AGRICULTURAL EXPERIMENT STATION
KANSAS STATE COLLEGE OF AGRICULTURE
AND APPLIED SCIENCE
MANHATTAN, KANSAS

POTATO PRODUCTION IN KANSAS

PRINTED BY KANSAS STATE PRINTING PLANT
W. C. AUSTIN, STATE PRINTER
TOPEKA, 1944
20-1787

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PART I.—PRODUCTION AND CULTURAL PRACTICES

INTRODUCTION

The potato competes for first place as the most important food on the tables of Kansas families. The potato is highly nutritious and may be prepared in a variety of ways. It is especially important in the diet of those doing physical labor, appearing on the table as a main dish one to three times daily.

The annual production of potatoes in Kansas, 1936 to 1940, inclusive, was approximately two and one-half million bushels. If all of this production were consumed at home, Kansas would produce only 50 percent of the potatoes normally consumed by the citizens of the state. However, a fair proportion of the potatoes grown in Kansas is shipped to distant markets during June and July.

Potatoes are grown commercially in the Kansas river valley from Manhattan to the east boundary of the state, and only to a limited extent in local western areas and by market gardeners in the vicinity of larger centers of population. The commercial plantings are largely concentrated in Wyandotte, Leavenworth, Johnson, Douglas, Jefferson, Shawnee, and Riley counties. Average acre production is around 150 bushels. The yield recorded for the commercial acreage is for No. 1 size potatoes $1\frac{7}{8}$ inches in diameter and up), as there is seldom a profitable market for potatoes of smaller sizes. Up to 25 percent of the total yield, depending on variety and seasonal growing conditions, is below the No. 1 size. Yields reported by commercial growers are much higher than yields obtained by home gardeners in the same area.

Approximately 65 percent of the potato acreage grown in the state is for home use and is grown in small quantities on a large number of the farms throughout the state and in many of the town gardens. The yields obtained seem to be lower than.might be expected. The best available data show the average acre yield for potatoes produced outside of the commercial areas to be approximately one-half that of the commercial areas. In the areas where commercial plant-

1. Contribution No. 199 from the Department of Horticulture; No. 452 from the Department of Botany; and No. 529 from the Department of Entomology.

ings play an important part In the total acreage, production may range from 106 to 176 bushels per acre.

Home gardeners and some truck gardeners may greatly increase their potato yields by adopting some of the cultural practices of the commercial growers. It would also appear likely that the quality of the potatoes harvested by home and market gardeners would increase as the yield is increased. Some of the more important factors to be considered are: The selection of soils suited to potato production, the preparation of the soil, the use of certified seed potatoes, the size of the seed piece planted, cultivation, insect and disease control, and harvesting methods.

The potato is a cool-weather crop, thriving best where the average mean daily temperature for the warmest month does not exceed 75° F. The potato is best grown in Kansas as an early-spring crop, planted mostly during March and harvested in late June and July, except for western Kansas. Only the earliest-maturing varieties are capable of producing a mature crop before high temperatures curtail potato growth.

Everything possible must be done to obtain early plant growth and to maintain vigorous growth throughout the season, if maximum yields are to be obtained. The use of strong, vigorous seed potatoes, free from disease, protection against seed-piece decay, fertile soil, and adequate soil moisture are vital to success. The secret of successful potato culture in Kansas depends upon early planting and the production of strong, vigorous plants of early-maturing varieties.

Soils

Soil requirements, soil management, and fertility are important factors for consideration in successful potato growing.

Soil Requirements.— The potato is rather cosmopolitan in its soil requirements. However, it succeeds best on certain kinds of soils. The ideal soils are loose and friable, well supplied with organic matter, deep, and well drained, yet holding moisture well. Heavy, sticky soils or very sandy soils are among the poorest and should be avoided. Potatoes produced on the lighter soils are brighter colored than those from heavy soils.

Soil Management.— Soils used for potatoes should be high in organic matter. No definite system of crop rotation for potatoes can be recommended which will suit all sections of the state or even the farming enterprises of a given area.

In parts of eastern Kansas, alfalfa is an important commercial crop and works well into a rotation with potatoes. Alfalfa or sweet clover sod is believed to be ideal for potatoes. These crops do not attract white grubs or wireworms. Potatoes should not be grown on the same land year after year, but when potatoes do follow potatoes in the rotation, an application of manure should be made after harvesting the potato crop. The land should then be planted to rye as a cover crop to be plowed under during the winter or early spring.

In the portion of Kansas west of a line drawn through Manhattan and Wichita, large potato yields are not to be expected unless the soil has an abundant moisture supply at the time of planting or unless irrigation is feasible. Where water for irrigation is not available, the use of summer fallowed land is recommended for potato production throughout this area. Indications are that large yields of high quality can be produced on irrigated land suited to potato production in western Kansas.

Soils heavily infested with weeds, especially Johnson grass, bindweed, Bermuda grass or nut grass, should be avoided because of increased cultivation costs. Potatoes growing in soils infested with nut grass *(Cyperus rotundus)* are frequently injured by the underground stolons of the nut grass which grow into the tubers and greatly impair their value. Nut grass overwinters as small hard tubers and these tubers may be spread during cultivation, although seed is also produced. The grass prefers low moist places but under favorable conditions may cover comparatively large areas.

Fertilizers.—A 100-bushel crop of potatoes will require approximately 23 pounds of nitrogen, 8.5 pounds of phosphoric acid, and 29 pounds of potash. In general, Kansas soils are well supplied with potash and do not respond to the addition of potash as a commercial fertilizer. Soils that are well supplied with organic matter are usually fairly well supplied with nitrogen. However, many eastern Kansas soils respond favorably to the use of a phosphorus fertilizer.

Soil fertility may be improved in three ways: By turning under a leguminous crop, as alfalfa sweet clover, or cowpeas; by the addition of barnyard manure; and by the addition of commercial fertiIizers.

The most commonly recommended commercial fertilizer for potato production contains 1 part nitrogen to 5 parts phosphoric acid and no potash. Potatoes are planted in March so that the nitrogen of the commercial fertilizer is used by the plants while the soil is cool.

In eastern Kansas an application of 200 pounds per acre of 6-30-0 fertilizer is recommended. The fertilizer may be applied to best advantage at the time the potatoes are planted. The commercial grower with the aid of an attachment on the potato planter applies the fertilizer as a band on either side of the seed and on a level with the seed pieces. In other cases the commercial fertilizer is applied after the potatoes are up, using a fertilizer attachment on the cultivator.

The home gardeners may find it more advantageous to apply commercial fertilizer in the furrow before planting the seed potatoes. One and one-half pounds of 6-30-0 fertilizer to a 100-foot row are equal to approximately 200 pounds per acre when the rows are spaced 3 feet apart. The fertilizer should be mixed with the soil before the seed pieces are planted.

Varieties

The length of the growing season adapted to potato production in Kansas limits the selection of varieties to the early-maturing group. Potatoes cannot be planted safely until March and the temperature becomes too high for potato growth late in June or early July. Varieties which do not mature by this date seldom produce large tubers.

Irish Cobbler, commonly called Cobbler, is an early-maturing variety of excellent quality. It is the most important variety for Kansas because it does well on a wide range of soil types. The tubers are creamy white, somewhat darker when grown on heavy soils, roundish to slightly flattened, and oblong. The eyes are deep

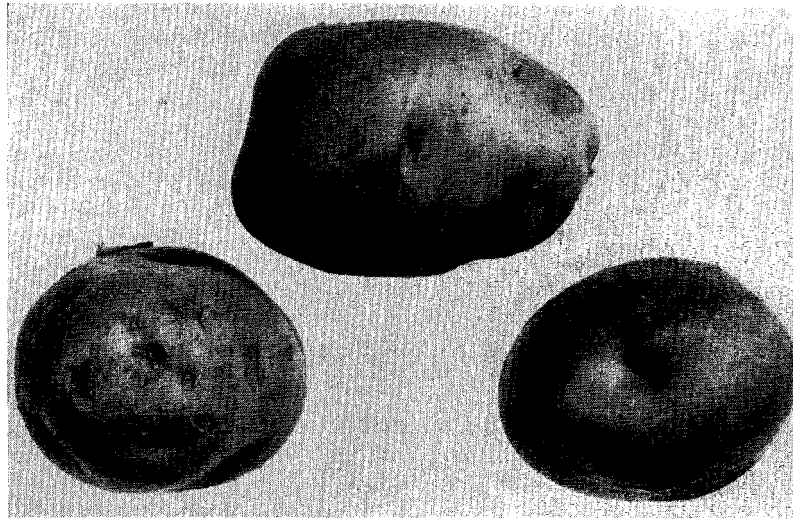


FIG. 1.—Irish Cobbler, a variety recommended for general planting in Kansas. Views, left to right: Terminal end, side, stem end.

and medium in number. Both the bud and stem ends of the tuber are deeply recessed. (Fig. 1.) The plant is medium in size and spreading in habit with stocky, green, short-jointed stems having purplish-tinged nodes. The leaves are medium light green, glossy, and broad. The flowers are light rose-purple, turning white in intense heat.

Bliss Triumph, commonly called Triumph, is the most popular red variety grown commercially in this area. Tubers tend to set freely on the plant, resulting in small to medium-sized potatoes; when weather conditions are unfavorable the tubers are small. Tubers are of a block shape, somewhat shouldered at the stem end. The eyes are not so abundant or so deep as on Cobbler. (Fig. 2.) The

plant is light green, upright and slightly branched. This variety produces a few flowers of lavender color which fade to white in bright sun and high temperature.

Red Warba is a comparatively new variety possessing the ability to produce large yields. The variety is, however, not sufficiently free from disease to make possible the production of certified seed in quantity. Red Warba is a week to ten days earlier in maturity than Cobbler. Tubers set freely and grow medium to large in size, usually out-yielding the other recommended varieties. The tubers are purplish-red but they tend to revert to white, unless solid red

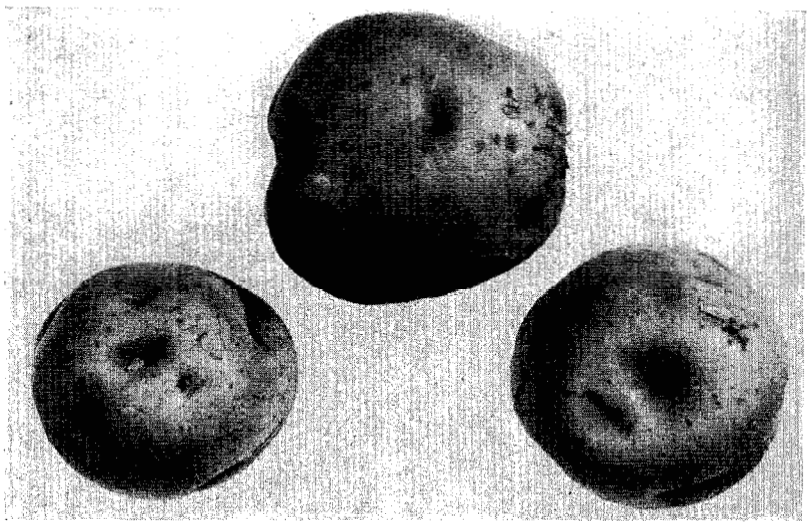


FIG. 2.—Bliss Triumph, a popular red variety. Views, left to right: Terminal end, side, stem end.

tubers are used for planting. (Fig. 3.) Red Warba tubers "growth crack" badly as compared to Triumph and under unfavorable conditions produce many small potatoes. The variety does best on light soils, frequently producing rough tubers when grown on heavy soil. Plant growth is medium to large, rather bushy with blue-green foliage.

Early Ohio was an old favorite of the home gardener, but has been replaced largely by other varieties. The principal objections to Early Ohio are: The inability to obtain good, smooth, certified seed; the tendency of the variety to produce rough, knobby tubers; and low yields. Second growth during unfavorable seasons appears as "knobs" at eyes of the tuber. When well grown, the tubers have good keeping quality. They are light pink to a reddish hue in color. The tubers are oblong with roundish ends. The variety matures slightly later than Cobbler.

Warba is an early variety, maturing a week to ten days earlier than Cobbler. The tuber resembles Cobbler in shape and color except Warba has pink eyes in the immature stage. The variety is similar to the Red Warba in ability to produce, free-setting habit, tendency of tubers to growth crack, and in soil requirements.

The commercial acreage planted to Irish Cobbler is about 75 to 80 percent; Bliss Triumph, 15 to 20 percent; and the remainder to Red Warba and Warba. Bliss Triumph is the only variety of this group subject to serious injury by potato leafhopper. When this variety is grown attention must be given to the control of this insect. See page 47.

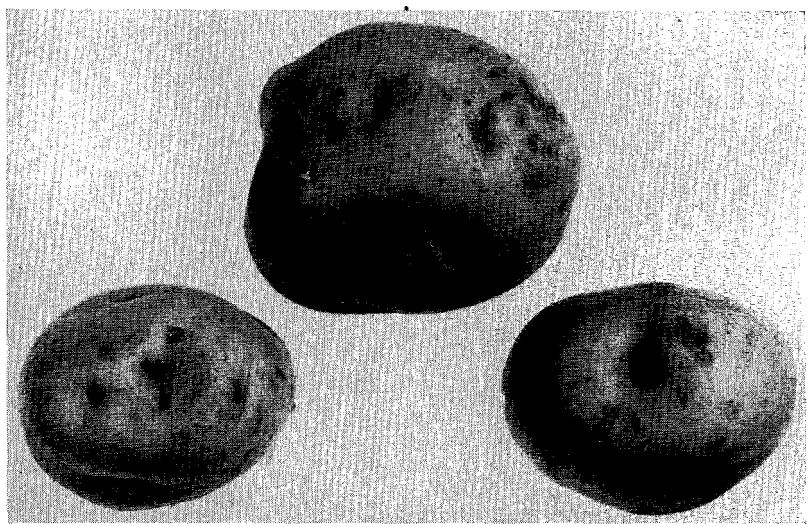


FIG. 3.—Red Warba, a new variety that is producing large yields. Views, left to right: Terminal end, side, stem end.

Irish Cobbler is the most important home-garden variety in Kansas. Red Warba is recommended rather than Bliss Triumph for a red-skinned, home variety. Warba is an early-maturing variety which produces high yield under favorable conditions. Early Ohio gradually has decreased in popularity but is remembered by the home gardener as a variety that keeps well.

SEED POTATOES

The use of good seed potatoes is important and is often the deciding factor between success and failure. Healthy, strong, vigorous plants are essential to large yields.

Tubers of medium size, uniformly well-shaped, unblemished, firm and sound, that have been properly stored are most economical for seed. Potatoes which have been frosted or exposed to temperatures

below 36° F., for a period of time, generally produce weakened shoot growth and do not make desirable seed potatoes.

The potato normally has a rest period of about three months after which time growth will start when conditions are favorable. The rest period may be shortened by storing potatoes at a temperature above 50° F., or by exposing newly harvested tubers to sunlight. Home-grown potatoes which mature in July must be kept for eight months if desired to be used as seed potatoes next season. Unless they are stored under favorable conditions, the potatoes either produce sprouts which must be removed or they shrivel while in storage, either of which tends to cause weak shoot growth and inferior yields. The use of home-grown seed year after year is not advisable because of the accumulation of degenerative diseases, especially virus diseases, and because the long storage period reduces the vigor of the tuber.

Home-grown tubers one year removed from certified stock that have not shriveled or sprouted may be expected to produce good yields. However, northern-grown tubers, especially certified potatoes, offer the most reliable source of seed potatoes. Badly shriveled seed potatoes produce poor yields. (Table 1.)

TABLE 1.—EFFECT OF POTATO SEED SOURCE ON YIELD, HORTICULTURE FARM, MANHATTAN, 1943.

	Yield in bushels per acre.	
	Total yield.	One and seven-eighths inches and over.
Cobbler, Northern Certified	430	376
Cobbler, good home seed*	379	285
Cobbler, home-grown seed badly shriveled*	214	166
Red Warba, Northern grown	472	394
Red Warba, good home-grown seed	333	306

* Cobbler home-grown seed one year removed from certified seed.

Northern-grown potatoes mature during cool weather. They are harvested in September and October, and are stored under nearly ideal conditions. The storage period is five to six months as compared to approximately eight months for the July-harvested, Kansas-grown potatoes. These factors favor northern-grown seed potatoes for the production of strong, vigorous plants.

Certified Seed.—Methods have been developed whereby disease-free seed potatoes are built up from a single tuber, commonly re-

ferred to as foundation stock. When the foundation stocks are grown under prescribed conditions and the fields and the tubers after harvesting pass inspection by a licensed inspector, the crop is certified as being practically free of many diseases which might make the tubers unsafe for seed potatoes. Certain externally-borne diseases such as Rhizoctonia may be present and, for the control of such diseases, seed potato treatment as described on page 42 is recommended.

A certification tag giving the name of the state that has certified the seed along with the grower's name is attached to each sack in such a manner that the seal must be broken in opening the sack. (Fig. 4.) Most of the seed potatoes planted in Kansas come from North Dakota, Minnesota, and Nebraska. Western Kansas growers

FIG. 4.—Front and back views of tags placed on certified seed potatoes by leading states that supply certified potatoes to Kansas growers. Blue tags are used for best grade, red tags for second grade, and white tags for third grade. Differences in grades are due to defects which do not affect productivity, such as mechanical injury or surface-borne disease for which seed may be treated.

may consider Colorado and Wyoming as economical sources of seed potatoes because of transportation costs.

Certified seed potatoes are recommended as the first choice for home gardeners, market gardeners, and commercial growers. While healthy seed potatoes may be obtained through other sources the true desirability of the seed cannot be determined until after the potatoes have been planted.

Potatoes grown for table stock are commonly sold under misleading brands such as "seed potatoes," "northern-grown seed potatoes," or "selected for seed." Such labels give no assurance of freedom from disease and are of questionable value as a guide in the purchase of seed potatoes. Such potatoes may be well graded and present a good appearance.

Size of Seed Pieces.—The potato is an underground stem modified for food storage purposes. It has a bud or "eye" arrangement similar to a branch of a tree. The buds are relatively far apart at the stem end of the potato but gradually become closer together until they cluster at the terminal end. The cluster of buds at the terminal end is considered least desirable for plant production, therefore, in cutting potatoes one cut should always pass through the cluster of buds at the terminal end. When small potatoes are used as one seed piece, the terminal cluster of buds should be removed.

At least one strong eye per seed piece is necessary for growth. The size of the seed piece is more important than further consideration of the number of eyes present on the seed piece.

The size of the seed piece has a direct bearing on yield as shown in Table 2. These data lead to the conclusion that maximum yields are to be expected when 1½-ounce seed pieces are used. Yields obtained when 1½-ounce seed pieces were planted were 28 bushels per acre higher than when ½-ounce seed pieces were used. The yield obtained by the use of 2-ounce seed pieces was no greater than that obtained from 1½-ounce seed pieces. From the data at hand it appears that seed pieces ranging in size between 1 and 1½ ounces should be used.

TABLE 2.—EFFECT OF SIZE OF SEED PIECE ON YIELD, NEWMAN FIELD.

WEIGHT OF SEED PIECES (OZ.).	Seed per acre (Bus.).	Yield per acre.	
		Total (Bus.).	No. 1 size (Bus.).
0.5	7.5	112	99
1.0	15.0	167	153
1.5	22.5	195	182

Cutting of Seed.—Potatoes stored at 40° F. should be removed from cold storage some time before being cut for seed so that growth will take place quickly when they are planted. All potatoes showing disease or serious mechanical injury should be discarded.

There are several methods of cutting seed potatoes. Potato-cutting machines have been perfected which cut potatoes in blocky seed pieces as shown in Figure 5, center. The potato shown in the illustration is of an ideal size for seed purposes weighing between 5 and 6 ounces. When cut into four parts the seed pieces are of a desirable size.

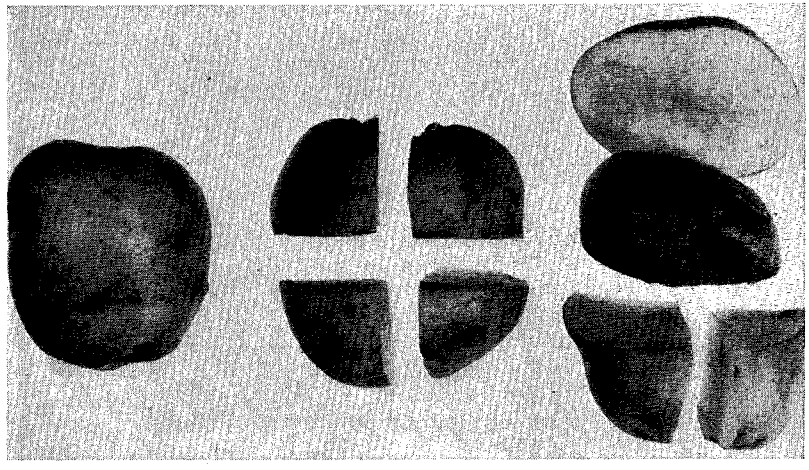


FIG. 5.—How to cut seed potatoes. (Left) A potato weighing 5 to 6 ounces. (Center) Potato cut into block seed pieces. (Right) Potato cut with a knife making desirable wedge cuts.

Potato-cutting machines are of several types, but they all operate on the same general principle in that they are made to accommodate three or four different sized potatoes. The small potatoes are cut into two seed pieces by a longitudinal cut, from the stem end through the cluster of buds at the terminal end. Slightly larger potatoes are cut into four pieces by a second blade set at right angles to the longitudinal blade. The seed potatoes are either carefully graded as to size by machine for each cup or the operator places the potato in the proper cup as he picks it up. The machine method is a rapid method of cutting seed but many commercial men object to them because many of the seed pieces are too small. The potato that is a little large for two seed pieces is not large enough to make four ideal seed pieces. The machine is likely to cut the potato so that two are ideal and the other two are small. If the small cut is from the stem end, one cut will most likely have no eye.

Hand cutting is most commonly practiced in Kansas. Some growers use the stationary knife method in which the potato is pulled through the knife. The first cut is from the stem end to the terminal end. If the potato is large enough to make more than two seed pieces, additional cuts are made at right angles to the first. This method of cutting makes blocky seed pieces as obtained by the machine method, but seed pieces of more uniform sizes are usually obtained by hand cutting.

Perhaps the majority of the commercial seed potatoes are cut by hand, using a slice cut as shown in Figure 5, right. Such seed pieces are not so blocky as those shown in Figure 5, center, but are more uniform in size when properly cut. The tubers may be cut into two, three, or more pieces according to the size of the potato. The first cut is made at the stem end and the final cut is through the cluster of buds at the terminal end.

Seed potatoes should be planted as soon after cutting as possible. When cut seed must be held, it should be stored in shallow piles or half-filled sacks in a well-ventilated room above freezing temperature but where rapid drying will not occur. Temperatures above 70° F. and a relative humidity of 85 to 90 percent cause rapid healing of the wounds and hasten shoot growth. Faulty storage of cut seed may lead to serious losses due to seed-piece decay, the losses being expressed as missing plants in the stand or as weak-growing plants.

Planting Date.— The potato is a cool-weather crop, thriving best when the average daily mean temperature range is below 75° F. The earliest-maturing varieties under Kansas conditions require approximately 95 days from planting date to maturity. Potatoes planted in March require about one month to emerge and the earliest-maturing varieties require 65 days to produce top growth and mature a crop. During late June or early July, temperatures become too high for potatoes, consequently early planting is essential if good yields of mature potatoes are to be produced. The planting date for the commercial acreage in the Kansas river valley is March 15 to 25.

Young potato plants are not injured by a frost but they cannot withstand freezing. When young plants are frozen, one of two things may happen, depending upon how much of the stem is killed. When the stem is killed to a point below the ground, new growth usually comes from another eye on the seed piece or from the secondary buds about the main bud of the eye. When the injury is not so severe, new growth may come from a bud in a leaf axil on the uninjured part of the shoot. Freezing injury commonly results in the harvesting of a large number of small, immature potatoes. Potato growers realize that if large yields are to be produced, earliness is essential and the risk of freezing injury late in April must be assumed. Growers do not attempt to protect the crop against freezing. However, cultivation is avoided during the afternoon when freezing temperatures are likely to occur at night.

A small acreage of fall potatoes is grown in Kansas, mostly in the eastern part of the Kansas river valley. They are planted July 20 to 30. For further details regarding a fall crop, see page 20.

Depth of Planting.— The commercial potato growers use a planting machine to plant the crop. The planter opens a furrow in which the seed pieces are dropped. Discs on either side of the furrow

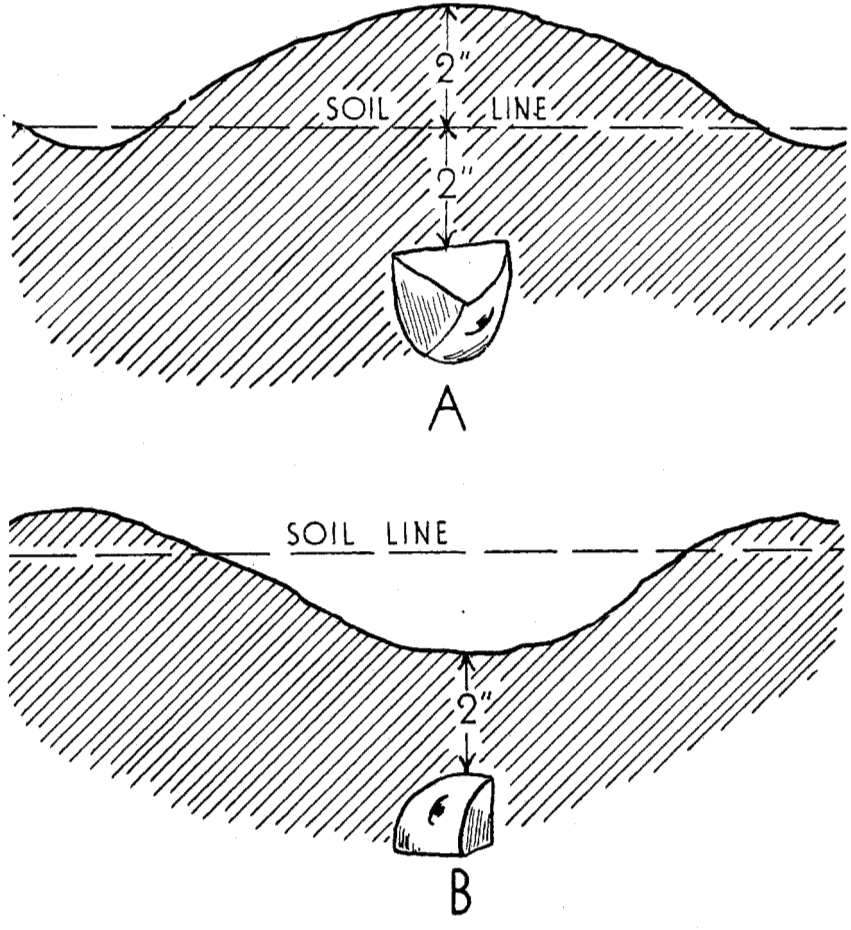


FIG. 6.—Planting seed potatoes. (A) Machine planted. (B) Hand planting as commonly practiced by home gardeners.

cover the seed piece and throw up a ridge over them. As a rule the seed pieces are planted 2 inches below the surface of the soil and the ridge thrown up is about 2 inches high so there are 4 inches of soil over the seed piece. (Fig. 6A.) Potatoes planted very early may be planted deeper to protect the seed piece against freezing.

Potatoes grown for home use are frequently planted by hand, the

seed pieces being dropped in a furrow and covered by a farm tool—a garden rake, harrow, or cultivator. The furrow is seldom completely filled, though the seed pieces are covered with 2 to 4 inches of soil. (Fig. 6B.)

Experienced growers believe that the most desirable depth to plant potatoes is 2 inches, unless there is danger of freezing the seed piece or injuring the new growth by frost. Potatoes are planted in early spring when the soil is cold. The sun during the spring days warms the soil sufficiently to start potatoes that are planted 2 inches deep to growing more quickly than when they are planted 4 inches deep.

Planting Distance.—The average rows are 36 inches apart and the seed pieces are spaced 11 to 16 inches apart in the row, depending upon the fertility of the soil, the variety, and the individual grower. Twelve- to fourteen-inch spacing in the row is most common. Ten to twelve sacks, or sixteen to twenty bushels of seed potatoes to the acre is a standard planting rate.

On the general farm, or in gardens where potatoes are cared for by general farm tools, the rows are commonly spaced 42 inches apart in order to use corn-growing equipment for cultivation.

The amount of seed required to plant an acre of potatoes using either 1-ounce or 1½-ounce seed pieces is shown in Table 3. A 100-pound sack of potatoes contains 1⅔ bushels.

CULTIVATION

The primary object of potato cultivation is to control weeds and to keep the potato tubers protected from sun and high soil temperature. The latter may be accomplished by gradually throwing soil toward the plants and more deeply covering the growing tubers,

TABLE 3.—SEED POTATOES REQUIRED TO PLANT AN ACRE.

SPACING (inches).		Size of seed pieces (ounces).			
		1.	1½.	1.	1½.
Between rows.	In rows.	Bushels per acre.		Approximate pounds per 100-foot row.	
36	12	15.1	22.7	6.2	9.2
	14	13.0	19.5	5.4	8.1
	16	11.3	17.0	4.7	7.0
	18	10.1	15.2	4.2	6.3
	36	5.0	7.6	2.1	3.1
42	12	13.0	19.5	6.2	9.2
	14	11.1	16.8	4.6	6.9
	16	9.7	14.6	4.0	6.0
	18	8.7	13.1	3.4	5.1
	36	4.3	6.4	1.7	2.6

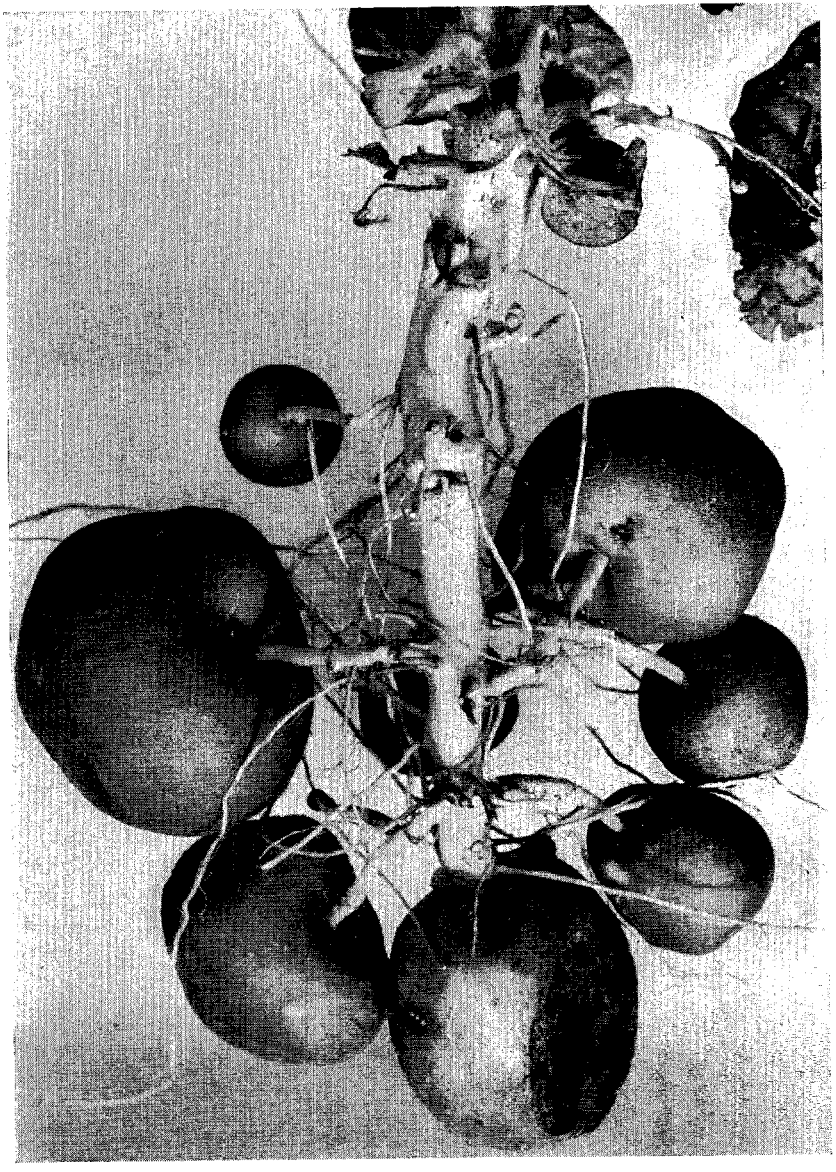


FIG. 7.—A young potato plant, showing origin of new potatoes. Note that the stolons develop at nodes on the stem below surface of the ground.

When potatoes are planted by machine a ridge is thrown up over the seed piece. (Fig. 6A.) The first cultivation in this case is made before the potatoes emerge, using a harrow or similar tool to tear down the ridge, thus destroying any weeds that may have started in the potato row. It is essential that this cultivation be made before the shoot growth is sufficient to be disturbed by the harrow. Frequently a poor stand can be traced to disturbance of the seed pieces during the first cultivation.

When potatoes are planted in a furrow and the furrow is not completely filled at pIanting time, the first cultivation is commonly delayed until the potatoes are emerging. (Fig. 6B.) Then, by means of a harrow, soil is dragged into the furrow, covering the small weeds.

Subsequent cultivations should be frequent enough to control weeds, and soil is moved toward the row so that by the end of the season the potato plants are on a ridge. The commercial grower plants with a machine, placing the seed piece about 2 inches below the surface of the soil. During cultivation a ridge is thrown about the plant until there is a ridge 8 or more inches high by the time the potatoes are laid by. The home gardener who plants in furrows seldom builds much of a ridge about the plants during cultivation. The final cultivation is usually made by June 15.

Potato varieties differ considerably in the way the new tubers set on the plant. The varieties recommended for Kansas produce tubers on short stolons, seldom over 6 inches long, so the tubers are comparatively close to the plant. (Fig. 7.) It is imperative that the young tubers are not disturbed during cultivation. Deep cultivation or close cultivation is harmful.

STRAW MULCH

The growing of potatoes under a straw mulch is not generally practiced, but it has proved successful under favorable conditions. The seed pieces of potatoes to be mulched should be covered at planting time with about 1 inch of soil and at the same time be covered with about 6 inches of straw. The chief advantages of a straw mulch are to control weeds, to conserve soil moisture, and to lessen heat injury and sunburn. The root system of potatoes grown under a straw mulch is much less extensive than under cultivation. Large yields under a straw mulch are to be expected only on very fertile soils.

Straw mulching of potatoes in Kansas is recommended only when there is a good supply of soil moisture at planting time. One-half inch of rainfall occurring during the growing season is of no value to a growing potato crop under a 6-inch straw mulch.

Straw mulch cannot be recommended as a commercial practice because of the time necessary to apply and remove the straw, and because of the scarcity of straw.

Straw is sometimes applied at the time of the last cultivation to protect the soil from the sun as the vines mature. It is difficult, however, without the use of an excessive amount of labor, to apply

the straw uniformly and deep enough to serve the desired purpose. Care must be taken, too, not to injure the vines. The practice can be justified only when the potatoes are to remain in the soil for a long period after maturing and when no other satisfactory ground cover is available. The scarcity of straw will tend to make this practice uneconomical in most areas.

Fall Crop.—Under favorable conditions, potatoes may be planted to mature in the fall. In the eastern third of the state, the fall crop is commonly planted July 20 to 30. Seed potatoes for the fall crop may be from one of the following sources: Northern-grown, certified seed potatoes which have been held in commercial cold storage; home-grown tubers from a fall crop, placed in commercial cold storage not later than March 15; or, from Red Warba tubers from the spring crop of the current season, treated to break the rest period. The home-grown tubers from a fall crop are often referred to as "Junior Seed" as the smaller tubers, 1¼ to 1½ inches in diameter, are saved for this purpose. Commercial growers usually grow a red-colored potato as a fall crop, as red varieties demand a higher price than white varieties,

The Red Warba has a shorter rest period than Cobbler and Bliss Triumph, and some success has been obtained by treating Red Warba seed harvested in late June or early July, for planting during late July. Some growers take the No. 2 size potatoes of Red Warba, 1¼ to 1⅞ inches in diameter, and spread them thinly in the shade of a tree. The bright sunlight causes the tubers to turn green in color and changes occur which cause vegetative growth to start when the tubers are placed under favorable conditions. A three-week treatment is believed sufficient.

A number of chemicals such as ethylene chlorhydrin and sodium thiocyanate have been placed upon the market which are recommended by their manufacturers to break the rest period of plants, including potato tubers. Such treatments are designed to make possible the use of potato tubers for planting soon after the crop has matured, thus, tubers of the spring-harvested crop could be used as seed potatoes for a fall crop. The desirability of the use of these materials for the treatment of tubers of the spring crop to be planted to produce a fall crop of potatoes in Kansas, has not been demonstrated at this experiment station. When the materials are used, the manufacturer's directions should be followed.

The soil for a fall crop should be in the best of tilth and well supplied with moisture, as seed-piece decay is very heavy in dry soil. Plant growth is weak during high temperatures and the cool season is of too short duration for normal maturity of a crop. Large yields are not to be expected from a fall crop. Growers planning on growing a fall crop should do so with the knowledge that the yields will be small and that total failures are frequent. Moisture, temperature, and date of killing frost are usually limiting factors.

HARVESTING

Under normal conditions the potato tuber continues to grow until the vines are nearly dead. Abnormally high temperatures may cause the vines to die before the potatoes mature.

Harvest Date.—If the skin no longer slips when rubbed under pressure by the thumb, the tubers have stopped growth, and are said to be mature. After the potatoes are mature, nothing is to be gained by leaving them in the ground and the commercial men strive to harvest the crop as quickly as possible. Commercial growers frequently find it to their advantage to begin harvesting before the potatoes are mature, as market demand and prices are sufficiently high to warrant harvesting before maximum yields are obtainable.

The Kansas potato crop matures with the advent of high summer temperatures. Frequently the daily mean temperature during the latter part of June and early in July is above 75° F., causing rapid maturity of potato vines and a rapid increase in soil temperature. The heated soil creates a condition which is most unfavorable for the subsequent keeping of the potatoes. The Kansas grower has few alternatives. The period between maturity of the crop and high soil temperature is seldom long, enough to permit commercial growers to harvest the crop before much loss results from decay. It is, therefore, a common practice to harvest immature potatoes and place them upon the market for immediate consumption. The success of such a practice depends upon the stage of maturity of the tubers, the care with which the crop is harvested, graded, and delivered to market, and the prevailing temperature. Soft rot frequently developes resulting in severe financial loss to the grower. See page 36.

A few growers wait until the crop is more nearly mature before harvest is begun. As many potatoes as can be sold immediately at a profit are marketed and the balance is placed in commercial cold storage to be placed upon the market at a later date.

The home gardeners' problems are somewhat different in that they desire to keep the crop for future use. Potatoes to be held for home use should not be harvested until they are mature. The crop is best harvested as soon as mature and before the soil temperature becomes high. A poor second choice is to protect against high soil temperature through the use of a straw mulch or by the growing of a ground cover of weeds, grass, or a cultivated crop and then harvest the potatoes in the fall.

The use of poor seed potatoes often becomes evident as the mature tubers are subjected to adverse conditions. Any condition which tends to weaken the plants during the growing season weakens the vigor of the mature tubers and makes them more subject to decay.

Time of Day.—The time of the day when potatoes are harvested becomes important when the temperature is high and the sun is bright. Newly-dug tubers, when exposed to bright sunlight and

high temperature, are easily blistered (sunscald) and such injury is a serious handicap to marketing or storage. To avoid sunscald injury, harvesting during excessively hot weather, 100° F. or over, should be done in the morning before 10 o'clock and in the evening after 5 o'clock. The tubers should be picked up as soon as feasible after being lifted and removed to shade.

Method of Harvesting.— The commercial potato crop is dug by means of specially designed machinery. Two types of machines are commonly used by Kansas growers. One is the elevated potato digger and the other is a turn plow with a rod turn-board.

The elevated potato digger has a flat plate 14 to 16 inches wide which passes under the potatoes. The loosened soil and potatoes are carried onto an elevator which carries the potatoes and soil over parallel rods extending in the same direction the elevator is moving. The loosened soil drops between the rods and finally the potatoes are dropped to the surface of the soil where they can be gathered easily. This equipment works well when the vines are mature and the soil contains a proper moisture content to crumble freely.

The turn plow with the rod turn-board is commonly used for digging potatoes while the vines are green and for digging when the soil is moist or very dry and cloddy. The rods in the turn-board may be adjusted so that the tubers are thrown to the surface. Otherwise the plow is similar to the common moldboard plow.

Commercial potato fields are decidedly ridged during the last cultivation, which makes it comparatively easy to remove the potatoes from the soil without great power or without moving much soil. It is difficult, however, to grow a cover crop capable of giving the soil adequate protection from the sun after the vines at the top of the ridge die.

Home-grown potatoes may be harvested with a plow, lister, or spading fork. Regardless of the equipment used, care should be exercised to keep mechanical injury and sunscald to the minimum. The common practice of planting home-grown potatoes in a furrow and to ridge the row only slightly during the cultivation causes the home-grown potatoes to be more difficult to harvest. Where the soil is nearly level it makes possible the establishment of a cover crop which may provide adequate shade as the potato vines ripen and, thus, keeps the soil relatively cool until fall harvest.

Growth Crack, Hollow Heart, and Second Growth.— Frequently plant growth is curtailed by high temperature or lack of soil moisture to such an extent that tuber growth is greatly reduced. Then conditions again become favorable for growth and rapid tuber growth is resumed. Potato varieties show their response to such environmental conditions in different ways. The Red Warba, Warba, and Bliss Triumph crack open; however, the Red Warba cracks more freely than Bliss Triumph. Cobbler develops a hollow center, commonly referred to as hollow heart, instead of cracking on the outside. Early Ohio commonly starts a new growth from an eye, producing a knob. The paring quality of such tubers is greatly

impaired. The selection of soils well supplied with soil moisture at time of planting and moisture retention, thorough cultivation, and irrigation are factors to be considered in preventing such losses.

Mechanical Wounds.—Potato tubers are easily bruised at time of harvest. Such wounds may not be plainly evident at time of harvest, but during storage, develop to such an extent as to cause serious paring losses. Great care should be exercised to avoid injury during digging, picking, and grading. Pickers should handle potatoes with care. They should not toss the tubers into a container or handle them roughly while removing to storage. Figure 8 illustrates two types of picking containers commonly used by commercial producers. The wire stave basket allows the soil which falls from the

FIG. 8.—Desirable types of picking baskets. Left, rubber-covered wire basket which protects tubers from bruises. Right, wire basket.

tubers to fall from the container. The container to the right is similar, but the wire is covered with rubber to protect against tuber injury. Such containers greatly reduce mechanical injury, especially when immature potatoes are harvested.

Grading and Sizing.—The commercial grading of potatoes is aimed at two objectives: (1) To remove all serious imperfections caused by disease, insect injury, second growth, and mechanical injury; and (2) to separate potatoes into lots according to size.

Machines are used to separate potatoes according to size. The Kansas grower commonly makes three grade sizes. The large potatoes above 1 7/8 inches in diameter are referred to as No. 1 size and those 1 1/2 to 1 7/8 inches in diameter as No. 2 size, while the small sizes are considered culls as there is seldom a market for them.

After being separated according to size, those grades to be mar-

keted are usually passed over a sorting table where the tubers with serious imperfections are removed by hand.

For home use, grading for size may be desirable, but great care should be given to the removal of all tubers which show serious blemishes because they may later decay and affect the healthy tubers.

STORAGE

The potato keeps best when stored in a dark place, in a temperature ranging from 40° to 45° F. and in a relative humidity ranging from 85 to 87 percent of saturation. During the first three months of storage, a temperature of 40° F. and a relative humidity of 85 percent is most commonly recommended. As the tubers approach the end of their rest period, about three months after maturity, those to be used for eating should be stored at 45° F., to prevent the development of sweet flavor. Tubers to be used for seed potatoes should be held at 40° F., until two to three weeks before planting.

Ideal storage of Kansas potatoes at the time the early crop matures is to be found only in commercial cold storage, which is not generally available to the home gardener.

Cave Storage.— Caves dug into the ground and covered with 3 to 4 feet of soil are well protected against rapid temperature changes and when carefully managed, provide a good storage place for potatoes. The cave should be equipped with a ventilating system. A satisfactory system provides for cold air to be taken into the cave at the corners and the warm air to be taken out at the center top. The cold air duct should be carried to within 1 foot of the floor of the cave and the warm air duct placed in the center top of the cave. This assures air movement in all parts of the room.

Potatoes stored in a cave should be placed in bins. A bin of convenient size is 3 to 4 feet wide and not over 2 feet deep. The bottom and sides should be of slats to provide for aeration.

A dirt floor is ideal for aiding in controlling the humidity. When the floor is concrete it may be necessary to place sand, which may be moistened, on the floor to maintain the humidity desired.

When the outdoor temperature is high, the ventilators should be opened at night and closed during the day. For best results, potatoes should be placed in storage when cool and the temperature kept as near 40° F. as possible.

Potatoes stored in a cave frequently appear to be healthy and firm, but upon cutting into the potato, dark fibers are found spreading from the stem end about 1/16 an inch below the skin. This is a physiological disease known as "heat vascular necrosis," caused by potatoes' being stored at too high temperature. (See page 39.) The disease is not known to develop in potatoes stored in commercial cold storage or in potatoes which mature in the fall when the weather is cool and the potatoes are stored at temperatures below 50 degrees F.

Cellar Storage.— This is a very broad term as conditions within cellars vary so widely. The better cellars may be equal to caves

for potato storage, while others are very much inferior. Normally, the temperature in cellar storage is higher than cave storage and the relative humidity is lower. Potatoes harvested in early July and stored in the cellar frequently keep satisfactorily until Thanksgiving or Christmas, after which time the quality deteriorates rapidly. Potatoes in cellar storage should be spread thinly or stored in bins as described for cave storage.

Fall Harvest.— Permitting potatoes which matured in July to remain in the soil until fall is considered permissible only when no better storage place is available. When spring-planted potatoes are allowed to remain in the ground until fall, a smaller total yield may be expected, due to loss resulting from insects and diseases. Also the tubers in the fall are likely to be dark in color. Fall harvest should take place before the tubers start fall growth as potatoes which start growth become water soaked, greatly impairing the cooking quality.

The fall-harvested potatoes are commonly stored in a cave or cellar as described above. However, when cellar storage is used a specially prepared fruit cellar should be employed, especially in furnace-heated homes.

The growing of a fall crop of potatoes is practiced to a limited extent. Seldom does the crop mature before the top growth is killed by frost, thus an immature crop is harvested. The crop should be harvested soon after the vines are killed, exercising special care to avoid mechanical injury. The fall crop of potatoes frequently cracks open, if harvesting when the soil is cool and moist, and the air is warm. Such cracking is commonly referred to as air cracks and may be a cause of serious loss in paring.

Storage Suggestions.— In the above storage discussion, several methods are considered, of which only commercial cold storage is fully satisfactory. However, a combination of the above storage methods may prove to be an economical solution to the storage problem for the home gardener in Kansas.

A few additional suggestions follow: Harvest the spring potato crop as soon as mature and before the ground becomes hot. Place those potatoes to be consumed by Thanksgiving or Christmas in cave or cellar storage. Place in commercial cold storage that quantity needed by the family from Christmas on, leaving them in commercial cold storage until late fall, (about October 15) when temperatures in the home storage room are low enough for good storage. The charge for three months of commercial storage should not exceed 30 cents per 100 pounds. Potatoes of high quality are thus made available over a long period.

PART II.—POTATO DISEASES AND THEIR CONTROL

The potato is subject to numerous infectious diseases caused by fungi, bacteria, and viruses and to a number of noninfectious diseases, caused by unfavorable environment. In Kansas the most destructive infectious diseases of the potato are Rhizoctonia, spindle tuber, blackleg, and tuber decay. Infectious diseases of lesser importance because they are less prevalent or less destructive, include ring rot, scab, fusarium wilt, and early blight. The most important diseases caused by unfavorable weather in Kansas include soil scurf, hollow heart, tuber, and seed-piece decay, and vascular necrosis or blackening of food-conducting tissues just below the skin.

It is the purpose in this section of this bulletin to describe the causes and the symptoms of potato diseases that occur in Kansas and to present methods through which these diseases can be prevented.

FUNGOUS DISEASES

Rhizoctonia.— Rhizoctonia, caused by the fungus *Corticium vagum* B. and C., is the most common disease of potatoes in Kansas. This fungus causes brown, decaying areas on the underground parts of the plant (Fig. 9A) and produces the black, dirt-like sclerotia (Fig. 9C) that are so frequently found adhering to the surfaces of seed potatoes obtained from northern states.

The lesions produced on the underground portions of the potato plant cause a variety of injuries. Infections occurring on the sprouts before they emerge through the soil may cause them to rot off completely. New sprouts or side sprouts must be produced and this causes delayed emergence of the plants. Delayed emergence is particularly harmful to the spring potato crop in eastern Kansas where it is essential that the plants have as long a growing season as possible before the plants die due to high temperatures. Lesions may occur that only partially rot off the underground stems. Such lesions cause a reduction in vigor of the affected plants.

Lesions are commonly produced on the stolons of the potato plant and frequently cause them to rot off completely. In Kansas this is, as a rule, the most destructive effect of Rhizoctonia infection. Tubers later produced on such plants are clustered near the main underground stem and are frequently malformed.

The hard, black sclerotia that adhere closely to potato tubers are vegetative reproductive bodies of the Rhizoctonia fungus. They are produced only when temperatures are relatively cool, which explains why they are uncommon on potatoes harvested in Kansas in July. These sclerotia detract from the appearance of affected potatoes, but their chief importance is the fact that on seed potatoes they supply a source of Rhizoctonia infection for the new crop. The Rhizoctonia organism lives over winter by means of its sclerotia just as the potato plant lives over winter by means of its tubers.

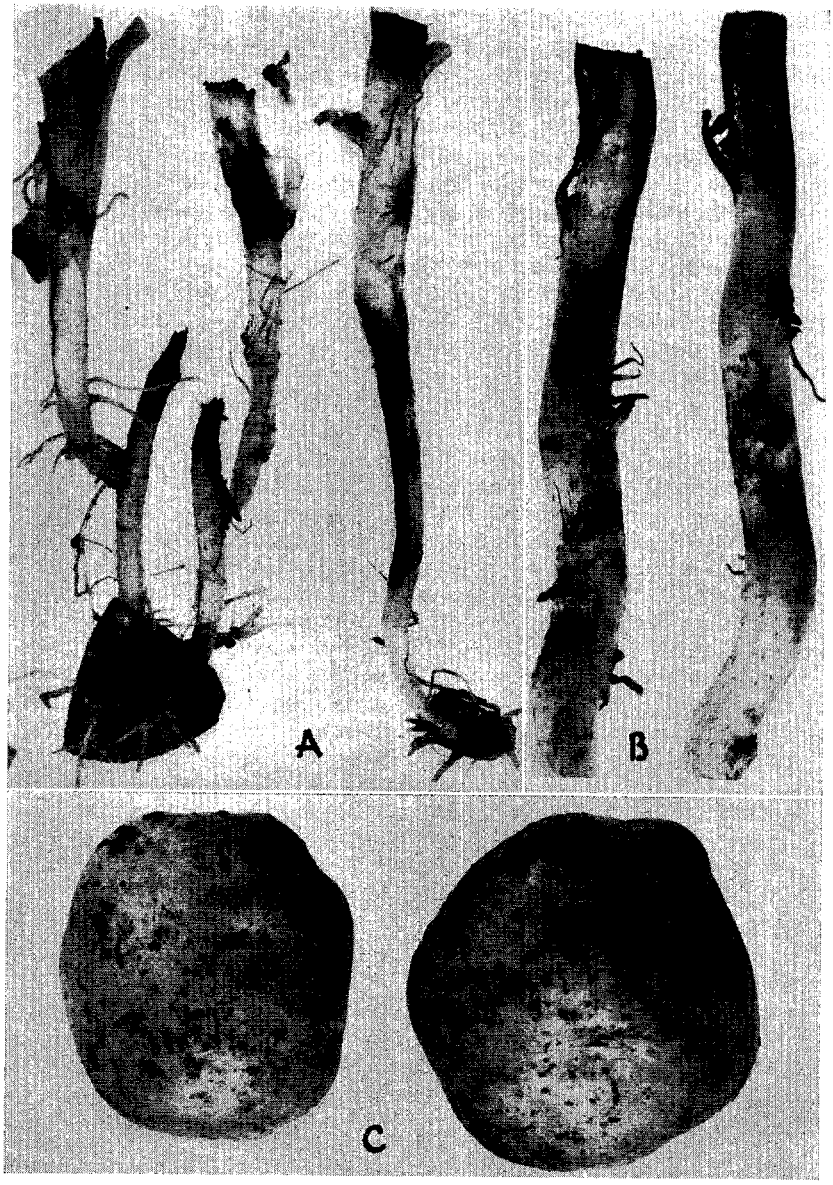


FIG. 9.—(A) Decay lesions produced by potato Rhizoctonia. Note side sprouts produced after the sprouts had rotted off. Such injury causes delayed emergence. (B) Potato stems infected with a damping-off type of Rhizoctonia. This Rhizoctonia causes damping off of the seedlings of many plants but produces only fleck-like lesions on potato stems. (C) Rhizoctonia sclerotia on potato tubers. Rhizoctonia fungus lives over winter by means of these sclerotia.

The practice of treating seed potatoes is largely for the purpose of killing these sclerotia.

Rhizoctonia can live from one year to the next not only by means of its sclerotia but it can also persist as mycelium (mould) in field soils or as sclerotia on decaying organic matter in these soils. Persistence of Rhizoctonia in the soil from year to year is dependent on environmental conditions. During July and August when temperatures in Kansas usually are too high for development of sclerotia, soil-borne Rhizoctonia is present only as mycelium. In this stage it can survive when the soil remains moist but dies during seasons when the soil becomes excessively dry.

Cultures of Rhizoctonia isolated from the potato, from various other plants, and from field soils have shown that strains of this organism occur that differ widely in virulence and in symptoms produced. Two general groups of cultures have been studied in Kansas, one of which causes characteristic Rhizoctonia lesions on the potato (Fig. 9A), the other practically harmless to the potato plant but which causes damping-off of the seedlings of many plants, including the legumes and many vegetables and flowers. The various cultures of the damping-off type of Rhizoctonia produce infection on potato plants but the lesions produced are mere flecks on the stem (Fig. 9B) and are less serious and entirely distinct from the symptoms produced by the potato Rhizoctonia type cultures. Potato type Rhizoctonia does not produce damping-off of seedlings but causes small necrotic areas on many of these, including alfalfa, vetch, cowpeas, and soybeans. This fact is of importance to the potato grower in Kansas as it indicates how these legumes which sometimes are utilized as soil-improvement crops in potato fields can serve as host plants to potato Rhizoctonia and carry this organism over periods when soil moisture becomes so low that the soil-borne organism would otherwise die.

Rhizoctonia can best be controlled by planting tubers free of sclerotia or by treating the infected seed potatoes with acidulated corrosive sublimate as described on page 42 of this bulletin.

Fusarium Wilt.—Fusarium wilt, caused by various species of fungi of the genus *Fusarium,* is a disease that produces wilting and death of potato plants and stem-end decay of the tubers. The symptoms of Fusarium wilt on the potato plant are usually a yellowing of leaves, beginning with the lower ones and progressing upward, more or less wilting of the leaves, and finally death of the plant. When affected plants die, the leaves turn brown and the stems remain erect. The water-conducting system of affected plants turns brown as can readily be seen by splitting the stems lengthwise. Plants may become infected at any time during the season, but infections occur most commonly on young plants.

The tubers on wilt-infected plants frequently become invaded by this fungus through their stolons. Wilt-infected tubers may exhibit blackened water-conducting tissues although blackening of these tissues may also be due to heat necrosis, blackleg, and other causes.

All wilt-infected tubers do not have blackened water-conducting tissues and freedom from this symptom does not furnish assurance that the wilt fungus is not present. Blackening of the water-conducting tissues is most likely to occur in advance stages of the disease, while such symptoms may be entirely lacking when the plants become infected late in the season.

Potato plants in the field having Fusarium wilt disease usually become infected by this fungus through wilt-infected seed. The plants may also become infected by soil-borne wilt fungus. Once introduced into the soil, this fungus can subsist there from year to year.

The planting of Fusarium wilt-free seed is the best method for preventing this disease of potatoes. Growers can avoid wilt-infected planting stock by planting certified seed.

Late Blight.— Inquiries are occasionally made by Kansas growers as to whether certain abnormal appearances, particularly wilting, of potato plants may be due to the late blight disease. It is for this reason that a short description of symptoms of this disease is given here.

Late blight, caused by the fungus *Phytophthora infestans* (Mont.) D By., requires cool moist weather. The disease causes affected areas of potato leaves to take on a water-soaked appearance and these areas soon become brown. Entire leaves or only portions of the leaflets may be attacked and, when severely affected, the plants die. Soon after becoming infected, a whitish, glistening, mould-like growth appears on the under surface of the leaf. This mould consists of the spore-producing structures of the fungus.

Late blight causes irregularly-shaped, sunken, brown, or metallic-colored decay areas on infected potatoes. The decay is rather dry in consistency but soft rot bacteria frequently follow and cause a wet decay. The disease may be carried long distances through tubers that do not decay and when planted these tubers produce late-blight-infected plants.

Early Blight.— Early blight, caused by the fungus *Alternaria solani* (E. and M.) J. and G., is one of the less serious diseases of the potato in Kansas. This disease is sometimes present on potato foliage in this state but rarely becomes sufficiently serious to cause appreciable crop losses. In Kansas this disease usually develops shortly before the crop matures in July. Tuber infections causing circular decay lesions on the potatoes are known to occur but have not been noted in Kansas.

Early-blight infections on potato foliage develop into small, circular or oval, dark-brown areas. The spots increase in size from minute dots to ½-inch or less in diameter, and concentric circles develop within these brown areas that give a target-board effect. Numerous infections on a leaf cause it to die prematurely and the death of many leaves before the tubers are mature causes a reduction in yield.

Owing to the fact that early blight does not cause appreciable crop losses in Kansas, efforts to control it are made only rarely. The disease can be prevented with bordeaux spray applied before infections become general.

BACTERIAL DISEASES

Potato Scab.—The potato scab disease, caused by *Actinomyces scabies* (Thax.) Guss., produces scabby spots and pits on the surface of infected tubers. (Fig. 10.) Individual lesions vary from minute spots to areas 1/3-inch or more in diameter. The scabby type infection consists of scaly-appearing areas, and the pit-type infection consists of open cavities that may extend approximately ¼-inch into the tuber. Numerous scab lesions may occur on the same tuber and a large portion of a tuber or its entire surface is sometimes covered by these lesions. Such areas are the result of the aggregation of many individual infections.

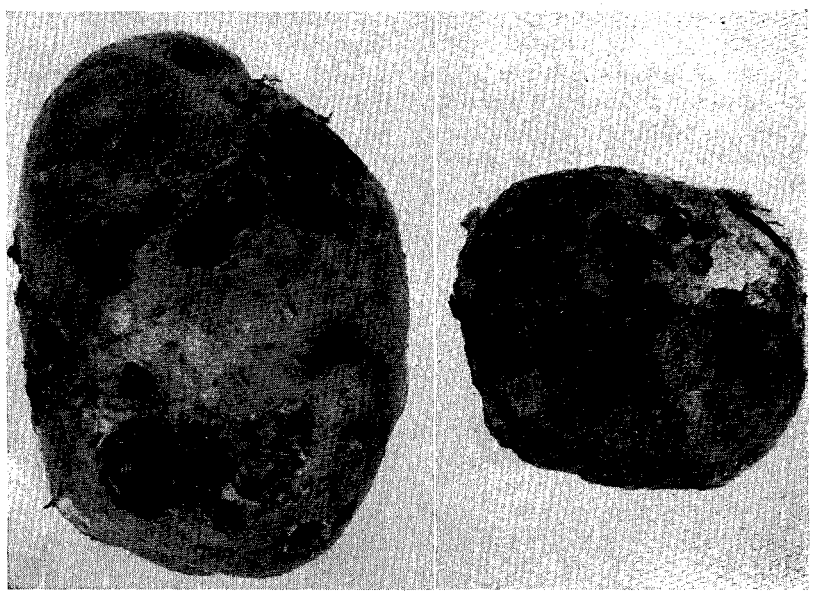


FIG. 10.—Potato scab. Right, tuber with the common corky, ruptured-type lesions. Left, tuber with deep or pit-type lesions.

The potato scab organism does not cause tuber decay but rotting of the tubers is frequently more serious in scab-infected than in scab-free potatoes. Rot-producing organisms that enter the tuber through the scab spots cause this decay. Such rotting is more prevalent when the soil is wet than when it is relatively dry.

The potato scab organism is introduced to field soils through infected seed potatoes. Once introduced, it lives on decaying organic

matter and can persist for many years even though potato plants are not present. The scab organism from lesions on potato seed pieces is of no great importance in causing infection of the current season's crop but causes field soil infestation. Soil-borne scab is the chief source of infection of the potato crop. The scab organism grows through the soil too slowly to spread from an infected seed piece to the newly developing tubers in time to infect them. The scab organism, however, multiplies and becomes distributed through the field soils during such cultural operations as plowing, harrowing, and cultivating.

Scab-infected potatoes are not produced every year in scab-infested fields in Kansas because weather conditions play a highly important role in determining whether the scab organism can or cannot attack the tubers. It has been found that scab cannot invade the tubers when the soil is relatively moist during the period the tubers are young and susceptible to infection. Infection occurs abundantly, however, when the soil is relatively dry during this period. The critical period being when the tubers are young and the skin immature, the amount of scab developing depends on the soil moisture condition during this period. Scab may be prevalent, during seasons that are generally wet, provided the soil is relatively dry at the time the tubers are susceptible to infection. This disease may, on the other hand, be absent during relatively dry seasons provided the moisture content of the soil is relatively high at the critical period.

No effective practical method of seed treatment has been found for sterilizing seed-borne scab lesions and it is advisable not to plant scab-infected seed. This is particularly true in fields not already infested with the scab organism.

Acidulated corrosive sublimate which is recommended for the prevention of Rhizoctonia apparently is not effective for sterilizing seed-borne scab lesions. The scab organism apparently is tolerant to mercurials. Information obtained in Kansas and elsewhere where corrosive sublimate and other mercurials were applied to scab-infasted soils in attempts to control this disease, resulted in an increase rather than in a decrease of scab. The application of corrosive sublimate and other mercurials to the soil apparently kills competing soil-borne microorganisms but does not kill the scab organism, and the scab organism is thus aided rather than injured.

Crop rotation and the growing of green manure crops have not proved of value for reducing scab infestation in Kansas soils. The application of sulfur to the soil caused a decided reduction in scab infection but sulfur injured the potato crop and also other crops planted in succeeding years so severely that this method of control caused more harm than benefit.

Blackleg of Potatoes.— The blackleg disease of potatoes causes considerable losses in Kansas. Fields in which 10 percent of the plants were killed by this disease were not uncommon in eastern Kansas during 1936 and 1942. In 1936 certain fields were found

FIG. 11.—Potato plant affected with blackleg. The stem is affected with a black decay upward from below the ground line. The disease is serious.

where blackleg had killed at least one-half of the plants. During most seasons, however, only a small percentage of infection occurs and even during 1936 and 1942, many potato fields remained free from blackleg infection.

Blackleg of potatoes, caused by a number of bacteria including *Erwinia cartovora* (Appel) Bergey *et al.,* affects both the plants (Fig. 11) and the tubers. The disease is essentially a soft rot. A dark brown or black decay of the stem, extending upward from below the soil line is a characteristic symptom on infected plants. The leaves of such plants turn yellow, curl upwards, and are usually held upright instead of spreading outward as they do in healthy plants. Potato plants that become infected while young remain stunted and usually die early. When older plants become infected, the blackening of the stems usually occurs in broad streaks that may extend upward along practically the entire length of the stem. Such plants may produce large tubers, a portion or all of which may become invaded by the blackleg bacteria through the stolons. Affected tubers may decay immediately or they may remain sound and if planted are a source of infection to the following season's crop.

Blackleg infection of potato plants usually originates from infected seed pieces. Seed-piece infection can occur in at least three different ways. One of these is through infected tubers borne on blackleg-infected plants. Another is the infection of planted seed pieces by blackleg disease bacteria that are present in field soils. A third way is by means of the seed-corn maggot. This maggot, which frequently is contaminated with blackleg-disease-producing bacteria, is attracted to the planted potatoes and as the maggot feeds on the seed pieces the bacteria are transmitted to them.

The prevention of potato blackleg disease includes consideration of the various means through which plant infections may take place. Prevention of the disease resulting from seed obviously can be accomplished by planting blackleg-free seed.

Preservation of the potato seed pieces largely will prevent the likelihood of their becoming invaded with soil-borne, blackleg-producing bacteria. Seed treatment with acidulated corrosive sublimate, as described on page 42 of this bulletin, is of great value for preventing seed-piece decay and thus for preventing infections by soil-borne, blackleg-producing bacteria.

Little is known concerning the importance of the seed corn maggot as a carrier of blackleg bacteria to seed potatoes in Kansas. The insect is present in this state and may at times cause infections here as it does in the northern states.

Bacterial Ring Rot.— Bacterial ring rot, caused by the bacterium *Phytomonas sepedonica* (Spieck.) Magrou, was first reported in the United States in 1932. Since its introduction, this disease has been reported from all potato-growing areas in this country and it is now recognized as one of the dangerous diseases of this crop.

Bacterial ring rot causes wilting and death of affected potato

plants and rotting of affected tubers. Wilting of the plants does not occur until comparatively late in the season when the new tubers are partly developed. The first wilting symptoms occur on the lower leaves and complete wilting and death of the plant may take place within a few days' time. Not all infected plants die prematurely, some of them remaining alive and producing full-grown tubers. Tubers decaying because of ring-rot infection first develop a yellowish, then a brownish discoloration of the vascular ring located a short distance below the skin. The ring rot bacteria themselves cause a decay of the flesh of the potato that has a cheesy consistency but due to additional infection with soft rot bacteria such tubers usually develop a wet, soft rot.

Tubers on infected plants are invaded by the ring rot bacteria through the stolons although all of the tubers borne on such plants may not become infected. Infected tubers may decay immediately, they may remain sound until shortly after they are harvested, or some may remain sound until the following spring when they are used as planting stock and serve as a source of infection for the new crop.

Infection of the potato plant usually results from the infected seed piece. The tubers may become infected through their stolons or the seed pieces may become infected with the ring rot bacteria through wounds. The inoculation of ring-rot-free seed pieces with ring-rot bacteria is very prevalent during cutting of the seed pieces and other planting operations, provided some of the tubers are affected with this disease. Countless numbers of ring-rot bacteria occur in infected tubers and during planting operations some of them adhere to the cutting knife, sacks, planters, or other planting equipment. These bacteria may subsequently be inoculated to seed pieces that are free of ring rot and the disease is thus spread widely among the planting stock.

The most effective way to prevent bacterial ring rot is to plant certified seed potatoes or seed stock known to be free of this disease. When such potatoes are not obtained and ring-rot infection is known or suspected to be present in the planting stock, provisions should be made to prevent its spread during planting operations by sterilizing the seed-piece surfaces after they are cut. The most practical method thus far devised and which has proved highly effective in tests in Kansas is to treat the cut seed with acidulated corrosive sublimate as described on page 42 of this bulletin. The seed pieces should be treated shortly after they are cut and they should be planted while they are still wet with the treating solution. Treatment soon after cutting is advisable so as to kill the bacteria before they penetrate deeply into the potato where they are protected from the treatment. Planting while the seed is still wet provides a continuous supply of corrosive sublimate solution for sterilizing planter pickers, sacks, and other surfaces with which seed pieces come in contact. Contaminated sacks and bin surfaces may be freed from ring-rot bacteria by wetting them with a formaldehyde solution at the concentration of one part formaldehyde to 120 parts water.

Decay of Potato Tubers.—Tuber decay is one of the chief sources of loss in the production and handling of the potato crop in Kansas. It occurs both as seed-piece decay of planting stock and as decay of the crop either before or after the tubers are harvested.

Seed-piece decay of potato seed pieces is frequently the cause of serious crop losses because of reduced stands and weak plants. The most common decay of the seed pieces is a soft rot produced by bacteria. Certain fungi also attack the seed pieces and cause their decay. Certain bacteria that produce soft rot attack the seed pieces but do not attack the stems, while others like the blackleg- and ring-rot-producing bacteria and some fungi attack both the seed piece and the plant.

Soft rot of seed potatoes, as the name suggests, consists in their disintegrating into wet, soft decay. In Kansas soft rot usually begins on the uncut surface and not on the cut surfaces of the seed pieces. The entire seed piece may decay, in which case a missing plant results. Weak spindling sprouts may be produced before the seed piece decays, in which case a weak plant results. The vigor of plants produced by decaying seed pieces varies from sprouts barely able to start growth to plants only slightly below normal. This variation depends on the amount of nutrients the sprouts obtain from the seed piece before it decays. The effect of decaying seed pieces on surviving plants is slower growth and later maturity. This effect is particularly serious in Kansas because such plants do not grow rapidly during the early part of the season and are unable to produce a good yield by the time the hot weather of early July stops their growth. The effect is similar to the effect of late planting.

The prevalence of seed-piece decay due to soft-rot-producing bacteria depends largely upon environmental conditions during the first few weeks following planting but may also be a result of the way the seed pieces were handled prior to planting. The amount of seed-piece decay varies greatly during different years. Excessive soil moisture is an important factor in determining its prevalence but serious decay does not always occur in wet soils. Rotting of seed pieces due to soft rot was very prevalent during the rainy spring of 1935 but was not serious in the spring of 1943 when soil moisture content was high.

The method of handling seed potatoes prior to planting has a great influence on the amount of seed-piece decay that develops after they are planted. The tubers should not be allowed to become too cold because injury may result even though actual freezing of the seed piece does not occur. Piling of cut seed in large piles, whether loose or in sacks, should be avoided, especially if planting is delayed because of unfavorable weather or other reasons. Potatoes used for propagation in Kansas preferably should be planted on the day or the day after they are cut. Investigations in this state indicate that seed-piece decay increases with the length of time elapsing between cutting and planting. Least decay results when the seed pieces are planted within a day or two after being cut.

Seed-piece decay can be reduced by proper handling of the seed potatoes and by seed treatment. As suggested above, chilling should be prevented, piling up of cut seed should be avoided, and the seed pieces should not be allowed to stand long before being planted. The acidulated corrosive sublimate treatment described on page 42 of this bulletin has proved highly beneficial for preventing seed-piece decay. In 1935 when seed-piece decay was exceptionally serious in eastern Kansas, particularly noticeable differences occurred in amount of decay in fields planted with treated and untreated seed. At the time the plants were blooming, considerably more than one-half of the untreated seed pieces were partially or entirely decayed, while less than 10 percent decay occurred among seed pieces that had been treated with acidulated corrosive sublimate. Equally good results followed treatment of the whole tubers or of the cut seed. When ring-rot-infected tubers are present, the treatment should, however, be applied to the cut seed.

The application of lime and gypsum to cut seed pieces, while not harmful, has not been found to protect them against decay. The application of these materials dries the cut surfaces but does not aid healing.

Decay of Kansas-grown potatoes, either before or after harvesting, is usually due to soft rot bacteria. The chief causes for this decay are wet soil, excessively high temperatures, and injuries of the tubers. The development of soft rot in Kansas-grown potatoes is one of the serious problems in producing, harvesting, and marketing the crop.

As a rule, it is difficult for potato growers to guard against soft rot induced by excessive soil moisture. Fields having good drainage sometimes can be selected for the potato crop and the chances of soft rot due to excessive soil moisture can thus be reduced.

Heat injury, which frequently is followed by soft rot, is common in Kansas because of high temperatures during the day and because of actual sunburn. Heat injury does not usually occur to potato tubers of growing plants whose leaves shade the ground but occurs principally after the plants die and lose their leaves and the ground is no longer shaded. Yields do not increase greatly after the leaves begin to die and in order to prevent tuber decay under Kansas summer conditions, the potatoes should not be allowed to remain in the ground after the plants are dead.

When potatoes are being dug, they should not be allowed to become hot by being exposed to the sun for long periods of time before they are picked up and transported to the shade. Heat injury, especially sunburn, largely can be avoided during excessively hot weather by digging only during the cooler part of the day, preferably in the morning. In order to reduce soft rot due to heat injury during such weather, digging should cease and no harvested tubers should be allowed to remain in the field from noon to near evening. Grading and packaging of the potatoes should be done in a shaded, well-ventilated place where the potatoes can be kept as cool as possible.

Soft rot of harvested potatoes is most likely to begin at points on the tuber where injuries have occurred. It consequently is highly important that the tubers be handled carefully during digging and thereafter in order to avoid cuts, bruises, or other injuries wherein the skin is broken.

VIRUS DISEASES

The potato is subject to a number of degeneration diseases caused by viruses. The effect of these virus diseases is a progressive degeneration from season to season until the plants no longer produce marketable tubers. Infections of healthy plants occur through inoculation into their cell sap of minute quantities of the virus in the cell sap of infected plants. Various insects transmit these viruses as they feed on the plants and inoculations also occur through cutting or otherwise wounding the tubers during planting operations. The most serious virus disease in Kansas is spindle tuber. Irish Cobbler, the most widely-grown potato variety in Kansas, is highly susceptible to this virus. Mosaic and other virus diseases are frequently present in Kansas, mosaic being particularly serious to Bliss Triumph but less serious to Warba and Irish Cobbler.

Spindle Tuber.—Spindle tuber causes a degenerative effect that results in greatly reduced yields. Recently infected plants produce only slightly decreased yields but when potatoes from such plants are planted the degenerative effect becomes progressively more severe in succeeding generations until no marketable tubers are borne.

The symptoms of spindle tuber can be noted both on the plants and on the tubers. The leaves of affected plants grow upright rather than spreading away from the stem as is the case in healthy plants. The angle between the leaf petiole and the stem is narrower in infected plants. The leaves of affected plants have a dull appearance rather than the shiny gloss of healthy leaves. This symptom is apparent from some distance and together with upright position of the leaves and absence of mottling or curling (a symptom of other virus diseases), furnishes evidence that the plant is affected with spindle tuber.

The symptoms of spindle tuber in affected potato tubers include an elongated spindling potato, an abnormally large number of eyes, and a roughness of the tuber surface caused by raised growths just above the eyes. These raised growths above the eyes are well described by the term "high eyebrows."

Plants that only recently have become infected with spindle tuber do not exhibit the symptoms of this disease so completely as do plants that have been infected for longer periods of time. Plants that become infected during the current growing season may not exhibit any recognizable symptoms of spindle tuber. The tubers borne on recently infected plants also may not exhibit any recognizable spindle-tuber symptoms. Tubers with and without spindle-tuber symptoms may be borne on the same plant.

Spindle tuber is transmitted from infected to healthy potatoes through inoculation of the virus-contaminated cell sap of an infected plant to that of a healthy plant. An infinitesimally small amount of virus introduced into a healthy plant has the ability to multiply in time to spread throughout this plant. The virus of spindle tuber may not progress to every part of the tubers borne by plants infected during the current season. When such tubers are planted, spindle-tuber-infected plants are produced only from those eyes in which the virus is present.

The most common means through which the virus of spindle tuber is transmitted to healthy potatoes is by means of insects or as a result of planting operations. Insects that feed on infected plants become contaminated with the virus and they may later transmit this to healthy plants. During planting operations spindle-tuber virus may be transferred from infected to healthy tubers through the cutting knife, through planter pickers, or by any other means through which the virus-infected cell sap of infected tubers is inoculated into healthy tubers.

Mosaic.—Certain potato virus diseases, including mild mosaic, rugose mosaic, and others, produce an abnormal mottled discoloration of the leaves. The mottling consists of yellowish green and dark green, indefinitely shaped areas in the leaf blade. These areas may or may not cross the veins. The mottling symptoms are most conspicuous following a cool period and they usually disappear entirely during hot weather. Affected plants may or may not exhibit stunting. Ruffling, wrinkling, or curling of the leaves is a symptom of distinct mosaic diseases by which they can be recognized.

Mosaic diseases are degeneration diseases and cause serious crop losses in most potato-growing areas. Their effect is to cause the plants to produce fewer and smaller potatoes. The degenerative effect becomes progressively more severe when tubers from succeeding crops are planted. Potato varieties differ in their susceptibility to the mosaics. The Irish Cobbler is resistant, Warba is fairly resistant, while Bliss Triumph is highly susceptible to injury by this disease. Consequently, care should be taken not to plant mosaic-infected Bliss Triumph or Warba seed stock.

The only way by which Kansas growers can avoid spindle tuber or mosaic is to plant seed that is free from these diseases. The appearance of seed potatoes as they arrive in Kansas is no certain indication that more or less spindle tuber or other virus disease infection is not present. The tubers that exhibit spindle-tuber symptoms may have been culled out. It was pointed out above that recently infected plants may produce tubers that are infected but do not exhibit symptoms of this disease. The best method for securing planting stock that is free from virus diseases is to obtain seed potatoes that have been certified by the potato seed certification agency of the state in which they were produced.

ENVIRONMENTAL OR NONPARASITIC DISEASES

Soil Scurf.—Soil scurf of potatoes is an abnormal condition of the outer skin of the tubers in which groups of those cells die and become brown and frayed, giving the tubers a scurfy appearance. The individual scurfy areas are small in size and they may vary in number from but a few to a sufficient number to cover the entire tuber surface. The scurfy areas involve only the outermost cell layers of the skin and an unsightly appearance of the tubers is caused which seriously lowers their sale value. Soil scurf is found not only in Kansas, but has also been observed on tubers from other states in the Great Plains area.

The cause of soil scurf is not known. Neither has any practicable method for its prevention been found. Proof as to whether it is caused by a specific organism or whether it is caused by environmental conditions requires further investigation.

Soil scurf occurs most frequently in fields where potatoes previously have been grown. It is a rule most prevalent on tubers produced in sandy soils, and because of this it is frequently referred to as "sand scurf." Potatoes growing on heavier and nonsandy soil, however, also develop scurf and the name "sand scurf" is consequently misleading.

Potatoes growing on sandy or loamy soils of eastern Kansas in which potatoes have not previously been grown usually do not develop soil scurf. It was noted that soil scurf did not occur on potatoes growing in newly-plowed fence rows where the tubers in the adjacent fields were severely affected.

Plowing under of alfalfa and vetch prior to planting potatoes may result in tubers that are free of soil scurf, but in other cases freedom from soil scurf does not follow the plowing under of these or other green manure crops.

The treatment of soils with chloropicrin (tear gas) and with formaldehyde in tests made in 1941, 1942, and 1943 resulted in the production of tubers that were practically free from soil scurf. The tubers produced in adjacent, untreated control plots were severely affected in 1941 but less so during the latter two years when soil scurf was not so serious. It has not been proved whether the application of chloropicrin and formaldehyde caused the sterilization of a scurf-producing microorganism or if the prevention of scurf in the treated plots was due to some other effect.

Heat Vascular Necrosis.—A condition frequently develops in potatoes harvested during the summer in Kansas where the vascular system of the tubers becomes necrotic and black. (Fig. 12.) The blackened vascular strands are located a short distance below the skin and can be exposed by peeling the tuber rather deeply. They are particularly noticeable in baked potatoes where they appear as a black, net-like structure. The necrosis of the vascular system may occur only at the stem end or it may extend over practically the entire surface of the affected tubers.

The vascular system of potato tubers may become blackened due to various causes as, for example, infection with Fusarium wilt fungi or ring-rot bacteria. Heat vascular necrosis is not due, however, to any microorganism but is caused by environmental conditions, particularly excessive and extended periods of high temperatures. Such environmental conditions evidently cause the death and subsequent blackening of the vascular cells while other tissues of the affected tubers remain alive.

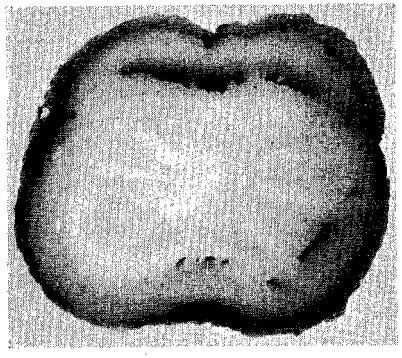


FIG. 12.—Heat vascular necrosis of potato tuber. This cross section shows the blackened food-conducting vessels of the tuber.

Vascular necrosis due to heat has not been noted in potatoes that matured in Kansas during the fall. The trouble is rarely evident in tubers of the commercial potato crop which is shipped and consumed early in the summer. The trouble is most common in tubers that are kept in the ground for considerable periods after the plants are dead or that have been stored under hot summer temperatures.

Heat vascular necrosis can be prevented by harvesting the tubers as soon as the vines die and after they no longer shade the ground, and by keeping the potatoes cool after they are harvested. The tubers preferably should be harvested in the morning while they are still cool. They should not be allowed to remain in the sun and become heated, and they should be kept in cool storage.

Tip Burn. — Tip burn of potato foliage is caused by environmental conditions and not by a pathogenic organism. This condition is most likely to occur during hot days that follow immediately after a period of cool, cloudy weather. The tender leaf growth that develops during the cool days is unable to become adjusted immediately to the hot weather, and wilting of the edges and tips of the leaves becomes so severe that these areas are unable to recover and the tissues die. Potato varieties differ in susceptibility to tip burn. Bliss Triumph is more susceptible in Kansas than is Irish Cobbler.

Tip burn should not be confused with hopper burn, caused by leaf hoppers and described on page 47 of this bulletin.

Spindling Sprout. — Potato tubers sometimes produce weak spindling sprouts or "hair sprouts" from a portion of, or all of their eyes. The production of such sprouts denotes a weakness of the tubers that may be due to various causes. Plants produced from such tubers are slow in emerging, slender and weak-appearing, and

do not produce good yields. Seed lots in which spindling sprout is prevalent should not be used for planting stock.

Spindling sprouts are sometimes produced by tubers whose sprouts have been repeatedly removed during storage. This condition may also develop from tubers that are affected with certain virus diseases. Spindling sprout may, however, also occur where no evidence of virus disease infection is present and denotes a constitutional weakness, resulting from the tuber having been subjected to unfavorable environmental conditions. Extremely high soil temperatures before harvesting and too low temperatures during storage are conditions believed to produce physiological weakness of tubers that results in the production of abnormally weak, spindling sprouts.

POTATO SEED TREATMENT

The purposes of treating seed potatoes are: First, to control seed-borne Rhizoctonia; second, to prevent seed-piece decay; third, to prevent the spread of ring-rot bacteria from infected to noninfected seed pieces during plant operations; and fourth, by preventing seed-piece decay to avoid blackleg infection caused by soil-borne, blackleg-producing bacteria. Evidence has been obtained that prevention of Rhizoctonia lesions on potato plants may also at times aid in preventing blackleg infection.

The most important potato seed treatments that have been used in the United States are with corrosive sublimate, formaldehyde, organic mercury compounds, and yellow oxide of mercury.

CORROSIVE SUBLIMATE

Corrosive sublimate (mercuric chloride) is the most widely used fungicidal chemical for treating seed potatoes. This fungicide, both with and without hydrochloric acid, is relatively effective for sterilizing tuber-borne Rhizoctonia sclerotia, for sterilizing ring-rot bacteria on the tuber surfaces, and for preventing seed-piece decay. Because of its ability to prevent seed-piece decay and Rhizoctonia infection, this fungicide also is indirectly useful in reducing the blackleg disease.

CAUTION

Corrosive sublimate and other mercurials are poisonous and great care must be taken that treating solutions are not taken internally, or that unpeeled treated tubers are not eaten either by man or by farm animals.

Unpainted, metal containers must not be used for corrosive sublimate solutions because of the chemical action that results wherein the corrosive sublimate breaks down and is lost as a fungicide and the metal container becomes corroded.

Potatoes should not be treated in sacks. The sacks absorb and consequently cause the loss of a considerable amount of the treating solution and in addition cause a decrease in concentration of the corrosive sublimate.

Corrosive Sublimate Treatment.—The corrosive sublimate treatment (without hydrochloric acid) consists of soaking the seed potatoes 90 minutes in a solution containing 4 ounces of corrosive sublimate dissolved in 32 gallons of water. A small quantity of hot water in a jar is convenient for dissolving the corrosive sublimate as this chemical dissolves very slowly in cold water. The treatment should be made in wooden barrels or asphalt-painted metal containers. Volume of treating solution should be maintained by adding solution prepared at the original concentration. Concentration of the treating solution decreases during treatment and should be maintained by adding ½ ounce dissolved corrosive sublimate after treating every 1,300 pounds of tubers.

Treating Small Lots of Potatoes.—Immerse potatoes 90 minutes in a solution containing ½ ounce (or 28 7.72-grain tablets) corrosive sublimate dissolved in a small quantity of hot water and then diluted to 4 gallons with water. Use wooden, earthernware, or painted metal containers. The same solution can be used three or four times.

The main objection against the use of nonacidulated corrosive sublimate when large quantities of potatoes are to be treated is the 90-minute treating period required. This objection is largely overcome by the acidulated corrosive sublimate treatment wherein the treating period is reduced to 10 minutes.

Acidulated Corrosive Sublimate Treatment.—Acidulated corrosive sublimate solution for the treatment of potatoes consists of 6 ounces of corrosive sublimate, 1 quart of commercial hydrochloric (muriatic) acid, and 25 gallons of water. The potatoes should be immersed in this solution for 10 minutes, after which they are ready to be planted.

Where large quantities of potatoes are to be treated it is convenient to prepare a concentrated stock solution by dissolving 1½ pounds of corrosive sublimate in 1 gallon of hydrochloric acid. One quart of this stock solution is the amount required for 25 gallons of diluted treating solution.

Containers, including pails, used for treating the tubers may be of wood or of asphalt-painted metal. Fifty-gallon capacity wooden barrels are convenient containers in which to make the treatments. Each will hold approximately 250 pounds of potatoes. A plugged hole should be provided at the bottom to drain off the treating solution after the tubers have been treated. The treating solution can be used repeatedly. Two barrels should be mounted on a platform and provisions should be made so that a barrel filled with potatoes is ready to receive the treating solution as it is drained from the barrel in which the treatment is completed.

During the treatment of large quantities of potatoes the treating solution becomes reduced both in volume and in concentration of corrosive sublimate. Provision consequently must be made to maintain the needed volume of liquid for immersing the tubers, and at

the same time maintain the required corrosive sublimate concentration necessary to produce effective results. A convenient way to maintain the needed volume is to provide a third barrel in which diluted acidulated corrosive sublimate is kept. Portions of this can be added to the treating solution as required. The required concentration of corrosive sublimate can be maintained in the treating solution by adding 1/3 pint of concentrated corrosive sublimate-hydrochloric acid stock solution (containing 1 ounce corrosive sublimate) to the diluted treating solution following the treatment of every 1,300 pounds of whole tubers. One-half pint of the stock solution (containing 1½ ounces of corrosive sublimate) should be added where cut seed pieces are being treated. The treating solution need not be discarded at the end of the day but accumulated dirt should be allowed to settle during the night and the clear liquid can be siphoned off in the morning.

Where tanks or containers larger than 50-gallon barrels are used for treating potatoes, similar provisions must be made to maintain the needed volume of liquid and the proper concentration of corrosive sublimate. Volume should be maintained by adding diluted treating solution as needed and loss in concentration of corrosive sublimate can be rectified by adding this chemical at intervals at the rate of 1/3 pint of the stock solution for whole tubers and ½ pint for cut seed following treatment of each 1,300 pounds of tubers.

Steps in the treatment of large quantities of potatoes with acidulated corrosive sublimate:

1. Provide a concentrated stock solution containing 1½ pounds corrosive sublimate dissolved in 1 gallon commercial hydrochloric acid.
2. Prepare diluted treating solution by mixing 1 quart of the concentrated stock solution in 25 gallons of water.
3. Provide an additional supply of diluted acidulated corrosive sublimate solution for maintaining original volume of the treating solution.
4. Treat tubers by immersing them for 10 minutes in the diluted treating solution. The treating solution may be used repeatedly and care should be taken to save it when it is being drained from the treated potatoes.
5. Maintain required concentration of corrosive sublimate by adding 1 ounce corrosive sublimate (1/3 pint stock solution) after treating each 1,300 pounds whole potatoes, or 1½ ounces corrosive sublimate (½ pint stock solution) after treating each 1,300 pounds of cut seed pieces.

Treating Small Lots of Potatoes.— Immerse potatoes for 10 minutes in a solution containing 1 ounce corrosive sublimate (or 56 7.72-grain tablets) dissolved in 1/3 pint hydrochloric acid and diluted in 4 gallons water. The same solution can be used three or four times. Do not use unpainted metal containers.

HOT FORMALDEHYDE

Hot formaldehyde is not so effective as corrosive sublimate for controlling Rhizoctonia and it causes injury to treated potatoes that results in delayed sprouting. Delayed sprouting is particularly injurious to yield of the spring potato crop in Kansas due to shortening of the growing season between the time the plants emerge and the advent of hot weather in early July when growth stops, irrespective of the stage of maturity of the plants.

The hot formaldehyde treatment consists in soaking the tubers from 3 to 5 minutes in a solution containing 1 quart of commercial formaldehyde to 30 gallons of water, the solution being maintained at a temperature of 123° F.

ORGANIC MERCURY COMPOUNDS

A number of organic mercury compounds are being manufactured and sold for the treatment of seed potatoes. Treatments consist in momentarily dipping the tubers in a solution containing the amount of organic mercury in water as recommended by the manufacturers. The concentration usually recommended is at the rate of 1 pound to 7½ gallons of water. All organic mercury compounds tested at the Kansas Agricultural Experiment Station were found less effective for preventing Rhizoctonia than acidulated corrosive sublimate.

YELLOW OXIDE OF MERCURY

Yellow oxide of mercury treatment of seed potatoes is particularly effective for preventing potato seed-piece decay but is relatively ineffective for preventing Rhizoctonia infection. Numerous instances have been noted where yield increases occurred following treatment with this fungicide even though Rhizoctonia infection was severe. Reduction of seed-piece decay that resulted in better stands was undoubtedly an important factor in causing the higher yields. Yellow oxide of mercury treatments consist of dipping the potatoes in a mixture containing 1 pound of yellow oxide of mercury in 15 gallons of water. Small quantities of potatoes can be treated by wetting them with a mixture containing 1 ounce of yellow oxide of mercury to 1 gallon of water.

PART III.—COMMON INSECTS ATTACKING POTATOES

Colorado Potato Beetle.—The adult, or beetle, is yellow with 10 black stripes on the wings. The body is about 3/8-inch long, ¼-inch wide, and very convex above. (Fig. 13.) The beetles spend the winter in the soil and begin to emerge in the spring about the time the potato plants are either coming up or are small. The orange-colored eggs are laid in clusters on the underside of the leaves. Within 4 or 5 weeks the female beetles will deposit on the underside of the leaves several clusters of eggs, or probably about 500 eggs. The eggs hatch in from 5 to 8 days and the humpbacked, reddish larvae or grubs feed on the tender leaves, grow rapidly, and

become full-grown in 2 or 3 weeks. They enter the soil to pupate. After 5 to 10 days, the beetles emerge from the pupae, crawl out of the ground, and, after feeding on the plants a few days, may lay eggs for a second generation of larvae, the adults of which pass the winter.

Control.— Spray or dust the potatoes with lead arsenate, calcium arsenate, cryolite, or paris green.

As a spray, use lead arsenate, 2 pounds; calcium arsenate, 1½ pounds; cryolite, 2 pounds; or paris green 1 pound, plus 2 pounds hydrated lime to 50 gallons of water.

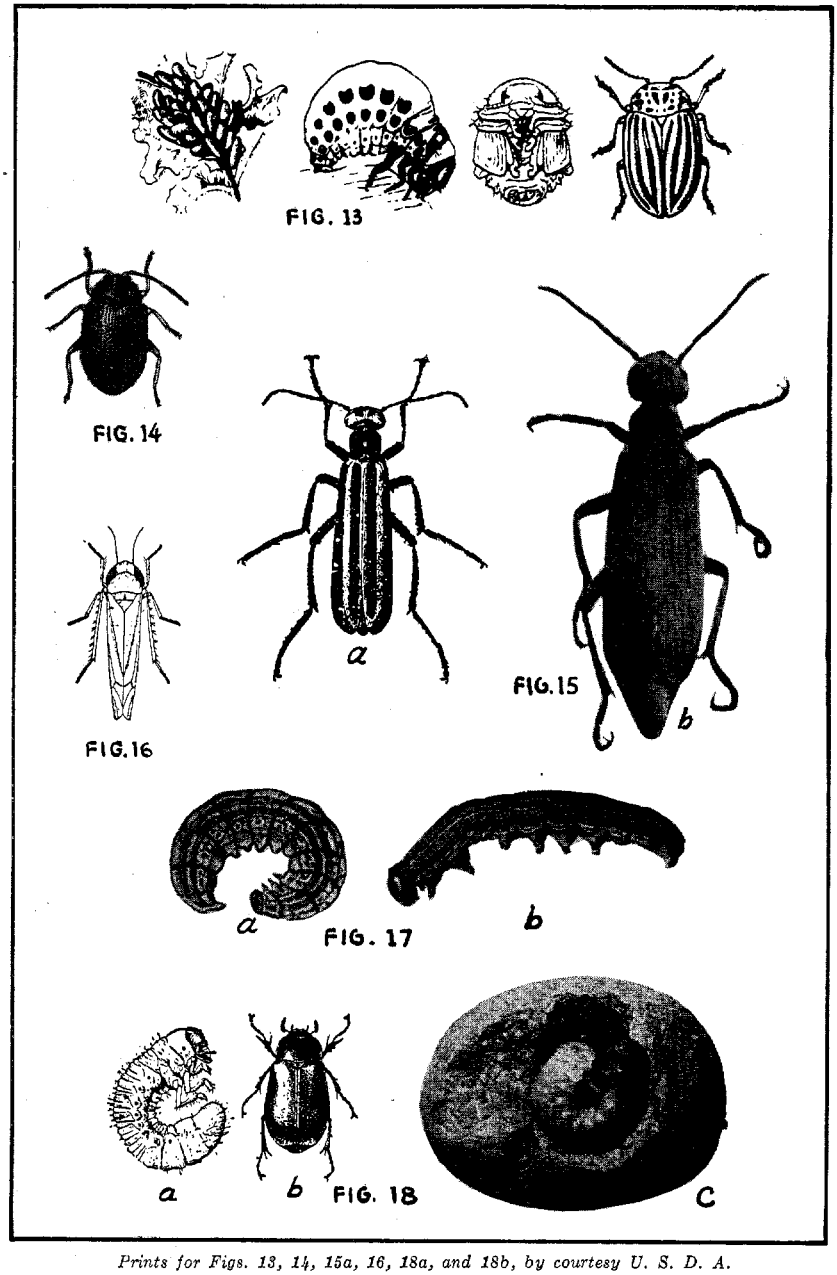
As a dust application, use lead arsenate, 1 pound to 5 pounds of lime, talc or flour; calcium arsenate, 1 pound to 7 of the diluent; paris green, 1 pound to 10 of the diluent; or cryolite, 1 pound to 2 pounds of talc, flour, or sulphur. (Do not use lime.)

Flea Beetles.— The name, "flea beetle," is applied to several small beetles which have the hind legs enlarged and adapted for jumping. One of the most common flea beetles found feeding on the leaves of the potato is the potato flea beetle *(Epitrix cucumeris* Harris). Flea beetles pass the winter in the adult stage. The beetles may be found in alfalfa fields hibernating under leaves, in trash and grass about the margin of the fields, along fence rows, ditches, and margins of wooded areas. The potato flea beetle is 1/16-inch long and nearly black. (Fig. 14.) The beetles emerge in the spring and injure the tender potato leaves by eating irregular holes through or into the leaves, giving them the appearance of having been peppered with fine shot. The potato flea beetle is a carrier of potato early blight. These beetles may carry certain disease organisms from one plant to another and spread them as they feed. The larvae of the beetles may feed on the roots of the same plants, eating the rootlets or burrowing in the roots.

Control.— Dust or spray with lead or calcium arsenate. Best results where bordeaux sprays are advisable have been had by applying a combination of bordeaux mixture at the regular strength and lead arsenate or calcium arsenate at the rate of 2 pounds to 50 gallons of the bordeaux. The sprays should begin early and be applied at intervals of 7 to 10 days. A thorough clean-up of the weeds, grasses, leaves, and other rubbish around the garden or field is recommended.

Blister Beetles.— Blister beetles are ash-gray, black, yellowish, or black and yellow striped. The beetles have long legs and soft, elongated bodies. (Fig. 15.) They sometimes suddenly appear in gardens and quickly destroy the leaves of potatoes, tomatoes, and other garden plants.

The life history of the blister beetle is unusual and complicated. The female beetle lays a large number of eggs in small cavities in the soil. In about 10 days these eggs hatch into long legged larvae which run about searching for the pods of grasshopper eggs upon which they feed. During the summer and early fall the larvae pass



Prints for Figs. 13, 14, 15a, 16, 18a, and 18b, by courtesy U. S. D. A.

FIGS. 13 to 18.—(13) Colorado potato beetle, enlarged 1½ times. (14) Potato flea beetle, enlarged about 10 times. (15) Blister beetles. (*a*) Striped blister beetle; (*b*) ash-gray blister beetle—both slightly enlarged. (16) Potato leafhopper, enlarged 4½ times. (17) (*a*) Cutworm; (*b*) armyworm. (18) White grubs. (*a*) Larva or grub; (*b*) adult or June beetle; (*c*) white grub in potato.

through several rather distinct forms with short legs, hibernate in the soil during the winter, continue as larvae the next spring, then pupate and transform to adults or beetles in the summer. They usually attack potatoes and other garden plants during the latter part of June and through July and August. Since they usually move in from some adjoining field, a close watch should be kept, and just as soon as they appear, methods of control should be used.

Control. — Dust with rotenone products (derris, Cube, 4 percent rotenone), 1 part to 3 parts of talc, clay or flour; or barium fluosilicate (Dutox), 1 part to 2 parts of talc, hydrated lime, or flour; or cryolite, 1 part to 2 parts of talc, sulphur, or flour.

Potato Leafhopper. — The potato leafhopper is one of the most serious insect enemies attacking the potato. The adults and the young forms, known as nymphs, feed by puncturing the veins on the under side of the leaves and sucking the plant juices. The injections of saliva while feeding cause a serious, injured condition of the potato plant called hopperburn or tipburn, which may result in heavy losses of the potato crop.

The potato leafhopper apparently does not winter in Kansas, but migrates annually from the south, becoming abundant the latter part of June and through July and August. The adult is a wedge-shaped insect, pale green, and 1/8-inch long. (Fig. 16.) The eggs are deposited in the tissue of the potato plant. The eggs hatch in about a week into wingless nymphs which feed upon the under surface of the leaves. They become winged adults in from 10 to 14 days. Under normal conditions, the adults begin laying eggs in 5 or 6 days for another generation. The life cycle is about 1 month.

Control. — To control the leafhopper and prevent hopperburn, spray with bordeaux mixture, 4-6-50. Repeat weekly if necessary. Usually, however, bordeaux sprays seldom are necessary in the Kaw valley and southcentral-Kansas areas, because the leafhoppers appear about the time the spring crop is ready to harvest. The Cobbler variety is resistant. In northeast and western Kansas, where planting is later and harvest takes place in early fall, it is necessary to use the bordeaux to prevent hopperburn.

Grasshoppers. — Potatoes and other garden vegetable crops are subject to attack by several different kinds of nymphs and adult grasshoppers which usually move or migrate into the vegetable garden from the surrounding fields, especially meadows, pastures, legumes, small grains, and wasteland.

Control. — The poisoned bran bait is a very satisfactory control method.

FORMULA FOR THE BAIT

	Small quantity	Large quantity
Wheat bran	5 lbs.	20 lbs.
Paris green, white arsenic, or sodium fluosilicate	¼ lb.	1 lb.
Molasses (black strap)	1 pt.	2 qts.
Water	2½ qts.	3 gals.

In preparing the poisoned bait, mix the bran and the poison thoroughly while dry in a pan or washtub. Dissolve the molasses in the water and wet the bran and poison with the sweetened water, stirring at the same time to dampen the mash thoroughly.

The grasshoppers should be poisoned before they enter the garden or potato field. A close watch should be kept, and as soon as the hoppers are beginning to move into the potato field, the bran mash should be sown broadcast in a strip along the edge of the field nearest the source of infestation. It should be sown early in the morning, or at the time the grasshoppers begin to move about or resume activity. In order to protect the potato plants, it may be necessary to make several applications of the bait. If the hoppers are already in the field, the bait should be sown sparingly over the potato plants. If the potato plants have been sprayed or dusted for the control of the Colorado potato beetle, and the leaves are still well covered with this poison, it will kill the hoppers attacking the plants.

Caution.— Receptacles containing the poisoned bait should not be left around where children, dogs, chickens, and livestock will have access to it. With proper care, there is no danger.

Cutworms and Armyworms.— Potatoes also are subject to attack by armyworms and several species of cutworms which usually migrate into the potato field from grasslands, alfalfa or sweet clover fields, and small grains, especially rye. (Fig. 17.) These insects or worms usually pass the winter as partly-grown larvae or worms in the soil, or under trash and in clumps of grasses. They begin feeding in April and continue through May and early June.

Control.— The most effective and practical method of control is to poison the cutworms or armyworms with poisoned bran mash prepared and applied in the same manner as for grasshoppers. The poisoned bait should be sown broadcast over the plants well toward evening or at dusk. Do not apply the bait on a windy, chilly evening. If the worms are coming in from adjoining alfalfa and grasslands, several applications of the bait may be necessary.

White Grubs.— White grubs are the larval stage of May or June beetles. (Fig. 18.) Most species require three years to complete their development. They frequently attack the tubers by burrowing or eating ragged holes in them, especially if the potatoes are not dug at time of maturity. The beetles lay their eggs in the soil. The grubs hatching from the eggs live entirely beneath the soil, feeding on roots and tubers. Grassy and weedy ground and old sodlands frequently are infested.

Control. — Disking in late summer and early fall and fall plowing will destroy many of the grubs. Prompt digging will prevent much injury. Crop rotation with a legume, such as sweet clover or alfalfa, is the most effective means of control. White grubs do not infest sweet clover and alfalfa plants. However, if there is a poor stand, and weeds and grasses have encroached, the white grubswill be in the soil feeding on the grasses and weeds.

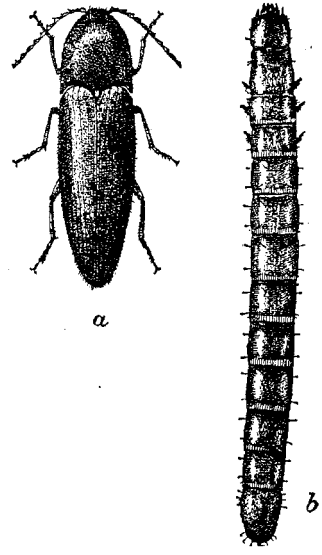


FIG. 19.—Common wireworm. (*a*) Adult, enlarged 1½ times. (*b*) Larva, enlarged 2½ times. (*Courtesy, United States Department of Agriculture.*)

Wireworms. — There are several species of wireworms which may attack potatoes. They are slender, cylindrically-shaped, hard-shelled, soil-inhabiting larvae or worms which vary from ¾-inch to 1 inch in length. (Fig. 19.) They are the larval stage of gray, brown, or nearly black "click beetles." These beetles vary from ½ to ¾-inch in length. The larvae live from 3 to 5 years before passing into the pupal stage.

Control. — The same as for white grubs, especially the rotation with sweet clover or alfalfa which is free from grasses.

SUMMARY

PART I.—CULTURE

A fertile, loose, friable soil, high in organic matter, and for western Kansas, a soil well supplied with soil moisture at planting time, is desirable for potato production.

Irish Cobbler, Bliss Triumph, Red Warba, and Warba are varieties grown commercially in Kansas.

Irish Cobbler, Red Warba, Warba, and Early Ohio are important home garden varieties.

The use of certified seed potatoes of recommended varieties is advocated.

Early spring planting is recommended for maximum yields.

Seed pieces ranging in size from 1 to 1½ ounces produce most economical yields.

Seed pieces planted by hand are commonly placed in furrows and covered with 2 inches of soil, while machine-planted seed pieces are commonly placed 2 inches below the surface of the soil and a mound thrown over the row.

Shallow cultivation to control weeds, to conserve soil moisture, and to move soil toward the plants to prevent tuber sunburn is recommended.

The crop is best harvested as soon as the plants become mature and before the tubers become heated.

All tubers showing mechanical injury or disease should be removed for immediate use or discarded.

Potatoes stored for future use keep best at a temperature of 40 to 45° F., in a relative humidity of 85 percent, and in darkness. In home storage these conditions should be maintained as nearly as possible.

PART II.—DISEASES

Plant disease-free seed for prevention of spindle tuber, mosaic, ring rot, fusarium wilt, and seed-borne infections with scab and blackleg. The safest way to provide disease-free planting stock is to plant certified potatoes.

Treat seed potatoes before they are cut for prevention of Rhizoctonia and seed-piece decay. When ring rot is present, treat the cut seed pieces to prevent the spread of this disease to the healthy seed pieces during cutting and planting.

The potato seed treatment recommended is a 10-minute soak in a solution of 6 ounces of corrosive sublimate and 1 quart of commercial hydrochloric acid in 25 gallons of water.

The prevention of delayed emergence due to Rhizoctonia, decaying seed pieces, or any other cause, has a great influence on yields in this state.

Potato scab infections originate from the soil-borne scab organism. Scab-infected potatoes should not be planted because this organism is introduced into the soil through the planting of such seed.

Invasion of the potato plant by blackleg disease usually occurs through decaying seed pieces. Prevention of seed-piece decay by effective seed treatments, by planting on well-drained soils, and by good cultural practices not only assures better plant stands, but also aids in preventing the blackleg disease.

Potatoes produced in Kansas for home use should not be allowed to become heated either in the soil or in storage.

PART III.—INSECTS

Nine common insects attack the potato crop of Kansas. These insects are: Colorado potato beetle, flea beetles, blister beetles, potato leafhoppers, grasshoppers, cutworms, armyworms, white grubs, and wireworms.

Either poison sprays, dusts, poison baits, or bordeaux mixture may be used to control these insects, with the exception of white grubs and wireworms, which can be controlled in a fairly effective manner by cultural methods.

Instructions for the preparation of sprays, dusts, or poison bran baits are given in the latter part of this bulletin under Part III for those insects that are controlled by the use of poisons. Cultural methods of control are given for those insects that are not susceptible to control by use of poisons.