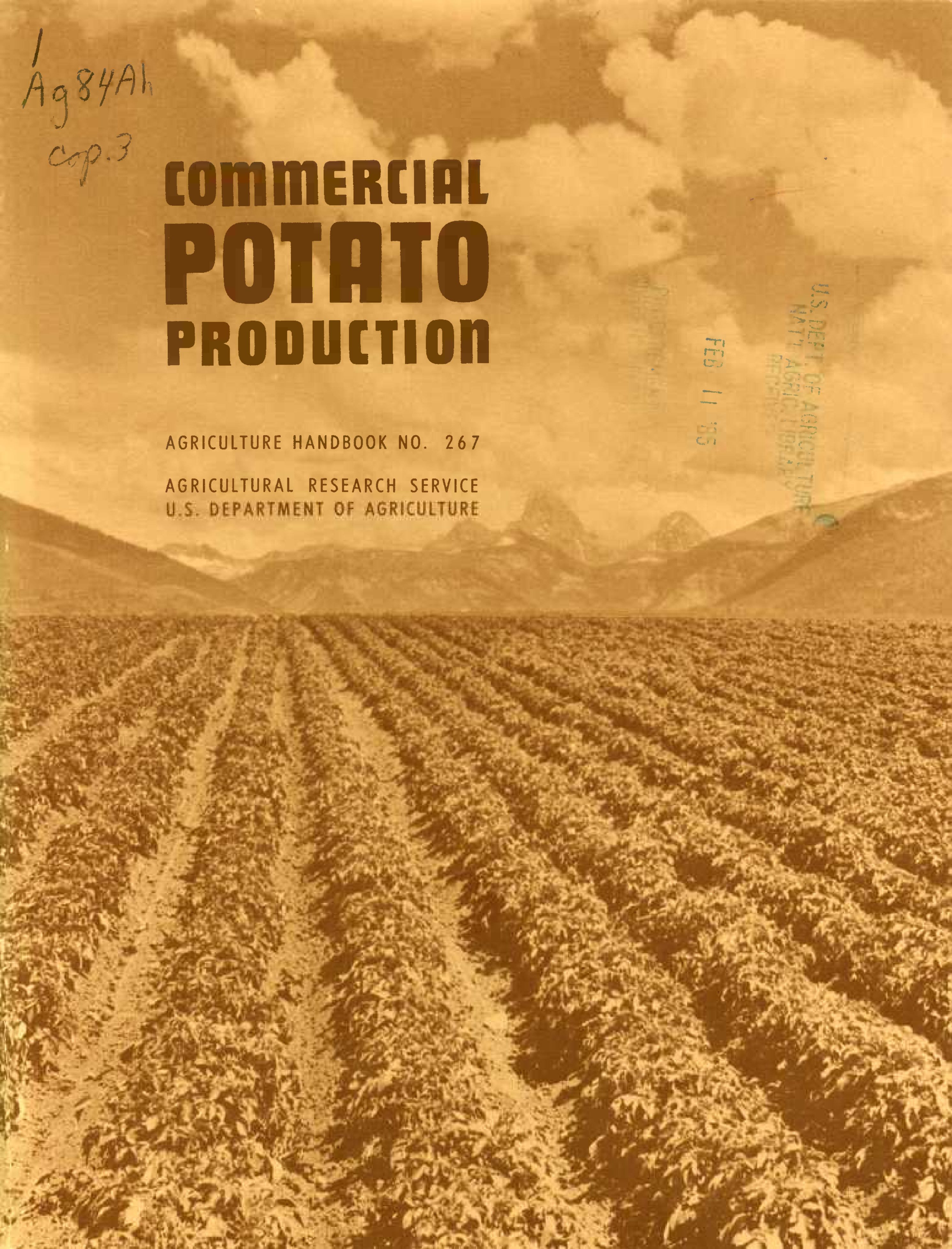
COMMERCIAL POTATO PRODUCTION

AGRICULTURE HANDBOOK NO. 267

AGRICULTURAL RESEARCH SERVICE
U.S. DEPARTMENT OF AGRICULTURE



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BY AUGUST E. KEHR, ROBERT V. AKELEY, AND GEOFFREY V.C. HOUGHLAND

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COMMERCIAL POTATO PRODUCTION

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INTRODUCTION

Commercial potato production is a highly specialized business requiring large capital investments. If the enterprise is to be profitable, farm operators must have both technical training and business experience. Each year since 1950, a progressively greater proportion of the annual crop has been processed in comparison to the proportion sold as fresh or stored raw potatoes. This trend has created new problems in potato production and marketing.

Problems facing potato growers today are far more complex than any immediately preceding the Second World War. Despite existing problems, yields per acre rose from a national average of 80 hundredweight per acre in 1940 to almost 200 hundredweight per acre in 1962 (table 1). It has been predicted that the national average acre yield should rise to as much as 250 hundredweight by 1975. Although national total production did not change markedly from 1940 to 1961, the acreage required to grow the normal annual crop has decreased by about 50 percent. Shifts in the geographical areas of production, changes in varieties grown, shifts to fewer and larger farms, marked changes in mechanization and crop utilization, and improved cultural methods all have contributed to intensification in production and increased yields per acre.

Table 1.—*Average total potato production and yields, selected years, 1930–62*

Year	Total acres harvested	Yield per harvested acre	Total production
	1,000 acres	*Cwt.*	*1,000 cwt.*
1930	3, 138. 9	65. 7	206, 290
1935	3, 468. 8	65. 5	227, 337
1940	2, 832. 1	79. 9	226, 152
1945	2, 664. 3	94. 4	251, 639
1950	1, 697. 9	152. 6	259, 112
1955	1, 405. 0	162. 1	227, 696
1956	1, 371. 0	179. 3	245, 792
1957	1, 359. 4	178. 4	242, 522
1958	1, 428. 4	186. 9	266, 897
1959	1, 336. 3	183. 9	245, 799
1960	1, 396. 9	184. 3	257, 435
1961	1, 496. 0	196. 3	293, 594
1962	1, 385. 0	193. 7	268, 280

History

Most botanists agree that the potato originated in the New World, though the exact locality of origin is uncertain. Historians record that the Spaniards found potatoes in Peru at the time of their conquest of that country beginning in 1524. The native home of the potato is often claimed to be in the Andes of Peru and Bolivia at altitudes of 4,000 to 6,000 feet, where its very close botanical relatives flourish even today.

Historians disagree about the first introduction of the potato into Europe. There is good evidence, however, that the Spaniards introduced the potato from South America into Spain by 1580, or even as early as 1565. Hieronymous Cardan, a monk, is supposed to have been the first to introduce it from Peru into Spain. From Spain the plant was taken into Italy about 1585, into Belgium and Germany by 1587, into Austria by 1588, and into France soon after 1600. Philip de Sivry, Prefect of Mons, Belgium, sent two potato tubers to Carolus Clusius in Vienna, Austria, where they were received on January 26, 1588. Philip de Sivry had received a plant from an attaché of the Papal Legation; he, in turn, had obtained plants from Italy. De Sivry's colored drawing, now in the Plantin-Moretus Museum at Antwerp, Belgium, was probably made soon after 1588 and is considered by some writers to be the first illustration made of the potato. However, the first published illustration and description was by Gerard, an English botanist. It appeared in 1597. Gerard, unfortunately, gave it the misleading name of *Batata virginiana*, and thereby created confusion in the origin, history, and proper identification of the potato. The accepted botanical name *Solanum tuberosum* was first used in 1596 by the Swiss botanist, Kaspar Bauhin, and this was the name adopted in 1753 by Linnaeus in his Species Plantarum.

Introduction of the potato into England probably was independent of its spread in Europe. The exact time of importation into England is clouded by the confusion that existed between the potato, the sweetpotato, and other tuber- and root-forming plants. In 1586, Sir Francis Drake introduced into England a plant that he incorrectly called potato. On this trip, Drake had stopped in Virginia and picked up survivors of Raleigh's Colony on Roanoke Island. Heriot, one of the colonists Drake brought back to England, later became farm manager of an estate in Ireland owned by Sir Walter Raleigh. However, the tubers Heriot took back to England could not have been potatoes because none of his written descriptions of six root- or tuber-forming plants even approximates the potato.

It could very well be that the Spaniards first brought the crop to Ireland, because trade was brisk between Spain and Ireland in the 17th century. Without question, the newly introduced plant first became an important agricultural crop in Ireland. Soon after its introduction there, the potato was readily accepted as a staple food, demonstrating for the first time the potential commercial value of a plant that previously was no more than a botanical curiosity. Between 1650 and 1840 potatoes had become a vital part of the basic food supply in Ireland. When late blight disease wiped out the crop in the 1840's, famine forced many Irish people to emigrate to America. Because of its early food use and importance in Ireland, the potato plant is sometimes *erroneously* called the Irish potato.

When or where the potato was introduced into the continental United States is not known. It is believed that potatoes did not exist in Virginia when Drake landed there in 1586; if he had potatoes aboard his flagship, it is thought that they came from Cartagena (Colombia). One of the early colonial records shows that potatoes were ordered to be taken from England to South Carolina by colonists settling on the Edisto River in 1674. There is no record that potatoes were actually introduced at that time, however. Potatoes were introduced from Ireland into Londonderry, N.H., in 1719 by a group of Presbyterian Irish. This is the first introduction into New England and possibly the United States. Acceptance of potatoes as food was very slow in North America. However, total production had reached 1,603,730 hundredweight in 1840, when potatoes were first mentioned in the U.S. Census.

Botany of the Potato

The name "potato" is believed to have originated from the Indian name, "Batatas."

The potato is one of about 2,000 species in the family Solanaceae. This family includes such plants as tobacco, tomato, eggplant, pepper, horse nettle, bittersweet, ground cherry, and petunia. Botanically, the potato cultivated in North America, Europe, and other lands is *Solanum tuberosum* L. There are nearly 160 wild species and 20 cultivated species of the tuber-bearing Solanums. All these relatives of the potato are of New World origin. Probably the closest wild relative is *S.* andigenum Juz. & Buk. which produces acceptable yields under the short-day conditions of the Andes Mountains. Some botanists consider *S. andigenum* to be a subspecies of *S. tuberosum*.

The potato may be classified as a dicotyledonous annual, although it can persist in the field vegetatively (as tubers) from one season to the next even in northern Maine. In fact, volunteer plants growing from unharvested potato tubers, unintentionally left in the field, create many problems in pest and disease control that affect the production of certified seed.

Being a dicotyledonous plant, the potato has the characteristics of all dicotyledons including stems with vascular bundles placed in a circular arrangement and containing definite layers of xylem and phloem. Because it is a dicotyledon, the potato may be grafted within the species *Solanum tuberosum* as well as upon related species. Frequently one reads of tomatoes being grafted upon potato root stocks to obtain plants bearing tomatoes on the tops and potatoes underground. Such plants have no commercial value. However, research workers, particularly in Russia, have performed many grafting experiments with potatoes and tomatoes and claim to have obtained "graft hybrid" effects. These experiments have been repeated many times elsewhere with negative results. In the United States and in Europe some potato breeders have grafted varieties of potatoes upon tomato stocks (or vice versa) to induce better flowering and seed setting and for disease studies.

Morphology and Anatomy

The potato tuber is an enlarged portion of an underground branch of a stem called a stolon or rhizome (fig. 1). Technically, these underground stems of the potato most nearly approximate rhizomes, but the term stolon is more common. The stolons have leaf scales located alternately on their surface in the same manner as the aboveground stems. The tubers originate from the tips of stolons, and occasionally tubers form along the stolon itself. The potato tubers contain all the characteristics of normal stems, including dormant true buds (eyes) formed at the base of a leaf (rudimentary in this case) with detectable leaf scars (the eyebrows). Lenticels or stem pores through which air penetrates to the stem interior are plainly found on most tubers. Lenticels often become enlarged to objectionable size when soils are overly wet and access of air is restricted.

The buds (eyes), from which further growth initiates, are found in a spiral pattern on all parts of the tuber. The eyes tend to be concentrated at the distal end (also called the seed or eye end) of the tuber. They are fewer in number and farther apart toward the proximal (or stem) end where the tuber is attached to the stolon.

The buds (eyes) of the seed end possess apical dominance and will normally sprout first, a condition characteristic of buds at or near the apex of all conventional stems. When the apical buds are removed or die, other buds are stimulated to sprout in the same manner as lateral buds on a woody stem are stimulated to sprout when the "leader" is removed. When whole tubers are planted, the effect of apical dominance is especially important because with whole seed, only one to three large productive stems per hill will usually emerge. The effect of apical dominance is reduced if a large tuber is cut into smaller seed pieces. Stems from cut seed pieces tend toward greater uniformity in rate of emergence, but a noticeable difference will still exist between stem-end and seed-end sprouts.

The outer layer of single cells of the tuber, the epidermis, is usually colorless. Anthocyanin, the pigment that colors red and blue potatoes, is found in the periderm (several layers of corky cells immediately below the epidermis). The epidermis and periderm together comprise the "skin" of the mature tuber (fig. 2). The varieties Dakota Red, Red McClure, Triumph, Pontiac, and Red Warba are commercial varieties with red pigment (anthocyanin) in their periderm. In a few varieties the colored pigment is in the outer layers of the cortex, the region immediately inside the periderm that extends inwardly to the vascular ring. Varieties known to have red pigment in the outer cortex are Spaulding Rose, Early Rose, and Early Ohio.

The remainder of the tuber from the vascular ring inward, designated as the medullary area, is divided into outer and inner medulla and constitutes the fleshy part of the tuber. The outer medulla generally contains the denser portion of this area; the inner medulla includes the watery and more translucent part. Persons unfamiliar with the internal structure of the potato sometimes mistake the inner medulla for an abnormality or defect. The inner medulla extends toward each eye, forming a continuous tissue that connects all the eyes of the tuber (fig. 2).

The initiation of young tubers at the tips of the stolons usually occurs when the plants are 6 to 8 inches high, or from 5 to 7 weeks after planting (fig. 3). Tuberization is affected by many environmental factors and depends largely on translocation and storage of food in excess of that needed by other parts of the plant in their growth and metabolism. Growth of the young tuber is the result of both cell division and elongation and storage of translocated food constituents within the cells.

Contrary to a commonly accepted notion, tuberization is not dependent upon flowering. Potato plants will form tubers without any flowers ever appearing on the tops. Some experimenters have even conversely suggested that tuberization is actually enhanced by removing the flowers or flower buds. The notion that tuberization depends on flowering arose because unfavorable climate such as hot and dry growing conditions, which are normally unfavorable for flowering, also retard or even inhibit tuber formation. Because climatic conditions that favor flowering also favor tuberization, it seems natural to make the mistake of associating flowering with high yields and poor flowering with low yields.

Descriptive morphology of leaves, stems, and flowers is included in the section Varieties.

Plant Introduction and Maintenance

For a long period after the potato was introduced into the United States, little effort was made to improve it or to introduce new kinds. Thus the period from 1719 to 1850 was characterized by no marked or lasting improvement in the crop. Improvement of potatoes near the end of this period became imperative because the available varieties "ran out" to the extent that yields decreased to low levels and production was uneconomical. "Running out" was caused largely by high levels of tuber-transmitted virus diseases in existing stocks and lack of proper seed maintenance methods.

In 1851, C. E. Goodrich, a clergyman of Utica, N.Y., introduced a small amount of potatoes received from the American consulate in Panama. A selection called Garnet Chili resulted from this

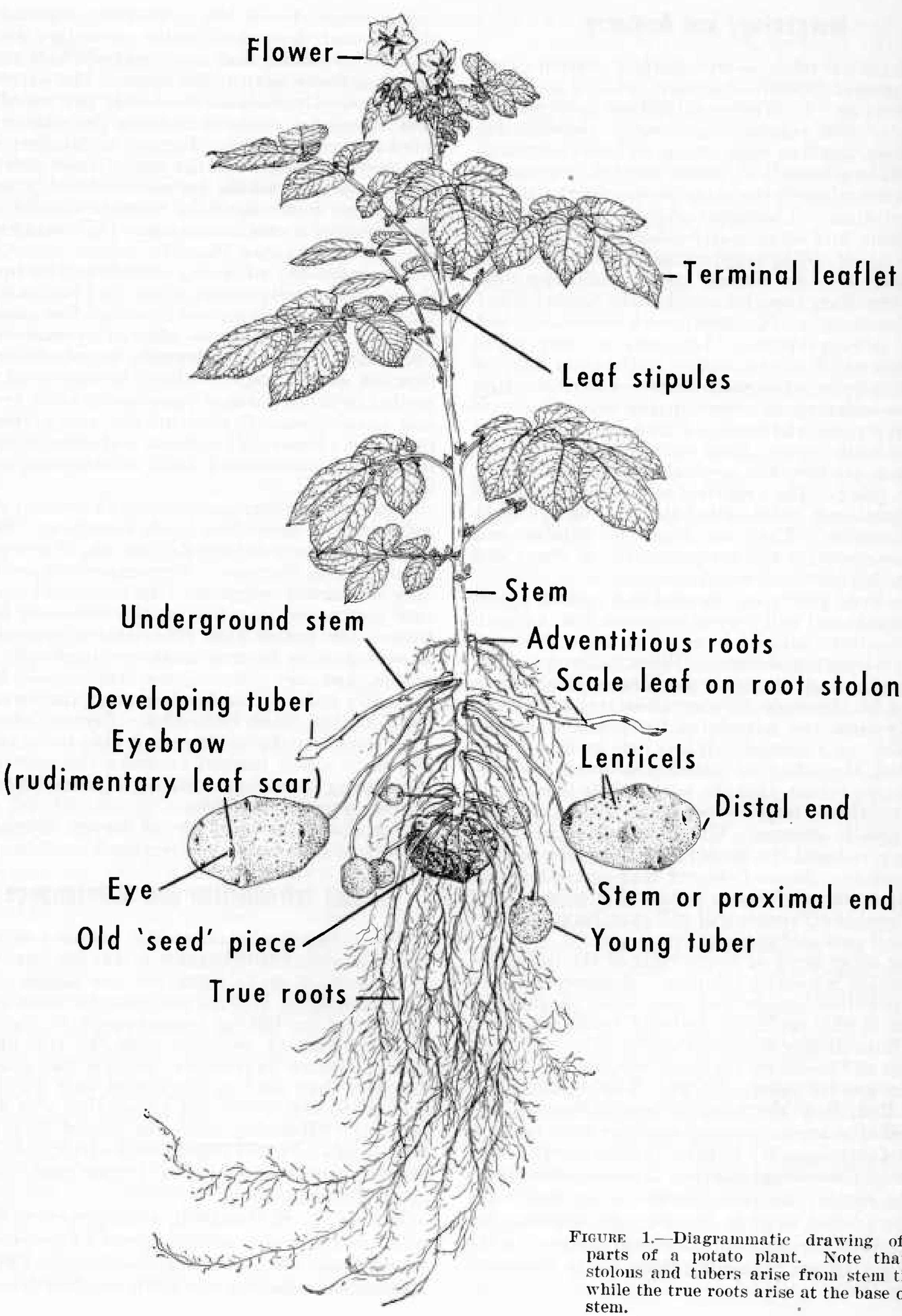

FIGURE 1.—Diagrammatic drawing of the parts of a potato plant. Note that the stolons and tubers arise from stem tissue, while the true roots arise at the base of the stem.

introduction. Nearly 200 named potato varieties, including several important commercial ones still grown, have this single variety represented in their ancestry.

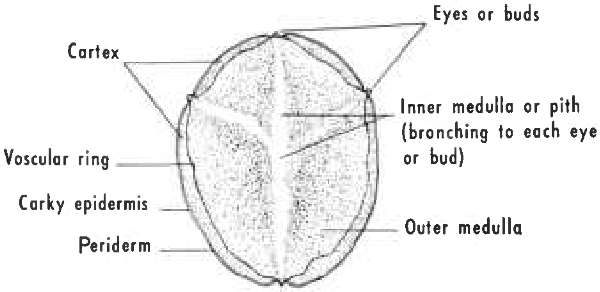

FIGURE 2.—Cross section of a potato tuber. Red pigment occurs in the periderm or outer cortex of some red varieties. The water-soaked appearance of the inner medulla is normal, though it may be more pronounced in some tubers than others.

Since 1925, several plant explorers have made plant exploration trips into Mexico, Central America, South America, and other areas where the potato is believed to have originated, in search of new forms of the potato for use in improving commercial types. In addition, many named varieties of potato have been introduced into the United States, from most of the potato-producing areas of the world. The continual flow of new material coming into this country is effectively coordinated by the New Crops Research Branch of the Agricultural Research Service in the U.S. Department of Agriculture.

The most challenging problem following the introduction of foreign potato varieties into the country is the maintenance of the collection in a vigorous, disease- and insect-free condition. Most of the introductions must be propagated and maintained vegetatively because they do not reproduce or breed true to their original type when grown from true seed, and many produce few, if any, true seeds under our conditions of culture. Vegetative propagation is the only sure means of maintaining unchanged original lines that possess important characteristics that otherwise might be lost. This vegetative method of propagation necessitates planting and growing the many introductions each year—a time-consuming and expensive process, which also exposes the plants to the continual danger of infection with tuber-borne diseases.

To help solve these problems and maintain the valuable characteristics of foreign plant introductions, a special potato introduction and maintenance station was established by the U.S. Department of Agriculture and cooperating State agricultural experiment stations. At this station, located at Sturgeon Bay, Wis., all introductions of the tuber-bearing *Solanum* species, valuable parental stocks, and varieties are maintained as true seed or tubers. A list of vegetatively propagated varieties is given in tables 2 and 3. Requests for two- or three-tuber samples of *Solanum* material from the Sturgeon Bay collection may be addressed to the Potato Introduction Station, Sturgeon Bay, Wis.

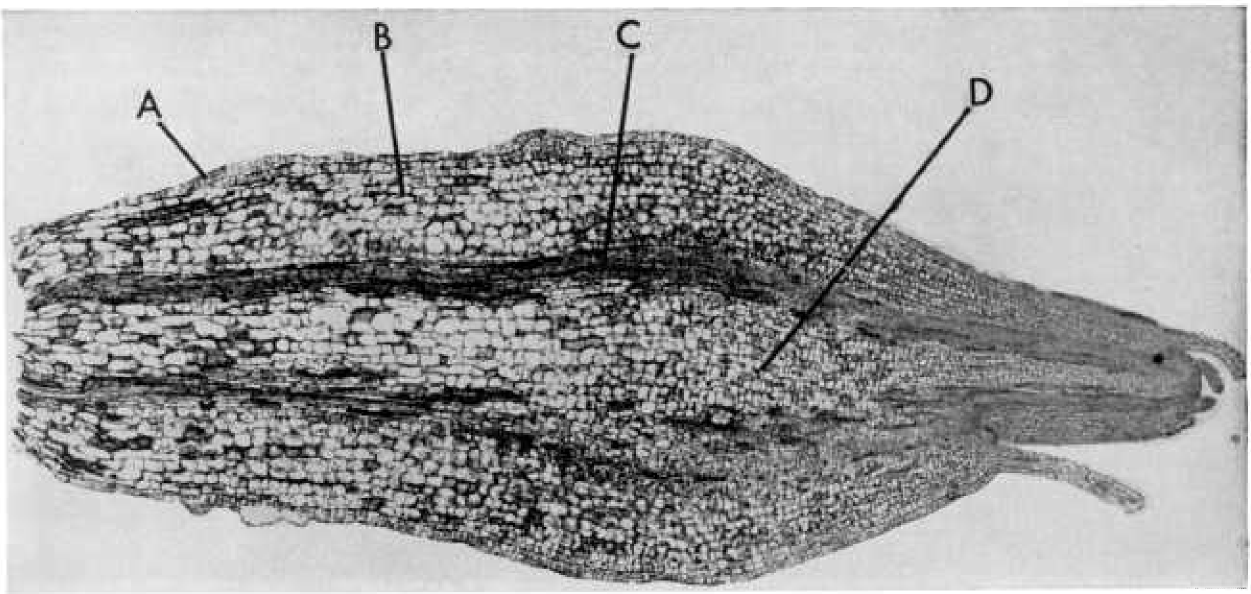

FIGURE 3.—Photomicrograph of the longitudinal section through a developing tuber at the tip of a stolon: *A*, epidermal cells; *B*, cortex; *C*, vascular ring; *D*, medulla.

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TABLE 2.—*Vegetatively propagated foreign varieties of* Solanum tuberosum *maintained at Sturgeon Bay, Wis.*

Variety	Origin or source	Remarks
Ackersegen	Germany	Resistant to common scab and late blight; immune to virus A.
Akebia	do	Resistant to common scab.
Albion	Netherlands	Resistant to leaf roll virus.
Alpha	do	Resistant to common scab and late blight.
Ambra	Czechoslovakia	
Apta	Germany	Resistant to leaf roll virus.
Aquila	do	Resistant to late blight and leaf roll virus.
Arran Banner	British Isles	Resistant to virus Y and dry rot.
Arran Cairn	do	Field immune to viruses A, B, and C.
Arran Consul	do	Field immune to virus C; resistant to late blight.
Arran Scout	do	
Aspotet	Norway	
Augusta	Germany	Resistant to leaf roll virus.
Aussie 96	Tasmania	Resistant to Verticillium wilt.
Avanzi	Italy	
Barima	Netherlands	Early maturity.
Belle de Fontenay	France	Do.
Bevelander	Netherlands	Resistant to late blight.
Bintje	do	Popular in Europe for chipping and cooking quality; immune to virus A.
Bismark	Australia	Resistant to leaf roll virus.
Bona	Germany	
Botirule	Netherlands	
British Queen	British Isles	Field immune to viruses A, B, and C; resistant to dry rot.
Canso	Canada	Resistant to late blight.
Centifolia	Germany	Resistant to common scab and late blight.
Craigs Snowwhite	British Isles	Field immune to viruses X, A, B, and C; foliage resistance to late blight.
Doon Early	do	Field immune to viruses A and B; resistant to virus Y.
Dore	Netherlands	Early maturity.
Duivelander	do	Resistant to late blight.
Eersteling	British Isles	Immune to virus A; early maturity.
Eigenheimer	Netherlands	Popular in Netherlands for cooking quality.
Ella	Russia	
Elsa	Sweden	
Erdgold	Germany	Resistant to common scab.
Erdnanna	do	Resistant to late blight, wet rots, and viruses.
Erstlinge	do	Early maturity.
Eva	Sweden	Resistant to late blight.
Factor	Scotland	Resistant to potato wart.
Falke	Germany	Resistant to common scab, late blight, and leaf roll virus.
Flava	do	
Forelle	do	Resistant to late blight, leaf roll virus, and virus Y.
Fortuna	do	Do.
Fruhmolle	do	Resistant to late blight and leaf roll virus; early maturity.
Fruhnudel	do	Resistant to late blight.
Fruhperle	do	Resistant to common scab; early maturity.
Furore	Netherlands	Resistant to ring rot.
Geelblom	do	Early maturity.
Gladstone	British Isles	Field immune to viruses A and B; resistant to dry rot.
Great Scot	do	Field immune to virus A; resistant to leaf roll virus and dry rot.
Grummel	Netherlands	
Heida	Germany	Resistant to leaf roll virus.
Hindenburg	do	Resistant to common scab.
Jacobi	do	Resistant to common scab and late blight; early maturity.
Jossing	Norway	
Jubel	Germany	Resistant to common scab and late blight.
Karmen	Czechoslovakia	
Kerkov Krasova	do	Resistant to drought.
Kerr's Pink	British Isles	Field immune to viruses Y, A, and B; resistant to dry rot.
Kitting	Czechoslovakia	Early maturity.
Kotnov	do	
Krasava	do	
Libertas	Netherlands	Resistant to late blight; high dry-matter content.
Limosa	do	Early maturity.
Majestic	British Isles	Field immune to virus C.
Maritta	Germany	Resistant to common scab, late blight, and virus Y.

TABLE 2.—*Vegetatively propagated foreign varieties of* Solanum tuberosum *maintained at Sturgeon Bay, Wis.*—Continued

Variety	Origin or source	Remarks
Marius	Norway	
Markt-Redwitzer Fruhe	Germany	Early maturity.
Marta	Czechoslovakia	Resistant to common scab
Matador	Netherlands	
Meerlander	do	Immune to virus A.
Mirka	Czechoslovakia	
Mittelfruhe	Germany	
Monak	Australia	
Moona	do	
Noordeling	Netherlands	Resistant to late blight and nematode.
Oberarnbacher Fruhe	Germany	Resistant to common scab and late blight; early maturity.
Olympia	do	
Ostbote	do	
Panther	do	Resistant to common scab and late blight.
Parnassia	do	Resistant to late blight.
Pentland Ace	British Isles	Field immune to viruses X, A, and B; resistant to late blight.
Pimpernel	Netherlands	Resistant to late blight.
Populair	do	Resistant to Verticillium wilt.
President	do	Field immune to viruses B and C; resistant to ring rot and late blight.
Primula	Germany	Immune to virus A; early maturity.
Record	Netherlands	Immune to virus A; resistant to late blight.
Rheingold	Germany	Resistant to common scab.
Rode Eersteling	Netherlands	Early maturity; immune to virus A.
Rosanel	Costa Rica	
Saskia	Netherlands	Immune to virus A; early maturity.
Sharps Express	Scotland	
Sientje	Netherlands	Immune to virus A.
Sikersegen	Germany	
Sirtema	Netherlands	Resistant to common scab; early maturity.
Skerry Champion	British Isles	Resistant to leaf roll virus.
Southesk	do	
Stewart Dawn	do	
Tebon	Norway	Resistant to common scab; early maturity.
Triumf	Netherlands	Resistant to leaf roll virus.
Ulster Ensign	British Isles	Resistant to dry rot.
Urgenta	Netherlands	
Urtica	Germany	Resistant to scab, late blight, and leaf roll virus.
Vera	do	Early maturity.
Victor	Spain	
Voran	Germany	Resistant to late blight.
Ysselster	Netherlands	Resistant to common scab.
Zaldi	Spain	
Zeeburger	Netherlands	Resistant to late blight and nematode; resistant to drought.

TABLE 3.—*Vegetatively propagated American varieties of* Solanum tuberosum *maintained at Sturgeon Bay, Wis.*

Variety	Remarks	Variety	Remarks
Antigo	Resistant to common scab.	Earlaine	Resistant to virus A; early maturity.
Canus		Early Blue	
Cayuga	Resistant to late blight and common scab; tolerant to *Fusarium solani* var. *eumartii*.	Early Gem	Resistant to common scab; early maturity.
Cherokee	Resistant to late blight, common scab, virus A, and net necrosis.	Early Rose	
Chippewa	Resistant to virus A.	Erie	
Chisago	Early maturity.	Essex	Resistant to late blight.
Columbia Russet		Garnet Chili	
Cortland	Resistant to late blight.	Glenmeer	Resistant to late blight; drought and frost tolerant.
DeSoto	Resistant to virus A.	Golden	

TABLE 3.—*Vegetatively propagated American varieties of* Solanum tuberosum *maintained at Sturgeon Bay, Wis.*—Continued

Variety	Remarks	Variety	Remarks
Harford	Resistant to late blight; drought tolerant.	Redglo	
Houma	Resistant to virus A, net necrosis, and drought.	Redkote	Resistant to common scab and internal discolorations.
Irish Cobbler	Resistant to virus A; early maturity.	Red LaSoda	
Kasota	Tolerant to *F. solani* var. *eumartii*.	Red Pontiac	
Katahdin	Resistant to viruses Y and A; drought tolerant.	Red Warba	Early maturity.
Kennebec	Resistant to late blight and net necrosis.	Rushmore	
Knik	Resistant to common scab.	Russet Burbank	Resistant to common scab.
Manota		Russet Rural	Do.
Marygold	Early maturity; yellow flesh.	Russet Sebago	Resistant to late blight, common scab, virus A, and yellow dwarf.
Menominee	Resistant to late blight and common scab.	Saco	Immune to viruses X and A; resistant to late blight and net necrosis.
Merrimack	Resistant to late blight, ring rot, early blight, and net necrosis; field immune to virus A.	Saranac	Resistant to late blight and ring rot.
Norland	Resistant to common scab.	Sebago	Resistant to late blight, common scab, virus A, and yellow dwarf.
Ontario	Resistant to late blight and common scab; tolerant to *F. solani* var. *eumartii*.	Seneca	Resistant to late blight, scab, and *F. solani* var. *eumartii*.
Osage	Resistant to common scab.	Sequoia	Resistant to late blight on the foliage, flea beetles, and leaf hoppers.
Osseo	Early maturity.	Snowdrift	Resistant to late blight.
Pawnee		Spaulding Rose	Resistant to mild mosaic; immune to potato wart.
Plymouth	Resistant to late blight and common scab.	Tawa	Resistant to late blight, scab, and mild mosaic; immune to latent mosaic.
Pungo	Resistant to late blight; early maturity.	Teton	Resistant to ring rot.
Red Beauty	Resistant to Verticillium wilt; tolerant to purple top virus.	Waseca	
Redburt		Whitecloud	
		Yampa	Resistant to early blight, leaf roll, and mosaic.

Per Capita Consumption of Potatoes

The rate at which potatoes are used for food is determined from the average consumption of potatoes per person. Per capita consumption figures (table 4) show that the average American in 1963 ate about half as many potatoes per year as his forebears did in 1910.

TABLE 4.—*Per capita consumption of potatoes in the United States, selected years, 1910–63*

Year	Potatoes	Year	Potatoes
	Pounds		*Pounds*
1910	198	1955	106
1915	185	1956	100
1920	140	1957	106
1925	157	1958	99
1930	132	1959	101
1935	142	1960	102
1940	123	1961	103
1945	122	1962	103
1950	106	1963	100

Despite the gradual decrease over the years, there is some evidence that per capita consumption may now be increasing slightly. This change is probably largely the result of newly developed methods of processing, which make it much easier to use potatoes in preparing meals in the home and in commercial and institutional kitchens. A growing realization of the high nutritive value of potatoes may also have contributed to the recent uptrend in per capita consumption.

Value as Food

It is an erroneous idea that potatoes are fattening. Nutritionists recognize that *all foods* eaten in excess are fattening. Actually potatoes are less fattening pound for pound than most items in the daily American diet. For example, about 11 pounds of potatoes are required to produce 1 pound of body fat, or about the same amount as milk, canned corn, canned peaches, or frozen peas (table 5). On the same basis, the "fattening" tendency of potatoes is 1/10 that of margarine, ⅕ that of dry cereal, ⅓ that of bread, and ½ that of beef or hamburger. Potatoes alone actually are comparatively low in calories per pound. When fried or served with a generous amount of butter or other fat preparation, however, the total caloric intake may be high. A unit weight of french-fried potatoes has about five times the caloric value as the same weight of mashed potatoes.

TABLE 5.—*Potatoes compared to other foods in cost per food unit and relative "fattening" potential*

Food	Market cost per pound	Calories per pound	Cost per 1,000 calories	Amount eaten *in excess* for 1 pound of body fat [1]
		Number		*Pounds*
Sugar	$0. 15	1, 800	$0. 08	1. 9
POTATOES	. 03	325	. 09	10. 8
Margarine	. 29	3, 300	. 09	1. 1
Oatmeal (dry)	. 20	1, 770	. 11	2. 0
Macaroni (dry)	. 23	1, 670	. 14	2. 1
Bread	. 21	1, 250	. 17	2. 8
POTATOES	. 06	325	. 18	10. 8
Cereal (dry)	. 32	1, 650	. 19	2. 1
Butter	. 74	3, 300	. 22	1. 1
Peanut butter	. 60	2, 615	. 23	1. 3
POTATOES	. 09	325	. 28	10. 8
Corn (canned)	. 14	350	. 40	10. 0
Milk (whole)	. 13	310	. 42	11. 2
Peaches (canned)	. 18	270	. 67	13. 0
Hamburger	. 59	830	. 71	4. 2
Beef steak (round)	1. 09	830	1. 31	4. 2
Cabbage	. 12	80	1. 50	43. 7
Peas (frozen)	. 53	340	1. 56	10. 0
Turnips	. 25	125	2. 00	28. 0
Beans (green canned)	. 22	85	2. 58	41. 1

[1] Based on 3,500 calories = 1 pound body fat.

Potatoes are an economical food; they provide a source of low-cost energy to the human diet, a fact well recognized in many parts of the world. When the price of potatoes is around 3 cents per pound ($1.80 per bushel), they are one of the cheapest sources of food energy (table 5). Even at 6 cents per pound, only sugar, margarine, oatmeal, and bread are less expensive per unit of food value.

The fact that potatoes also provide significant amounts of vitamins and minerals at low cost has been stressed too little by some food specialists and others. The nutrients supplied by potatoes are shown in table 6. Potatoes are outstanding as a source of vitamin C. If properly processed and prepared, potatoes can provide large amounts of the minimum daily requirement of this vitamin in the American diet. Potatoes are also an economical source of vitamin B_1 (thiamin). The average American spends approximately 2 cents of each food dollar on potatoes and for this small expenditure receives an intake of 2 percent of his energy, 4 percent of his iron, 5 percent of his thiamin (B_1), 6 percent of his niacin, and 10 percent of his vitamin C.

TABLE 6.—*Nutrient value of potatoes prepared in various ways* [1]

Nutrient	Baked in jacket: 1 medium 2½ inch	Boiled; peeled before boiling: 1 medium 2½ inch	Chips: 10 medium	Frozen french fries: 10 pieces 2½ x ½ inch	Mashed; 1 cup: milk added
Food energy ... cal	90	90	110	95	145
Protein ... g	3	3	1	2	4
Fat ... g	Trace	Trace	7	4	1
Carbohydrates ... g	21	21	10	15	30
Calcium ... mg	9	9	6	4	47
Iron ... mg	0. 7	0. 7	0. 4	0. 8	1. 0
Vitamins:					
A ... I.U.	Trace	Trace	Trace	Trace	50
Thiamin ... mg	0. 10	0. 11	0. 04	0. 08	0. 17
Riboflavin ... mg	0. 04	0. 04	0. 02	0. 01	0. 11
Niacin ... mg	1. 7	1. 4	0. 6	1. 2	0. 2
C ... mg	20. 0	20. 0	2. 0	10. 0	17. 0

[1] Source: 1959 Yearbook of Agriculture.

If potatoes were the only source of the total daily food energy requirement, they would provide the full requirement of riboflavin, 1½ times the iron requirement, 3 to 4 times the thiamin and niacin requirement, and more than 10 times the vitamin C requirement. Some calcium, protein, and vitamin A would be supplied, but the full requirements would not be met. A diet of whole milk and potatoes would supply almost all the necessary food elements for the maintenance of the human body.

PRODUCTION

Production Areas in the United States

Potatoes are grown commercially in every State in the country (fig. 4). Throughout the United States there is not a single month in the year when potatoes are not being planted or harvested somewhere. In the Northeast, production of the fall crop is highly developed in Aroostook County, Maine (fig. 5). In the Atlantic coastal areas from Long Island to northeast North Carolina, there are numerous smaller but important districts of production. Inland centers include western New

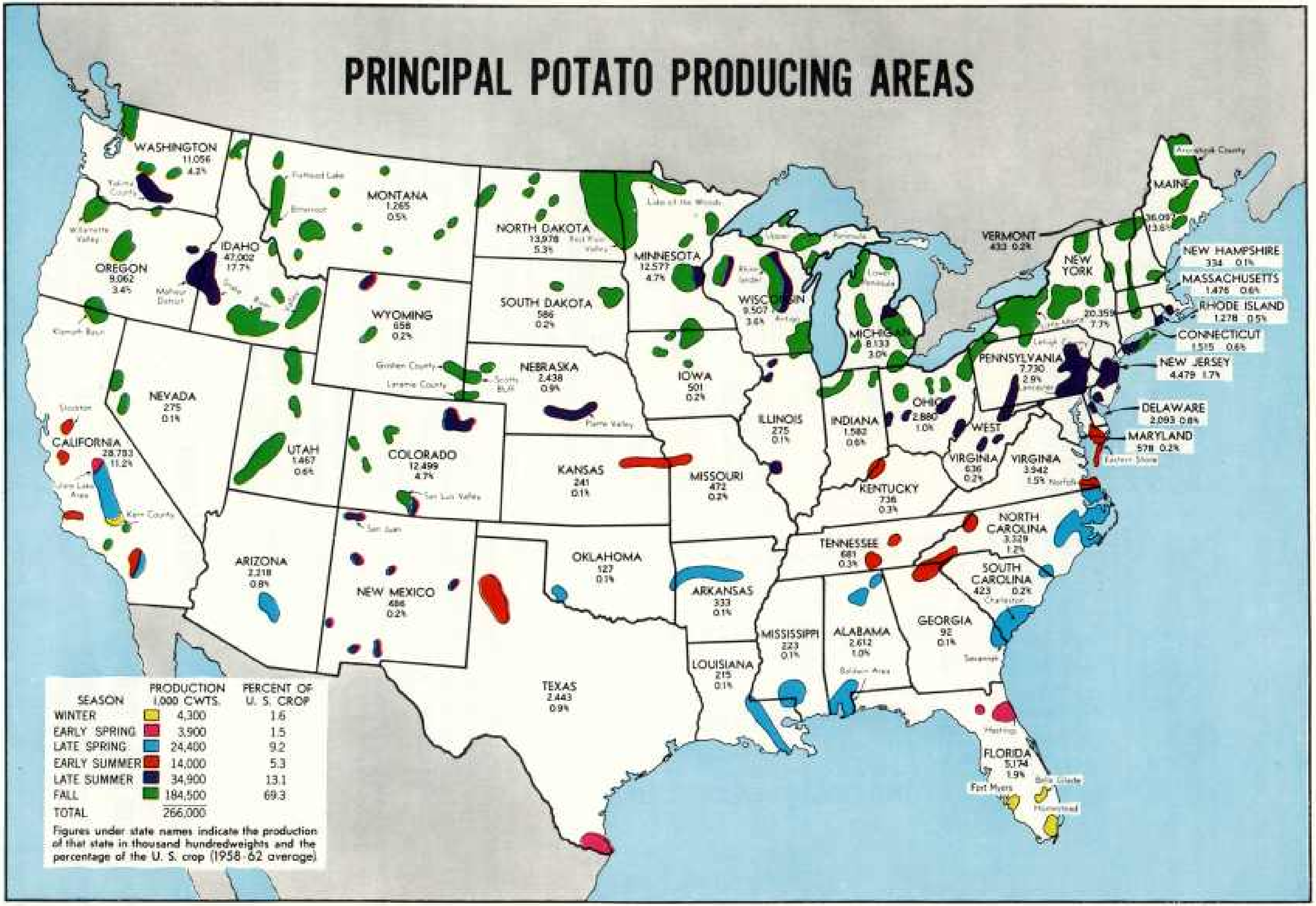

FIGURE 4.—Principal potato-producing areas.

FIGURE 5.—Potato-producing area in Aroostook County, Maine. About 85 percent of the total potato production in Maine is grown in Aroostook County. Planting begins as soon as the soil can be prepared, usually from May 5 to June 1. In the background are fields of clover and oats used in the rotation with potatoes.

York, Michigan, north-central Wisconsin, and the Red River Valley of North Dakota and Minnesota.

The potato is a major farm crop in nearly all the Southern States. It is grown chiefly as an early crop during the winter months because it yields better when grown at temperatures averaging not more than 70° F. The yield per acre of early-crop potatoes in the South is usually less than that of late-crop potatoes grown in other areas, but the market price of the southern crop is generally high enough to help make up for the difference in yield.

Potatoes are grown extensively in the Western States, chiefly on irrigated land. In recent years dam construction and well drilling have brought into cultivation additional land available for growing this crop under irrigation. Potatoes are also grown without irrigation on some acreage in the humid parts of the West. Idaho now leads all other States in potato production, and Bingham, Cassia, and Minidoka Counties, Idaho, are famous for their potato farms (fig. 6).

Production Factors in Relation to Profits

Profitable potato production depends on several factors, including size of the enterprise and market price received by growers. Growers who obtain high yields generally have lower production costs per hundredweight. However, among growers in any given production area with the same yields per acre, there is considerable range in operation costs per unit or hundredweight.

It is often assumed that high yields alone indicate efficient production and economical land use, but a valid estimate of real or net income profit from a farm operation cannot be obtained until the cost of seed, fertilizer, labor, and other production costs are charged against the selling price of the crop. This point is well illustrated in figure 7, in which fertilizer costs are used as an example of what happens when gross returns and net returns per acre beyond the cost of potato fertilizer are considered.

Increasing the amount of fertilizer per acre does not necessarily increase the yield at a fixed rate since the productivity of the land is limited. The gross return in bushels and dollars per acre from the application of 1,200 to 1,800 pounds of fertilizer per acre (fig. 7) increased, but the net return remained about the same even with a 50-percent increase in fertilizer applied per acre. Further increase over 1,800 pounds per acre did not increase yields and lowered the net return per bushel.

FIGURE 6.—A potato seed field in Teton County, Idaho. Overhead irrigation is very common in this area. Idaho is now the leading potato-producing State. Production in Bingham, Cassia, and Minidoka Counties represents a large portion of total national potato production.

The upper curve in figure 7, representing gross return, is based on "the law of diminishing need." Simply stated, this law operates because there is a physiological limit to the amount of fertilizer that can be utilized by the crop in producing an increase in yield. The lower curve representing net return illustrates the "law of diminishing returns." It follows that for each set of conditions maximum net returns can be obtained at a certain level of fertilization, but further increase in the fertilizer level will result in decreased net profits.

A small number of farms produce most of the potato crop. In the 1960 census, farms with 50 acres or more comprised less than 1 percent of the 684,853 potato farms but produced almost 65 percent of the total U.S. crop (table 7).

Farm management studies usually prove that the larger the acreage of crops per farm, the higher the profits per farm. The financial advan-

TABLE 7.—*Acres of potatoes harvested in 1959 on farms of different sizes* [1]

Acres of potatoes per farm	Farms	Acres harvested	Percentage of total harvested
	Number	*Number*	*Percent*
Under 5	670, 499	77, 380	6. 4
5–9.9	4, 366	28, 843	2. 4
10–24.9	7, 688	120, 746	10. 0
25–49.9	5, 828	205, 765	17. 1
50 or more	6, 472	767, 697	64. 1
Total	684, 853	1, 200, 431	100

[1] Agricultural Census, 1960.

tage of large-scale operations is usually related to greater efficiency in use of labor, machinery, and land. Large enterprises are also more conducive to savings in buying and selling practices.

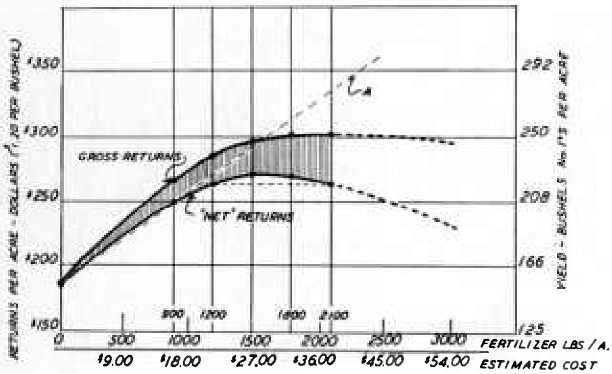

FIGURE 7.—Gross and net returns beyond the cost of potato fertilizer applied at different rates per acre (based on 7 years' data on Long Island). The curve for gross returns flattens because of the diminishing needs of the crop for plant food. The curve for net returns illustrates the law of diminishing returns. Note that applications of 1,200 and of 2,100 pounds per acre both gave the same net return per acre. The theoretical linear relationship between return per acre from yields and fertilizer application (A) is valid only with small applications of fertilizer.

VARIETIES

Anatomical Features of Potato Varieties Used for Identification

Sometimes it becomes necessary to identify varieties of uncertain identity, or those that may have become mixed or mislabeled. Certain varieties fortunately can be identified by their plant growth habits in the field. However, different environments markedly influence the expression of many characteristics of growth. For varietal identification the plant characteristics least affected by environment are: (1) stem and stem wings, (2) terminal leaflets, (3) stipules, (4) flower characters, (5) tuber characters, and (6) sprout characters. Although not anatomical, known disease reaction characters often help to identify some varieties.

Stem and Stem Wing

The angles of the potato stem are extended to form structures called wings. The wings may be prominent or inconspicuous, straight or waved, far apart or so close they appear as double wings. (See fig. 8.)

The stem pigments are more variable. Stems may be entirely green, reddish, or purple. The anthocyanin pigments present may be mottled or uniformly distributed along the entire stem or they may be localized at nodes or certain internodes.

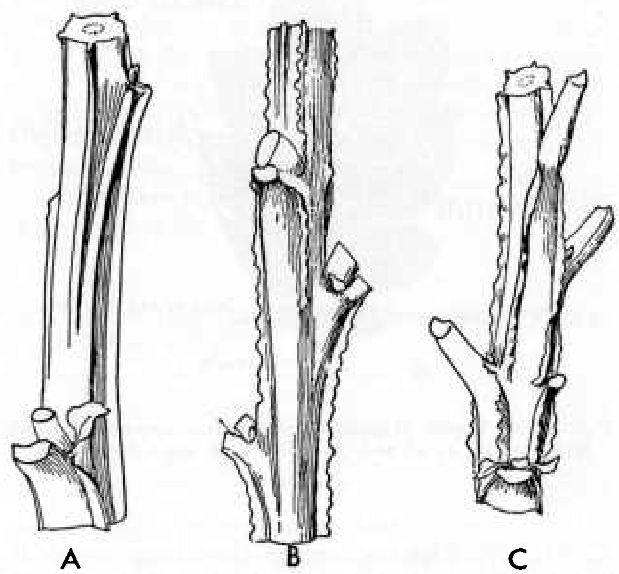

FIGURE 8.—Potato stems showing types of wings: *A*, straight, double (Pontiac); *B*, waved, double (Garnet Chili); *C*, slightly waved, double (Irish Cobbler). Wing characters are not greatly changed by differences in environment.

Leaves and Terminal Leaflets

The leaf of the potato is compound and consists of a petiole, a terminal leaflet, and several pairs of primary leaflets, interspersed with smaller secondary leaflets and sometimes tertiary ones arranged along the midrib. When the pairs of primary leaflets are widely separated and there are few secondary leaflets, the leaf is designated as open. When primary leaflets are close together and the secondary ones are numerous, the leaf is described as closed (fig. 9).

The terminal leaflets are readily classified as lobed, partially truncate, or decurrent (fig. 10, *A*, *B*, *C*).

In the Chippewa variety, terminal leaflets are lobed only on one side, usually on the lower leaves. Since this distinctive feature does not occur consistently, it is best to make observations only on older leaves that are completely formed.

Stipules

Stipules, the leaflike growths at the base of the peduncles and petioles of the lowest inflorescence, provide one of the most useful plant charac-

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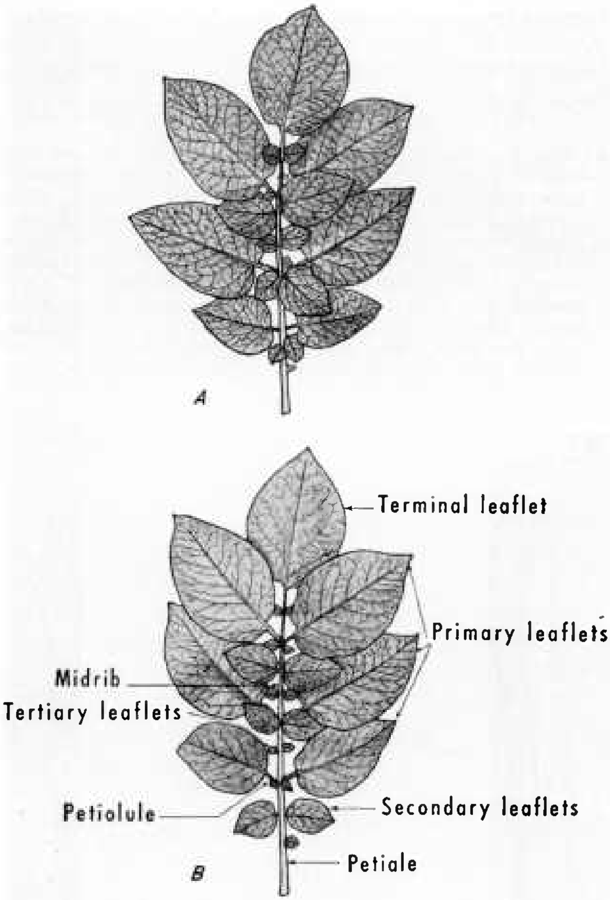

FIGURE 9.—Types of potato leaves and enumeration of leaf parts: *A*, closed-type leaf; *B*, open-type leaf.

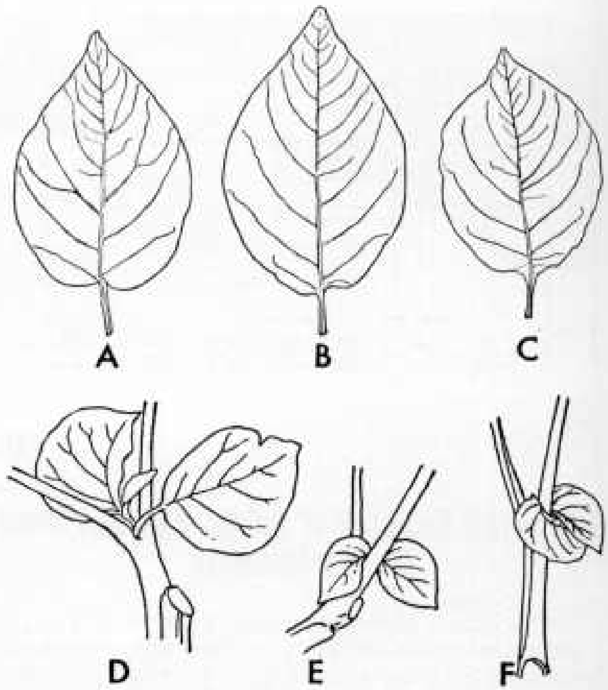

FIGURE 10.—Leaf characteristics of importance in the classification of potato varieties: *A*, lobed terminal leaflet (Katahdin); *B*, partly truncate terminal leaflet (Chippewa); *C*, decurrent terminal leaflet (President); *D*, very large leaflike stipule—at base of peduncle of lowest inflorescence (Earlaine); *E*, stipule medium in size, spreading (Katahdin); *F*, stipule medium in size, clasping (Green Mountain).

teristics for varietal identification (fig. 10, *D*, *E*, *F*). Stipules may range from large to small in size. They may be spreading or may entirely clasp the peduncles or petioles.

Flowers

Flower color is probably the most distinctive plant characteristic used for variety identification. Flower color ranges from white for Burbank, White Rose, and Green Mountain to reddish for Pontiac, Warba, Katahdin, and Sebago to purplish for the Rural varieties. Some varieties produce an abundance of blossoms while others bloom sparsely. Certain varieties may bloom profusely in one environment and not at all in a different one. Anther colors also vary; they may be orange, lemon yellow, or greenish yellow.

Tubers

The skin color of mature tubers is one of the best single means of variety identification. Most varieties may be classified as either russets, whites, pinks, reds, or purples. The intensity of skin color and russeting varies with location and cultural practices, but the layer in which the tuber color occurs in red varieties is distinctive. Color pigmentation is located in the periderm layer of Triumph, Red Pontiac, Red Warba, and Red McClure and in the underlying cortical layer of Early Rose, Spaulding Rose, and Early Ohio varieties. The depth of eyes and shape of tubers, although distinct varietal characteristics, are not always reliable means of identification because of their wide variability caused by differences in environment. Comparative chipping tests and total solids determinations also can be helpful for identification if the potato varieties compared were grown under similar conditions.

Sprout Characters

When potatoes are allowed to sprout under certain conditions of light, temperature, and humidity, they develop distinct characteristics at definite stages of growth that are valuable aids in identification. If potato tubers are sprouted in darkness or in diffused daylight, sprout characters

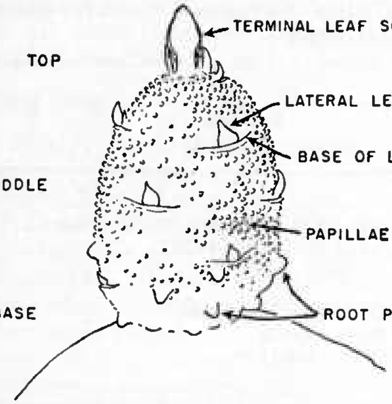

FIGURE 11.—A sprout developed in the dark showing distinctive features useful in variety identification.

develop that are typical for certain varieties (fig. 11). These features are the most useful for identification.

Disease Resistance

Reaction to certain plant pathogens is the basis for another method of varietal identification. Tests for resistance to specialized races of the late blight organism and to scab and viruses X, A, Y, and S can readily be used to determine varietal identity through differences in susceptibility.

Varieties From Which To Choose

A relatively large number of varieties of potatoes are grown in the early-, intermediate-, and late-crop sections of the United States. They differ in time of maturity, yield, appearance, cooking and marketing qualities, and resistance to various diseases and insects. All other characteristics being equal, a variety resistant to even one disease or insect is better than a susceptible one.

A variety that is good in one geographical area, however, may be of little value in another. The grower is warned, therefore, against buying large quantities of high-priced seed stock of a recently introduced variety or one reported superior in other localities until he learns whether it is adapted to his particular environmental conditions. He had best obtain the needed varietal information from his county agent or State agricultural college or to test the variety himself on a limited scale.

Descriptive information for 30 leading varieties is given in table 8 and as follows:

TABLE 8.—*Varieties of most importance in potato production in the United States and Canada, listed according to acres of seed certified in 1960*

Variety	Acres certified, 1960	Origin: date and place	Parents
	Number		
Katahdin	48, 393	1932, USDA	USDA Seedling 40568 × USDA Seedling 24642.
Russet Burbank	36, 145	Unknown	Mutation from Burbank, a seedling of Early Rose.
Red Pontiac	25, 175	1949, USDA, Michigan	Mutation from Pontiac (Triumph × Katahdin).
Sebago	20, 820	1938, USDA	Chippewa × Katahdin.
Kennebec	20, 107	1948, USDA, Maine	USDA B 127 × USDA 96-56.
Irish Cobbler	18, 770	Unknown	Unknown.
Red LaSoda	5, 996	1954, Louisiana	Triumph × Katahdin.
Norland	4, 657	1959, North Dakota	ND 626 × Redkote.
White Rose	4, 156	1893(?), Private	Seedling of Jackson.
Chippewa	3, 401	1933, USDA	USDA 40568 × USDA 24642.
Early Gem	2, 708	1955, USDA, Idaho, North Dakota.	Russet Burbank × USDA 96-56.
Green Mountain	2, 073	1878, Private	Dunmore × Excelsior.
Red McClure	1, 529	Unknown	Mutation from Peachblow.
Cherokee	1, 242	1953, USDA, Iowa, Indiana.	USDA 96-56 × USDA 528-170.
Keswick	1, 109	1951, Canada, E.F.S	*S. demissum* BC_2 × Green Mountain to Earlaine.
Pungo	852	1954, Virginia, USDA	USDA 96-44 × USDA 528-170.
Early Ohio	769	1871, Private	Seedling of Early Rose.
Fundy	675	1960, Canada Department of Agriculture.	Keswick × USDA 96-56.
Russet Rural	669	Private release by E. S. Carmen.	Mutation from Rural New Yorker. Parentage of indefinite origin.
Russet Sebago	525	1947, Wisconsin	Mutation from Sebago.
Plymouth	503	1956, USDA, North Carolina.	Mohawk × USDA 96-56.
Triumph	492	1878, Private	Peerless × Early Rose.
Onaway	482	1954, USDA, Michigan	Katahdin × USDA 96-56.
Waseca	475	1949, Minnesota	Bliss Triumph × Minn. 15-2-10.

TABLE 8.—*Varieties of most importance in potato production in the United States and Canada, listed according to acres of seed certified in 1960*—Continued

Variety	Acres certified, 1960	Origin: date and place	Parents
	Number		
Dazoc	448	1953, Nebraska	Minn. 5-10-3-23-2 × Minn. 29-32-1-34.
Ontario	414	1946, USDA, New York	Richter's Jubel × USDA 44537.
Warba	361	1927, Minnesota (selected in Iowa).	Triumph × Minn. 4-16.
Rushmore	306	1954, Louisiana	Katahdin × Green Mountain.
Red Warba	263	1939, Minnesota	Mutation from Warba.
Teton	239	1946, Maine, Wyoming, USDA.	USDA 45146 × Earlaine.

Cherokee

Medium early. Adaptation not widely determined; performance in Maine and on midwestern muck soils has been better than that of Irish Cobbler. Tubers medium size, roundish with blunt ends; skin smooth, creamy white; eyes medium deep; flesh white. Flowers white. Resistant to common strains of late blight fungus, to common scab, and to mild mosaic. Resistant to net necrosis caused by leaf roll infection. Starch content of Cherokee compares with that of Irish Cobbler. Cooking quality good. Valued most for its resistance to scab, especially on some of the muck soils of Indiana, Iowa, and Minnesota.

Chippewa

Midseason, 10 to 15 days later than Irish Cobbler. Widely distributed, reaching its greatest importance in Indiana, Maine, Michigan, Minnesota, New Jersey, New York, North Dakota, and Wisconsin. Does well on peat or muck, especially adapted to such soils in Indiana and New York, where large, good-quality crops are produced; but in most other sections table quality poor. Tubers (fig. 12) large, elliptical to oblong, medium thick; skin smooth, dark creamy buff; eyes shallow, same color as skin; flesh white. Flowers lilac with white tips. Susceptible to wart, spindle tuber, and leaf roll, but to date no net necrosis found in tubers as a result of leaf roll infection; resistant to mild mosaic. Cooking quality good to poor.

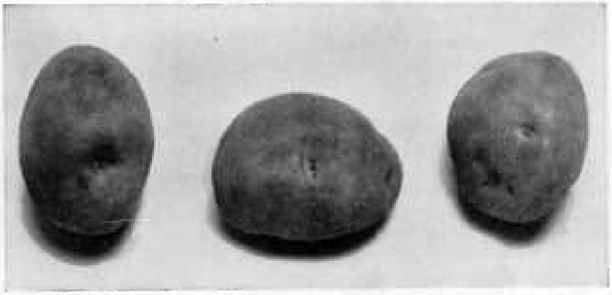

FIGURE 12.—Tubers of Chippewa variety. Widely distributed. Greatest importance in Indiana, Maine, Michigan, Minnesota, New Jersey, New York, North Dakota, and Wisconsin.

Dazoc

Very early. Grown mostly in Minnesota, Nebraska, and Wyoming. Small, medium compact plants with medium thick, erect stems; medium to small, open, dark-green leaves. Tubers medium size, oblong ovate and thick; eyes medium to deep; skin deep, bright red, smooth; flesh white. Medium in solids content and among the best early red varieties for tuber type. No known disease resistance; foliage and tubers highly susceptible to late blight.

Early Gem

Early. Usually grown in Idaho but also in Minnesota, North Dakota, and Wisconsin as an early-maturing russet type that can be marketed before Russet Burbank matures. Tubers tend to develop growth cracks under wet growing conditions. Plants medium to small. Tubers medium long to long, medium thick; eyes shallow; skin russeted; flesh white (fig. 13). Flowers white.

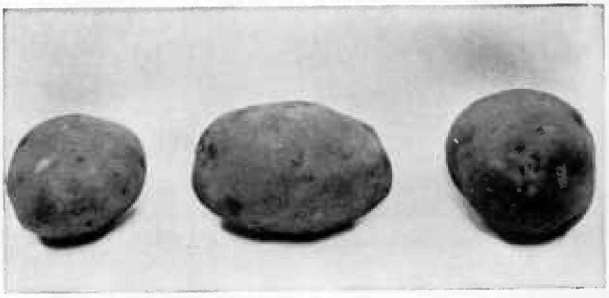

FIGURE 13.—Tubers of Early Gem. Greatest importance in Idaho, Minnesota, North Dakota, and Wisconsin.

Resistant to common scab; apparently susceptible to all other common potato diseases. Cooking quality medium to good; keeps well in storage.

Early Ohio

Early; matures about 10 days later than Triumph. Grown to a limited extent in Iowa, Minnesota, North Dakota, Oregon, South Dakota, and Wisconsin. Adapted to the Red River Valley gumbo soils and to the sandy soil districts of Minnesota. Tubers medium size, round-oblong to somewhat cylindrical (largest tubers), seed and stem ends rounded; skin smooth, pink, lighter at base than at apex; lenticels prominent; eyes numerous, moderately shallow, sometimes protuberant, pink; flesh white, sometimes with color in cortex. Flowers white. Susceptible to virus diseases and wart. Cooking quality good.

Fundy

Early to midseason. Plants moderately vigorous with a slightly spreading habit of growth. Leaves slightly crinkled; tend to rim roll as maturity advances. Tubers elliptical, medium thick; skin smooth, slightly netted; eyes shallow; type excellent; appearance attractive. Flowers white and sparse. Resistant to common races of late blight. Medium dry-matter content; excellent cooking qualities for boiling and baking. Fundy compares favorably in yielding ability to Irish Cobbler and Katahdin when grown as a main crop in New Brunswick, Canada.

Green Mountain

Late. Grown in the Northeastern States, where it produces high yields of good-quality tubers. Being replaced in some States by newer varieties, chiefly Katahdin, Chippewa, Sebago, and Kennebec. Production limited to cool and reasonably moist climate and to lighter soils. Tubers large, short-oblong to oblong, broad, flattened ends usually blunt; skin smooth or often netted, white; eyes medium deep, white; flesh white. Flowers white. Immune to wart but susceptible to most of the other common potato diseases; net necrosis develops extensively in storage from current-year leaf roll infection. Cooking quality usually very good but potatoes tend to blacken after cooking.

Irish Cobbler

Early. Wide adaptation; grown in nearly every State. Adapted to muck and the lighter soils; best adapted to cool weather and ample moisture. Tubers large to medium, roundish with blunt ends, the stem end often notched rather deeply, giving a shouldered appearance to the tuber; skin smooth, creamy white; eyes shallow to rather deep, particularly in bud-eye cluster; flesh white (fig. 14). Flowers lilac with white tips, bleaching nearly white under prolonged, intense heat. Susceptible to most virus diseases and very susceptible to common scab; resistant to mild mosaic and immune to wart. Cooking quality usually good.

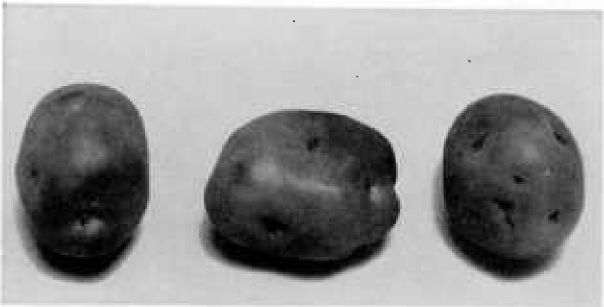

FIGURE 14.—Tubers of Irish Cobbler. Grown in nearly every State. Grown principally for seed in Maine and Minnesota and for table stock in Southeastern States. One of the most widely adapted potato varieties grown in this country. High in quality but very susceptible to scab.

Katahdin

Late; matures a little later than Green Mountain and at about the same time as Smooth Rural. Adaptation wider than that of Chippewa. Tubers large, elliptical to roundish, medium thick; skin smooth, dark creamy buff; eyes shallow, same color as skin; flesh white (fig. 15). Flowers lilac with white tips. Resistant to mild mosaic, net necrosis, and brown rot and immune to wart; not infected with leaf roll as readily as most other varieties. Cooking quality medium to good.

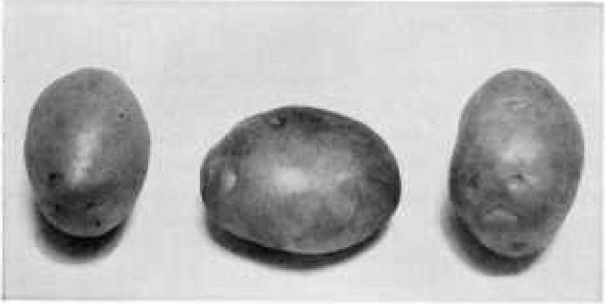

FIGURE 15.—Tubers of Katahdin. Widely grown. Greatest importance in Maine and other Atlantic Coast States. Leads all other varieties in number of acres grown for certified seed.

Kennebec

Late; matures a little earlier than Katahdin. Adaptation wider than that of Chippewa but less than that of Katahdin. Tubers large, elliptical to oblong, medium thick; eyes shallow; skin smooth, creamy buff; flesh white (fig. 16). Flowers white. Resistant to common strains of the late blight fungus, mild mosaic, and net necrosis in the tubers caused by seasonal infection with the leaf roll virus. Cooking quality: A general-purpose potato that bakes, boils, and fries satisfactorily. Very desirable for french frying or for chipping.

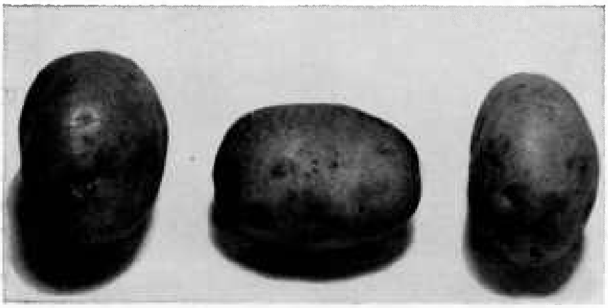

FIGURE 16.—Tubers of Kennebec. Widely adapted and grown in most States for processing and table stock. Gradually replacing Katahdin.

Keswick

Medium to late. Plants large, erect; stems medium to thick and slightly angled, green. Leaves moderately long and broad. Tubers elliptical to oblong; eyes medium deep; skin dark cream; flesh white. Flowers white. Susceptible to leaf roll and bunch top viruses; resistant to common races of late blight. As a main crop in New Brunswick, Canada, it has equaled Green Mountain in yield and cooking quality.

Norland

Early. Smooth, shallow-eyed, red-skinned with early yielding ability (fig. 17). Moderate resistance to common scab; susceptible to infection by the common potato viruses and to the fungus causing late blight. Norland possesses good cooking and chipping qualities and produces a high percentage of U.S. No. 1 tubers.

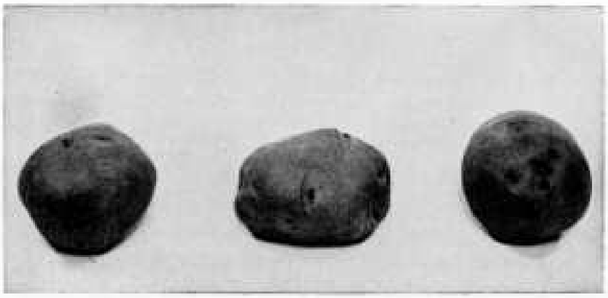

FIGURE 17.—Tubers of Norland. Grown mostly in the North Central States.

Onaway

Early. Grown mostly in Michigan as an early crop. Medium to large upright plants with thick stems and large leaves. Tubers elongated; skin smooth, creamy white; eyes medium deep; flesh white. Tubers rough when large and not good for chipping. Resistant to common scab and considerable field resistance to late blight. Tubers susceptible to injury from early blight and from Fusarium wilt.

Ontario

Late. Very high-yielding variety; highly resistant to scab. Tubers oblong; skin smooth, dark creamy buff; eyes shallow except at bud end, which is sometimes sunken, same color as skin but turning pink or purple on exposure to light; flesh white. Flowers pale lilac in center of each petal, white at edges. Has an undesirable tendency at times to form sprouts and often secondary tubers at the bud end of the tubers. Cooking quality ranges from poor to good, depending on conditions under which it is grown. Highly recommended for scabby soils.

Plymouth

Midseason. Grown mostly in Maine, Minnesota, New York, Ohio, and Wisconsin. Production is increasing in other areas. A high-yielding variety. Tubers oblong-flattened; shallow eyed; skin cream buff. Flowers white. Moderately resistant to common scab; immune to the common race of late blight. Cooking quality good and chipping quality good to excellent.

Pungo

Midseason. Adaptation not fully determined; yielding ability in Maine and Virginia very good. Acreage is continually increasing among the Atlantic Coastal States. Tubers large, elliptical to round-elliptical, medium thick, blunt ends; skin flaked, self-colored, creamy buff; flesh white. Flowers white. Resistant to the common strain of late blight fungus and to mild mosaic; good resistance to net necrosis caused by leaf roll virus—similar to Sebago. Dry-matter content high, similar to Green Mountain.

Red LaSoda

Medium early. Similar to LaSoda except darker red skin. Grown mostly for seed in Minnesota, North Dakota, South Dakota, and Wisconsin and for table stock in other areas. Tubers round to slightly oblong; skin bright red, very smooth; eyes medium to shallow; flesh white (fig. 18). Flowers purple. Some resistance to mosaic. High yielder.

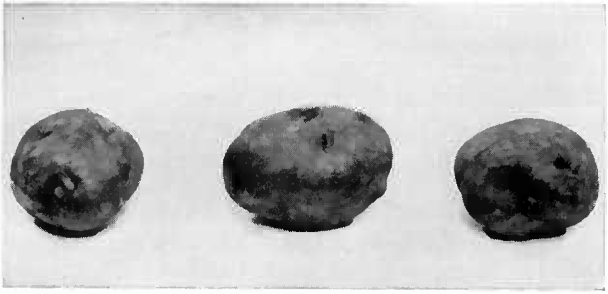

FIGURE 18.—Tubers of Red LaSoda. Grown mostly in the North Central States of Minnesota, North Dakota, and South Dakota; and in the South Central States of Alabama, Louisiana, and Mississippi.

Red McClure

Apparently a mutation of Perfect Peachblow, differing only in tuber color. Red McClure has a netted red skin, whereas Peachblow has a pinkish skin. Grown mostly in Colorado and Wyoming. Plants large with purple pigmented stems. Tubers round, flattened; eyes few, shallow; bud-eye cluster frequently depressed; flesh white. Immune to potato wart but susceptible to virus diseases.

Red Pontiac

Late. High-yielding variety of value in sections where red varieties are in demand; especially adapted to muck soils in Michigan, in the Everglades area of Florida, and in Minnesota, North Dakota, and Wisconsin. Similar to Pontiac except darker red skin. Tubers large, oblong to round, blunt at ends; skin smooth or sometimes netted, uniformly red; eyes medium deep, red; flesh white (fig. 19). Flowers light reddish purple with white tips. Not markedly resistant to common scab or virus diseases; in some trials in Michigan and Ohio more drought resistant and freer than other varieties from hollow heart and misshapen tubers. Cooking quality good.

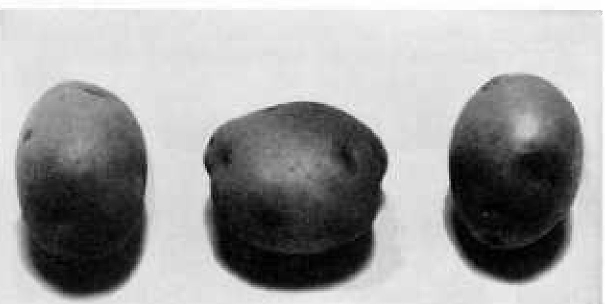

FIGURE 19.—Tubers of Red Pontiac. Grown mostly in Florida, Michigan, Minnesota, North Dakota, and Wisconsin.

Red Warba

Very early. Tubers medium size, short, round; skin smooth, red, uniformly colored except for an occasional tuber with small white areas; eyes mostly deep, red; flesh white. Flowers pink. Suspectible to virus diseases. Good cooking quality.

Rushmore

Early to medium early. Medium yielding ability; adapted to the northern potato-producing area. Tubers oblong, russet color, brighter and lighter than Russet Burbank. No claim is made for disease resistance in either foliage or tubers. Cooking and baking qualities very good to excellent, similar to those of Green Mountain.

Russet Burbank

Late. Usually grown in the Northwestern States, but production is increasing in Maine, Michigan, North Dakota, and Wisconsin. Much of this increased production of Russet Burbank is due to its favorable marketing and processing qualities. Tubers large, long, cylindrical or slightly flattened; skin russeted, heavily netted; eyes numerous and shallow; flesh white (fig. 20). Flowers white and few in number. Some scab resistance but susceptible to most other potato diseases, especially leaf roll, net necrosis, and Verticillium wilt. Cooking and processing qualities very good; keeps well in storage.

FIGURE 20.—Tubers of Russet Burbank. Widely grown in the Northern States, especially the Northwestern States, and Maine, Michigan, North Dakota, and Wisconsin. Sometimes called the Netted Gem. Knobby tubers may develop under growing conditions of uneven moisture and temperature.

Russet Rural

Late. Grown mostly in Colorado, Maine, Michigan, New York, Pennsylvania, and Wisconsin. Tubers large, broadly oblong, flattened; skin somewhat netted, russet, occasional tubers only partly russet; eyes few, shallow; bud-eye cluster frequently depressed; flesh white. Flowers violet with lilac tips. Very susceptible to wart but resistant to common scab. Cooking quality good; keeps well in storage.

Russet Sebago

Late. Characteristics identical with those of Sebago except for two important differences: It has russet skin and is more highly resistant to scab than Sebago. Because of its scab resistance, its production is increasing in Wisconsin, where it originated.

Sebago

Late. Firmly established commercially and increasing in production as an early variety in Alabama, Florida, and South Carolina, and as a late variety in the North Central and Northeastern States. High yielding. Tubers large, elliptical to round-elliptical, medium thick; skin smooth, ivory yellow; eyes shallow, same color as skin; flesh white (fig. 21). Flowers lilac with slightly lighter tips. Resistant to mild mosaic and net necrosis; vines and tubers moderately resistant to late blight; resistant to brown rot in Florida; resistant to yellow dwarf, indicated by tests in New York and Wisconsin; susceptible to wart. Cooking quality variable but usually good if tubers are allowed to mature fully before being dug.

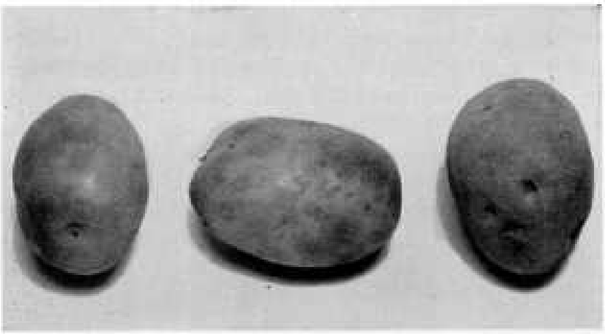

FIGURE 21.—Tubers of Sebago. Grown mostly in Alabama, Florida, South Carolina, and the North Central and Northeastern States.

Teton

Medium late. Adaptation good in Maine, Pennsylvania, and Wyoming. Tubers round to oblong, medium size; skin flaked, self-colored, light buff; eyes few, medium deep to shallow, same color as skin; flesh white. Flowers white. Resistant to ring rot and mild mosaic. Cooking quality and starch content are medium to good and compare favorably with those of Katahdin.

Triumph

Early. Widely adapted; grown commercially in 25 States; of greatest importance in Southern and Midwestern States. Tubers large to medium, round, thick; skin smooth, uniformly red; eyes medium deep; flesh white. Flowers pink. Susceptible to most diseases, including wart. Fairly mealy when cooked.

Warba

Early. Plants medium size, spreading, with thick, prominently angled, green stems and long, medium-wide dark-green leaves. Tubers medium size, short, round; skin creamy white; eyes rather deep and red; flesh white. Flowers pink. Susceptible to mosaic and wart diseases.

Waseca

Very early. Plants small to medium size, compact to spreading with medium thick, slightly pigmented stems. Long, narrow, slightly rugose, dark-green leaves. Tubers medium to large, oblong to round; eyes medium shallow; skin reddish; flesh white. Flowers white, tinged with purple. Very few small-sized tubers produced.

White Rose

Late. Grown primarily in California and Northwestern States. Large, spreading plants; stems prominently angled, green or slightly reddish purple pigment on the upper part of medium thick stems; leaves medium in length, breadth, and type. Tubers large, long, elliptically flattened; skin smooth, white; eyes numerous, medium deep (fig. 22); flesh white. Flowers white. Susceptible to most common potato diseases, including wart.

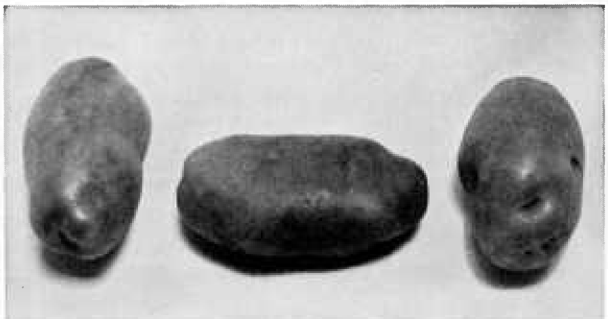

FIGURE 22.—Tubers of White Rose. Grown mostly in California and the Northwestern States.

Varieties Introduced Since 1960

Arenac

Late-maturing variety; immune from latent mosaic and resistant to scab and late blight. Tubers white, smooth. Arenac is rated relatively high in yielding ability, total solids content, chipping qualities after harvest and after reconditioning out of storage, and general cooking qualities.

Blanca

High-yielding, medium-maturing, scab-resistant variety adaptable to Colorado. Tubers smooth, white, oval to round, slightly flattened. Equal to Katahdin in yielding ability and usually superior in solids content. Good baker; tubers produce high-quality chips after harvest and when reconditioned after storage.

Catoosa

High-yielding, medium-early red variety; resistant to scab, immune to common races of late blight fungus. Tubers smooth, oblong to round. First introduced red variety that is resistant to both late blight and scab and should do well in areas where Pontiac is grown successfully. Catoosa has good cooking quality and, as grown in Florida, makes good french fries directly after harvest.

Emmet

Emmet, a sib of Arenac, possesses most of the characteristics listed for Arenac. Usually Emmet yields less than Arenac and is lower in solids content. It is not acceptable for chipping after reconditioning out of storage.

LaChipper

A variety of the Irish Cobbler type; medium-maturing; flesh very white. It has some resistance to late blight; has proved superior to other standard varieties in chipping qualities when grown in the South.

LaRouge

Medium- to late-maturing; skin smooth, attractive, red; flesh white to cream. LaRouge has some scab resistance, matures 10 days earlier than LaSoda when grown in the North, and is well adapted to production in the north-central and southern potato-growing areas.

Navajo

Similar to Blanca in most plant characteristics. Less desirable than Blanca for resistance to scab and for chipping after storage and conditioning.

Ona

High-yielding; resistant to scab, late blight, mild mosaic, and Verticillium wilt; desirable variety, especially in Florida, Maine, and Minnesota, or wherever common scab, late blight, or Verticillium wilt are production problems. Skin smooth, white; eyes shallow. Ona has produced satisfactory chips after harvest and after 10 months of storage with reconditioning. When grown in Maine, its solids content compares favorably with standard varieties.

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Penobscot

Evaluation tests have shown Penobscot to be satisfactory in yield, consistently high in solids content, and more resistant to leaf roll than standard varieties now being grown. It possesses field immunity from mild mosaic and produces oblong to ovate tubers with white flesh and cream to buff skin and medium to shallow depth of eye. It has shown good chipping and french frying qualities at harvesttime and at intervals after storage and reconditioning.

Redskin

Smooth skin, medium-red color, medium-early maturity, resistance to wind damage and scab, high yielding ability, high solids content, and recovery from frost damage are characteristics of Redskin that make it a very desirable potato for production in the South, especially in areas where Red Pontiac is grown. Its yielding ability, its resistance to scab and to net necrosis in the tuber, and its high resistance to Verticillium wilt when grown in the North make it especially adaptable to grow for seed production.

Reliance

Medium maturing; has shown moderate resistance to late blight, common scab, russet scab, silver scurf, aster yellows, and leaf roll. Immune to latent mosaic, and net necrosis has not been observed in leaf roll infected tubers. Tubers white, smooth, oval; eyes shallow. Although acceptable chips have been made directly after harvest, Reliance does not recondition as well as some other varieties and is being released primarily as a fresh-market variety.

Shoshoni

Late-maturing variety; tubers round to oblong; skin, medium russet; eyes, medium-deep, slightly pink. Tubers grown in areas of high summer temperatures have a tendency to become rough and form hollow heart. Evaluation tests have shown that Shoshoni is a high-yielding variety with good processing characteristics for dehydrated products and that it has field resistance to scab and Verticillium wilt.

Snowflake

Matures about the same time as Irish Cobbler. Tubers smooth and shallow-eyed, oblong to round, and seldom develop knobs or growth cracks. Eye distribution is comparable to that of Kennebec. Highly field resistant to virus Y, but susceptible to other potato viruses. Cooking qualities excellent for baking, boiling, or processing into potato chips or flakes.

Viking

High yield and good culinary quality are two important characteristics of Viking. Medium- to late-maturing; tubers range from medium red to bright red; slightly resistant to scab and drought. Flesh extremely white. Excellent for boiling and baking.

Varieties for Disease Resistance and Special Purposes

A few varieties are grown for special uses. The information given below is intended as a broad classification of these varieties to be used as a guide, keeping in mind that different environmental conditions can appreciably alter the characteristics listed.

Varieties Resistant to Specific Diseases

Scab: Blanca, Cherokee, Early Gem, Menominee, Navajo, Ontario, Plymouth, Pungo, and Redskin.

Late blight: Catoosa, Cherokee, Fundy, Kennebec, Menominee, Merrimack, Ontario, Plymouth, Pungo, Saco, and Sebago.

Early blight: Merrimack.

Verticillium wilt: Houma, Menominee, Ontario, Red Beauty, Saranac, and Sequoia.

Mild mosaic: Cherokee, Chippewa, Katahdin, Kennebec, Merrimack, Redskin, Saco, Sebago, and Teton.

Latent mosaic: Saco and Tawa.

Rugose mosaic: Chippewa, Katahdin, Kennebec, Norland, and Snowflake.

Yellow dwarf: Sebago.

Leaf roll: Houma and Katahdin.

Net necrosis: Cherokee, Chippewa, Houma, Katahdin, Kennebec, Merrimack, Redskin, Saco, and Sebago.

Wart: Katahdin, Mesaba, Mohawk, and Sequoia.

Ring rot: Merrimack and Teton.

Corky ring spot: Delus, Merrimack, Plymouth, Pungo, and Saco.

Southern bacterial wilt: Early Gem, Katahdin, Saco, Sebago, and Sequoia.

Varieties With Special Food Value and Other Qualities

High solids: Delus, Green Mountain, Irish Cobbler, Keswick, Merrimack, Russet Burbank, and Saco.

High vitamin C content: Houma, Katahdin, Mohawk, Sebago, Sequoia, and White Rose.

Nondarkening after cooking: Chippewa, Russet Burbank, and Triumph.

Varieties for Special Uses

Home gardens: Irish Cobbler, Katahdin, Kennebec, Plymouth, Red Pontiac, and Redskin.

Chip manufacture: Chippewa, Irish Cobbler, Katahdin, Kennebec, Russet Burbank, Rural New Yorker, Russet Rural, Sebago, and Teton.

Starch recovery: Delus, Irish Cobbler, Green Mountain, Merrimack, Russet Burbank, and Saco.

Frozen french fries: Katahdin, Kennebec, and Russet Burbank.

Early market: Chippewa, Early Gem, Plymouth, Pungo, Red LaSoda, Red Pontiac, Sebago, and Triumph.

Baking: Delus, Green Mountain, Kennebec, Merrimack, Mohawk, Saco, and Snowflake.

Boiling: Chippewa, Katahdin, Kennebec, Norland, Plymouth, Pungo, Red LaSoda, Red Pontiac, and White Rose.

GROWTH REQUIREMENTS OF THE POTATO

Soil Requirements

The yield of tubers and their shape and general attractiveness depend to a great extent on the texture and physical nature of the soil. Among the best soils for potatoes are well-drained, sandy, gravelly, and shale loams well supplied with organic matter and available plant food. Peat or muck soils are particularly adapted for potato production if they are well drained. Potatoes should not be planted in soils that tend to stick to the tubers. Above all, the soil must be well drained because potatoes cannot tolerate conditions that restrict the air needed by the roots. In poorly drained soils, water fills the pore spaces and replaces soil air. When air is excluded, the chemical reactions necessary for maintaining a proper environment for potato roots cannot take place, plant material cannot decompose normally, and the potato roots cannot make vigorous growth.

Even a sandy loam topsoil cannot produce satisfactory crops of potatoes if the subsoil is slow to drain. Unless a soil has good natural drainage, it should be drained artificially before it is used for growing potatoes. Heavy clay soils, which are hard to prepare and tend to puddle when wet and produce poorly shaped tubers, can be made satisfactory if they are adequately drained and a high organic-matter content is maintained.

Soils that lack desirable physical and chemical qualities for potatoes or are infested with disease-producing organisms should be avoided. Potato soils that have produced many scabbed tubers in the past are likely to produce similarly diseased tubers unless resistant varieties are grown. Premature dying of vines and subsequent reduced yield are likely to occur on deep sandy soils that tend to blow, are subject to leaching, and possess low water-holding capacity. The potato needs a steady, adequate supply of soil moisture, particularly when the tubers are forming. Any interruption in growth occurring anytime between tuberization and harvest can result in knobby tubers caused by second growth.

Climatic Requirements

The amount of food produced per acre depends on both the yield of potatoes and the amount of dry matter they contain. The total yield of dry matter per acre depends on a complex of variable factors including moisture, soil properties, variety planted, fertilization, temperatures, and light. The amount of storage of elaborated food in the tubers is a function of the difference between the food produced by photosynthesis and that needed by the plant.

The yield per acre of total dry matter is becoming increasingly important with the rapidly expanding potato-processing industry.

The rate of photosynthesis may be governed by the following: Light intensity, light quality, and light duration; temperature of the air and soil; carbon dioxide supply; moisture supply; chlorophyll content of the plant tissues, especially the leaves; and the accumulation of the products of photosynthetic reaction. Rate of photosynthesis is limited when any one of these factors or a combination of factors is insufficient. Thus if temperature is a limiting factor, increasing air temperature may increase photosynthesis to the point where carbon dioxide becomes limiting or chlorophyll is destroyed. Any single factor may increase only to a certain optimal point, beyond which it may be harmful. When air temperature increases above the optimal point, photosynthesis may be reduced while the plant may use more food in respiration. Under these conditions little or no stored food is accumulated in the tubers. This interaction of climatic factors has been largely responsible for the concentration of potato production in specific geographical areas.

Temperature

The potato has made its greatest development as a source of food in areas where the average daylight temperature seldom exceeds 70° F., and night temperatures are cooler. Cool night temperatures are more essential than cool day temperatures. Experimental evidence indicates that the optimum air temperature for tuber formation is about 60° to 65° F. (15° to 18° C.). At temperatures of 68° to 85° F. (20° to 29° C.) tuber development is markedly reduced, while at temperatures of 85° F. or above few tubers are formed and those that do form are poorly developed.

The optimum temperature for photosynthesis in potatoes is about 68° F. At higher temperatures photosynthesis increases slowly within certain limits, but the rate of respiration increases in accordance with the increase in temperature. Hence the higher the mean temperature above the photosynthetic optimum, the greater the proportion of elaborated food used in respiration, and the smaller the proportion that can be accumulated and stored in the tubers. These effects of temperature explain why potatoes can be grown profitably only in areas where the average air temperatures are seldom higher than 70° F. The critical period in the growth of the potato plant insofar as yield per acre of dry matter is concerned occurs during tuberization.

Heat tolerance differs with varieties. The variety Dakota Red (Jersey Redskin) is known to be especially heat tolerant. Attempts are being made to develop other varieties resistant to heat and drought.

Soil temperatures are related to air temperatures, so both are of great importance in the storing of dry matter in the tubers. Unfavorable heat and drought also modify shape and appearance of the tubers.

Moisture

Moisture, especially if it is a limiting factor, greatly affects yield and quality of the crop. At the other extreme, excess moisture can cause the soil to be waterlogged and poorly aerated, and result in poor root growth and reduced yield. Low soil moisture will reduce yield and also total dry matter. From 300 to 636 pounds of water are required to produce 1 pound of potato dry matter in humid areas, whereas in irrigated areas this ratio may increase five times.

The average water supply and its distribution during the growing season are critical factors determining yields. In the best potato-growing areas in humid regions, total rainfall ranges between 12 and 18 inches for the period between planting and harvesting.

The optimum water needs for potatoes may be affected by fertilizer treatment as well as by soil, air temperature, winds, and cultural practices. It is important to recognize the interaction of these factors in potato production. For example, if moisture is a factor limiting yields, large applications of inorganic fertilizers may actually depress rather than increase yields.

Day Length

Although growth and production of the potato are affected by light—its intensity, quality, and duration—the crop is nevertheless capable of utilizing relatively low light intensities for long durations.

Potatoes are greatly influenced by the length of the light period. During long days vegetative top growth, particularly stem elongation, is increased, while during short days stems are relatively short. Long days tend to encourage formation of long-branched tuber stolons in certain varieties, while short days tend to encourage the production of shorter stolons and increase the rate of tuberization. Under short days potato leaves tend to be soft and more susceptible to late blight, while the same varieties grown under long days are more resistant to blight. For example, the Sebago variety grown in the winter in Florida is notably susceptible to late blight, although when grown under longer summer days in Maine it is acceptably resistant. Blossom buds form under short days but readily drop off, while under long days there is commonly full development of flowers if the mean temperatures are below 70° F. Species of the potato collected and described in Mexico and Central and South America have entirely different growth habits when grown in the northern United States.

Temperature effects frequently overshadow day length effects. Thus, in cool climates even early potato varieties tuberize well under short days. Both late and early potatoes tuberize well under extremely long days in Alaska, largely because of the cool temperature and ability to utilize light of low intensity.

The interaction between length of days, temperatures, genetic factors for maturity, and length of growing season is complex. For this reason maturity of a variety can be compared among varieties at only one location.

Length of Growing Season

With any potato variety grown under optimal conditions, the yield of total solids per acre is usually a direct function of the length of growing season. Every effort should be made to plant as early as feasible and delay harvesting the crop as long as possible in order to lengthen the growing season. A long growing season usually results in higher solids and better quality potatoes than does a short season.

One often hears reports about the high solids produced by certain varieties of potatoes grown in Europe. When European varieties are grown in this country, however, the production of solids per acre is relatively low because yields are significantly below those of our higher producing American varieties. The probable explanation is that the growing season in most potato areas of Europe is long and the temperature is ideal for tuberization (low day and night temperatures with adequate moisture), whereas temperatures in this country are likely to be unfavorably high or the growing season may be too short.

Rotations

Potatoes should be grown in a planned crop rotation to keep the soil fertile, maintain a loose friable texture, check weeds, build up organic matter, and reduce crop loss from insect damage and plant diseases, thus making possible the largest yields per acre.

No detailed information can be given about crops to be grown in rotation with potatoes, as combinations vary from place to place. Potato growers must develop the rotation best suited to local conditions, getting assistance if needed from a county agricultural agent.

In general, long rotations (potato crops planted 3 or more years apart on the same land) are particularly good for reducing potato losses caused by soil-borne organisms causing such diseases as scab, Verticillium wilt, Fusarium wilt, and black leg. Wheat wireworms (*Agriotes mancus*) increase in abundance in fields planted for several years to hay crops and may be a serious threat to a potato crop immediately following the plowing under of a heavy sod. On the other hand, the Pacific Coast wireworm (*Limonius canus*) increases in fields under intense cultivation, but the population decreases in soils planted to hay crops.

Dryland farmers normally plant potatoes on summer-fallowed land or after a cultivated crop such as corn or beans. A small grain crop is considered unsuitable preceding potatoes on dry land because it depletes the soil moisture to depths of 4 to 6½ feet or more. The best soil moisture storage conditions for dryland potatoes are maintained by summer-fallowing the land before potatoes are grown. In some places where summer-fallowed land is liable to blow badly, growers may find it desirable to sow the land to grain in the fall and then plant potatoes in the spring.

Soil Preparation and Improvement

In general, except where a winter cover crop is planted, plow the land for the late-potato crop in late summer or early fall. This recommendation holds not only for green-manure crops, such as combinations of oats, peas, and vetch, but also for clover and alfalfa sod. Fall plowing aids decay of the sod, and leaves the soil exposed to the natural weathering processes during the winter months. How deep to plow depends largely on the depth of the surface soil and the character of the subsoil. Plow a deep and fertile surface soil to a depth of 8 to 10 inches, but plow a shallow soil not deeper than an inch below the plow sole. A 14-inch plow or a larger one is required to do a good job of plowing for potatoes. If much trash is to be turned under, plows with 16- and 18-inch bottoms and with large clearance are needed. Strip-plant fields with a decided slope. It is preferable to plow these sloping lands in very late fall or in the spring and leave them rough, to help prevent erosion.

Disk the fall-plowed land the following spring as soon as the land is dry enough to work. On most potato soils the disk harow should be followed by the spring-tooth harrow. It penetrates the soil deep enough to tear up clods, and the flexible teeth are damaged very little from stones or other obstructions. On some fields it may be necessary to finish the land with the spiked-tooth harrow to break clods and level the ground. The spiked-tooth harrow is also effective in eradicating small weeds.

In general, heavy soil benefits most from fall plowing because the action of frost, snow, and winter rain on exposed soil makes it more mellow. Fields from which soil is likely to be washed away by winter rains and rapidly melting snow, however, should be plowed in the spring.

Prevention of soil erosion cannot be overemphasized. Any waste of topsoil ultimately means a serious loss of capital to the potato grower. Erosion problems should be discussed with your county agent or local soil conservation specialist.

In some parts of the West, alfalfa is turned under just before potato-planting time, and neither the cutoff crowns nor the surviving alfalfa plants give trouble. Thorough plowing of alfalfa soil is essential. The plow should be equipped with alfalfa shares, so that no plants will be left uncut.

Many growers find it beneficial to loosen heavy soil to a depth of 16 to 20 inches with a land chisel.

Soil should not be plowed when too wet. If plowed when too wet, the land is likely to remain in poor condition throughout the growing season. In the South where heavy rainfall may occur, potato land is ridged to facilitate better runoff of excess water and to provide better drainage.

Basin listing is sometimes a good way to prepare an area for dryland potato growing. The basin lister makes a furrow with small earthen dams at regular intervals. The dams keep rainwater from running off the surface and thus increase the quantity of moisture that is taken up by the soil. If fields are to be irrigated, proper leveling of the land is essential before final preparation of the seedbed (fig. 23).

FIGURE 23.—Careful leveling of land is essential when potatoes are to be grown under irrigation.

The importance of thorough seedbed preparation under all conditions cannot be overemphasized. Poor land preparation cannot be remedied by later cultivations.

Building Up Soil Organic-Matter Content

One of the most important soil problems in practically all potato regions, except those with muck and peat, is that of supplying and maintaining soil organic matter. In warm regions with long seasons, the decomposition of organic matter in the soil is rapid and almost continuous. In colder regions decomposition is less rapid in summer and does not occur appreciably during the winter. An ample supply of decaying organic matter helps to keep the soil loose and mellow and thus prevents packing. Organic matter also facilitates plowing and cultivating; it enables roots of potato plants to penetrate the soil more readily, and it retains rainwater; it provides food energy for the growth of desirable soil micro-organisms; and it supplies plant nutrients. Potato tubers develop and maintain their normal shape better where there is adequate soil organic matter. Tuber shape is an important consideration in marketing the crop.

Each potato farm must ordinarily produce its own organic-matter supply. There are four general methods of getting organic matter into the soil: (1) Follow a suitable crop rotation in which a leguminous crop such as clover or alfalfa is grown; (2) grow and plow under green-manure crops (including catch and cover crops), such as crimson clover, vetch or a combination of peas and vetch, soybeans, cowpeas, rye, oats, barley, wheat, millet, Sudan grass, field corn, or other suitable crop plants (fig. 24); (3) apply barnyard manure; and (4) plow under any other organic residues that will increase the humus content of the soil.

FIGURE 24.—Plowing under crimson clover in Aroostook County, Maine. Organic matter thus added improves the physical condition of the soil. Plowing under legumes adds nitrogen as well as organic matter.

Barnyard manures improve the physical condition of the soil, add plant nutrients, and increase the bacterial activity. Handle manure properly so as to prevent as much as possible the loss of valuable nutrients. Never pile manure loosely in the open yard or under the eaves of the barn, because both storage methods permit leaching of valuable plant nutrients.

If left in the open, build the manure pile with a slight depression at the top and with nearly straight sides. Keep the manure moist throughout to avoid excessive heating, for, if the pile is allowed to dry out too much, firing results with loss of nitrogen. To be used most efficiently for potatoes, haul the manure directly to the field and spread it uniformly on sod land before fall plowing. Rainwater will wash the soluble plant nutrients of the manure into the soil. On sloping land, losses from runoff can be reduced by spreading the manure just before plowing.

Light applications of manure are better than excessively heavy ones. From 5 to 8 tons of manure applied per acre gives better returns than 12 to 15 tons. Generally it is a good practice to add 40 to 50 pounds of superphosphate to each ton of manure.

Fresh manure, especially horse manure or chicken manure, should not be applied just before the potato crop is planted. These manures may produce a favorable environment for common scab development, particularly if the soil is near neutral or pH 7.0 reaction. There is less danger from scab development on soils having a pH of 5.0 than on those having a pH near 6.0. The best rule to follow in using fresh manure is to get it plowed under as soon as convenient, so that it will decay before the crop is planted, and to avoid using horse manure or chicken manure on potato land by applying these manures to other crops in the rotation.

Liming

Liming is important in successful potato production in most humid regions. When the soil is too acid, clover or other soil-improvement crops in the rotation begin to thin out and bare spots are liable to appear in the fields. The question that concerns potato growers, however, is how much lime to apply to benefit the clover without favoring the development of common scab on the potatoes. Growth of the common scab organism in the soil is promoted by alkaline or mildly acid soil reactions.

Increasing the soil acidity will usually check the development of the organism to a point where mostly clean tubers are obtained. Too much acidity (below pH 4.8) is undesirable for the potato crop, and a reaction above pH 5.2 will favor scab.

If lime is needed, it can be used effectively in potato rotations when applied before the land is seeded; then clover does well, and common scab is held in check. In Aroostook County, Maine, potato growers have greatly increased their use of liming materials. In dryland and irrigated areas of the West, the soil reaction is usually above pH 7.0. It is seldom economical to attempt to increase acidity by using soil amendments such as sulfur. Where scab is a problem, rotation practices, especially those involving the turning under of considerable amounts of organic matter, are more practical.

It is a good policy to have potato soils tested periodically to determine soil amendment requirements. Soil tests are made by State agricultural experiment stations for a nominal fee and recommendations are made on the basis of the soil test.

FERTILIZERS

Importance

Fertilizing potatoes is a highly important practice in all sections, especially where they are grown for commercial trade. Since satisfactory answers to many fertilizer problems require first-hand knowledge about the soil and its previous treatment, only general information can be given. Best advice on local problems of kind, amount, ratio, and placement of fertilizer is available through your county agent and State agricultural college. In many States soil-testing services furnish fertilizer recommendations based on the analysis of a soil sample from the field to be planted.

Numerous comparisons of fertilized and unfertilized plots have shown the importance of supplying nutrients to the potato crop. Potato growers can easily recognize a row or part of a row that has been planted without fertilizer, because the effects are generally indicated by retarded, spindly growth, light-green color, and reduced yield. The efficient use of fertilizer is highly important economically to growers.

In some sections of Western States, sulfate of ammonia or ammonium nitrate is the only fertilizer material used on potatoes.

Potato plants require an ample supply of plant nutrients to insure rapid, steady growth and proper tuber development. Moreover, these requirements need to be met at the beginning of growth; any delay in applying the fertilizer much beyond planting time may reduce the yield. Although some available nutrients are naturally present in the soil, fertilizer is usually needed to supply readily available plant nutrients for maximum production. Decaying organic matter and barnyard manure also supply nutrients, but the rate of availability usually is inadequate for the needs of the potato crop during the early growth.

Kind and Amount

The kind and amount of fertilizer required for successful potato production depend to a considerable extent on the kind of soil and its fertility, on the available manure and its condition, on the rotation practiced, on the potato variety, and on seed-spacing distances. It is also generally agreed that the effectiveness of fertilizer is greater when the supply of moisture in the soil is adequate.

The most satisfactory fertilizer for the potato crop in most sections contains nitrogen, phosphoric acid, and potash in proper proportions. In sections where their need is indicated, magnesium and calcium compounds are usually included. Complete fertilizer is generally used in commercial potato-producing sections, although sometimes nitrogen may not be considered necessary on muck or peat. In some sections where well-kept manure is used, the only additional material needed may be superphosphate. Good yields occasionally may be obtained with manure reinforced with superphosphate, but a complete fertilizer usually gives better yields.

The nitrogen, phosphoric acid, and potash ratio of potato fertilizers is important. No one ratio will suit all potato soils or all potato varieties grown, but 1–2–1, 1–2–2, 2–3–3, and 1–1–1 are the ratios most widely recommended and used.

The rate of fertilizer application varies from one potato-producing section to another, depending to a large extent on rainfall, soil, potato variety, spacing, and other growth factors. In most sections of New England, particularly in Aroostook County, Maine, growers customarily use a ton or more of fertilizer to the acre, the rate depending largely on the closeness of seed spacing and on the variety planted.

Many growers in the highly commercial potato-producing districts use from 2,000 to 2,500 pounds of fertilizer to the acre. However, on lighter sandy soils in sections where lack of moisture is a problem, 500 pounds per acre is often considered the maximum rate.

The use of high-analysis and double-strength fertilizers for potatoes has increased rapidly in recent years, particularly in sections where heavy applications of fertilizers are customary. Growers using the higher analysis fertilizers appreciate the reduction in weight attained, the smaller storage space required, the savings on transportation and bags realized, and the greater efficiency in all labor involved.

In addition to cutting in half the costs of bags, freight, storage, and handling, use of double-strength fertilizer saves time and labor at planting time because the hopper on the planter does not have to be filled so often.

Fertilizer Placement

The most effective method of applying fertilizer for potatoes is to place it in a band on each side of the seed pieces, about 2 inches away from them, at their level or slightly below. On sloping land, in order to prevent fertilizer from getting too close to the seed pieces through angling of the planter, apply the fertilizer bands about an inch below the seed-piece level.

When applied in the row and mixed with the soil, some of the fertilizer is liable to come in contact with the seed pieces and result in retarded germination, weak plants, and greatly reduced yields. In Maine, for example, a 4-year average yield when fertilizer was placed at the side was 43 bushels per acre higher than when the fertilizer was mixed with soil in the row; in Michigan, 29 bushels higher; in New Jersey, 18 bushels higher; and in Virginia, 21 bushels higher.

Comparisons in other States gave similar results. The additional yields were obtained not from any change in the kind or quantity of fertilizer used, but simply from a difference in the placement of the fertilizer.

Do not apply fertilizer so it will come in direct contact with seed pieces or deposit it directly over them. Either position may mean a poor stand. To avoid possibility of fertilizer injury when applying more than 2,500 pounds per acre, some growers apply one-third of the total application to the plow sole with a distributor that attaches to the plow or they broadcast part of the fertilizer before planting. The remainder of the fertilizer is then applied in bands at planting time.

Avoidance of Nutrient Deficiencies

Magnesium, an essential plant food element, is included in the group of plant nutrients with nitrogen, phosphorus, and potash. It is an essential component of chlorophyll, the green coloring matter of plants. If available magnesium is lacking in the soil, the formation of chlorophyll in the plant is checked and normal growth activities are seriously disturbed. The first symptoms of magnesium deficiency appear on the lower leaves, but in advanced stages the entire plant may be affected. Yellowing first appears at the margins of the leaflets and spreads between the veins toward the midrib, where a characteristic bulging develops. The leaflets become thicker and brittle, unlike leaves that are yellowing naturally through age. Irregular, brown, dead patches develop, and then the lower leaves often drop off the plant.

Potato fertilizers can now be obtained with 30, 40, or 50 pounds of soluble magnesium oxide per ton, sufficient to help prevent magnesium deficiency in many soils. Potato vines showing early symptoms of magnesium deficiency can be sprayed with a solution of epsom salts. Dissolve 20 pounds of epsom salts in 100 gallons of water and apply this amount of spray per acre. Although spraying is a quick-acting remedy, soil applications of magnesium compounds produce more lasting effects.

In areas where soils lack sufficient manganese, such as the Homestead area of Florida, applications of 100 pounds of 65-percent manganese sulfate per ton of fertilizer have improved yields. The boron requirement of the potato is relatively low; manganese and zinc, like iron, are available in acid soils in sufficient amounts. Certain mucks and peats are sometimes deficient in copper, but the amount naturally present plus that added in some fungicidal sprays appears sufficient to prevent a deficiency of this element in most potato soils.

SELECTING AND PREPARING SEED

Selecting Seed Stock

Although much has been written on the importance of good potato seed stock, some growers continue to use inferior seed. Seed is satisfactory only if it is an adaptable variety, is true to name, and is sound, not oversize, and free from frost injury and disease.

Commercial potato growers should always use certified seed. It costs more than uncertified seed, but the extra cost is small in view of the greater yield that can be expected. Using quality seed practically free of infection is very important in potato production because a number of potato diseases affecting both yield and quality are caused by infections carried inside the tuber and are not affected by external treatments. Many diseases show no visible sign of infection on the outer surface of the tuber. This is true of wilt, some of the bacterial diseases, and nearly all the viruses. When an infected seed piece is planted, not only does the disease reappear in the plant grown from that seed piece but the entire field is exposed to spread of infection.

Certified Seed

A grower cannot tell by looking at potato tubers whether they will be good for seed. However, it is true that a few symptoms of diseases which will endanger the next potato crop can be seen on the tubers. Among these are scab, Rhizoctonia, and late blight lesions, or actual breakdown caused by ring rot, bacteria, and Fusarium. But the most experienced grower cannot detect by tuber inspection, infection by mosaics, which cause losses as high as 20 percent of the crop, or leaf-roll disease, often reported to cause losses of 10 percent. Other seedborne diseases can be detected only through plant symptoms in the field. Examples of diseases that can be introduced on poor seed and later may permanently infest the soil include Fusarium wilt, wart, corky ringspot, and powdery scab. The use of certified seed is the best guarantee against the introduction of seedborne diseases.

Certified potato seed is grown chiefly in northern areas where lower growing temperatures not only favor the expression of virus disease symptoms but also aid in the control of insect vectors that spread these diseases. Certified seed potato growers use all the methods available for eliminating infections from their seed stock so that their fields will meet the rigid requirements of a State certification service. Infected plants in seed potato fields can be detected and removed before infection spreads. In 1915 seed-potato certification was begun in the United States to provide growers of tablestock with disease-free seed true to varietal name. Since that time the enforcement of more and more rigid certification standards has helped considerably to improve the quality of certified seed.

Certified seed is produced on both irrigated and nonirrigated land in all potato-seed-producing States. For many years potato growers were prejudiced against seed stock grown under irrigation, but experiments have shown that irrigation has little or no effect on either the vitality of the seed or the vigor of plants grown from it.

Potatoes of average size are more desirable for seed than larger ones, partly because seed pieces cut from them have smaller cut surfaces. Seed-piece rot, the most common cause of poor stands of potatoes, is generally more severe when the seed pieces have large areas of cut surface exposed to infection. Many growers today prefer to buy small whole tubers for seed at premium prices to avoid the risk that exists when cut seed pieces are used for planting.

Effect of Geographical Source of Seed

Experiments conducted, particularly in Southern States, have indicated the desirability of buying seedstocks from certain geographical areas. Yield differences found between seed of the same variety originating in different locations are considered to be caused by "place effect." This "effect" is sometimes attributed to differences in seed dormancy which can cause retarded and uneven emergence, but other possible influences, such as tuber-transmitted diseases differing in their virulence from place to place, variable soil and moisture conditions, differing fertilizer practices, and possible natural selection of somatic mutations, cannot be ruled out as contributing causes. Further research is needed to study the nature of "place effect" and to determine its probable causes.

Seed potatoes grown under adverse climatic environments seldom produce a good crop. It is seldom profitable to use seed potatoes grown in certain areas of the South even though they are disease free. Crops grown from such seed cannot be expected to give good yields. The nature of this adverse physiological "place effect" is not known at present. "Place effect" is not easily remedied in planting stock; several seasons of repropagation and growth under ideal climatic conditions are necessary to overcome this effect on seed potatoes.

Effect of Storage

Storage temperatures and humidities are known to affect seed quality. High temperatures in storage encourage sprouting too early in the season. These sprouts should be removed. Potatoes that have been desprouted once usually make satisfactory seed even though they may be somewhat shriveled. Repeated desprouting, however, impairs the propagating value of the tubers. Varieties differ in the number of desproutings they can stand before their tubers are unfit for seed. For example, the variety Ontario is unfit for seed after two desproutings, but Kennebec can be desprouted four times before its vigor is seriously affected. A storage temperature of 40° F. or slightly less is considered ideal for keeping seed potatoes.

Seed potatoes stored at low temperatures (below 40° F.) should be warmed up at 60° or higher for about 10 to 14 days before planting. Warming up the potatoes will start sprouts growing and emergence after planting will be quicker. This treatment is especially recommended if the soil temperature is also low (45° to 50°).

Effect of Greensprouting

Greensprouting is seldom used commercially in this country, but it is a common practice in northern Europe. Greensprouting is accomplished by exposing the seed tubers to indirect daylight at temperatures of 60° to 65° F. for 14 to 21 days before planting. Tubers treated this way form short stubby green sprouts. Under unfavorable growing conditions, the sprouts from these small tubers (seed pieces) emerge rapidly with little incidence of decay. When growing conditions are favorable, there is no marked advantage from greensprouting. Much of the beneficial effect of greensprouting is simply the result of warming the tubers. (See "Effect of Storage.")

Breaking Rest Period

The true rest period occurs after harvest when the tuber buds will not develop sprouts even though environmental conditions are favorable. Dormancy is that stage when the sprouts will initiate growth only when environmental conditions are favorable. Potato tubers when freshly harvested are normally in a pronounced state of rest. In cold storage, potatoes normally do not sprout until late winter or early spring, although they may have already emerged from their rest period. Potato varieties differ markedly in the length of time they will remain in the rest period or in a nonsprouting condition. For example, Kennebec and Katahdin are noted for a long rest period, whereas Calrose and Golden are varieties with a relatively short rest period (table 9).

Frequently potatoes must be planted soon after harvest and it is necessary to break the rest period. The two chemicals used most successfully for this purpose are potassium or sodium thiocyanate and ethylene chlorohydrin. The thiocyanate treatment is more convenient when the tubers are to be cut and planted soon afterward. The ethylene chlorohydrin treatment is more satisfactory where potatoes must be treated whole and shipped after treating.

TABLE 9.—*Time required to sprout potatoes stored at various temperatures (average of 3 storage seasons)*[1]

Variety	Storage temperature			
	70° F.	60° F.	50° F.	40° F.
	Weeks	*Weeks*	*Weeks*	*Weeks*
Calrose	5	7	9	24
Cayuga	7	7	10	25
Cherokee	7	9	[2] 38	[2] 38
Chippewa	8	8	12	[2] 36
Earlaine	8	8	11	26
Earlaine 2	6	7	10	25
Erie	6	7	13	[2] 39
Golden	5	5	7	10
Green Mountain	8	10	15	33
Houma	8	8	12	27
Irish Cobbler	8	9	13	20
Kasota	8	8	11	25
Katahdin	8	8	13	[2] 40
Kennebec	9	9	19	[2] 38
Menominee	6	6	12	30
Mesaba	7	8	11	29
Mohawk	9	10	14	27
Norkota	7	8	10	28
Pawnee	7	8	12	26
Pontiac	8	9	18	[2] 35
Potomac	9	10	[2] 41	[2] 41
Red Warba	7	8	12	29
Russet Burbank	8	10	13	27
Russet Rural	9	9	12	25
Rural New Yorker	9	9	12	25
Sebago	6	6	11	[2] 41
Sequoia	8	8	15	[2] 37
Teton	8	8	20	[2] 41
Triumph	8	9	11	35
Warba	7	7	12	29
White Rose	8	12	15	27
Average, all varieties	7	8	14	[2] 31

[1] Adapted from Wright, R. C., and Whiteman, T. M., 1949. "The Comparative Length of Dormant Periods of 35 Varieties of Potatoes at Different Storage Temperatures." Amer. Potato Jour. 26: 330–335.

[2] No sprouting was visible at termination of this storage test.

Thiocyanate Treatment

Either potassium or sodium thiocyanate can be used. Soak the cut tubers in 1½ percent of solution for 1½ hours. Cut the seed tubers through the seed or bud ends, or at least through one of the eyes. Plant the seed in moist soil soon after it is treated.

CAUTION

Potassium and sodium thiocyanate solutions are highly poisonous. Great care must be taken that they do not get into the mouth. Do not leave treated potatoes where animals have access to them, or where they may be accidentally mixed with untreated tubers. All vessels used should be thoroughly cleaned before storing. Dispose of old solutions so that humans or animals cannot get them. Do not dispose these poisons in streams or ponds.

Ethylene Chlorohydrin Treatment

Because ethylene chlorohydrin treatment is a gas treatment, airtight gas containers are required. For small lots, glass desiccators or large garbage cans with tight-fitting lids sealed with potter's clay can be used; for large lots, a large airtight room is necessary. The sacks should be arranged in the gas chamber so that the gas can circulate freely.

The potatoes should be heated before the gassing is started and must be kept at 75° to 80° F. during the 5-day gas treatment; higher temperatures are likely to develop blackheart in the tubers. During the early part of the 5-day treatment, the anhydrous chemical is diluted by adding six parts of water to four of the chemical by weight. An attempt is made to have the ethylene chlorohydrin evaporate throughout the entire 5-day treatment. One quart of 40-percent ethylene chlorohydrin should be evaporated for every 600 to 720 pounds of potatoes in the gas chamber.

If the temperature rises above 82° F., or if the humidity rises to the saturation point, it is advisable to provide outside ventilation. This may be done by opening the door of the gas chamber a few inches for 5 or 6 hours, depending on conditions. The gas chambers are ventilated for 12 hours after the 5-day treatment. The gassed potatoes are kept at a temperature of 75° to 78° until loaded for shipment.

Not all varieties react to the gas treatment in the same way. The rest period of most of them can be broken by the 5-day treatment, but varieties like Irish Cobbler, Mohawk, and Russet Burbank require a second 5-day treatment after an interval of 12 to 15 hours.

CAUTION

Ethylene chlorohydrin gas is poisonous and also explosive in certain mixtures with air; keep lights and fire away from the room or bin where it is being used. Thoroughly ventilate the room or bin after treatment and before permitting anyone to enter. In some areas local or State permits may be required.

Seed Treatment

Surface disinfection of potato seed with chemicals such as mercuric chloride, formaldehyde, and commercial preparations was once considered a necessary practice. More efficient production methods and ample supplies of disease-free certified seed have made this practice unnecessary, except in special or small localized production areas.

Seed disinfection can affect only the disease organisms borne on the surface of the tuber. It cannot control virus diseases transmitted by mechanical means, by insects, by wind and water, or by organisms such as the one causing scab which also infests the soil. Seed disinfection tends to reduce seedborne scab and Rhizoctonia and hence improves the chances for a better stand of plants under adverse growing conditions. It is difficult to justify seed treatment as an efficient practice for commercial potato production when relatively disease-free seed is available. In addition, if seed treatment is not done properly with warm acid or caustic solutions, it may damage the seed, especially some varieties such as Sebago or Chippewa.

Whole Versus Cut Seed

Many growers prefer to plant uncut B-size seed potatoes because uncut seed has the advantage of saving the expense and inconvenience of cutting the larger No. 1 size tubers for planting. Use of whole seed also helps to insure a better stand and to prevent the spread of certain diseases by contaminated seed-cutting knives. Potato growers in some irrigated areas prefer whole seed tubers, because whole tubers are less likely to rot or become dry in the soil before the sprouts are rooted. Using certified B-size whole seed is generally a good practice because, on an equal seed-piece-size basis, whole seed produces more tubers per plant than does cut seed. Some growers are reluctant to use B-size whole seed because of a belief that this seed often contains a higher incidence of virus disease than do cut seed pieces from large tubers. Virus-infected plants tend to produce smaller tubers but certified seed lowers disease incidence, making the use of B-size seed a safe practice.

Standard production practices are designed to produce seed potatoes at nominal cost per hundredweight and result in a high percentage of the potatoes going into grades larger than B-size. More B-size whole seed would be used if it could be produced more economically. Seed buyers usually expect to pay at least 50 cents per hundredweight more for whole seed.

Cutting Seed Potatoes

Formerly most seed potatoes were cut by hand, but recently more and more cutting is being done with mechanical seed cutters. The continued improvement of these seed-cutting devices is increasing their use. Best results are obtained with mechanical seed cutters when the seed has been graded to a uniform size. Such varieties as Katahdin and Chippewa, having few eyes on the basal half of the tuber, produce considerable waste when the large tubers of these varieties are cut for seed. Before cutting is begun, always allow the seed potatoes to warm up, especially if they have been held in cold storage.

Blocky seed pieces are desirable (fig. 25). The planter can handle the blocky pieces to better advantage, and they are less liable to decay in the ground if weather is unfavorable. The seed piece, in general, should weigh 1½ to 2 ounces and should have from one to three eyes. The Katahdin and Kennebec varieties usually set a smaller number of tubers per plant than most varieties; therefore, each seed piece of these varieties should have two or more eyes, or the spacing in the row should be reduced in order to help lower the percentage of oversized tubers that might otherwise develop.

FIGURE 25.—Even stands are more likely to be produced by large, blocky seed pieces than by smaller ones.

Suberization of Cut Seed

The general practice among potato growers is to cut seed about the time it is needed for planting; usually not more than a 2-day supply is cut in advance because rain may interfere with planting and unplanted cut seed is likely to deteriorate unless given special care. However, it is safe to cut seed some time in advance of planting if storage conditions are provided to heal the cut surfaces, a process known as suberization.

Some growers who have large acreages to plant and are limited in time and labor have found it more economical and also convenient to cut the seed potatoes well in advance of planting. When seed is to be cut and stored for 10 days or more, proper care should be taken to heal, or suberize, the cut surfaces of the seed pieces. If the fresh-cut seed is not suberized, it should be planted as soon as possible after cutting.

Properly healed, or suberized, seed has several advantages over freshly cut seed (fig. 26). Cutting can be done before the rush of spring planting begins. Suberized seed is less likely to shrivel if the soil is dry at planting time or to rot if conditions are too wet. With suberized seed the danger of heating, which often happens in the case of freshly cut seed improperly stored in barrels or bins, is greatly reduced. Many a bad stand has been attributed to the poor quality of seed, when in reality it probably was the direct result of improper handling.

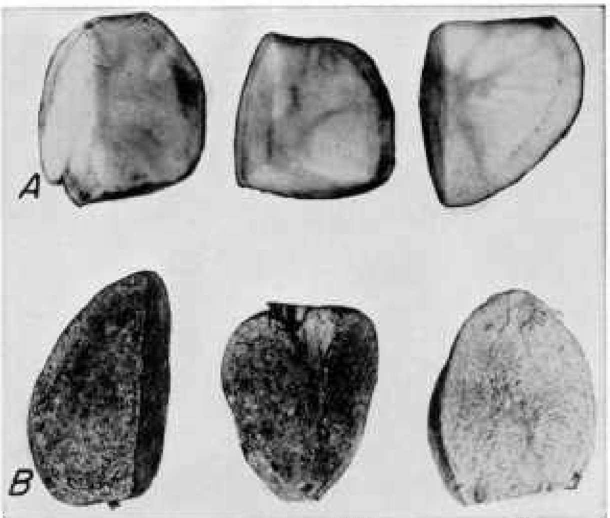

FIGURE 26.—Comparison of *A*, freshly cut, and *B*, suberized, or corked-over, seed pieces.

Suberization is best accomplished by holding the cut seed for a week or 10 days at a temperature from 60° to 70° F. and a relative humidity of approximately 85 percent. Recently it has been found feasible to cut potato seed at the point of origin and ship it by railroad in specially heated refrigeration cars. Suberization takes place during transit and the seed arrives at its destination in excellent condition for planting.

Slatted crates are the best type of container in which to suberize cut seed; and if the crates are kept covered with damp sacks, suberizing is usually good at the temperature range recommended. To prevent the seed pieces from sticking together, rack the containers from side to side within 24 hours after cutting the seed. If the seed is suberized in burlap sacks, fill these only half full and pile the sacks in such a way as to avoid undue heating. The piles may be covered with moist sacks that are kept damp by occasionally sprinkling with water, but care should be taken not to get the seed too wet; otherwise, rot may start on some of the seed pieces.

Care of Cut Seed

If cut potato seed is exposed to the sun or wind on a hot day for even a short time, decay may start before or soon after planting. On such a day it is good practice to shade all seed taken to the field for planting, including seed left in the planter during the noon hour. A canvas shade, if used, should be placed above the potatoes so that hot air will not be trapped under it.

Freshly cut seed if sacked and piled may develop heat, one of the principal causes of seed-piece decay.

Cut seed should never be put into unwashed used fertilizer bags.

Some growers dust freshly cut seed pieces with lime or gypsum to keep them from sticking together.

PLANTING THE CROP

Time of Planting

Planting time depends chiefly on local climatic conditions. In general, potatoes should be planted as soon as the soil has begun to warm up and can be tilled without danger of compaction. The most favorable time to plant in this country differs from North to South. Growers in the Northern States usually plant the bulk of their crop in May, the Central States in April, and the Southern States from November to February. Planting the crop too early in the season often results in frost damage and poor stands because of wet or cold soils. Using whole seed or cut suberized seed lessens the chances of poor plant stands caused by seed-piece decay. Within reasonable limits the earlier the crop is planted the greater will be the total yield and the solids content of the tubers.

In sections where the growing season is longer than required to mature the potato crop, it is customary to select a planting date that will provide the most favorable environment during the critical period of tuberization.

Seed Spacing

The natural fertility of the soil, its moisture-holding capacity, the climate, the variety grown, and the amount of fertilizer applied usually govern the spacing within the row and the distance between rows. In the best potato sections of the

Northeastern States the rows are occasionally spaced as close as 34 inches. To make better use of mechanized equipment, some growers prefer a wider row spacing, up to 36 inches.

Within the rows, hill spacing averages about 12 inches, and the tendency is to shorten the distance to 10, 8, or even 6 inches when such varieties as Kennebec and Katahdin are planted. These varieties usually set a small number of tubers, and closer spacing helps prevent the development of a high percentage of oversize tubers. In Aroostook County, Maine, the combination of good seed, good cultural practices, and heavy fertilization tends to produce a large percentage of oversize tubers unless the spacing within the row is reduced to less than 12 inches. Close spacing in the row also tends to reduce loses from hollow heart, and on good land it generally increases the number of marketable tubers.

In dryland potato production in the Western States, the distance between rows is usually 42 inches and the seed pieces are spaced 14 to 30 inches apart in the row. Under irrigation, the rows and seed pieces can be spaced much closer together; usually, for convenience in cultivating, ditching, irrigating, and digging, the rows are spaced 34 to 36 inches apart and the seed pieces are planted 9 to 14 inches apart in the row, according to variety and the fertility of the soil. For early potatoes, the distance between rows is sometimes reduced to 32 or even 30 inches.

Some varieties when grown under irrigation require close spacing to keep the tubers from growing too large, to minimize growth cracks and hollow heart, and to produce maximum yields. Where rainfall in the West is sufficient to produce a good crop without irrigation, as in the western parts of Oregon and Washington, the seed pieces are spaced the same as on irrigated land.

Wide ridges are desirable for growing potatoes on most irrigated land, because they allow the tubers ample room for development and also protect them from frost in the fall.

In the South, spacing generally depends on the type of cultivation equipment used. In the sugarcane regions of Louisiana, spacing between rows is often 72 inches. Most commonly, however, row spacings of 34 to 36 inches are used with 9- to 14-inch spacing in the row.

Larger seed pieces and closer spacing are used in sections with soil and weather that are optimum for potato culture than are used in less favorable sections.

Depth of Planting

No specific depth of planting will give equally good results under all conditions. Seasonal, cultural, and climatic conditions that prevail during the growing season are the determining factors. If seed pieces are planted shallow, it is necessary to ridge the row after early cultivations so that stolons will be formed well below the ridge surface. Where ridging is practiced, the custom is to plant the seed pieces 2 or 3 inches deep, measured from the top of the seed piece to ground level. The row ridge is built up gradually, starting as soon as the plants break the ground and continuing at 7- to 10-day intervals until the proper ridge is formed.

Tubers formed at a depth of 2½ to 5 inches usually develop under satisfactory temperature conditions favorable for high quality. If the seed pieces are planted too shallow, the tubers formed may be subject to "sunburn" and quality is lowered.

In fields where Rhizoctonia cankers occur, the seed pieces should be planted shallow or planted deep with a shallow covering. This practice insures quick emergence of the sprouts above ground and avoids the early attack of this fungus disease which is less damaging to a healthy, fast-growing plant. For level culture where Rhizoctonia is present, plant the seed pieces 3 to 4 inches below the field level but with a covering of not more than 2 inches of soil over the seed piece.

In the West seed pieces are usually planted from 3 to 5 inches deep to make sure that they will be covered at all times with moist soil. Deep planting is more necessary in dryland farming than under irrigation. "Irrigating up" is a common practice in furrow-irrigated areas. (See p. 37.)

Planters

Four general types of potato planters are now used in this country: the automatic picker, the assisted feed, the cup-type, and the automatic tuber-unit planter. The automatic picker type is the one most widely used in the major producing areas (fig. 27). This type of planter has been gradually improved for operating at higher speeds by increasing the number of pickers from 12 to 16

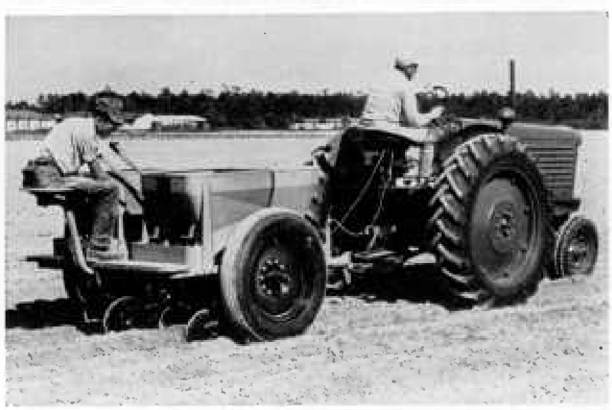

Figure 27.—A two-row picker-type planter.

per wheel and by redesigning other parts to achieve more uniform delivery of seed pieces and to obtain more regular seed spacing at high operating speeds. Greater economy of operation is possible when two-row automatic planters can be operated up to 5 or 6 miles per hour. Good results may be obtained with planters of this type if the seed potatoes are cut in blocky pieces of about the same size. Punctures made by the pickers jabbing into the seed pieces, however, may spread disease-producing organisms and viruses from one piece to another.

Planting costs are reduced by using four-row planters for large acreages (100 acres or more). Two two-row planters can be assembled to make a four-row planter by means of conversion kits now available commercially. The assembled four-row machines are adequately flexible for operating on uneven ground and are capable of planting 50 acres a day while operating at speeds of 5 miles per hour. A much larger acreage can be planted in a day with a picker-type planter than with an assisted-feed type, but the assisted-feed type usually insures a better stand of potatoes.

Table 10.—*Seed pieces required to plant an acre of potatoes at different spacings*

Distance between rows	Pieces required for an acre at stated spacing distances within rows					
	6 inches	8 inches	10 inches	12 inches	14 inches	16 inches
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
30 inches	34, 848	26, 136	20, 909	17, 424	14, 935	13, 068
32 inches	32, 670	24, 502	19, 602	16, 335	14, 001	12, 251
34 inches	30, 748	23, 061	18, 449	15, 374	13, 178	11, 531
36 inches	29, 040	21, 780	17, 424	14, 520	12, 446	10, 890

A tractor driver and helper constitute the field crew required to operate either a two- or a four-row automatic planter. The helper rides the planter, keeps a constant check on the seed feeding to the picker wheels, and watches other details of the machine operation.

The task of refilling the seed hoppers is being mechanized to an increasing degree. Much seed formerly handled manually in bags is now being transported to the field in bulk by truck and loaded into the seed hoppers of the planter in a few minutes by suitable high-capacity elevating conveyors. Hopper extensions are also added to increase the hopper capacity so that enough seed can be carried to plant four rows 4 miles long.

Equipment and methods for hauling seed to the field and handling it from truck to planter are illustrated in ARS 42–21, "Mechanical Seed Cutting and Handling of Potatoes." Copies may be obtained from: Red River Valley Potato Research Center, East Grand Forks, Minn.

The two-row assisted-feed planter requires a man in the rear for each unit, besides the tractor driver, to see that there is one seed piece in each pocket of the revolving, horizontal disk before it discharges the individual seed pieces as it passes over the dropping tube. Although assisted-feed planters are simple in construction and their purchase price is low, their low capacity tends to limit

Table 11.—*Seed potatoes required to plant an acre at different spacings with seed pieces of various weights*

Spacing of rows and of seed pieces within rows (average)	Seed required per acre when seed pieces weigh an average of—				
	1 ounce	1¼ ounces	1½ ounces	1¾ ounces	2 ounces
Rows 30 inches apart:	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*
6-inch spacing	21. 7	27. 2	32. 6	38. 0	43. 6
8-inch spacing	16. 3	20. 4	24. 5	28. 6	32. 6
10-inch spacing	13. 1	16. 3	19. 6	22. 8	26. 1
12-inch spacing	10. 9	13. 6	16. 3	19. 0	21. 8
14-inch spacing	9. 4	11. 7	14. 0	16. 4	18. 7
16-inch spacing	8. 2	10. 2	12. 2	14. 3	16. 3
Rows 32 inches apart:					
6-inch spacing	20. 5	25. 6	30. 7	35. 9	40. 9
8-inch spacing	15. 3	18. 7	22. 9	26. 8	30. 6
10-inch spacing	12. 2	15. 3	18. 4	21. 4	24. 5
12-inch spacing	10. 3	12. 8	15. 4	17. 9	20. 5
14-inch spacing	8. 7	10. 9	13. 1	15. 2	17. 5
16-inch spacing	7. 7	9. 6	11. 5	13. 4	15. 4
Rows 34 inches apart:					
6-inch spacing	19. 2	28. 0	28. 8	33. 6	38. 4
8-inch spacing	14. 4	18. 0	21. 6	25. 2	28. 8
10-inch spacing	11. 5	14. 4	17. 3	20. 2	23. 0
12-inch spacing	9. 6	12. 0	14. 4	16. 8	19. 2
14 inch spacing	8. 2	10. 3	12. 4	14. 4	16. 5
16-inch spacing	7. 2	9. 0	10. 8	12. 6	14. 4
Rows 36 inches apart:					
6-inch spacing	18. 1	22. 7	27. 1	31. 7	36. 1
8-inch spacing	13. 6	17. 0	20. 4	23. 8	27. 2
10-inch spacing	10. 9	13. 6	16. 3	19. 0	21. 8
12-inch spacing	9. 1	11. 3	13. 5	15. 8	18. 1
14-inch spacing	7. 7	9. 7	11. 6	13. 6	15. 5
16-inch spacing	6. 9	8. 5	10. 2	11. 9	13. 6

their use to smaller acreages. They are sometimes used by foundation seed growers for tuber-unit planting.

Cup-type planters are automatic in operation and require about the same attention in operation as picker-type planters. They are well adapted to use whole seed and for this reason are used extensively, although not exclusively, in areas where whole seed is preferred for planting.

Automatic tuber-unit planters are available commercially. The operation of a two-row tuber-unit planter requires a tractor driver and two feeders who place the individual tubers on the four-way knives of the cutter wheels. The four seed pieces from each tuber are dropped and spaced in the usual manner, except that a wider space is left between each group of four seed pieces. On some tuber-unit planters liquid disinfectant is applied to the cutting blades in each cycle between tuber cuts.

Every potato planter should be carefully inspected and put in good, dependable working condition before the planting season begins. Dependable operation not only increases planting efficiency but also avoids delays from breakdowns. Breakdowns can cause serious trouble, especially in Northern States where early planting is essential to fully mature the crop. Planting adjustments for proper seed-piece spacing and accurate fertilizer application should be made in accord with the variety grown, the climatic conditions, the type of soil, and the cultural practices to be followed.

Amount of Seed to Plant

The amount of seed needed to plant 1 acre of potatoes varies considerably and depends on the spacing and the size of the seed pieces. The number of seed pieces required to plant an acre of potatoes at different distances (table 10) shows that the closest spacing, 30 by 6 inches, requires 34,848 seed pieces to the acre, as compared with 14,520 for a spacing of 36 by 12 inches.

The general practice in the North is to use large seed pieces. On land well supplied with organic matter, moisture, and available plant food, large seed pieces or whole tubers from 1 to 2 ounces in weight usually are profitable. The larger the seed pieces the greater the total amount of seed required per acre. Table 11 shows the weight of seed potatoes required when an acre is planted with any one of five different weights of seed pieces at given spacings. Table 11 also emphasizes the extremely wide seed-piece requirements—from 6.9 to 43.6 hundredweight depending on spacing and size of seed piece.

GROWING THE CROP

Cultivation

The objectives in cultivation are to destroy weeds, aerate the soil, and ridge the rows to provide soil covering for the developing tubers. Cultivation really starts, however, when the soil is being prepared for planting. Thorough preparation of the land before planting makes later cultivation easier and more effective. One good harrowing before the potatoes come up is worth several cultivations afterward. A good practice is to roll the ridges immediately after planting. This tends to compact the soil about the seed pieces, hastens germination, and makes the work of the smoothing harrow and weeder more effective. The use of a weeder lengthwise on the rows once or twice is very effective in controlling weeds, especially when the potato plants are small.

Both level and ridge cultivations are practiced in the areas producing late potatoes. In the level system of cultivation, use the weeder or the smoothing harrow once or twice just before the plants emerge. The teeth of the harrow are angled back to avoid breaking off the young potato sprouts. As soon as the plants can be seen in the rows, cultivate deeply in the middles between the rows but shallow close to the plants. For two successive cultivations, use cultivator wings or hilling attachments in order to form a small ridge 2 or 3 inches high close to the plants. Make later cultivations, if necessary, to control weeds, but take great care to avoid breaking many potato roots while cultivating, as this may reduce the yield.

In the row-ridge system, use the cultivator to loosen the soil and to destroy weeds between the rows. After each cultivation use disks or hilling attachments to form a ridge 6 to 8 inches high. With modern equipment, cultivation and hilling are done in one operation. It is important to commence ridging early with varieties like Katahdin, which form tubers shallower than some other varieties and produce abundant low-growing vines. In the early cultivation the potato sprouts or young plants are commonly buried once or twice to smother small weeds near the plants and to protect the young potato plants from late killing frosts. However, do not cover the plants too deeply, as this may reduce yields.

Discontinue cultivation as soon as the plants come into full bloom or when the vines meet between the rows. If weeds persist after the plants have reached this stage and the rows are ridged, use a "spade" with adjustable wings or other adjustable hilling attachments. The spade removes the weeds from the middle between the rows and the sides of the ridges, and it disturbs very little soil close to the plants.

Irrigation—Humid Areas

Unquestionably, the amount and distribution of rainfall are the most important factors in potato production over which the potato grower has no direct control. In some seasons, insufficient rainfall or uneven distribution greatly reduces late-potato yields, even though seed, fertilizer, and cultural operations have been the best. For this reason increasing numbers of table-stock and seed-potato growers are depending on supplemental irrigation systems to insure against crop losses from drought.

Irrigation will increase yields and quality whenever the soil moisture falls below 50 percent of the soil water-holding capacity. Great care must be taken to avoid supplying more irrigation water than needed to bring the soil only to its optimum moisture capacity. Overirrigation not only may cause unnecessary leaching but also may increase incidence of potato diseases, which could result in losses more severe than the losses by drought. There is always danger in humid areas that heavy rains may follow a normal irrigation to cause the soils to become supersaturated.

In the Northeast and North Central potato areas, overhead sprinkler-type irrigation is most common. Lightweight seamless aluminum pipe with quick couplers is used for movable main lines and laterals.

The questions relating to installation of an irrigation system are too numerous to be dealt with here, but if the grower considering such a move has an adequate supply of water available, much of his problem is solved. Kind of soil, slope of land, value of crop, acreage, engineering details, and other points will need to be considered. The grower should consult the engineering staff of his agricultural college, and also find out what his neighbors who have installed irrigation systems have learned firsthand about irrigation.

Furrow Irrigation—Dryland Areas

Furrows for irrigating potato fields are usually run between rows or pairs or rows (fig. 28). The kind of furrow to use depends on the type of soil, the row length, and the slope of the land. Ordinarily, the furrows are made with two-row cultivators on which the shovels have been replaced with special ditchers. On flat land with heavy soil, the irrigation furrows must be deep and narrow, so that the water will be applied to the soil below the tubers and will not wet the ridge tops before it has reached the far ends of the rows. If deep furrows are used, the soil in the potato rows is less likely to pack. On a steep slope or in soil that washes badly, small furrows should be used.

FIGURE 28.—Furrow irrigation of potatoes. This method has been used for many years in the western potato-producing areas.

To prevent washing, only small streams of water should be applied on steep slopes. Length of run should be governed by the rate at which the soil absorbs water. As a general rule, it is best to avoid runs of more than 600 or 700 feet. Longer runs would waste too much water and cause excessive wetness.

The usual method of applying water for row irrigation is to run a small head in each furrow by making a cut into the bank of the head ditch. One cut may serve either for a single row or for several rows. Instead of cutting into the bank, many growers take water out of the head ditch through horizontal tubes or siphon it over the bank. An adjustable canvas dam may be used in a head ditch to check the flow and thus raise the water level. Two or three such dams are sometimes used in a relatively short length of ditch to obtain even distribution of water in the furrows.

The yield and quality of potatoes grown under irrigation depend largely on how the water is used. Irrigation does not lower the quality of the crop if the water is used correctly. In some parts of the West, 3 or 4 applications of water may be sufficient to grow a crop; in others, 5, 6, or even 10 applications may be necessary. The number of irrigations needed varies from year to year as rainfall and other natural conditions vary. In a 14-year study at Greeley, Colo., consistently larger yields were obtained where the soil moisture was favorable for vigorous plant growth until the tubers reached full size. Frequent light applications (2 to 4 acre-inches) of water gave better results than infrequent heavy ones (4 to 5 acre-inches).

Because of differences in water-holding capacity of soils and variations in temperature, rainfall, and other natural conditions, it is impossible to set definite rules as to the time to begin irrigating, the number of irrigations, or the time to stop irrigating. This general rule should be followed: Apply the first water whenever the plants seem to need it in order to maintain vigorous growth, and thereafter keep the soil moist until the tubers have reached full size. Ideally, all the soil except the tops of the ridges should be kept moist all the time.

On the peat lands of the delta area at the confluence of the San Joaquin and Sacramento Rivers, in California, irrigation ditches 60 to 75 feet apart and 24 to 30 inches deep are cut between rows of potatoes. The head ditch connecting these ditches receives its water supply through a head gate or siphon direct from the river or canal. The soil is open and porous, so that a higher water level in the ditches also raises the water table throughout the irrigated area. When a tract of land has received the right amount of water, the supply is cut off and the water level is lowered by pumping the excess water back into the river. Some potato lands in the San Luis Valley of Colorado, and in the Egin Bench district of Fremont and Madison Counties in eastern Idaho, are irrigated by raising and lowering the water table in much the same way.

Sometimes when snowfall or spring rain has been insufficient, or when there have been drying winds or continued hot weather, or both, it is necessary to irrigate before planting potatoes or to "irrigate up" the crop (fig. 29). "Irrigating up" means applying water immediately after planting. If spring plowing has been delayed, the land may be irrigated before it is plowed. When alfalfa sod has been crowned in the fall (the tops of the plants have been cut off by very shallow plowing) and the land has been plowed early in the spring, it is not

FIGURE 29.—"Irrigating up" a field of potatoes in Colorado. The field is irrigated immediately after the seed has been planted.

practical to irrigate by flooding so the land may be furrowed, or ditched, and irrigated before being planted. Irrigating in the fall or in the early spring before planting, when water is available, is a good practice, preferable to irrigating immediately after planting.

"Irrigating up" must be done very carefully, especially in hot weather, or it is likely to cause seed-piece decay. Good germination and little decay of seed pieces can result from "irrigating up" if the water is applied by the furrow method and moisture is allowed to reach only the seed pieces or sprouts, without wetting the soil above the seed pieces. This practice should be used only if the soil lacks enough moisture for seed germination.

Overhead Irrigation

The use of portable, overhead sprinkler irrigation on potatoes has steadily increased in the intermediate- and late-crop sections of the Eastern and Midwestern States. More than 80 percent of all irrigation in 28 Eastern States is now done by portable sprinklers. There is also a growing preference for portable, overhead sprinkler irrigation in Southern and Western States, wherever this method can be used. Overhead irrigation of several kinds may be used effectively on potatoes, but all are the portable type, except on some farms where permanent header pipes are installed beside each field. Water is generally pumped from wells, streams, and ponds and supplied directly to the system at pressures required to operate the different types of sprinklers used.

With potatoes, the type of overhead irrigation installed is not nearly so important as the manner in which it is used. To obtain maximum benefits, exacting decisions must be made as to the amount of water to apply and the time to apply it. These decisions and the results obtained are influenced to a great extent by the amount and distribution of rainfall each season. With very little to guide him but experience, the potato grower must regulate the amount and timing of supplementary water applied to meet the exacting requirements of potatoes for uniform but not excessive moisture during the growing season. If potatoes are irrigated after the soil moisture has fallen below 50 or 60 percent of the soil water-holding capacity, there is generally a risk of causing second growth in the tubers. Conversely, soil moisture in excess of optimum is liable to reduce both yield and quality of the crop. Although scientific facts underlie much of the available information on overhead irrigation of potatoes, successful operation still remains as much an art as a science.

The cost of overhead irrigation equipment and its seasonal operation varies between farms, but these financial considerations and other incidental expenses determine the increase in yield required, at current potato prices, before the investment can be justified. Average increases of from 45 to 85 bushels per acre have been reported from overhead irrigation over an 8-year period, and this would seem an adequate return from a nominal investment. When used properly to supplement natural rainfall, overhead irrigation can be a profitable investment for any potato grower with a suitable source of water on his farm.

Overhead irrigation results in greater incidence of foliar diseases than does furrow irrigation. Spores of disease organisms causing such diseases as early and late blight are rapidly disseminated by splashing droplets of water. In addition, the wet leaf surfaces provide ideal conditions for primary and secondary infection, conditions not usually found in furrow irrigation. The widespread use of overhead irrigation in the Northwest, therefore, creates conditions for potential losses by leaf diseases which in the past have been almost nonexistent in the irrigated areas of the West.

Hail Injury

Hailstorms during the growing season may seriously damage potato plants (fig. 30). A fall of hail, generally accompanied by wind and heavy rain, often defoliates the plants and breaks their stems. Potato plants badly injured by hail may still produce a good yield if sufficient time remains during the growing season and conditions are favorable for recovery of vine growth and tuber development. Stem wounds caused by hail heal quickly, and stems that have been beaten to the ground gradually become erect and develop new branches and leaves. Healthy, vigorous plants with well-developed root systems have a much better chance to recover than weak or diseased ones. Plants that are destroyed down to ground level have little chance to recover; generally their underground stems rot and further growth is impossible. Hail-damaged potatoes are readily susceptible to infection by a few disease organisms that normally are not serious on potato vines.

When plants have been injured by hail but not completely destroyed, it is advisable to put the soil in good physical condition immediately, if this can be done without further injuring the plants. Other cultivation should be delayed until the plants become more erect. After that, regular cultural practices should be followed.

Plants that are badly injured by hail after the tubers have formed must develop new tops before the tubers can make any further growth. If the tubers are only partly developed at the time of injury, they may mature without growing any larger, or may develop knobs known as second growth (discussed later), or they may send out sprouts or stolons. Generally, the best potatoes produced by hail-injured plants come from small

FIGURE 30.—Hail injury to a field of potatoes.

tubers that normaly would not develop. An early crop has a better chance of good recovery after hail injury than a late one; the late one may not have sufficient time to develop fully before frost. If hail injury occurs near the normal harvest period, the crop usually should be harvested early.

Spraying and Dusting

To control insect pests and leaf diseases such as late blight and early blight, spray or dust the plants with insecticides and fungicides, or a combination of both. Good control of insects can be obtained with either a dust or a spray, if properly applied; however, a spray is much more effective for controlling late blight.

Sprays tend to drift less than dusts and may be applied more satisfactorily on windy days. With a well-adjusted spray boom, adequate spray coverage can be obtained in winds up to 7 or 8 miles per hour.

Dusts are sometimes preferred where the water supply for sprays is not convenient. Dusting equipment is also light in weight and causes little compaction of the soil. When the wind velocity exceeds 3 miles per hour, the drift of dusts can be reduced by attaching to the duster boom a trailing apron 8 to 15 feet long made of 9-ounce cotton ducking. With the duster moving 3 to 4 miles per hour, the dust is confined long enough to allow good foliage coverage, even in winds up to 7 or 8 miles per hour. The apron will remain spread out over the plants if its outer rim is weighted with a rope. Dust coverage is also affected by the velocity of the dust leaving the nozzle orifice, the wind velocity of the air around the plants, and whether there is a brief period when the expelled dust is confined around the plants. With most row-crop dusters, at least two nozzles per row are needed, preferably three: one on each side of the row and one above.

With both sprays and dusts, adequate coverage of the foliage is necessary for good insect or disease control. For most insects this means covering both the upper and lower surfaces of the leaves.

Thoroughness of spray coverage depends largely on the number, kind, and placement of the nozzles, the speed the sprayer travels, and the pressure. The sprayer should be equipped with three or four nozzles per row, preferably the hollow- or solid-cone type rather than the flat, fan-type nozzle. Two nozzles should be placed on drop pipes, or on trailing arms that regulate their position with one nozzle on each side of the row between the plants. Both of these nozzles should be directed slightly forward so as to cover foliage of the lower half of the plants. Direct one or two of the upper nozzles downward and slightly forward to spray the upper half of the plants. If there are two upper nozzles, place one on each side of the row. To get best spray coverage, raise the spray boom to increase the height of the nozzles as the plants grow. When the boom is raised, it may be necessary to substitute longer drop pipes.

The amount of spray or dust for adequate coverage increases as the plants grow. Some pesticide can be saved if the application rate is low at first and then increased as the plants become larger. However, any saving may be offset by the time required to make the necessary adjustments. Instead of adjusting the rate of application as the plants grow, most growers prefer to use the same rate required for large plants all season. With ground equipment, use 25 to 35 pounds of dust per acre; or if spraying, use 75 to 150 gallons at 200 to 400 pounds' pressure per square inch, or 20 to 40 gallons at 40 to 60 pounds' pressure. With aircraft, by using nozzles with a small orifice and 50 to 100 pounds' pressure, 20 to 40 gallons per acre may be applied. With aircraft, use 35 pounds of dust or 5 to 8 gallons of spray per acre early in the season and 9 to 12 gallons during the latter part. Thorough coverage with insecticides or fungicides by aircraft is difficult.

Carefully adjust the machinery to deliver the proper amount of spray or dust, and check adjustment each time before use to insure proper application rates throughout the season. Also check, clean, and adjust the nozzles frequently. Make necessary corrections or replacements as soon as you detect any malfunctioning of the equipment.

Use prepared spray concentrates or dust mixtures of fungicides and insecticides in preference to home mixes because of safety factors. Reliable commercial formulators usually furnish a finished product of uniform quality that costs less than a home mix. **Be Sure You Fully Understand the Manufacturer's Directions for Use. They Are Usually Printed on the Label of the Container.**

The proportion of active ingredient in stock materials is shown on the container label as the percentage of total weight, but the active ingredient in emulsifiable concentrates is generally stated as pounds per gallon. Use this information to determine the proper amount of active ingredient needed per acre. To prepare a spray, fill the spray tank with a measured amount of water and add to it the amount of emulsion concentrate or wettable powder required to supply the desired concentration of active ingredient. Thoroughly mix. Apply the finished spray at a rate sufficient to supply the amount of active ingredient recommended per acre. The active ingredient content of dusts and granules is also used in computing application rates per acre.

Properly timed applications of sprays and dusts not only increase their efficiency against pests but also save time, effort, and money. For best control of insects and diseases, start applications each year before damage occurs. Start applying fungicide to control late blight when the plants are 4 to 6 inches high. For greatest protection against aphids and flea beetles, start insecticide applications when about one-fourth of the stand of potato plants has emerged. Until danger of late blight has passed, fungicide should be applied weekly to protect the new growth and to renew the fungicide on the old growth. Most of the newer organic fungicides for late blight should be applied about every 5 days during an epidemic, or when the weather is favorable for an outbreak of the disease. For specific advice about disease and insect control, consult your agricultural extension specialist, county agent, or other local agricultural authority.

How often to apply insecticides for best insect control depends on the degree of control needed and also on the number of pests remaining on the plants after each application. Since relatively little additional cost is involved, some growers, to be safe, include an insecticide with each weekly application of fungicide. Outbreaks of many insect pests are difficult to forecast, so it will pay to examine carefully the leaves and tops of the plants in your potato fields for insect buildup. Be prepared to apply insecticide at the first sign of damaging numbers of the insects on the plants.

A convenient reference list on potato diseases, their occurrence and control, is given in table 12. Insect control information is available in USDA Agriculture Handbook 264, "Potato Insects." Market diseases of potatoes are described in USDA Miscellaneous Publication 98, "Market Diseases of Fruits and Vegetables: Potatoes."

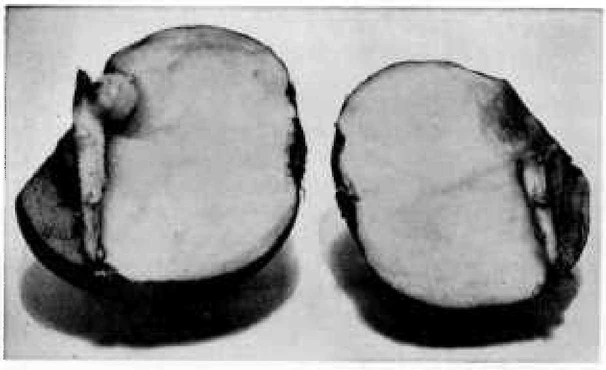

FIGURE 31.—Potato tuber cut in half showing internal sprouting, a physiological abnormality. In this unusual case the sprout has tuberized.

TABLE 12.—*Reference table of some potato diseases*

Name	Causal organism	Part of plant affected	Mode of transmission	Seasonal carryover	Control
Bacterial brown rot.	Bacterium (*Pseudomonas solanacearum*).	Tubers and soil.	Soil	Soil	Avoid infested fields; use resistant varieties (Sebago, Katahdin).
Bacterial soft rot	Bacterium (*Erwinia carotovora*).	Tubers	Soil and contact.	do	Allow tubers to suberize after harvest; do not wash tubers, or dry 4 minutes at 150° F. after washing.
Bacterial tuber rot	Bacteria and fungi	do	Soil and wash water.	do	Same as for bacterial soft rot.
Blackheart	Physiologic	do	None	None	Store at temperatures below 70° F. with proper ventilation.
Blackleg	Bacterium (*Erwinia phytophthora*).	Tubers and foliage.	Soil, seed, and seed-corn maggot.	Soil, seed, and seed-corn maggot.	Use disease-free seed; prevent wounding in tillage; control seed-corn maggot; rotate crops; suberize seed pieces.
Calico	Virus (alfalfa mosaic).	Vines and tubers.	Aphids and seeds.	Seed and other crops.	Eliminate "volunteer" alfalfa plants; use disease-free seed; control aphids.
Corky ring spot	Virus (tobacco rattle).	Tubers	Nematodes	Soil	Avoid infested fields; use resistant varieties; control nematodes.
Curly top	Virus (beet curly top).	Vines	Insects (beet leafhopper).	Weed hosts	Avoid beet leafhopper areas; use disease-free seed; control leafhoppers.
Dry rot	Fungus (*Fusarium* spp.).	Tubers	Soil	Soil	Prevent wounding at harvest; allow tubers to suberize and then store at 40° to 50° F.
Early blight	Fungus (*Alternaria solani*).	Vines and tubers.	Air	Soil; plant debris.	Spray with organic dithiocarbamate fungicides or bordeaux mixture; practice crop rotation and sanitation.
Enlarged lenticel	Physiologic	Tubers	Not transmitted.	None	Promote soil aeration and drainage.
Fusarium wilt	Fungus (*Fusarium solani* var. *eumartii* and *F. oxysporum*).	Vines and tubers.	Soil and seed	Soil and seed	Avoid infested fields; use disease-free seed; practice crop rotation.
Growth cracks	Physiologic	Tubers	Not transmitted.	None	Use resistant varieties; keep soil moisture optimum and uniform.
Haywire	See purple-top wilt	Vines	Insects and seed.	Weed hosts and seed.	
Heat necrosis	Physiologic				Use resistant varieties; provide adequate moisture; harvest early.
Heat sprout	Genetic and physiologic.	Tubers	Not transmitted.	None	Use resistant varieties.
Hollow heart	do	do	do	do	Space plants closer in rows; use resistant varieties.
Internal black spot	Physiologic	do	Not known	Not known	Reduce harvest and grading bruises; prevent potassium deficiency; keep soil moist prior to harvest.
Internal brown spot.	do	do	Not transmitted.	None	Use nonsusceptible varieties; provide adequate soil moisture.

TABLE 12.—*Reference table of some potato diseases*—Continued

Name	Causal organism	Part of plant affected	Mode of transmission	Seasonal carryover	Control
Internal sprouting	Physiologic	Tubers	Not transmitted.	None	Do not store at high temperatures. Probably caused by interaction of various storage conditions (fig. 31).
Jelly-end rot	Fungus (*Fusarium* spp.).	Tubers (especially long ones).	Soil	Soil	Provide uniform and adequate soil moisture continuously through season from 30–40 days after planting.
Late blight	Fungus (*Phytophthora infestans*).	Vines and tubers.	Air and seed	Seed; cull piles.	Use resistant varieties; spray with dithiocarbamate fungicides or bordeaux mixture; spray cull piles with herbicides or eliminate entirely; kill potato foliage 10 days to 2 weeks before digging.
Latent mosaic	Virus (potato virus X).	Vines	Mechanical	Seed	Use resistant varieties or disease-free seed.
Leaf roll	Virus (potato leaf roll).	Vines and tubers.	Aphids and seed.	Seed (minor weed hosts).	Use disease-free seed; control aphids; use resistant varieties; rogue diseased plants; isolate from other potatoes; market potatoes early.
Leak	Fungus (*Pythium debaryanum*).	Tubers	Soil	Soil	Prevent harvest injury; cool tubers to 40°–45° F. after harvest.
Mahogany browning.	Physiologic	do	Not transmitted.	None	Use resistant varieties; store at 40° F. or above.
Mild mosaic	Virus (potato virus A + X).	Vines and tubers.	Aphid and seed.	Seed	Use disease-free seed or immune varieties; control aphids; rogue diseased plants early.
Nematode (eelworm) diseases.	Nematodes: Golden (*Heterodera rostochiensis*).	Roots	Soil and tubers.	Soil, seed, and equipment.	Fumigate soil with nematocides; rotate crops or fallow fields; prevent movement of material from infested fields; use nematode-free seed; use resistant varieties. For golden nematodes, observe quarantine regulations.
	Potato tuber rot (*Ditylenchus destructor*).	Tubers	Drainage water.		
	Root knot (*Meloidogyne* spp.).	Tubers and roots.			
	Root lesion, or meadow (*Pratylenchus* spp.).	Tubers			
Net necrosis	See leaf roll	do	Not known	Seed and culture.	
Psyllid yellows	Insect (*Paratrioza cockerelli*).	Vines and tubers.	Insect (Psyllids).	Seed and weed hosts.	Control psyllids.
Purple-top wilt (haywire).	Virus (aster yellows)	do	Insects (leafhoppers).	Crop and weed hosts.	Control leafhoppers; rotate susceptible perennial crops.
Rhizoctonia	Fungus (*Rhizoctonia solani*).	Stems and tubers.	Soil	Soil and seed	Disinfect seed tubers; avoid planting in cold soils; rotate crops; use disease-free seed.
Ring rot	Bacterium (*Corynebacterium sepedonicum*).	Vines and tubers.	Mechanical	Seed and storage.	Plant disease-free seed; use whole seed or disinfect cut seed pieces; disinfect storages and equipment; use resistant varieties.

TABLE 12.—*Reference table of some potato diseases*—Continued

Name	Causal organism	Part of plant affected	Mode of transmission	Seasonal carryover	Control
Rugose mosaic	Virus (potato virus Y+X).	Vines	Aphids and seed	Seed (minor weed hosts).	Plant disease-free seed; control aphids; use resistant varieties; rogue diseased plants early.
Scab, common	Fungus (*Streptomyces scabies*).	Tubers	Soil	Soil and seed	Avoid infested fields; use resistant varieties; rotate crops; disinfect seed; acidify soil or treat with soil fungicide (pentachloronitrobenzene).
Scab, powdery	Fungus (*Spongospora subterranea*).	do	do	do	Avoid infested fields; use disease-free seed; rotate crops; plant where average soil temperature exceeds 57° F.
Second growth	Genetic and physiologic.	do	Not transmitted.	None	Provide adequate and uniform soil moisture; use resistant varieties.
Silver scurf	Fungus (*Spondylocladium atrovirens*).	do	Soil	Soil and seed	Use disease-free seed; practice crop rotation; store at 40° F.
Southern blight	Fungus (*Sclerotium rolfsii*).	Vines and tubers.	do	Soil	Avoid infested fields; treat soil with pentachloronitrobenzene; practice deep plowing where feasible; use disease-free seed.
Spindle tuber	Virus (potato spindle tuber).	do	Seed and mechanical.	Seed	Use disease-free seed; reduce machinery use in fields after plants emerge.
Spindling sprout	See purple-top and leaf roll.	Tubers	Seed	Probably aphids.	
Stem-end browning.	Unknown	do	Not transmitted.	None	Use resistant varieties; store at normal cool storage temperatures.
Verticillium wilt	Fungus (*Verticillium albo-atrum*).	Vines and tubers.	Soil and drainage water.	Soil and seed.	Fumigate infested soil; use resistant varieties; practice long rotations; plant disease-free seed.
Wart	Fungus (*Synchytrium endobioticum*).	Tubers	Soil	Soil	Do *not* plant in infested fields; areas known to have been infested in Maryland, Pennsylvania, and West Virginia are under strict quarantine. Resistant varieties are available.
Yellow dwarf	Virus (potato yellow dwarf).	Vines and tubers.	Seed, leafhoppers, and mechanical.	Seed and clovers.	Use disease-free seed; control leafhoppers; rotate clover fields.

Weed Control[1]

If good cultural practices are followed in growing potatoes, weeds are not often a serious problem. Use of a weeder when the crop is first emerging controls most early-season weeds; the usual cultivations along with the shading provided by the vines normally control weeds later in the season. Weeds that emerge following the last cultivation are a serious problem in some areas of production because they reduce the efficiency of mechanical harvesting.

Perennial grasses and sedges including bermudagrass, nutgrass, and quackgrass cannot be completely controlled by cultivations (fig. 32). They compete with the potato crop for nutrients, moisture, and light. They also cause severe quality losses by rhizome and root penetration of the potato tubers. Some perennial grasses and sedge

[1] Prepared in cooperation with Dr. L. L. Danielson, Crops Protection Research Branch, Crops Research Division, Agricultural Research Service.

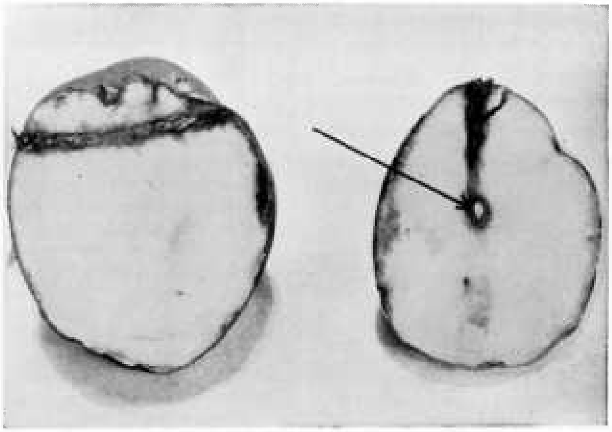

FIGURE 32.—Potato tubers damaged by nutgrass. Nutgrass is the most serious weed in some potato areas, especially along the Eastern seaboard. Nutgrass is very difficult to control and persists in the soil for long periods. The arrow points to a "nut" imbedded in the tuber at the right.

can be controlled by applying herbicides to the soil before planting or during the early stages of growth.

Directions for safe use of herbicides are given on the manufacturer's label and should be carefully read and followed. These directions give the correct time, rate, and method of application, crops on which use is approved, and precautions for the user. When in doubt about correct use, consult your State experiment station weed control specialist.

A number of early-season annual weeds can be controlled by herbicides applied immediately after planting and before the potatoes come up. Where late-season annual weeds are a problem, herbicides may be applied immediately after the last cultivation to prevent further germination of weed seeds.

Herbicides for use on potatoes are given in table 13. The choice of herbicide depends on the weeds to be controlled and the specific recommendations of the local State experiment station.

TABLE 13.—*Herbicides for potatoes*

Common name [1]	Chemical name	Time and method of application	Type of weed	Growth stage of weed
DATC, CP15336	2,3-dichloroallyl diisopropylthiolcarbamate.	Preplanting soil incorporation.	Wild oats	Germination.
CDAA	2-chloro-*N,N*-diallylacetamide.	Immediately after lay-by.	Annual broadleaved weeds and weed grasses.	Do.
Dalapon	2,2-dichloropropionic acid	Preplanting, lay-by	Annual and perennial weed grasses.	Active growth only.
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea.	Preemergence	Annuals broadleaved weeds and weed grasses.	Germination and young seedlings.
DNBP	4,6-dinitro-*o-sec*-butylphenol.	do	do	Germination.
EPTC	Ethyl *N,N-di-n*-propylthiolcarbamate.	Preplanting soil incorporation, lay-by soil incorporation.	Annual broadleaved weeds and annual and perennial weed grasses.	Seed germination and rhizome sprouting.
PCP	Pentachlorophenol	Preemergence	Annuals broadleaved weeds and weed grasses.	Germination and seedling stage.
Petroleum solvent		do	do	Young emerged seedlings.
Sesone	Sodium 2,4-dichlorophenoxyethyl sulfate.	Preemergence, lay-by	do	Germination.
2,4-D	2,4-dichlorophenoxyacetic acid.	Preemergence	Annual broadleaved weeds.	Young emerged seedlings.
2,4-DEP	tris-(2,4-dichlorophenoxyethyl) phosphite.	Lay-by	do	Germination.

[1] Taken from Nomenclature of Committee Report of the Weed Society of America, 1962.

HARVESTING THE CROP

Vine Killing

Now that insecticides are widely used to control insects and better and less toxic fungicides are used to control blights of the potato, the leaf injury formerly caused by insects and fungus diseases is reduced to a minimum. Under these conditions, maturity of the vines is delayed and unless the green plants are killed by early frosts, it becomes necessary to destroy the vines by other means in order to harvest the crop. This can be done by mechanical or chemical means or by a combination of the two methods. Machines such as beaters with rubber flails or chains are extensively used and do a good job of destroying the vines, but they cover only two rows at a time and are relatively expensive (fig. 33). Certain chemical sprays such as dinitro compounds and arsenites can be applied with regular 4- to 12-row spray equipment, preferably fitted with fan-type nozzles. A good vine kill can be obtained with chemicals in 4 to 10 days, depending on the weather after application. If the vines are infected with late blight, spraying with a contact chemical vine killer is preferable, especially if the crop is to be stored, because these chemicals lessen the danger of late blight tuber rot. For mechanical harvesting operations, vines are often cut even after they have been killed by frosts or chemicals (fig. 34.).

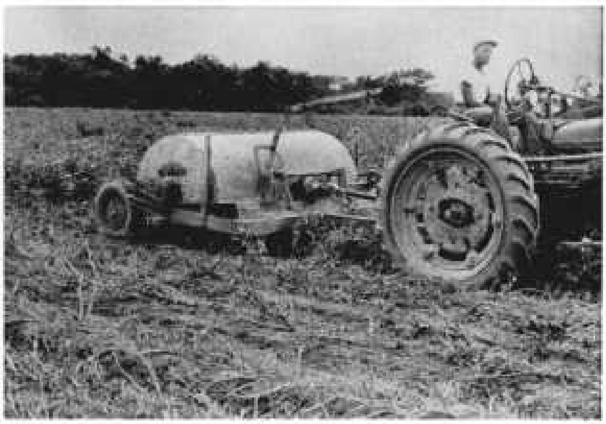

FIGURE 33.—One type of beater used for destroying potato vines.

FIGURE 34.—Vine cutter in operation after vines have died. Vine cutting is essential in mechanized harvesting.

Certain dusts, including anhydrous copper sulfate and calcium cyanamide, have been used to a limited extent as vine killers, but they are usually slower acting and less effective than sprays and mechanical methods. Although all methods of vine killing at times tend to produce a definite type of flesh discoloration in the tuber, this trouble has so far had little retarding effect on the growing use of vine-killing methods on late potatoes. Vine killing is regarded favorably by many growers, because it gives them a means of artificially hastening the maturity of their crop whenever, for any reason, they decide to dig it

Season of Harvest

The proper time for harvesting potatoes is determined chiefly by the maturity of the crop. Actually, the decision as to when to dig is often influenced by such considerations as market prospects, availability of help, and weather. The principal reason for waiting until the crop is fully matured before digging is that the skin of the tubers "sets" after the vines die and then there is less likelihood of skinning and bruising. Even when digging a mature crop, however, precautions should be taken to avoid skinning and bruising by padding the rough places on the digger and by handling the harvested potatoes carefully. If late potatoes are dug while the vines are green, besides the chances of skinning and bruising, there is danger of transferring spores of the late blight fungus from the vines to the tubers where they can later produce rot in storage. In the production of certified seed potatoes, however, early harvesting has been found desirable in order to avoid current-season infection with the virus disease leaf roll, which is transmitted by certain insects. In general, early harvesting reduces the yield, but this loss may often be offset by other advantages—disease-free seed and desirable tuber size.

The usual harvesting seasons are as follows: Winter, January through March; early spring, April through the first half of May; late spring, second half of May and June; early summer, June through first half of August; late summer, second half of August and September; fall, October through December. The beginning and end of these harvesting seasons are not fixed dates but approximations, and overlapping occurs. Generally, the marketing season follows close to the harvesting season, except for the fall crop where marketing from storage extends into the first 6 months of the following year.

Harvesting Machinery

The crop is harvested with a wide variety of equipment and methods in different parts of the country. The type of equipment and predominant harvesting methods vary greatly with the size of individual operation, local topography, soil and field characteristics, labor supply, and market disposition of the crop. Harvesting equipment used by small operators generally consists of one-row or two-row elevator-type diggers and flat-rack trucks for hauling the potatoes in bags, barrels, boxes, or crates filled by handpickers following the digger.

The digger aprons are usually driven from the power-takeoff of the tractor, sometimes through a three-speed transmission used to change the speed of the apron relative to digger speed whenever the operation of the tractor is adjusted for different field conditions. Potato diggers powered independently by 1-, 2-, and 4-cylinder engines equipped with a clutch and sometimes a 3-speed gear set are common in some areas. Certain advantages are obtained through independent control of tractor speed and digger-apron speed whenever digging conditions vary considerably.

When properly operated, the digger should convey enough soil to cushion the potatoes against bruising for three-fourths or more of the digger apron. If the digger apron does not retain sufficient soil because it is sandy or too dry, change the agitator sprockets to reduce agitation or substitute idler rollers and reduce apron speed. When the soil is very dry, irrigating the field several days in advance of digging usually provides a satisfactory soil cushion on the apron and makes digging easier and faster.

During the last decade great interest has been shown in the design and construction of various types of potato harvesters. Potato growers themselves have devised and built many of these machines. Mechanical harvesters are now being used to harvest 80 to 95 percent of the crop in some of the important producing areas where conditions are favorable for their use. The machines represent a great variety of designs, special features, optional accessories, and specifications, all of which are rapidly evolving and changing from year to year.

A few have ingenious devices for removing potato vines and stones. Some harvesters consist of supplementary equipment that attaches to conventional diggers; some are more elaborate self-propelled outfits that permit workers on the machine to grade and bag the potatoes; and other machines deliver the potatoes in bulk into a truck. Potato harvesters are coming into wider use in sections where there are few stones and long level fields.

Various types of bag loaders also have been devised. Some are used for loading in the field and may also be used in the storage house.

All these laborsaving devices have reduced tremendously the extremely heavy work and the time formerly required to harvest potatoes.

Avoiding Mechanical Bruises at Harvest

Methods of handling potatoes after they have been dug vary with the locality. In Maine, the tubers are picked up in baskets, from which they are poured into barrels and hauled to the storage house where they are stored in bulk, the empty barrels being returned to the field. In many sections of the Northeast the potatoes are picked up in slatted crates, hauled to the storage house, and either stored in the crates or stored loose in bins. On Long Island, N.Y., and in New Jersey the potatoes are hauled to the storage house or grading shed in burlap bags, except those that are loaded in bulk from a harvester. Handling potatoes in crates, however, is perhaps the most widespread method in the South and Northeast, and to a lesser extent in the North Central States. Potatoes in crates are usually bruised less than those in bags or barrels. Careful handling of the tubers at harvest can pay big dividends when the crop is sold.

Mechanical harvesting and bulk handling are preferred practices in most of the western production areas, as well as on the larger potato farms throughout the rest of the country.

In the mechanical harvesting of potatoes, great care must be taken to avoid excessive bruising and injury. Special attention should be given to provide proper adjustments of all conveyors and drops. Bruises are not always noticeable at harvest, but may show up after storage and result in heavy losses by lowering the grade and increasing the number of culls. Considerable knowledge and practical experience plus constant alertness and skill are required to operate any machine properly so as to obtain the best possible performance with minimum damage to the crop. Mechanical harvest injuries result in millions of dollars in losses annually to potato growers. For a full discussion, see USDA Agriculture Handbook 171, "Increasing Potato-Harvester Efficiency."

A few simple rules will go far in reducing mechanical injury. Set rotobeaters so that flails just clear the ground; set digger points deep enough to carry soil three-quarters of the length of the digger chain; and maintain a digger groundspeed of 100 to 125 feet per minute. The digger belt should operate at about this same speed, with the agitators set so the tubers do not bounce. Chain agitation should be slowed to a minimum consistent with good separation of tubers from soil and trash. A tight digger chain causes less bruising by whipping than a loose one. Use padded deflectors and, when feasible, rubber-covered chain links. Avoid dropping the potatoes more than 5 to 6 inches.

Washing

Washing potatoes before shipping them is widely practiced in most important potato-producing areas. Washing improves the appearance of the tubers and makes grading easier.

In the past it was customary to run the potatoes through a soaking tank and then through a rinsing spray. Such washing generally left a considerable percentage of the tubers infected with a soft rot organism introduced into the tank water by infested soil clinging to tubers. The potatoes were readily infected through bruises in their skin. Spraying jets have now largely replaced the soaking tank, and this change has greatly reduced rot infection. Some rot still occurs, however, since the washing does not remove all soil particles infected with rot organisms.

From the washer, the potatoes are carried on a conveyor-belt system to a grader and then past manual sorters, who remove all decayed or otherwise undesirable tubers.

Although the potatoes are not dry when packed, they generally arrive at market in excellent condition, provided they were washed and loaded when the relative humidity of the air was low. It is unsafe to ship washed potatoes immediately, without drying them, if the relative humidity of the air is above 70 percent. If shipped under these conditions, the potatoes are liable to decay badly before they reach their destination.

Dry Cooling

Dehydrocooling, a treatment which withdraws moisture from the air and rapidly moves cold, dry air through the load, has proved fairly effective in preventing washed potatoes from decaying in transit. The benefits are probably due more to the drying than to cooling.

Drying potatoes with air from a large electric fan definitely reduces soft rot, but the rapidity and thoroughness of fan drying are limited by such factors as air temperature, relative humidity, and size of tubers.

Commercial hot-air potato driers are used to dry large quantities of potatoes after washing. Heating the air increases its capacity to absorb and hold moisture. Potatoes are not damaged when dried for 4 minutes in air heated to 150° F., and bacterial soft rot is less likely to develop.

Most commercial potato driers are insulated chambers heated by a forced blast of hot air through which the potatoes move slowly. Speed of travel is adjusted to allow the potatoes about 4 minutes in the drier. Air temperature inside the drier may also be adjusted to suit variations in air relative humidity. When the drier is properly adjusted, the temperature of the tubers is increased only slightly because of the cooling effect of evaporation.

STORING THE CROP[2]

Practically all the fall crop potatoes that are stored on farms are produced in the northern half of the United States. Possibly 75 percent of this crop is stored in farm and commercial warehouses.

Potato storage designs have been changed in the past few years to take advantage of modern bulk handling methods. Potatoes are still handled in barrels in Maine, but in some areas most of the potatoes are handled in bulk trucks (fig. 35). Bulk trucks are unloaded over mesh belts and the potatoes are conveyed down into storage bins, often with less than ½ of 1 percent of injury. As the draper chain conveyor in the truck unloads the potatoes, it sifts out small clods and soil. In addition, vines and trash are removed manually as the potatoes are carried into the bin over mesh or draper chain conveyor belts, which also sift out small clods and soil.

The type of farm storage used in Maine (fig. 36) is often filled 12 to 14 feet deep. This can be done without danger from heat damage because of the cool weather at harvesttime and the average annual soil temperature of approximately 40° F. The Idaho type of storage (fig. 38) may be filled only to a depth of 8 to 10 feet because the temperatures at harvesttime and the soil temperatures are higher. More effective ventilation may be required with deep storage to keep the potatoes

FIGURE 35.—A mechanized potato-harvesting operation.

[2] This section was prepared by A. D. Edgar, agricultural engineer; Herbert Findlen, horticulturist; and P. H. Heinze, plant physiologist, Agricultural Marketing Service, U.S. Department of Agriculture.

FIGURE 36.—Deep-bin storage in Maine. Potatoes are unloaded from barrels or from bulk trucks (fig. 37) standing in the upper drive alley. Potatoes may be removed from storage through the lower cross-alley.

FIGURE 37.—Trash and clods being removed from the mesh conveyor belt. Soil sifts through, as potatoes are conveyed from bulk trucks into the deep bins (fig. 36) or conveyed into truck-level bins (fig. 38).

below sprouting temperatures. The earth-covered storage (fig. 38) is practical only in the semiarid sections of the West; the insulated roof storage (fig. 36) is adapted to more humid sections. Windows are not recommended in potato storages, because sunlight and artificial light cause greening of the potatoes. All lights should be used sparingly. (See "Tuber Greening," p. 55.)

As potato storages have increased in size, forced-air circulation and ventilation have become a necessity; and with electricity and air-moving equipment now available, forced-air systems are now practical.

In the cooler part of the fall crop area, forced shell circulation is adequate for table- and seed-stock storage. Shell circulation may be described as perimeter air distribution with wall airspaces that lead air up from the wall-floor ducts between the insulation and adjoining potatoes. From the top of the wall airspace, the air returns over the bins of potatoes to the control center. At the control center, dampers route the air either to be recirculated by fan or to be exhausted, as more air is drawn into the distribution system.

Forced-through circulation is required for the higher temperature storage of processing potatoes, and for large masses of table or seed stock in the warmer parts of the fall crop area. Forced-through circulation systems distribute air from the control center to bin-floor ducts. From these ducts, it is forced up through the bin between the potatoes to the airspace above. From above the bins, air returns to the control center as in the shell circulation systems.

Ventilation is required to remove potato heat in the fall, but little or no ventilation is required for this purpose in the winter. However, there is usually enough ventilation during the period of temperature regulation in the fall to remove excess water vapor and prevent condensation and dripping. Some ventilation is always needed in winter to remove the water vapor produced by the potatoes and to prevent ceiling condensation and dripping. Heat is sometimes required in extremely cold weather and in a partly filled storage in average winter weather. The more abovegrade wall and ceiling insulation used, the higher the storage humidity possible before it is limited, in cold weather, by condensation and dripping; and the higher the humidity, the lower the potato shrinkage. More ventilation is needed, therefore, in poorly insulated than in well-insulated storage to remove water vapor before it condenses and wets the potatoes. The amount of insulation needed varies with the ratio of exposed (abovegrade) wall and ceiling area to the usual amount of potatoes in storage during cold weather. A well-designed storage when full will have about 0.35 square foot of exposed wall and ceiling area per hundredweight of potatoes. If a storage is one-third full in cold weather, the ratio is equivalent to 3 times 0.35, or about 1 square foot per hundredweight. Usually a 6- to 8-inch mineral wool or fiber glass insulation is practical in colder climates, 4 inches in moderate climates, and less in warmer parts of the fall crop area. To be fully effective, the insulation should have a vapor barrier between it and the warm, relatively moist storage. A 4-mil polyethylene membrane, carefully lapped, and stapled between studding, rafters, or ceiling joists and inside storage sheathing, makes a good vapor barrier.

Potatoes when stored should be dry and reasonably free from soil. If excess soil accumulates in the bin, air circulation is impaired with the result that temperatures in some places in the storage may be high enough to cause sprouting and excessive decay, while in other places freezing damage may occur.

Ventilation should be regulated to hold the potatoes at about 50° to 60° F. and high relative

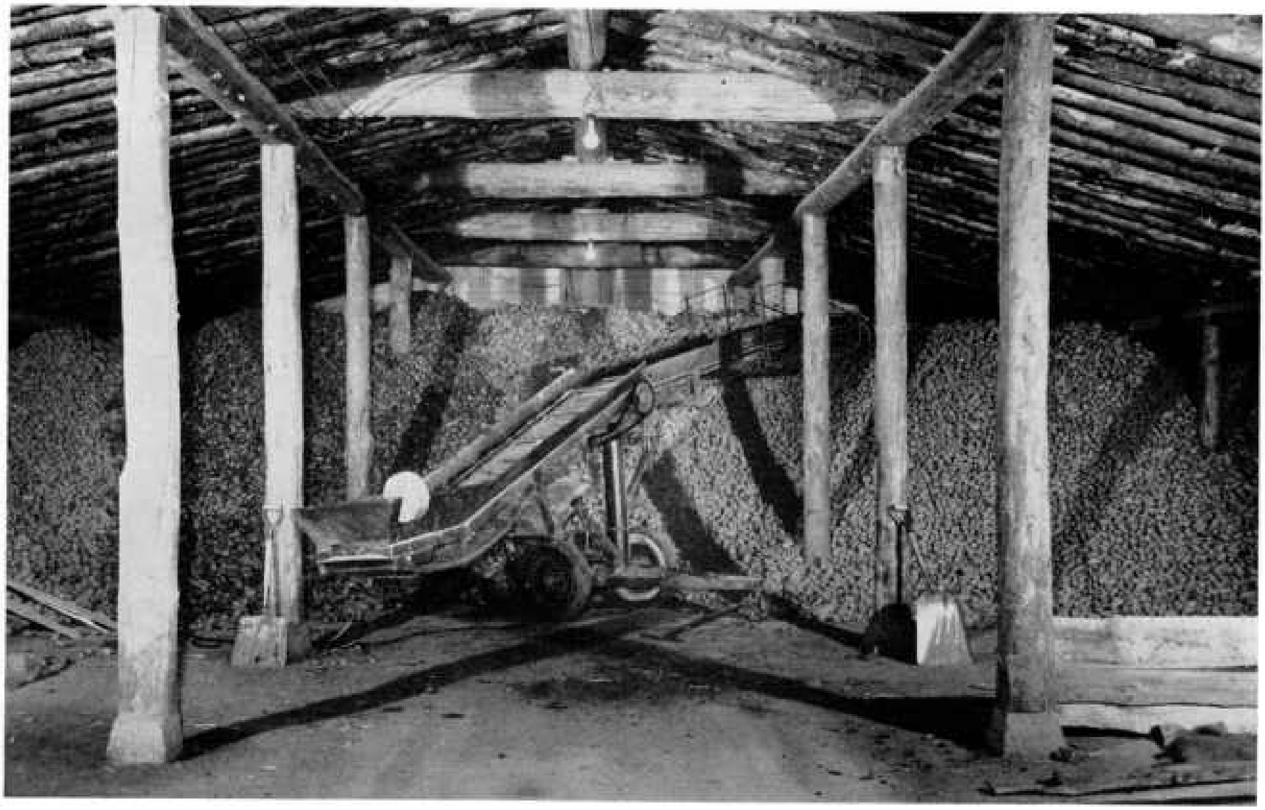

FIGURE 38.—Interior of earth-covered storage in Idaho.

humidity during the first 10 to 14 days. Under these conditions, cuts and bruises heal rapidly, and losses from shrinkage and decay are reduced. A low temperature at the beginning of the storage period is not necessary to prevent sprouting because the potatoes are then in a state of rest and are unable to sprout.

If field frost or late blight is present in the field, the temperature in the storage should be lowered to between 38° and 40° F. as soon as possible to retard decay. Lower humidity also is desirable under these conditions to dry the surface of potatoes and reduce the spread of decay.

After the preliminary curing period, temperatures may be lowered. It is desirable to store seed potatoes at 38° to 40° F., since at this temperature they will not sprout. The relative humidity should be maintained at 75 to 90 percent.

Potatoes stored at 50° to 60° F. have better cooking and processing qualities because they contain less sugar than those stored at lower temperatures. At 50° to 60°, however, sprouting will occur after about 2 to 3 months. Although limited sprouting does not affect potatoes for food purposes, badly sprouted stock shrinks and is difficult to market. Certain growth-regulating chemicals have been approved by the U.S. Food and Drug Administration to control or reduce sprouting on potatoes. One of these (maleic hydrazide) is applied on the plants in the field 2 to 3 weeks after full bloom. Others are occasionally applied as the potatoes are put into storage. More often the inhibitors are applied after a period in storage to avoid interference with wound healing or are applied as the potatoes are removed from storage to control sprouting during the marketing period. Do not use these chemicals on seed potatoes as they may retard or completely prevent sprouting. Before applying chemicals to stored potatoes, obtain specific instructions from your county agricultural agent on the proper way to use them.

Potatoes stored at 40° F. are acceptable for most purposes, but not for processing. Holding such potatoes at 60° to 70° for from 2 to 4 weeks before they are used usually improves their cooking and processing qualities. This change in storage permits some of the sweetness to disappear. High reducing sugar content of potatoes is the cause of undesirable dark-brown color of potato chips and french fries, and is responsible for the browning of dehydrated potatoes following processing.

Potatoes stored throughout the winter at temperatures of 38° to 40° F. should not shrink more than 5 percent. At higher temperatures, shinkage will be greater.

Before the potatoes are removed from storage, their temperature should be raised to about 50° F., if this can be done without raising the temperature of potatoes in adjoining bins. The higher temperature will reduce injury from bruises and internal black spot during grading and other handling.

Early-crop, or summer-harvested, potatoes usually are not stored or held except for relatively short periods. For table stock, however, early potatoes that are nearly free of disease and injury can be stored 4 to 5 months at 40° F. if they are cured 4 days or longer at 60° to 80° before storage. They can be stored about 2 months at 50° without curing. Careful handling to avoid injury and exposure to sun and heat during harvesting will help minimize losses caused by decay.

A considerable portion of the early crop is used for making chips. Holding these potatoes in cold storage, or even at moderate temperatures of 50° to 55° F., for only a few days causes an excessive accumulation of reducing sugars in the tubers, which results in the production of dark-colored chips. Subsequent holding of these potatoes at 70° or higher usually fails to lighten the color appreciably. Transit and storage temperatures near 70° are required to maintain chipping quality in early-crop potatoes.

GRADING AND MARKETING

It is distinctly to the advantage of the potato grower, and likewise anyone offering potatoes for sale to the consuming public, to see that the potatoes going on the market present a good appearance. This is good advertising for the potato industry. Potatoes having cuts, bruises, and insect or disease injuries neither sell well nor command a premium price. Such potatoes should be promptly diverted from market channels so that the consumer will not suffer undue loss in preparing them for the table. Potato growers everywhere must do everything possible to safeguard consumer goodwill and work continually to prevent the possible development of consumer prejudice against potatoes in general. Tubers of undesirable size or shape and with excess soil on them should also be culled out when preparing potatoes for market. Only in this way can the individual grower hope to build up a reputation for good table stock and, similarly, can any potato-producing region hope to establish a good reputation for its product.

The United States Standards for Potatoes, issued by the U.S. Department of Agriculture, fully describes officially designated potato grades and the tolerances for defects pertaining thereto, and presents a definition of terms used in the prescribed standards. Copies of the latest Standards may be obtained from the U.S. Department of Agriculture, Washington, D.C., 20250.

BREEDING IMPROVED POTATO VARIETIES

Old potato varieties are continually being replaced by new ones developed through breeding programs. The potato breeding program of the U.S. Department of Agriculture and cooperating State experiment stations has been highly effective in developing new, improved varieties of potato. Most of the varieties being grown commercially in this country today originated through this program. Only a few important varieties such as Irish Cobbler, Russet Burbank, White Rose, and Bliss Triumph were developed prior to the establishment of the potato breeding work in the Department of Agriculture.

The parts of the potato flower are large and it is a simple technique to remove the anthers and apply pollen for making controlled crosses. The steps are illustrated in figures 39 and 40.

Flower production and seed formation occur in the field or garden only when the plants have ideal growing conditions, with especially cool temperatures. Such ideal conditions are easily produced in the greenhouse in winter, especially in areas where the incident sunlight is high during the winter months.

Whenever cross-fertilization is successful, the ovaries develop within 10 days, and approximately 60 days later the potato fruit, resembling a small tomato, is mature (fig. 41). As the fruit matures, there is only a slight fading of the green color; the fully ripened fruits become light green to cream in color, depending on variety. Most seed balls contain from 100 to 300 mature seed (fig. 42). The seed, which resembles miniature tomato seed without fuzz, germinates erratically soon after

FIGURE 39.—Collecting pollen in a glass vial, using a mechanical vibrator to shake the pollen from the anthers.

maturity. After storage for a few months it will germinate and grow more readily. Each of the small seedling plants originating from the seed constitutes a potential new variety. Small tubers (fig. 42) form on the seedling plants and they can be harvested within 3 to 4 months, if growing temperatures are cool and light intensities are high. From these seedling tubers new potato varieties are produced. At the Plant Industry Station, Beltsville, Md., from 40,000 to 50,000 seedlings are grown each year. Comparable numbers are grown in the Federal program at Prosser, Wash., Baton Rouge, La., Greeley, Colo., and Aberdeen, Idaho, and in many State programs including Iowa, Michigan, Minnesota, Nebraska, New York, North Carolina, North Dakota, West Virginia, and Wisconsin.

The objectives of the National Potato Breeding Program are (1) high yields, (2) high quality for fresh and processing uses, and (3) high resistance to all important potato diseases and insects.

FIGURE 40.—Applying pollen to the receptive stigma of an emasculated bud.

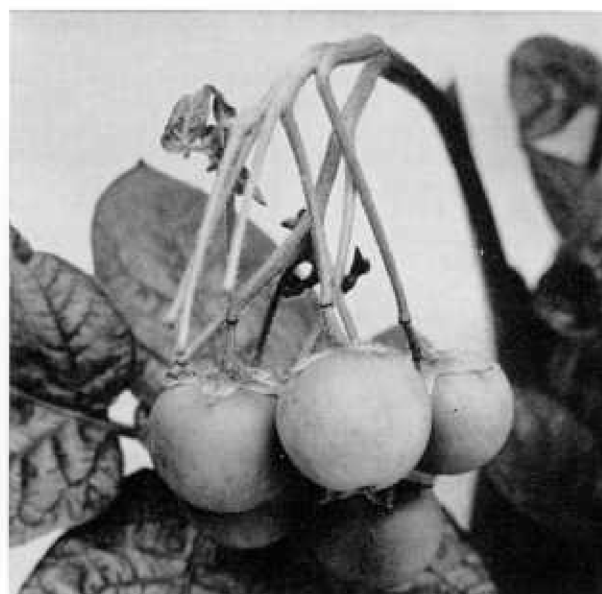

FIGURE 41.—Potato seed balls formed after successful fertilization. The seed balls resemble small green tomatoes, but do not change color appreciably on ripening.

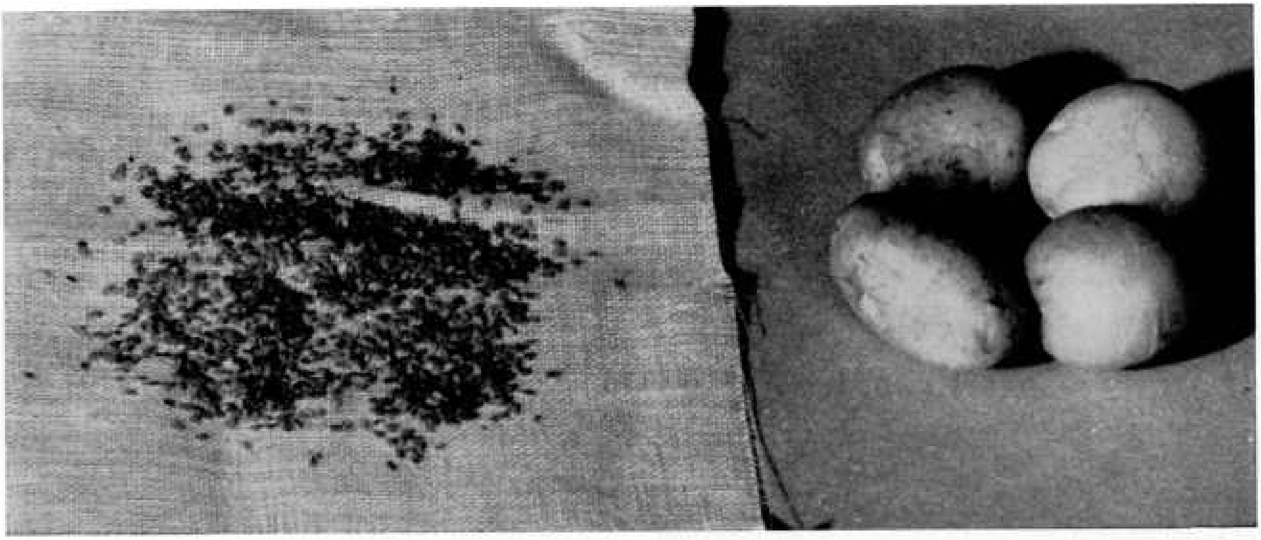

FIGURE 42.—True potato seed (left) and seedling tubers (right). (Natural size.)

POTATO QUALITY

Production Factors Affecting Solids and Mealiness of Potatoes

Occasionally one hears that potato quality is not as good today as it was in years past. However, before comparing the quality of present-day potato varieties with that of varieties grown years ago, one should be careful to define the qualities being compared. Although mealiness is often assumed to indicate good quality, it is not always the consumer's criterion of desirable quality in a potato. Quality in potatoes is usually referred to as a specific characteristic, but it is well established that desirable cooking quality can mean several things to several people. Because of this lack of agreement on the factors that make a potato good, it is difficult to decide which qualities, if any, need improvement before attempting to finds ways of improving them. In all fairness to growers, shippers, and retailers, it should be stated that the general appearance and, to a large degree, the cooking quality of potatoes being sold on many retail markets have markedly improved during the last decade. Much credit for this improvement is due the potato breeder who has been criticized in some quarters for selecting for shape, shallow eyes, and disease resistance at the expense of quality and flavor.

The task of improving cooking quality in potatoes is not an easy one. It takes 10 years or more of constant selecting and testing before a promising seedling can establish itself as superior to those already introduced. Furthermore, as one attempts to dissect the components of good culinary quality and palatability in potatoes in order to make selections, the problem appears to be a paradox. A rational approach to the problem inevitably leads to the conclusion that quality is the result of an equilibrium between a combination of factors and not one factor alone. If one factor is abnormal, it can have a controlling influence on the resulting quality of even the best variety available. Some of the factors known to influence potato quality are listed below:

(1) *Temperatures of soil or air.*—High temperatures exceeding 70° F. during the period of tuberization, especially toward the end of the season, lower potato quality.

(2) *Rainfall or moisture.*—In general, high levels of moisture at maturity and low levels earlier in the season lower quality. The relation of moisture levels to potato quality is not fully understood, but it is believed that high levels of irrigation on heavy soils tend to decrease total solids.

(3) *Soil type.*—In general, well-drained loam soils have produced crops with higher solids than heavy clay or poorly drained soils. In most cases total solids are higher in potatoes grown on mineral soils than on muck or peat soils.

(4) *Variety.*—Given identical environmental and cultural conditions, some varieties will consistently give higher solids than others. (See section under choice of varieties.)

(5) *Date of planting.*—Earlier planting of the crop at any given location will increase potato quality over that of later planting. Probably no other single cultural practice so greatly affects potato quality. Warming seed at 70° F. for 2 weeks just before planting will result in quicker emergence and early-season growth, factors contributing to higher solids and higher yields.

(6) *Date of harvest.*—As long as the vines are green, harvest should be delayed, if feasible, to lengthen the growing season. Early planting and late harvest provide a maximum growing season, one of the prime requisites for high quality.

(7) *Fertilization practices.*—Usually, high nitrogen and potash levels result in higher yields but lower total solids and quality than do moderate levels. Soils of low fertility will often yield small crops of high quality. Today's agricultural competition does not permit growers with low yields to remain in business.

(8) *Spraying practices.*—Control of insects and diseases by spraying with insecticides and fungicides undoubtedly increases yield. However, it is believed that *gradual* dying of the vines and slow "maturing" of the tubers in the fall from inadequate control of pests in former years resulted in higher potato quality. If this observation is correct, spraying practices used today may tend to lower potato quality by delaying maturity and making vine killing necessary. These relations are not well understood and need more research. In the meantime there is a growing tendency to discontinue some of the later sprays to allow earlier dying of the vines by natural means.

(9) *Vine killing.*—Vine killing has become necessary for most varieties because improved insect and disease control keeps the vines lush and green and the tubers immature up to harvesttime. Sudden killing of vines by any means (chemical or mechanical) obviously allows little time for normal maturity, and consequently potatoes harvested directly after the vines are killed are not of the highest quality. Growers, however, usually have little choice in this regard if they plan to complete harvest of large acreages on schedule, unless the vines are killed naturally by frost. For highest solids, slow-killing chemicals are preferable to fast-killing methods.

(10) *Day length.*—Maturity is hastened by short days and vine growth is encouraged by long days. This has been more fully discussed under climate. Full maturity gives higher quality.

(11) *Light intensity and temperature.*—Bright sunny weather late in the season, especially if accompanied by day temperatures below 70° and slightly cooler night temperatures, will result in higher solids and higher quality than continued cloudy weather.

(12) *Geographic location.*—Geographic location has a marked effect on potato quality. Certain areas have a combination of climatic conditions which especially favor high potato quality; for example, southeastern Idaho, the Red River Valley of North Dakota and Minnesota, and Aroostook County, Maine. Geographical location has more effect on total solids than does variety. The solids variation in nine potato varieties grown at four locations in Maine in 1952 is illustrated in table 14. Differences caused by location are higher for each variety than the greatest difference between varieties grown at one place. Ontario, the variety lowest in the test at Presque Isle, Maine, was higher in percent of solids when grown there than Green Mountain or any of the other varieties grown at Pittsfield or Exeter, Maine.

TABLE 14.—*Solids in 9 varieties of potatoes grown at 4 locations in Maine* [1]

Variety	Solids in potatoes grown at—				Greatest difference in solids
	Pittsfield (May 26–Sept. 25)	Exeter (May 27–Sept. 26)	Sherman (May 28–Sept. 29)	Presque Isle (May 6–Sept. 30)	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Irish Cobbler	16. 2	17. 7	19. 2	21. 9	5. 7
Green Mountain	15. 6	17. 4	19. 9	21. 8	6. 2
Katahdin	14. 5	16. 7	17. 7	19. 9	5. 4
Kennebec	14. 6	15. 7	18. 2	19. 9	5. 3
Cherokee	15. 0	17. 7	19. 4	21. 8	6. 8
Triumph	14. 4	16. 5	16. 2	20. 4	6. 0
Ontario	14. 0	14. 8	16. 7	18. 2	4. 2
Pungo	15. 0	16. 7	19. 9	20. 9	4. 9
Early Gem	14. 7	16. 5	16. 9	19. 9	5. 2
Greatest difference in solids	2. 2	2. 9	3. 7	3. 7	

[1] Locations represent different environmental conditions of potato-growing areas in Maine.

Determining Solids in Potatoes

Growers occasionally need to determine the solids content of their potatoes for special marketing purposes. But potato breeders usually have a special need for this kind of information in order to evaluate family lines segregating for solids content. The determination of solids by the laboratory method based on the loss of moisture after drying is not fast enough and has proved too costly. As an alternative, a specific gravity method may be used to obtain a good estimate of total solids. Two specific gravity methods are available, one requiring the weight of the sample in air and in water and another known as the hydrometer method. Table 15 shows the evaluation scale used by U.S. Department of Agriculture potato breeders to convert specific gravity readings to solids and starch equivalents.

Tuber samples selected for specific gravity determinations should represent several locations in the field and should be a random sample with respect to size. The tubers should be strictly clean and entirely free from hollow heart. Soil on potatoes will make the specific gravity reading too high and hollow heart will cause the reading to be too low.

TABLE 15.—*Chart for converting specific gravity readings to total solid and starch readings* [1]

Specific gravity	Total solids	Starch	Specific gravity	Total solids	Starch
1. 040	11. 2	-------	1. 073	18. 2	12. 5
1. 041	11. 4	-------	1. 074	18. 4	12. 7
1. 042	11. 6	-------	1. 075	18. 6	12. 9
1. 043	11. 8	-------	1. 076	18. 8	13. 1
1. 044	12. 0	-------	1. 077	19. 0	13. 3
1. 045	12. 2	-------	1. 078	19. 2	13. 5
1. 046	12. 5	-------	1. 079	19. 4	13. 7
1. 047	12. 7	-------	1. 080	19. 7	13. 9
1. 048	12. 9	-------	1. 081	19. 9	14. 1
1. 049	13. 1	-------	1. 082	20. 1	14. 3
1. 050	13. 3	-------	1. 083	20. 3	14. 5
1. 051	13. 5	-------	1. 084	20. 5	14. 7
1. 052	13. 7	-------	1. 085	20. 7	14. 9
1. 053	13. 9	-------	1. 086	20. 9	15. 1
1. 054	14. 1	-------	1. 087	21. 2	15. 4
1. 055	14. 3	-------	1. 088	21. 4	15. 6
1. 056	14. 5	-------	1. 089	21. 6	15. 8
1. 057	14. 8	-------	1. 090	21. 8	16. 0
1. 058	15. 0	-------	1. 091	22. 0	16. 2
1. 059	15. 2	-------	1. 092	22. 2	16. 4
1. 060	15. 4	-------	1. 093	22. 4	16. 6
1. 061	15. 6	-------	1. 094	22. 7	16. 9
1. 062	15. 8	10. 2	1. 095	22. 9	17. 1
1. 063	16. 0	10. 4	1. 096	23. 1	17. 3
1. 064	16. 2	10. 6	1. 097	23. 3	17. 5
1. 065	16. 5	10. 8	1. 098	23. 5	17. 7
1. 066	16. 7	11. 0	1. 099	23. 7	17. 9
1. 067	16. 9	11. 2	1. 100	24. 0	18. 2
1. 068	17. 1	11. 4	1. 101	24. 2	18. 4
1. 069	17. 3	11. 6	1. 102	24. 4	18. 6
1. 070	17. 5	11. 8	1. 103	24. 6	18. 8
1. 071	17. 7	12. 1	1. 104	24. 8	19. 0
1. 072	18. 0	12. 3	1. 105	25. 0	19. 2

TABLE 15.—*Chart for converting specific gravity readings to total solid and starch readings* [1]—Continued

Specific gravity	Total solids	Starch	Specific gravity	Total solids	Starch
1. 106	25. 2	19. 4	1. 125	29. 3	23. 5
1. 107	25. 5	19. 7	1. 126	29. 5	23. 7
1. 108	25. 7	19. 9	1. 127	29. 8	24. 0
1. 109	25. 9	20. 1	1. 128	30. 0	24. 2
1. 110	26. 1	20. 3	1. 129	30. 2	24. 4
1. 111	26. 3	20. 5	1. 130	30. 4	24. 6
1. 112	26. 5	20. 7	1. 131	30. 6	24. 8
1. 113	26. 7	20. 9	1. 132	30. 8	25. 0
1. 114	26. 9	21. 1	1. 133	31. 0	25. 2
1. 115	27. 2	21. 4	1. 134	31. 3	25. 5
1. 116	27. 4	21. 6	1. 135	31. 5	25. 7
1. 117	27. 6	21. 8	1. 136	31. 7	25. 9
1. 118	27. 8	22. 0	1. 137	31. 9	26. 1
1. 119	28. 0	22. 2	1. 138	32. 1	26. 3
1. 120	28. 3	22. 5	1. 139	32. 3	26. 5
1. 121	28. 5	22. 7	1. 140	32. 5	26. 7
1. 122	28. 7	22. 9	1. 141	32. 8	27. 0
1. 123	28. 9	23. 1	1. 142	33. 0	27. 2
1. 124	29. 1	23. 3			

[1] Adapted from M. Maercker. Landwerths Band 25: 107. 1880.

Air-and-Water Method

Two advantages of the air-and-water method of determining specific gravity are: (a) samples may be very small to large, and (b) very simple, ordinarily available equipment is needed. The samples are weighed first in air and then in water. Specific gravity is determined by the equation:

$$\text{Specific gravity} = \frac{\text{weight of sample in air}}{(\text{weight of sample in air}) - (\text{weight of sample in water})}$$

Accuracy of determinations by this method may be increased by increasing the sample size to 25 pounds or more (fig. 43). Scales must be accurate and readings made in decimals of pounds and ounces.

Potato Hydrometer Method

A potato hydrometer devised by the American Potato Chip Institute [3] gives direct specific gravity readings. *Exactly* 8 pounds of potatoes are weighed in air and placed in a basket suspended below the hydrometer. The assembly with potatoes is placed in a container of water deep enough to float it, and the specific gravity is read directly from the scale on the hydrometer.

Blackening After Cooking

One of the most prevalent complaints of housewives is the blackening of the flesh of market po-

[3] Address: National Potato Chip Institute, Cleveland, Ohio.

FIGURE 43.—Simple apparatus, made from stock materials, for determining specific gravity of potato samples of different sizes by weighing in air and water.

tatoes that occurs sometimes after cooking (fig. 44). Experts do not agree on the reasons for potatoes turning dark after cooking, but certain relations to cultural practices have been reported. The condition is worse in some seasons than in others. More research is needed on this very important problem. The following relations have been noted:

1. *Variety.*—Some potato varieties are more susceptible than others to darkening. Varieties with a tendency to darken are Irish Cobbler, Green Mountain, Rural New Yorker, Russet Rural, and Russet Burbank. Slight tendency toward darkening after cooking occurs in Katahdin, Red Warba, Warba, and Red Pontiac. Varieties with a tendency to remain white after cooking are Bliss Triumph, Chippewa, and Sebago. The varieties that show the greatest tendency to after-cooking darkening include most of the older potato varieties developed before 1920. The varieties Sebago and Chippewa—more recent introductions by the USDA—are among those least susceptible. Resistance to after-cooking blackening is a characteristic that has been given increased emphasis in most breeding programs. For many years, potato breeders have tried to avoid introduction of varieties known to be susceptible to blackening. Exhaustive testing and selection are necessary to eliminate or minimize this undesirable tendency in varieties.

2. *Climatic conditions.*—Low air temperatures (50° F. or lower) during long periods in the month prior to harvest have been associated with after-cooking blackening. Cloudy weather is likewise claimed to increase the tendency to blacken.

3. *Maturity of vines and tubers at harvest.*—There is some indication that harvesting before the vines and tubers are fully matured tends to increase the incidence of after-cooking blackening.

4. *Fertilizers.*—No concrete evidence can be given directly linking fertilizer practices with darkening of cooked potatoes, except that heavy fertilization delays maturity and therefore may indirectly favor blackening.

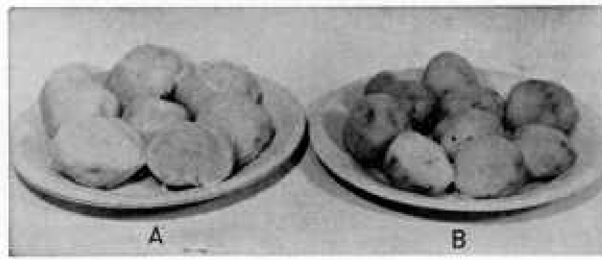

FIGURE 44.—After-cooking blackening of two potato samples from a breeding program: *A*, no appreciable blackening; *B*, rather marked external and internal blackening.

Internal Blackening of Raw Tissues

Blackening of the flesh in uncooked potatoes is referred to by various workers as internal black spot, internal bluing, or internal blackening. It has been studied rather extensively but the exact cause is still obscure. Most frequently it is considered to be a physiological disorder. It occurs in raw as well as in cooked potatoes, as dark areas in the flesh beneath the skin. Harvesting bruises, or pressures, "trigger" the development of this ailment in subsequent storage. It is probable that cultural practices, climatic conditions, or even a virus may be predisposing factors of this disorder. Irrigation practices, moisture relations, and fertilizer nutrient balances have at various times been correlated with it to some degree, but much more needs to be known about blackening before it can be prevented entirely. Under similar conditions, varietal differences in degree of blackening are apparent, but under favorable conditions all varieties show some symptoms.

Tuber Greening

The development of green color in the tubers of potatoes exposed to light is a familiar defect commonly referred to as sunburnt, light-struck, or greening. Most potatoes will not be green when properly cared for during growth, through harvest, in storage, and in the market, but it is often impossible to avoid all traces of greening before potatoes reach the consumer. The first signs of greening may occur in the field because of poor soil coverage and subsequent exposure to sunlight. Later, other sources of light may add to tuber greening while the potatoes are being stored, graded, and packaged for the retail market where further light exposure may occur in varying amounts and intensities. Although some of these exposures may be of short duration, or the light weak, the effects are cumulative so that the ultimate intensity of greening may be serious.

It has been known for some time that tubers from varieties and seedlings differ in their greening tendencies, but only recently has significance been attached to these differences obtained under light exposures similar to those existing in retail stores. These differences are now believed to be inherited so that it is recognized that a solution to the problem lies in potato breeding. The economic importance of a nongreening commercial potato variety, especially for the fresh market trade, is without question.

In a study of genetic differences in potato tuber greening, the tubers of certain varieties and seedlings were exposed intermittently to combinations of daylight and fluorescent light similar to those existing in retail grocery stores. Figure 45 shows the comparative results obtained when the tubers of two commercial varieties (Kennebec and Katahdin) and four seedlings (B4523–8, B922–6, B922–3, and B3696–13) were exposed to combined daylight and fluorescent light intermittently for different periods. The greening intensity in general was only slightly increased after 123 hours of light exposure, but the tubers from seedlings B4523–8, B922–6, and B922–3 were remarkably less green than those from Kennebec and Katahdin. This experiment and others like it with the tubers obtained from progenies of crosses between greening and nongreening parents have indicated that multiple genes and incomplete dominance are involved in the inheritance of the nongreening character. This finding is the first step toward the production of nongreening commercial potato varieties, which is the objective of a continuing project being conducted by the National Potato Breeding Program.

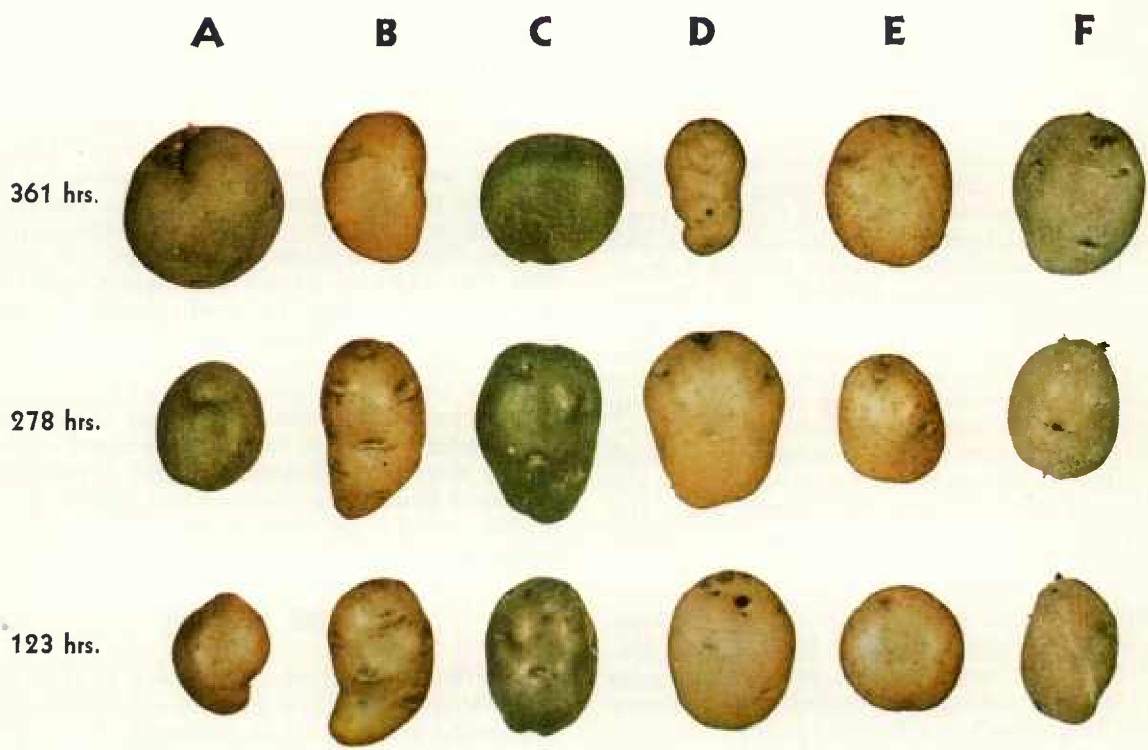

FIGURE 45.—The effects of combined daylight and fluorescent light on the greening of potato tubers of varieties and seedlings exposed intermittently for different periods: *A*, Katahdin; *B*, B4523–8; *C*, Kennebec; *D*, B922–6; *E*, B922–3; and *F*, B3696–13.

GROWING AND DEVELOPING POTATOES FOR SPECIAL USES

One of the fastest growing developments in the food industry today is the trend toward processing of potatoes. Production practices and varietal characteristics must be altered to meet the demand for potatoes better adapted to this rapidly expanding processing industry. The processing industries now use about 25 percent of the total U.S. production (table 16) as compared to only 1.4 percent in 1940.

Potatoes for Chips

Large amounts of potatoes are being manufactured into chips (table 16). Potatoes intended for chipmaking must meet definite specifications of the manufacturer. From a production standpoint, farmers growing potatoes for chip manufacture should follow only the best practices recommended for commercial potato production. Particular emphasis must be placed on (1) use of cultural practices that produce tubers of maximum solids content, and (2) selection of varieties best for chipmaking that are adapted to a given production area.

High solids content is especially important in growing potatoes for chips because the yield of chips per 100 pounds of potatoes is in direct proportion to their solids content. Potatoes with solids of 15 percent or less will usually yield less than 21 pounds of chips per 100 pounds of fresh weight. However, the same fresh weight of potatoes with solids of 24 percent will yield in excess of 32 pounds of chips. Also, chips made from potatoes of high solids content absorb less frying oil than those made from potatoes of low solids content. High solids potatoes not only reduce the cost of the finished product but also improve chip keeping quality because chips low in fat content, made from such potatoes, remain in good condition longer than those high in fat.

Potato varieties vary considerably in their adaptability for chip manufacture. Some varieties consistently will produce dark-colored chips even at harvesttime, largely because of their relatively high sugar content. Many varieties will produce light-colored chips at harvest when the sugar content is usually low, but will always chip dark after storage when sugars have accumulated. Chip

TABLE 16.—*Potatoes: Utilization of the 1957–61 crops*

Utilization items	1957 crop	1958 crop	1959 crop	1960 crop	1961 crop
Sales:	*1,000 cwt.*	*1,000 cwt.*	*1,000 cwt.*	*1,000 cwt.*	*1,000 cwt.*
Table stock	148, 408	148, 868	149, 013	149, 376	154, 834
For processing:					
Chips and shoestrings	17, 356	17, 063	20, 195	21, 310	22, 556
Dehydration	3, 776	5, 917	7, 656	10, 104	8, 518
Frozen french fries	4, 215	7, 352	8, 745	13, 373	15, 911
Other frozen products	612	911	1, 173	1, 669	2, 227
Canned potatoes	1, 216	1, 250	1, 185	1, 572	1, 458
Other canned products (hash, stews, soups)	1, 390	1, 614	1, 262	1, 237	1, 317
Starch and flour	12, 691	18, 387	7, 718	10, 177	20, 493
Total	41, 256	52, 494	47, 934	59, 442	72, 480
Other sales:					
Livestock feed	8, 950	18, 918	6, 607	5, 348	18, 918
Seed	13, 641	13, 079	13, 583	14, 547	13, 850
Total	22, 591	31, 997	20, 190	19, 895	32, 768
Total sales	212, 255	233, 359	217, 137	228, 713	260, 082
Nonsales:					
Seed used on farm where grown	7, 577	7, 086	7, 166	7, 504	7, 436
Household use	8, 176	7, 279	5, 920	5, 459	5, 236
Feed	2, 718	3, 916	3, 085	2, 887	4, 234
Shrinkage and loss	11, 796	15, 257	12, 491	12, 872	16, 606
Total nonsales	30, 267	33, 538	28, 662	28, 722	33, 512
Total production	242, 522	266, 897	245, 799	257, 435	293, 594

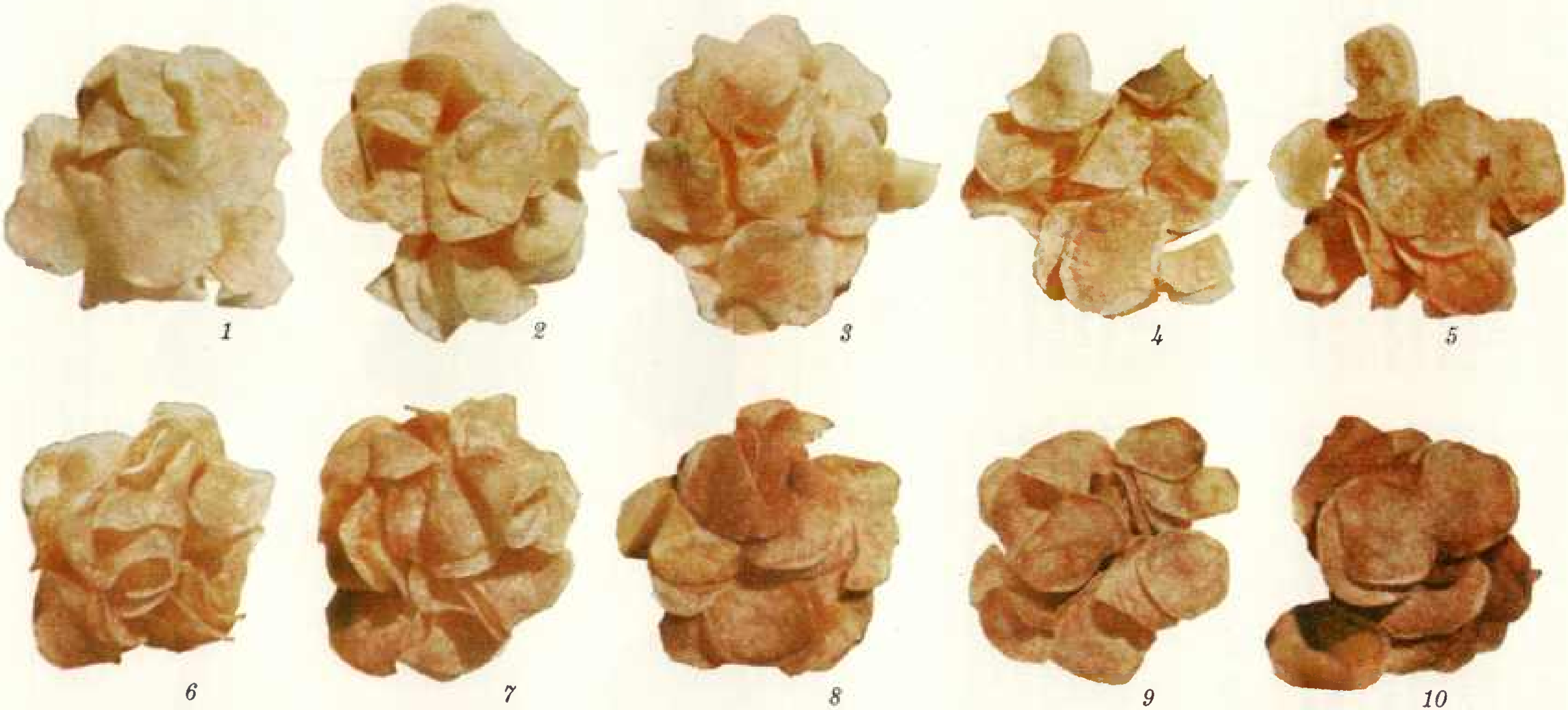

FIGURE 46.—Color reference standards for evaluating varieties and breeding lines for chip manufacture. These color standards have been officially approved by the American Potato Association. Grades 1 and 2 are preferred by most chip manufacturers. (Courtesy of B. L. Thomas, Cincinnati, Ohio.)

manufacturers prefer varieties that will produce light chips at harvest, will accumulate sugars slowly at the usual storage temperatures, and will lose their high sugar content readily upon "reconditioning" after storage.

Potato breeders, especially in the USDA, are actively engaged in making selections for new potato varieties which will produce chips of high quality both at harvesttime and after "reconditioning" from storage. Chips from promising selections are ranked according to a scale of colors shown in figure 46. Because of the special requirements of potatoes for chip manufacture, particular emphasis in the National Potato Breeding Program is being placed on developing new varieties for chipmaking.

Potatoes for Dehydrated Products

Dehydrated products including flakes, granules, and dices require potatoes meeting special needs. In addition to a high solids requirement, there is a special need for greater uniformity in solids within the same variety grown in one geographical location. To fulfill this requirement, growers must have maximum control of moisture, fertilization practices, spacing, and other cultural practices. On the other hand, breeders are attempting to develop varieties with desired qualities and less influenced by environment than are present varieties. Considerable research is needed before growers can be supplied the help needed to produce potatoes specially adapted for manufacturing dehydrated products.

Potatoes for Frozen Products

Frozen potato products consist largely of frozen french fries, but there are other frozen products being developed such as diced potatoes, mashed, hash brown, potato puffs, au gratin, rissole, cakes, shreds, and dehydrofrozen products (partial dehydration combined with freezing). Flavor is especially important in these products. Until the basic components of flavor are more fully understood, development of potatoes adapted for these uses will of necessity be delayed. Tests are being conducted with cooperating processing firms to enable selection of lines best adapted for these uses which will also maintain favorable flavor and texture after being thawed and cooked.

Potatoes for Certified Seed

Production of certified seed potatoes is also a specialized kind of potato enterprise. The term "certified" as applied to potatoes means that the fields and harvested crops have been periodically inspected by a staff trained to detect evidences of seedborne diseases and varietal mixtures. Potato seed certification standards and their enforcement are the responsibility of each State. There are no Federal standards for certification. The primary purposes and advantages of certified seed are discussed under "Selecting and Preparing Seed," p. 28.

The certified seed grower must purchase seed for his own use from specified sources and then continually protect it from contamination by diseases and prevent variety mixture. He must have had training in identifying disease symptoms and must be capable of roguing infected plants from his fields. Growers interested in producing certified seed should write to the official agency in charge of potato seed certification in their State. The names and addresses of such officials and other information on growing certified seed may be found in the 1956 Potato Handbook of the Potato Association of America, New Brunswick, N.J.

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