Soil and Plant Relationships
FOLLOWING the general trend of scientific development, the men investigating soils and the men investigating plant life have come to be separate tribes, each specializing in fields that have become more and more complex. But if such a division is necessary and convenient, it is also in a sense artificial, like the division between the throat specialist and the ear specialist, both of whom deal with branches of the science of medicine. The primary function of the soil, so far as human beings are concerned, is to grow plants, and the real point of all soil investigations is to discover more and more about the relationships between the plant and the soil in all of their many aspects.

This part of the Yearbook discusses some of these relationships—the soil requirements of the more important crops; the effects of the major chemical elements in the soil on plant nutrition, and on the nutrition of the animals that use the plants for food; the effects of certain other chemical elements that were not given much attention in the past but today are increasingly seen to be very important in many cases; the special problem of the effects of selenium in soils; and the association of broad types of native vegetation with soil series, which often makes it possible to diagnose certain soil conditions by observing the native vegetation.
This article gives six conditions that are essential if the soil is to be suitable for the growth of crop plants. Some of these favorable conditions can be brought about, under certain circumstances, by management practices; others must be inherent in the soil. Following a brief discussion of these general soil requirements, the article takes up the important crop plants in alphabetical order, describing the soils most suitable for each.

The Soil Requirements of Economic Plants

By M. F. Morgan, J. H. Gourley, and J. K. Ableiter

If a soil is to compete successfully in the production of an economic plant that is climatically adapted to a given region, it must provide, either naturally or by economical adjustment, certain favorable conditions.

Six Essential Soil Conditions

The fundamental requirements of crop plants as to soil condition may be summarized as follows:

1. Suitability for the cultural implements required for most efficient production;
2. Effective resistance to destructive soil erosion or soil depletion under the cropping system involved in profitable management;
3. Adequate moisture storage to meet the water requirements of the crop, under normal rainfall or irrigation;
4. Adequate aeration to a suitable depth to permit the development of a favorable root system for the mature plant;
5. Available plant nutrients sufficient for profitable yields; and
6. Freedom from adverse chemical conditions such as harmful concentrations of soluble constituents, and from other special soil conditions that favor the development of organisms parasitic to the crop.

The prevailing topography, or lay of the land, associated with a given soil is often the determining factor in its suitability for crops, with respect to both cultural operations and soil erosion. The undesirable physical properties that make the tillage of intractable clay soils very difficult are often an effective barrier to their profitable utilization. The prevalence of tillage-impeding boulders throughout many soils places them under a handicap that cannot be surmounted.

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under present labor costs. The peculiar erodibility of certain silt loams and very fine sandy loams, such as those developed on the loessial deposits of the Mississippi Basin, operates against their long-time use for many valuable cultivated crops to which they are otherwise adapted.

The third requirement, adequate moisture storage, while capable of direct modification by irrigation, is not possible of fulfillment on great areas of excessively sandy soils, or in vast regions where there is no available source of irrigation water. The supply of both water and oxygen for plant roots is determined by several conditions of the soil, such as texture, structure, and depth to the water table. These may be grouped together for convenience as the moisture relationships of the soils. They, in turn, are of almost equal importance in determining the chemical status of the soil, since they are factors in microbiological activities influencing nitrogen transformation, sulphation, oxidation, carbon dioxide production, etc., rate of solubility of the constituent soil minerals, oxidizing or reducing conditions, and the degree of concentration of dissolved substances.²

The fourth condition, adequate aeration, is precluded in many soils with a water table near the surface, or with heavy, impervious subsoils that cannot be drained satisfactorily. In many regions well-drained, suitably aerated soils, with mellow or friable subsoils overlying porous substrata, are available, and the waterlogged soils are relegated to native vegetation or to the low-grade grazing provided by certain grasses and sedges that withstand such a condition. On the other hand, many soils with only slightly imperfect aeration seem to be satisfactory for a time, but in seasons of especially heavy rainfall, or with increase in the age of the growing plants and consequently greater root requirements—as with orchard fruits—they prove to be unsatisfactory.

The fifth requirement, an adequate supply of plant nutrients, is adjusted most readily. The chemical condition of the soil as a requirement for plant growth involves its ability to supply adequate amounts of available nutrients to meet the needs of the plant during all periods of growth, without permitting the development of harmful concentrations of any constituent. The decreasing relative cost of fertilizer materials and the growing scarcity of soils that give profitable yields without added nutrients both tend to minimize the unfavorable economic situation of a chemically "poor" soil. It is still true, however, that a truly fertile soil requires a comparatively small investment of fertilizer for the growing of the common farm crops.

The sixth condition, freedom from adverse chemical conditions, is also largely subject to intelligent control. For example, excess salts may be leached from the soil and harmful alkalinity corrected by the application of gypsum or sulphur, provided plentiful water and adequate drainage can be supplied. Adverse acidity may be overcome by liming.

² Many efforts have been made toward the isolation of a single soil characteristic that defines the moisture status of the soil. The "moisture equivalent" measurement developed by Briggs and McLane (1925) while empirical in character, appears to be a reasonably satisfactory basis of comparison since it represents a fairly approximate weighted average of the influences of soil texture, composition of soil colloids, humus content, and soil structure. Thus, when existing conditions of soil moisture are considered in relation to the moisture equivalent, the degree to which the soil maintains a deficient, favorable, or excessive moisture condition for adequate plant growth can be determined. This is well illustrated by the studies of Conrad and Viehmeyer (76), Lunt (62), and others.

³ Italic numbers in parentheses refer to Literature Cited, p. 1181.
Injurious plant diseases or root parasites that are related to soil reaction or drainage condition may be avoided in part by good soil management. The cost of such steps, however, may place such ill-favored soils in an adverse position in competition with more suitable ones.

Conditions of favorable physiological balance must be provided. The ability of the plant to absorb a basic constituent is modified by the quantities of other bases active in the soil. Thus, magnesium is less available in a soil containing large amounts of active calcium and potassium, and the intake of potassium may be insufficient if calcium or magnesium is disproportionately high. Some plant nutrients utilized in large amounts, such as the nitrate ion, may be distinctly harmful in excessive concentration; others, chiefly boron, zinc, and copper, although definitely required in minute amounts, produce toxic effects at relatively low concentrations. Others, such as thallium or selenium, have never been found to be of any benefit and are extremely poisonous when any appreciable amount is present in the soil solution.

The reaction (acidity or alkalinity) of the soil is an important factor influencing plant growth either directly or indirectly. Under strongly alkaline conditions, harmful effects accompany the development of excessive amounts of alkali carbonates. In very acid soils there may be injurious concentrations of certain constituents, such as aluminum and manganese, that are only slightly soluble at a moderate degree of acidity. The microbial activities of the soil are greatly influenced by the soil reaction. Availability of phosphorus is affected by factors related to the soil reaction. The degree to which nitrate and ammonium nitrogen may be assimilated by the plant is also a function of the acidity or basicity of the soil solution.

It is possible to provide normal growing conditions in the absence of soil if the roots are provided with adequate water, oxygen, and plant nutrients in proper balance; if the conditions of light, temperature, and carbon dioxide content of the air are favorable; and if adequate support is furnished for the plant. Results obtained by growing plants in culture solutions amply demonstrate that the soil factors requisite to plant growth are those directly or indirectly related to the needs of plant roots for an adequate supply of water, favorable conditions with respect to oxygen, and sufficient plant nutrients in the proper chemical proportions.

DETERMINATION OF SUITABLE SOIL TYPES

It is brought out in other sections of this Yearbook that a soil type connotes a series of interrelated internal and external characteristics. A careful study of these characteristics gives an excellent picture of the degree to which the six fundamental conditions discussed are favorably expressed. Thus, the detailed description of the soil profile may show by a mottled color or impervious structure of the subsoil that aeration is inherently unfavorable. The texture of the upper layers, in association with the features of surface relief, indicates cultural possibilities. The moisture relationships must be evaluated in terms of the entire soil profile. The fertility of a virgin soil—its content of available plant nutrients—is dependent upon the nature of the soil-forming processes and the length of time they have operated, as well as upon the chemical nature of the parent soil material.
The natural characteristics of a soil type are capable of modification by cultural practices, the effects of lime, crop residues, and destruction of organic matter or depletion of chemical fertility by long-continued cropping and accelerated erosion. Hence, many areas of soil types once favorable for a particular crop are no longer suitable, while in many instances naturally infertile soils have been built up to a much more productive state than is normal for the soil type in question. A careful study of the characteristics of the important soil types which are supporting particularly profitable crops of a given plant in each climatic region, however, affords a basis for the evaluation of the soil requirements of the plant.

In all of this discussion it will be noted that climatic conditions are considered to be favorable. Actually, however, it must be remembered that climate is a most important factor determining plant distribution. On the other hand, because soils are an expression of environment, including the climatic forces, a discussion of existing soil types favorable for specific crop plants necessarily connotes also a favorable climatic regime. Any consideration of climate as something apart and distinct from a geographical soil area results only in a hypothetical and artificial situation.

Broadly speaking, relatively permeable and fertile soils of good water-holding capacity are favorable for the growth of most important crop plants. With suitable climatic environment, some soils seem to possess an especially wide range of crop adaptation. Thus, the Hagers-town silt loam of the Appalachian limestone valleys is capable of growing satisfactory yields of practically every field crop, forage crop, vegetable, or fruit of the North Temperate Zone. On the other hand, optimum conditions for corn are more readily provided on the Carrington loam of the Central States, for early market vegetables on the Norfolk sandy loam of the Coastal Plain, or for fruit on the neighboring Frankstown gravelly silt loam of the Shenandoah section. Yet satisfactory crops of corn are produced in every State east of the High Plains from the Gulf of Mexico to the Canadian border. Within this vast expanse one may find good fields of corn on soils differing widely in important soil characteristics. Despite these apparent contradictions, economic plants differ greatly in the degree to which the various soil conditions previously mentioned must be satisfied.

Space does not permit a detailed treatment here of the soil relationships of the wide range of commercial crops grown in the United States and its possessions. The most outstanding soil requirements of the important crop plants will be discussed, however, together with illustrations of especially favorable soils for each. The crops are grouped and arranged alphabetically for convenient reference.

**IMPORTANT CROP PLANTS AND THEIR SOIL REQUIREMENTS**

**Cereal Crops**

**Barley**

Barley, a cool-weather crop, is rather widely distributed in continental United States. Three major barley regions are recognized—the semiarid or western; the humid spring, or northeastern; and the humid winter, or southeastern. It is
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grown most extensively in the spring-wheat belt, although it is very important in parts of the hay and dairy region, in the central Great Plains, and as a winter crop in California. Since good drainage is a primary soil requirement, barley is not as well suited as are oats and wheat to certain heavy clay soils of the humid sections. It is more sensitive to mineral deficiency than the wheat crop and is less tolerant of acidity than most other cereals. As a result, sandy soils generally are very unsatisfactory. On the other hand, barley withstands moderate concentrations of alkali and soluble salts. The fact that barley is damaged easily by hot humid weather prevents its being grown on many soils of the Corn Belt that are otherwise favorable. Barley is generally better adapted to the northern Great Plains and less suited to the Corn Belt than oats.

The chief centers of barley production lie in areas represented by the Barnes, Bearden, and Fargo soils of the eastern Dakotas and western Minnesota; the Carrington, Tama, and Clinton soils of southeastern Minnesota; the Kewaunee and Miami soils of eastern Wisconsin; the Clarion, Carrington, and Miami soils of northeastern Illinois; the Keith, Weld, Bridgeport, and Tripp soils of northwestern Kansas, southwestern Nebraska, and eastern Colorado; and the Yolo and Capay soils of the Sacramento Valley of California.

Buckwheat

Buckwheat is a locally important crop in the northern Appalachian area and in certain portions of the Lakes States. It does best where the climate is moist and cool, but it is very susceptible to frost. Its short growing season of 10 to 12 weeks permits maturity at high altitudes and latitudes, and cool nights appear to be quite essential for seed formation.

Buckwheat will produce a better crop on relatively infertile soil than any other grain, provided other conditions, notably climate, are satisfactory. It is well suited to light well-drained acid sandy loams. In fact, an acid soil is apparently preferable for buckwheat. It does not do well on heavy, poorly drained land, or on sandy soils that are exceedingly droughty and infertile. It may be grown on newly cleared land or drained marshland, which carry too much decaying organic matter for ordinary grain crops.

Because of its adaptability buckwheat is largely used as a catch crop. It does not have a definite place in the rotation except in areas notably lacking in productive soils where the more favored cereals will not grow.

The principal areas for buckwheat are the Allegheny Plateau section of New York, Pennsylvania, Maryland, and West Virginia, and the sandy soils of Michigan, Wisconsin, and Minnesota. The principal soils are the Lordstown and Dekalb of the Allegheny Plateau, and the Plainfield, Coloma, Rubicon, and Rose-lawn of the Lakes States. Phosphorus is usually the only fertilizing element added in the areas where buckwheat is grown to any extent as a cash crop.

Corn

This is a rapidly growing crop, making its maximum demands upon the soil during the late summer period. Varieties differ widely in growth characteristics, ranging in size from the Tuxpan, which frequently attains a height of 12 feet or more, to types like the Gehu that mature at less than 3 feet. In its normal habitat in North Dakota, Gehu will mature in about 90 days, whereas in southern Texas, Tuxpan probably requires about 150 days.

As to the soil requirements for the corn plant, varieties appear to differ chiefly in moisture requirements. Although the water requirement of corn (pounds of water transpired per pound of dry matter) is comparatively low, the tonnage grown per acre brings about a heavy demand for moisture. It may be stated that in practically all instances corn that is adapted to a given climatic region, regardless of variety, must obtain water from the soil during the period of its most rapid growth at a faster rate than any other field crop of the region. In the northern Great Plains at the border of its climatic region, it is to be noted that corn survives hot, dry weather better than spring wheat and because of thin planting does not deplete the soil of moisture so completely. The corn plant is sensitive also to conditions of deficient soil aeration that may result from either excessive soil water, poor tilth, or impervious character of the subsoil.

Corn is grown rather successfully over a considerable range of soil reaction, at least from a pH of 5 to 8. Yields are usually adversely affected, however, by
degrees of acidity represented by pH values less than 5.5, and below a pH of 5 serious diminution in yield is normally experienced. In the United States, corn is not ecologically adapted to the climatic regions where alkaline soils are common. Under irrigation these soils, however, may produce good yields of corn.

Corn requires an abundance of readily available plant nutrients. Nitrates must be furnished by the soil at a rapid rate during the late summer months. A deficiency in phosphorus is especially reflected in a slow initial growth. Although corn has relatively a good ability to obtain potassium from most soils that are not excessively sandy, in a number of Eastern States the soils must be enriched with available potash. This is done either through manuring or fertilization. Magnesium has been found to be deficient for normal growth on some acid, sandy soils of the Middle and North Atlantic States, particularly in seasons of excessive soil leaching. In the South, corn is usually fertilized heavily with complete fertilizer and top dressings of soluble nitrogen except when it is grown on the better soils of the bottom lands.

Of the zonal, or great soil groups, the Prairie soils are inherently the best suited for corn, since they fulfill its requirements most completely and are developed in the region in which the climate is especially favorable. It is no mere accident that the Corn Belt, although more extensive geographically, centers about the Prairie soils, extending from western Indiana to eastern Nebraska. Here the climate and grass vegetation have been largely responsible for the development of fertile soils of favorable reaction and high in organic matter and exchangeable bases. The benefits of the relatively high content of organic matter, such as tilth, water-holding capacity, and available nutrients, are well known and scarcely need further comment. The dark color of the surface of these soils of the grasslands also promotes to some degree a desirable soil temperature.

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Probably the best producing soils of the Corn Belt are the artificially drained, dark soils of the glacial-lake depressions and flood plains. They include the Wabash, Webster, Brookston, and Clyde series. From the point of view of soil classification, these highly productive soils are the zonal and intrazonal associates of the Prairie soils. The Tama, Marshall, Clarion, Carrington, and Wakkesha are representative and extensive series of the Prairie soils. The Grundy and Muscatine, known as Planosols because of their claypan development, are important corn-producing soils in southern Iowa and northern Missouri. The generalized soil map at the end of the Yearbook shows the general geographic distribution of the Tama, Marshall, Carrington, Clarion, Webster, and Grundy soils. Recent soil survey reports should be referred to for the distinctions that characterize each series as to profile features, physiographic position, and the nature of the parent soil material.

To the west, in the Chernozem region, the Moody soils of Nebraska and South Dakota deserve mention for the production of corn. Other important soils for corn, though less ideally adapted to the crop, are the silt loams of the following series: Clinton (central Corn Belt), Miami (eastern Corn Belt), Hagerstown (Appalachian limestone valleys), Maury (bluegrass region of Kentucky and Tennessee), and Bladen (southern Coastal Plain).

Three other soils that deserve especial mention for their production of corn and their distinctive role in the local agriculture of certain areas of the South and East are the Huntington, Congaree, and Genesee series. These are the well-drained, relatively brown soils of flood plains which differ primarily from each other in the mineralogical composition of the parent material. The associated soils of the uplands, often hilly, stony, and infertile, are used largely for forage, pasture, hay, and grain. A small acreage of these fertile soils on the bottom lands enables successful farm units to be established in areas that otherwise would be relegated to forest. Corn is frequently grown year after year without any appreciable loss in productivity.

**Oats**

Although grown throughout continental United States, oats are best suited to a cool moist climate. Soil requirements include fair drainage to avoid lodging and disease. A favorable amount of available nitrogen is essential, but at a lower level than for corn. Excessive nitrates cause serious losses from lodging. Responses to phosphorus and potassium are usually less definite than for either corn or wheat, and oats are apparently able to thrive at a lower level with respect

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4 The soil groups and series and their locations are discussed in Soils of the United States, p. 1019.
to these mineral nutrients, although on the sandy soils of the Carolinas and Georgia, the crop responds well to applications of muriate of potash. In certain areas of the Middle West it has been observed that the gray-speck disease of oats is a physiological condition related to manganese deficiency in soils. Although the chief oat-producing soils are nearly neutral in reaction, the crop is not exacting in its lime needs and does well on eastern soils at as low a pH as 5.2. It is not adapted to distinctly alkaline soils. In the South, oats are sown in the fall.

The principal oat-producing region includes much of the Corn Belt of Illinois, Iowa, and southern Minnesota, and overlaps into the Gray-Brown Podzolic region in Minnesota, Wisconsin, Michigan, Ohio, and New York, to the north and east, and into the Chernozem belt to the west. The two most important centers for oats are the northern Iowa-southern Minnesota and east-central Illinois areas where oats are an important crop following corn in rotation. On the soil map at the back of the Yearbook, both of these areas are shown to have the Clarion-Webster and Carrington-Clyde soil associations. Other important soil series are the Moody and Barnes of the eastern Dakotas and western Minnesota, the Tama and Marshall of Iowa, the Miami, Kewanee, Clinton, and Isabella of Wisconsin and Michigan, and the Ontario and Honeyoe of western New York.

Areas of less importance include the belt extending southward from Iowa across eastern Kansas, Oklahoma, and central Texas, valleys in the intermountain States and the Pacific Northwest, and the Southeastern States. The use of oats as a feed crop or as a nurse crop for clover explains in part their distribution in these regions of diverse climatic and soil conditions. An enumeration of the soils producing oats in these areas will not be attempted.

**Rice**

The physical conditions controlling rice production are temperature, water supply, and soils. This crop in the United States must be grown on soils that (1) are capable of holding irrigation water over the surface for a considerable period, (2) may be drained promptly and quickly, and (3) provide a solid footing for cultural machinery after the removal of water. Rich, dark-colored alluvial soils with impervious subsoils are generally utilized. Fertilization is rarely required under such conditions, although the use of nitrogen in ammonia or organic form, as well as phosphates, is often of benefit.

The culture of rice in continental United States is confined largely to the clays, clay loams, silty clay loams, and silt loams of the Lake Charles series in Texas, the Lake Charles and Crowley series in Louisiana, and the Crowley series in Arkansas. In California the clays, clay loams, and adobe clays of the Stockton, Landlow, and Sacramento series are used.

**Rye**

Rye is less exacting in its soil requirements than any of the other important cereals. It grows well over a wide range of conditions with respect to soil moisture, although it is adversely affected by deficient drainage. It is able to withstand considerable degrees of acidity and alkalinity. The crop makes a reasonable growth at low levels of fertility, both with respect to available nitrogen and mineral nutrients. On the other hand, it is able to make a relatively luxuriant growth under especially favorable conditions without damage to grain quality. Losses due to lodging from excessive nitrates are much less than with wheat or oats.

As a result of its tolerance for sandy and other relatively infertile soils, it is generally grown on them or as a catch crop where other crops have failed. It is also used as a winter cover and pasture crop, although in the South it is being replaced by winter legumes. The principal rye areas are the sandy lands in North Dakota, South Dakota, Nebraska, Minnesota, Wisconsin, and Michigan, although in the Great Plains rye finds general favor because of greater certainty as a crop than wheat, use for pasture, and the fact that fall sowing lessens spring labor. Some of the soils that may be mentioned are the Barnes and Bearden sandy and fine sandy loams of North Dakota, South Dakota, and Minnesota, the Thurman and Anselmo soils of Nebraska, the Plainfield and Coloma of Minnesota, Wisconsin, Michigan, and the Boone of Wisconsin.
Sorghums

These crops are grown chiefly in southern Great Plains areas under climatic conditions too dry for corn. Their drought resistance enables them to serve as a substitute feed crop for corn. Like corn, sorghums are especially favored by an abundance of organic matter, good aeration, and a liberal supply of plant nutrients. The sorghums probably withstand moderately saline or alkaline soil conditions to a greater degree than corn.

The sorghum-producing area of the Southwest (Kansas, Oklahoma, Texas) is closely associated with the winter-wheat area, although the two areas cannot be said to be identical. In this area where light-textured and heavy-textured soils often occur in an intimate association, the lighter soils of the farm are frequently used for sorghums and the heavier for wheat. Included in these soils are the Amarillo, Miles, St. Paul, Pratt, Abilene, and Grant. Sorghums are also important in southeastern Kansas, where they are produced on the claypan soils (Parsons, Cherokee) and on the Bates. Sorghums for grain are grown also to some extent in the Salt River and Yuma Valleys in Arizona and the Imperial, San Joaquin, and Sacramento Valleys in California.

Other sorghums that have not been included in this discussion are the sorgos or sweet sorghums, broomcorn, and Sudan grass. A scattered acreage of sorgos extends northeastward from Texas as far north as Wisconsin and as far east as North Carolina and Virginia. Sudan grass is known in nearly every part of the United States. Broomcorn is centralized in Oklahoma and Illinois.

Wheat

Although its water requirement is greater, the wheat crop makes a less rapid drain on soil moisture per unit of area than corn. As previously stated, it is recognized in the northern Great Plains that corn produces a better crop than spring wheat in the more droughty years, probably owing to the lower water requirements for the relatively low tonnage of corn produced per acre on the edge of its climatic region. Wheat is less adversely affected by poor aeration resulting from heavy soils than corn. Winter wheat, however, is especially subject to injury on soils maintaining a high water content during the winter months. A favorable organic content is desirable in order to promote good tillth, but in general, the best dark-colored Corn Belt soils are not so well suited to wheat. A moderate liberation of available nitrogen of the soil is required, but excessive nitrates favor serious damage by lodging during the later stages of growth. Available phosphorus must be at a fairly high level in order to promote the formation of grain. Potash is rarely deficient in soils otherwise well adapted to wheat, although in the States east of the Mississippi River, potash fertilization is becoming increasingly necessary where manure is not used during the rotation. Lime is probably of less direct benefit to wheat than to corn, although wheat is grown most extensively in areas with neutral to slightly alkaline soils. Wheat withstands a moderate concentration of soluble salts and carbonates, but is not adapted to strongly saline or alkaline conditions.

The Chernozem and Chestnut soils may be said to play a role in wheat production similar to that of the Prairie soils in corn production. Although production is less hazardous in the Chernozem belt where rainfall is heavier and the soils are darker and deeper, wheat is relatively a more important crop in the Chestnut and Reddish Chestnut zones, largely because of its ability to produce a product of excellent quality (high protein content), under the semiarid conditions. In fact, under the economic stimulus of high prices during and immediately after the World War too much wheat was grown on land the alternative use of which was grazing.

This condition serves to illustrate the importance of economic as well as environmental conditions in determining the major centers of production of crops.

The principal soils of the subhumid to semiarid grasslands of the Great Plains and Columbia Plateau that are used for wheat are the loams and silt loams of the smoother upland areas, although the Fargo clay and the Pullman and Richfield silty clay loams are exceptions, both in texture and in their physiographic position. The Chernozem soils include the Barnes, Bearden, and Fargo of the eastern Dakotas and western Minnesota; the Holdrege and Hastings of Nebraska and northern Kansas; the Hays of central Kansas; and the Palouse of Washington and Oregon. The principal Chestnut soils include the Williams and Morton
soils of North Dakota and Montana, the Rosebud of South Dakota and Nebraska, the Keith of Nebraska and Kansas, the Weld of Colorado, and the Walla Walla of Washington and Oregon. The principal soils of the Reddish Chestnuts which are used include the St. Paul, Abilene, Pullman, and Richfield of Oklahoma, Texas, and Kansas.

The Yolo soils of the Sacramento Valley of California, developed on alluvial fans, have been important producers of wheat, although today many areas are used more intensively for fruit production. These soils are usually capable of producing up to their climatic yield limits without fertilization. Under continuous cropping, however, it is difficult to maintain organic matter against erosional losses sufficient for favorable tilth and moisture-holding capacity.

Desirable wheat soils in humid sections are Miami silt loam of the eastern Corn Belt, Wooster silt loam, Ontario and Honeoye silt loams of eastern Ohio and western New York, Hagerstown silt loam of the Appalachian limestone valleys, and Georgeville silty clay loam of the Piedmont Plateau. The productivity of these soils is dependent upon adequate fertilization and good rotational practices.

**Citrus Fruits**

In the restricted climatic limits within which citrus fruits are grown in continental United States—in Florida, the Rio Grande Valley, and southern California—the soils that have been found most desirable are of light or medium texture. Their drainage conditions are almost perfect, with somewhat excessive under-drainage. Commercial fertilizers are required in liberal amounts. The highest quality of fruit is probably obtained on soils containing a relatively high supply of bases. An excessive basicity, however, tends to produce chlorotic foliage. This is probably associated with the unavailability of those elements required for plant growth in only minute amounts. Zinc \(Zn\) and iron \(Fe\) compounds have both been beneficial to citrus fruits on such soils.

Under a more restricted moisture supply, the sandy, porous soils most commonly used for oranges might prove too poor in moisture retentiveness. Water, however, is either supplied by irrigation or provided through an abundant, well-distributed rainfall, as in Florida.

The following soils have been extensively used for citrus fruits: Norfolk fine sand, Norfolk fine sand, hammock phase, Blanton fine sand and Orlando fine sand in Florida; Hidalgo fine sandy loam and Victoria fine sandy loam in the Rio Grande Valley of Texas; Fallbrooke fine sandy loam, Hanford sandy loam, and Placentia gravelly loam in California; and the Mohave gravelly and sandy loams in the Salt River Valley in Arizona.

**Cotton**

This long-season southern crop is represented by a number of types varying considerably in their soil adaptations. It requires a soil of good moisture-holding capacity, with favorable drainage and aeration. Soils well supplied with organic matter are the most productive, although much of the southeastern area is on seriously humus-deficient soil. The crop is successfully grown at various degrees of acidity, the most favorable range being pH 5.2 to 7. The soils east of the Mississippi lowland are generally so deficient in available nutrients that fertilizers are used very extensively. The available nitrogen in the soil is rarely adequate, and both phosphorus and potassium must also be supplemented from fertilizer sources. The rich, dark-colored Rendzina soils of Texas are much more fertile, and fertilization is not so extensively practiced. The breeding of cotton types especially adapted to areas of more restricted rainfall has added extensive acreages in cotton in northern Texas and western Oklahoma on soils of high mineral fertility and well supplied with available nitrogen.

The boll weevil infestation has brought about a distinct change in the use of land for cotton in the Southeastern States. Formerly, the heavier soils were preferred because of their better productivity. With the advent of the boll weevil, cotton has been pushed onto the less fertile, light-textured soils of the uplands, where it matures earlier and partially escapes the ravages of the boll weevil. The withdrawal of cotton production from parts of the Black Belt of central Alabama is an example.

The following soil types are representative of the various cotton sections: Greenville sandy loam, generally regarded as one of the best cotton soils of the
Coastal Plain; Tifton sandy loam of Georgia; Orangeburg fine sandy loam of the Coastal Plain; Norfolk sandy loam of the Coastal Plain; Cecil sandy loam of the Piedmont Plateau; Sarpy, Sharkey, and Yazoo soils of the Mississippi lowland extending from Kentucky to Louisiana; Miller and Portland soils along the flood plains of the Arkansas and Red Rivers in Arkansas, Louisiana, Texas, and Oklahoma; Houston black clay of Texas; Miles fine sandy loam of northwest Texas; Enterprise very fine sandy loam of Oklahoma; Gila, Pima, Mohave, and Laveen soils of New Mexico and Arizona; Imperial, Holtville, Meloland, Hanford, and Delano soils of California. These soils of the arid Southwest have a wide range in texture, from sandy loam to clay.

**Flax**

In the United States flax is grown almost entirely for its seed, flaxseed or linenseed, although some 3,000 to 5,000 acres of fiber flax are grown annually in the Willamette Valley of Oregon. Seed flax is grown chiefly in the spring wheat area of Minnesota and the eastern Dakotas and in southeastern Kansas. Recently flax has been grown very successfully as a fall-sown crop under irrigation in California. The acreage of flax varies considerably from year to year in spite of favorable prices as compared to spring wheat, its chief competing crop. Flax is well adapted to the cool climate of the North Central States where the principal precipitation occurs during the growing season. Some years ago the crop was grown to some extent farther west in the northern Great Plains, but during the recent drought years its cultivation in that area has been almost entirely discontinued.

Flax is not exacting in its soil requirements, its production depending principally on rainfall and a moderately cool climate. It is tolerant of a comparatively wide range in pH values. The crop is well adapted to the Chernozems of the eastern Dakotas, the Prairie soils of southern Minnesota, and the Pianosols of southeastern Kansas. The crop does well also on sandy loam soils if the supply of moisture is adequate. In California, flax is grown very successfully under irrigation on sandy soils of the Imperial Valley, the so-called soft lands. In the North Central States the hazard of wilt has been overcome by the development of wilt-resistant varieties. Flax diseases are not a factor thus far in Kansas and California. Weeds are perhaps the greatest hazard to successful flax production. The control of weeds by means of crop rotation is an important practice in every area where flax is grown.

**Grasses**

**Kentucky Bluegrass**

This grass is the dominant species in the best grazing areas east of the Great Plains. Both good drainage and moisture-holding capacity of the soil are essential. The conditions of chemical fertility for best results are rather exacting. Large amounts of nitrogen must be available during the periods of most active growth, particularly in the spring, early summer, and autumn. Kentucky bluegrass is frequently associated with white clover, a nitrogen-fixing plant. Nitrogen fertilization, however, is generally needed, as the usual irregular occurrence of the white clover does not furnish sufficient nitrogen for maximum production of grass under present farm practices. Phosphorus is important, particularly for associated legumes, and soils must be either naturally rich in this element or maintained at a reasonable level of phosphorus availability by farm practices. Although the plant is able to obtain a sufficient amount of potash from most soils that are otherwise favorable, nitrogen and potash are the most effective fertilizers for growth on certain soils, such as the Sassafras silt loam.

The soils must be well supplied with calcium. The most desirable pH range is probably 5.8 to 8.2. Because of the cost of lime applications on an extensive scale, the chief areas of bluegrass grazing are still confined to soils developed from calcareous material.

Representative soils suitable for the crop in important grazing sections are Maury silt loam of Kentucky and Tennessee; Hagerstown, Frederick, and Dunmore silt loams of the Appalachian limestone valleys; Calais loam of Vermont; the Baxter silt loam of the Ozarks; the Clinton silt loam of the upper Mississippi Valley; Fairmount silty clay loam of Kentucky, Ohio, and Indiana; Honeoye and Ontario silt loams of New York. The typical Corn Belt soils are also usually very productive for bluegrass.
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Timothy

Timothy, the most commonly used hay crop in the Northeast, is grown extensively on a wide range of soil conditions over most of the area north of the Cotton Belt and east of the Great Plains. It is also grown in the Pacific Northwest and to a very limited extent in the intermountain region, both with and without irrigation. It is rather sensitive to deficient moisture conditions during the early summer period when it is producing its seed-bearing spike. Fairly good drainage is required. Timothy is adapted to a considerable range of soil reactions but is adversely affected by high acidity to about the same degree as corn. Natural moisture conditions in most soils containing carbonate accumulations are rarely adequate, but under irrigation timothy is an important crop, usually in mixtures with clover. Timothy produces good crops on many eastern soils at a relatively low fertility level, although yields are improved by manuring and fertilization. Nitrogen is especially beneficial in the top dressing of timothy hay lands.

The most favorable soils for timothy, in general, are those of the flood plains, such as the Tioga and Chagrin of New York, the Genesee of New York, Ohio, Indiana, and Michigan, the Huntington of the limestone valleys of Pennsylvania, Virginia, and Tennessee, and the Wabash of Iowa and Missouri. These soils, as previously stated, are also most favorable for corn. As a result, hay production is commonly more important on other soils, less suited for the other crops. In the North Central States corn, oats, and hay form the common rotation, so that the principal hay-producing soils such as the Miami, Clarion, and Carrington are also important for corn and oats. In sections farther north where climatic conditions are relatively unfavorable for crops other than the grasses and where topography and stoniness interfere with tillage, hay is grown in a longer rotation, and the soils become important primarily for the production of this crop. The Spencer of Wisconsin, Ontonagon of Michigan, Canfield, Dutchess, Lordstown of New York, and the Worthington, Berkshire, and Blanford soils of New England are examples, although their relative importance varies with the type and kind of associated soils.

Legumes

Alfalfa

This perennial legume is grown extensively in long rotations on dairy farms of the East and Middle West. It is also grown directly for the market, and is being used more and more in relatively short rotations. West of the range of red clover, it is the chief legume hay crop. Its exceptionally deep and extensive root system gives it an especial advantage in certain areas where surface moisture may be deficient, although a moderately moist soil must be provided for its initial stages of seedling growth and best yields are obtained on irrigated soils. It requires excellent underdrainage for its best growth in long rotations. Some of the soils of the eastern Corn Belt, capable of growing good corn or wheat, are thus ill-favored for alfalfa, especially those with impermeable subsoils. Other unsuitcd soils are those underlain by bedrock at a comparatively shallow depth.

Alfalfa is especially sensitive to soil acidity and rarely grows to advantage at pH levels below 6. It tolerates alkali and salt concentrations better than most other farm crops, although sweetclover excels alfalfa in this respect. Alfalfa is also quite averse to phosphorus deficiency, and in the eastern half of the area of its occurrence it must be heavily phosphated. Potash is often a limiting factor, especially on the sandy soils, which have a poor reserve of available potash in the subsoil.

Being less limited by deficiencies of soil moisture than most other legumes, alfalfa is especially well distributed over the western half of the United States. As to the relative merits of sweetclover and alfalfa in respect to water requirements over a period of years, comparisons between perennial and biennial plants cannot well be made. If comparison is made of the seedlings in the second year's growth, sweetclover is more drought-resistant than alfalfa. In the West, however, the main centers of alfalfa production are on irrigated lands. The characteristics of practically all soils developed under conditions of low rainfall are both chemically and physically favorable to alfalfa, with the exception of those which are strongly alkaline, salty, or excessively sandy.

Important alfalfa-producing soil series in various sections are the Hagerstown of Pennsylvania-Virginia-Indiana; the Honeoye and Ontario of New York; the
Kewaunee, Miami, and Fox of Wisconsin-Michigan-Indiana-Ohio; the Waukesha, Hall, and Moody of Nebraska; the Summit of Kansas-Missouri; the Boarden of the Red River Valley; the Miller, Yahola, and Reinaich of Texas and Oklahoma; the Fort Collins and Prowers of Colorado; the Ralston of the Big Horn Basin, Wyo.; the Gila and Mohave of Arizona; the Hanford and Yolo of California; the Portneuf of Idaho; and the Ritzville of Idaho, Washington, and Oregon. The Davidson clay loam of the Piedmont section is locally very important, although its contribution to national production is small. Other soils locally important have been omitted, and no mention has been made of soils in Utah because the recent date of soil surveys in much of the State has prevented the correlation of the soils there.

**Beans (Dry)**

Beans to sell in the dry shelled state are grown on a relatively wide variety of soils. The best yields are obtained on the soils of medium and heavy texture that are well supplied with plant nutrients and organic matter. The highest producing fields in Michigan, for example, are on the dark-colored soils in the Saginaw Valley. Beans can be grown on the lighter-colored, sandier soils if properly fertilized and grown in rotation with other leguminous crops, such as the clovers and alfalfa.

The principal bean-producing sections include the Ontario-Honeoye soil area of western New York; the Saginaw Valley and adjoining glaciated upland of southern Michigan, where the Kawkawlin, Brookston, and Miami soils are important (these are included in the Toledo-Vergennes and Miami-Kewaunee areas of the soil map at the end of the Yearbook); the irrigated northeastern Colorado section of the Weld and associated soils; the Portneuf soils of the irrigated Twin Falls section of Idaho; and irrigated valleys in New Mexico, Montana, and California.

**Red Clover**

In the humid region, red clover is the most commonly used legume in general crop rotations, either seeded alone with grain crops, or in combination with grasses such as timothy. While somewhat deep-rooted in its habit, it requires a soil of good moisture-holding capacity. On the other hand, it is sensitive to poor underdrainage. On heavy soils practically saturated with water during winter months, serious winter-killing is often experienced.

Red clover is moderately exacting in its requirements with respect to soil reaction. Soils more acid than pH 5.6 rarely produce good clover crops. It is fairly tolerant of alkali and saline conditions. Being a legume, when the soil contains the proper strain of *Rhizobium* for nodule production, it is practically independent of available nitrogen from the soil. Soils that are especially deficient in humus, however, rarely provide suitable physical conditions. Readily available phosphorus in the soil is especially important, and phosphorus-deficient soils must be liberally fertilized with phosphatic fertilizers. This crop, which uses a relatively large amount of potash, is capable of utilizing both surface and subsoil potassium to good advantage. As a result, potash fertilization gives direct benefit only on a few especially potash-deficient soils.

This crop is grown extensively on a wide range of soil type, from eastern Nebraska to New England and from Tennessee to northern Minnesota. It is also important in the Pacific Northwest and intermountain States. The chief factors that have restricted its success are heavy, intractable subsoils, excessive soil acidity, and depleted mineral fertility. Representative types especially well suited to clover are Marshall and Carrington silt loams and Clarion loam of the central Corn Belt; Fox and Miami silt loams of Ohio, Indiana, Michigan, and Wisconsin; Brookston silty clay loam (drained) of Michigan, Indiana, and Ohio; Ontario and Honeoye loams of New York; Hagerstown silt loam of Pennsylvania and Virginia; Davidson clay loam of Virginia and North Carolina; Maury silt loam of Tennessee and Kentucky. These soils are characterized by their relatively high content of bases, particularly potassium, and with the exception of the Davidson have been developed from calcareous parent material. The Maury is noted for its high content of available phosphorus. The Willamette and Chehalis soils in the Willamette Valley deserve mention for their production of red clover. The irrigated Portneuf soils of Idaho are used for hay and seed.
Peanuts

Peanuts are one of the important cash crops in southeastern Virginia, north-eastern North Carolina, southwestern Georgia, and southeastern Alabama. They are used chiefly in the manufacture of oil, peanut butter, candy, confectionery products, salted peanuts, and for stock feed. Suffolk, Va., is said to be the largest peanut market in the world, while Dothan, Ala., claims to be the center of the section of greatest production.

The soil requirements for this crop differ according to the varieties. The Spanish White has a much wider soil adaptation than the Virginia Bunch, Virginia Runner, and the North Carolina varieties. It does well on both light-textured and heavy-textured soils, but it produces the best yields and the best quality product on the Red soils. It is grown principally in southwestern Georgia and southeastern Alabama on the Orangeburg, Greenville, Tifton, Norfolk, and Ruston soils. The Lenoir and Craven soils of southeastern Virginia are also utilized.

The large peanuts commonly sold in hulls on the open market are of the Virginia and North Carolina varieties. These varieties are confined largely to lighter-textured and well-drained soils. The Norfolk sandy loams, Norfolk sandy loam, deep phase, and to some extent the loamy fine sand produce an excellent quality of these varieties. Dark-colored soils are objectionable as they stain the hull and lower the market price.

Peanuts require light fertilization, that is, from about 200 to 400 pounds of 2-8-6 or 400 pounds of 0-10-6. Good results are obtained also from a light application of lime.

Soybeans

Although this crop is grown in many sections from Missouri and Iowa eastward to the Middle Atlantic States and southward to the Gulf of Mexico, its chief commercial development is in Illinois, Indiana, and neighboring States. Central and eastern North Carolina are relatively important sections also. Soil conditions favorable to corn are normally well suited to soybeans. Growth is limited on humus-deficient heavy clay, and very strongly acid soils, although soybeans are comparatively much more tolerant of acid soils than is red clover. Abundant soil moisture is desirable, although the soybean does withstand drought remarkably well.

The soybean section in Illinois and Indiana is found principally on the Carrington-Clyde, Tama-Marshall, Putnam-Vigo, and Miami-Brookston areas as outlined on the generalized soil map at the back of the Yearbook. In northeastern Missouri, soybeans are grown on the claypan soils such as the Grundy and Putnam. In the Piedmont of North Carolina the Georgeville silty clay loam may be mentioned, while to the east on the Coastal Plain the Bladen, where drained, is used successfully. In Louisiana, soybeans are grown largely on the alluvial and low terrace lands of the Mississippi and Red Rivers.

Orchard Fruits

No one criterion will serve in selecting an orchard site. Several are closely interrelated, notably elevation above surrounding country, topography, soils, and the weather characteristics of the immediate region. In special cases the proximity of large bodies of water is an important factor, as in States bordering the Great Lakes. Occasionally, economic factors encourage the selection of soils of only mediocre orchard quality. It has been well stated (336), however, that experience indicates that the soil alone may often cause a 50- to 100-percent difference in yield.

The prime requisites for soils to be suitable for orchards are that they must hold within the root zone sufficient water to carry the trees through periods of drought and yet be sufficiently permeable to permit ready penetration of roots, air, and water. The profile characteristics of the soil in relation to drainage and depth to bedrock are of especial importance. Sweet and Oskamp (391) have emphasized the factors associated with drainage, in the orchards of western New York, which included "the degree and extent of mottling in the subsurface and upper subsoil, pronounced mottling and iron concretions often being observed where the movement of water is slowest; the presence of a so-called gray layer or a well-defined change in the horizon revealing a sharp transition from a darker
subsurface to a light gray stratum, where drainage is poor; an impervious layer of clay rather near the surface, retarding the downward movement of water. Depressional or pocketed areas, particularly where the subsoil is clay, are associated with missing, dead, or dying trees."

The limestone valley of Virginia, Maryland, and Pennsylvania is an example of a region in which the root zone of certain soils is limited by rock rather than by a high water table. In western irrigated areas, the most important consideration is to have a soil that is light textured or pervious enough to take up water from irrigation satisfactorily but not so light textured or porous that its water-holding capacity is too low.

In earlier times there was a prevailing idea that land too infertile for farm crops might well be used for an orchard. This notion may have resulted from the observation that trees usually lived and bore fruit on obviously poor soil, while fruit trees on exceedingly fertile soil were subject to winter injury, frequently unreliable in bearing, and more subject to blight and other troubles than those which made a slower growth. The prevailing opinion at present would counsel the avoidance of extremes with respect to available plant nutrients. A moderate degree of fertility is desirable, especially in order to promote the satisfactory growth of cover crops desired to maintain the organic matter of the soil at a favorable level. Most commercial orchardists now practice nitrogenous fertilization, and complete fertilizers are increasingly considered desirable in long-time orchard fertility maintenance.

The deciduous fruits have such a wide tolerance to soil reaction that no definite optimum can be identified. Veatch and Partridge (44) state that "the range in reaction in the surface layers, or solum proper, was found to be from a pH of 4.5 to 7.5, but no definite correlation of either good or unsatisfactory growth was established within this range." The effects of soil reaction are to be considered chiefly in relation to the growth of cover or interplanted crops. Liming of the

![Figure 1.—Root distribution on Alton gravelly loam. A1, brown gravelly sandy loam; A2, brownish-yellow sandy loam; B, water-worn sandstone and gravel embedded in reddish-brown sand; C, gray sand, loose. Satisfactory rooting in a uniform brown profile. The different sizes of circles represent approximate root diameters as follows: Black dot 0–2 mm, smallest light circle 2–5 mm, next larger heavy circle 5–10 mm, next larger light circle 10–20 mm, and so on, in gradations of 10 mm, the circles being alternately heavy and light.](image-url)
soils beneath fruit trees has never been an established practice. Very alkaline soils must be avoided, since various types of chlorosis are common under such conditions and the early death of the trees may occur.

From a physical standpoint the ideal texture is a loam. Loamy sand, sandy loam, heavy silt loam or clay surface soils, however, may be suitable for orchards if the other conditions are favorable. In no case should there be bedrock, hardpan, or a waterlogged stratum within the rooting zone.

The requirements and limitations of orchard soils are well illustrated by Os-kamp's (290) descriptions of a good and a poor orchard soil in western New York, summarized in the following paragraphs.

The Alton gravelly loam contains varying proportions of sand and gravel, as it has been developed over irregularly stratified deposits of these materials. It is open and porous, with excellent internal drainage. The colors of the soil profile are slightly varying shades of brown except at the lower depths, where layers of grayish water-washed sand and gravel may predominate. The average annual yield (3-year average) of Baldwin apples on this soil is 12.3 bushels per tree, as contrasted with an average of 6 bushels on 10 soils studied. The yield of Rhode Island Greening is 8.9 bushels, as compared to an average of 7.4 bushels. The root distribution found in this favorable soil is shown in figure 1.

In contrast, the Lockport loam is an inferior heavy type. A rather large proportion of gravel and slabs of red sandstone occurs in the soil, and particularly in the subsoil, the stoniness increasing with depth to an almost impenetrable mass at 3 or 4 feet. The average yield of Baldwin apples on this soil was 3.6 bushels, as compared with 12.3 bushels for the Alton gravelly loam, and 6.9 bushels as the average for 10 soils studied. Rhode Island Greenings yielded 2.2 bushels as compared with 8.9 bushels on the Alton soil, and 7.4 bushels for the 10 soils. The shallow root system is well illustrated in figure 2.

Orchardists are becoming more and more conscious of the adverse influence of compactness of soils for orchards. Heavy implements and constant cultivation of the land are important agents in compacting a soil and hence in bringing about poor aeration and lack of porosity. One index of the openness of the soil is its percolation rate. A large number of tests must be made at different soil depths, since the soil varies greatly even within small areas. The laboratory method of Bouyoucos (41) has been found useful in such studies.

Remedial measures are often attempted to overcome undesirable features of soil used for orchards. Large amounts of organic matter may be worked into the soil in order to improve the physical condition and water-holding capacity. Often this is attempted on soils that are infertile, very acid, or wet, with disappointing or unprofitable results. Wet soils are tiled, shallow soils are plowed
deep, sometimes with special deep-tillage tools to break up a hardpan or impervious subsoil. Dynamite is used at times to loosen a compact substratum where the tree is to stand. Improvements resulting from the above measures sometimes warrant their expense. They rarely overcome the handicaps of a poor soil, however, and cannot compare with results obtained when a deep, well-drained, well-aerated, and moderately fertile soil is selected at the outset.

**Apples**

The foregoing considerations are especially applicable to the apple crop. There are also special varietal considerations. Thus, the Rhode Island Greening appears better suited to rich, heavy soils than the Baldwin. Most of the apple acreage is found in the eastern and northern parts of the United States where the summers are comparatively cool and the winters are less severe than in the interior of the continent. These include the Hudson River Valley section and the Lake Ontario plain of New York; the limestone valleys of Virginia, West Virginia, Maryland, and Pennsylvania; sections of New England; the western Michigan area; the western Illinois district; and the Ozark region.

Although most of the apple acreage is in the East, the most important individual apple-producing areas from the point of view of intensity of production are the Wenatchee and Yakima Valleys of Washington. Other areas of the West that are irrigated or receive supplementary irrigation are the Hood River Valley in Oregon; the Payette-Weiser area, Idaho; the Grand Junction-Delta-Montrose district, Colo.; and the Sebastopol and Watsonville districts, Calif.

Among the many soils that are used for apples throughout the country, the following are distinctly important: The Dunkirk of the Ontario district; the Dutchess of the Hudson Valley; the Frederick, Frankstown, and Murrill, of the limestone valleys; the Isabella, Miami, and Hillsdale loams of Michigan; the Baxter and Clarksville soils of northwestern Arkansas and southwestern Missouri; the Wind River loam of the Hood River Valley; and the Wenatchee loam of Washington.

**Cherries**

Cherries require less moisture than apples and are frequently grown on soils of light texture. Deep, dry sands are objectionable, however, except in a few instances where water may easily be supplied in plentiful amounts. The following soils are especially productive in important centers of production: Dunkirk and Alton sandy loams of western New York, Rosclawn loamy sand of Michigan, and the Whatcom silt loam of northwestern Washington. Cherries are also produced in the Yakima Valley of Washington on what was broadly mapped as Yakima sandy loam in 1901. The Longrie, Posen, and associated soils should be mentioned for their production of cherries in Door County, Wis., although they were not recognized as such on the older soil map of this important cherry-producing peninsula.

**Peaches**

This crop is most commonly grown on soils of somewhat lighter texture than is considered most desirable for apples, although the best apple soils are also suitable for peaches, within their climatic limitations. The following are typical of important peach sections: Palmyra and Alton gravelly sandy loams of western New York; Manchester gravelly sandy loam of Connecticut; Norfolk sand of North Carolina; Greenville sandy loam of Georgia; Fox sandy loam of Michigan; Princeton fine sandy loam and silt loam of southwestern Indiana; Memphis (Ava) silt loam of southern Illinois; Tujunga sand, irrigated, and Yolo fine sandy loam of California.

**Pears**

In general, pears appear better adapted to somewhat heavier soils than other orchard trees. However, adequate depth of soil suitable for root development, with good drainage and aeration, is especially important. Excessive available fertility, particularly with respect to nitrogen, is to be avoided from the standpoint of twig injury. The following soils have been found desirable in important areas of pear production: Hudson silty clay loam of the Hudson Valley, N. Y.; Darien and Col-
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lamer silty clay loams of western New York; Nappanee silt loam of Michigan; Gibson silt loam of southern Indiana and Illinois; Medford gravelly clay loam of Oregon; and Aiken silty clay loam of California.

Plums

The soil requirements for plums appear to be similar to those for pears. In California, where the prune types are most extensively grown, the Yolo silt loam is typical of a highly productive prune soil.

Potatoes

Although primarily a crop of cool and moist climates, potatoes are extensively grown over a wide range of soils, throughout the northern humid sections and in irrigated districts. Loam, fine sandy loam, or silt loam soils having deep mellow subsoils with especially good underdrainage are most desirable. The crop requires moist soil conditions at all times, without any tendency toward poor aeration. A high state of chemical fertility must be either naturally present or artificially provided. The potassium requirements are relatively high. The crop does well over a considerable range of soil reaction. In the Northeast, where scab-sensitive varieties are grown, reactions between pH 4.8 and 5.4 are considered best. Much of the western production, however, is on less acid or slightly alkaline soils.

Soils upon which potatoes are grown successfully in various parts of the country are as follows: Caribou loam of Maine; Enfield very fine sandy loam of Connecticut; Bridgehampton loam of Long Island, N. Y.; Wooster and Bath gravelly silt loams of western New York; Sassafras loam of New Jersey; Bladen fine sandy loam, drained, of Florida; Fox silt loam of Ohio, Indiana, and Michigan; Isabella sandy loam of Michigan; Plainfield sandy loam of Wisconsin and Minnesota; Bearden very fine sandy loam of the Red River Valley of North Dakota and Minnesota; Weld fine sandy loam of Colorado; Havre loam of Montana; Portneuf silt loam of Idaho; Sauvie silt loam of Oregon; peat of the Sacramento-San Joaquin delta, Calif.; and Yakima sandy loam of the Yakima Valley, Wash., as it was broadly mapped in 1901.

Small Fruits

Blackberries, Raspberries, and Dewberries

These crops may be grown on a variety of soils provided the soils are moderately fertile, well drained, easily cultivated, and of good moisture-holding capacity. Conditions of air drainage are important. Air pockets are subject to frost and disease, while exposure to strong winds causes unfavorable drying, both in winter and summer. These crops are generally grown on acid soils without the use of lime. Fertilization is practiced to only a limited degree. It is difficult to point out distinctive soils for the production of blackberries, raspberries, and dewberries, because of their wide distribution in small acreages. In many areas, these crops are grown on soils also selected for orchards, especially for peaches and cherries. Some of the representative soils on which they are grown are the Napanee silt loam of Michigan, the Baxter silt loam of the Ozarks of Missouri and Arkansas, and the Norfolk fine sandy loam of Texas. The Puyallup Valley of Washington probably represents the most intensive small fruit district in the United States. The Everett-Alderwood-Kittitas association of soils occupies this area. Detailed surveys now in progress will furnish more specific information as to soil conditions in this and other small-fruit districts in the West.

Blueberries

Blueberry culture in recent years has rapidly reached importance in a few special areas of the Coastal Plain, as in New Jersey and North Carolina. As a part of the native vegetation, wild blueberries are associated with the leached and acid soils of the Podzols, Brown Podzolic, Gray-Brown Podzolic, and the Red and Yellow Podzolic groups, including both dry and imperfectly drained sandy soils.

It is recommended that land to be planted to blueberries in New Jersey (29) consist of shallow muck overlying sand that is underlain with hardpan at 3 to
Irrigation is necessary in dry weather if higher lying and less moist land is used. Deep peats are unsatisfactory. Methods of fertilization are being developed. The soil types best suited are Leon fine sand and Leon sand. These are associated members of the Lakewood-Dukes soil area shown on the soil map in the Yearbook.

Cranberries

Cranberry culture like blueberry culture is of particular importance in a few special areas. Massachusetts, the outstanding State for cranberry production, markets more cranberries than the other States combined. The next States in the order of their production are New Jersey, Wisconsin, Washington, and Oregon.

The cranberry grown for commercial production is the large or American cranberry that is found growing wild in the swamps of northern United States from Virginia to the Pacific coast. Various varieties have been selected and developed for commercial production. Other related plants include the small or European cranberry, the southern mountain cranberry, and the highbush cranberry used for ornamental purposes.

The cranberry is like the blueberry in that it requires an acid soil. Conditions of water supply for controlled flooding are very important and the plant is grown in bogs and never on the upland. In Massachusetts, peat and muck bogs are used, to the surface of which sand has been added. In New Jersey, shallow muck overlying sand underlain by hardpan is recommended (45) as it is for blueberries, although apparently a much greater depth of muck and peat is tolerated by the cranberry.

The principal sites for cranberry bogs in Massachusetts and New Jersey occur within the Lakewood-Dukes soil associations, as shown on the soil map at the back of the Yearbook. Besides bogs, the St. Johns sand and Leon fine sand are used in New Jersey. The muck and peat lands associated with the Plainfield-Coloma area of central Wisconsin make that the important cranberry-producing section of the State. The bogs of the Olympic-Melbourne and Everett-Alderwood-Kittsop associations account for the cranberry production in the Northwest.

Grapes

The exact explanation of the apparent superiority of certain soils for the production of grapes of especially fine quality for fruit or wine has not yet been discovered. It may well be that local climatic factors associated with the occurrence of these soils are more important than the soil itself.

Most good grape soils are deep, mellow, well-drained sandy loam, loam, or silt loam soils, containing a considerable amount of gravel or shaly rock fragments. Favorable moisture retentiveness must go hand in hand with highly favorable soil aeration. A moderately high level of available chemical fertility must be maintained, especially with respect to phosphorus and potassium. While the soil may be moderately acid to slightly alkaline in reaction, the best soils for grapes are not seriously depleted in basic constituents.

The following soils are typical of the important grape districts: Dutchess gravelly silt loam of the Hudson Valley; Dunkirk gravelly loam of the Lake Erie shore, in New York and Pennsylvania; Chenango loam, gravelly phase, of western New York; Baxter silt loam of the Ozarks; Aiken gravelly clay loam, Pleasanton gravelly sandy loam, Placentia sandy loam, and Hanford sandy loam of California.

Strawberries

Although light loams and sandy loams appear to be especially desirable, strawberries may be grown upon almost any type of soil, provided it is retentive of moisture, fairly fertile, and well drained. A moderate level of fertility is desirable. Fertilization is most intensively practiced in the Southeastern States. Phosphorus appears to be the element most needed in the soils of the Mississippi Valley region and nitrogen in the soils of the Coastal Plain. The reaction of the soil is not apparently a limiting factor in strawberry production, as the plant does reasonably well on soils very strongly acid to alkaline. Experiments have shown that best growth is obtained on soils with a range of pH 5.0 to 7.0 provided the organic content is relatively high, but with lower organic content the range for best growth is much less—5.7 to 6.5 or less.
The following soils are typical of areas well suited to the crop in commercial districts: Elkton sandy loam, artificially drained, of Delaware; Keyport sandy loam, artificially drained, of Virginia; Denham and Olivier silt loam of Louisiana; Baxter silt loam, Clarksville shale loam, and Hanceville shale loam of western Tennessee and the Ozarks area of Missouri and Arkansas.

Sugar Crops

The sugar crops consist of sugarcane and sugar beets. Of the raw sugar produced in the United States (continental United States, Hawaii, and Puerto Rico), approximately 65 percent is cane sugar and 35 percent beet sugar. In 1936, about 40 percent of the raw cane sugar was grown in Puerto Rico and about 45 percent in Hawaii. All of the beet sugar and the remainder of the cane sugar was grown in continental United States. The total production amounted to about 3,726,000 short tons of raw sugar.

Sugarcane

This crop requires a relatively high temperature and considerable sunshine together with liberal amounts of available soil moisture during the growing season. For best yields, other soil requirements are good availability of soil nitrogen, abundant supply of available mineral nutrients, and a relatively deep and friable subsoil for root development. Sugarcane is tolerant of moderately acid to moderately alkaline conditions. In general, those soils developed under relatively low rainfall, when properly irrigated, are more productive in terms of sugar per acre than the soils of the humid areas.

The chief development of sugarcane for sugar production in continental United States has been on the fertile alluvial soils of the lower Mississippi Valley in Louisiana, although Florida also contributes. The Iberia, Lintonia, and Olivier are the principal soils. The Yazoo soils shown on the older soil maps probably would be correlated differently today. Climatically, the region is handicapped by the danger of frost. In addition to the more localized production of sugar, sugarcane is generally grown in small patches throughout the Gulf Coastal Plain for local sirup production.

A comparison of yields for 1936 as reported in Agricultural Statistics for 1937 shows the average acre yields of cane in Hawaii, Puerto Rico, Louisiana, and Florida to be 70.1, 25.3, 17.6, and 35.3 short tons, respectively. In the same order, the pounds of sugar made per ton of sugarcane are given as 222, 244, 156, and 180.

Sugar Beets

The production of the crop is highly localized by economic, climatic, and to less degree by soil factors. The growing of sugar beets has developed chiefly within the zone marked off by the isotherms of summer temperature of 68° and 72° F. mean temperature. Sugar beets are influenced strongly by temperature conditions of the growing season. Under conditions of warmer temperature than those of the zone mentioned, sucrose accumulation in the roots may be depressed. Under cooler conditions, the growing season becomes too short.

Soil requirements include a well-drained, deep, and permeable seedbed of good moisture-holding capacity. The fertility level including the lime content should be comparatively high. Attention to these requirements must be given to sugar beets grown under irrigation as well as to those grown without.

Although many districts of northern United States have suitable conditions of temperature, other factors such as type of agriculture, economic conditions, soil conditions, and hazards of disease have limited the production of sugar beets largely to the irrigated sections of the West, the Lakes States, and the Middle West. Protective trade measures have enabled these sections to compete with the cane-sugar production of tropical areas.

The principal centers of sugar-beet production in the humid region are the Saginaw Valley of Michigan, where the Brookston and Kawkawlin soils are utilized; the lake plain in northwestern Ohio, where the Brookston, Pandora, Clyde, and Toledo soils are used; the area in northern Iowa and southern Minnesota of the Webster and Clarion soils; and the Red River Valley in Minnesota and North Dakota where the Fargo and Bearden are the dominant soils.
Important irrigated sugar-beet areas and accompanying soil series include the Scotts Bluff area of Nebraska of Tripp soils; the northeast portion of Colorado of Weld soils; the Arkansas Valley of Colorado and western Kansas of Prowers soils; the Yellowstone Valley districts of Montana and North Dakota of Havre soils; the irrigated sections of southern Idaho of Portneuf soils; the irrigated valleys of Utah, where the soils have not as yet been finally correlated as to series name; and the valleys of California of the Yolo and Sacramento soils.

Sweetpotatoes

The sweetpotato is rather lenient in its soil requirements provided the climatic conditions are satisfactory. These include a growing season of about 4 months with warm days and nights, considerable rainfall early in the season, and plenty of sunshine. Well-drained soils are a prerequisite, with sandy loams the most desirable texture.

The commercial sweetpotato crop is largely centered in the Cotton Belt, northwestern Tennessee, eastern Virginia, Maryland, Delaware, and southern New Jersey. The principal soils are the sandy loams of the Norfolk and Sassafras series. This crop largely replaces the potato throughout the South for home consumption.

Tobacco

The soil requirements of tobacco are somewhat unique, in that in addition to the needs for normal growth, there are certain rather special correlations between soil type and characteristics of quality in respect to each of the various types of tobacco.

In general, tobacco is a crop making very rapid growth during a short season. It requires large amounts of available soil moisture within reach of its comparatively shallow root system, but, at the same time, it is relatively sensitive to poorly drained conditions. Carefully adjusted, though relatively large amounts of readily available nitrogen must be supplied. Bright-leaf tobacco may be somewhat of an exception as to its need for large amounts. The phosphorus needs of the plant are not great, although soils with low levels of available phosphorus permit little growth until corrected by phosphatic fertilizers. Potash is utilized by the tobacco plant in especially large amounts, and the crop has little or no ability to obtain potassium from the "nonexchangeable" potassium of soil minerals. Hence, liberal potash fertilization is ordinarily practiced, except in rotations on land receiving a supply of available potash from large amounts of animal manures.

The relative proportions of basic constituents (calcium, magnesium, and potassium) capable of ready assimilation by the plant are important in determining the burning qualities and ash characteristics, especially in cigar types. Chlorides in the soil solution are undesirable because of the objectionable burning effect. In Puerto Rico, there is apparently sufficient sodium chloride brought in as a fine spray by the northeast trade winds for the atmosphere to have a deleterious effect upon the quality of tobacco for a distance of approximately 4 miles from the coast.

Tobacco is capable of normal growth over a wide range of soil acidity. Excessive acidity, however, at pH levels below 5.0, is often harmful to quality or yield, as it results in low supplies of calcium and magnesium, low phosphorus availability, and excessive solubility of manganese and aluminum. As the soil reaction approaches the alkaline range, the black root rot disease is favored, especially in areas like the Connecticut Valley where the crop is grown year after year on the same fields.

The special soil adaptations of various tobacco types have been the subject of considerable investigation. The variation in soil requirements is well illustrated by the representative soil types in the important producing centers for the leading tobacco types, as follows: Cigar wrapper—Merrimac sandy loam, deep phase, of Connecticut and Massachusetts; shade-grown cigar wrapper—Greenville and Magnolia soils of Florida and Georgia; cigar binder and filler—Hagerstown silt loam of Pennsylvania, Russell silt loam of Ohio, and Clinton silt loam of Wisconsin; Burley tobacco—Maury silt loam of Kentucky and Clarksville silt loam of Tennessee and Missouri; flue-cured bright tobacco—Durham, Appling, and Cecil sandy loams of the Piedmont of North Carolina, Norfolk fine sandy loam of the Coastal Plain of North Carolina and South Carolina; fire-cured tobacco—Cecil clay of Virginia and Memphis silt loam of Tennessee and Kentucky; Maryland section—Sassafras fine sandy loam of Maryland.
It is interesting to note that the high-quality cigarette tobacco, the flue-cured bright tobacco, is grown on the light-colored and light-textured soils of the Piedmont and Coastal Plain, which are low in organic matter and in nutrients. The significant thing about these soils is their physical condition, which permits them to serve as a medium to which proper amounts of nutrients may be added. In other words, they are responsive to management because of inherent physical characteristics, and their productivity is a result of the cooperation of management practices with soil characteristics.

Vegetable Crops

Vegetables are most extensively grown on deep, well-drained, friable and permeable soils that may range in texture from fine sands to clay loams. Peat and muck are also important for certain vegetable crops. In general, a high level of readily available chemical fertility and a good supply of actively decomposing organic matter are essential. The high money value of vegetables permits artificial adjustment by the wide use of commercial fertilizers and stable and green manures. Most sandy soils that are best adapted, both physically and climatically, to vegetables are low in a natural supply of nutrients. Special attention is now being given to the adjustment of minor-element deficiencies that are most likely to be encountered on such soils when intensively cropped and heavily fertilized with the purer grades of chemical fertilizer salts. This is not only because of the direct influence of these minor elements on plant growth, but also because of their importance from the standpoint of human nutrition.

Soil-reaction requirements of vegetable crops vary considerably. The majority of vegetables are intolerant of strong degrees of acidity or alkalinity, and liming is a common practice on the vegetable areas of the East and South. Liming on light, poorly buffered soils must be carefully adjusted, however, to meet the needs of the individual crops.

The principal area for commercial vegetable production extends from New York to Norfolk, Va. A second important area in western New York extends westward along Lake Erie to Toledo and Detroit. The area about southern Lake Michigan is important and extends southward into Indiana and Illinois and northward into Wisconsin and Michigan. Other important areas have been developed in Minnesota, Iowa, Missouri, Arkansas, and Texas. Winter vegetables are important in a belt extending across Florida, Georgia, South Carolina, Alabama, Mississippi, and Louisiana to Texas and reaching to Arizona and California. The important sections in California are the Sacramento-Stockton, Los Angeles, and Imperial Valley districts.

The greatest acreages of vegetables grown for home use are found primarily in regions of small farms or subsistence farming. The more important areas include southeastern Pennsylvania, the upper Ohio Valley, the mountainous districts of eastern Kentucky and Tennessee and of northern Alabama, the upper Piedmont region of the Carolinas and Georgia, northern Mississippi, eastern Oklahoma, the Lake Michigan shore of Wisconsin, southeastern Michigan, and central New York. The size of the average farm garden is smallest in the Great Plains.

An important technical development that may well mean an expansion in the acreage of vegetable crops is the frozen-pack method or the preservation of green vegetables by freezing, which so far has been developed principally in the Pacific Northwest.

For convenience the vegetables will be discussed by groups of related plants. No attempt will be made to give in all instances the names of soil series or types upon which the production of the individual groups of vegetables occurs. Certain vegetables would require a relatively long list of limited types while in other instances the information itself as to soil types is limited. The distribution of vegetable production, of course, has been greatly influenced by the location of population centers.

Asparagus

Asparagus does best in locations where the winters are sufficiently cold to freeze the ground to at least a few inches in depth. South-central Georgia is about the southern limit of satisfactory cultivation. A well-drained, very fertile, and deeply porous soil is necessary, as asparagus is a very heavy and deep feeder. There is little possibility of having the soil too rich, especially through
the use of manure. Annual applications of both manure and complete fertilizer at the end of the cutting season are recommended. The outstanding area for the production of asparagus is the delta district of the Sacramento-San Joaquin Valley, where peat and muck are utilized. A second commercial district is in New Jersey, Delaware, and Maryland.

**Cruciferae**

This group of vegetables includes such plants as cabbage, cauliflower, broccoli, brussels sprouts, kale, collards, and kohlrabi. These plants are noteworthy for their hardiness to cold and for their adaptation to culture in most parts of the country.

The more important soil requirements of cabbage are adequate supplies of moisture and plant nutrients. It is a relatively gross feeder of most of the nutrients and makes rapid growth under favorable conditions. Cabbage usually gives a moderate response to liming. The quality is closely associated with quick growth. Manure and complete commercial fertilizer both should be used liberally, and if fusarium wilt is present in the soil resistant varieties should be selected.

Other members of this group differ in hardiness. For example, collards withstand summer heat the best, while the cauliflower is very sensitive to warm weather, and brussels sprouts are somewhat more hardy to cold than cabbage.

The principal district for late cabbage is in western New York on the Toledo-Vergennes and Ontario-Honeoye-Pittsfield soil associations, as shown on the map at the end of the Yearbook. The Sassafras and Hempstead soils of Long Island are important producers also. Other producing areas illustrate the tolerance of cabbage for different geographical regions. These areas include parts of New Jersey, southeastern Virginia near Norfolk, southwestern Virginia, the lake plain of northern Ohio, the western shore section of Lake Michigan between Chicago and Milwaukee, the district about Green Bay, Wis., and a part of the irrigated section of northeastern Colorado. Early cabbages are an important vegetable crop in Florida, southern Texas, Louisiana, Mississippi, South Carolina, and California.

**Cucurbits**

This family includes cucumbers, muskmelons, watermelons, pumpkins, and squash.

The cucumber is distinctly a warm-weather crop. It may be grown during the warmer months over much of the country, but is adapted for winter growing in only a very few of the more southerly locations. Again, extreme temperatures of midsummer in certain areas limit it to spring and autumn culture.

The cucumber requires primarily a soil of good physical condition to which the necessary nutrients may be added. A well-drained fine sandy loam is generally most suitable. Fertilization and prevention of insect damage are of prime significance in management.

Although cucumbers are produced quite generally throughout the country, the pickling industry centers in Michigan, Wisconsin, Indiana, Ohio, and New York, while the cucumbers for market (early and fall) are grown largely in the Southeastern and Southern States, with Florida, Texas, South Carolina, and North Carolina having leading acreages. Maryland and New Jersey should also be noted.

The Sassafras-Collington and Norfolk-Ruston soil associations of the Coastal Plain are the outstanding soil areas for cucumbers grown for the market. It is difficult to point out any particular soils for the pickling area aside from the Miami-Kewaunee soil association of Wisconsin and Michigan.

The climatic and soil requirements of muskmelons are about the same as for cucumbers, although in humid sections they seem to develop more perfectly on light-textured soils, whereas cucumbers appear able to do well on moderately heavy soils.

Although muskmelons are grown in nearly every State, the principal centers of commercial production are in irrigated sections of California, Arizona, New Mexico, Colorado, and Texas, and in Arkansas, Michigan, Indiana, Maryland, Delaware, New Jersey, and Georgia.

The pumpkin is one of the few vegetables that thrive under partial shade and for this reason can be grown with corn.
Squash is one of the easiest truck crops to grow and is found in practically all parts of the United States where there is sufficient moisture, although soils relatively high in organic matter are recommended.

Watermelons are rather restricted for their best commercial development to sands and sandy loams in areas with a sufficiently warm and long growing season and in which liberal supplies of nutrients are available. Georgia is the outstanding State for watermelon production, followed by Texas, Florida, South Carolina, and California. The other Gulf Coast States are important, as well as local centers in Missouri, Indiana, and other States.

**Onions**

Members of this group are the onion, chive, garlic, leek, and shallot. These plants generally thrive under a wide variety of climatic and soil conditions, provided an abundance of moisture and fertility is maintained, together with good physical conditions. Nitrogen, phosphorus, and potash are required in relatively large amounts. The wide adaptability of onions is illustrated by their production in the Connecticut Valley of Massachusetts, in the Red River Valley of Minnesota, in southern Texas, and in western Colorado. Other areas of importance are New York, northern Indiana, and the Sacramento-San Joaquin Valley of California. Some of these soils are mucks, while others include sandy loams and heavy dark calcareous soils, such as the Victoria soils of Texas.

**Peas and Beans**

Peas are distinctly a crop of cool regions. In the South they are grown during all seasons except summer. Farther north they are a spring and autumn crop. Only in the extreme North and at high altitudes are they grown during the summer. Even there, best yields occur in the spring rather than in the fall or summer.

Well-drained soils are essential, and at the same time they must have a suitable texture and structure to permit a relatively large amount of moisture to be readily available to the plant. Soil reactions should fall between slightly acid and slightly alkaline for best results. Fertility should be maintained at a moderately high level.

Peas are widely grown for the market. Early peas are grown principally in Florida, Texas, and California. Second-early peas are produced primarily in California, South Carolina, Mississippi, and Louisiana. Sections for later peas are located in Colorado, New York, California, Washington, Idaho, New Jersey, North Carolina, and Virginia. The leading States for the canning of peas are Wisconsin, New York, Minnesota, Maryland, Washington, and Michigan.

The general conditions for garden and green beans (snap and lima) are not greatly different from those for the pea, except that beans are less hardy to cold and are evidently somewhat more tolerant of a wider range in soil reaction. One prime prerequisite is to have a soil of suitable physical condition so that there will be no interference with germination and the emergence of the young seedlings.

**Root Vegetables**

This group includes the turnip, rutabaga, radish, beet, carrot, parsnip, salsify, and taro. These are biennials and store starches and sugars in their roots the first year. They are generally widely adapted climatically and tolerate a wide range of soil conditions. As a result they constitute the most common of the garden vegetables. In general, soils that are well drained, of good physical condition, fertile, and not strongly acid are suitable.

Beets are sensitive to acid conditions. For best results, a well-drained soil of good physical condition, slightly acid to neutral in reaction, and well supplied with available nutrients is recommended.

Carrots are relatively hardy and grow on almost any soil that is moist, fertile, and loose. The best color is obtained on the lighter soils. Sandy loams and mucks are recommended. About the same considerations apply to parsnips, although precautions should be taken against too long a growing season, as they are liable to become oversized, tough, and fibrous.

Radishes are hardy, but they do not withstand heat. The soil should be fertile, moist, and permeable to provide rapid growth. Radishes that grow slowly have an undesirable flavor.

Turnips and rutabagas are essentially cool-weather vegetables. Of the two, turnips can be grown farthest south.
Taro, an important root crop of warm countries, is grown only in a few countries of the South. It is relatively important as a food crop in Puerto Rico and Hawaii and is grown principally on imperfectly and poorly drained soils.

Salad Crops

This group includes lettuce, celery, endive, chicory, cress, and parsley, of which lettuce and celery are the most important.

Lettuce and celery are cool-weather crops and adapted to winter culture in the milder sections. In much of the North they are spring and fall crops, as the summers are too hot. These crops do not tolerate acid soils and they feed heavily on nitrogen. Phosphorus and potash in generous amounts are also essential, as well as conditions of good drainage and moisture supply. Where these requirements are met, production occurs on soils ranging from sand to clay loams and peats. The depth of the permeable soil is particularly important for celery, and this crop seems to be better adapted to the sandier soils than lettuce.

A rapid increase has occurred during the past 10 years in celery and lettuce production. Most of the commercial lettuce crop in winter is grown in California. Other sections contributing are Arizona, Florida, and the Carolinas. The commercial production of lettuce in summer is chiefly in Colorado, Idaho, Washington, New York, New Jersey, and Massachusetts.

Almost all of the celery grown comes from California, Florida, Michigan, New York, New Jersey, and Oregon. In much of the Northeast the principal soils for both celery and lettuce are found on the well-decomposed muck beds that have been artificially drained and to which heavy applications of fertilizer have been made.

Solanaceae (Tomatoes, Peppers, Eggplants)

The tomato is a warm-season plant and requires a relatively long growing season. High humidity and high temperatures together favor foliage diseases, while hot drying winds and low soil-moisture content may result in the dropping of the blossoms. The plant is suited to a wide range of soils ranging from clay to sand in texture. It is comparatively tolerant to acid conditions. It is a relatively heavy feeder and is sensitive to an unbalanced nutrient condition. The setting of fruit is relatively sensitive to the ratio of the nitrogen to the phosphorus supply. For early ripening a warm fertile sandy loam is recommended, while if earliness is not so important, a clay loam may be very desirable, depending, of course, in part on the other associated soil characteristics.

Tomatoes are widespread in their distribution except where the growing season is short, as in the spring wheat belt and the cut-over sections of the Lakes States. The most important district is in eastern Maryland, Delaware, and southern New Jersey on the Sassafras soils. Other important districts occur in Florida, California, Texas, the Ozarks, Indiana, Virginia, Mississippi, and western New York. As tomatoes are produced on a variety of soils, it does not seem advisable to list the soils upon which they are grown. For example, in Florida they are grown on well-drained sandy land, on marl, and on muck, while in the lower Rio Grande Valley, where they are more widely grown than any other vegetable, the soils are principally sandy loams and clay loams of the Brennan, Victoria, Hidalgo, Laredo, and Rio Grande series.

Peppers are much like tomatoes in their requirements, but are more exacting, particularly in regard to temperature conditions. Southern California, Florida, and Texas are regions of principal production.

The eggplant is still more sensitive to the conditions under which it is grown, particularly in relation to temperature and the balance of nutrients.

Spinach

Spinach is a member of the group of garden plants known as greens, although such a classification is largely one of convenience. Other plants of this group are chard and kale. The general requirements of soil and climate are rather similar to those for lettuce and celery, as the plant does not tolerate acid soils, is a heavy feeder on nitrogen and other nutrients, is relatively hardy, and does best on soils of high organic-matter content. The important producing areas are the Norfolk district of Virginia and the winter garden district of Texas.