the field.

Silage corn. Silage corn can be planted until about July 15. Even if the grain does not mature, the crop will still produce more dry matter and TDN per acre than most alternative crops. Corn planted in early July can be expected to yield 6 to 10 tons of silage per acre. Although early maturing hybrids are preferable because they will add more grain, longer-season ones can be used for late-planted silage corn, because they will produce large amounts of total dry matter.

Summer annuals. Forage sorghum is also a good choice as a late-planted silage crop because of

its high yield potential. Sudangrass, sorghum-sudan hybrids, and millets can be used as a late-planted crop for green chop or hay. When planted late, they may produce more dry matter per acre than similarly planted corn. However, because they have a lower grain content, their feeding value is usually lower. Hence, corn is preferable for planting up to the first of July. Late planting in July and August would then favor one of these summer annuals.

Grain sorghum. If a grain crop is needed and it is so late that corn is risky, an alternative is grain sorghum. Grain yields from 90-day-maturity sorghums are usually less affected by late planting than are yields of equivalent-maturity corn. A problem with grain sorghum planted late is that it will need artificial drying.

Buckwheat. Buckwheat is another suitable grain crop for late planting, because it will mature in 75 to 90 days, and is normally planted as late as mid-July. It is very sensitive to frost, however, so planting should not be delayed too long. Otherwise, it may not mature before frost.

Small grains. Oat and barley grain yields will be poor if planting is delayed past the first of June. Later plantings, however, will make good silage. Yields of 2 to 5 tons per acre can be obtained from mid-August plantings. A disadvantage with such late plantings is that harvesting is delayed to mid- to late October when the weather may create problems.

DOUBLE CROPPING

Because of New York's relatively short growing season, double cropping is not particularly suitable for the state. Many areas lack sufficient growing degree days or have a first fall frost too early to allow a warm-season crop planted as the second crop to mature. Also, because the growing season often begins late, the first crop matures relatively late, and this then limits the second crop.

Limited double cropping may be feasible for some New York farms, however. Table 16 gives some of the possible double-cropping combinations that can be considered in different regions of the state.

In addition to these general geographical possibilities, however, some other considerations should be noted.

- Soils that are not well drained are not well suited for double cropping.
- If the soil is dry when the second crop should be planted, double cropping is not recommended.
- Because of the short growing season, for best results the second crop should be planted no-till. This is particularly true with warm-season row crops.
- It is important that the first crop be harvested as early as possible. This may require changes in harvest methods such as swathing or artificially drying a winter grain crop instead of directly combining and storing it.
- Only early maturing varieties of the second crop should be planted.
- Facilities to dry the second crop or to harvest it in an alternative way need to be available in case of an early frost or poor drying conditions.
- Presently, no specific double-cropping systems can be recommended.

Table 16. Possible double-cropping combinations in New York State

<i>No. of growing degree days</i>	<i>Double-cropping possibilities</i>
Less than 2000	Very little potential
2000–2200	Little potential Early hay crop—corn silage, summer annual
2200–2400	Some potential Same as above Rye silage—corn silage, summer annual, buckwheat Rye or winter barley—buckwheat, summer annual
2400–2600	Moderate potential Same as above two Winter wheat or barley silage—soybeans, kidney beans, sorghum, summer annual, vegetables Rye or winter barley—soybeans, sorghum Early hay crop—grain corn Oat silage—summer annual
More than 2600	Best potential Same as above three Winter wheat—soybeans, vegetables

NOTE: Summer annuals include sudangrass, Japanese millet, foxtail and proso millet, and sorghum-sudan hybrids.

Corn Production



Corn is a major field crop in New York State. Currently, 55% of the acreage is harvested as grain corn (including dry-shelled, high-moisture, and ground-ear corn), whereas the remaining acreage is harvested as corn silage. Although corn can be a profitable crop on New York farms, it is also the most expensive to produce. The high costs of seed, fertilizers, and chemicals require a high degree of crop management to obtain top yields and economic returns. Production of grain corn also requires careful management to ensure a high quality product.

GROWTH AND DEVELOPMENT

Growth and development of corn are governed primarily by hybrid maturity group and accumulated GDD. Under moist soil conditions and a planting depth of 1½ inches, corn in New York requires about 70 GDD for emergence. Consequently, an aver-

age temperature of 60° F after planting results in a 7- to 9-day emergence time, whereas a 55° F average temperature results in about a 14-day period. Understandably, dry soil conditions or a deeper planting depth delays emergence time. No-till corn requires a few more GDD for emergence because of the cooler soil temperature under the residue. Emergence can thus be delayed a day or so under no-till conditions.

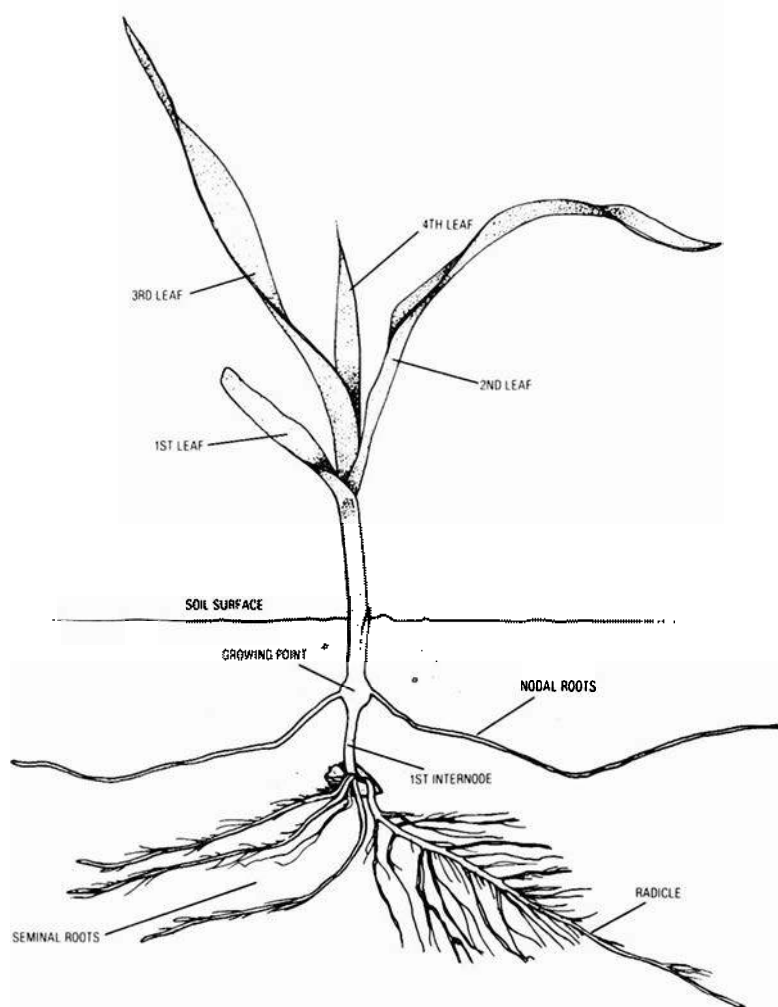
After the seed is planted, the first internode of the corn plant must elongate to push the shoot through the surface. The amount of elongation of the internode between the seed and crown area, or growing point, depends on planting depth. A shallow planting requires only limited elongation, whereas a deep planting results in considerable elongation by the first internode. Consequently, the crown area, where the permanent root system and growing point are located, is found 1 to 1½ inches below the soil surface shortly

after emergence regardless of the planting depth. Deep planting, thus, does not provide any added protection to the growing point from a freeze after corn emergence.

The growing point of corn remains below the soil surface until the 5-leaf stage or until the corn plant is about 10-inches tall. As a result, the growing point is somewhat protected from a freeze by the 1- to 1½-inch soil layer until the corn is about 10 inches tall. Depending upon hybrid maturity group, corn requires about 400 GDD from planting to the 6-leaf stage. With an early May planting date, corn in New York will be in the 6-leaf stage sometime in June, depending upon accumulated GDD at the site. A frost (28–32° F) before corn is in the 6-leaf stage will damage the leaves but probably not the growing point. Yields are only slightly reduced if a frost occurs when the corn has less than 6 leaves. A hard freeze (<28° F) often kills the growing point at this time, and subsequent crop loss is considerable. Because of microclimate effects, the loss of the corn crop stand can be patchy in a field that has encountered a hard freeze or even a frost.

The permanent root system that develops from the crown area shortly after emergence provides most of the water and nutrient uptake for the corn crop from the late seedling through physiological maturity period. Growth of the permanent root system is initially both downward and outward. By the 8-leaf stage, the permanent root system has extended to the center of the row. If cultivation or ridge construction is performed, both operations should be completed before the corn is 12 to 15 inches tall to avoid damage to this root system.

Corn in New York silks sometime between mid-July and early August, depending upon hybrid maturity group, planting date, and accumu-



The growing point of corn remains below the soil surface until the 5-leaf stage or until corn is about 10-inches tall.

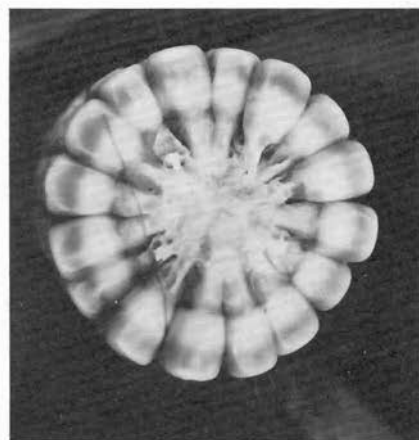
lated GDD during the growing season. A medium-early hybrid (85- to 105-day hybrids) requires about 1000 to 1200 GDD from planting to tasseling under central New York growing conditions. A long-season hybrid (105- to 120-day hybrids) requires 1200 to 1400 GDD, whereas an early hybrid (70- to 85-day hybrids) requires 800 to 1000 GDD. Hybrid maturity group and accumulated GDD, thus, determine the date of tasseling in a particular location for a particular growing season. Because planting date can strongly influence accumu-

lated GDD, the date of tasseling is also influenced by planting date.

Hybrid maturity group and accumulated GDD also determine the length of time from silking to physiological maturity. Medium-season hybrids require about 1100 GDD or 60 days from silking to physiological maturity under New York growing conditions. Long-season or short-season hybrids also influence this time period somewhat. Planting date has no influence on this time period. Planting date, however, influences the calendar date for physiological



Corn should be in the silking stage in New York sometime between mid- and late July.



When the milkline is half-way down the kernel, grain moisture is about 40% and silage harvest should commence.

maturity because of its effect on days to silking.

Black layer formation near the tip of the kernel is a visual indicator of physiological maturity. Black layer formation, however, can be difficult to determine under field conditions. Another method to determine physiological maturity is the observation of milk-line formation on the face of the kernel. When the milk line has moved three-fourths of the way down the kernel (from tip to the cob), grain moisture is around 35%, and physiological maturity has been attained. Whole-plant moisture is close to 65% at this time. Silage harvest should begin about a week before physiological maturity or when the milk line is halfway down the kernel. Grain moisture is about 40% and whole plant moisture 68% at this time.

FIELD SELECTION

Corn performs best on well-drained and moderately well drained soils (see illustration p. 139). Although corn can be produced on soils that are somewhat poorly drained, problems with timely planting and harvest often occur. Also, in wet years, corn yields are severely reduced because of poor aeration in the water-logged soils. In contrast, corn produced on excessively drained sites are favored by wet years, and very high corn yields can be achieved on these sites in wet years. Nevertheless, average corn yields are somewhat lower on excessively drained sites compared with moderately well drained sites because of short-term dry spells at critical periods of corn development (i.e., tasseling, silking, early kernel development, etc.).

Corn is intermediate in sensitivity to acid soils when compared with other field crops (see illustration p.

139). Corn does produce best, however, on soils with a pH of 6.2 to 7.0. A good liming program on acid soils frequently results in a higher cash return with corn than with other crops in the rotation. Very acid soils will result in crop failures.

Corn requires warm weather for good growth and yield. In New York State the highest corn yields are obtained in areas with the longest growing seasons and the highest amount of GDD. The development of high-yielding early maturing hybrids now makes it possible to grow grain corn in areas where the growing season is relatively short (i.e., 1600 GDD). Even so, in these areas, corn grain yields are often not high enough to compete profitably with corn silage. Also, spring barley may be a better-adapted grain crop in very cool regions.



For maximum corn production and sustained soil productivity, corn should be rotated out of a field after 3 years.

CORN ROTATION

Corn should be rotated with alfalfa or some type of grass and perennial-forage-legume mixture. First-year corn after sod has demonstrated a consistent yield advantage over continuous corn. Equally important is that higher corn yields are obtained with substantially less inputs. Soil insecticides at planting are not recommended for first-year corn under conventional tillage following a sod crop. Also, sidedressing of nitrogen is not recommended on first-year corn following a legume-sod crop. Generally, for maximum corn production and sustained soil productivity, corn should be rotated out of a field after 3 years.

When a small grain is the previous crop in the rotation, corn does not require a soil insecticide at planting. Consequently, corn can be produced more profitably when a well-planned crop rotation is used on each field.

LAND PREPARATION

The purpose of land preparation or tillage is to prepare the soil to make it more suitable for corn growth. A timely tillage operation improves the physical condition of the soil, provides a measure of pest control, and incorporates organic matter, pesticides, and fertilizers into the soil. All these factors can contribute to a high-yielding corn crop. Nevertheless, tillage in a corn system can also be detrimental. For example, on erodible soils, conventional tillage increases erosion, which subsequently reduces the sustainability of the soil and future corn yields. Also, conventional tillage under wet or excessively dry soil conditions produces clods that are difficult to break up even with intensive secondary tillage operations. Compaction is often the result of conventional tillage under these less-than-desirable soil conditions.

Corn in New York generally yields equally well or better in a conventional tillage system if plowing is

done at the proper time and at the right soil moisture level. On heavy-textured clayey soils (soil management group 1) with low erosion potential, fall plowing is recommended because the freezing and thawing action during winter breaks up clods and produces better soil tilth. In contrast, on sandy and many of the silt loam soils, fall plowing results in a somewhat poorly structured soil in the spring. As a result, spring plowing is strongly recommended on these soils.

After plowing the soil, some type of secondary tillage operation is required for final seedbed preparation. If plowing was performed at the right soil moisture level, fitting the field with a harrow or cultimulcher is often the only secondary tillage operation required. If plowing was done under somewhat wet or dry soil conditions, repeated secondary tillage operations may be necessary for suitable seedbed conditions. Because corn is a large-seeded crop, perfect seedbed conditions are not

required for emergence. Only a minimum number of secondary tillage operations is recommended for seedbed preparation for corn. An excessive number of secondary tillage operations induces more compaction of the soil and increases fuel costs.

No-till systems can be successful for corn production in New York if proper consideration is given to field selection and crop management. Advantages of a no-till system include soil erosion control, timeliness of operations (i.e., earlier planting date, especially in wet springs), reduced fuel costs, and better traction at harvest under wet soil conditions. Major challenges to a no-till corn system in New York include cooler and wetter soil conditions, the attainment of recommended and uniform plant populations, and increased pesticide costs



Corn yields equally well or better in a conventional tillage system if plowing is done at the proper time.

for adequate pest management. Most cases of corn problems under no-till systems can be attributed to one of these factors.

Field selection or soil conditions are an important consideration for a no-till system. In New York, especially in cooler regions, lack of GDD and cool soil temperatures are al-



A no-till system can be successful if proper consideration is given to field selection and crop management.

ready major constraints to successful corn production, another being wet soil conditions. Because of the residue on the surface, a no-till system results in cooler and wetter soils. In areas or fields where cool or wet soil conditions are already a constraint, no-till systems should not be practiced. If erosion is a problem at these sites, some other type of conservation practice (i.e., strip-cropping, contour strip-cropping, conservation tillage) should be used.

Because a no-till system conserves water in the soil, a no-till system may have a yield advantage where droughty soils are a major constraint to corn production. Also, excessively drained soils warm up faster than most other soils in the spring. Thus, a no-till system is well adapted to these soil conditions.

On moderately well drained to well-drained soils, careful management is essential for successful no-till corn. A major challenge in crop management is to obtain recommended and uniform plant populations. To obtain the desired plant population, good seed-soil contact at the proper depth is essential. To achieve this in a no-till system, soil conditions must be favorable and a well-equipped planter must be properly adjusted. Wet soil conditions prevent the covering wheels from closing the seed slot, whereas dry conditions can prevent the planter from penetrating to the desired soil depth. Because non-uniform populations can occur under both soil conditions at planting, planting should be delayed until soil conditions improve.

Planters without the proper attachments (i.e., tillage coulters) or driven at too rapid a speed (> 5 mph) can also result in nonuniform stands in a no-till situation. The use of trash-clearing devices mounted before the planter shoe may improve planter performance and result in more-uniform emergence of corn. Also, if the residue is cleared in the seed zone area, soil temperatures may be raised in the no-till system.

Another major challenge to corn production under no-till conditions is pest management. Tillage is a fundamental method for the control of weeds, insects, and plant pathogens. To offset the loss of tillage as a pest management technique, increased pesticide use may be necessary. For example, if weeds are present before or at planting, a knockdown herbicide is necessary for control of these weeds. Heavy crop residue may also increase the occurrence of cutworms, seedcorn maggots, adult corn rootworm beetles, or slugs. Soil-applied insecticides at planting may have to be relied on more often in a no-till situation. After the crop has been planted, fields should be carefully monitored for the next few weeks for potential pest problems. Slugs can be particularly troublesome in no-till fields during wet years.

Because no-till is the best tillage system for erosion control, its use is recommended on erodible soils on which no-till is adapted and corn is well managed. A complete residue cover, however, is not necessary for erosion control. In fact, with most crops grown in New York, only a 30% residue is required to effectively reduce soil erosion. Various conservation tillage systems (essentially anything that does not involve the moldboard plow) can be used to leave more than 30% residue on the surface. A conservation tillage sys-

tem may, thus, effectively reduce soil erosion without the degree of management problems encountered in the no-till situation.

CHOOSING A CORN HYBRID

Each corn hybrid has its own strengths and weaknesses. One may yield well, but have weak stalks. Another may yield and stand well, but be too wet at harvest. In choosing corn hybrids for your farm (or before recommending them for someone else), check each hybrid carefully. Match its strengths with your on-farm needs. Be sure that maturity, yield, and standability fit your fields and your management. You invest well over \$20 per acre in seed costs. Do not gamble this on unknown or risky hybrids.

Proper maturity selection is most important. If you plant hybrids too late for your location, you will have "soupy" silage or wet grain. Shifting to hybrids that are too early will waste part of your growing season.

The growing degree day system used in New York is explained on pages 8–9. This is based on 50 years of weather records from stations all over New York; we have found it more helpful than any other system. To determine the growing degree days (GDDs) on your farm, check your location on the map on page 8. Add 100 GDDs if you are on a valley floor or other area that warms up fast. Subtract 100 if you are on a high hill or in a frost pocket. If you cannot pinpoint this close enough, check with your county extension agent, who can help you determine your GDD level.

The corn hybrid ratings in the annual *Cornell Recommends for Field Crops* are listed according to the average numbers of GDDs needed to reach 35% moisture (i.e., physiological maturity). In choosing hybrids,

select those that require *fewer* GDDs or the same as your average. Note that the GDD rating for your farm is an average, and therefore, you will have less heat than that nearly half the time.

Always plant several hybrids to spread risks and maturities. Many farmers plant three to five varieties. These include one early hybrid that is 300 GDDs or so earlier than needed; for their major acreage, two to three hybrids that are 100–200 GDDs earlier than their average; and finally, one or two hybrids listed at about their GDD quota. Anyone planting later hybrids is risking wet corn more than 1 out of 2 years.

Growing degree days accumulate through the year. If you plant on June 1st, you will already have missed 150 to 300 GDD. To compensate, select hybrids at least that much earlier.

Other systems for rating hybrid maturities are in use, and the results can be confusing. Some midwestern seed companies describe hybrids according to their relative "days to maturity." These rarely fit New York, where our cool growing season can easily cause a "90-day" hybrid to require 120 days to reach 35% moisture. In Ontario, a different system is used. It is similar to ours, but calculated differently, and gives most hybrids ratings of about 800 more GDDs than they receive in the New York system. Still another GDD system is used by several Corn Belt companies that sell seed in New York. This compares fairly closely with New York ratings in medium- and long-season hybrids, but rates early hybrids with too many GDDs for New York conditions. At Cornell we have a study underway attempting to identify a workable and consistent system for all regions to adopt. Early indications are that conditions differ enough to make this difficult.



Corn standability is an important consideration when selecting a hybrid

High yield is everyone's goal, and most corn hybrids on the market can yield reasonably well. Still, hybrids do differ in yield potential, and there is no reason not to plant the best. Cornell plant breeders test over 200 corn hybrids annually and rate them in the annual *Cornell Recommends for Field Crops*. This is a good place to start when selecting corn hybrids, but it is not the final word. Even though these tests include sites on typical soils over the whole state, your farm is unique and may differ from test site conditions.

For further information on hybrid yield performance, check with seed company representatives, neighbors, and others who have experience with specific hybrids. Choose ones that look good in unbiased trials like Cornell's and also get good ratings from other sources. Many good corn growers like to try one or two new hybrids each year on small acreages. These should be planted next to hybrids they have found to be dependable in the past.

The ability of corn plants to stand up until harvest is another important trait. Some stalk strength is needed to keep the plant up for silage, and most hybrids on the market today can be satisfactory. However, standability for grain harvest is more critical and harder to come by. Check this carefully if you are planning to harvest part or all of your crop for grain. You can grow a weak stander for grain if its yield and maturity are right; but plan to harvest it early, as soon as it is dry enough to pick. Do not plant weak-stalked hybrids on more than a small percentage of your grain acreage.

Disease and insect resistance is the major target of most corn breeders. There is promise ahead of improved resistance to corn borers, rootworms, stalk rot, and several blights. Many hybrids already have resistance to certain leaf-blighting diseases. If you have had insect or disease problems, discuss these with your seed corn dealer or your county extension agent.

Single crosses, special crosses, and three-way crosses are now common on the market, replacing the once popular double-cross hybrids. The type of cross is important to breeders and seedpeople who must develop it. However, it is less important to the corn grower who is producing silage or grain. Single and special crosses tend to be more uniform than three-way crosses, and three-ways are more uniform than double crosses. Single-cross seed costs more per unit, although not much more on a per acre basis. The yield potential of the hybrid is of importance to you, not how it was bred. There are excellent single crosses and poor ones. The same is true for other types. Choose hybrids that have performed well in tests and done well for you or your neighbors.

Seed size and shape have little or nothing to do with crop yield or any other performance characteristic. Several years ago we compared a wide range of seed sizes and shapes, all graded out from the same lots of seed. We found plants grown from small rounds yielding just as well as those from medium flats, even large flats. They all came up at the same time, flowered together, and ripened the same way. The key is getting equal stands. This is no problem with plateless planters or with proper plate selection in plate planters.

PLANTING CORN

Planting Date

Early planting is necessary for best corn yields. Research in New York has shown that even in cold, wet springs, planting before mid-May is necessary for maximum corn yields. In central and western New York, a delay in planting after May 15 results in a grain yield reduction of $\frac{1}{2}$ and $\frac{3}{10}$ bushel per acre per day for early and full-season hybrids, respectively.

The recommended time to plant corn is 5 to 10 days before the average date of the last killing frost. In most of New York the optimum period to plant corn occurs between April 25 and May 15. Corn requires a soil temperature of 45° to 50° F to begin the germination process. Soil temperatures in most agricultural regions of the state are in this range or above during the last week of April. If soil conditions are favorable, corn planting should begin in late April in most areas. In areas where a killing freeze can occur in June, planting should be delayed until the second or third week of May.

Full-season hybrids (i.e., hybrids that match the GDD in a region)

should be planted at the late April or early May planting date. If full-season hybrids are planted early, their yield potential is usually 10 to 15 bushels higher than that of their medium-season counterparts, and maturity is not a problem in most years. The use of full-season hybrids in combination with an early planting date increases yield without a substantial increase in the variable costs. Because of the cooler conditions at the early planting date, however, the planting rate should be 10 to 15% higher than recommended for the particular soil type.

Early planted corn should be sown $1\frac{1}{4}$ to $1\frac{1}{2}$ inches deep. A somewhat shallow planting depth will accelerate the germination process, because the shallower depth warms up faster and less elongation by the internode is necessary. Also, the soil does not dry out as rapidly in late April, so moisture in the seed zone is usually not a problem at this time.

If soil conditions are wet in late April or early May, the planting date should be delayed until the soil can be worked without resulting in excessive compaction. Early planted corn seeded under compacted soil conditions will yield considerably

less than late-planted corn seeded into favorable soil conditions. As the planting date is delayed, however, the hybrid maturity group must be changed. Full-season hybrids should never be used if corn planting occurs after the second week of May in most areas. Medium-season hybrids (i.e., 100 to 200 GDD shorter than the GDD for the area) should be planted during the second, third, or perhaps fourth week of May in most areas. For late May or June plantings, early hybrids (i.e., 300 GDD or more shorter than the GDD for the area) should be used.

Plant Population

Corn populations depend greatly on soil type, planting date, crop use, hybrid selection, and tillage practices. For many New York corn soils (i.e., well-drained to moderately well drained silt loams), 20,000 to 23,000 plants per acre at harvest is the optimum range for grain corn (table 17). Soils with a higher yield potential (i.e., deep, well-drained loams with a high-moisture capacity) require 23,000 to 28,000 plants per acre at harvest for maximum grain corn yields. As the yield potential of the soil decreases because of poorly drained or droughty conditions, harvest populations must be reduced accordingly.

Various factors, such as planting date, tillage practices, pest problems, and planter performance, influence populations obtained in the field. For example, emergence of corn at an early planting date averages only 75% compared with 85% emergence at a later planting date. For a late April planting date on a moderately well drained silt loam soil, the planter should be adjusted to plant 25% more than the mean population of the optimum harvest population range (i.e., 21,500 plants per acre for a mod-



The planting of corn is one of the most important management practices.



Nonuniform stands reduce corn yields.

erately well drained silt loam soil), or about 27,000 plants per acre (21,500 x 1.25). At a mid-May planting date, the planter should be adjusted to plant 15% more than the desired harvest population, or about 25,000 plants per acre (21,500 x 1.15), on the same soil type.

It is also generally recognized that corn emergence is reduced under

no-till conditions. Data gathered at Cornell suggest that, at an early planting date under no-till conditions, the planter should be adjusted to plant 30% more than the mean of the optimum harvest population range. At a recommended or late planting date under no-till conditions, the planter should be adjusted to plant 20% more than the mean.

Corn silage tolerates higher plant populations than grain corn. For this reason, harvest populations for silage should be 2,000 plants higher than those for grain corn for each respective soil type. The planting rate for early planted silage corn on a moderately well drained silt loam soil is thus over 29,000 plants per acre (23,500 x 1.25).

Some hybrids cannot tolerate the increased plant competition at high populations, whereas other hybrids perform best at higher than normal populations. Because of the number of available hybrids on the market, the response of individual hybrids to plant populations can only be tested by seed companies. The seed companies make general recommendations (i.e., high, medium, etc.) for their particular hybrids.

Uniform plant populations in the field are as important as the number of plants per acre. Like most crops, corn will compensate for skips in the field by producing higher-yielding plants that are contiguous to the skip. Research data suggest that grain corn can tolerate a 2.0-foot skip every 20 feet without encountering a significant yield reduction. Once the skip exceeds 3.0 feet, however, grain corn

Table 17. Corn populations and soil type

Soil conditions	Grain corn		Silage corn	
	Planting rate (85% emergence)	Harvest population	Planting rate (85% emergence)	Harvest population
	Plants/A			
Very deep loams and silt loams with high moisture-holding capacity	29,325	23,000–28,000	31,625	25,000–30,000
Well to moderately well drained loams to clay loams	24,725	20,000–23,000	27,025	22,000–25,000
Sandy loams, clays, or somewhat poorly drained loams to clay loams	21,850	18,000–20,000	24,150	20,000–22,000
Sandy loams or very gravelly or shallow loams to clay loams	19,550	16,000–18,000	21,850	18,000–20,000

yields are significantly reduced. Corn silage, however, appears less tolerant of skips. The data suggest that a 2.0-foot skip every 20 feet can substantially reduce silage yields. To obtain uniform populations in the field, seed treated with a planter box fungicide and planted by a well-adjusted planter driven at the recommended speed into favorable seedbed conditions is required.

Proper planter calibration is very important in achieving recommended plant populations. Calibration can be accomplished by measuring a length that results in 1/1000 acre for the row width of the planter (table 18). Then plant along a driveway or other fairly hard surface at normal planting speed. Count the number of kernels in each row within the measured distance. Determine the average number of kernels per row and multiply this number by 1000 to get the seeding population per acre. Keep adjusting the planting rate of the planter until you achieve the desired kernel drop.

To determine plant populations in the field later in the season, measure a 50-foot length of row in several places in the field. Count the number of plants in each of these lengths and determine the average number per 50-foot length. Compare this number with the appropriate row spacing in

table 19 to estimate the number of plants per acre.

Row Spacing

Narrow-row spacing can increase grain and silage yields when other conditions are optimum for corn growth. A yield increase of about 5% can be expected when row spacing is decreased from 36- to 30-inch rows. A further reduction in row spacing down to 20 inches usually increases yields another 2-3%. If consistently good yields are not being obtained with the present row spacing, it will usually be more profitable to improve other cultural practices before shifting to narrower rows. Also, be sure that both planting and harvesting equipment can be used in the narrower-row spacing.

Poor Emergence

As soon as there is any indication of a problem with emergence, digging in the corn rows should be done immediately. Too long a delay makes it difficult or impossible to determine the cause of the emergence problem. Too long a delay can also result in a missed opportunity for correcting the problem. Factors to check when inspecting a field with nonuniform emergence include the following:

Seed not present in soil. If seed is not found in the soil where the skips

occur, the problem is probably due to the planter, planting operation, or seedbed conditions. Be sure that the planter is functioning properly and is driven at the recommended speed. With uneven seedbed conditions, the planter should be driven slowly to minimize skips.

Seed not sprouted. If the kernels are not swollen, nonsprouting indicates that the soil has been too dry. This situation can be found in no-till conditions if the seed is not fully covered with soil. Swollen but not sprouted kernels, on the other hand, often indicate that the soil has been either too wet or too cold. Swollen but unsprouted kernels also result from salt injury caused by planting the seed too close to N or K fertilizers. To prevent this type of injury, side-place the fertilizer or use smaller amounts. Germinating corn is also very sensitive to boron near the seed; so use special care if the fertilizer contains any.

If preplant anhydrous or aqua ammonia was used, long and short skips in rows scattered throughout the field indicate that the corn row happened to be directly above the N band. Injury results because the ammonia rate was too high, the placement was too shallow, or the corn was planted too soon after application. Planting directly over a urea-diammonium phosphate band can have a

Table 18. Length of row required for 1/1000 acre at various row widths

Row width (in.)	Length of row for 1/1000 acre
20	26' 2"
30	17' 5"
32	16' 4"
36	14' 6"
38	13' 9"
40	13' 1"

Table 19. Plants per acre, determined from plant count in 50 feet of row

Row width (in.)	Plant population (1000s/acre)								
	14	16	18	20	22	24	26	28	30
No. of plants in 50 feet of row									
20	26	30	34	38	42	46	50	55	60
30	40	46	52	57	63	69	75	80	86
32	43	50	55	61	67	74	80	86	92
36	48	55	62	69	76	83	90	96	103
38	51	58	65	73	80	87	95	102	109
40	54	61	69	77	84	92	100	107	115

similar effect because these compounds release ammonia.

Seeds or seedlings rotted. Rotting of seeds or seedlings suggests an attack by seed rots or seedling blights. *Pythium* is a fungus that often causes such damage because it thrives in cold, wet soil where corn germination and growth are retarded. Other fungi that may be involved are *Diplodia* and *Gibberella*. Seedlings infected with these various diseases have brown, water-soaked areas in their roots and underground stems. Rot and blight problems are almost never a problem now because most hybrids are of high-quality seed, which prevents the problem. A planter-box fungicide seed treatment should be used to eliminate the possibility of this occurrence.

Sprout twisted or leaves expanded underground. Crusting can often create emergence problems. If the crust is not broken within 2 or 3 days after germination, the leaf will open underground, and the plant is unable to penetrate farther, even if the crust is later broken. In cases where a hard rain causes crusting after planting, a rotary hoe pulled backwards, a spike-tooth harrow, or a cultipacker should be used promptly to break the crust. Crusting, however, is usually not a severe problem on corn because the coleoptile can penetrate through very hard soil conditions.

Poorly prepared, cloddy soils may also result in the leaves opening underground. Sunlight filters between the clods and reaches the seedling too soon. Proper seedbed preparation will keep this from occurring.

Twisted shoots and underground leaf opening also result if the seed is planted too deep. This can be a problem particularly in cold, wet soils where growth is delayed and the plant does not emerge before the leaf expands. Avoid this by planting shall-

low when planting early or in a wet, cool soil.

Herbicide damage can also cause twisted or thickened shoots and failure to emerge. But usually the roots are also deformed, whereas with crusting and deep planting the roots are normal. To avoid this injury, use only recommended herbicides applied at the recommended time and rate.

Seed eaten, dug up, or sprout cut off. Hollowed-out kernels are usually the work of underground insects that feed on the corn seed. Seedcorn maggots and seedcorn beetles often eat all but the seed coat. The maggots are white and about ¼ inch long; the beetle is black and about the same size. Partially eaten kernels may germinate, but usually die later. Damage is often scattered over the field and becomes greater where conditions delay germination. These insects can be controlled by a planter box treatment or a soil-applied insecticide.

Wireworms eat the germ out of kernels, attack young seedlings, and can continue feeding on the plants until they are knee-high. The insect is a slender, shiny, yellow brown worm about 1½ inches long. It is most commonly found in poorly drained areas and where corn follows sod, especially under no-till conditions. Damage is more severe in cool, wet spring weather. Because several species are involved, changing rotations usually is not effective for control. Seed treatment will help, and a soil-applied insecticide will provide extended protection. When replanting an infested field, plant between the old rows, for the wireworms will not move to the new ones.

Crows, blackbirds, pheasants, and other birds may go down the row and dig up the corn seeds. After emergence and until the plants are 6 to 8 inches tall, birds will also pull up the

young plants, eat the kernel, and leave the seedling on the ground. Mice and ground squirrels also dig up seeds and eat young seedlings. Mice, particularly, may cause serious damage in no-till situations. The plant residue provides cover for them, and sometimes they will tunnel along the furrows eating all the seeds.

When to Replant Corn

If a field does not emerge evenly or is damaged later, a decision must be made concerning replanting the field. The first step, of course, is to examine the field closely to identify the problem. Next, a stand count should be made in several areas of the field to determine the plant population in the field. Finally, the costs (i.e., seed, perhaps herbicide, insecticide, fertilizer) of replanting must be compared with the potential yield gain. In general, whenever the stand is 50% or less, replanting is recommended. If only 25–30% of the field is damaged, the answer is more difficult. One guideline is that if the population is 16,000 plants or more per acre, it is probably best to leave the original stand. A harvest population of 16,000 plants per acre on a moderately well drained silt loam soil reduces grain and silage yields 25% and 35%, respectively, in comparison with 24,000 plants per acre. An early planted crop at 16,000 plants per acre, however, will yield almost as well as a population of 24,000 plants per acre when the latter is planted 1 month later. Consequently, in this situation, replanting is not recommended. Spot planting may be helpful in areas where there are large skips. An earlier-maturing hybrid should be used in this situation, so both hybrids will be ready to harvest at the same time.

CORN FERTILIZATION

The objectives for corn fertilization are to produce maximum economic yields and to minimize the losses of fertilizer nutrients. To accomplish the objectives, both the rate and timing of the fertilizer applications are important. The fertilizer efficiency is dependent upon the overall yield of the corn; therefore, the soil pH, soil characteristics, and other cultural practices must also be considered. We are concerned with fertilizing the crop for optimum yields, not the soil.

Soil pH

Corn will grow normally over a range of soil pH from 5.8 to 7.0 or higher. If the pH falls below 5.8, some yield reduction may occur, and the efficiency of fertilizer is poor. Thus, for optimum corn production the soil pH should be maintained at pH 6.0 or above. For further information, see lime section.

Nitrogen

Nitrogen is the most difficult plant nutrient to manage within the cropping program because of its many chemical forms and conversions from one chemical form to another. The conversions of nitrogen from organic to plant-available forms (nitrate and ammonium) depend upon the climatic conditions. Fortunately, more plant-available nitrogen is released from the organic matter in the soil when growing conditions are best. If the released nitrogen is not used by the growing crop, it is lost from the system. Thus, we must estimate accurately not only the quantity of nitrogen needed by the crop, but also the quantity released by the soil system over the growing season.

No dependable nitrogen soil test is available because of the many changes in nitrogen forms that occur



Determining nitrogen needs of corn is critical to maximum economic production. The short corn (*right*) received no nitrogen, and the taller corn (*left*) received 135 pounds per acre.

during the growing season. The recommendations for nitrogen must be made on the basis of soil type, soil characteristics, yield potentials, cropping history (crop residues), and manure additions.

The recommendations for various soil and cropping situations are given in the current *Cornell Recommends for Field Crops*. Only some general guidelines will be given within this text.

Nitrogen in corn plants. The total quantity of nitrogen required in the corn plant to produce maximum economic yields has been estimated to be 1.2 to 1.3% of the total dry matter at hard dent. Since 1 ton of corn silage, at 70% moisture, contains 600 pounds per acre of dry matter, 7.2 to 7.8 pounds of nitrogen (600 lb dry matter/ton \times .012 lb N/lb dry matter) are required to be in the mature corn plants for each 1 ton of corn silage. Thus, for a 20-ton corn-silage

yield, about 150 pounds of nitrogen per acre (20 tons \times 7.5 lb N/ton) are required within the aboveground portions of the mature corn.

From the average relationship of 17 tons of corn silage per 100 bushels of corn-grain yield, obtained from research plots over the last several years, about 1.25 pounds of nitrogen are required within the corn plants per bushel of corn produced. With this value, the total nitrogen requirement (within the crop) can be estimated by multiplying the yield (in bu/A) by 1.25. For example, a 100-bushel corn crop would contain 125 pounds of nitrogen within the total aboveground portion of the plant at maturity.

The total nitrogen within the corn plant is not the same as the total nitrogen required to grow the crop, because of nitrogen losses, efficiency of plant uptake, and so forth. Consideration must be given to several

other factors in calculating the fertilizer nitrogen that must be added. These factors are (1) the soil nitrogen supply, (2) the quantity of nitrogen obtained from crop residues, (3) the nitrogen added in manures, and (4) the efficiency obtained from the added fertilizer.

The fertilizer nitrogen can be calculated by the following equation:

Fertilizer nitrogen (lb/A) = (total N required - soil N - crop residue N - manure N)/efficiency of added fertilizer.

Using this equation, one can calculate the fertilizer requirement, provided an estimate for the various sources of nitrogen and the efficiency of the added fertilizer can be determined.

Soil N supply. The soils of New York vary in their ability to supply nitrogen. The range in nitrogen used by soil test is from 30 to 100 pounds per acre per year. The variation in nitrogen supply depends upon the soil texture, drainage, and organic-matter content. A general range of nitrogen availability from the soil to the corn crop for the soil management groups are group I—80 to 100, group II—70 to 80, group III—70 to 75, group IV—60 to 70, and group V—30 to 60 pounds of nitrogen per acre per year. More specific values are used for each soil within each group by the soil-test system.

Crop residues. Various types of crop residues and rotations release plant-available nitrogen to crops grown in following years. Alfalfa and alfalfa-grass sods released 150 to 200 pounds per acre of nitrogen during the first year after plowing. The actual quantity depends on the amount of legume present at the time the sod was plowed. The release of nitrogen from the crop residue is slightly less than one-half the quan-

tity released in the previous year for each year following plowing. Thus, for an alfalfa sod there would be about 150, 60, 30, 15, and 8 pounds per acre of nitrogen supplied by the sod to the corn crop during years 1 through 5 following plowing, respectively.

Birdsfoot trefoil-grass sods will supply nitrogen at approximately three fourths the rate as alfalfa for a similar percentage of legumes in the sod. Clover-grass and mostly grass-legume sods supply one-half to two-thirds as much nitrogen as the alfalfa-grass sods, whereas grass sods supply approximately one-third to one-half as much nitrogen as alfalfa.

Manure nitrogen. The estimates used within the soil-testing system are 4 pounds of nitrogen per ton of cattle manure. This calculation assumes that the manure was applied in the fall or winter and almost all the inorganic nitrogen was lost. If the manure was applied in the late spring, 1 pound of nitrogen can be subtracted from the recommended rate of nitrogen for each ton of manure applied.

If the manure was applied in the late spring and plowed down immediately or topdressed preplant, 2 pounds of N per ton of manure can be subtracted from the recommended fertilizer nitrogen.

The nitrogen value used for poultry manure is 20 pounds per ton; for hog manure, 5 pounds per ton. The nitrogen value of liquid and (or) manure slurries is reduced according to an estimated quantity of dilution water. Refer to the section dealing with manure management for additional details.

Efficiency of applied fertilizers. When fertilizer nitrogen is applied to the soil, several types of losses may occur. The longer the time span between nitrogen application and plant uptake, the greater the nitrogen loss.

The losses for fall-applied nitrogen usually exceed 75% of the total nitrogen applied. Thus, fall applications are not recommended for applying nitrogen to corn. Spring plow-down losses generally average about 35% of the total quantity of applied nitrogen, but the loss varies from 0 to about 95% of applied nitrogen. The extreme variation in preplant losses prevents accurate adjustments of the application rate to account for the preplant losses; therefore, making the N application when the corn is 6 to 12 inches in height is the best way to prevent nitrogen loss and optimize fertilizer efficiency and response.

Calculation of the Nitrogen Requirement

By using the previous information the nitrogen requirement of the corn crop can be estimated as follows:

Example 1. Continuous corn, grain, or silage; no manure; on a Honeoye silt loam

N inputs

- Yield potential—130 bu/A shelled corn or 22 tons/A silage.
- Soil N supply—Honeoye is a group II soil with 70 to 80 lb/A N.
- Rotational N for continuous corn (5+ years since sod plowed)—rotational N = 0.
- Manure—no manure; therefore, manure N = 0.
- Fertilizer N efficiency = 0.75 for well-drained soils.

Calculations

- Total N required = 130 bu/A x 1.25 lb/bu N = 162 lb/A N.
- Fertilizer N required = (162 lb/A N - 75 lb/A soil N)/0.75 = 116 lb/A.
- Recommendation—apply 10 to 20 lb/A N in the fertilizer band and sidedress the remainder (about 100 lb/A) when the corn is 6–12 inches high.

Example 2. Corn silage 2d year following alfalfa, with 10 tons/A of manure, on a Mardin silt loam.

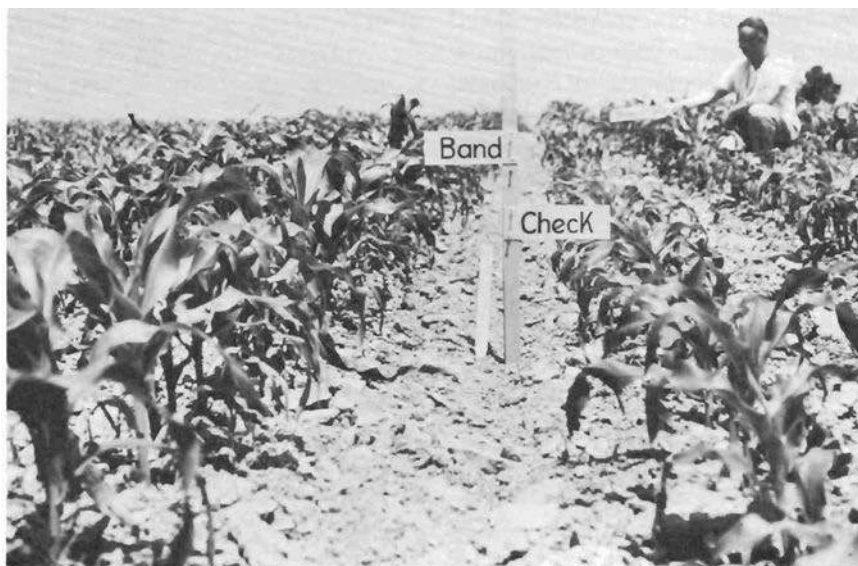
N Inputs

- A. Yield potential—20 tons/A corn silage or 115 bu/A grain.
- B. Soil N supply—75 lb/A.
- C. Rotational N—2d year following alfalfa, sod supplies a residue of 60 lb/A.
- D. Manure N—10 tons/A at 4 lb N/ton = 40 lb/A manure N.
- E. Fertilizer N efficiency = 0.70 for moderately well drained soils.

Calculations

- A. Total N required = 20 tons/A corn silage \times 7.2 lb/ton N = 144 lb/A N.
- B. Fertilizer N required = (144 lb/A — 75 lb/A soil N — 60 lb/A crop residue N — 40 lb/A manure N) = —31 lb/A N or no nitrogen required beyond starter.
- C. Recommendations—more N is available to the corn crop than will be required to produce the specified yield, but 10–20 pounds per acre N as a starter in the fertilizer band are recommended. The starter N is necessary because much of the N will not be available to the plant until the soils warm up during the early summer and mineralization of organic to inorganic N can occur.

A method for the evaluation of the nitrogen status of the corn plant is given in *Cornell Recommends for Field Crops*. This method consists of determining, at hard dent, the number of leaves that show nitrogen deficiency. If leaves above the ear show nitrogen deficiency at hard dent, too little nitrogen was used and should be increased by 10 to 20 pounds for the same situation the following year. If fewer than two to four leaves at the bottom of the plant show nitrogen



Band-placed phosphorus (*left*) promoted faster early-season growth of corn than occurred when no phosphorus was added (*right*).

deficiency at hard dent, too much nitrogen was used, and the rate should be decreased by 10 to 20 pounds for the same situation in the following year.

The efficiency of applied nitrogen fertilizers differs by soil type and drainage. In general, the efficiency of sidedressed nitrogen varies between 0.55 for poorly drained to 0.75 for well-drained soils.

Phosphorus

Phosphorus promotes rapid growth and development of seedling plants. Thus, the placement of phosphorus in a band near the seed is often more critical than the rate of phosphorus applied. The recommendations generally suggest that most, if not all, of the phosphorus be applied in the band at planting. Research has demonstrated that at least three to four times as much phosphorus must be applied in a plow-down or disk-in treatment to produce the same yield

as obtained by application in the band at planting. Yields obtained on most of New York soils show 10 to 30% yield increases from applied phosphorus. Areas that have been adequately fertilized over a period of years normally provide only 10 to 15% yield increases from applied phosphorus, but the response is variable from year to year. Cold, wet springs usually produce the most response from phosphorus.

Recommendations for phosphorus are provided through the complete soil-testing program. A complete soil test and recommendations should be obtained for corn about every 3 years. If a soil test is not available, the following recommendations may be used as general guidelines until a complete soil test can be obtained.

- *Areas not fertilized for several years.* Apply 40–60 pounds per acre of P_2O_5 , most of which should be applied in the fertilizer band at planting.

- *Areas not adequately fertilized for several years*, i.e., crops fertilized only every other year or less. Apply 40–50 pounds per acre of P_2O_5 , most of which should be applied in the fertilizer band at planting.

- *Areas adequately fertilized for several years*, i.e., rates of 30–40 pounds per acre of P_2O_5 applied each year. Apply 20–40 pounds per acre of P_2O_5 in the fertilizer band at planting.

- *Areas more than adequately fertilized for several years*, i.e., rates in excess of 60 pounds per acre of P_2O_5 per year. Apply 10–20 pounds per acre of P_2O_5 in the fertilizer band at planting.

Potassium

Corn has a fairly high potassium requirement, but most New York soils have a medium to high potassium-supplying power. Moreover, corn is efficient in potassium uptake from the soil; hence, the potassium recommendations are usually not as large as for some nearby states. The potassium recommendations also vary with soil type—the more sandy the soil, the greater the potassium recommendations.

A complete soil test provides the best means for determining the potassium requirement for corn. When a soil test is not available, the following recommendations can be used as general guidelines until a complete soil test can be obtained.

Group I, II, and III soils

- Previous crops not adequately fertilized: Apply 40–50 pounds per acre potash, either preplant or in fertilizer band.
- Previous crops adequately fertilized: Apply 30–40 pounds per acre potash, either preplant or in the fertilizer band.

Group IV soils

Increase recommendations for group I, II, or III soils by 20 pounds potash per acre for each situation.

Group V soils

Increase the recommendations for group I, II, or III soils by 40 pounds potash per acre for each situation.

Zinc Deficiency

Zinc deficiency in corn begins as an interveinal chlorosis (thin yellow stripes) usually during the 4- to 6-leaf stage of the seedling, although it might occur earlier. In more severe cases the interveinal yellow or bleached stripes will join together to form broad bands on one or both sides of the midrib on the lower two-thirds of the leaf. The bleached tissue may die. As the plants get older and the root system removes zinc from a larger volume of soil, the newer leaves may be normal. The older leaves tend to retain the striping. Silking and tasseling are delayed 2 to 6 days, and barren ears may result. When the zinc deficiency is mild (only 1 or 2 leaves per plant are affected and new leaves are normal), little or no yield reductions occur. Under severe conditions (plants stunted and 4 or more leaves show symptoms), yields may be reduced by 10 to 30% as a result of zinc deficiency.

Zinc deficiency of corn can occur on many of the soils of New York. The deficiency is more common on the originally acid soils that have been limed to pH values near 7.0. It also occurs on high lime soils with low organic matter levels such as on eroded areas or places where subsoils have replaced surface soils as in ditching.

The potential for zinc deficiency can be predicted from soil test, but the occurrence and severity are somewhat dependent on the weather conditions. Zinc deficiency is more

severe under cold soil conditions during early season corn growth. This is probably the result of limited root growth, because the root system cannot remove zinc from a large volume of soil.

There are three conditions recognized for applying fertilizer zinc: (1) Low zinc soil test low and zinc deficiency occurred in the previous crops—apply 8 to 10 pounds per acre of zinc broadcast and mix with the soil before planting. This should provide adequate zinc for the next 5 to 10 years. After about 5 years some zinc will be needed occasionally (1 to 2 lb/A zinc, every 2 to 3 yr), either broadcast or in band to maintain soil zinc levels. (2) Low zinc soil test, but zinc deficiency has not been observed—apply either 5 to 10 pounds per acre of zinc broadcast or 2 to 3 pounds per acre in the band each year for next 2 or 3 years. (3) High zinc soil test, but plant deficiency symptoms have been observed. This probably means the soil pH and phosphorus are very high, organic matter is low, and the plant roots are not developing, possibly because of soil compaction. Apply 2 to 5 pounds of zinc, either in band or broadcast.

Research on the Mt. Pleasant Research Farm has shown very little plant response to banding the zinc near the seed in the year of application, but several yearly band applications build up the soil zinc level in a manner similar to broadcast applications.

Foliage sprays have not been very successful in increasing the plant responses or yield compared with broadcasting the zinc. Thus, when the plants are extremely zinc deficient, one might try a zinc spray, but spray should not be used as a substitute for the broadcast-zinc recommendation for the following crop.



Weeds compete with crops for plant nutrients. Inadequate weed control (*in front*) resulted in nitrogen-deficient corn, but with adequate control (*in rear*) the corn was normal.

CONTROLLING WEEDS IN CORN

Weed control is essential for high corn yields. If weeds are not controlled, yields are commonly reduced by 10 to 35%. Weed competition for soil moisture, nutrients, and sunlight is responsible for much of this loss. Although late emerging weeds may be unsightly, weed competition during the first 4 to 6 weeks of the growing season is responsible for most of the yield loss. In addition to causing direct losses, weeds serve as hosts for insects and diseases. The potato stem borer, which feeds on young corn plants destroying the growing point, is most commonly found in quackgrass-infested fields, whereas maize dwarf mosaic, a corn disease, overwinters in another per-

ennial grass, johnsongrass. Other losses may result from harvest problems in weedy fields.

A variety of herbicides are available for preplant-incorporated, preemergence, and postemergence weed control in corn. The latest edition of *Cornell Recommends for Field Crops* should be consulted for recommendations on their use. These herbicides vary in their effectiveness in controlling different weeds and in the length of time they remain active in the soil. Some corn herbicides, like atrazine and simazine (Princep), can carry over to affect triazine-sensitive rotational crops like small-seeded forage legumes, small grains, and soybeans. Herbicide selection should be based on a knowledge of the weeds present, herbicide effec-

tiveness, and rotational plans.

Although herbicides can be a safe and effective method of controlling weeds, corn growers should not depend on them as their only method of weed control. Growers should employ every cultural practice known to make the corn most competitive and be willing to supplement chemical weed control programs with cultivation when difficult-to-control weeds escape herbicide applications or when weather conditions reduce herbicide efficacy.

Cultural weed control begins with the selection of a hybrid that is adapted to local growing conditions. Timely planting along with proper fitting in tilled situations or proper adjustment of no-till planters ensures rapid germination and a competitive edge for the corn. Another cultural practice that favors rapid establishment of corn is the proper band application of fertilizer at planting.

Although cultivation plays an important role in other corn-producing areas of the United States, it is not used by many New York corn growers. Cultivation is an effective way of controlling weeds in corn that is up to 2½ feet tall. Rotary hoes and finger weeders do an excellent job of destroying weed seedlings in small corn. After corn is 5 or 6 inches tall, a row cultivator should be used. Row cultivators should be adjusted to minimize pruning of the corn roots.

MANAGING DISEASES IN CORN

Diseases of corn in New York are seldom dramatically obvious; yet they constitute an important production constraint. They reduce yield and quality of grain and silage and pose an increasing threat as our acreage of corn continues to expand and corn production becomes more intensive.



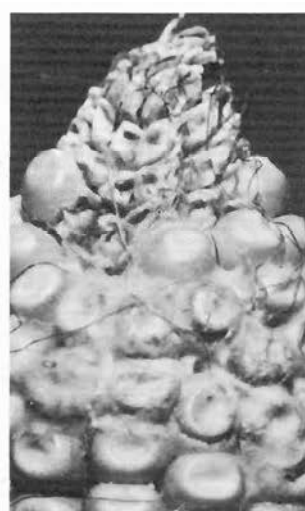
Eyespot of corn



Northern corn leaf blight



Anthracnose stalk rot of corn



Red (Gibberella) ear rot of corn

The increasing use of reduced tillage and continuous corn production is causing shifts in the occurrence and severity of diseases. Fungal leaf blights and stalk rots are the major diseases affecting New York corn. Check with your local Cooperative Extension office for recent fact sheets and other information available to aid in identification of corn diseases.

Chemicals play a relatively minor role in the management of corn diseases in the Northeast. With the exception of treatment of seed with fungicides, disease management involves the selection of hybrids with genetic resistance to diseases and the adoption of sound crop management practices.

Seed treatment for corn. During the developmental stage between seed germination and seedling establishment, the corn plant often requires chemical protection from seed rots and seedling blights caused by fungi on seed or in the soil. Treatment of seed with fungicides is always good insurance against these problems, particularly if soils are cold and wet or else excessively dry. Under these conditions the

rate of germination and seedling emergence is retarded, and the seed and seedlings are more susceptible to attack.

Most seed dealers pretreat corn with a fungicide before sale. However, there are exceptions. Growers who purchase seed not already treated are urged to thoroughly mix fungicides with seed in the hopper at planting time.

For effective planter-box treatment, chemicals can be thoroughly mixed with seed as follows:

- Half fill the planter box with seed.
- Add half the amount of chemical required for the entire planter box.
- Stir thoroughly with a stick—not with bare hands.
- Fill the planter box with seed.
- Add the remaining half of chemical.
- Stir again thoroughly.

Many seed-treating chemicals have graphite added to them to facilitate good coverage of seed.

NOTE: It should be pointed out that some seed corn is treated with

an insecticide before storage to guard against stored grain insects. This chemical treatment does not protect against seed rots or seedling blights. Consult *Cornell Recommends for Field Crops* for an updated listing of fungicides registered for application to corn seed.

Selection of disease-resistant varieties. Resistance to several diseases common to New York State is often incorporated in modern hybrids. Because no hybrid is resistant to all diseases and the importance and prevalence of diseases vary over time and location, it is important to keep up-to-date on what diseases are currently causing problems in your area. Even a moderate level of resistance is enough to prevent losses to certain diseases; other diseases warrant the highest level of resistance available. Tolerance, the ability to produce acceptable yields even though symptom development occurs, can also be selected for in hybrids. Your seed dealer can help you to select hybrids that have appropriate levels of resistance or tolerance to specific diseases.

All New York hybrids should possess good standability. Strong stalk rind characteristics may be as important as, or more important than, resistance to internal stalk-rotting organisms, although hybrids do vary in stalk rot resistance. *Gibberella* stalk rot is endemic in New York, and harvest losses occur annually, especially in fields that are otherwise stressed. Anthracnose stalk rot can be severe in certain seasons, especially in fields heavily infested with European corn borer.

Although heavy losses are rare, leaf blight epidemics are potentially devastating if they develop during or before the first 4 weeks after pollination. In addition to directly reducing grain yields, leaf blights can predispose corn plants to stalk rots and grain molds. Resistance to strongly debris-associated diseases, such as anthracnose leaf blight, eyespot, gray leaf spot, and yellow leaf blight, is most important for hybrids being sown into or near to infested corn debris as in no-till corn production.

Three leaf diseases (southern leaf blight, northern leaf blight, and northern [carbonum] leaf spot), each caused by a *Helminthosporium*-type fungus, can threaten corn yields even at a considerable distance from infested corn debris. This is because the spores of the causal fungi can be dispersed long distances by high air currents. Traditionally, hybrid resistance to these diseases has been based on single genes that condition strong resistance to the predominant fungal races. The hybrids are susceptible, however, to new races of these highly variable fungi, which occasionally appear.

Plant breeders are putting increasing effort now into the development of hybrids with partial resistance effective against all races of a pathogen. These hybrids can avoid serious losses by slowing down the rate of

epidemic development within the crop.

Diseases such as common smut and common rust are relatively minor problems today because most modern field corn hybrids have been selected for resistance to them. However, they could become severe again if we don't continue to grow resistant hybrids.

Sound crop management. Management decisions throughout the season can affect the prevalence of corn diseases. Attention to the following is important:

- **Cropping sequence.** Because many diseases of corn are perpetuated by contaminated crop debris, the practice of continuously planting corn on the same land is discouraged. This applies particularly to reduced-tillage culture. Debris-borne diseases that can build up in systems of corn monoculture include southern, northern, and yellow leaf blights, eyespot, gray leaf spot, and anthracnose.

- **Selection of planting site.** Avoidance of poorly drained soils can help to reduce stand losses caused by seed rots and seedling blights. Likewise, if a farmer has a choice, it is good policy not to plant corn in low-lying, shaded fields with poor air drainage and constantly high relative humidity. These conditions may allow serious development of leaf diseases.

- **Seedbed preparation.** Among important considerations are thorough incorporation of previous crop debris, especially if corn follows corn and diseases have been serious. Correct soil pH (6.0 or above) and fertilizing according to soil test will help plants to withstand several diseases such as stalk rot, common smut, and leaf blights. Balanced fertility is the key; in particular, avoid too much N and too little K.

- **Date of planting.** From a disease control standpoint, early planting is recommended unless soils are excessively cold and wet. Grain that is thoroughly mature at harvest is less likely to become moldy.

- **Plant population.** Dense stands can increase stalk rot, particularly if nitrogen fertilization is excessive. Where fields have a history of stalk rot, it may be advisable to reduce plant populations from those used in previous years.

- **Varietal maturity.** The tendency in New York is to select early maturing hybrids. Provided they are harvested promptly after maturity and are not allowed to stand until late fall, early hybrids alleviate ear rots associated with immature grain and early frost. But remember that stalk rot will be more severe if mature corn is allowed to stand in the field for too long.

CORN INSECTS

Corn Rootworm (CRW)

Northern CRW, *Diabrotica longicornis* (Say) (NCR)

Western CRW, *Diabrotica virgifera* (LeConte) (WCR)

How to recognize the insect and injury.

This insect is found in all the corn-growing areas of New York. The adults are beetles about ¼ inch long and are uniformly pale green (NCR) or yellow with dark stripes (WCR). The larvae are small, white to grayish white, with a brown head with well-developed mandibles. They are found in the soil at the root zone, as well as tunneling in the roots. The adults emerge from pupation in the soil about corn pollination time and attack the tassels and corn silks. Where pollination is prevented, the ears are poorly filled with grain. The



Adult northern and adult western corn rootworm beetles. Northern corn rootworm beetles are yellowish green. Western corn rootworm beetles are yellow with black stripes. Adults of both species are commonly seen in corn fields that are silking.



Corn plants damaged by rootworm larval feeding lodge in a characteristic "gooseneck" manner.



Pinhole leaf-feeding damage of first-generation European corn borer larvae.

larvae attack the roots during the early growth period; lodging, stunted ears, and reduced yields result.

Control. Corn rootworm is primarily a problem where corn is grown year after year in the same area. Rotation will reduce or even eliminate the need for chemical control. If the field is in the second or third continuous year of corn and 5% lodging due to rootworm larval feeding is present, treat the next year if it is to be planted to corn or rotate with another crop. Granular insecticides, as listed in *Cornell Recommends*, should be applied according to label instructions. Do not apply if they are not needed. Treat adults when they are numerous (more than 5 adults/plant) and feeding on silks before pollination of late varieties to reduce grain loss due to poor ear fill. Recommended insecticides for adult control can also be found in *Cornell Recommends*.

European Corn Borer

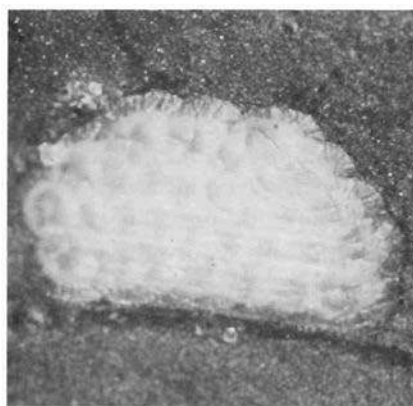
Pyrausta nubilalis (Hubner)

How to recognize the insect and injury. Signs often noted include leaf feeding by caterpillars, causing destruction of leaf surface and midrib breakage; stalk tunneling, often resulting in stalk breakage; ear damage from tunneling in the shank and

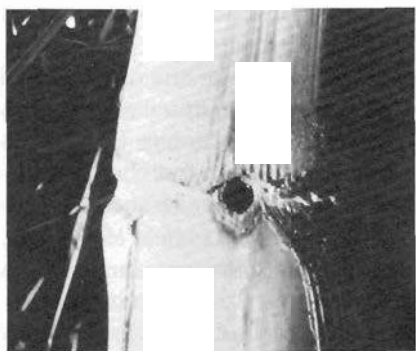
feeding on silks, cob, and kernels; wind breakage of damaged stalks; and dark frass together with dark slimy borings throughout the whole stalk.

The eggs are laid in clusters of 5 to 40 or more, fastened on the undersides of the leaves. Just before hatching, the dark heads of the caterpillars can be seen through the shells. The caterpillars when fully grown are $\frac{3}{4}$ –1 inch long, pale flesh colored, inconspicuously marked with small round spots on each body segment. The adults are medium-sized night-flying moths. The female is pale yellow brown with irregular lines in geometric patterns across the wings. The male is smaller and more heavily marked with darker brown. The moths have a wingspan of about $\frac{3}{4}$ inch.

Control. Apply recommended insecticide when 75% or more of the plants show first-generation larval feeding in the whorl. Treat for second



Egg mass of the European corn borer. Egg masses are usually laid along the midrib on the underside of corn leaves.



Stalk tunneling by second generation European corn borer larvae. Stalk tunneling can lead to harvest losses from reduced grain production and lodging problems.

generation, where found, when 100 egg masses are found per 100 plants in the row.

Corn Leaf Aphid

Rhopalosiphum maidis (Fitch)

How to recognize the insect and injury. The adult corn leaf aphid is about $\frac{1}{16}$ inch in length and dark greenish blue. The adults may be winged or wingless. They are found most commonly in late summer at the time of tassel emergence. Severely injured tassels may turn white and fail to produce pollen. Infested leaves and corn shoots often become a mottled yellow or reddish yellow.

Control. Apply recommended insecticide when the aphids are noted in numbers doing damage.

Armyworms

Pseudaletia unipuncta (Haworth), armyworm

Spodoptera frugiperda (J. E. Smith), fall armyworm

How to recognize the insect and injury. The armyworm is the caterpillar stage of a (1- to 1½-inch wing-spread) night-flying, grayish brown moth with a small silver white dot on

the center of each forewing. The moths fly at night and hide by day. The moths are seldom recognized by most people.

The fully grown armyworm caterpillar is about 30 mm or more in length, nearly completely free of any hairs, dark gray, tan to greenish black, with five longitudinal yellowish stripes, three on the back and one on either side of these. When the larvae are numerous, they are dark greenish black; when sparse, pale gray to tan.

The sixth instar caterpillar does 20 times as much feeding as do the first four instars put together and 7 times as much as the fifth instar. Damage may be seen as a simple ragging of the foliage to a complete stripping of the plant. In some cases the grass or corn may be totally destroyed.

Fall armyworm. The caterpillar of the fall armyworm is light brown to greenish brown, resembling the armyworm, with three, more or less obvious, yellowish white hairlike stripes down the back and prominent dark tubercles on the body from which hairs grow. The mandibles are conspicuously toothed, conclusively differentiating it from the armyworm. Fully grown larvae are about 30 mm long. Damage is generally similar to that of the armyworm.

The night-flying moths resemble cutworms; the front wings (40 mm wide when spread) are mottled dark gray with a conspicuous light spot near the tip.

Control. Apply recommended insecticides when larvae are found in numbers doing damage. Usually, best results are achieved in late afternoon and when larvae are 15 mm or smaller. When larvae are in fifth or sixth instar, 15–30 mm, a heavier or repeated dosage of insecticide may be needed. If it is cool, organophosphates may give poor control.



Black cutworm larvae are a corn seedling pest and are most severe on late-planted corn and corn planted in wet fields.

Bait can be used in protective furrows surrounding uninfested corn fields near infested areas. Baits should be applied in the evening and will need to be renewed every 2–3 days.

Cutworms

Some common caterpillars found on corn follow. Infestations are variable and unpredictable.

Black cutworm, *Agrotis ypsilon* (Rott.)

Dingy cutworm, *Feltia subgothica* (Haw.)

How to recognize the insect and injury. Injury in corn and other row crops occurs as areas of killed-out young plants early in the season. Digging in these areas will often reveal subterranean-feeding caterpillars. Other injury shows as stripped areas of foliage. Young plants that are wilted in the early morning may be damaged by cutworms.

Species of cutworms can best be identified by an expert only when they are in the larval stages. Cutworms are larval stages of moths. Contact your local county agricultural agent. Identification is not im-

portant in choosing a pesticide, because all pesticides listed in *Cornell Recommends for Field Crops* are effective on the species present in New York.

Control. Apply recommended chemicals to the crop in the evening. Most of these caterpillars feed at night. Baits attractive to these insects can also be used. Such baits are available commercially or can be mixed locally.

Potato Stem Borer

Hydroecia micacea (Esper)

The potato stem borer was first reported as a pest of field corn in New York in 1975. It is known to be present in Clinton, Essex, Franklin, and St. Lawrence counties. The white, active larva is brick red on its upper side. Upon hatching in May, it feeds by boring into the stems of quackgrass and orchardgrass, as well as other grasses and curlydock, around and in the cornfield. It feeds on young corn plants (2–12 in. in height), destroying the growing point of the plant and, hence, the entire plant.

Improved grassy weed control in and around cornfields will provide the best control known at this time.

HAIL OR OTHER DEFOLIATION DAMAGE

Hail or any other factor, that causes loss of leaf area during active growth, such as contact herbicides, leaf-eating insects, and leaf diseases, can decrease corn yields. Defoliation reduces the capability of the plant to manufacture sugars. The seriousness of the effect on the plant depends on the extent of damage and the stage of plant development. Some guidelines for assessing such damage follow.

When hail damages small corn plants, the effect on them is usually minor as long as the growing point is not damaged. If the growing point is destroyed, the plant is lost.

Shredded leaves on young or old plants are not a total loss because the shredding is between the veins that run lengthwise in the leaves. Although this gives a tattered appearance, as long as the leaf sections remain green and alive, the shredded leaves continue to make some sugars.

Studies have shown that simulated hail-damaged corn yielded only about 3% less grain than undamaged corn when the damage occurred at tassel emergence. Corn damaged a week later, when in full tassel, had a 17% yield decrease. When damage occurred in the early silking stage, essentially all grain production was lost. From that point on, reduction in yield became progressively less as the damage occurred later in plant development.

Another study showed that a yield reduction of less than 10% followed leaf removal at the six-leaf stage. When all the leaves were shredded at tasseling, the grain yield was reduced 63%. Earlier or later shredding had less effect. For instance, at the blister stage the average yield reduction was 40%. Breaking all the midribs at tasseling reduced yield 20%. Bruising the stalks decreased

yield 10% beyond that due to leaf shredding alone.

In general, up to silking time yield loss due to hail injury can be estimated as the percentage of final leaf area destroyed or a two-thirds reduction if all the leaf area is shredded. After silking time the yield loss is less, depending on the number of days between grain formation and damage. Losses due to other leaf-damaging agents can be estimated in the same way.

HARVESTING CORN

Corn for Silage

For top-quality silage corn silage must be harvested and stored properly. Harvesting at the correct stage of maturity is critical to obtain maximum yields of dry matter and nutrients per acre, to minimize field and storage losses, and to ensure palatability and maximize intake by animals. To attain these criteria, corn should be harvested for silage just before physiological maturity.

Corn is physiologically mature about 60 days after the corn has silked. At this point the kernels contain about 35% moisture, and the "black layer" has generally formed at the tips of the kernels. The whole plant contains about 65% moisture. Under favorable moisture and fertility conditions, most leaves will still be green, and the kernels will have begun to glaze. To obtain high-quality silage from a single field, this is the ideal time to harvest silage. Because a number of fields must usually be harvested and also because of uncertain weather conditions, silage harvest should begin a week earlier than physiological maturity. At this time, the grain moisture is about 40% and whole-plant moisture about 68%. An excellent indicator of this

stage of development is the milk line on the face of the kernel. Silage harvest should begin when the milk line is halfway down the kernel (i.e., 40% grain moisture).

If the crop is harvested too early, dry matter yield is reduced because the kernels are not completely filled. Early harvesting can also result in seepage loss because of the higher moisture in the plants. Corn harvested with over 70% moisture will seep, especially when stored in upright silos. The seepage carries with it soluble sugars, proteins, and organic acids. Cattle also eat less dry matter when fed high-moisture silage; so feed efficiency is reduced.

When corn is harvested too late, dry matter yield is reduced because of leaf loss, dropped ears, and stalk breakage. Because proper packing is also difficult, heating can result. Silo capacity is also reduced because of difficulty in packing. To help offset this, if silage contains less than 55% moisture when harvested, water should be added to bring the moisture to at least 60%. About 4 gallons of water should be added per ton for each desired 1-percentage-unit increase in moisture. If the silage is preserved well, feeding value is reduced little by late cutting.

Frosted corn should be ensiled as soon as possible after freezing to lessen the problem of dry plant material and poor packing.

Regardless of stage of maturity or dry matter content, all corn silage should be chopped at lengths between $\frac{1}{4}$ and $\frac{3}{4}$ inch. If the silage contains less than 60% moisture, a recutter screen may be necessary to get this length of cut. Finely chopped silage packs better, improves the type of fermentation that occurs in the silo, increases silo capacity, reduces spoilage losses, and increases palatability. The keys to making high-quality



Silage harvest should begin when the whole plant is at 68% moisture.

ity silage are to chop fine, fill fast, and pack tight. The type of storage structure has little effect on silage quality if these practices are followed. Also, preservatives are of little value if the corn crop is harvested and stored in the silo properly.

Corn for Grain

Grain corn can be harvested for either dry grain or high-moisture grain. Although corn is mature when the grain contains about 35% moisture, the best time to harvest depends on the method of harvest. For dry grain harvested with a picker, picker-sheller, or combine, the ideal moisture content in the kernels is 25%, and a range of 21–28% is preferred. These moisture levels minimize harvest losses. The corn must then be artificially dried down to 15.5% moisture or less for safe grain storage. The ideal kernel moisture for harvesting high-moisture grain that is to be stored in a silo is 28%,

and the preferred range is 25–30%. For ground ear corn silage the ideal harvest moisture is 32%, with a preferred range of 30–35%.

Timely harvesting of grain corn is important because lodging and ear drop are reduced, less grain is shelled off in the snapping rolls, and the chance of encountering waterlogged fields is less. To harvest the entire crop with minimum field losses, it is advisable to start harvesting just before the ideal stage. For shelled grain, however, harvesting should not begin until the grain dries down to below 30% moisture. Otherwise, considerable kernel damage occurs, and the cost of energy for drying increases.

After corn is dented, it dries at a rate of about 0.67 percentage point a day until it reaches 30 to 35% moisture content. Weather usually will not affect this drying. Below 30% moisture, if favorable weather conditions exist, corn will then dry at a rate of

0.5 percentage point a day to about 20% moisture. If the weather is too humid, however, it will take much longer to dry down.

For safe long-term storage, shelled corn should be down to 13% moisture. Even a few percentage points higher can cause the center of the bin to heat from the natural respiration of the grain. This can then cause the humidity in the grain mass to increase enough for molding to begin. Ear corn can be stored at a maximum of 25% moisture in the grain. However, narrow cribs (4½ ft wide) are necessary because of New York's high humidity. High-moisture grain requires storage in a silo or treatment with an organic acid preservative.

Because moisture is such an important consideration for harvesting and storing grain corn, a moisture tester is highly recommended.

Molds in Harvested Corn

Our climate in New York all too often brings early frosts and wet falls. Premature death of plants frequently causes grain corn to have an excessively high moisture content, which favors mold development. Wet weather at the time corn should be "drying down" likewise aggravates mold growth on standing corn and frequently delays harvest. The longer immature corn remains in the field under such conditions, the greater the potential for serious mold problems.

Conditions favoring mold growth in stored grain. Molds or fungi are the cause and not the result of spoilage in stored grains. A combination of high grain-moisture content and warm storage temperature is extremely favorable for their growth and reproduction. In the case of

"dry" corn stored in conventional structures, a kernel moisture content of 13% can be regarded as the critical threshold for mold development. Below this figure, molds will not grow; above it, mold growth increases as kernel moisture content increases and as storage temperatures rise. Temperatures of 40°–50° F will slow down growth of most storage molds, whereas temperatures above 70° F greatly accelerate their growth. Temperatures at or below the freezing point are insufficient to kill some molds. This means that molds may continue to live in a relatively inactive state in moist grain stored at very low temperatures and may later "blossom out" to cause extensive spoilage when temperatures rise. A case in point is the storage of moldy corn in cribs during our extreme winters. In the presence of high moisture and warm temperatures, abundant oxygen favors growth of storage molds. This explains the need to exclude oxygen from structures in which high-moisture corn is to be stored. The extent to which corn is molded before storage can be expected to influence subsequent mold damage in storage. As mentioned previously, immature grain exposed to wet conditions in the field may develop extensive rotting before harvest. This is often aggravated by bird or insect damage, which facilitates invasion of poorly "closed" ears by ear fungi. Ears in contact with the soil as a result of lodging or those that mature in an upright position are particularly susceptible to mold invasion. Physical injury to corn and improper cleaning may also lead to mold problems. Cracked or broken seed coats, resulting from improper combine adjustments and an excessive amount of "fines," often create conditions favorable for mold invasion.

Significance of moldy corn.

Molds can cause a variety of problems in stored corn. If they develop in grain held in bins or in ear corn stored in wide cribs, heat may be produced. This favors additional mold growth and often leads to "hot spots" in which severe spoilage occurs. Mustiness and off-flavor are frequently associated with moldy grain. These reduce palatability and subsequent acceptance by animals. The nutritional value of grain may also be lowered by molds; less intake of less-nutritious feed obviously leads to reduced animal productivity. Of greatest concern is the possibility that certain molds may produce mycotoxins (mold poisons). A greenish yellow mold, *Aspergillus flavus*, has a particularly serious potential. Some strains of this fungus may liberate poisons called aflatoxins, which can cause serious ailments such as liver cancer, convulsions, hemorrhage, and nervousness. Poultry are more susceptible to aflatoxins than mammals, of which sheep and mature cattle are the least affected. Fortunately we have not encountered aflatoxins in recently analyzed samples of moldy corn, and symptoms of severe poisoning have not come to our attention. A pink mold, *Fusarium* sp., has been common on ears of late-harvested corn in the field and has developed in storage. This fungus can produce estrogenlike toxins, which cause reproductive difficulties particularly in swine but also in poultry and cattle. Several other molds have been isolated from moldy corn in the state, and their potential for producing toxins is being investigated. Obviously, the hazard of feeding moldy corn depends on the species of mold involved, the extent of mold growth, the extent of mycotoxin production, and the species and maturity of the

consuming animals. In general, young animals are more susceptible to mycotoxins than mature ones. The identity and relative abundance of molds can be established by plant pathologists at Cornell, but unfortunately identity alone does not indicate whether mycotoxins are being produced and in what amount. The latter answers require highly sophisticated chemical tests, which can be conducted by several commercial analytical laboratories (see your Cooperative Extension agent for names and addresses). If a lot of grain is severely molded and a potential poisoning hazard exists, it would be unwise to feed it.

Mold prevention. Mold prevention is a "package proposition" that starts not after harvest but at the beginning of the growing season. Everything should be done to promote the growth and timely harvesting of a mature crop as free of insect injury, diseases, and bird damage as possible. This involves considerations such as the selection of a hybrid of the correct maturity with the maximum "built-in" disease resistance, fertilizing according to soil test, practicing effective weed control, and

keeping insects in check. Crop maturity at the time of harvest obviously affects moisture content of grain and the possibility of subsequent mold development. If possible, corn should not be harvested with a moisture content above 30%. The least field loss in combining or picking and minimal grain damage are suffered when kernel moisture is 20–25%. Proper adjustment and operation of harvesting machinery will reduce damage to kernels and the accumulation of "fines" and foreign matter. Shelled corn should preferably be mechanically cleaned and dried to the recommended level (normally 13% for long-term storage) soon after harvest. Cribs for ear corn should be sufficiently narrow to allow good thorough movement of air and should be exposed to prevailing winds. High-moisture corn can be effectively stored in airtight structures. If these are not available, the addition of organic acids (propionic or a mixture of propionic and acetic) at recommended rates will effectively prevent mold development.

Forage Crops Production



On many New York farms, corn–alfalfa rotations fit both soil resource and feed requirements.

PERENNIAL FORAGE LEGUMES

Alfalfa

Medicago sativa L.

Alfalfa is the highest-yielding perennial forage crop grown in New York. It can be harvested three times per year, yielding 4 to 8 tons of hay. Alfalfa can be grown alone or in combination with a grass. Grasses often reduce heaving and lodging of alfalfa, slow weed encroachment, and give insurance of forage production in years when there is severe winterkill of legumes.

Alfalfa should be grown on deep, well-drained soils of pH 6.8 to 7.0 or higher. Annual fertilization and insect control are required for maximum forage production.

Modern alfalfa varieties have superior resistance and tolerance to diseases. In addition to high yield potential and winterhardiness, disease resistance should be an important



Alfalfa plants heaved by freezing of wet soil. To avoid heaving damage, grow alfalfa on well-drained, fertile soils.

factor in the choice of varieties for specific sites. Alfalfa varieties that feature resistance to bacterial wilt, phytophthora root rot, Verticillium wilt, anthracnose, and Fusarium wilt are available. Farmers should choose



Birdsfoot trefoil (*left*) will grow on soil too wet for alfalfa (*right*).



Use certified seed of forages, birdsfoot trefoil (*left*) and alfalfa (*right*), for best performance.

varieties that have multiple resistance to diseases found in their vicinity.

Birdsfoot Trefoil

Lotus corniculatus

There are two general types of birdsfoot trefoil. The early, erect, Viking-type varieties serve best for hay and silage. Empire types are usually later maturing, have a somewhat prostrate growth habit, and are suitable for use as pasture or hay. Newer varieties, like Norcen, are intermediate in growth type and can serve for hay, pasture, or silage.

Birdsfoot trefoil grows well on neutral or slightly acid soil, too wet for alfalfa. Used for pasture, trefoil will not cause bloat in cattle. If allowed to reseed, it will persist for many years.

Red Clover

Trifolium pratense L.

Red clover is a short-lived perennial. In most instances, very little forage production can be expected the second year after establishment. Red clo-

ver will grow on soils too acid or wet for alfalfa. Red clover should *not* be included in alfalfa-grass mixtures. The clover seedlings compete severely with the alfalfa. This leaves a



In pastures, seed pods of birdsfoot trefoil will shatter seed onto ground. New plants will develop to maintain stands over many years.

thin alfalfa stand after the clover dies out.

Several new red clover varieties now on the market offer promise of an extra year of production and

added yield by having resistance to anthracnose, a major disease of red clover in New York.

There are two general types of red clover: medium, which is early flowering and produces several crops per year, and mammoth, which is late flowering and produces a single crop and very little aftermath. Most red clover varieties grown in the United States are the medium type.

True mammoth red clover will often establish under more-difficult conditions, such as dry or acid soils, than will medium clover. It develops no stems the first year, only basal leaves from the crown. Plants in the first year are leafy and short compared with medium clover. Second-year growth of mammoth is also different from medium clover. Mammoth clover blooms 10–14 days later, stems are thicker, and first-growth forage yields usually are greater than with medium clover. There is very little second, or aftermath, growth of mammoth red clover. Mammoth is most frequently used as a crop for plow-down.

Ladino White Clover

Trifolium repens L.

Ladino is a large type of native white clover. It makes particularly high quality pasture for livestock. Ladino does well in years with frequent rains. But it has a shallow root system and lacks sufficient drought tolerance to survive prolonged dry spells. Because of bloat hazard and the low midsummer yield of ladino, birdsfoot trefoil is a preferred pasture species.

Several varieties of ladino clover are available. In New York no difference has been noted in drought survival or production between these varieties.

White, wild white, and Dutch clovers are interchangeable names for low-growing strains of white clover, *Trifolium repens*. These volunteer naturally on well-limed pastures in most of New York. They rank far below ladino in yield and drought susceptibility. As volunteers these may add minor value to pastures, but yields are too low to make them worth sowing. If a pasture-type white clover is desired, sow ladino.

Alsike Clover

Trifolium hybridum L.

Alsike clover will grow on wet, acid soils. It is not considered a desirable pasture or hay plant because of sensitivity to heat and dry soils.

Crownvetch

Coronilla varia L.

Crownvetch is widely used to control erosion on roadbanks and other steep or erosive sites. One advantage is its ability to spread by underground roots and natural reseeding. It is used for hay or pasture, although long stems make curing and harvest as dry hay difficult. Forage yields are approximately the same as for birds-



Flowers of legumes grown in New York: left to right, alfalfa, birdsfoot trefoil, red clover, crownvetch, white clover.

foot trefoil. Like birdsfoot trefoil, crownvetch does not cause bloat. Crownvetch should be grown on well-drained, slightly acid to neutral soils.

PERENNIAL FORAGE GRASSES

Timothy

Phleum pratense L.

Timothy is commonly used as a companion grass for alfalfa and birdsfoot trefoil. It is widely adapted and can be established in early spring or late summer. Regrowth and midsummer production after first harvest are not as great as regrowth of smooth bromegrass or orchardgrass.

Timothy is less competitive with alfalfa and trefoil than are other grasses; yet it can contribute substantially to first harvest yields. Timothy sometimes has difficulty surviving in alfalfa fields that are cut three to four times per year. Even so, enough timothy plants normally persist to provide insurance against stand loss.



Timothy makes an excellent companion grass for alfalfa, birdsfoot trefoil, or clover.

Smooth Bromegrass

Bromus inermis Leyss

Smooth bromegrass is an excellent companion grass for alfalfa. It makes good regrowth after first harvest. Although relatively slow to establish, it spreads by short rhizomes to form a dense sod. Bromegrass sometimes has difficulty persisting in alfalfa fields under three-cutting management, particularly when the first cutting is taken early.

Orchardgrass

Dactylis glomerata L.

Orchardgrass is a vigorous grass with more potential for midsummer growth than timothy or bromegrass. It is excellent for pasture because of early spring growth and good midsummer production. Orchardgrass is not as winterhardy as timothy or bromegrass and will not persist on wet soils.

Improved varieties of early and late maturity are available. Most of these outyield the common strains. Where improved forage quality is desired, later maturing varieties may be preferable.

Tall Fescue

Festuca arundinacea Schreb

In New York tall fescue is used primarily for conservation purposes. It can be used in pastures, although palatability in midsummer is relatively low. It grows well on poorly drained or well-drained soils and spreads slowly by underground stems to form a tough sod, tolerant of treading and overgrazing.

If tall fescue is to be used as a forage, the new fungus-free or endophyte-free varieties should be used for improved animal performance.

Reed Canarygrass

Phalaris arundinacea L.

Reed canarygrass is noted for its ability to do well in wet areas and on poorly drained soils. It also can produce high yields on well-drained, even droughty soils. Like orchardgrass, it matures early and should be used early in the season before palatability declines. Viability of seed declines more rapidly than for other species. Germination of carry-over seed should be checked before planting.

For increased palatability and animal performance, use varieties having low alkaloid content.

Kentucky Bluegrass

Poa pratensis L.

Kentucky bluegrass is most productive in the spring or during periods of cool, moist weather. Although slow to establish, it spreads by underground rhizomes and forms a dense sod. It is very palatable and a favorite of horses.

Perennial Ryegrass

Lolium Perenne L.

Ryegrass is a vigorous, moderately winterhardy bunch grass, which grows best during cool, moist periods. Seedling growth is very rapid, so ryegrass can be rather competitive when grown in combination with slower-growing legumes and grasses. At similar stages of maturity, ryegrasses are of higher quality than other cool-season grasses such as timothy and bromegrass. Ryegrass can be used for both pasture and hay.

Grazing horses on ryegrass or ryegrass straw can sometimes result in a condition called "ryegrass staggers." To eliminate the potential for appearance of this condition, do not include ryegrass in the diet of horses.

Warm-Season Grasses

Warm-season grasses that have been grown and tested in New York include switchgrass, *Panicum virgatum*; big bluestem, *Andropogon gerardii*; and Indian-grass, *Sorghastrum nutans*. Of these, switchgrass appears the most promising for trial on New York farms.

Switchgrass starts growth at about 55° F and reaches optimum growth at 85°–90° F. Switchgrass is more productive than the cool-season grasses like timothy or bromegrass during hot, dry periods of midsummer. Switchgrass will grow on moderately well drained to excessively drained soils. It will not persist on wet soils, particularly during early establishment when plants are small and susceptible to heaving. It grows best on fertile, slightly acid to neutral soil (pH 6.0–7.0), although it will tolerate low pH (pH 5.0–5.5) and low fertility.

Switchgrass is slow to establish and so requires careful attention to seedbed preparation and control of weed competition. The best use of switchgrass in New York is for conservation plantings or for late midsummer pastures.

Brassica Species: Rape, Kale, Turnip, and Swede

Brassica crops can be grown as forage crops for livestock. Leaves of rape and kale, and roots and tops of turnip and swedes can be pastured by various classes of livestock and provide highly digestible forage, particularly during late summer to late fall. These crops are annuals or biannuals, so the yearly cost of establishment and growing the crop must be compared with their value as pasture to determine their economic value in pasture management programs. Check with crop specialists for specific information on latest variety and management recommendations.

MIXTURES OF PURE STANDS OF LEGUMES AND GRASSES

Adaptation of Legume and Grass Mixtures

Soil conditions are important criteria in selecting forage crops for your farm. Because of the variable soil conditions in New York, several mixtures are often used on the same farm to optimize forage production potential.

The forage mixtures recommended for specific soil conditions are listed in table 20.

Legumes are usually grown with a companion grass. In New York, timothy and brome grass are the two most important companion grasses grown with alfalfa. On well-drained soils straight alfalfa will yield about the same as an alfalfa-grass mixture. Alfalfa-grass mixtures are superior to clear alfalfa on soils having marginal drainage. Advantages of alfalfa-grass mixtures on these soils include (1) less heaving and winterkill, (2) slower weed encroachment, (3) higher yield, (4) more-rapid curing, and (5) less lodging.

Pure stands of legumes must be grown when using Eptam, Balan, or other grasskilling herbicides for establishment. If weed problems dictate the use of such herbicides, there is little alternative but to grow straight legume, even though a mixture would be more desirable.

Overseeding legumes with grasses is not a reliable practice. However, if moisture conditions are favorable and competition is not too great, grasses overseeded in legumes may establish if seeded in late summer after harvest of the legume or in early spring before growth starts. The risk is great for overseeding in this manner; so investment in this practice is a gamble.

Table 20. Forage mixtures

Soil conditions and desired managements §	Crop	Variety*	Seeding rate (lb/A)
Well-drained soils, early first cut, 3 to 4 cuttings	alfalfa	Saranac, Saranac AR, or Iroquois	8–12‡
	and timothy or brome grass or orchardgrass	Climax or Champlain	4–6
		Saratoga	5–8
		Pennmead or Pennlate	4–6
Moderately to well drained soils, 2 to 3 cuttings	alfalfa	Iroquois	8–12‡
	and timothy or brome grass	Climax or Champlain	4–6
		Saratoga	5–8
Variable drainage with spots in field too wet for alfalfa, 2 to 3 cuttings	alfalfa	Iroquois	6
	birdsfoot trefoil and timothy	Viking	4
		Climax or Champlain	6
Poorly to well drained soils, long-term hay or pasture	birdsfoot trefoil and timothy	Viking or Empire	6–8
		Climax or Champlain	4
Poorly to well drained soils, short-term hay 1–2 years	red clover and timothy	Pennscott	6–8
		Climax or Champlain	6
Poorly drained soils often flooded, long-term pasture	reed canarygrass		8–10
Moderately to well drained soils, grasses for hay or pasture	timothy or brome grass or orchardgrass	Climax or Champlain	8
		Saratoga	10
		Pennmead or Pennlate	10

*See pages 104–107 for other recommended varieties.

§See page 16 for descriptions of soil drainage classes.

‡When making spring seedings of alfalfa without a companion crop, increase seeding rate to 15–18 lb per acre and control weeds with herbicides.



On many soils, alfalfa-grass mixtures (*left*) are more productive than clear alfalfa (*right*).

ANNUAL CROPS FOR FORAGE

Annual crops can be used for mid- to late-summer forage production. Several of these are described here, and species, seeding rates, and seeding dates are given in table 21.

Sorghum and Sorghum-Sudangrass Hybrids

Sorghum and sorghum-sudangrass hybrids are used for summer green chop, pasture, or silage. Because of coarse stems and heavy growth, they are generally not used for hay. Growth during high midsummer temperatures is very rapid, so that first harvest can be made 6 to 8 weeks after planting. Early first harvest allows time for regrowth and additional harvests. Rapidly growing stands can be harvested two to three times per season.

Many sorghum-sudan varieties and brands are available, with most coming from seed company breeding programs. Cornell tests have noted only small differences between varieties in yield, vigor, and regrowth potential.

Table 21. Annual forages

Species	Date of seeding	Seeding rate per acre	Pounds per bushel	Approximate dry matter yield
				Tons/acre
Sorghum and sorghum-sudangrass hybrids	May 20–June 10	20–40 lb	50	3.0–6.0
Sudangrass	May 25–June 15	30–50 lb	40	2.5–3.5
Oats	Early spring	2–3 bu	32	2.0–3.0
	August	2–3 bu	32	1.0–2.0
Rye	Aug. 15–Oct. 15	2 bu	56	—
Wheat	Sept. 5–Oct. 1	2 bu	60	—
Millet	July 1–July 10	½ bu		
Japanese			32	
German, Hungarian, common			48–50	

Forage sorghums tested in Cornell trials have been inferior to sorghum-sudan hybrids in yield, thicker stemmed, and generally less desirable for green chop or pasture.

Black Amber, once popular as an annual forage in New York, is now obsolete. Farmers considering annual

forages will gain more and better feed from a sorghum-sudan hybrid.

Sudangrass

Sudangrass, a fast growing annual, has finer stems than sorghum and is sometimes used for hay. It is excellent

for pasture, green chop, and silage. Rapid regrowth allows two to three harvests with dry matter yields of 2 to 3 tons per acre.

Sudangrass varieties and hybrids tend to be lower in prussic acid content than do sorghum-sudan hybrids. They also tend to be lower in yield.

Piper has continued to be the most popular variety of sudangrass for the past two decades. Developed for low prussic acid content, *Piper* yields well, fitting into pasture and green-chop management programs.

Sudangrass hybrids are also available. These generally outyield *Piper* and are similar in having low prussic acid content. Several varieties are marketed by seed companies serving New York. Though they tend to outyield *Piper*, overall difference has not been great.

Prussic acid poisoning. Sudangrass and sorghum contain a substance that can release a poison, prussic (hydrocyanic) acid. To avoid animal poisoning, graze green forage when plants of sudangrass are 18 to 20 inches or taller and sorghum or sorghum-sudangrass hybrids are 24 to 30 inches or taller. Do not graze new regrowth that develops after a frost or a period of dry weather. This regrowth often contains high levels of prussic acid. Plants that are frozen should be completely dried out before feeding.

Do not graze horses on sudangrass or sorghum-sudangrass hybrids. These crops cause a serious condition in horses called cystitis syndrome.

Spring Oats

Oats planted in early spring and grazed or chopped early will regrow sufficiently for an additional harvest. Normally, they can be pastured 5 to 7

weeks after planting. For silage, harvest at the early heading or milk stage. Late summer planting can provide some grazing during September and October. Oats grow well during periods of cool temperature, which would restrict growth of sorghum or sudangrass.

Wheat, Barley, or Rye

The small grains wheat, barley, and rye provide grazing in the fall and early spring if sites are dry enough to support animals. If grown for grain, these crops can be grazed lightly in fall and early spring until shortly before plants begin to grow erect or stems begin to elongate. Grazing after stems elongate will severely reduce grain yields.

Rye is best for fall and spring pasture, for it is not damaged by Hessian flies when planted early; also it grows at cooler temperatures and provides later fall and earlier spring pasturage than do other winter grains.

Millets

Millets are occasionally used as emergency forage crops for late planting where other crops have failed or could not be planted. Japanese millet once found common use on poorly drained soils that stayed wet late into June. German millets are also used for this purpose. None yield as much as the sudans and sudan-sorghum hybrids, but they are easier to make into hay.

For best-quality hay, cut the plants at the bloom stage. Curing being somewhat slow because of the thick stems, conditioning is recommended. For grazing, it is usually best to begin about 6 to 8 weeks after planting or when the plants are 6 to 12 inches tall. After this stage, the nutritive value for grazing decreases.

FORAGES FOR CONSERVATION

Table 22 lists grasses and legumes useful for permanent cover and conservation plantings. Use those species best adapted to existing soil conditions. If possible, use species with rhizomes, for they tend to spread and fill in bare spots. Seeding rates in pounds per acre can be converted to pounds per 1000 square feet by multiplying by the factor .023. For example, 15 pounds of seed per acre $\times .023 = 0.34$ pound of seed per 1000 square feet.

Cover Crops

Both grasses and legumes can be used as cover crops to protect soils from erosion, increase water infiltration, and maintain soil organic matter and structure.

Winter rye is one of the best cover crops for fall planting. It is easy to establish and, planted early, provides good soil cover during the winter. Spring growth is rapid, but can be controlled with tillage or herbicides. Of all the small grains, winter rye is the most tolerant of atrazine. See table 21 for seeding rates and dates.

Winter wheat, barley, and ryegrass are also used for winter cover. Ryegrass can be seeded into row crops in the summer without seriously competing with the crop. Both annual and perennial strains of ryegrass are available.

Oats seeded in August will make considerable growth during the fall. Plants winter-kill, but provide a protective layer of vegetation during winter and spring.

Table 22. Grasses and legumes used for conservation plantings***Agrostis alba* L.—Redtop**

Quite tolerant of acid, poorly drained soils. Emerges quickly to form protective cover. Is low growing and spreads by stolons or creeping stems. Although vigorous in the seedling stage, redtop does not seriously compete with slower growing species. Seed 5–10 lb per acre.

***Alopecurus arundinaceus* Poir.—Creeping Foxtail**

A broadleaf, cool-season grass which grows well on wet, acid soils. Plants are strongly rhizomatous and start growth early in the spring. Light fluffy seeds and slow seedling development sometimes make planting and establishment difficult. Seed 5–10 lb per acre.

***Andropogon gerardi* Vitman—Big Bluestem and *Andropogon scoparium* Michx.—Little Bluestem**

Warm-season grasses having dense root systems and growing in large clumps. Under favorable conditions big bluestem grows up to 6 ft tall and little bluestem up to 3 ft tall. Little bluestem is more drought resistant than big bluestem. Seed 10–15 lb per acre.

***Bromus inermis* Leyss.—Smooth Bromegrass**

A winterhardy forage grass, which spreads by rhizomes (underground stems) to form a coarse, dense sod. Is very tolerant of heat and drought. Grows on a diversity of soil types but is not tolerant of poorly drained areas. Has good seedling vigor, but is slow to establish a sod. Seed 10–20 lb per acre.

***Coronilla varia* L.—Crownvetch**

A winterhardy perennial legume which requires well or moderately well drained soils. Spreads by creeping underground roots. Will persist on moderately acid soils, but seedling growth and establishment are improved by liming acid soils before planting. Seed 10–15 lb per acre.

***Eragrostis curvula* (Schrad.)—Weeping Lovegrass**

A warm-season bunchgrass having rapid early growth. Spread by tillering so that individual plants may be 12 to 15 in. in diameter in 2 to 3 yr. Will grow on low-fertility soils. Seed 1–3 lb per acre.

***Festuca arundinacea* Schreb.—Tall Fescue**

Tolerates poor drainage and can survive flooding in the winter. Will grow on alkaline or saline soils. Although considered a bunch-type grass, tall fescue spreads slowly by short rhizomes. Produces a coarse, tough turf that resists traffic. Not as winterhardy as smooth bromegrass or timothy. Seed 10–25 lb per acre.

***Festuca rubra* L.—Creeping Red Fescue**

A cool-season grass which spreads by underground stems. Adapted to a wide range of soil types. Tolerant of dry sites and valued for its shade tolerance. A short grass used for mowed areas or general purpose turf. Seed 15–40 lb per acre.

***Lathyrus sylvestris* L.—Flatpea**

A perennial, rhizomatous legume with long, viney stems. Not adapted to wet sites, although will persist on moderately well drained soils. Seedlings are slow to develop, but once established, plants are vigorous and form a thick vegetative ground cover. Variety Lathco developed by Soil Conservation Service, Big Flats Plant Materials Center, Big Flats, New York. Seed 25–35 lb per acre.

***Lolium perenne* L.—Perennial Ryegrass**

A bunchgrass having very rapid seedling growth. Can winter-kill in northern states. Tolerates wet soils and can stand short periods of flooding. Used to provide quick protective cover on exposed soils. Unsuitable for droughty sites. Seed 25–35 lb per acre.

***Lotus corniculatus* L.—Birdsfoot Trefoil**

A winterhardy perennial legume adapted to well or poorly drained soils. Under favorable conditions trefoil will spread by reseeding. Tolerant of medium acid soils. Seed 5–10 lb per acre.

***Panicum clandestinum* L.—Deertongue**

A rhizomatous, warm-season, perennial grass with wide adaptation on sandy to silty clay loams and soils with pH as low as 3.8–4.0. Useful for mine spoil areas, gravel pits, and sandy roadbanks. Variety Tioga developed by Soil Conservation Service, Big Flats Plant Materials Center, Big Flats, New York. Seed 10–15 lb per acre.

***Panicum virgatum* L.—Switchgrass**

A perennial, warm-season grass with short rhizomes and coarse stems. Has good seedling vigor and is best adapted to moist, fertile soils. Will tolerate acid soils, pH as low as 4.0 to 4.5, and droughty sites. Seed 10–15 lb per acre.

***Phalaris arundinacea* L.—Reed Canarygrass**

Will grow on poorly or well drained soils. Is tolerant of both flooding and drought. Especially suited to swampy areas. Spreads by short rhizomes which can be used for vegetative propagation. Seed germinates slowly and loses viability after 1 yr of storage. Use only fresh seed. Tolerates a pH range of 4.9–8.2. Seed 5–10 lb per acre.

***Poa pratensis* L.—Kentucky Bluegrass**

Grows best on well-drained fertile soils. Establishes slowly, but spreads by rhizomes to make excellent smooth turf. Becomes dormant during hot, dry weather. Used as both lawn and pasture grass. Seed 15–25 lb per acre.

STAND ESTABLISHMENT

Preparation of Seedbed

Small-seeded legumes and grasses require a fine, firm seedbed. A fine surface promotes uniform depth of planting, and a firm seedbed aids in bringing soil moisture to the surface for the seed. The use of large tillage equipment often results in a very loose seedbed, which may require firming with a cultipacker or roller before planting. Fine-textured soils should not be overworked or compacted, for this increases the possibility of crusting and poor emergence.

Seeding Rates

Seeding rates vary for different forage crops. In general, the amount of seed planted is between 40 and 100 seeds per square foot. For most legumes and grasses only 6 to 8 plants per square foot are needed in established stands for maximum forage production. Seeding rates for specific forage mixtures are listed in table 20.

Table 23 gives the number of seeds per square foot at a seeding rate of 1 pound of seed per acre.

Table 23. Forage seed numbers

Species	Seeds/lb	Approx. seed/sq ft at 1 lb/A
Alfalfa	200,000	4.6
Birdsfoot trefoil	375,000	8.6
Red clover	275,000	6.3
Crownvetch	110,000	2.5
Timothy	1,230,000	28.2
Bromegrass	136,000	3.1
Orchardgrass	654,000	15.0
Reed canary-grass	533,000	12.2
Bluegrass	2,177,000	50.0



A fine, firm seedbed (*left*) is necessary for good establishment of small-seeded legumes and grasses.

Coated Legume Seed

Coatings used on alfalfa seed contain various combinations of rhizobium bacteria, lime, nutrients, and bonding substances. Coatings are intended to improve emergence and establishment of alfalfa. To date, tests in New York have shown no difference in forage yields when coated or uncoated seed is used. However, with the use of coated seed over a wide range of soil conditions, benefits may occur in some cases.

When planting coated seed, use the same seeding rate normally used for uncoated seed. For example, if the normal seeding rate is 10 pounds of alfalfa per acre, plant enough coated seed to equal 10 pounds of actual seed per acre (50 seeds per sq ft). Using lower seeding rates than recommended will result in poor stands and low forage yields.

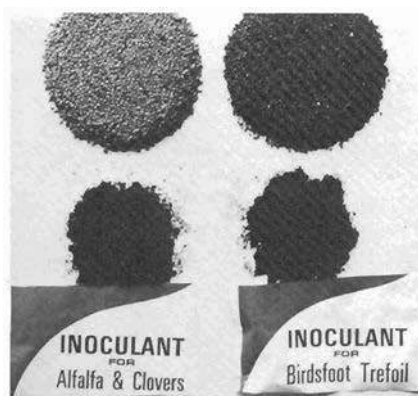
Inoculation of Legume

Legume seed should be mixed with the proper rhizobium inoculum shortly before planting. The inoculum contains bacteria that form nodules on the legume roots and fix nitrogen from the air. Treated seed that has been stored should be reinoculated to ensure that viable bacteria are present on the seed at the time of planting. Proper inoculation is particularly important for legumes planted in fields where they previously have not been grown.

Seeding Method

Seed should be distributed uniformly and covered with $\frac{1}{4}$ to $\frac{1}{2}$ inch of soil. In late spring or summer when soil is dry, slightly deeper placement into moist soil will aid emergence. After sowing seed, firm the soil with roller, cultipacker, or press wheels.

If a grain drill is used for seeding, seed tubes should be attached so that



Inoculate legume seed with proper rhizobium inoculum shortly before planting.

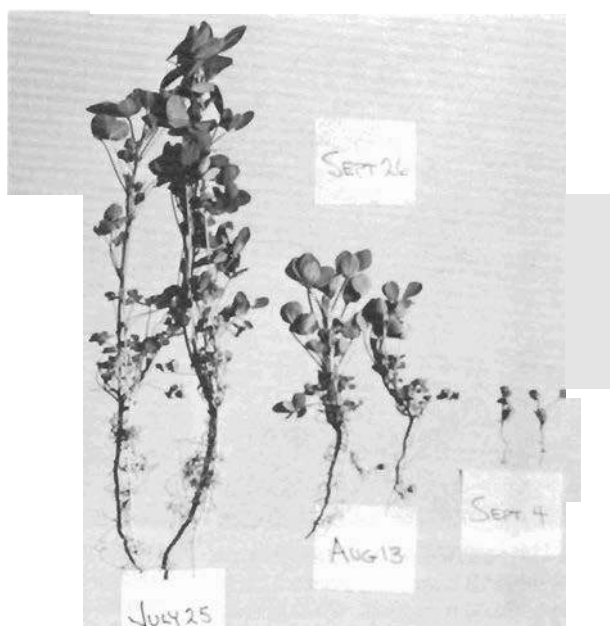
seed is placed on the soil surface directly above the band of fertilizer. Band seeding is particularly desirable on low-fertility soils.

Seeding with a Small Grain

Forage legumes and grasses are often seeded with spring oats or winter wheat. Seeding in wheat can be done in the fall or early spring. Reducing the seeding rate of the small grain companion crop is desirable to reduce competition to the forage plants.

Seeding with a companion crop has several advantages. The small grain can (1) decrease soil erosion, (2) be used for grain and straw, and (3) slow the growth of weeds.

Small grain companion crops compete with forage seedings for light, nutrients, and water. Lodging of the grain can also be detrimental. For these reasons better stands of legumes can often be obtained when seeded without a companion crop. The competitive effect of the companion crop on the forage seeding is greater when the companion crop is harvested for grain than when it is green chopped or cut for silage.



Make summer seedings of alfalfa no later than mid-August. Alfalfa seeded on (from left) July 25, August 13, and September 4. Photo taken September 26.

Seeding without a Small Grain

Under favorable weather conditions, legumes or legume-grass mixtures seeded without a companion crop will produce enough growth for harvest in the seeding year. Alfalfa planted in early May can be harvested in July and again in 6–7 weeks. Forage yields of 2–4 tons of alfalfa per acre can be harvested in the seeding year.

To obtain good yields in the seeding year, weeds must be controlled with herbicides or by timely mowing. Herbicides are available for control of both weedy grasses and broadleaf weeds.

Date of Seeding

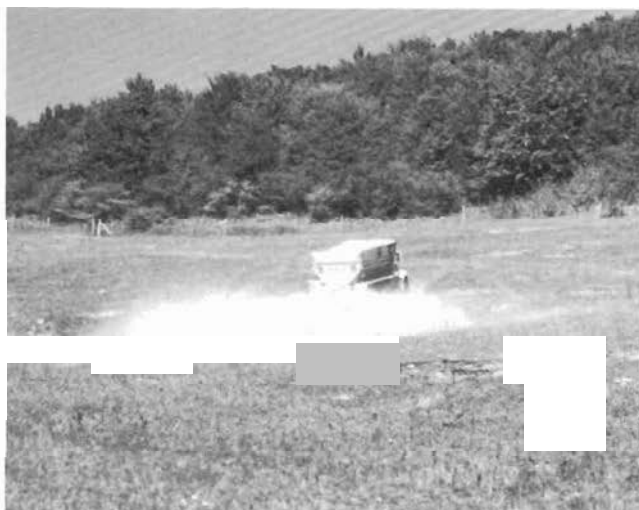
During the seeding year, forage plants must develop sufficient size to resist low winter temperatures and spring heaving. Forages should be seeded early enough to allow adequate growth. In most areas of up-

state New York, alfalfa should be seeded before August 15; and birdsfoot trefoil, before July 15.

The advantages of seeding in early spring are more-frequent rains, longer growing season, and production of 2–3 tons of hay per acre. Later summer seedings also have several advantages: forages can follow another crop; tillage, liming, and fertilization can be accomplished on wet fields; and germination and growth of weeds are less in fall than in spring. In general, forage production the year after seeding is greater for early spring than for late summer seedings.

Liming for Legume Establishment

An adequate soil pH is one of the most important factors in achieving good legume stands. The lime recommendations should be obtained from a complete soil test. See the sec-



Proper liming for correct soil pH is essential for good crop production, especially with legumes.



A soil pH near 7.0 is necessary for maximum alfalfa production and stand longevity. The shorter plants are mostly weeds, growing on an acid soil the first year after alfalfa establishment. In contrast, the area where the taller alfalfa plants are growing received 6 tons per acre limestone the year before seeding.

tion on lime, page 30, for additional information.

Alfalfa requires a soil pH of near 7 for maximum productivity and stand longevity. Seeding alfalfa into soils with pH values less than 6.5 is inviting failure or shortened stand life. Apply lime after plowing and mix into the seeding zone when the soil pH is 5.8 to 6.6. If the pH is below 5.8, apply the lime 6 months to 1 year in advance of seeding. A split application of about one-half of the lime before and after plowing will usually give the best results on very acid soils or when large quantities of lime (greater than 4 tons) are required.

Birdsfoot trefoil requires a soil pH near 6.5 for maximum production. Birdsfoot trefoil will establish under lower soil pH values than 6.5, but production and longevity are significantly reduced. For soil pH values of 5.6 to 6.0, apply the lime and mix into the seeding zone. When the pH is below 5.6, apply the lime 6 months to 1 year before seeding. About one-half

of the lime should be applied before and after plowing.

Clovers should have a soil pH of about 6.3 at establishment for maximum production. Usually a successful clover stand can be obtained by liming soils with very low pH values (5.2 or above) immediately before planting. When liming very low pH soils, use a split application. Mix one-half to two-thirds of the lime in the seeding zone.

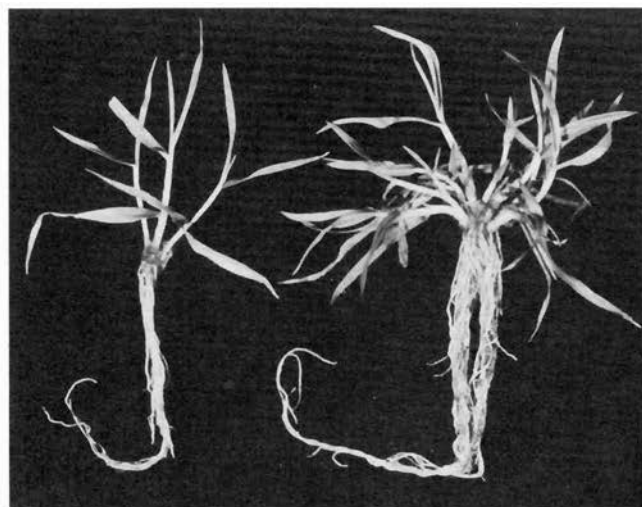
Fertilizers for Legume Establishment

Well-inoculated legumes do not need nitrogen fertilizers for establishment or growth. The bacteria placed on the seed at planting live in nodules of the roots in association with the plant and provide nitrogen. The bacteria-plant association is established quickly; therefore, there is no advantage to applying even a small amount of nitrogen at planting. Too much nitrogen reduces nodulation and always favors establishment of grasses

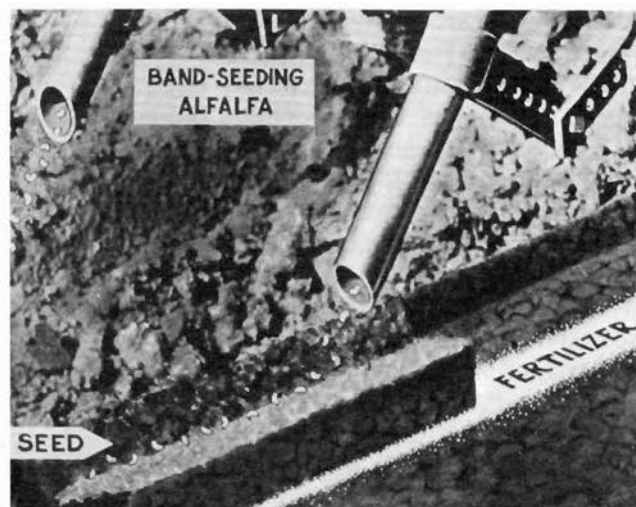
and weeds to the detriment of the legume.

Phosphorus is usually the most important fertilizer nutrient for legume establishment. The small seedling needs relatively large quantities of phosphorus for growth. The root system of the seedling is small and, therefore, cannot obtain the phosphorus from a large volume of soil. Legumes produce a single taproot that grows almost straight down from the seed. To supply the seedling with adequate phosphorus, the fertilizer should be placed directly below the seed at planting. See the diagram for band seeding on page 115. Applying the phosphorus broadcast mixes the phosphorus with a large volume of soil. The small legume cannot take up as much phosphorus as when it is banded. It requires at least 4 times as much broadcast phosphorus to give the same response as when the phosphorus is banded for legume establishment.

Potassium requirements for legumes increase with plant growth.



Adequate phosphorus (*right*) at time of seeding of timothy promotes strong vigorous top and root growth



Proper band placement of fertilizer is about 1 inch below the seed for most perennial forages. When seed and fertilizer are placed in this manner, it is called band seeding.

The legume seedling does not require large quantities of potassium for establishment. Potassium is usually neither fixed by the soil as readily as phosphorus nor lost from the soil as readily as nitrogen. Hence, there is greater flexibility in the methods and rates of potassium fertilization. Some potassium can be applied before, or at, planting and some can be topdressed at a later date.

More than 60 to 80 pounds per acre of potash (K_2O) in the fertilizer band at planting may result in some seedling injury. Therefore, one should use rates of potash lower than 60 to 80 pounds per acre in the fertilizer band. The remaining potassium can be applied preplant or, on higher fertility soils, after the first cut. In cases of higher available potassium, it is possible to wait until the next year.

Boron is the only micronutrient known to be deficient for legumes in New York soils. Boron may be deficient on coarser-textured loams, sandy loams, loamy sands, and sands.



The improved results from using band seeding techniques are shown *on the left* vs. broadcasting seed and fertilizer *on the right*.

On soils known to be deficient in boron, topdress the first year with a fertilizer containing sufficient boron to apply 2 to 3 pounds per acre of boron. This quantity is usually sufficient for 2 or more years. If boron deficiency is not severe or is unknown, 1 to 2 pounds per acre topdressed the first year after establishment are usually sufficient. Soil testing provides the best means for determining the boron requirement.

Fertilizer Rates and Ratios for Establishment of Legumes

The fertilizer rates and ratios should be determined from a complete soil test. When a complete soil test is not available, the following guidelines can be used to determine the approximate rates of fertilizers to be applied for establishment of legumes.

- On soils that have received an average of 350 pounds per acre or more of fertilizer containing phosphorus and potassium or manure plus 200 pounds per acre fertilizer for the last 5 to 10 years, band a 0-1-2 or similar ratio fertilizer, such as 0-15-30, to supply 20 to 30 pounds per acre phosphorus.
- On soils that have received 200 to 350 pounds per acre fertilizer containing phosphorus and potassium for the last 5 to 10 years or manure plus some fertilizer, band a 0-2-3 or 0-1-1 or similar ratio fertilizer to supply at least 40 pounds per acre of phosphorus.
- On soils that have received little commercial fertilizer or manure on a regular basis for the past several years, band a 0-1-1 ratio fertilizer or concentrated superphosphate at seeding to supply 60 to 80 pounds per acre of phosphorus. Do not exceed 60 to 80 pounds per acre of potash (K_2O).

For any of these situations, take a soil sample and have a complete soil test to determine the fertilizers required for topdressing.

Lime for Grass Establishment

Soils should be limed to 6.0 or higher for pure grass stands. Although grass will survive at much lower pH values, production and longevity are reduced. In addition, the efficiency of applied fertilizers is also reduced. Lower soil pH values also permit easier encroachment of less-desirable species.

Lime for grass stands can be applied and mixed with the seeding zone immediately before seeding. When lime rates exceed 4 tons per acre, a split application is desirable.

Fertilizers for Grass Establishment

Grasses require nitrogen, phosphorus, and potassium fertilization as best determined by a soil test. Although banding the fertilizer may not be as critical for grasses as for legumes, it will give the best results.

On soils with moderate to high fertility, use a 1-1-1 or similar ratio fertilizer to provide 20 to 30 pounds of nitrogen, phosphorus, and potassium. On previously unfertilized or low-fertility soils, band a 1-1-1, 1-2-2, or similar ratio fertilizer to provide 30 to 40 pounds of phosphorus and 30 to 60 pounds of potassium.

Minimum-Tillage Forage Establishment

Special no-till drills can be used to plant forages on sites that cannot be plowed because of slope, erosion hazard, or stones. Planting directly into sods or crop residues requires careful attention to the same practices used in conventional seeding, particularly the lime requirement of

legumes and the control of existing vegetation and weeds.

Legumes should not be seeded by the no-till method if your soil test indicates need for incorporation of a large amount of lime. If lime is to be broadcast without incorporation, soil pH before application of lime should be 6.3 or higher for alfalfa, or 6.0 or higher for birdsfoot trefoil or clover. Lime should be broadcast the year before seeding.

Herbicides are available for control of existing vegetation and weeds before and after planting. Good control of competing vegetation is essential for the successful establishment of no-till legumes and grasses. See *Cornell Recommends for Field Crops* for latest herbicide recommendations.

Harvest in Seeding Year

Under good growing conditions, legumes, particularly alfalfa seeded without a companion crop, can be harvested in the seeding year. Early-type varieties of alfalfa planted the first part of May usually can be harvested 10 to 12 weeks after seeding. Second harvest can follow in 6 to 7 weeks. Two or three harvests of alfalfa in the seeding year will not adversely affect forage production the following year if the interval between cuts is no less than 6 to 7 weeks.

Grazing during Seeding Year

The amount of growth and production during the year of establishment depends on many factors, particularly the amount of rainfall. Even under favorable conditions, newly seeded pastures should be grazed lightly and never lower than 4 to 6 inches. Heavy grazing and trampling the first year can weaken and destroy young seedling plants.



Good management can produce a high yield of alfalfa in the seeding year. Photo shows second cut growth of new alfalfa seeding.

FERTILIZING ESTABLISHED PERENNIAL FORAGES

Established perennial forages must receive adequate plant nutrients on a sustained basis for maximum economic yields and stand longevity. The usual method for providing the needed plant nutrients is by yearly topdressing.

The rates of fertilizers needed to supply the plant nutrients for maximum economic production should be determined by complete soil tests. The rates given in this section are to be used as a guide when complete soil tests are not available.

Legume and Legume-Grass Mixtures

Nitrogen, phosphorus, and potassium fertilizers for legume-grass mixtures must be carefully balanced to provide adequate nutrients to both the legume and the grass. Under New

York conditions, an adapted grass species can usually survive the competition from the legume. Most legumes do not survive excessive competition from the grasses. Most legumes do not require nitrogen fertilizers. As discussed earlier, the rhizobia bacteria fix nitrogen for use by the legume. Grasses must have a source of inorganic nitrogen for growth. Both species must have phosphorus and potassium. Thus, by controlling the quantity of fertilizer nitrogen added, one can influence the amount of legume in the stand. Adding nitrogen to a good grass-legume sod usually increases the grass and weed competition without increasing yields.

Nitrogen. Legume-grass mixtures may or may not need additional nitrogen depending upon the quantity of legume in the stand. If nitrogen is added, the grass will become more competitive. The results will

be a higher grass yield and a lower legume yield, but total yield remains about the same. The following year there will be considerably less legume in the stand, and more nitrogen fertilizer will be required to maintain yields.

When there is 25% or less legume in the stand, an economic response to nitrogen topdressing will usually occur. The increased yield is from the grass component. The legume yield and stand will be further reduced. Usually some nitrogen is recommended for the less than 25% legume stands, especially if they are to be plowed the following year.

The rates of nitrogen on legume-grass stands containing less than 25% legumes should be 30 to 60 pounds of nitrogen per acre. If a field contains no legumes, but has a good stand of the species of grasses that respond adequately to N fertilization, such as timothy and brome grass, refer to the section dealing with grass fertilization.

Mixtures containing 25 to 50% legume will occasionally give an economic response to added nitrogen. The considerations for adding nitrogen to a stand with 25 to 50% nitrogen are (1) one is likely to be short of forage for the year, (2) it is the last year of the stand, (3) the grass species present will respond adequately to nitrogen fertilization, and (or) (4) one will continue to topdress the stand with nitrogen in following years. Once a stand with 25 to 50% legume is topdressed with substantial quantities of nitrogen, the legume component is usually reduced below the 25% level. Nitrogen is then required in the following years for maximum economic production.

A stand containing 25 to 50% legume will not respond to large quantities of nitrogen. Rates that produce near maximum economic production are 0 to 40 pounds per acre.

Again, it is usually best not to apply nitrogen to stands with near 50% legumes. The low rate of nitrogen should be used on the stands with the higher percentage of legume. Increase the rate of N as the percentage of legume is decreased.

Nitrogen topdressing to legume-grass mixtures should be applied in the early spring. The nitrogen is applied for grass growth; it should be applied as soon as the grass starts to actively grow (late April or early May). Applying nitrogen after the first cut may stimulate some additional growth; but this is past the period of maximum grass growth, and a response will be limited.

Phosphorus. Phosphorus must be added in the topdress fertilizer to maintain both adequate growth and healthy plants. When the phosphorus is deficient, the plants appear somewhat stunted and do not have adequate vigor. Other visual symptoms for phosphorus deficiency may be a reddish color on the newest mature leaves, especially in the early spring or during early regrowth after cutting. These symptoms are sometimes confusing because a sudden cold spell can cause the symptoms when phosphorus is not deficient. Likewise, phosphorus can be deficient without these symptoms. Use them only as a warning. Soil tests are a much better guide.

The rates of phosphorus fertilizer necessary for maximum economic yields vary between 0 and 60 pounds per acre, depending upon the species, the yields obtained, and previous fertilization practices. Some general guidelines for phosphorus rates are as follows:

1. On soils that have received yearly fertilizer additions at recommended rates
 - a. Alfalfa and birdsfoot trefoil—20 to 40 pounds P_2O_5 per acre per year.



The benefit of adequate potassium topdressing is illustrated by the quantity of alfalfa remaining *on the left*, where 240 pounds per acre of K_2O were applied yearly, vs. the lack of alfalfa and presence of many dandelions *on the right* where no K_2O was applied to this 5-year-old alfalfa stand in Saratoga County.

- b. Clovers—20 to 30 pounds P_2O_5 per acre per year
2. On soils that have not received yearly fertilizer additions at recommended rates, but have received some fertilizers
 - a. Alfalfa and birdsfoot trefoil—30 to 50 pounds per acre per year
 - b. Clovers—30 to 40 pounds per acre per year
3. On soils that have received little or no previous fertilizers
 - a. Alfalfa and birdsfoot trefoil—40 to 60 pounds per acre per year
 - b. Clovers—30 to 50 pounds per acre per year

On soils with a high yield potential and from which 5 tons per acre or more of alfalfa have been harvested, increase the phosphorus rate by 10 to 20 pounds per acre. On soils with yield potentials of 4 tons or less, use the lower rates given.

Potassium. Alfalfa must have fairly large quantities of potassium for maximum economic yields and

stand longevity. Potassium is of utmost importance in winter survival and maintaining the alfalfa in the stand. The illustration on this page shows the difference in the alfalfa maintained in a 5-year-old stand where adequate vs. no potassium was applied.

Potassium deficiency symptoms on alfalfa first appear as small white spots along the older leaf (photo on left-hand side at top of p. 119). The white spots later change to dark brown. If the spots appear randomly throughout the leaf rather than primarily concentrated along the edges, it is usually not a potassium deficiency.

Grasses

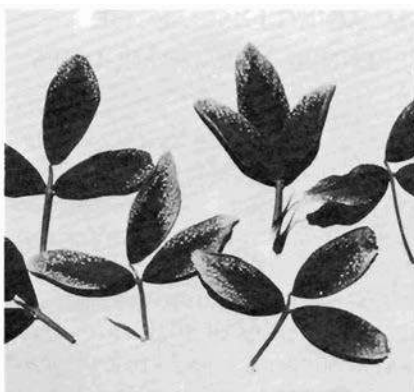
Economic fertilization rates for grasses depend upon the species, timing of application, and the management of the forage. Timothy, brome, orchardgrass, and fescue respond to greater quantities of nitrogen than do the native bluegrasses and other native species.

When the management of the grasses is for maximum economic

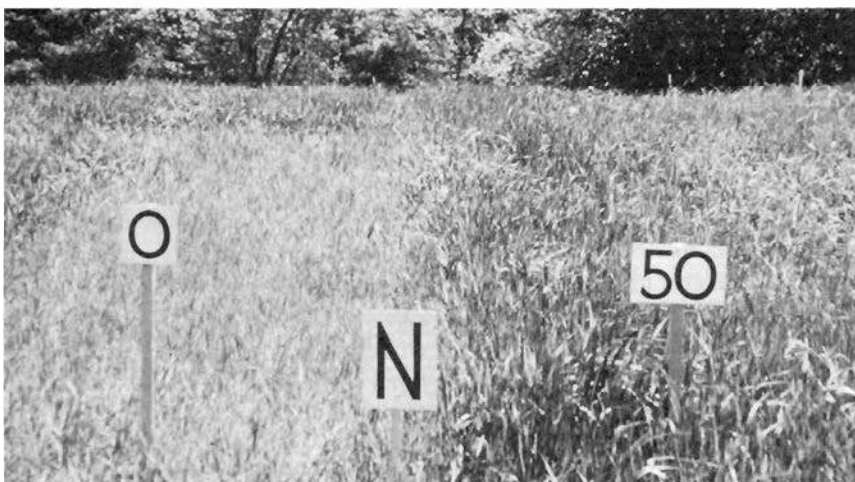
hay production, two-thirds of the nitrogen should be applied in the early spring, just after the grass begins to grow; and the remainder, after first cut. Just as for wheat, ammonium nitrate and ammonium sulfate usually are the best sources to use.

When grasses are used for pasture production, nitrogen applications need to be timed according to the needs of the grass. For early grass production, fertilize in the early spring. For midseason production, apply some nitrogen in late May. For early fall production, fertilize in early August. For the most-uniform total-season production, and usually the maximum production, apply about two-thirds of the nitrogen in the early spring and the remaining one-third in June.

The rates of potassium needed for maximum economic production vary with the soil type or potassium-supplying power, the species, past fertilization practice, and the yield potential. It is difficult to provide accurate recommendations without a soil test. The potassium rates given in table 24 will usually provide sufficient potash until a soil test can be taken and analyzed.



Potassium deficiency is a white spotting and (or) yellowing of the alfalfa leaves at the tips and edges. Potassium deficiency (*left*) is often confused with white spot disease (*right*), which appears as white spots more or less at random on the leaf, although they may be concentrated near the leaf tip and along the leaf edge.



Bromegrass *on the left* of the photograph received no nitrogen. The increased grass height *on the right* is the result of applying 50 pounds of actual nitrogen in the spring.

Table 24. Potassium (K_2O) rates for topdressing established legumes and legume-grass mixtures with greater than 25% legume

Fertilization practice	Group I Clays	Group II Silty clay loams	Group III Silt loams	Group IV Loams	Group V Sands
Alfalfa and alfalfa-grass mixtures					
Previously well fertilized	20–40	20– 40	30– 60	40– 80	60–100
Moderately fertilized	30–50	40– 80	60–120	80–160	100–200
Little or no previous fertilization	50–80	60–100	100–130	130–180	200–250
Birdsfoot trefoil and legume					
Previously well fertilized	20–40	20– 40	30– 40	40– 60	50– 80
Previously moderately fertilized	20–40	30– 60	30– 60	40– 80	60–100
Little or no previous fertilization	20–40	30– 60	30– 60	40– 80	80–120

WEED CONTROL IN FORAGES

Though it is relatively easy to show the value of herbicides during legume establishment, it is more difficult to determine their value in established stands. To be economical, herbicide applications on legumes must control the weeds, and the stand must have the potential for increased legume yield. If the legume stand is so thin that total forage yield declines when the weeds and (or) grasses are controlled, the economics are questionable. In a good stand, the removal of weed competition should increase the quantity and the quality of the forage produced. Although it is difficult to evaluate the potential of a legume stand, it is suggested that clear stands should have a minimum of five healthy crowns per square foot to justify herbicide application. Because grasses are sensitive to many of the herbicides available for use in established legumes, the recommendations given in *Cornell Recommends for Field Crops* are for clear stands; and in some cases, there are label restrictions that limit their use to clear alfalfa.

MANAGING DISEASES OF PERENNIAL FORAGE LEGUMES

Because of the dominance of alfalfa as a forage legume in New York State, disease management in alfalfa alone will be discussed. The same disease management strategies, however, can be applied to birdsfoot trefoil, clovers, and mixed legume/grass forage stands. Diseases of alfalfa are common in our area, but as a rule they do not consistently cause severe losses within a single crop growth (cutting) period. Rather, they weaken plants over time, and along with other stress factors, they contribute to reduced stand longevity. Infectious diseases contribute significantly to the killing of alfalfa plants over the winter dormant period. Management of alfalfa diseases in New York does not involve chemicals, except for limited use of fungicidal seed treatment, but relies instead on sound crop management and the use of varieties resistant to a few serious diseases. Diseases of importance include vascular wilts; root, crown, and stem rots; and foliar diseases. Check with your local Cooperative Extension office for recent fact sheets and other information available to aid in identification and control of forage legume diseases.

Vascular Wilts

Vascular wilt diseases arguably pose the greatest threat to alfalfa yields. These diseases result when the plant's vascular (water-conducting) tissues are colonized by the pathogens and become plugged. This prevents water and nutrients from moving into the shoots, and the plants wilt and eventually die. Varietal resistance is the single most important means of controlling vascular wilts. The bacterial wilt pathogen is endemic in New York soils, and all adapted varieties need to possess a



Verticillium wilt of alfalfa

high level of bacterial wilt resistance. Verticillium wilt occurred widely throughout New York State in the 1980s; it is advisable that any variety grown in New York possess at least a moderate level of Verticillium wilt resistance. Recent evidence indicates that Fusarium wilt may also be a problem in the state, but the need for resistance has not yet been established.

Root, Crown, and Stem Rots

A wide range of pathogenic microorganisms cause disease in alfalfa by attacking the roots, crowns, or lower portions of the stem. These diseases interfere with water and nutrient uptake and/or translocation and thus result in stunting, yellowing, reduced dry matter accumulation, and premature plant death. Phytophthora root rot causes significant losses during seedling establishment in wet, poorly drained soils. It can be controlled by a combination of appropriate site selection, resistant varieties, and sound management. The root



Phytophthora root rot of alfalfa

and crown rot complex, which includes *Fusarium* fungi, is a debilitating and perhaps underestimated problem in alfalfa stands older than 1 year. Currently, sound management to minimize the effects of the disease is the only feasible control strategy. Anthracnose is a fungal disease that attacks the lower stem and can girdle shoots; it also has a crown rot phase. Anthracnose can be severe in the warmer areas of eastern and southern New York, where it is largely controlled through the use of resistant varieties. Sclerotinia crown and stem rot is becoming more prevalent in the state in recent years, but losses have been negligible. Disease incidence can be reduced by avoidance of fall seeding, especially under minimum tillage. Where the disease develops, deep plowing of infected crop residues and long rotations between legume crops are necessary.

Leaf and Stem Blights

Alfalfa foliage can be attacked by a number of fungal pathogens. Most



Common leaf spot of alfalfa

foliar diseases are favored by wet weather and moderate temperatures. Severe leaf disease development can reduce yield and nutritional quality of the forage and depletes the reserves of carbohydrate in the roots necessary for plant regrowth and dormant period survival. The effect of leaf diseases is minimized by maintaining a timely harvest schedule. Harvest should be delayed until a stage when root reserves have been replenished, but should occur before full flower, when leaf spots tend to become more severe. Foliar diseases of concern in New York include downy mildew, spring black stem and leaf spot, *Leptosphaerulina* leaf spot, common leaf spot, bacterial leaf spot, and *Stemphyllium* leaf spot.

The following disease management tactics help to reduce losses from plant diseases when integrated into an overall forage management program.

Seed Treatment

Fungicide application to alfalfa seed is recommended as part of the integrated control of two diseases, *Verticillium* wilt and *Phytophthora* root rot. Thiram seed treatment helps reduce the chance of introducing or

reintroducing the *Verticillium* wilt fungus into uninfested areas via infested seed. Metalaxyl (Apron) seed treatment, when used along with resistant varieties, protects alfalfa seedlings from *Phytophthora* root rot during the vulnerable period of stand establishment.

Selection of Disease-resistant Varieties

Forage varieties are heterogeneous populations of individual plants that vary within defined limits for many traits, including their reactions to diseases. Forage crops can tolerate a certain amount of symptom development and even loss of plants to disease before a significant yield reduction occurs. The response of alfalfa varieties to specific diseases varies from susceptible (less than 6% of plants having resistance) to highly resistant (greater than 50% of plants having resistance). The level of disease resistance required in a variety depends on the nature of the disease, the type of site where the forage is being grown, and the relative importance of various diseases in the local area. Publications such as *Cornell Recommends for Field Crops* are good sources of updated information on the yield performance and disease resistances of alfalfa varieties adapted to your area.

Sound Stand Management

Stand management practices that limit the development and impact of diseases are basically the same as those recommended in the absence of serious disease problems. Any practice that reduces stress (biotic or abiotic) on the crop and promotes vigor will help to extend the productive life of the stand. This becomes even more critical in the presence of serious disease organisms. The most

critical management practices to consider include the following:

- **Site selection.** Avoidance of poorly drained soils can help to reduce stand losses caused by *Phytophthora* root rot and other soilborne diseases.
- **Cropping sequence.** Avoid planting forage legumes into fields recently cropped to legumes. Where diseases such as *Verticillium* wilt or *Sclerotinia* crown and stem rot have occurred, rotations of 3 or more years are advisable before replanting to forages.
- **Stand establishment.** The use of establishment procedures recommended previously will result in a vigorous stand. Good seedbed preparation, weed control, adjustment of pH to 6.5 or above, and balanced fertilization are essential.
- **Sanitation procedures.** To reduce the spread of pathogens between fields, harvest and perform other cultural procedures in young stands before you do so in older stands. Where infectious diseases such as anthracnose or *Verticillium* wilt are known to occur, remove debris from equipment before moving it to other fields.
- **Harvest schedules.** A harvest schedule that allows for replenishment of root reserve carbohydrates is the most critical factor in stand management. Vigorous, nonstressed plants are best able to resist disease development. Harvest before full bloom often reduces losses from leaf blights.

INSECTS OF PERENNIAL FORAGES

How to Check for Insects of Forage Crops

Many forage pests are small or rapid in movement or both. They cannot be found readily by merely turning over a few leaves. Check your fields regularly, preferably at least once a week, by swinging an insect beating net through a field of hay, just hitting the tops of the plants. Swing the net in a half circle in front of you 10 or 20 times, taking a stride or two between sweeps; turn the bag out; and make a quick estimate of your insect pests as to species and numbers. Examine stem samples for eggs by carefully pulling apart the closed leaflets at their terminals and splitting the stem. Check a number of random areas in a field; if one or two pest insects are present in large numbers and crop damage appears imminent, contact your local Cooperative Extension agent or college of agriculture and ask for advice on what to do.

Chewed, whitened, or matted foliage should be checked closely for insects. Discolored foliage, especially where early streaking with red and yellow occurs, should be viewed with suspicion, because these are "maybe" signs of the presence of the potato leafhopper, nutrient deficiency, or plant diseases. Dead plants should be pulled and inspected. If the roots are chewed or if large dead areas suddenly appear on the field, dig into dead, killed-out areas and look for grubs. If any are found, contact your Cooperative Extension agent or Cornell University and ask for identification and advice.



Continuous close observation of each alfalfa field and then prompt action can prevent excessive feeding damage by alfalfa weevil larvae.

Insects of Alfalfa

Alfalfa weevil, *Hypera postica* (Gyll.). *How to recognize the insect and injury.* Both the adults and larvae feed on the top leaves, buds, and young shoots. The leaves are skeletonized, and young shoots are often completely destroyed. The injured leaves dry up, giving the field a greyish white cast much like that caused by frost (most noticeable on first cutting). The larvae when young like to feed in the tightly folded leaf tips.

The adult is a robust, brown snout beetle or weevil about ¼ inch long with a dark brown, V-shaped stripe extending along its head, thorax, and back. At first the weevils are rather tan in color, but later change to dark brown or nearly black as scales are lost from their bodies.

When fully grown, the larva is nearly ½ inch long and has a green body with a wide white stripe and two fine white stripes down the middle of its back. It has a distinct head, which is black or dark brown. The very young larvae are pale, dirty yellow. All larvae have black heads and are legless.

Control. With continuous close observation and with proper timing, good, if not outstanding, alfalfa weevil control can be achieved with the presently labeled and recommended

insecticides as listed in the current *Cornell Recommends for Field Crops*. For best results, follow these rules of thumb.

- Do not treat any field of alfalfa unless it is absolutely necessary to do so, based on feeding damage and weevil (and larval) populations during the current year. Weevil infestations in adjacent fields of alfalfa may vary greatly. To determine whether and when to treat, there is no substitute for close and frequent observation of each alfalfa field. Some fields may not need treatment even in the most heavily infested areas. Treat only if necessary and only at the proper dosage and time. Check your fields often in April–June. Occasionally two treatments per season may be desirable or necessary to protect your stand. Economics will decide whether you wish to treat or not.

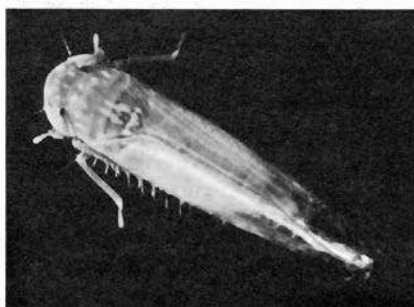
- Where and whenever possible, harvest the first crop early for hay or silage without any chemical treatment. Otherwise, time your treatments as follows:

If 30–40% of the alfalfa tips show any signs of feeding from alfalfa weevil, treat the first crop or harvest and treat stubble if regrowth is being delayed from larval feeding. Attention, however, must be paid to any date limitations between chemical treatment and harvest. All limitations for necessary intervals between treatment and harvest must be observed. Where infestations are heavy on the first cutting, an immediate stubble treatment following harvest may be necessary to protect the new growth buds. Only excellent stands of alfalfa justify such control measures.

- Poor stands of alfalfa mixed with grasses do not justify chemical treatment. Do not spray such fields because they serve as important sources of weevil parasite buildup.



An adult alfalfa weevil can be recognized by the dark brown V-shaped stripe along its back.



Heavy infestations of potato leafhoppers can cause serious damage to both seedling alfalfa and established stands.

Protect your alfalfa weevil parasites! Leave a strip of alfalfa untreated and uncut as an area for alfalfa weevil parasite survival.

Potato leafhopper, *Empoasca fabae* (Harris). *How to recognize the insects and injury.* The potato leafhopper is a pale pea-green, wedge-shaped sucking insect about $\frac{1}{8}$ inch long. The nymphs are yellow to yellowish green. Both the adults and nymphs run sideways or backwards rapidly and usually try to keep on the underside of a leaf if it is turned over.

Injury is characterized by a general stunting and yellowing of the plants. Injury in older plants appears as a yellowing of the leaves or as various shades of red, pink, and purple. Usually leafhopper yellows is characterized by streaking of the color, beginning at the midrib and extending

to the margins of the leaf in a V-shape.

Control. Heavy infestations of potato leafhoppers may seriously reduce stands of new legume seedlings. Protect young seedlings with recommended insecticides, especially in very dry years.

Never apply insecticides to the first cutting of alfalfa. If injury begins to appear on the first cutting, harvest and apply insecticide to the stubble immediately or soon thereafter before the crop is 4 to 6 inches tall.

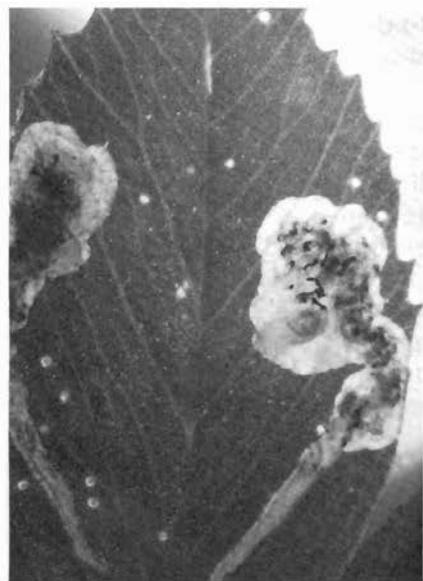
Leafhopper populations are estimated with an insect sweep net. To estimate populations, take a minimum of 25 sweeps in 4 different field locations (total 100 sweeps) and count the leafhoppers. If the field average exceeds the threshold for the alfalfa growth stage, then control measures are recommended. If the alfalfa is within 10 days of harvest, early harvest is recommended. Otherwise, treat with one of the registered insecticides according to label directions.

Stem height in inches	Avg. no. of leafhoppers per net sweep
under 3	0.2 adult
6	0.5 adult
8 to 10	1.0 adult or nymph
12 to 14	2.0 adults or nymphs

Potato leafhopper infestations must be controlled when they exceed these thresholds to prevent damaging yield loss. Yield loss occurs before visible damage is evident.

Alfalfa blotch leafminer, *Agromyza frontella* (Rondani). *How to recognize the insect and injury.* This insect is new to the Northeast in recent years and is, in general, spread in alfalfa fields throughout New York State.

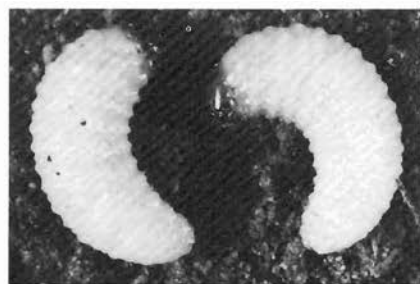
The insect has at least three generations per year, which coincide closely with the three normal alfalfa harvest dates. Adult forms are small,



Alfalfa blotch leafminers produce irregular blotch patterns on leaflets of alfalfa.



White foamy masses on a crop such as alfalfa indicate the presence of spittlebugs.



The alfalfa snout beetle larva is a legless grub. The adult is wingless.

hump-backed, shiny black flies, similar in appearance to the common biting black fly. The female makes many feedings and some egg-laying punctures on the lower surface of alfalfa leaflets, giving a pinhole effect.

Control. In heavy infestations control may be necessary. Use one of the materials listed in *Cornell Recommendations* when first pinholes appear.

Spittlebugs: *Philaenus spumarius* (L.), meadow spittlebug; *Philaenus lineatus* (L.), lined spittlebug. *How to recognize the insects and injury.* The injury of the spittlebug varies from a stunting of the plant, with a pronounced rosetting, as may be seen in alfalfa, to a simple crinkling and cupping of the leaves, as is readily seen on red clover.

The adult spittlebug is about $\frac{1}{4}$ inch long, broadly wedge shaped, and varies in color from straw yellow to dark brown or nearly black. The wing covers may bear longitudinal stripes, cross bands, or spots of dark brown, black, or red.

The nymph is pale yellow to pea green. It is found beneath a "spittle-mass," a mass of white froth on the plant.

Control. Apply recommended insecticides as early as possible in April or early May just as soon as spittle-masses begin to appear. Make frequent and close observations of weeds (curly dock) and trefoil for indications of egg hatch. Treatment is recommended when populations exceed 75–80 spittlemasses/100 stems.

Alfalfa snout beetle, *Otiorynchus ligustici* (L.). *How to recognize the insects and injury.* Both adults and larvae cause injury, though that of the larva is the more important.

The beetle is a wingless, rather robust, large snout beetle, about $\frac{1}{2}$ inch long. The wing covers are coarsely granulate, black, covered with fine reddish hairs and pearly grey scales to form irregular spots. There are no underwings, and the wing covers are fused. Because all beetles are females, any one may

cause a new infestation. All have naturally fertile eggs. The adults feed on the leaves, cutting notches in them or stripping them completely. When the plants are young, they may be completely eaten.

The grub is yellowish white, with a brownish head, legless, and robust. It is about $\frac{1}{2}$ inch long when fully grown. The grubs bore into the taproots of alfalfa or cut wide, deep grooves into the sides of the taproot after eating all the side roots. Often the taproot is chewed off completely at the crown.

Cultural control and other good practices. Rotate legumes with row crops as often as practical. Infested legume sod should be fall plowed and maintained in row crops for at least 2 consecutive years. Rotate out of alfalfa or other forage legumes every 3 years, if possible.

Grow more birdsfoot trefoil, which is more tolerant of alfalfa snout beetle attack than are most other legumes. Plant especially in areas that are seldom plowed.

Destroy all volunteer legumes, especially alfalfa, in row crops or abandoned fields and headlands, because such plants serve as a reservoir of beetle infestation.

Protect new seedlings from adjacent infested fields with two or three deep furrows about them. These furrows should have a deep hole dug every few feet to trap the beetles in April and May during beetle migration.

Observe ditch banks and roadsides during periods of beetle migration to determine level of population.

Chemical control. When beetles are present, treat with one of the materials listed in the current issue of *Cornell Recommends for Field Crops*.

Green cloverworm, *Plathypena scabra* (F.). *How to recognize the insect and injury.* The damage is caused by a slender, pale-green caterpillar with faintish, thin white stripes. Larvae can attain a length of 1 inch or more. The adults are dark brown, almost black, moths with lighter markings. They have a wingspread of 1¼ inches.

Control. Control measures are seldom necessary, but occasionally, as in 1964, damage can be extensive and serious. Apply recommended insecticides to foliage when larvae are small and numerous and when damage is likely to be serious. This insect may be a serious pest of soybeans.

Pea aphid, *Acyrtosiphon pisum* (Harris). *How to recognize the insect and injury.* The adult aphid is nearly 3/16 inch long and 1/16 inch wide. It is light to deep green and has red eyes; the legs and cornicles are tipped with yellow. The young are smaller, but match this description. The aphids are usually found on the stems and new leaves at the growing tips of the plants. Injury to forages is expressed in stunting, wilting, and often yellowing of the foliage. When the aphid is present in injurious

numbers, sticky honeydew is secreted on the leaves; white-cast skins and the aphid itself are readily noticeable.

Control. Apply recommended insecticide in early spring, usually before any bloom, when visible injury, such as stunting and deformation of leaves and stems, is seen. At this time, plants may be shiny with honeydew and covered with white-cast skins.

Grasshoppers, most common species: *Melanoplus femur-rubrum* (DeGeer), redlegged grasshopper; *M. differentialis* (Thomas), differential grasshopper; *M. bivittatus* (Walker), two-striped grasshopper; and other local species. *How to recognize the insects and injury.* Grasshopper injury may vary from a ragged appearance of the margins of the foliage to a complete destruction of the plant.

The redlegged grasshopper is reddish brown above and sulphur yellow below and is about ¾ inch long. The hopper has colorless wings, and its hind legs are tinged with bright red.

The two-striped grasshopper is greenish yellow with contrasting black or brown markings. There are two prominent light-colored stripes from the head to the wing tips. The wings are colorless, and the adult is 1¼ inches long, overall.

The differential grasshopper is yellow with contrasting black markings and clear, glossy outer wings. The hind thighs have black chevronlike markings. The hopper is 1½ inches long.

Control. Apply one of the pesticides currently listed in *Cornell Recommends* when needed. If possible, harvest and apply the pesticide to stubble and new young regrowth.

Cutworms and Loopers

Some common caterpillars found on forages follow. Infestations are variable and unpredictable.

Clover looper	<i>Caenurgina crassiuscula</i> (Haw.)
Forage looper	<i>Caenurgina erechtea</i> (Cram.)
Black cutworm	<i>Agrotis ypsilon</i> (Rott.)
Dingy cutworm	<i>Feltia subgothica</i> (Haw.)
Spotted cutworm	<i>Amathea c-nigrum</i> (L.)
Variiegated cutworm	<i>Peridroma saucia</i> (Haw.)

How to recognize the insect and injury. Injury shows as stripped areas of foliage. Young plants that are wilted in the early morning may be damaged by cutworms. Digging in the top 1 inch of soil in these areas will often reveal subterranean feeding caterpillars.

Species of cutworms can best be identified by an expert only when they are in the larval stages. Cutworms are larval stages of moths. Contact your local county agricultural agent. Identification is not important in choosing a pesticide, because all pesticides listed in *Cornell Recommends for Field Crops* work on the species present in New York.

Control. Apply recommended chemicals to the crop in the evening. Most of these caterpillars feed at night. Baits that attract these insects can also be used. Such baits are available commercially or can be mixed locally.

Insects of Birdsfoot Trefoil

Lygus bugs, potato leafhopper, spittle bug: *Lygus lineolaris* (P. de B.), tarnished plant bug; *Adelphocoris lineolaris* (Goeze), alfalfa plant bug; *Adelphocoris rapidus* (Say), rapid plant bug; *Empoasca fabae* (Harris), potato

leafhopper; *Philaenus spumarius* (L.), meadow spittlebug; *Philaenus lineatus* (L.), lined spittlebug. *How to recognize the insects and injury.* Injury to the plants is caused by the probing and sucking of the plant bugs. It is most pronounced on birdsfoot trefoil where the shoots are killed back about ½ inch and feeding on the blossoms causes these to drop. Injury on the petioles of the leaves appears as a pitting and discoloration. Injury to buds results in "bud blasting." The buds appear white or gray. Damage to flowers results in "stripping." The flowers fall from the racemes and leave a "naked" spike.

The general body color of lygus nymphs is bluish green or yellowish green. In later stages of growth the insects are marked by four dark spots on the thorax. During the early stages of growth, young lygus bugs may be mistaken for aphids. They may be distinguished from aphids, however, by their sturdier legs and bodies and their ability to run about rapidly. Aphids possess extremely soft bodies, with long slender legs, and their movements are slow and awkward.

The tarnished plant bug is a flattened, brownish bug, mottled with irregular spots of dark brown, white, yellow, black, and red. The alfalfa plant bug is grossly similar in appearance to the tarnished plant bug, but is uniformly pale green and about ⅜ inch long. It is quite slender, about ⅜ inch wide. The rapid plant bug is about ⅞ inch long and about ⅜ inch wide. It is dark brown to black with yellowish margins on its wings.

Descriptions of the potato leafhopper and spittlebugs are found on pages 123 and 124, respectively.

Control. Chemicals listed in *Cornell Recommends for Field Crops* are registered for birdsfoot trefoil. For-

age registrations generally do not include birdsfoot trefoil. Treat lygus bugs when 20 to 30 nymphs are taken per 100 net sweeps or when damage is apparent. Treat potato leafhopper when 10 to 20 nymphs are taken in 100 net sweeps. Treat spittlebugs when first spittlemass is seen.

Insects of Clover

Clover bud weevil, *Hypera nigrirostris* (F.). *How to recognize the insects and injury.* The injury appears as slits in the stem, misshapen flower heads, stunted heads, dead buds, dead leaves, and general stunting of the plants.

The adults are a beautiful deep green, although some may be blue green or brownish green with black heads and slender black beaks. The weevils are about ⅛ inch long.

The full-grown larva is legless, milky white, with a black head and a dark line just behind the head. The larvae can be found in the heads, developing buds, and even in the stems.

Control. Apply recommended insecticides only to first cuttings of hay when weevils are taken in numbers of 10–25 per 100 net sweeps.

Clover leaf weevil, *Hypera punctata* (Fab.). *How to recognize the insects and injury.* Injury appears as notches eaten into the leaflets, but in some cases the entire leaflet is eaten.

The adult is a dark brown weevil, about ⅝ inch long, with a stout beak. The weevil is robust in appearance and the largest of the weevils commonly found on clover. The weevil is chocolate brown, but is flecked with black and pale brown spots. On the thorax are visible three light-brown longitudinal stripes, and the sides and undersides of the weevil are a light tan to rich brown.

The larva is about ½ inch long when fully grown, fat, green, and leg-

less. The larva is always curved. It has a pale yellowish white stripe, edged with red, down the middle of the back.

Control. A fungus disease, *Empusa sphaerosperma*, will usually control the larva wherever it is present, but little fungus will be found in fields that have grown only pure stands of grass. To ensure a good fungus supply, grow a little legume with your grasses every year.

Apply recommended insecticides in spring when larvae become destructive (about late April or early May). Ten to 20 larvae per square foot will cause serious injury to a crop.

Fall treatment the year before spring harvest will give good control of the larvae the following spring without presenting a residue problem. If done near September 2, it will reduce spittlebug populations and control clover leaf weevil larvae with the one application. See meadow spittlebug, page 124.

Green cloverworm, *Plathpera scabra* (F.). *How to recognize the insects and injury.* The damage is caused by a slender, pale-green caterpillar with faintish, thin white stripes. Larvae can attain a length of 1 inch or more. The adults are dark brown (almost black) moths with lighter markings. They have a wingspread of 2 to 2 ¼ inches.

Control. Control measures are seldom necessary, but occasionally, as in 1964, damage can be extensive and serious. Apply recommended insecticides to foliage when larvae are small and numerous and when damage is likely to be serious.

HARVEST SCHEDULES FOR PERENNIAL FORAGES

Harvest schedules of perennial legumes and grasses are designed to maximize forage yield and quality and assure stand survival over a period of years. As a general recommendation, all forage crops should be harvested at early stages of maturity. Early harvest has several advantages. First, palatability and nutrient content are highest at early stages of growth. Second, early harvest allows time for regrowth and additional harvest.

Relationship between Plant Maturity and Forage Quality

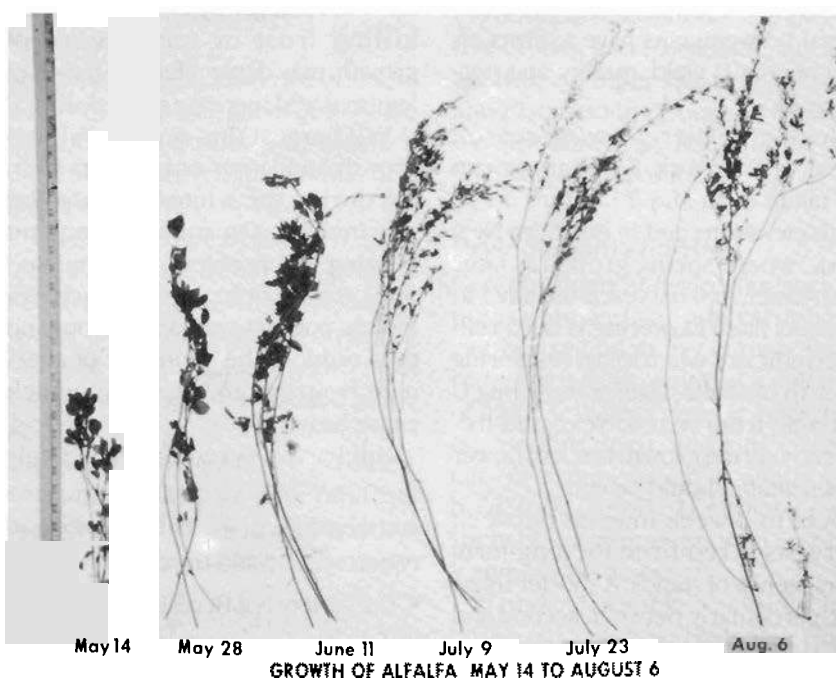
Both the concentration of feed nutrients and the rate of consumption by animals (intake) decrease as forage crops mature. The increase of fibrous constituents with advancing maturity results in a decrease of digestible dry matter (DDM) at the rate of about 0.5% per day. At Ithaca, New York, the percentage of DDM (Y) can be calculated by using the days from April 30 to date of cut (X) in the equation $Y = 85.0 - 0.48 X$. The starting date of April 30 will be different for other geographic areas.

The digestible dry matter (DDM) in aftermath forage of alfalfa is generally less than in first growth, and the rate of decline in DDM is slower in aftermath hay. In general, later cuttings of alfalfa are not as high in feeding value at the early stages of growth and not as low at the late stages as is the first cutting. However, from the standpoint of practical on-farm difference in quality between first- and second- or third-cut hay, second and third cuts are often of better quality because of relatively earlier harvest and less weather damage.

Alfalfa. In most areas of New York, alfalfa can be cut two to three times



Timely cutting is necessary for best hay quality and long life of the forage stand.



Forage quality declines as plants mature. Proper time of harvest maximizes both yield and quality. From left to right, alfalfa on May 14 to August 6.



Higher stubble of fall-harvested alfalfa (*left*) holds snow, which reduces winter damage.

per year. The date of first cut and interval between cuts have a direct effect on alfalfa yield, quality, and persistence.

In the earlier-growing-season areas of New York, first harvest can be taken from May 25 to June 10. At high elevations and in northern New York, where spring growth is later and slower, first harvest is usually 1 to 2 weeks later. Flowering is not a reliable indicator when to harvest spring growth of alfalfa. Date of flowering is variable from year to year, and frequently spring growth is not in flower when alfalfa should be cut.

A 6- to 7-week interval between harvests is required for long-term persistence of stands. A shorter interval, particularly between second and third harvests, can decrease plant vigor and result in reduction of stand.

Fall harvest. Under certain conditions, fall harvest of alfalfa and other legumes will damage stands. A combination of rapid regrowth after

fall harvest, followed by a sudden killing frost or termination of growth, may deplete food reserves of legumes and increase winterkill.

Fall harvest that removes all top growth and leaves only a short stubble during the winter may also be detrimental. On soils where plant heaving is a problem, accumulated plant growth or high stubble acts as a mulch, collects insulating snow, and thus reduces the incidence of alternate freezing and thawing, which cause heaving.

Fall harvest is recommended only if

- there has been 6–7 weeks between second and third cuts;
- the variety is wilt resistant and winterhardy;
- the stand has been adequately fertilized;
- the soil is well drained; and
- the first cut the following spring is not taken unusually early.

Birdsfoot trefoil. Spring growth of birdsfoot trefoil is later than that of alfalfa. Therefore, the recommended date of first harvest is usually 1 to 2 weeks later. Also, because of slower regrowth, a 7–8-week interval is required between harvests.

Grasses. The time of heading of timothy, brome grass, and orchardgrass is a reliable indicator of when to harvest spring growth. Harvesting at early heading gives forage of high quality and allows time for regrowth. In general, second and third harvests can be made after 6 to 8 weeks of regrowth. During dry periods, grasses are not as productive as deep-rooted legumes. Thus, midsummer dry periods often reduce forage yields of second and third harvests.

Hay Crop Silage

The nutrient content and animal intake of forages are highest at early stages of maturity. Thus, early harvest is one of the most important factors in producing high-quality hay or silage. As an example, in table 25, protein content of alfalfa hay can drop from 21% on June 2 to 13% on July 1, an average reduction of about 0.25% per day.

Weather damage and harvest losses also affect forage quality. Estimates of dry matter losses range from 5% to 15% for leaching by rain and 5% to 35% for leaf shattering during normal raking and baling operations.

Dry matter and quality losses caused by weather damage can be reduced by harvesting forages as silage. Exposure time in the field is shorter, and thus, chance of weather damage is reduced.

Immature forages contain 75–80% water. To make good-quality silage, high-moisture forages should be cut and wilted until moisture content is lowered to approximately 65%.

Table 25. Effect of stage of maturity on TDN and protein in legumes

Date of harvest	Approximate stage of growth	TDN*	Protein
		%	
June 1	Vegetative	63	21
June 15	Flower buds	57	17
July 1	Bloom	50	13
July 15	Seed	44	10

*TDN: total digestible nutrients.

Forages ensiled in the range of 55 to 65% moisture are usually superior to higher-moisture silages.

Ensiling forage below 50% moisture is not recommended. Heating can occur in low-moisture silage and may result in fire or the formation of indigestible compounds, which lower feeding value.

Forage Analysis

Forage analysis is an essential part of modern day feed programming. Quality analyses are used to balance rations for optimum production and as a tool for diagnosing health- and nutrition-related problems. Many types and combinations of forage analyses are available with most reporting values for moisture, protein, fiber, energy, and mineral contents. New technology, especially the use of near infrared (NIR) spectroscopy, has provided a rapid means for assessing forage quality, thus enabling the producer to make timely adjustments to their rations. More information can be obtained from Forage Laboratory, NYDHIC, 730 Warren Road, Ithaca, NY 14850-1293.



Organic acids applied to moist hay at time of baling can aid in preventing heating and molding.

Organic Acids for Hay Preservation

Hay baled at 20% moisture or above will heat and mold; a loss of dry matter and feeding value will result. If the temperature is high, hay may also ignite and burn.

Chemical hay preservatives can be used to treat moist hay and prevent heating and molding. The most widely tested and effective preservatives are organic acids, the two most common being propionic and acetic acid. These organic acids are liquids and can be obtained in several different formulations. In general, tests have shown that 25–30% moisture hay should be treated with an organic acid or mixture of acids at the rate of 1% of the weight of the hay (20 lb of actual acid per 1 ton of hay).

When using organic acids to preserve hay, give careful attention to (1) safety in handling acid, (2) calibration of sprayer and baler, (3) determination of moisture content of hay,

(4) uniform distribution of preservative on hay, and (5) maintenance of applicator. Proper rate of application and distribution of organic acids on hay are necessary for uniform and complete preservation.

Drying Agents for Hay

Certain chemical desiccants, such as potassium and sodium carbonate, can be applied to hay at mowing to reduce the time required for drying of hay. These desiccants are effective on second, third, and subsequent cuts of legumes such as alfalfa and birdsfoot trefoil. They have only slight effect on grasses or on first-cut legumes or grasses.

If under favorable conditions hay can be cut, dried, and baled the third day, the use and application of a desiccant under such conditions will speed drying time so that hay can be baled the second day.

Savings in more timely harvest and avoiding weather damage during

drying should be balanced against the cost of material and application to determine the cost effectiveness of using chemical desiccants on hay crops.

Silage Inoculants

Claims for the advantages of using silage inoculants include increase in dry matter recovery from silos and improved animal intake and digestibility of the silage. Research on the various silage inoculants has indicated that some products are effective and some are not. Before using a specific product, one should understand how it is supposed to work and be sure there is reliable evidence to support claims of what the product is supposed to accomplish. Ask your Cooperative Extension office for the latest information on silage inoculants.

PASTURE MANAGEMENT

Use of Pastures

The effective use of pastures requires good management of both animals and forage crops. Good management involves careful planning, close observation of pastures during the growing season, and continued adjustment of animal grazing pressure during the summer. Poor pasture management adversely affects both pasture productivity and animal performance. The goal of good pasture management is to minimize the cost of animal production and to maximize the profit derived from the animal enterprise.

Seasonal Distribution of Forage Dry Matter

Uneven seasonal growth is a problem with all perennial grasses and legumes. Within-season differences in growth patterns of various species

can be used to "even out" pasture production during the summer. Early and late maturing varieties or species, summer annuals, warm-season grasses, winter annuals, and *Brassica* spp. are alternatives for continued production of forage throughout the growing season.

In planning a pasture program, one should consider the uneven seasonal growth of perennial forages. If sufficient acreage is planned to furnish pasturage in mid and late summer, then this acreage will supply a surplus of forage in early summer and will have to be harvested or grazed with extra animals.

Variation in forage production between years is also a problem in pasture management. Climatic factors, particularly temperature and moisture, cause wide variation in production. Use of heat- and drought-tolerant species helps reduce variation between years.



Hillside pastures can produce high-quality forage for livestock.

Deferred Grazing, or Stockpiling

Pasture production often declines in September and October because of cool weather, heavy grazing during the summer, low fertility, or a combination of these factors. With proper planning, pastures can be managed so that pasturage is available during September and October, thus increasing the length of the pasturing season by 50 percent (4 months to 6 months). Both grasses and legumes can be harvested in June, fertilized, and then stockpiled during July and August. Grasses may be better where heavy frosts and weather conditions cause lodging and leaf loss.

In stockpiling systems, maximum forage availability is usually attained by allowing plants to grow to near maturity. Thus, the quality of forage is usually lower than that available in well-managed rotationally grazed pastures.

Perennial Forages for Pasture

Both grasses and legumes can be used for pasture. Legume-grass combinations will usually result in better forage production and animal performance than a single species grown alone.

The choice of what species to grow on a particular site should be based on (1) species adaptation to the site, (2) species response to the grazing system, (3) potential forage yield and seasonal distribution, (4) palatability and nutritional value, and (5) persistence. Also, consider the fact that all grasses, birdsfoot trefoil, and crownvetch do not cause bloat. With other legumes, bloat can be a problem. Short-growing species, like Kentucky bluegrass or white clover, should be used if pastures are to be grazed heavily and continuously.

For maximum production the tall-growing species like birdsfoot trefoil, alfalfa, red clover, timothy,



Good legume-grass pasture is a nutritious, low-cost feed for horses.

bromegrass, and orchardgrass should be rotationally grazed, with short periods of grazing (1–3 days) and long periods of rest (20–40 days). Length of the rest period will depend on the species grown and seasonal climatic conditions.

To spread maturity and forage production more evenly throughout the growing season, several forage mixtures should be grown. Orchardgrass is very early in maturity followed by tall fescue, reed canarygrass, bromegrass, and, the latest in maturity, timothy. Within the species timothy, orchardgrass, and bromegrass, varieties that differ about 10 days in maturity are available. Alfalfa matures early followed by red clover, Viking birdsfoot trefoil, crownvetch, and late maturing Empire birdsfoot trefoil. When growing forage mixtures, blend species and varieties that are similar in maturity.

Using Grasses or Legumes for Pastures

The grasses most commonly seeded in pastures are timothy, bromegrass,

Kentucky bluegrass, and orchardgrass. Grasses that are receiving more recognition as pasture species in New York are the winterhardy types of ryegrass, fungus- or endophyte-free tall fescues, and the warm-season grasses. Compared with legumes, the grasses mentioned are generally more tolerant of wet, slightly acid soils, have fewer insect and disease problems, and can be used more effectively for deferred or fall grazing because of better leaf retention.

Legumes used for pasture include common or ladino white clover and birdsfoot trefoil. Also used for pasture, but more commonly for hay, are red clover and alfalfa. All these legumes, compared with grasses, are generally more drought tolerant and higher yielding in midsummer, and higher in protein at comparable stages of maturity.

Two requirements, one for the growth of legumes and one for grasses, are distinct "trade-offs" in cost of pasture production and should be considered along with other factors when selecting pasture

species. These requirements are (1) the yearly application of nitrogen needed to optimize forage yield of grasses and (2) the maintenance of pH levels of 6.0 to 7.0 for best production and persistence of most legumes. On soils that are slightly acid one has the choice of using grasses plus nitrogen or legumes plus lime.

Grass-Legume Mixtures

The different characteristics of grasses and legumes give rise to several advantages in growing grass-legume mixtures for pasture. Legumes fix nitrogen, which can be used by the grass. This offsets the need for yearly topdressing of grass with nitrogen. Mixtures are also more productive during midsummer and have a higher nutritional value than grass alone. A grass-legume mixture is also better for pastures than a pure legume. The grass adds protection against bloat, fills in spots where the legume will not grow, and increases longevity and production of the pasture.

Palatability and Intake

The palatability of a species depends on its chemical and physical composition. A grazing animal's reaction to individual plants through taste, smell, touch, or sight produces a selective response or preference. Because palatability is directly related to quality or nutritional value, selectivity by grazing animals results in the use of the most nutritional forage in the sward. If grazing pressure is adjusted (lowered) to allow selectivity, often animal performance is satisfactory on mixed swards having, on the average, mediocre quality. Within such swards, however, certain plants must be of good to excellent quality. Selectivity is influenced by both stocking rate and grazing pressure. As either or both are increased, se-

Table 26. Pasture mixtures

For cattle	<i>lb per acre</i>
Birdsfoot trefoil	8
and timothy	4
or orchardgrass	3
or brome grass	5
Smooth brome grass	6
and orchardgrass	5
Orchardgrass	10
Reed canarygrass for poorly drained soils	10
For horses	
Birdsfoot trefoil	8
and Kentucky bluegrass	4
and timothy	2
or orchardgrass	2
Ladino white clover	2
and Kentucky bluegrass	3
and timothy	2
or orchardgrass	2

lectivity is reduced and animal performance declines.

Mechanics of Grazing

On improved pastures milk cows graze about 7 to 8 hours per day taking 50 to 70 bites per minute. Distance traveled may be 1.5 to 2.5 miles, resulting in the requirement of 15 to 25% more energy than for barn-fed cows. As the amount of forage decreases, cows increase grazing time, to some extent, to keep intake relatively constant. However, reduction of the herbage from 1000 pounds of dry matter per acre (bluegrass-white clover, 4 in. in height) to 500 pounds per acre has been shown to reduce average intake by almost 40%. For optimum grazing (intake) there should be 1000 to 1500 pounds of pasture dry matter per acre.

Grazing Management Terminology

Stocking rate is the number of animals per unit area.

Grazing pressure is the number of animals per unit of available forage.

Grazing intensity is the closeness of defoliation of the forage.

Carrying capacity is the stocking rate at the optimum grazing pressure.

Grazing Management

Grazing management is one of the most important phases of efficient pasture use, for it can influence the yield and quality of the pasturage, the botanical composition of the sward, the animal performance, and the amount of animal product produced per unit of pasture area. One of the most common problems in grazing management is the reduction of forage yields by excessive and untimely grazing. Overgrazing reduces rate of regrowth and, if excessive, can kill many forage species.

Botanical composition of a sward is largely determined by the grazing management applied. For this reason one should determine what grazing management is to be used before recommending what species should be used for pasture renovation. In a mixed sward of tall- and low-growing plants (e.g., brome grass and bluegrass), tall-growing plants usually

become dominant under light grazing and are eliminated under continuous heavy grazing. For low-growing species the reverse is true; they are dominant under heavy grazing and eliminated under light grazing.

Types of Grazing Systems

In *continuous grazing* animals have access to the entire pasture area over a continuous period of time. *Set stocking* is continuous grazing with the same number of animals.

In *rotational grazing* animals graze one area for a given time and then are moved to a different pasture. Rotational grazing may involve two groups or species of animals. In the Hohenheim system of grazing, commonly called "top and bottom" or "first and last," animals with high nutritional requirement are placed on a pasture, then removed, and followed by animals with lower nutritional requirement. In rotational systems the length of the grazing period may vary from several hours to several weeks. The use of very short periods of grazing (hours or 1 day) is often referred to as *strip grazing*. In *creep grazing*, young lambs or calves are grazed with ewes or cows and given exclusive access to an additional pasture area that is of higher quality than that of the pasture grazed by both young and old animals.

Response of Plants to Grazing Systems

The response of all forage species to grazing depends on photosynthetic capacity, stored reserve carbohydrate material, and tillers and growing points. When plants are grazed, the ability to manufacture plant food is reduced and the growth rate is decreased. At the same time the size and activity of the root system are reduced. As a result water and nutrient uptake is decreased, and growth is slowed.

Carbohydrate reserves are stored in bases of stems and in roots, rhizomes, or stolons. When plant growth is stopped by defoliation, these reserves are used to initiate regrowth. Thus, regrowth of forage plants after grazing depends on the amount of photosynthetic area remaining and the amount of stored reserves. Regrowth also depends on the bud and shoot development. If grazing removes the meristematic area of many buds and shoots, new sites must be regenerated before top growth is resumed.

In a pasture of mixed forage species, grasses, and broadleaf plants, continued overgrazing or close defoliation of the most palatable species decreases photosynthetic capacity, lowers reserves, and destroys tillers and growing points. In time plants die and are replaced by species grazed less frequently.

In general, the low-growing, less-productive species persist and dominate in a sward under continuous heavy grazing. Rotational or light continuous grazing favors the tall-growing, more-productive species. Species such as white clover and bluegrass withstand close grazing better than do birdsfoot trefoil and timothy.

Continuous versus Rotational Grazing

Many studies comparing rotational and continuous grazing have shown no difference in animal performance, indicating that intake and quality of forage in both systems were adequate to meet the nutritional requirement of the animals. Continuous grazing systems with light stocking rates can result in excellent production per animal because of selective grazing.

To maintain forage at an optimum growth stage is easier with some system of rotational grazing than with

continuous grazing. However, within a rotationally grazed pasture, the ungrazed portion of the sward progressively declines in nutritional value as animals select the more-leafy palatable herbage. Grazing pressure also increases. A point is then reached where the combination of low intake and low nutrition depresses animal production. Rotating animals before this point is reached is necessary not only for maintaining optimum animal production but also for maintaining adequate regrowth of the sward. Regrowth depends on stored food reserves and/or photosynthetic capacity (leaf area). For plants that depend on both reserves and leaf area for rapid regrowth (e.g., Empire birdsfoot trefoil), rotational grazing can be used to conserve adequate leaf area for regrowth and replenishment of reserves.

The length of time animals are off pasture is very important. Both legumes and grass require adequate time to restore food reserves, develop tillers and buds, and regenerate the root system. The optimum rest period would approach the known interval used in a regular hay-cut system. In pastures, however, this is usually reduced to maintain a relatively short sward and reduce losses from fouling and trampling. In rotational grazing the rest period in mid and late summer is usually longer than that in spring and early summer when climatic conditions are more favorable for rapid plant growth.

Mowing Pastures

Mowing pastures helps control weeds and brush and improves production and quality of the forage. Mow pastures after plants have become mature and unpalatable. This stimulates regrowth, which is readily grazed. If pastures are rotationally grazed, clipping after grazing will maintain uniformity and improve

quality of pasture for subsequent grazing.

Animal Product per Acre

Animal production per acre is directly related to the quantity and quality of pasturage produced under a grazing system. If tall-growing, highly productive forage crops like alfalfa and birdsfoot trefoil can be maintained, grazing such species will give more animal product per acre. If we consider some of the more-common grazing systems in use, forage production and, therefore, animal production per acre in-

crease by system in the following order:

1. Continuous grazing with constant stocking rate
2. Continuous grazing with controlled stocking rate
3. Rotational grazing with equal periods of grazing and rest
4. Rotational grazing with shorter periods for grazing than for rest
5. Strip grazing, or very short periods of grazing and long periods of rest
6. Green chop or zero grazing

In general, forage production per animal and production of animal product per acre are indicators of grazing efficiency. Maximum animal production per acre, however, may not return the most profit compared with other grazing systems using lower stocking rates and producing less animal product per acre. The cost of caring for and owning the animal may offset the additional gain in product per acre obtained by adding one or more animals per acre to the grazing system. The ultimate test of any grazing system is the profit or return on investment generated by the system.

Table 27. Estimates of forage available for grazing

Type of pasture	Yield rating	Total* seasonal yield	Monthly yield						
			May	June	July	Aug.	Sept.	Oct.	Nov.
Tons of dry matter per acre									
Bluegrass and common white clover	Med.	1.0	.40	.30	.15	.10	.05	—	—
Ladino white clover and timothy	High	2.0	.65	.65	.25	.15	.30	—	—
	Med.	1.5	.55	.55	.15	.10	.15	—	—
	Low	1.0	.40	.40	.10	.05	.05	—	—
Tall grasses plus 100 lb N	High	2.5	.85	.90	.35	.10	.30	—	—
	Med.	2.0	.70	.75	.25	.10	.20	—	—
	Low	1.0	.40	.40	.10	.05	.05	—	—
Empire trefoil and timothy	High	2.6	.35	.80	.70	.50	.25	—	—
	Med.	2.1	.30	.70	.65	.30	.15	—	—
	Low	1.1	.20	.50	.20	.15	.05	—	—
Viking trefoil and timothy—rotational grazing	High	3.1	.70	.85	.70	.55	.30	—	—
	Med.	2.4	.62	.74	.46	.34	.22	—	—
	Low	1.2	.35	.40	.20	.20	.05	—	—
Alfalfa—rotational grazing	High	3.9	.95	1.00	.90	.65	.40	—	—
	Med.	2.6	.70	.75	.50	.40	.25	—	—
	Low	1.4	.45	.50	.20	.15	.10	—	—
Orchard or bromegrass plus 50 lb N in spring and 50 lb N on June 30. No grazing during July & Aug.	High	2.4	.80	.85	—	—	.40	.24	.11
	Med.	2.0	.71	.70	—	—	.29	.20	.10
	Low	1.0	.35	.33	—	—	.17	.10	.05
Empire trefoil and timothy. No grazing during July & Aug.	High	2.5	.35	.95	—	—	.70	.30	.20
	Med.	1.7	.30	.70	—	—	.40	.20	.10
	Low	1.1	.20	.50	—	—	.30	.10	—
Sudangrass or sorghum-sudangrass hybrids		1.9	—	—	.50	1.00	.40	—	—
Rye		1.2	1.00	—	—	—	—	.20	—
Oats		1.0	—	.50	.50	—	—	—	—

*Total seasonal yield indicates forage dry matter *actually consumed by animals*. Hay yields for these forages would be somewhat higher.

Forage Production and Carrying Capacity

Estimates of hay yields of different forage mixtures can be used to estimate carrying capacity. Legumes and grasses managed as pasture yield 15 to 25% less than they yield when cut for hay. In addition, grazing results in 10 to 25% waste, depending on stocking rate, type of grazing, and plant height at start of grazing. Thus, the amount of forage actually used by grazing cattle may be 25 to 45% less than the potential hay yield of pastures.

As a guide to the forage yield of pastures during the growing season, May through October, estimates of dry matter forage yields and grazing days are shown in tables 27 and 28. A grazing day is 1 day of grazing by an animal with a body weight of 1000 pounds. A grazing day in terms of forage yield would equal approximately 25 pounds of dry matter (1000-lb animal \times 2.5 lb dry matter eaten for each 100 lb of body weight) or 12 to 15 pounds of total digestible nutrients (TDN). Use these estimates only as a guide to how much forage can be produced during the growing sea-

son. The actual amounts of forage produced will be greatly affected by growing conditions and the type of grazing system used during the summer.

Pastureland is one of the greatest unused natural resources in New York. For livestock it offers a potentially low cost source of feed. To realize a profit on investments made in pasture use and management, considerable time and thought must be put into planning and manipulating both pasture (plants) and animals.

Table 28. Estimates of pasture days per acre available for grazing dairy or beef cattle

Type of pasture	Yield rating	Pasture days per acre							
		May	June	July	Aug.	Sept.	Oct.	Nov.	Total
Bluegrass and common white clover	Med.	32	24	12	8	4	—	—	80
Ladino white clover and timothy	High	52	52	20	12	24	—	—	160
	Med.	44	44	12	8	12	—	—	120
	Low	32	32	8	4	4	—	—	80
Tall grasses plus 100 lb N	High	68	72	28	8	24	—	—	200
	Med.	56	60	20	8	16	—	—	160
	Low	32	32	8	4	4	—	—	80
Empire trefoil and timothy	High	28	64	56	40	20	—	—	208
	Med.	24	56	52	24	12	—	—	168
	Low	16	40	16	12	4	—	—	88
Viking trefoil and timothy—rotational grazing	High	56	68	56	44	24	—	—	248
	Med.	50	59	37	27	18	—	—	191
	Low	28	32	16	16	4	—	—	96
Alfalfa—rotational grazing	High	76	80	72	52	32	—	—	312
	Med.	56	60	40	32	20	—	—	208
	Low	36	40	16	12	8	—	—	112
Orchard- or bromegrass plus 50 lb N in spring and 50 lb N on June 30. No grazing during July & Aug.	High	64	68	—	—	32	19	9	192
	Med.	57	56	—	—	23	16	8	160
	Low	28	26	—	—	14	8	4	80
Empire trefoil and timothy. No grazing during July & Aug.	High	28	76	—	—	56	24	16	200
	Med.	24	56	—	—	32	16	8	136
	Low	16	40	—	—	24	8	—	88
Sudangrass or sorghum-sudangrass hybrids				40	80	32	—	—	152
Rye		80	—	—	—	—	16	—	96
Oats		—	—	40	40	—	—	—	80

NOTE: One pasture day is the forage needed to maintain one 1000-lb animal for 1 day. One pasture day equals 25 lb of forage dry matter or 12 to 15 lb of total digestible nutrients (TDN).

Small Grains Production

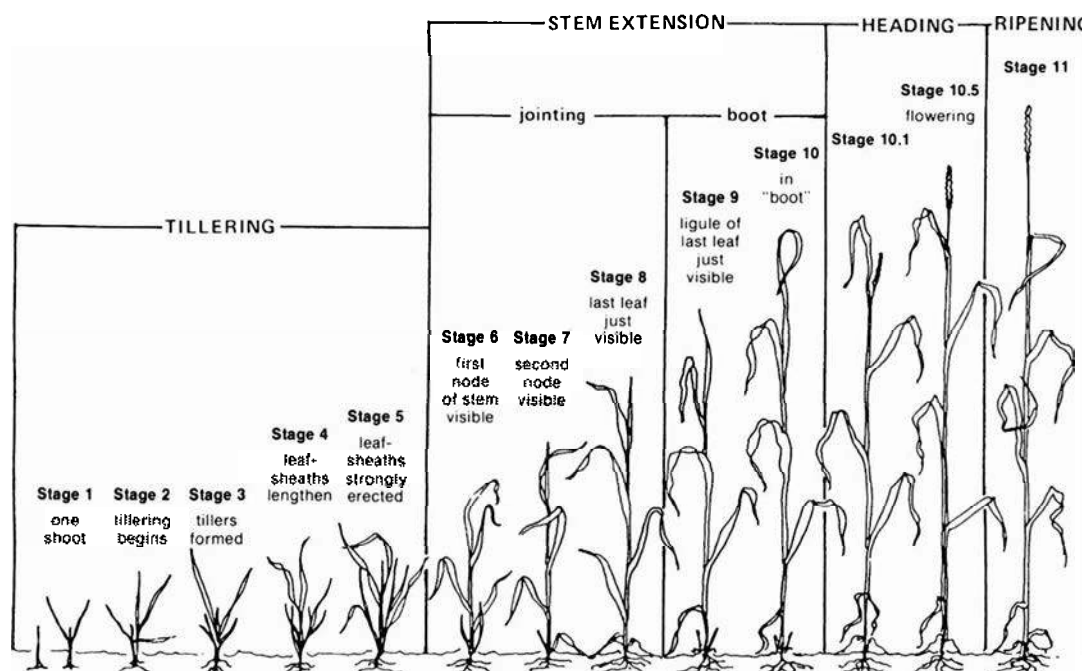


Small grains can produce profitable yields of grain and straw and can also be used as a nurse crop.

Approximately 200,000 acres of winter grains and over 300,000 acres of spring grains are produced annually in New York State. Although this acreage is relatively low compared with corn and alfalfa acreage, small grains continue to play an important role on New York farms. Properly managed small grains produce profitable yields of grain and straw. The straw is an important by-product of small grains in New York because of the strong demand by the dairy industry. Consequently, small grains, regardless of grain prices, are often grown on dairy farms for use of the straw as well as for a nurse crop. Small grains also fit well into a cropping rotation. Finally, because of the

timing of field operations in small grain production, small grains help to distribute a farm's labor requirements more uniformly.

Small grains are not difficult to grow. For maximum economic yields, however, a complete production program must be followed. Management inputs include proper species and variety selection; timely planting and fertilization; thorough weed, disease, and insect control; and timely harvest. All these cultural practices must be executed in a timely manner to produce high yields of small grains.



Growth and development of winter wheat according to the Feekes scale.

GROWTH AND DEVELOPMENT

The morphological development of small grains can be divided into distinct growth stages (GS). Growth stages can be expressed in general terms such as seedling, tillering, stem extension, heading, flowering, and grain-filling stages. Some management inputs such as application of a growth regulator require more-precise timing within these general stages of development. The general classification of the growth and development of wheat and the corresponding growth stages according to the Feekes scale are illustrated.

Winter Grains

Winter grains, when planted sometime in September, are in the seedling stage during the first half of October. The seedling stage (GS 1) is characterized by a single shoot or stem bearing 1–4 leaves. The seedling stage usually lasts 2–3 weeks

and is the stage of development when fields should be scouted for fall-germinating weeds. If weeds such as corn chamomile are a problem, herbicides can be used at this time for control.

In warm autumns timely planted winter grains will initiate and actually form tillers (GS 2–3) in late October and November. An early arrival of winter or a late planting date, however, restricts fall development of the crop to seedling or early tillering stages (GS 1–2). In most years growth and development of winter grains cease in late November, and the crop enters dormancy sometime in December.

Spring green-up of winter grains occurs sometime in late March or early April depending on weather conditions and crop species. If air temperatures average above 40° F in the last 2 weeks of March, all three species will green up sometime in late March. In the case of cold

weather conditions in the latter half of March, green-up is delayed until temperatures rise above 40° F in April. Rye, in general, will green up first in the spring, followed by winter wheat and then winter barley.

Active tiller formation (GS 3) begins shortly after green-up for timely planted winter grains. At GS 3 the crop is about 4–6 inches high. During the next 3- to 4-week period, crop growth of winter grains is very active as evidenced by the number of tillers and leaves produced on each tiller. At the end of the tillering period (GS 5), the crop is about 12–14 inches high and bears 3 to 4 tillers with 4 to 5 leaves on each tiller.

The tillering period in the spring usually lasts 3 to 4 weeks, depending on temperatures. Warm temperatures accelerate crop development, and tillering can be completed by late April. In colder Aprils, the tillering period may not cease until mid-May. Again, the development of rye will be

a few days earlier than that of winter wheat and winter barley.

The tillering period is a very critical period in the management of winter grains. Application of phenoxy herbicides and topdressing of N should occur sometime during GS 3–5 in winter grains. Usually this period coincides with the month of April under typical New York environmental conditions.

Stem elongation (GS 6–10) is the next phase of development in the growth cycle of small grains. Under typical New York environmental conditions, the stem elongation period occurs mostly in May. The beginning of this phase can be identified by the appearance of a joint or first node at the base of the plant. Crop growth is very rapid during stem elongation as evidenced by the rapid extension of the stem and the increase in plant height to 30 to 36 inches. During this period, the head completes its development within the stem. The stem extension period for winter grains in New York usually lasts about 3 to 4 weeks. Depending on crop species and temperatures, the stem extension period terminates sometime between mid-May and early June. The stem elongation period is the time when winter grain fields, especially winter wheat fields, should be closely monitored for foliar diseases.

The next phase of development is the heading out and flowering period (GS 10.1 to 10.5). With warm spring temperatures, heading out can begin in winter grains as early as May 15. In cold springs and cooler climatic regions, heading out of winter grains can be delayed until the first or second week of June. Winter barley and rye usually head out about 7 to 14 days earlier than winter wheat, depending on variety selection within species. Heading out usually takes a few days to complete, and flowering occurs a few days later.



Small grains are 12 to 14 inches high during the late tillering period.

Seed set and subsequent kernel number per ear are very dependent upon environmental conditions during the heading and flowering period. Any type of stress such as heat, moisture, or disease stress during this period can reduce seed set. Fields should be closely monitored from the boot (GS 10) through flowering period for disease occurrence. If severe foliar disease pressure is present at this time, foliar fungicides are necessary for maximum yields.

The grain-filling period is the final stage of development. The grain-filling period of winter grains in New York usually lasts about 30 days. Warm temperatures during grain filling will shorten the period, whereas cool temperatures will lengthen it. The grain-filling period of winter grains occurs during June and early July in most of New York's climatic regions.

The grain-filling period can be further divided into the milk stage (GS 11.1), soft-dough stage (GS 11.2), and hard-dough stage (GS 11.3). The milk stage is easily recognized by the milklike fluid found in the grain at this time. During the milk stage, the crop still appears green, but some of the lower leaves have begun their

normal yellowing. Monitoring for foliar and head diseases should continue through the milk stage.

The soft-dough stage is recognized by the doughlike material that is released from the grain upon squeezing it. During the soft-dough stage, only the upper leaves and head remain green. A few days later the hard-dough stage occurs. During the hard-dough stage, the grain becomes very difficult to press with the thumbnail. Sometime in the hard-dough stage the crop turns completely yellow in the field; this coincides with physiological maturity of the grain or the end of the grain-filling period. Grain moisture approximates 30 to 35% moisture at this time, and a dry-down period is necessary before harvesting.

The Field Crops Fact Sheet 403.10, *Growth and Development of Winter Wheat in New York*, contains more detailed information on the subject.

Spring Grains

Spring grains proceed through the same general morphological stages of development as winter grains. As with winter grains, temperature, planting date, and crop species influence the time of occurrence of the developmental stages. For example, spring barley planted in early April in a very warm spring will head out in early June. In contrast, oats planted in May during a cool spring head out in mid-July.

When spring grains are planted in mid-April, the seedling stage occurs in late April and early May. If temperatures are cool during April and May, spring grains will be in the tillering phase throughout the month of May. If temperatures are warm during May, tillering will be completed 1 to 2 weeks earlier. As in winter grains, the tillering period is the time to apply phenoxy herbicides or to topdress N on spring grains.

The stem extension period of spring grains usually occurs over a 3-week period. Air temperatures, of course, can lengthen or shorten this period. In typical years the first node or joint appears at the base of the plant in late May, and the crop heads out in mid to late June. As with winter grains, the grain-filling period is about 30 days in length, but can be lengthened or shortened according to temperature at this time. Consequently, spring grains usually attain physiological maturity in late July and are ready for harvest sometime in August. In cooler regions of the state, however, cool temperatures delay the development of spring grains, and the sequence of events described here is usually delayed a couple of weeks. Likewise, in warm seasons, the sequence of events can be accelerated a couple of weeks. In general, spring barley is the earliest spring grain followed by oats and spring wheat. Variety selection within crop species, however, can shift this order.

SITE SELECTION

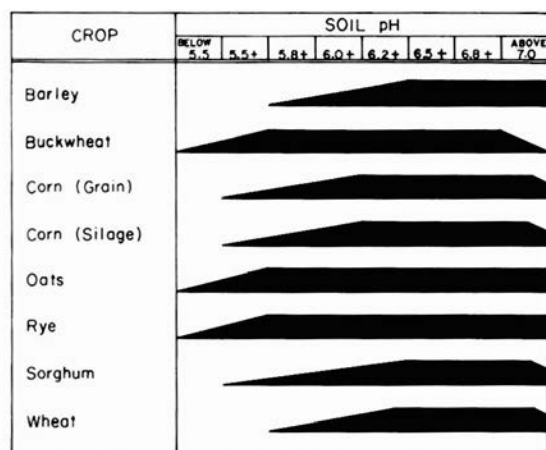
Small grains vary somewhat in their adaption to environmental conditions. Because of this, several factors should be considered when choosing a small grain for a particular farm or field.

The climate of New York is generally well suited for producing winter grains as indicated by the 50-bushel-per-acre average yield of New York winter wheat, which is well above the national average. Because rye is the most cold-tolerant winter cereal, it can be grown in most climatic regions of the state. Winter wheat also has good winterhardiness and can be grown in many areas of the state provided there is adequate snow cover. Winter barley has less winterhardiness than rye and wheat; thus, it is more likely to produce a profitable crop only in the western plains and Hudson Valley. Winter oats, which have the least winterhardiness, are not successfully grown in New York.

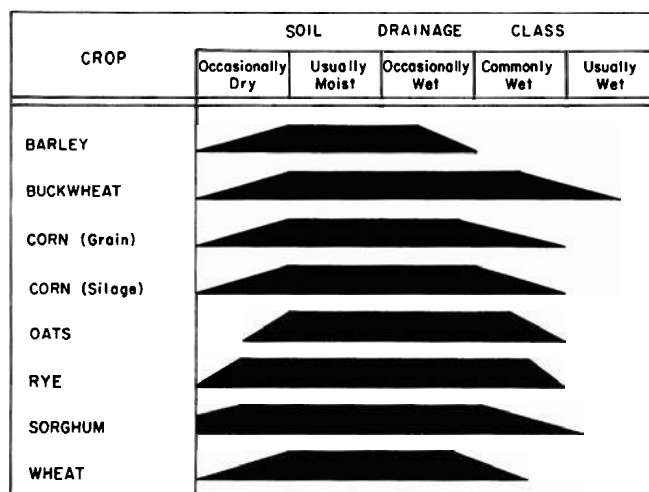
Spring oats and barley are also well adapted to the state's climate. In fact, the average yield of both crops in New York is considerably above the national average. The growth of both crops is favored by the cool, moist

conditions in the spring and early summer. In most cases, however, if winter barley can be grown, it will outyield spring barley. Spring wheat, including durum wheat, can also be successfully produced in New York. The yield of spring wheat, however, is much lower than that of winter wheat in most regions of the state. Another problem with spring wheat is the lack of consistency in grain quality under New York environmental conditions. The development or introduction of new varieties of spring wheat with excellent bread-making qualities is expected to help solve this problem.

Small grains grow best on well-drained, medium-textured to moderately fine textured soils. As can be expected, small grains vary in their tolerance to various soil conditions. Oats and rye are more tolerant of wet, somewhat poorly drained, and acid soils. Wheat and particularly barley are not well adapted to these conditions, but artificial drainage and liming can alleviate these problems. In general, winter grains are affected more adversely by imperfectly drained soils than are spring grains. Because such soils are especially wet in the late fall and early spring, con-



Adaptation of grain crops to soil pH



Adaptation of grain crops to soil drainage

siderable plant heaving of winter grains often occurs at this time. Likewise, ice sheeting can be found in late fall and early spring in poorly drained soils with relatively flat topography. In this situation winter grains usually suffer permanent damage, which greatly reduces the stand and subsequent grain yield.

Rye is the only small grain that can be expected to produce well on dry, sandy soils. In areas where summer droughts are likely to occur, winter grains, if adapted to the climatic region, should be grown. Winter grains complete their growth cycle by early summer and can thus avoid severe droughty conditions.

A soil with well-balanced fertility produces the best small-grain fields. Excessive nitrogen results in excessive vegetative growth and subsequent lodging. Winter wheat and oats are particularly susceptible to lodging problems. Plant growth regulators can prevent lodging of winter wheat under excessive nitrogen. At this time, however, plant growth regulators are not registered for use on oats. A low level of soil phosphorus is also very detrimental, especially with winter grains. Low phosphorus levels result in reduced winter survival and grain yields of both winter wheat and winter barley.

Winter grains should not be planted on wind-swept hills or other exposed locations, if possible. Snow cover provides protection from cold temperatures, and plants on such exposed sites are likely to be uncovered. As a result, winterkilling may be quite serious.



Spring grains do well following corn in the rotation.

CROP ROTATION

Winter Grains

Success of a small grain crop is influenced by the preceding crop in the rotation. Winter wheat or barley does best when following an early harvested crop such as oats, snapbeans, or possibly corn silage. This permits early planting in a well-prepared seedbed. Plowing under a sod, which has a limited amount of legumes, in late July for winter grain production may also produce satisfactory results.

Crops not recommended as the previous crop in small grain production include legume sods, grain corn, or the same small grain. A potential problem with following a legume sod crop is that excessive nitrogen could be released the following spring, resulting in crop lodging. Also, the corn crop would probably benefit more following sod than would a winter grain. Grain corn is not rec-

ommended as the previous crop for winter grains because the corn is harvested late and leaves much residue. Planting successive wheat or barley crops should always be avoided. Several diseases are carried over in the soil and old stubble, leading to serious production problems. When used as a cover crop, rye can be planted after any crop; however, for grain production, it should be rotated in the same manner as winter wheat.

Spring Grains

Spring grains easily fit into a number of rotations and can follow such crops as corn, soybeans, and potatoes. In addition, spring grains can be used successfully as a nurse crop for the establishment of a seeding. Because oats are less competitive than barley, oats are preferred as a nurse crop over barley.

All small grains are susceptible to atrazine carryover. In planning a

small-grain–corn rotation, the rate and timing of atrazine use on corn must be considered. Small grains should not be planted in fields that received more than 1 pound of atrazine the previous year.

CHOOSING A VARIETY

Choosing a suitable variety is an important step in small grain production. The proper choice can make the difference in whether or not the crop will be profitable in terms of both yield and grain quality. In selecting a small grain variety, important characteristics to consider are grain and straw yield per acre, lodging resistance, resistance to serious diseases and insects, and grain test weight. Other considerations are grain quality and maturity. Winter grains should also be evaluated for winterhardiness. Because varieties differ in all their characteristics, the good and poor attributes need to be weighed against each other. Then, select the varieties that give the best combination of desirable characteristics.

Each variety performs somewhat differently under each set of soil, moisture, and temperature conditions. Each farm has its own set of environmental conditions; so only by trying a variety can its performance under those specific conditions be determined. New and better varieties become available as plant breeders continue to develop superior strains. For suggestions on the best varieties available, check the most recent issue of *Cornell Recommends for Field Crops*.

Soft White Winter Wheat

Most wheat grown in New York is classed as soft white winter wheat. This finds wide use in crackers, cookies, shredded wheat, and other prod-

ucts that require a high quality, soft white flour.

In selecting white wheats, look for varieties capable of high yields, strong straw strength, high test weight, and disease resistance. Chaff color and the presence or absence of awns can differentiate between varieties, but neither affects yields. Check variety performance in Cornell yield trials.

Soft Red Winter Wheats

Soft red winter wheats are not commonly grown in New York, though some interest exists in producing this type for local specialty markets or for export to red wheat markets in Pennsylvania and Maryland. In some years market prices favor red wheats, but other years white wheats bring the better price. Current soft red varieties tend to yield less than white varieties bred specifically for New York conditions. Growers should avoid mixing the two classes in any way, because white and red wheat sells at substantial discounts. Check the most recent issue of *Cornell Recommends* for variety suggestions for soft red winter wheat.

Hard Red Spring Wheat

Hard red spring wheats can supply special markets or fill out wheat acreages not planted in the fall. Yields have historically been 30% or more below those of winter wheats, but prices are usually substantially higher. Check *Cornell Recommends* for varieties that yield high, stand well, resist rust and mildew, and produce grain with high milling and baking quality. For high-quality spring wheat, plant early, the earlier the better.

Winter Barley

Winter barley produces a high-quality feed grain. Growers who prefer barley note its early maturity, providing a grain they can harvest before wheat is ready. Winter barley is less hardy than winter wheat. It can do well in the Finger Lakes region and in western New York, but is not adapted in northern New York or higher elevations across the southern tier. Check *Cornell Recommends* for varieties with high-yield potential, stiff straw, and strong winterhardiness.

Spring Barley

Spring barley is often grown as a feed grain, and if planted early, it can out-yield oats in tons of feed produced per acre. Spring barley must be planted early on well-drained soils to do well. Most spring barley varieties can produce malting-quality barley, if weather permits the harvest of bright, plump, high-quality seed. Potential markets exist at malthouses in western New York, but returns have not historically been sufficient to encourage malting barley production in New York. Most New York barley is grown and used for livestock feed. Check *Cornell Recommends* for varieties that yield and stand well under New York conditions.

Rye

Rye in New York is grown primarily as a winter cover crop, and most plantings are plowed down in early spring. Rye serves well in this role, because it produces more fall growth and is more winterhardy than any other small grain. Plowing in the spring should be early, well before heading. Rye grows tall, and the straw can be difficult to plow down or disk in late spring. Rye also serves as a straw crop, with horse owners and race tracks providing markets for bright, clean straw. Some farmers

harvest rye for grain or seed. Markets exist, but returns for rye grain have not been high. Most rye grown is classed as "common" type, though limited seed supplies of several varieties are available. Check the most recent issue of *Cornell Recommends* for suggestions.

Spring Oats

Spring oats are the major small-grain crop grown in New York. Oats are grown for grain and straw in central and western New York, and for hay, haylage, or pasture in the eastern counties of the state. Oats should be planted early for best yields. Growers should check varieties with high yield potential; stiff, erect straw; and high test weight. Varieties should also have resistance to common races of rust. Check the most recent issue of *Cornell Recommends* for varieties that have done best in Cornell trials.

As with any other crop, small grains respond to various cultural techniques. The success of a wheat, barley, oat, or rye crop depends on timely land preparation, planting, fertilization, weed control, disease control, and harvest.

LAND PREPARATION

Winter Grains

A well-prepared seedbed is necessary for proper seed germination and seedling development. With winter grains it is preferable to plow, disk, or chisel the field at least 3 to 4 weeks before planting so that weeds and trash can be destroyed. Plowing is the better choice if the field has been in sod or another trashy crop. If there is little residue, disking or chiseling is sufficient. Just before planting, the field should be cultimulched or harrowed to produce a final seedbed, which is firm with 1 to 2 inches of loose soil on the surface. Because small grains are a large-seeded crop, perfect seedbed conditions and, thus, numerous secondary tillage operations are not necessary.

Spring Grains

Spring grains also require a well-prepared, firm seedbed for rapid ger-

mination and growth. If oats or barley follows grain corn, plowing is recommended. After crops with little residue or if corn stalks have been thoroughly chopped, disking or chiseling is sufficient. Harrowing the field once or twice is usually sufficient to produce adequate seedbed conditions for spring grains.

No-till studies with spring grains have shown consistent yield reductions when spring grains have been planted early. Perennial weed problems have been particularly troublesome in early planted spring grains under no-till conditions. As the planting date has been delayed, a no-till system has performed significantly better provided a translocated herbicide such as glyphosphate has been applied to the existing vegetation before planting. If the planting of spring grains must be delayed until May, a no-till system in conjunction with a translocated herbicide is a viable tillage system for spring grains.



Land preparation for winter grains, which often follow spring grains in the rotation, should occur 3 to 4 weeks before planting.

PLANTING SMALL GRAINS

Winter Grains

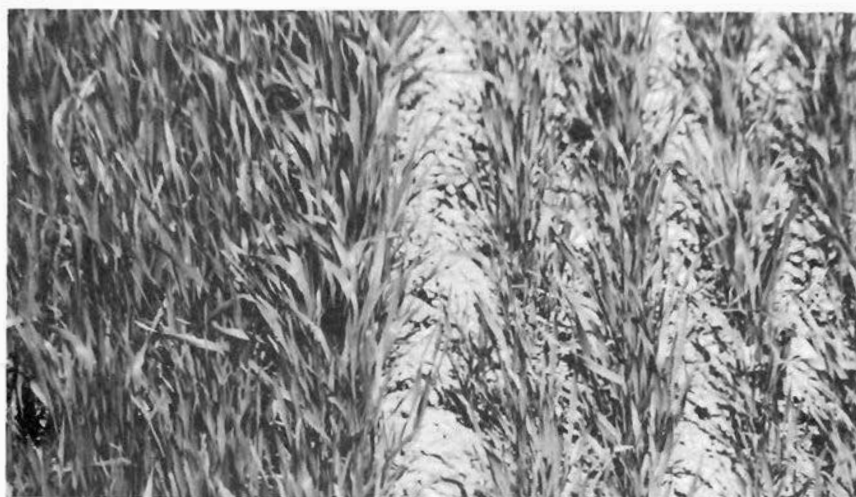
Winter grains should be planted with a grain drill rather than the broadcast method. Broadcasting may be faster; but drilling saves seed, ensures better germination and uniform stands, and reduces winter injury. More important, experiments have shown that drilling increases yield by 5 to 10 bushels per acre compared with broadcasting. A seeding rate of 2 bushels per acre is generally recommended for winter grains under conventional management. In an intensive management system in which high rates of N as well as fungicides and plant growth regulators are to be used, the seeding rate should be increased to 2½ bushels per acre. If broadcasting is the only method of planting, the seeding rate should be about 3 bushels per acre.

Winter grains should be sown 1 to 2 inches deep. Shallower seeding can result in poor germination, whereas deeper planting may result in poor

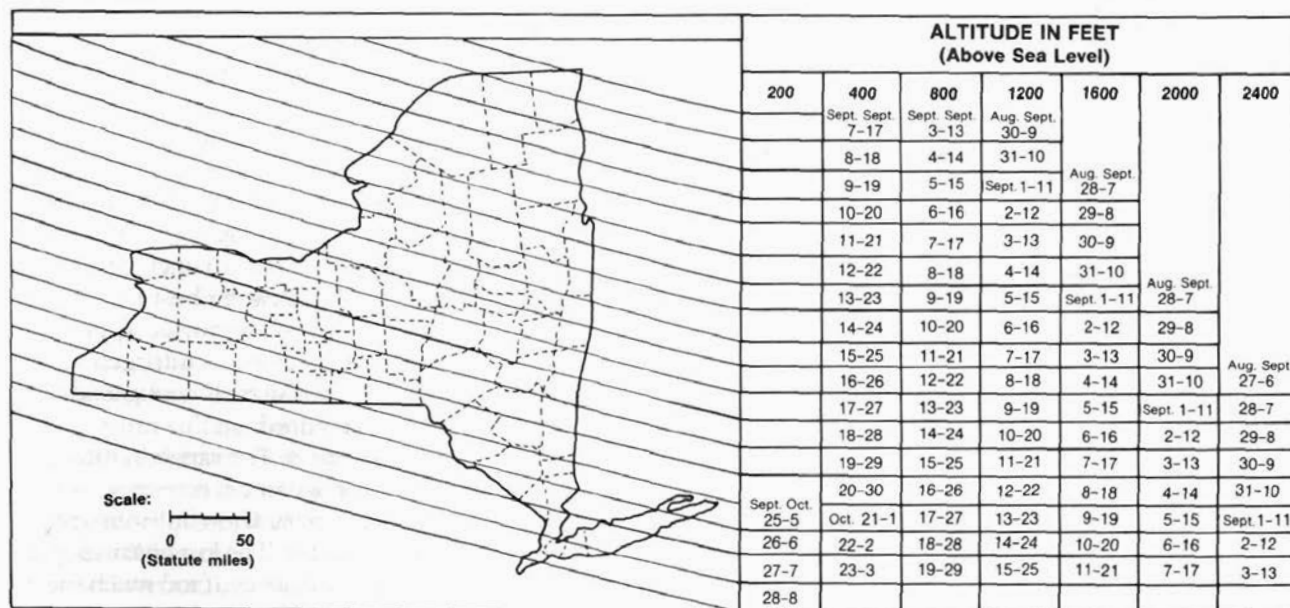
emergence. Before planting, the seed should be treated with a fungicide to prevent seed decay and seedling diseases. Recommended rates of fertilizer, as discussed later, should also be applied in a band when planting. If the drill does not have press wheels, it is recommended that the field be rolled or cultipacked after

planting. This helps to firm the seedbed and improve contact between the seed and soil.

The best time to plant winter wheat in most production regions of the state is between mid-September and early October. In cooler or warmer regions of the state, the planting date can be somewhat earlier or later ac-



Late-planted wheat, *on the right*, produces fewer tillers and heads, resulting in reduced grain yield.



Hessian fly-free dates in New York

cording to conditions. Because the Hessian fly is a serious potential problem, winter wheat should not be planted until after the fly-free date. Too early a planting date also increases the risk of infestation by aphids, which transmit the barley yellow dwarf virus. In some years an early planting date does not result in either Hessian fly or barley yellow dwarf problems. In other years, however, damage can be quite extensive. Because early planting does not increase grain yields when these pests are absent, but markedly reduces yield when they are present, planting should always be delayed until after the fly-free date.

Planting after October 15 should also be avoided. In most years such late planting often does not give winter wheat enough time to make adequate full growth. As a result the chances for winterkilling are significantly increased. Because tillering is markedly reduced with late planting, at least 2½ bushels of seed per acre should be sown with an October planting date.

Winter barley is less winterhardy than wheat and less susceptible to Hessian fly damage. It is, however, more susceptible to infestation by aphids and the subsequent barley yellow dwarf virus. Because of this, it should be planted only a few days earlier than winter wheat. A planting date sometime between September 10 and 20 is the recommended time in regions where winter barley is adapted. Rye, on the other hand, is more hardy than wheat. Successful stands can usually be expected from planting up through October 15, especially in warmer agricultural regions in the state. With all three species, for planting in high elevations or in more northern areas of the state, the planting date should be somewhat earlier than the general recommendations.

Spring Grains

Early planting is the most important requirement for top spring-grain yields. As soon as the soil can be worked in the spring, the field should be fitted and planted. Spring grains germinate at temperatures as low as 40° F. In the warmer regions of the state, soil temperatures are often above 40° in late March, and spring grains can be safely planted at that time. In cooler regions, spring grains can be safely planted in early April.

Experiments have shown that delaying planting from early April to mid-May decreases oat and barley grain yields by as much as 50%. Late-planted grain produces fewer tillers, resulting in fewer heads at harvest-time. Late-planted spring grains also go through the flowering and grain-filling period under warmer and often drier conditions. Hot, dry weather at flowering, especially in oats, results in significant yield losses due to blasting of the heads. Hot, dry weather during grain filling reduces both grain yield and test weight of spring grains. To avoid these problems, an early planting date of spring grains is strongly recommended.

Oats should be seeded at a rate of 2½ to 3 bushels per acre, and barley, at 2 bushels, with a grain drill for maximum grain and straw yields. If a forage seeding is made with either crop, the planting rates of oats and barley should be reduced by 50%. As with winter grains, the seed should be treated with a fungicide and then drilled approximately 1 to 2 inches deep. Again, cultipacking after planting is recommended if the drill does not have press wheels. Also, if broadcasting the seed is the only method for planting spring grains, the seeding rate should be increased by 25%.

LIME AND FERTILIZERS FOR WINTER GRAINS

The lime and fertilizer recommendations should be determined from a complete soil test (see p. 27). The rates provided in the following section are to be used as guides when soil test recommendations are not available.

Lime

The lime requirements for wheat and barley are similar. The soil pH should be in the range of 6.4 to 7.5 for adequate growth and yields. Lime is recommended from complete soil tests when the pH is 6.3 or below to increase the soil to pH 6.5. Rye is more tolerant to low pH than barley, but the soil pH should be maintained at or above 6.0. For more information on lime and lime rates, see "Lime Recommendations" on page 40.

Fertilizers

The growth habit of winter grains is during two different periods of the year: (1) fall growth for establishment and winter survival and (2) spring growth for tillering, growth, and yield. Nutrient requirements differ for these two growth periods. Small amounts of nitrogen and all the phosphorus and potassium should be applied during the fall at planting. Placing the nitrogen and the phosphorus in a band 1 inch below the seed produces the best results. All the nitrogen cannot be applied at planting because of nitrogen losses over winter. An early spring topdressing is required.

Nitrogen. The range in nitrogen rates for maximum economic yield is rather narrow. If too little nitrogen is used, yield will be lost because of nitrogen deficiency. If too much nitrogen is used, yield and often quality are lost by lodging.



Band-placed phosphorus increases winterhardness and yields of fall-seeded small grains. The barley in the early spring photo received (*from left to right*) 20, 0, 40, and 80 pounds per acre of P_2O_5 on a soil that was medium in soil test phosphorus.

Some nitrogen (usually 10 to 20 lb per acre) should be placed in the fertilizer band along with all the phosphorus at planting. The remaining nitrogen should be topdressed in the spring. The spring nitrogen should be applied after the plants begin to grow vigorously. This is usually in mid-April. Do not apply nitrogen to excessively wet or frozen ground. Most of the nitrogen will be lost by leaching or with the runoff water.

Sources of nitrogen for spring topdressing are ammonium nitrate, ammonium sulfate, solution nitrogen, and urea. Ammonium nitrate and ammonium sulfate are usually the best sources because less nitrogen is lost by volatilization, although they may be more expensive per pound of nitrogen. When urea is applied to the bare soil surface, up to 40% of the nitrogen (probably averages 20%) may be lost by volatilization as ammonia

gas to the air. Thus, urea is not generally the best source for topdressing small grains. It may be used as a nitrogen source when the cost per pound of nitrogen for urea is more than 20% lower than for ammonium nitrate or ammonium sulfate.

When urea is used, one is faced with the problem of how much nitrogen will be lost. The loss is weather dependent, and warm, dry weather normally favors the loss. If losses of urea nitrogen are likely to occur at a high rate, some additional urea nitrogen should be used; but if no losses occur, the additional nitrogen may cause excessive lodging and reduce yields. Therefore, little or no more nitrogen as urea should be applied to small grains than would be recommended from other sources, unless a growth regulator is also used.

Solution nitrogen (urea + ammo-

nium nitrate in water) is not the most desirable source to use for spring topdressing because of foliar burning as well as some volatilization losses from the urea. If it is applied early when there is little foliage, the injury is usually not serious. Anhydrous ammonia has not been found to be a good source of nitrogen for spring applications. Anhydrous ammonia must be injected into the soil, and the application knives kill or cause injury to some of the plants. The loss of plants results in lower yields than occur when other nitrogen sources are used.

Phosphorus. The plant needs a concentrated source of phosphorus at planting for initial and rapid growth to create winterhardness. Phosphorus at planting also promotes early spring growth and tillering. The concentrated source of phosphorus should be provided by

banding all the recommended phosphorus at planting. The effects of increasing the rate of banded phosphorus on spring recovery of barley are illustrated. Notice the effect of the phosphorus on the appearance of the plants. The higher phosphorus rates improved winterhardiness and the rate of early spring growth. This greater winterhardiness and growth increased yields by 8 bushels per acre in 1975 and 25 bushels per acre in 1977.

Potassium. Potassium promotes stronger and stiffer straw and plants that are more resistant to diseases, thus a better grain fill. Small seedling plants have a low potassium requirement. The potassium requirement of the plant increases with the stage of growth. Because potassium is held in the cation exchange complex, it is not subject to much leaching. Thus, the placement and timing of potassium applications are not as critical as those for phosphorus and nitrogen. The potassium does not necessarily need to be banded, but can be broadcast before planting.

Band Fertilizer Requirements

Winter grains should receive some nitrogen and most, if not all, of the phosphorus in the fertilizer band at planting. The potassium can be placed in the fertilizer band provided the total nitrogen plus potassium rates do not exceed 60 to 80 pounds per acre of N + K₂O. Do not use urea and/or diammonium phosphate (18-46-0) materials in the fertilizer band for small grains.

The rate of fertilizers to be used in the fertilizer band depends upon the relative soil fertility and previous fertilizer practices. The following guides should be used only when a soil test is not available:

- If the area has been cultivated to adequately fertilized row crops for several years, use a 1-2-2 or similar ratio fertilizer to provide approximately 15 to 20 pounds of N, 20 to 40 pounds of phosphorus (P₂O₅), and 20 to 40 pounds of potash (K₂O).
- If the area has been primarily in hay crops or marginally fertilized row crops for several years, use a 1-3-2 or similar ratio fertilizer to provide 15 to 25 pounds of N, 30 to 50 pounds of phosphorus, and 30 to 50 pounds of potash.
- If the area has been drastically underfertilized or out of production for several years, use a 1-3-2 or a 1-4-2 or similar ratio fertilizer to provide 15 to 25 pounds of N, 60 to 80 pounds of phosphorus, and 40 to 60 pounds of potash.

Topdressing Rates

Only nitrogen needs to be supplied as a spring topdressing. The rate of nitrogen to be used depends upon the soil type and the estimated degree of lodging that is likely to occur. Excessive nitrogen increases lodging. Usually lodging decreases harvested yield and possibly quality to a greater degree than slightly underfertilizing with nitrogen. If lodging is not likely, topdress with 30 to 50 pounds of nitrogen on the medium- to fine-textured soils such as loams, silt loams, and silty clay loams. The rate can be increased to 50 to 75 pounds per acre on the sandy soils. If severe lodging is likely every year, do not topdress with nitrogen. For intermediate lodging problems (some lodging may occur), use 20 to 40 pounds per acre of nitrogen.

LIME AND FERTILIZERS FOR SPRING GRAINS

The lime and fertilizer rates for spring-seeded small grains should be determined by a complete soil test (see p. 27). The rates provided in this section are to be used only as guides when complete soil test results are not available.

Lime

The lime recommendations for spring seeded small grains vary with the species and with forage seeding. When barley is seeded with alfalfa, the soil should be limed to a pH near 7.0 for the alfalfa. If barley is seeded with or without other legumes, the soil pH should be 6.4 or higher.

Oats are fairly tolerant to acid soils, but require a soil pH of 6.0 or above for maximum yield and (or) fertilizer efficiency. If oats are forage seeded, the soil must be limed to meet the legume requirements. For example, when oats are seeded with alfalfa, the soil pH should be near 7.0; and with birdsfoot trefoil, the pH should be 6.4 or above. See "Lime Recommendations" on page 40.

Fertilizers

After spring grains are planted, their growth to maturity takes a relatively short period of time. This permits all the fertilizer to be applied at or just before planting, although some increase in fertilizer efficiency and occasionally yield will occur with split nitrogen applications. For split applications the N requirement should be greater than 50 pounds per acre. About half the nitrogen should be applied in the fertilizer band at planting. The remaining should be applied at tillering. There is some increase in the fertilizer requirements when the spring grains are forage seeded. The differences are pri-

marily in the phosphorus and potassium rates. These will be explained later in this section.

Nitrogen. As with winter grains, the range in nitrogen rates for maximum economic production is very narrow. Too little nitrogen causes yield to be lost because of nitrogen deficiency. Too much nitrogen causes excessive lodging and, thereby, decreases yield by increasing harvest losses and often reduces the quality of the harvested grain.

If the grain is seeded with a legume, the lodged grain and (or) volunteer crop that occurs from grain lost at harvest will likely prevent a successful legume establishment.

The nitrogen fertilizer rate is not affected by seeding with a legume. It is determined primarily by the amount of lodging that is likely to occur. If lodging has not been a problem in the past, 40 to 50 pounds of nitrogen are recommended on fine-textured loams, silt loams, and silty clay loams. On sandy soils the nitrogen rate can be increased to 60 to 75 pounds per acre. If lodging has occurred in most years and is quite severe in some years, the nitrogen rate should not exceed 20 to 25 pounds per acre for all soils. If lodging has occurred some years, but is not usually severe, 30 to 40 pounds of nitrogen can be used.

The shorter varieties with stiffer straw can usually be fertilized at the higher rate within each range. The taller varieties should receive the lower N rates.

The sources of nitrogen depend somewhat upon the method of application. For broadcast, disk-in, or plow-down applications urea, ammonium nitrate, ammonium sulfate, solution nitrogen, complete fertiliz-



The excess of nitrogen causes lodging and loss of yield in small grains. The severely lodged area *on the right* resulted from plowing down a small plot of a legume sod just before planting the oats. The area where the oats are standing had no legume sod.

ers, and, in some cases, anhydrous ammonia (properly applied) are suitable sources. If the fertilizer materials are broadcast and allowed to remain on the soil surface, ammonium nitrate and ammonium sulfate are probably the best sources. Some nitrogen may be lost by volatilization even from these sources on high lime soils. It is usually best to incorporate the nitrogen into the soil in some manner regardless of the source.

If anhydrous ammonia is to be used it should be applied with plows at the bottom of the plow sole rather than with knives. Applying with knives leaves a concentrated band of ammonia and may reduce the stand.

Phosphorus. Phosphorus requirements for spring grains depend upon the residual phosphorus in the soil, whether or not they are forage seeded, and the species of small grain. Spring barley should receive a

higher phosphorus rate than oats. Likewise, if either are forage seeded, there is a much higher phosphorus requirement. When the spring grain is forage seeded, the phosphorus rates are the same as for the legume (see "Fertilizers for Legume Establishment", p. 114). The lower the residual soil fertility, the more important it becomes to apply the fertilizer in bands about 1 inch below the seed.

Potassium. As with winter grains, potassium improves stalk strength and the health and vigor of the plants. Thus, potassium helps to prevent lodging and increase grain fill. The potassium requirement increases with the age of the plant. The roots have time to grow and contact a larger soil volume before the K requirement becomes large; therefore, band placement of the potassium is not critical.

Fertilizer Rates

The fertilizer rates to be used when a complete soil test is not available follow:

1. Following several years of well-fertilized crops

a. Not forage seeded: Apply a 2-1-1 or similar ratio in the band to obtain 40 to 50 pounds of nitrogen, 20 pounds of phosphorus, and 20 pounds of potassium. If lodging occurs in some years, reduce nitrogen to 20 pounds.

b. Forage seeded: Apply 1-1-1 or similar ratio in the band to obtain about 40 pounds of nitrogen, phosphorus, and potassium. If lodging is likely to occur, band a 1-2-2 ratio to supply only 20 pounds of nitrogen.

2. Following several years of crops that have not been fertilized adequately and on low fertility soils

a. Not forage seeded: If lodging is not likely, band a 1-1-1 or similar ratio to supply 40 pounds of nitrogen, phosphorus, and potassium. If lodging is likely, use a 1-2-2 or similar ratio to supply 20 pounds or less of nitrogen and 40 pounds of phosphorus and potassium.

b. Forage seeded: If lodging is not likely, band a 1-2-1 or similar ratio to provide 40 pounds of nitrogen, 80 pounds of phosphorus, and 40 pounds of potassium. If lodging is likely, band a 1-2-1 or similar ratio to

provide 20 pounds or less of nitrogen, 40 pounds of phosphorus, and 20 pounds of potassium; and broadcast an additional 20 pounds of nitrogen, 40 pounds of phosphorus, and 60 pounds of potassium.

The fertilizers made for band applications should not contain urea or diammonium phosphate. These materials will cause germination problems and seedling injury. Greater than 60 to 80 pounds per acre of N and K₂O should not be used in the fertilizer band because seedling injury may result.

Small Grains following Manure and Sods

To follow a sod with a small grain is not a good practice. The nitrogen released from the plowed sod will usually exceed the nitrogen needs of the small grain, and severe lodging may result. The lodged area in the illustration on page 147 is oats following an alfalfa sod on the Aurora Research Farm. The areas where the oats are not lodged were the alleyways between the original alfalfa plots and, thus, were not planted to a crop.

Manure can have the same effect as the sod, unless the manure is spread evenly and at fairly low rates (less than 10 tons/acre). It is usually more efficient to use residual nitrogen from a sod or manure for a high nitrogen-requiring crop such as corn rather than for small grains.

WEED CONTROL IN SMALL GRAINS

Although weeds are usually less of a problem in small grains than in row crops, heavy infestations of annual weeds, quackgrass, or wild garlic reduce grain yields and (or) quality. Weeds do most of their damage during the early growth stages of small grain development by competing for soil moisture, nutrients, and sunlight. Because this early competition results in reduced small grain plant populations and in a reduction in the number of tillers per plant, early weed control is essential. Herbicide application during grain ripening can aid harvest operations, but will not increase grain yields.

Good cultural practices will result in a thick, healthy stand of small grains, which will compete effectively with weeds during the early stages of crop development. Crop rotation, sound soil management practices, use of certified seed of recommended varieties, proper seedbed preparation, and timely planting all contribute to weed control in small grains. Herbicides can be used to supplement these cultural practices as needed. The latest edition of *Cornell Recommends for Field Crops* should be consulted for small grain herbicide recommendations.

Growth-regulator-type herbicides like 2,4-D and dicamba (Banvel) will cause crop injury if they are not applied at the proper stage of crop development. Small grains are most sensitive to these herbicides during seedling development, stem elongation, and head formation. These herbicides should be applied in the spring when the small grain plants are fully tillered. At this stage they are approximately 4 to 8 inches tall and have 12 or more leaves. Applying growth-regulator-type herbicides

before this stage may cause abnormal root development resulting in stunted top growth and reduced yields. Hence, winter wheat and barley are normally not sprayed with these herbicides in the fall.

Once stem elongation begins, application of these herbicides should cease. This is especially critical with oats. Yields of all small grains are seriously reduced if herbicides are applied during the boot stage. After the grain has passed the milk stage, it is again safe to spray with some chemicals. Although yield losses due to weeds have occurred by this stage, these late applications may prevent weed seed production, aid harvest operations, and keep green weed pieces out of the harvested grain.

Because the development of small grains is critical for the timing of herbicide applications, it is important to be familiar with the growth stages of the crop. The period of rapid stem elongation includes the jointing and boot stages. During jointing, the head begins to develop, but remains enclosed in the sheath of the top (flag) leaf. During the last few days of stem elongation, the head increases greatly in size, but is still wrapped in the sheath. This phase is the boot stage.

No herbicide is available for controlling quackgrass in small grains once the crop is established. Quackgrass must be controlled at some other time during the crop rotation. Planting in a field heavily infested with quackgrass should be avoided, for this perennial weed can cause significant yield reductions. Wild garlic is also of special concern because the presence of aerial bulblets in wheat limits the grain's use. Recommendations for controlling these troublesome weeds can be found in *Cornell Recommends for Field Crops*.



The time to apply herbicide is when small grains are in the fully tillered stage.

MANAGING DISEASES OF SMALL GRAIN CEREALS

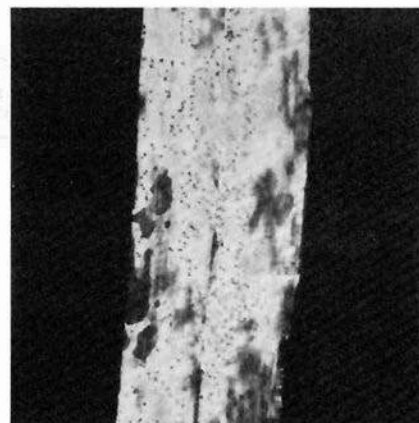
Diseases are often a major yield constraint in the production of wheat, oats, and barley in New York State. Many disease-induced losses have just been accepted by growers because of either a lack of acceptable control practices or a lack of disease detection. To the extent that diseases have been managed, this has been accomplished through the use of sound cultural practices, seed treatment fungicides, and varieties resistant (or at least less susceptible) to certain diseases. With the recent ad-

vent of intensive management, the severity and importance of diseases have increased, and greater emphasis has been placed on the use of foliar fungicides.

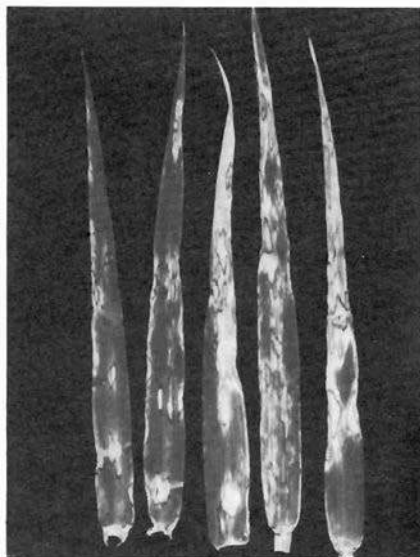
Overall, the most important diseases are fungal foliar diseases. These include diseases such as *Septoria nodorum* spot, tan spot, powdery mildew and leaf rust on wheat; crown rust, *Septoria* blight, and leaf blotch on oats; and powdery mildew, net blotch, scald, and leaf rust on barley. Foliar diseases, if severe during the first few weeks after flowering, can drastically reduce grain yields.



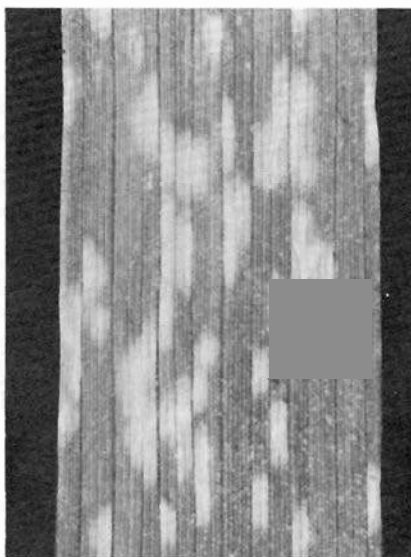
Leaf spot complex of wheat



Powdery mildew of wheat



Barley scald



Crown rust of oats



Yellow dwarf (red leaf) of oats

Soilborne fungal diseases affecting the roots, crowns, and lower stems occur on cereals in New York, but are seldom severe. This is probably due to the fact that small grains seldom follow each other in rotational sequence in New York, and the same cereal species is almost never continuously cropped. Diseases such as takeall, *Fusarium* root and crown rot, and various foot rot diseases can reduce cereal yields under certain conditions in New York.

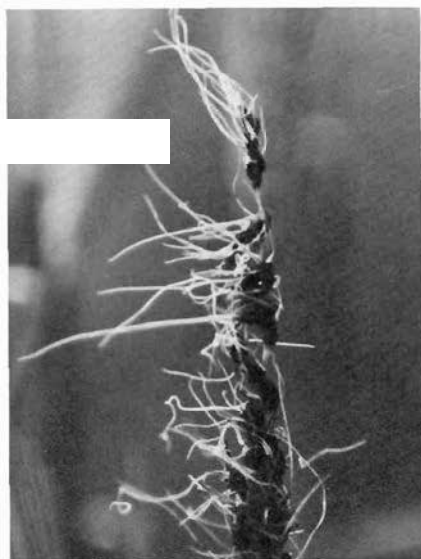
Yellow dwarf, caused by aphid-transmitted viruses collectively called barley yellow dwarf virus, affects all cereals in New York and can be a serious problem. Wheat spindle streak mosaic, caused by a virus that is transmitted by a soilborne fungus, occurs widely on wheat, but its relationship to yield reduction is unclear.

Smut and bunt diseases attack cereals by replacing the tissues of the developing kernels with masses of fungal spores. Although still potentially devastating, smut diseases have largely been controlled through the use of systemic seed treatments.

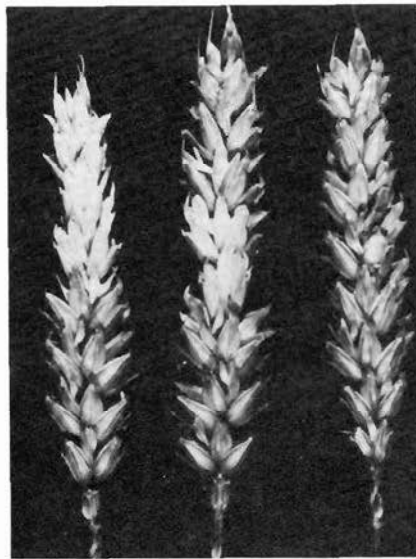
Scab or head blight can seriously reduce yields and result in mycotoxin-contaminated grain and low-vigor seed in all cereal crops, if moist conditions exist at the time of flowering.

Contact your local Cooperative Extension office for recent fact sheets and other information available to aid in the identification and control of small grain diseases.

Small grain diseases are most effectively managed by an integrated approach, which makes use of genetic, cultural, and chemical tactics of disease control. The following tactics are most often incorporated into cereal disease management.



Loose smut of barley



Scab of wheat



A planter-box fungicide treatment will protect young plants from seedling diseases.

Selection of Disease-resistant or -tolerant Varieties

Cereal varieties with resistance or tolerance to diseases important in your area can be selected with the help of publications such as *Cornell Recommends for Field Crops*. Keep in mind that even a moderate level of resistance may be adequate to avoid significant losses to certain diseases. Resistance to diseases such as rusts and smuts is specific against certain pathogen races, so make sure that the variety you select is resistant to all fungus races known to occur in your area.

Seed Treatment

Seed treatment of cereal grains with fungicides is good insurance against various diseases that reduce stands, lower yields, and decrease grain quality. Application of these chemicals to seeds serves a four-fold purpose:

1. To kill harmful microorganisms that may be present on the surface of kernels. Examples of these are the

fungi that cause several smut diseases including bunt (covered or stinking smut) of wheat, covered and loose smuts of oats, and covered and black (loose) smuts of barley. Also included in this category are several fungi that cause seed decay and seedling blights.

2. To provide a chemical barrier that will protect seed and young seedlings from invasion by disease-producing microorganisms in the soil. Among these are fungi that cause rotting of seed and roots and blighting of seedlings.

3. To kill harmful microorganisms that may be present inside the embryos of kernels. The fungi that cause loose smuts of wheat and barley are in this category. Because they are deeply established in seeds, they can be killed only by systemic compounds, which are absorbed and move within plant tissues.

4. To kill, via systemic action, airborne fungi that attack leaves of young seedlings. A few of the new, seed-applied systemic fungicides

such as triadimenol have the capacity to be translocated into developing leaves and provide short-term protection against certain foliar diseases such as powdery mildew.

Fungicides can be applied to seeds in several ways:

Dust treatment. Dry fungicide dusts are mixed with the seed by means of a treating machine or by hand shoveling.

Slurry treatment. Fungicides in dry or liquid form are mixed with water and then applied to the seed in a treating machine.

Planter-box or drill-box application. Dry fungicide dusts are manually mixed with the seed in the drill box immediately before sowing. This method reduces the chances of unused treated seed grain being used for animal feed or human consumption and can be readily employed when emergency planting of untreated seed is necessary. Care should be taken to ensure thorough mixing. Apply half the required amount of fungicide to the half-filled drill box, stir grain well, then add re-

maintaining seed and fungicide, and stir again.

In all cases, fungicides should be applied as close to time of planting as possible. See the current issue of *Cornell Recommends for Field Crops* for recommended fungicides for seed treatment.

Foliar-applied Fungicides

The number of New York growers applying fungicides for disease control, especially in winter and spring wheat, has increased recently. Experiments with fungicides in nonmaximum-yield situations have sometimes shown reduction in disease with little resulting yield benefit. Fungicides, therefore, should be used as one part of a total high-yield management system; that is factors such as variety selection, planting date, weed and insect control, and fertility should be optimized before fungicide use is considered. Powdery mildew, leaf rust, stem rust, and fungal leaf and glume spots are among the diseases most frequently encountered. Because disease occurrence varies between fields and between seasons, fungicides are most effectively used in conjunction with a scouting program. One of the major aims of a foliar fungicide program is to keep the flag leaves free from disease, because flag leaf function is important for filling the grain. Early season diseases can also adversely affect yield, however. Registered fungicides are listed annually in *Cornell Recommends for Field Crops* on the basis of their efficacy in disease control. Growers are also urged to consult extension agents for updated research results on the agronomic (yield) and economic returns on pesticide inputs.

Sound Agronomic Practices

Management practices that optimize cereal yields in the absence of disease are basically the same ones used to limit the impact of diseases. The following are most critical:

- **Optimal planting date.** Fall grains should be planted soon after the Hessian fly-free date. This strategy helps to avoid peak populations of aphids carrying barley yellow dwarf virus and also minimize fall infections of seedlings by soilborne diseases. The strategy for spring grains is to plant as early as soil temperatures and moisture will allow. By so doing, plants will often be past the most vulnerable stages when they are exposed to viruliferous aphids and pathogenic fungi.
- **Rotational sequence.** Planting a small grain, especially the same species, twice in succession should be avoided. Rotation helps to reduce the buildup of disease inoculum in the soil and in crop debris. Planting small grains following corn that is badly affected with stalk rot is also inadvisable, for the *Fusarium*-infected debris can provide inoculum for scab epidemics on small grains.
- **Balanced fertility.** Although it is true that increased fertility, especially nitrogen, often increases the severity of diseases, the well-fertilized, vigorous stand has an increased yield potential even in the presence of disease.
- **Weed and insect control.** Weed and insect management is a part of disease management because these pests may serve as reservoirs and vectors, respectively, of plant pathogens. Also, weeds reduce airflow in the crop canopy and produce higher humidities conducive for disease development.

SMALL GRAIN INSECTS

Hessian Fly

Phytophaga destructor (Say)

How to recognize the insects and injury. The young injured plant is usually stouter, broader, and dark green, resembling oats. The plants stand more erect and are the plants that perish during the winter. Plants that survive are shorter, thinner, and have fewer seeds in the head at maturity.

The adult is a minute fly resembling a mosquito. The eggs are bright red and are found on the grooves of the upper surfaces of the leaves. The larvae are white, pointed at both ends, and about 1/4 inch long. The larvae are found near the roots of the plant and later under the leaf sheaths at the joints of the plant near the ground. Later the larva turns dark brown and forms the "flaxseed" stage, or puparium.

Control. No insecticide treatments have proved practical to date. Cultural control is successful if done on a communitywide basis.

- Plant only after the fly-free date for your area. Seeding of grain should be done upon arrival of the fly-free date and finished as soon as possible, for late seeding usually depresses yields because of poor germination, rooting, and growth. Late-seeded grain is more susceptible to freezing, winter-killing, and drought.
- Plow under stubble of infested wheat, if possible, at least 6 inches as soon as the grain is harvested.
- Destroy all volunteer grain, disking when plants are small.

Cereal Leaf Beetle

Oulema melanopus (L.)

The cereal leaf beetle has been found in New York since 1969 and has now been identified in 50 counties. This insect can be highly destructive to oats and will probably build up to damaging levels and spread eastward through the state in future years. Chemicals are available for control. Plant breeders have identified resistant strains of wheat, but not of oats. Egg and larval parasites of the cereal leaf beetle were released by the USDA and Cornell in Ontario and Monroe counties in western New York and have been spreading rapidly; so biological control will continue to reduce populations of this pest.



Adult and larval cereal leaf beetles are found in small grain fields in much of New York. Larvae feed by stripping off the upper surface of the leaf.

How to recognize the insect and injury. The adults eat longitudinal slits between the veins and completely through the leaves. The larvae eat only the outer surface of the leaves; a frosted appearance results.

The adults are beetles, measuring about $\frac{3}{16}$ inch with metallic, shiny bluish black wing covers and reddish orange legs and thorax. The larvae

resemble slugs, black from a glob of moist dung material on their backs. The eggs are yellow, laid singly in rows of up to three or four, never in clusters. They are usually found close to the midrib of leaves on the upper surface. On corn they are often laid on the underside of leaves.

Control. Plant winter grains immediately after first Hessian fly-free date for your area to give grain a better chance to grow in size. Beetles prefer younger, tender cereal, less than 6 inches tall. Mature older grains can tolerate more larval and adult feeding.

The cereal leaf beetle is present in New York in all western counties. Recommendations for its control are based on work done in Michigan, Ohio, and Indiana. Beetles are present in Pennsylvania and Ontario, also. Spray recommended insecticides as listed in *Cornell Recommends* when larvae number one or more per stem.

Armyworms

Pseudaletia unipuncta (Haworth), armyworm

Spodoptera frugiperda (L.), fall armyworm

How to recognize the insect and injury. Armyworms attack oats and wheat.

The armyworm is the caterpillar stage of a small (1-1½-in. wing spread), night-flying, grayish brown moth with a small silver white dot on the center of each forewing. The moths fly at night and hide by day. The moths are seldom recognized by most people. The fully grown armyworm caterpillar is about 1 inch or more in length; nearly completely free of any hairs; dark gray, tan to greenish black, with five longitudinal yellowish stripes, three on the back and one on either side of these. When the larvae are numerous, they are

dark greenish black; when sparse, pale gray to tan.

The sixth instar caterpillar does 20 times as much feeding as do the first four instars put together and 7 times as much as the fifth instar. Damage may be seen as a simple ragging of the foliage to a complete stripping of the plant. Usually the heads of grain are not eaten, but these may be cut off and dropped on the ground. In some cases the grass or corn may be totally destroyed.

The caterpillar of the fall armyworm is light brown to greenish brown, resembling the armyworm with three, more or less obvious, yellowish white hairlike stripes down the back and prominent dark tubercles on the body, from which hairs grow. The mandibles are conspicuously toothed, conclusively differentiating it from the armyworm. Fully grown larvae are about 1 inch long, and damage is generally similar to that of the armyworm.

The night-flying moths resemble cutworms, the front wings (1½ in. wide when spread) are mottled dark grey with a conspicuous light spot near the tip.

Control. These insects attack corn, oats, and wheat, as well as most grasses. Apply recommended insecticides when the insects are found in numbers doing damage. Best results are usually achieved in late afternoon and when larvae are $\frac{3}{8}$ inch or smaller. When larvae are in fifth or sixth instar, $\frac{3}{8}$ –1 inch, a heavier or repeated dosage of insecticide may be needed. In cool temperatures, organophosphates may give poor kills.

Bait can be used in small areas of infestation in grown or tall grain or in protective furrows surrounding uninfested grain or corn fields near infested areas. Baits should be applied in the evening and renewed every 2–3 days.

Internal Wheat Stem Feeders

Harmolita tritici (Fitch), wheat jointworms

Cephus tabidus (F) and *Cephus pygmaeus* (F), wheat sawflies *Calendra* spp., wheat stem billbug

How to recognize the insects and the injury. The wheat jointworm larvae are always found in a hardened gall, 8–10 inches above the ground. The stem is usually twisted, flattened, and thickened at this point and is very hard. If the gall is sliced through, usually two or more pale yellowish larvae are found within.

Wheat sawflies bore throughout the stem, leaving a loose, pure-white frass. The larva may be nearly ½ inch long, is slender, and has legs and a nearly colorless head. When ready to pupate, the larva cuts a V-shaped groove near the base of the plant and forms a plug over its head. Later the plant will break at this weakened place in the stem.

The wheat billbug larva is small, legless, and has a dark brown head. The full-grown larva is about ¾ inch long. It nearly always feeds in wheat culms, below the first joint from the ground. It fills its gallery with a fine, tightly packed, dark brown frass.

Control. No insecticide control measures are known. Cultural control measures should be practiced, if possible, on a communitywide basis.

- Plow under stubble at least 6 inches.
- Destroy volunteer grain.
- Badly infested straw, particularly that from wheat-jointworm-infested fields should be destroyed by burning where permitted.
- Rotate with corn, oats, and legumes.

USE OF SMALL GRAINS

New York wheat is usually grown as a food grain for the cash market. The cool, humid growing season in New York favors the production of high-quality soft white wheat, which has traditionally been used in breakfast foods and pastry. The present New York wheat market is built around this wheat. Soft red wheat, also used in pastries and crackers, can produce well in New York. Before it is planted, however, an adapted variety must be identified and a market should be located. Another option for its use is for feeding on the farm. Both soft wheat types are relatively low in protein, approximately 8–11%; but in general, the soft red wheats are 1–2% higher than the white wheats. Hard red wheat, the type grown in the Great Plains and used for bread flour, is not currently adapted to New York conditions. The high humidity in this area induces a number of foliar disease problems and prevents formation of hard, high-quality kernels that mill properly. The development or introduction of new varieties may solve these problems.

As feed grains, small grains are good sources of energy. Wheat, barley, and rye contain about 97–98% of the total digestible nutrients (TDN) of corn. Oats are somewhat lower because of their higher fiber content. Oats and barley contain up to 13% protein, compared with about 9% in corn. All the small grains except rye are also very palatable.

Small grains have other uses besides grain production, and their value differs with species. Straw is an important by-product of all the crops. Oat straw is especially desirable for a bedding material for dairy operations, whereas rye straw is preferred by the horse industry. As a winter cover crop or green manure crop, rye is best. Rye and wheat are most suitable for livestock grazing, whereas oats are preferable for hay or silage. If the small grain is to be a companion crop for a forage seeding, oats are usually best because they are less competitive. Spring barley is the next best choice, followed by winter wheat, winter barley, and rye. Currently, there is no established market for malting barley in New York. Malting varieties can be grown in this area, but yield and quality vary from year to year. Again, the development or introduction of new varieties may improve the performance and quality of barley for malting purposes.

HARVESTING SMALL GRAINS

Grain

Timely harvest of small grains is important to prevent lodging, sprouting, and shattering. Soft white winter wheat is especially susceptible to preharvest sprouting under sustained moist or humid conditions during the late dry-down period. Less sprouting, shattering, and lodging usually occur at early harvesting. Small grains can be combined directly when they contain up to about 22% moisture. Moisture levels higher than this cause a high percentage of kernel damage. Also, the heads often do not completely thresh at relatively high grain moisture contents. For grain in the 16–22% range, artificial drying is necessary. With soft white winter wheat, an early harvest at 16–22% moisture substantially reduces the risk of preharvest sprouting.

If the grain cannot be artificially dried, combining should be delayed until the moisture level has dropped to about 14%. At this point, when a grain head is rubbed between the hands, the kernels should shell out, and most of the central stems of the head should break.

An alternative to direct combining is to windrow the crop when the grain contains 20–25% moisture. Then, after several days of drying, it can be threshed by using a combine with a pick-up head. Windrowing will decrease shattering losses. It is also useful when a field is not ripening uniformly or if many green weeds are present.

During harvesting the combine must be adjusted properly to prevent grain loss, to thresh cleanly, and to prevent excessive cracking of the kernels. The ground speed should be slow enough to prevent overloading the machine. Combining should not

be done when the grain is wet and the straw is tough. Such conditions frequently occur in early morning, in the evening, and after showers.

Wheat, barley, or rye that is in good physical condition and relatively free of trash can be stored at 13% moisture. For oats 12% is the safe maximum. With all small grains a 10–11% moisture content is desired for long-term storage. For safe storage a moisture meter should be used to determine the true moisture content. Grain should not be dried at temperatures above 110° F if it is to be used for seed or above 140° F if it is to be milled. High-moisture grain can also be treated with an acid preservative. Such grain can only be used for feed, however.

While grain is in storage on the farm, bins should be checked regularly for heating, moisture accumulation, and insect damage. In warm weather, insect infestation will begin

near the surface; in cold weather, it will be near the center.

Hay or Silage

Small grains produce respectable yields of high-quality silage or hay. When other forages are in short supply, small grains can be used quite effectively. A good way to use a grain crop that becomes badly lodged is as hay or silage. Also, if the small grain is being used as a companion crop with a forage, this early removal of the plants will decrease their competitive effects on the forage seedlings. Yields of 5 to 8 tons of silage per acre can be expected from a small grain, but amounts as high as 15 tons are possible. In general, oats make the best hay or silage. Cultural practices are similar to those for grain production.

Nutritive value of small grain silage or hay varies with maturity of the



Grain harvest should begin at about 14% grain moisture if the grain is not to be artificially dried.

crop. Dry matter digestibility decreases and crude fiber content increases from the boot to the hard dough stage. Percentage of crude protein also decreases with maturity, whereas total dry matter production increases rapidly up through the milk stage. Although younger plants have the highest feed value, harvest before the milk stage is not generally recommended because of the large yield losses that can result.

Small grains to be used for hay should be cut when in the milk to soft dough stage. After this time, leafiness and protein content decrease rapidly. To facilitate drying, the crop should be run through a hay conditioner before windrowing. Baling should be delayed until the forage moisture content is 22% or less. Drying time is shorter with a pure oat stand compared with a oat and legume mixture.

Good silage can be made at any stage provided the crop is ensiled at the right moisture content, is well packed, and is supplied with adequate carbohydrate. Although the flowering stage is most nutritious, total dry matter and protein production per acre are usually greater at the soft dough stage. Also, this stage provides more available carbohydrates for better fermentation. So for most farmers, harvesting at the soft dough stage is probably best. Because small grains mature rapidly, harvest should begin slightly ahead of the stage desired. Small grains in the soft dough stage usually contain about 65% moisture, which is ideal for putting them directly into the silo. Earlier stages may need to be wilted in the field until they reach 60% to 70% moisture to prevent seepage.



Intensive management of wheat requires timely and cost-effective inputs for maximum economic yields.

INTENSIVE MANAGEMENT OF SMALL GRAINS

An intensive management system for small grains allows a grower to actively manage the crop through additional inputs to obtain maximum grain and straw yields. Additional inputs in an intensive management system include increased seeding rates (precision applied in narrow rows), increased N rates (split applied at critical growth stages), timely applications of foliar-applied fungicides, and the use of growth regulators. European growers adopted this type of management system in the mid-1970s, and average wheat yields in those countries have increased dramatically.

The aim of intensive management is to maximize each yield component by additional inputs of fertilizers and other chemicals. Yield components, characteristics of small grains that determine grain yield, include the number of heads per unit area (head

density), the number of kernels in each head, and the weight of each kernel. Because yield components are interrelated, however, an increase in head density is often accompanied by a decrease in kernel number, kernel weight, or both. Likewise, low head density often results in an increase in kernel number, kernel weight, or both. The intent of intensive management is not to maximize each yield component, but rather to optimize each yield component with respect to each other, thereby obtaining maximum yields.

Each yield component responds readily to environmental and/or management factors. Head density is the yield component most influenced by management factors. Variety selection, planting date, seeding rate, and N fertility status greatly influence the number of heads in the field at harvesttime. Kernel number per head, especially in spring grains, is very responsive to environmental conditions. Heat, moisture, or disease

stress around the flowering period can greatly reduce kernel set in small grains. Because the flowering period of spring grains often occurs in early summer, kernel set can often be adversely affected by excessively hot or dry conditions. In contrast, winter grains flower in late May or early June and often avoid heat or moisture stress at this time. As a result, variety and head density play a dominant role in determining kernel number of winter grains in most years.

Kernel weight is also strongly influenced by environmental factors such as heat, moisture, and disease stress during the grain-filling period. The grain-filling period of spring grains usually takes place in July when it can be hot and dry. Consequently, in some years, spring grains are likely to encounter some stress during grain filling and to incur a subsequent reduction in kernel weight. Winter grains, on the other hand, go through the grain-filling period during the month of June when it is cooler and more moist. Winter grains, thus, also often avoid heat and moisture stress during the grain-filling period. Winter and spring grains, however, are both susceptible to lodging and diseases during grain filling, which can also significantly reduce kernel weight.

Because spring grains are more likely to encounter heat or moisture stress, intensive management is not as successful or currently recommended for them. Spring grains have also not responded consistently to some of the intensive inputs such as high N rates, fungicides, or growth regulators. Winter grains, however, have shown a consistent 15 to 20% increase in grain and straw yields from intensive management inputs. Nevertheless, a full intensive management program modeled after the European system is not always cost effective on winter grains in New York, be-

cause the increased cost of additional inputs cannot be justified in years of depressed wheat prices. A somewhat modified intensive management approach, however, is both agronomically and economically feasible.

The first step in an intensive management program is to execute all the basic agronomic practices in a timely manner. These include selection of well-drained to moderately well drained soils, appropriate tillage methods for the soil, high-yielding varieties, timely planting and fertilization, thorough weed control, and timely harvest. Winter grains will only respond to intensive management inputs if the recommended basic agronomic practices have been followed. Intensive management inputs will not compensate for poor or untimely basic management practices.

Additional inputs in an intensive management system include increased seeding and N rates and foliar applications of fungicides and growth regulators. Research at Cornell indicates that the optimum seeding rate under intensive management conditions is approximately 2.5 bushels per acre. This represents a seeding rate, depending on kernel weight, of 1,650,000 to 1,950,000 kernels per acre (22 to 26 kernels per ft of row in 7-in. row spacing). Crop emergence usually averages about 90%; thus, 1,475,000 to 1,750,000 kernels per acre (19 to 23 kernels per ft of row in 7-in. row spacing) will be established in the fall. Row spacing studies (i.e., 4.5 vs. 7 in.) at Cornell have been inconclusive; thus, narrow row spacing cannot be recommended at this time.

Spring management inputs such as N, fungicide, and growth regulator applications have received most of the attention in intensive management programs. European growers

make multiple applications of N in the spring to limit excessive tillering, reduce lodging, and provide readily available N during stem elongation, the period of maximum N uptake. Research at Cornell on silt loam soils with split applications of N has given inconsistent results. In years of very favorable growing conditions, an economical response to 60 + 60 lb of N at GS 3 and GS 6 has been observed. In most years, a single 70- to 80-lb N application at GS 3 has been the most cost-effective for grain yields. For straw yields, however, a single 90-lb N application at GS 3 has been the most economical rate. Consequently, on silt loam soils in New York, a single 75-lb N application at GS 3 is recommended for intensive management of winter wheat. If the straw is also marketed, a single 90-lb N application at GS 3 is recommended. The previous crop in the rotation or soil type, however, will alter these recommendations. For example, if the field has recently been manured or planted to a legume, the N rates should be decreased accordingly. If winter grains are being produced on somewhat excessively drained soils, with low organic matter contents, the N rates probably should be split applied to reduce the early-season leaching potential on these soils. For grain production, 50 + 40 lb of N at GS 3 and GS 6 are recommended. For grain and straw yields, 50 + 50 lb of N at GS 3 and GS 6 will probably be most cost-effective on excessively drained soils with low organic matter.

Because increased N and seeding rates also increase disease incidence, disease control is essential in a high-yield wheat program. Major foliar diseases prevalent on winter grains in New York include powdery mildew, leaf spots, and leaf rust. Systemic and protectant fungicides that can effectively control these specific



High nitrogen rates increase the lodging potential in winter wheat, and a growth regulator should be used if nitrogen rates exceed 75 pounds/A.

diseases are registered on wheat. Research at Cornell indicates that a timely fungicide application can be economical when disease incidence is moderate to severe and the yield potential of the field is high. Although the Europeans have effectively employed split applications of fungicides in their intensive management program, split applications of fungicides are not recommended on New York winter grains because of economic and time constraints.

High seeding and N rates also create an environment conducive to lodging. Lodging reduces the yield and quality of the crop, while increasing the harvest costs. Plant growth regulators applied at the correct time can prevent or reduce the occurrence of lodging, thereby protecting the yield potential and quality of the crop. In an intensive management program in which high N rates are used, plant growth regulators are recommended.

In conclusion, intensive management of winter grains is agronomi-

cally feasible. Through the use of intensive management inputs, grain and straw yields can be increased by 15 to 20%. Before adopting an intensive management program, however, economic factors must also be carefully considered. In years of low prices, the yield increase may not offset the costs of added inputs. Another factor to consider is the time commitment required for scouting and applying the inputs. The scouting of fields for diseases and the actual application of fungicides and growth regulators occur during May and early June. This time period may conflict with corn planting or hay harvest. In an intensive management program, however, close attention must also be given to the winter grain crop during this busy time of season.

The Field Crop Fact Sheet 403.11, *Intensive Management of Winter Wheat in New York*, contains more detailed information on the subject.

Other Crops



Soybeans are adapted to areas where corn succeeds.

SOYBEANS

Soybeans have occupied from 10,000 to 30,000 acres in New York State for several decades. At one time their acreage was confined to the warmer parts of upstate, but now there are many early maturing varieties, so the distribution of the crop is determined by other considerations. Average yields in New York are about the same as in areas where soybeans are a major crop. The marketing system, however, has never developed to the point where sale is as convenient as it is for corn, wheat, or oats, and on-farm uses have grown slowly.

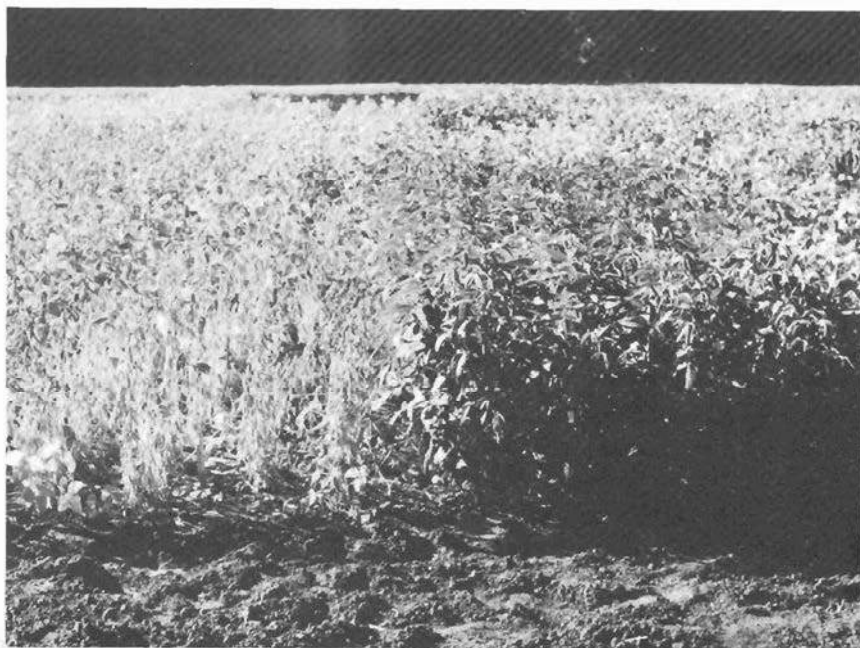
Where to Grow Soybeans

Soybeans are sensitive to frost and drought, so the selection of a site requires a knowledge of field conditions. Most of the acreage in the state has been on medium to medium-heavy soils in the Central and Western plains. These soils are mainly high in lime, and the region also has a long growing season. Some good results have also been obtained in the St. Lawrence and Champlain valleys, which are much cooler, and at some locations in the Southern Tier; however, in these places more attention must be paid to correcting acidity and to "on-time" operations. In general, results have not been satisfactory on sandy or gravelly soils, be-

cause the droughty intervals of late summer often coincide with the sensitive pod-filling stage; and if the crop does not have a generous supply of soil moisture near the surface, yield will suffer. Sandy and gravelly soils are also subject to erosion while soybeans are being grown. In stony fields the combine cutter bar may have to be raised, leaving part of the crop on the stump.

Selecting a Variety

Varieties of soybeans are classified by "maturity groups" to indicate how long a growing period they need. In New York the range of suitable maturity is from Group 00 to Group II.



Soybean varieties mature at different rates, even when planted side by side on the same day.

Generally speaking, late varieties are potentially higher yielding, but are also more likely to be frosted before they are fully ripe.

Soybean breeders in the northern part of the Corn Belt and in eastern Canada have produced many varieties suited to New York. Because older varieties are being replaced, a grower should consult *Cornell Recommends for Field Crops* or another current listing before making a choice.

Soybean seed, like many seeds high in oil content, has a short life in storage. Do not use old seed for planting. Choice of certified seed ensures genetic potential; if a decision is made to use field-run seed, its germination should be guaranteed by a test at the Seed Laboratory, New York State Agricultural Experiment Station, Geneva, New York 14456.

Planting Soybeans

Certain problems associated with planting soybeans are of long standing. Recently some others are being noted.

In states that have longer, warmer seasons, the soybean plants grow taller, and many are grown in 30-inch rows like corn. They are planted with a corn planter, which ensures controlled placement and allows fertilizer to be banded to the side. In New York, yields of soybeans are substantially reduced by such wide rows, so the seeds are customarily drilled at 7- or 14-inch spacing.

Many New York soybeans get off to a poor start because the grower uses an unsuitable drill. The soybean seed, though large and sturdy appearing, is actually quite fragile. Injury usually takes the form of breaking the cotyledons (the large fleshy food-storage leaves) away from the stem and root, so that a weak, "bald-headed" seedling struggles to sur-

Table 29. Soybean planting rate at various row widths

Row width	Seed drop per foot of row*	Planting rate‡
in.	no.	lb/acre
7-9	2-3	75-100
14-16	4-5	60-80
20-24	6-8	50-70
28-30	8-10	45-60
34-36	10-12	40-55

*Based on 85% germination.

‡The larger the seed, the higher the planting rate required. Seed size varies greatly for different varieties.

vive. The device inflicting this injury is usually the fluted feed at the bottom of the seed hopper. To limit the seeding rate, the machine operator sets a narrow gate opening in which the sharp-edged feed mechanism may be forced against the seed, breaking it.

Older drills may also penalize the soybean crop by having no depth bands or presswheels. It takes a large amount of moisture to wet a soybean seed so that it will sprout, and this moisture must be transferred from the soil near the seed. A firm and complete contact between seed and soil is essential at planting.

Time of planting is traditionally just after corn planting. The soybean seedling grows slowly at temperatures below 50° F and is more sensitive to frost after emergence than corn is. But further delay in planting soybeans limits the development of stems and leaves and, therefore, the yield potential. Deep planting, over 1½ inches, also retards growth.

Soybeans and the nitrogen-fixing bacteria they harbor are favored by a soil reaction near pH 7. The crop is

Table 30. Fertilizers for soybeans

Fertilizer nutrients to be added	Soil management groups*	
	I, II, III	IV, V
	lb/acre	
Nitrogen (N)		
Manure added (T/A)		
0	5-20	10-20
10+	5-10	5-10
Phosphorus (P_2O_5)		
Soil test results		
V. low	50	50
Low	40	40
Med.	20	20
High	20	20
V. high	20	20
Potassium (K_2O)		
Soil test results		
V. low	40	60
Low	40	60
Med.	20	40
High	20	20
V. high	0	0

*See explanation of groups in "Soils and Soil Management Groups of New York," p. 10.

also favored by high levels of available phosphorus and potassium. Applications of lime and fertilizer just ahead of planting may not produce results as good as those from fields where high pH and fertility have been maintained. Fertilizer recommendations based on soil test data are summarized in table 30.

An effective nodulation of the soybean roots is one of the objectives of good management. In fields where soybeans have often been grown, bacteria of the desired kind may already be present. But because the cost of inoculating the seed with the special soybean inoculant is small, routine use of inoculant is recommended.

Soybean Pests

Soybeans start growing late and commonly do not grow more than 3 feet tall, so they must be protected from weeds. Cultivation can be carried out with a rotary hoe near emergence; but this implement is uncommon in the state, and most growers rely on preplant or preemergence herbicides.

There are several effective herbicides or combinations of herbicides for use during the season when the soybean crop is on the field. Some perennial weeds, however, must be held in check by a planned sequence of crops and herbicides. Consult *Cornell Recommends for Field Crops* to obtain specific information on choice of herbicide, rates, and timing.

Diseases are common in New York soybean fields. The most conspicuous diseases are bacterial blight, which causes dark speckling of the lower leaves; phytophthora root rot, which causes sudden wilting of young plants; downy and powdery mildews, which produce yellow leaf spots and a silvery surface coating, respectively; and pod and stem blight, which appears as black dots and blotches on the maturing stems. The extent of losses caused by these diseases has not been measured, but the severity of symptoms varies from year to year. At present, fungicidal sprays are not recommended. Using vigorous seed of well-adapted varieties and avoiding repeated crops of soybeans on a field are currently the best protective measures.

Leaf-feeding insects of several kinds are usually present, but none are known to do serious damage with regularity. Nematodes have not been studied.



Four soybeans per square foot on the ground is a loss of 1 bushel per acre.

Harvesting and Handling Soybeans

As the beans ripen, they shrink; the pods turn brown and brittle, and the leaves fall. Stems may remain green or yellow and moist enough to interfere with combining. Lodging can be a problem, but the stems commonly bend above, rather than at, the soil surface. Harvest begins when the beans reach the safe storage moisture level of 13% or somewhat before that if drying and blending facilities are available. Usual recommendations are for a combine ground speed of 2.5 to 3 miles per hour, with a reel circumference speed 25% greater than ground speed.

It is easy to split, crack, or smash the soybeans in a misadjusted cylinder. The operator's manual will give proper settings and speeds for soybeans, which are regarded as easy to clean.



Timely harvest of buckwheat is essential to minimize shattering losses.

BUCKWHEAT

Buckwheat was one of the earliest crops grown in the United States, being first planted by Dutch colonists along the Hudson River. To this date, more than 50% of the U.S. buckwheat production occurs in New York State. Average yields in the United States and New York have been relatively constant since the turn of the century. Once a major crop in the United States, buckwheat now ranks twelfth in grain harvest. The lack of improvement in grain yield as well as the reduced demand for buckwheat by the American consumer is responsible for the relegation of buckwheat to a minor crop.

Buckwheat can have a valuable place on many New York farms. Because of its minimal soil requirements and need for cool climatic conditions, buckwheat is well adapted to many New York farming regions. Recently, there has been an increase in demand for buckwheat by Japan. Also, the expanding popularity of natural food products has created

more demand for buckwheat. Both factors could result in increased buckwheat production in New York State.

Where to Grow Buckwheat

Buckwheat grows best in a cool, moist climate, which is found in many growing regions in New York State. Buckwheat, however, is very sensitive to freezing temperatures. High temperatures and dry weather can also seriously limit buckwheat production. Hot, dry weather at blooming time is especially detrimental because it often results in flower blasting. Because of the sensitivity of buckwheat to extreme temperatures, planting date is a very important consideration for avoiding temperature extremes.

Buckwheat is not particular in its soil requirements and grows well on low-fertility, acid, and other poor soils. Because high fertility levels often cause lodging, buckwheat should not be grown on land best suited for other grain crops. Generally, buck-

wheat produces best on a light, well-drained soil and does not do particularly well on heavy, wet soils.

How to Grow Buckwheat

Several varieties of buckwheat have been grown in New York in years past. Many of these varieties have intermixed through the years until they make up what is now termed common buckwheat. This is the type that had been grown in the state extensively until the last few years. Recently, varieties that are well adapted to New York growing conditions have been developed in Canada. The Canadian varieties have much better milling quality and are preferred by the mills that handle buckwheat.

Buckwheat should be planted after the danger of spring frost is past. Buckwheat blooms 4 to 6 weeks after planting and is mature after 10 to 12 weeks. Because hot weather at blooming causes blasting, the crop should be planted so that flowering occurs in late August to early September after the most severe hot dry weather has already occurred. In warmer regions of New York, the crop should be planted between late June and mid-July for best results. In cooler regions, the planting date should be moved up a couple of weeks.

Buckwheat should be sown with a grain drill at a planting depth of 1 to 2 inches. Although broadcasting is not as satisfactory as drilling, it usually results in adequate stands. If the seed is broadcast, it should be covered by harrowing. The seed should be sown at a rate of 36 to 72 pounds ($\frac{3}{4}$ to $1\frac{1}{2}$ bu) per acre. If the seed is broadcast, the higher rate is advisable. Regardless of planting method, seed with high germination should be used, and a good seedbed prepared. Early plowing is suggested, particularly on rough land. Disking

or harrowing before planting should be used to destroy any weeds and provide a good seedbed.

Nitrogen fertilization is not necessary on fertile soils and, in fact, can reduce yields by increasing lodging. Phosphorus and sometimes potassium can be applied to fertile soils to increase yields. Rates of 20 to 40 pounds of phosphorus per acre should be sufficient. On poor soils a complete fertilizer such as 10-20-20 should be applied at a rate of 150 to 200 pounds per acre. Moderate lime applications to highly acid soils are usually beneficial.

Harvesting Buckwheat

In New York, buckwheat is generally combined directly. Harvesting should be done when the maximum number of seeds are ripe and the plants have lost most of their leaves. If buckwheat is harvested too early, the large number of green seeds cause storage problems.

On the other hand, delayed harvesting can lead to excessive shattering. Because the crop does not ripen uniformly, it is advisable to dry the grain after combining. As an alternative to direct combining, buckwheat can be windrowed and left in the field. After drying for a few days, the windrows are then combined. This method helps reduce shattering.

MILLETS

Four types of millets are produced in the United States. Proso millet is used for grain and is produced primarily in the northern Great Plains. Pearl and Japanese millets are grown for forage. Pearl millet is common in the southeastern United States, and a limited Japanese acreage is grown in New York and Pennsylvania. Foxtail millet is also grown mainly in the Great Plains and the South for use as



Pearl millet can be used for hay or as greenchop.

forage and birdseed. Commonly grown types of foxtail millet include German, Hungarian, and Siberian millet.

Proso Millet

Proso millet is adapted to regions where spring-sown grains are successful, so it offers potential for New York. It is a short-season plant, requiring only 60 to 80 days to mature, depending on the variety. However, it does need warm weather for best growth and is very sensitive to frost. Proso can grow on about any soil type, except coarse sands. It also has the lowest water requirement of any grain crop.

Proso millet should be planted after all danger of frost is past. For most of New York this means early June or about 2 to 4 weeks after corn is planted. Because it does mature quickly, it can be planted later in the summer as a catch crop on a late field or after another crop has failed or has been harvested. Proso should be sown with a grain drill at a seeding rate of 30–35 pounds per acre. A firm, weed-free seedbed is neces-

sary, and planting should not be deeper than 1 inch. On low-fertility soils 30 pounds of P_2O_5 and 40 pounds of N are recommended.

The heads do not ripen uniformly, so the crop should be harvested when the seeds in the upper half of the heads are ripe. At this stage the plant is still green. The plants should be windrowed and allowed to cure in the field. After the required time for curing, Proso millet can be threshed with a combine with a pick-up attachment. Direct combining is not suitable for harvesting proso because of shattering, lodging, and green material problems.

Foxtail, Japanese, and Pearl Millet

The millets are annual grasses, useful for hay and grazing. Japanese millet is very early and can mature in 45 days. The grain from foxtail millet makes excellent birdseed when harvested like proso. Of the foxtail millets, the German type will produce the highest grain yield under New York conditions, with Hungarian and Siberian types far behind. Even at best, foxtail millet yields per acre are low compared with those of corn, wheat, barley, or oats. These millets should be planted for grain only when the grower is assured in advance of a market for the crop, as birdseed or for some other special purpose.

Cultural methods for these species are similar to those for proso, and like proso they fit in well on late fields or after another crop.

For best-quality hay, cut the plants at the bloom stage. Curing is somewhat slow because of the thick stems, so conditioning is recommended. For grazing, it is usually best to begin about 6–8 weeks after planting or when the plants are 6–12 inches tall. After this stage the nutritive value from grazing decreases.

SORGHUM

Sorghum is now a minor crop in New York; but in certain situations and with proper management, it offers an excellent alternative to corn. Because sorghum is more resistant than corn to droughty soils, and some sorghum hybrids tolerate bird damage better than corn, it may outyield corn under such conditions. In general, sorghum has the same temperature and soil requirements as corn for maximum production.

Cultural practices for sorghum are generally similar to those for corn. Early- to medium-maturity hybrids or varieties should be planted. In areas where birds are a problem, bird-resistant hybrids are recommended.

Because the seed is small with limited food reserves, a fine, firm seedbed with a loose surface is required for adequate germination and emergence. Sorghum requires a minimum temperature of 60° to 65° F to germinate; thus, it is usually best to plant sorghum about 1 week later than corn. The most-accurate seeding can be done with a corn planter, but grain drills can be used where the rate of flow can be restricted enough to give the proper seeding rate. For maximum yields grain sorghum should be planted in rows of 30 inches or less. For sorghum to be used as silage, a 30- or 36-inch row spacing is easier to handle, because it is better adapted to chopping equipment. Sorghum seedlings cannot emerge from deep planting as corn can, so the seed should be planted about 1 inch deep and never deeper than 2 inches.

The seeding rate should be about 8 to 12 pounds per acre, with the



Grain sorghum is ready to combine after the seeds are hard and the plants have been killed by frost.

higher rate being used for large-seeded hybrids. Under good field conditions about 75% field emergence can be expected. For top yields a minimum plant population of 70,000 to 85,000 plants per acre is desirable under most New York conditions. In fields where soil moisture and fertility will not be limiting, as many as 100,000 plants are preferable.

Nitrogen, phosphorus, and potassium fertilization rates similar to those used for corn are recommended. Adequate fertilization gives the crop a good start, increases water-use efficiency, improves quality, and increases yields.

Sorghum seedlings are small and start slowly; therefore, good weed control is necessary. Herbicides are registered for both preemergence and postemergence use on sorghum. Because some corn herbicides are unlabeled and also detrimental for sorghum production, check with your local Cooperative Extension agent before selecting a herbicide.

Harvesting Sorghum

Sorghum for silage should be harvested when the grain is in the soft to hard dough stage. At this time the silage contains about 50% grain, the stems contain a maximum sugar content, and excessive leaf loss has not occurred. The forage should be chopped and ensiled in the same way as corn.

Grain sorghum is mature when the seeds are fully colored and have started to harden; this corresponds to a grain moisture of 35 to 40%. Combining should not begin until the grain moisture is 25% or less. Harvesting is complicated by the fact that sorghum does not die when it matures. As a result the leaves remain green until a frost occurs. Harvesting should begin after a frost and when the grain is dry enough to combine. Harvesting should not be delayed after these conditions because lodging, shattering, and sprouting are potential problems. In harvesting, the combine cylinder should be operated at a slower speed than that used for small grains, because the kernels crack easily.

For safe storage the moisture content in the grain must be reduced to 12–13%. Because the grain will seldom field dry to these levels under New York conditions, drying is usually necessary. Alternative storage methods are to store high-moisture grain in an airtight silo or else to treat the grain with organic acid and store it in a noncorrosive bin.



Cultural practices for sunflowers are similar to those for corn.

SUNFLOWERS

Although sunflowers are the major oilseed crop in some parts of the world and have been used to a small extent as a silage crop in New York in years past, our present production is largely in the hands of specialists who produce the oilseed type of sunflower for sale as feed for wild birds. They often mix it with millet or other grains and package it before sale. Several seed companies maintain large breeding programs and offer many hybrid varieties of sunflower.

Growing sunflowers involves equipment and practices that are similar in many respects to those used for growing corn. The crop is planted in rows as the soil becomes warm. Because sandy soils may not support the crop in midsummer and clays may be harmfully wet, medium-textured soils are preferable. Only 6 or 7 pounds of seed are required to provide a plant every 6 inches. Fertilizer and liming recommendations are guided by a soil test,

with target values close to those for corn; and side-dressing with nitrogen at the knee-high stage is routinely practiced. There are herbicides that are labeled for sunflowers. Disease resistance has been improved by breeding, but some diseases continue to be a threat, especially if the harvest season is wet. Small, isolated fields are likely to suffer heavy losses to birds.

As harvest approaches, the seeds dry much faster than the fleshy disk that supports them, and it is necessary to allow the entire head to become dry so that it will shatter and thresh satisfactorily. Combines can be equipped with special devices and adjusted in speed and clearance to suit sunflowers. Often the combine-run material is above the safe 10% moisture level and must be artificially dried. The seed weighs only 22 to 28 pounds per bushel. That makes it easy to dry, but bulky to store and costly to transport.

Useful Tables

Weights and Measures

LIQUID MEASURE

- 1 gallon = 4 quarts = 128 fluid ounces
- 1 gallon of water weighs 8.34 pounds
- 1 quart = 2 pints = 32 fluid ounces
- 1 pint = 2 cups = 16 fluid ounces
- 1 cup = 16 tablespoonfuls = 8 fluid ounces
- 3 teaspoonfuls = 1 tablespoonful = $\frac{1}{2}$ fluid ounce

DRY MEASURE

- 1 bushel = 4 pecks
- 1 peck = 8 quarts dry
- 1 quart dry = 2 pints dry

LINEAR MEASURE

- 1 mile = 5,280 feet = 1,760 yards = 320 rods
- 1 rod = 16.5 feet = 5.5 yards
- 1 yard = 3 feet = 36 inches
- 1 foot = 12 inches
- 1 inch = .0833 foot
- 1 mile an hour = 88 feet a minute

SQUARE MEASURE

- 1 acre = 43,560 square feet = 4,840 square yards = 160 square rods
- 1 square yard = 9 square feet
- 1 square foot = 144 square inches

CUBIC MEASURE

- 1 cubic yard = 27 cubic feet
 - 1 cubic foot = 1,728 cubic inches = 7.4805 gallons
 - 1 gallon = 231 cubic inches
 - 1 bushel = 2,150.4 cubic inches = 1.244 cubic feet
-

Metric System

The basic units of the metric system are meters (length), grams (weight), and liters (volume). All the other metric units are decimal subdivisions or multiples of these units.

PREFIX	MEANING	UNITS
milli- = one thousandth	1/1000, 0.001	
centi- = one hundredth	1/100, 0.01	meter,
deci- = one tenth	1/10, 0.1	gram,
unit = one	1	or
deka- = ten	10	liter
hecto- = one hundred	100	
kilo- = one thousand	1000	

EXAMPLES:

Length

10 millimeters (mm)	= 1 centimeter (cm)
10 centimeters	= 1 decimeter (dm)
10 meters (m)	= 1 dekameter (dkm)
1000 meters	= 1 kilometer (km)

Mass or weight

10 milligrams (mg)	= 1 centigram (cg)
100 centigrams	= 1 gram (g)
1000 grams	= 1 kilogram (kg)
100 kilograms	= 1 quintal
1000 kilograms	= 1 tonne (t)

Capacity or volume

10 milliliters (ml)	= 1 centiliter (cl)
1000 milliliters	= 1 liter (l)
100 liters	= 1 hectoliter (hl)
10 hectoliters	= 1 kiloliter (kl)

All the metric units are related so that the volume of 1 gram of water is equal to 1 cubic centimeter, or 1 kilogram = 1 liter = 1 cubic decimeter of water. The ordinary unit of land area is the hectare. It is equal to 100 square meters.

Metric—U.S. System Conversions**LENGTH**

1 inch = 2.54 cm	1 centimeter = 0.3937 in
1 foot = 0.3048 m = 30.48 cm	1 decimeter = 3.937 in
1 yard = 0.914 m	1 meter = 39.37 in = 3.28 ft
1 mile = 1.609 km	1 kilometer = 0.621 mi

WEIGHT

1 ounce = 28.349 g	1 gram = 0.035 oz
1 pound = 453.592 g = 0.4536 kg	1 kilogram = 2.205 lb
1 hundredweight = 45.4 kg	1 quintal = 221 lb
1 ton = 0.907 metric ton or tonne	1 tonne = 2,205 lb

VOLUME (liquid)

1 fluid ounce = 29.57 ml	1 liter = 1.05 qt = 33.6 fl oz
1 quart = 0.946 l	1 hectoliter = 26.25 gal
1 gallon = 3.785 l	

VOLUME (dry)

1 cubic inch = 16.387 cm ³	1 cubic cm = 0.061 in ³
1 cubic foot = 0.028 m ³	1 cubic m = 31.338 ft ³ = 1.308 yd ³
1 cubic yard = 0.765 m ³	1 hectoliter = 2.8 bu
1 bushel = 36.368 l	

AREA

1 square inch = 6.452 cm ²	1 square cm = 0.155 in ²
1 square foot = 0.093 m ²	1 square m = 1.196 yd ²
1 square yard = 0.836 m ²	1 square km = 0.386 mi ²
1 square mile = 2.69 km ²	1 hectare = 2.471 acres
1 acre = 0.405 ha	

PROPORTIONS

1 gal/acre = 9.35 l/ha	1 liter/ha = .42 qt/acre
1 lb/acre = 1.12 kg/ha	1 kg/ha = 14.5 oz/acre
1 lb/in ² = 0.0702 kg/cm ²	1 kg/cm ² = 14.227 lb/in ²

Temperature conversions

°C	°F
100	212
90	194
80	176
70	158
60	140
50	122
40	104
35	95
30	86
25	77
20	68
15	59
10	50
5	41
0	32
-5	23
-10	14
-15	5
-20	-4
-25	-13
-30	-22
-40	-40

Characteristics of grain, protein, and oil crops

Crop	Scientific name	Seeds per pound	Seeds per gram	Bushel weight	Germination time
		1000s	no.	lb/bu	days
Barley	<i>Hordeum vulgare</i> L.	13	30	48	7
Bean, field	<i>Phaseolus vulgaris</i> L.	1–2	4	60	8
Buckwheat	<i>Fagopyrum esculentum</i> Gaertn.	20	45	48	6
Corn, field	<i>Zea mays</i> L.	1.2	3	56	7
pop	<i>Zea mays</i> L.	3	7	56	7
sweet	<i>Zea mays</i> L.	2	4	50	7
Field pea	<i>Pisum arvense</i> L.	4	8	60	8
Flax	<i>Linum usitatissimum</i> L.	82	180	56	7
Millet-foxtail:	<i>Setaria italica</i> (L.) Beauv.	220	470	50	10
proso	<i>Panicum miliaceum</i> L.	80	180	56	7
Oats, common	<i>Avena sativa</i> L.	14	30	32	10
Rape, oilseed	<i>Brassica napus</i> Koch.	160	345	50	7
Rye	<i>Secale cereale</i> L.	18	40	56	7
Sorghum, grain	<i>Sorghum vulgare</i> Pers.	15	33	56	10
Soybean	<i>Glycine max</i> Merrill	2–3	6–13	60	8
Sunflower	<i>Helianthus annuus</i> L.	3–9	13	24	7
Wheat, common	<i>Triticum aestivum</i> L.	12–20	35	60	7

Quick Conversions of rates or yields

kg/ha	bu/acre			tonne/ha	ton/acre	bu/acre	
	lb/acre	56 lb	60 lb			56 lb	60 lb
1	0.9			1	0.45	16	15
1.1	1			2	0.9	32	30
5	4.5			2.3	1	36	33
5.7	5			4.6	2	71	67
10	9			5	2.25	80	75
11.4	10			6.8	3	107	100
50	45			9.1	4	143	133
57	50	0.9		10	4.5	160	150
100	90	1.6	1.5	11.4	5	179	167
114	100	1.8	1.6	13.7	6	214	200
500	450	7	7.5	15.9	7	250	233
570	500	8.9	8.3	18.2	8	286	267
1000	900	16	15	20.5	9	321	300
1120	1000	18	16	22.8	10	357	333

Number of feet of row per acre at various row spacings

Distance between rows in inches	Feet of row per acre
7	74,674
12	43,560
15	34,848
18	29,040
20	26,136
21	24,891
24	21,780
28	18,669
30	17,424
32	16,335
36	14,520
40	13,068

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Helping You Put Knowledge to Work**

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