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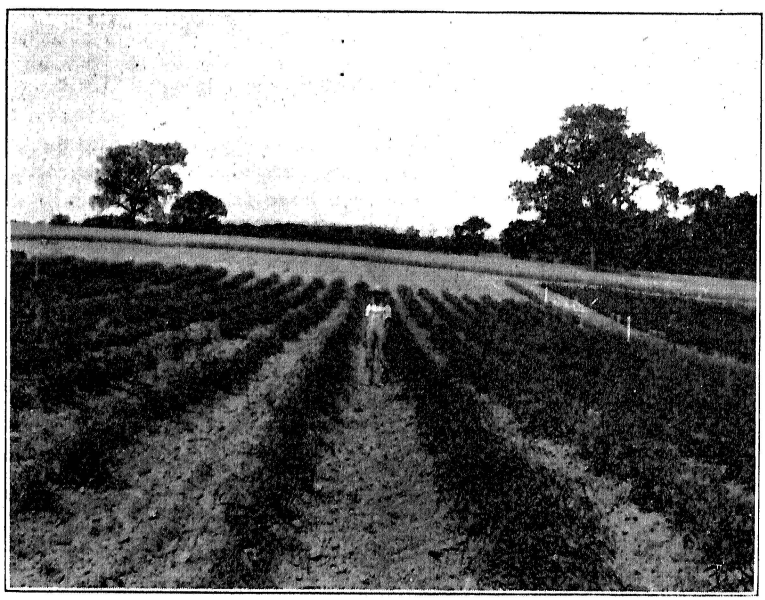
BETTER METHODS OF TOMATO PRODUCTION



Tomatoes grown on black silt soil at Columbia. On left, no fertilizer; on right, 178 pounds per acre of steamed bonemeal. June, 1921.

COLUMBIA, MISSOURI
JANUARY, 1922

MORE AND BETTER TOMATOES

The more a tomato grower invests in good seed, good plants, good cultivation and fertilizers, the greater become his profits. With yields less than 8 tons an acre the cost of growing a ton of tomatoes is $26.04; but when the yield exceeds 11 tons the cost per ton drops to $12.95. (Page 3).

The grower should buy seed from a seedsman of thoroughly established reputation for high grade products even though the cost seems high; or he should save seed from his own crop giving special attention to the vigor and productivity of the plant, the earliness of the fruit and its quality. (Page 4.)

The desirable plant for setting in the field is 10 to 12 inches tall, with thick, tough stem, plenty of dark green leaves, crown bud developed but not open, and a large fibrous root system. (Page 5.)

Tomatoes grow well on almost any type of soil—provided it is well drained. (Page 7.)

The earlier the transplanting is done—yet escaping frost—the better the crop is likely to be. (Page 8.)

Clean cultivation is necessary till the plants cover the ground. A straw mulch 5 or 6 inches deep also gives excellent results, but is too costly for use on a large scale. (Page 9.)

Staking and pruning do not pay. These practices even result in reduction of yields. (Page 10.)

Net returns from fertilizers used in tomato production are high. An investment of $8.80 in acid phosphate yielded a net return of $121.00 (Page 15.)

Increased earliness—very important to the market grower—also results from the use of fertilizer. Fertilized plots come into bearing three or four weeks earlier than those not fertilized. (Page 16.)

Best results from commercial fertilizers may be expected when this is drilled into the row and mixed with the soil before the plants are set. (Page 17.)

Tomato wilt can be prevented by growing the crop on fresh land. Resistant varieties are available which will produce a fair crop on badly infected soil. (Page 19.)

Leaf spot or "blight" can be controlled by rotation of crops, use of fresh soil in the plant bed, spraying or dipping plants in bordeaux mixture, and by application of copper sprays to plants in the field. (Page 20.)

Spraying for disease control is necessary in many localities where leaf diseases are serious. By spraying, the plants are kept in vigorous condition until the end of the season. (Page 21.)

Better Methods of Tomato Production

J. T. Rosa, Jr.

The tomato is the most profitable and dependable of home-garden crops. Large quantities are grown also by market gardeners for local sale and for shipment. And the culture of tomatoes for the canning factory has reached large proportions in Missouri, especially in the southwestern part of the state. The average yield of canning tomatoes in Missouri during the past four years has varied from 2.2 to 3.5 tons per acre while the average for the whole United States is 3 to 4.2 tons. Obviously there is need in many cases for Missouri growers to adopt improved methods of culture. Considerable attention has been given by this Experiment Station to means whereby the yield of tomatoes can be profitably increased. This publication combines the main points presented in two earlier publications,[1] together with additional information developed by recent experiments.

As a rule, the more a grower invests in good seed, good plants, good cultivation and fertilizers, the larger are his yields. Yet the cost of growing an acre of tomatoes need not be very much greater in order to secure a good yield than a poor one, and the cost per ton probably will be reduced. In one county in New York[2] it was found that the farmers whose yield of tomatoes averaged 5.6 tons per acre were producing the crop at a cost of $24.95 per ton; while the growers whose yields averaged 11 tons per acre produced tomatoes for $13.61 per ton. In another county, growers whose yields were less than 8 tons per acre were producing tomatoes at a cost of $26.04 per ton; while growers whose yields were over 11 tons per acre produced tomatoes for $12.95 per ton. In these localities the canneries were paying about $21.00 per ton for tomatoes. The growers producing the larger yields made a fair profit, while those producing the lower yields lost money by growing the crop. Unquestionably, the grower can in many cases greatly increase his net profits, and save land, time and labor by cutting down acreage and adopting practices which considerably increase yields..

VARIETIES

A large number of varieties of tomatoes are now grown in Missouri, many of which have been tested for several years at this Experiment Station. There is no one best variety, but the grower should attempt to secure varieties adapted to his special purposes. The market gardener whose greatest profits come from extra early fruit, should not only make every effort by cultural methods to advance the earliness of his crop, but use the best early maturing variety as well. The cannery grower should use a medium late, strong-growing variety with large smooth red fruits. Among those which have been found most satisfactory for canning purposes are: Stone, Greater Baltimore and Red Rock. Earlier varieties, better adapted

[1]Mo. Exp. Sta. Circ. 87, "Growing Tomatoes for the Canning Factory", and Mo. Exp. Sta. Bul. 169, "Profitable Tomato Fertilizers".
[2]Market Growers Journal 23: p. 157, March 1, 1921.

for home and market garden use, are Bonny Best, Livingstone's Globe and June Pink.

Source of Seed.—Care should be exercised in obtaining seed. Varietal names often mean little. Experiments have shown that there may be more variation between different lots of seeds bought under the same name than between distinct varieties. When a large quantity of seed is used, there is an inclination to buy at the lowest price regardless of quality. Low-priced seed may be a by-product from the canneries and catsup makers' establishments, perhaps an indiscriminate mixture of seed of different varieties and of low grade plants. Mixed seed, varieties untrue to name, or unsuited for the purpose desired and seed from fruit of low quality or plants of poor type, even though of a desirable variety, cannot be expected to give the best returns. The grower should buy from a reliable seedsman or grower who has a reputation for high grade products even though such seed may at first seem expensive; or he should save his own seed.

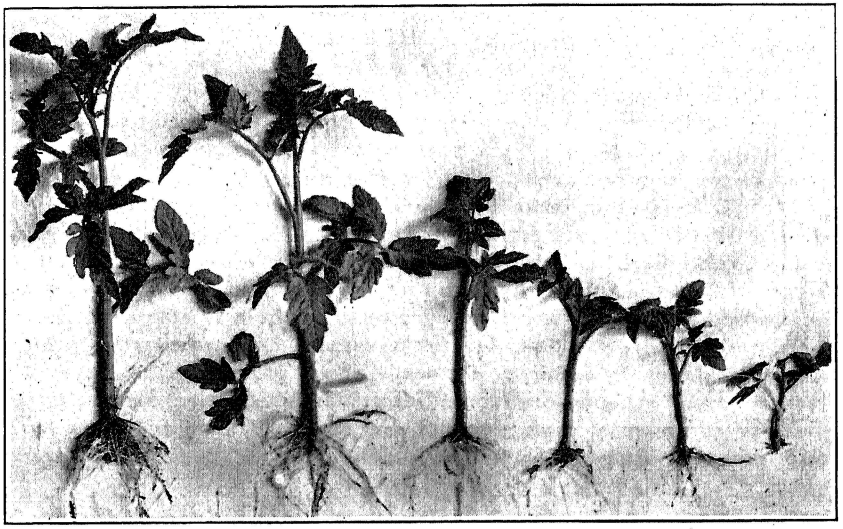


Fig. 2.—Variation in tomato plants from the same packet of seed. Use high quality seed to produce uniformly vigorous plants.

Seed Saving.—A good way to obtain seed is for the grower to save it for himself, selecting from the best plants in his field. Some factors which should be considered in saving seed from the tomato crop are:

1. The plant is the primary unit on which to make selections. Its vigor, disease resistance and productivity, as well as the quality of its fruit, should be considered.
2. Seed saved from early fruit are larger and heavier, and produce an earlier crop and more vigorous plants than that from late fruit.
3. The desired shape, size, flesh and color of the fruit should be considered and selection made accordingly.

If seed is to be saved by the grower, the following procedure is suggest-

ed: Inspect the field early in the season before the first fruits ripen. Mark with stakes some of the most promising plants—more than are necessary to furnish seed for the next season's crop. A few weeks later inspect the field again and leave the stakes beside those plants only which are healthy and give promise of continued heavy bearing. Fruits of desirable type are taken from these selected plants. The best results are obtained if selection is practiced year after year, keeping the same ideals as to plant and fruit characters. However, some improvement may be expected in such a selected strain the first year, as indicated by the results in Table 1. During 1919, selections were made according to the above plan by several growers. In 1920, the selected seed were planted at Columbia under uniform conditions,

TABLE 1.—YIELD OF TOMATOES FROM SEEDSMAN'S STOCK AND FROM GROWER'S MASS SELECTIONS.

Variety	Average for seedsman's stock lbs. per acre	Yield for selected seed-lbs. per acre		Average percent gain for selections
		Grower No. 1	Grower No. 2	
Stone	18,686	19,840	20,335	7.5
Earliana	17,885	18,035	18,270	1.4
Greater Baltimore	18,700	21,495	------	14.9
John Baer	17,205	------	18,820	9.3
Bonny Best	15,735	------	18,820	26.3
Red Head	14,950	26,410	------	63.3
Average gain	------	------	------	20.4

together with one or more lots of the same varieties grown from seedsmen's stock. In practically every case, the growers' selected seed yielded more than the best of the seedmen's stock. Averages only for the two classes of seed are given in the table, but they indicate that the practice of seed selection may be quite profitable to the grower.

METHODS OF PLANT PRODUCTION

The exact method to be followed in producing tomato plants depends on the object for which the crop is grown. As a rule, a cheap method will be followed by cannery growers, but that which seems the cheapest may prove costly in the long run, due to lower yields and late maturity. The larger and stronger the plants are at transplanting time, the greater are the chances of a successful crop. From the market gardener's standpoint, much depends on securing large stocky plants for early setting, consequently greater care should be taken in plant production. A desirable plant for setting in the field will be 10 or 12 inches tall, with thick, tough stem, plenty of dark green leaves, the crown bud developed and a large fibrous root system which will enable it to stand transplanting. It is well to set plants in the field before the crown buds bloom, otherwise the blossoms usually drop without setting fruit, causing a loss of the extra early fruit.

The Open Bed Method.—The simplest method of producing tomato plants is to sow the seed in open beds after the season is far enough advanced so

that they can grow without protection. This produces small, hardy plants, easy to transplant, if thinned so that they are not crowded in the bed. The objection to this method is that it is impossible to get the plants ready for early setting, they do not mature fruit until late in the season and the yield of ripe fruit is low.

The Coldframe Method.—An improved method is to sow the seed in coldframes prepared the latter part of March in a warm sunny location. The seed is sown thinly in rows four inches apart; later the plants should be thinned if necessary. The beds may be protected with ordinary glass hotbed sash, or with cloth treated with hot linseed oil to render it waterproof and more translucent. This is an excellent method for producing plants suitable for cannery crops if the beds are handled carefully to prevent the plants becoming weak and spindling.

The Hotbed Method.—Stocky early tomato plants may be produced at low cost by sowing the seed rather thickly in rows 4 inches apart in a mild hotbed containing a layer of 10 or 12 inches of fresh stable manure. In Central Missouri the hotbed should be prepared the latter part of February. When the plants are about 3 inches high, they are transplanted to stand 3 or 4 inches apart in a coldframe covered with cloth or sash. This method is recommended for the average market gardener and shipper, as it furnishes strong vigorous plants for early setting rather cheaply. Enough seedlings for 5 acres can be started in a hotbed 6 by 18 feet. If the plants are transplanted to a coldframe, setting 3 by 3 inches apart, it will require a frame 6 by 30 feet to hold enough plants for each acre. Overcrowding in the plant bed is to be avoided, for it results in tall spindling plants with weak stems and small roots; many of such plants die upon transplanting and those which survive start growth slowly.

Plants for Extra Early Crop.—A method especially well suited to market gardeners desiring an extra early crop is to sow the seed in a greenhouse or strong hotbed, early in February in Central Missouri. When the first rough leaves appear, the seedling plants are transplanted to flats, folded paper pots, clay pots or dirt bands, which are then placed on the greenhouse benches or in a mild hotbed. This favors the development of a compact fibrous root system which is not disturbed in transplanting to the field and vigorous growth may begin at once. This method is good particularly because of the favorable conditions for rapid early growth, the importance of which can hardly be over emphasized.

Care of Plants in the Beds.—A mixture of equal parts of sand, well rotted manure and garden loam is very satisfactory for growing tomato plants. Use of such soil in the plant bed will favor moderately rapid growth and the development of a large root system. It should be renewed each season to avoid disease.

While tomato plants are growing in the beds the soil should at first be kept moderately moist by thorough waterings. Watering too frequently is likely to favor "damping off". The temperatures should be carefully regulated by ventilation. Day temperatures should range from 70° to 80° F. during the early part of the season and night temperatures from 45° to 60°. Ventilation is necessary also to permit the escape of moisture from the bed. On cold or cloudy days a little ventilation can be given by rais-

ing one end of the sash. When the sun is shining brightly, ventilation must be given freely. On cold nights, the beds should be covered closely. A way to provide additional protection on cold nigths is to spread a quantity of loose straw over the frames.

As the season advances, more exposure may be allowed by removing the covers from the bed during the day. For several days before shifting the plants to the field, covers should be removed entirely and moisture withheld to such an extent that the plants wilt somewhat. Under these conditions growth is checked, the plants become tough and woody and are thereby made better able to withstand sun, wind, cold and dry soils when transplanted to the field.

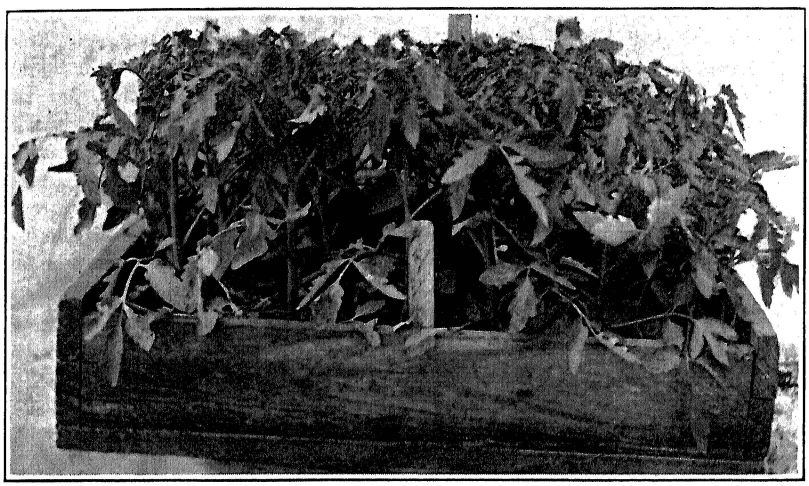


Fig. 3.—Stocky tomato plants grown 4 by 4 inches apart.

SOILS

The tomato is not exacting in its soil requirements. Good crops can be grown on nearly any soil, although the production of large crops at small cost is usually limited to certain soil types. The gravelly and stony loams of Southwest Missouri are particularly desirable. On them the tomato produces a crop of fruit unusually high in quality, though in most cases the fertility of the upland soils in that region is so low that manure or commercial fertilizer is needed for profitable production. Sandy loam soils are better suited to the production of tomatoes for the early market than a heavy mid-season crop for canning. The loess soils, especially in the hills along the Missouri River, are well suited to the culture of tomatoes for any purpose. Soils for tomatoes must always be well drained.

Red clover is one of the best crops to precede tomatoes in the rotation. Grain stubble land also is used frequently by cannery growers. Land which has been planted to tomatoes within five years should not be used because of the greater danger of disease. Land recently planted to corn is likely to harbor large numbers of the fruit worms, hence it should be

avoided. It has been found that more nitrogen, phosphorous and potash are returned to the soil in the vines and roots of tomatoes than is removed in the fruit. Hence, the generally observed fact that other crops grow especially well after tomatoes.

TRANSPLANTING

Tomato plants should not be set in the field until danger of frost is over, although they will withstand a light frost if properly hardened. As a rule, transplanting the early crop should be deferred until after May 1 in the latitude of Central Missouri. Where a large area is to be planted the horse-drawn machine planters will prove of great advantage. Some of the machine transplanters are constructed to supply water to each plant automatically but this is not necessary if plants and soil are in good conditions.

When setting plants by hand, a furrow should be opened in advance, its depth depending on the size of the plants to be set. If they are tall, the rows should be 6 inches deep so that a large part of the stem can be placed below ground. Shallow setting of large plants is very undesirable, as they are likely to fall over and be broken. However, when the stem is placed in the ground, roots will be formed along the underground portion, resulting in a more extensive root system. Overgrown leggy plants should be laid in the furrow horizontally and the tip end turned up 4 or 5 inches. It is especially desirable to firm the soil well around the roots of the plants as they are set, leaving the soil on the surface loose to prevent rapid drying out.

The most favorable time for transplanting to the field is in the afternoon, or on a cloudy day, preferably when the soil is quite moist. To prevent excessive wilting the plants should be well watered before removal from the plant bed and care should be taken to avoid mutilation of the roots. A small ball of earth should be retained around the roots of each plant when it is taken up for transplanting. If plants have been hardened by exposure to growth-checking conditions for a week or two, they should withstand transplanting without wilting. Shortly after the plants have been set, it is well to go over the field with a hoe or light cultivator, drawing earth toward the stems to give additional support to the plant and prevent excessive loss of moisture.

Planting distance.—The proper distance between the plants depends on the fertility of the soil, the variety and the method of culture. The richer the soil, the greater is the amount of space that should be allowed for each plant. Late, rank-growing varieties, such as Greater Baltimore, require more space than those of slight growth, as Bonny Best. On soils of average fertility the planting distances should be approximately 3 by 5 feet. Vigorous growing varieties can be planted 4 by 5 feet. For garden plots the plants can be spaced much closer. Experiments show that the total acre-yield is generally about the same, regardless of planting distances, but close setting requires a greater number of plants and increases the labor cost.

Importance of Early Setting.—The earlier tomato plants are transplanted to the field, the more satisfactory the crop is likely to be. This is es-

pecially true in this section, where the midsummer is usually hot and dry. Plants set before the middle of May will make a vigorous start and set a good crop of early fruit before the extreme heat and drouth of the summer. Plants set out June 1 or later are usually less successful, since they reach the fruiting stage at a period rendered extremely unfavorable by excessive heat and lack of moisture. Furthermore it is well to remember that when commercial fertilizers are used, they are utilized by the plants most efficiently when the soil is moist. In the case of rather late transplantings, moisture is deficient and commercial fertilizers are less effective in increasing yields.

CULTIVATION

Ordinary method.—Tomatoes require careful cultivation from the time the plants are set in the field until the vines begin to cover the ground. The first row-cultivation should be rather deep, forming a slight ridge of earth around the plants, for which purpose the ordinary corn cultivator is excellent. As the plants become larger, this tool should be discarded for a one-row cultivator. Later cultivations should be shallow so as not to injure the roots. Even after horse cultivation is discontinued the tomato field should be gone over with hoes to kill late weeds. It simplifies the tillage question very much if the plants are set in check rows so that cultivation can be carried on in both directions with horse drawn tools.

Mulching.—The practice of placing a straw mulch around the plants early in the season has been found to increase yields greatly the latter part of the summer when plants usually suffer from lack of moisture. Mulching is desirable for home gardeners and for market gardeners who have a demand for late tomatoes. The mulch keeps down weeds, eliminates the necessity for further cultivation, keeps the vines healthy and the fruit clean. It requires about 16 tons of straw to mulch an acre 5 or 6 inches deep. The cost of the mulching material and of its application will probably prevent its use on a large scale. In the home garden, grass clippings, strawy manure, cornstalks, leaves, etc., can be used for mulching.

Staking and Pruning.—Where tomatoes are grown for home use or for early markets it is a common practice to train the plants on stakes. Staking and pruning to a single stem is claimed to give a larger crop of earlier and fancy fruit, but these claims are not substantiated by the results of four years' experiments at Columbia. Four methods for handling tomato plants were tried; their effect on yield and earliness of fruit is shown in Table 2. Early varieties, Bonny Best and Earliana, were used. The plants were grown in the greenhouse and set in the field early in May each year. This experiment, therefore, deals with an early tomato crop such as a market grower would desire.

Table 2 shows that the largest total yield was produced by plants neither staked nor pruned.

The highest percentage of early fruit was produced by plants staked and pruned to one stem—but the amount of early fruit was actually greater from the plants allowed to grow in the natural way and their yield of late fruit was much greater. Staking plants without pruning did not reduce the

TABLE 2.—EFFECT OF DIFFERENT METHODS OF TRAINING ON YIELD AND EARLINESS OF TOMATOES.

Treatment	Year	Yield in pounds per acre				Percent early fruit
		Early	Mid-season	Late	Total	
Plants set 2′ x 3′, staked and pruned to single stem	1918	8,630	11,080	5,720	25,420	24.0
	1919	2,940	6,120	9,320	18,380	16.0
	1920	3,380	11,233	6,617	23,230	14.5
	1921	9,620	5,510	1,743	16,873	57.0
	Av.	6,140	8,485	5,850	20,976	30.8
Plants set 2′ x 3′, staked but not pruned	1918	----	----	----	----	----
	1919	----	----	----	----	----
	1920	2,640	27,470	13,730	43,840	6.0
	1921	7,040	9,130	2,160	18,330	38.4
	Av.	4,840	18,300	7,945	31,085	22.2
Plants set 3′ x 3′ staked but not pruned	1918	5,720	26,360	6,780	38,680	14.6
	1919	8,080	16,000	20,000	40,080	19.8
	1920	3,240	18,600	9,300	31,140	10.3
	1921	6,380	9,320	2,740	18,440	34.6
	Av.	5,855	17,570	9,705	32,085	19.8
Plants set 3′ x 3′, not staked nor pruned	1918	10,620	43,200	4,030	53,200	20.0
	1919	3,100	21,300	12,000	36,400	8.5
	1920	2,800	24,730	12,370	42,900	13.5
	1921	9,000	12,820	3,600	25,420	35.3
	Av.	7,130	25,513	8,000	39,840	19.3

yield so much as pruning to a single stem, but the amount of early fruit was much less.

Though staking and pruning tomato plants permits closer planting, facilitates cultivation and gathering the fruit, it is more expensive in plants, labor and materials. Since the practice also results in reduced yields, it appears to be decidedly unprofitable under Missouri conditions. These results are in general agreement with those obtained in Illinois, Kentucky and Nebraska.

COMMERCIAL FERTILIZERS

Fertilizer tests were made during 1919, 1920 and 1921 in various parts of the state in cooperation with tomato growers. Table 3 summarizes the averaged results of ten series of tests in 1919, including five different commercial fertilizers and stable manure.

The 1919 experiments indicated clearly that on soils of medium to low productivity, such as most of those used in these tests, a moderate application of well rotted stable manure applied in the row just before setting the plants may greatly increase the yield. However, this material did not increase the earliness of the crop, the bulk of the fruit ripening the latter part of the season.

Nitrate of soda used alone gave practically no increase on the average; in four tests, a slight increase resulted and in five tests a decrease. Sulphate of potash used alone caused a slight increase in yield on the average, but

TABLE 3.—SUMMARY OF TEN COOPERATIVE FERTILIZER EXPERIMENTS IN 1919.* (In lbs. per acre.)

Kind of Fertilizer	Amount per acre	Average yield lbs.	Average gain lbs.	Average percent gain
Stable manure	8 tons	11,548	6,072	112.5
5-8-7†	250 lbs.	11,346	5,684	105 5
5-8-0‡	250 lbs.	10,803	5,022	93.3
Acid Phosphate (16%)	250 lbs.	10,582	4,863	90.2
Sulfate of Potash	150 lbs.	6,196	1,155	21.4
Nitrate of Soda	150 lbs.	5,859	359	6.7
Check (Av. of 20)	None	5,391	----	----

*See Mo. Agr. Exp. Sta. Bul. 169 for full discussion of 1919 work.
†Commercial fertilizer containing 5% nitrogen, 8% phosphoric acid, and 7% potash.
‡Commercial fertilizer containing 5% nitrogen, 8% phosphoric acid, but no potash.

apparently on the soils used in these tests potash is not likely to be an important element in fertilizing tomatoes.

Of the commercial fertilizers, the complete high grade formula 5-8-7 produced the highest yield, considering the average of the ten tests. How-

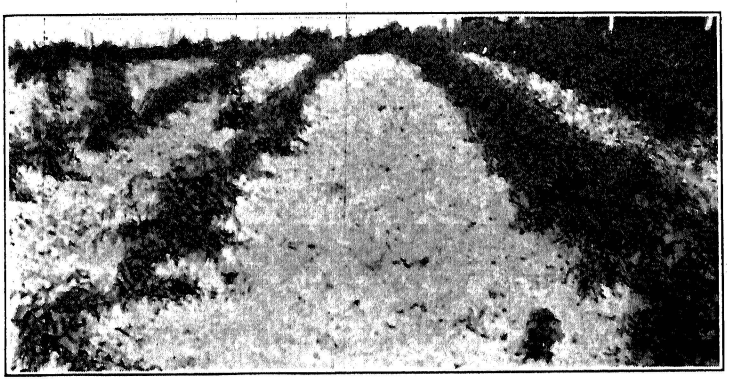


Fig. 4.—Tomatoes on stony Ozark soil: On left, no fertilizer; on right, 125 lbs. per acre 5-8-0 fertilizer applied.

ever, it actually produced the highest yield in only three tests. The no-potash fertilizer, 5-8-0, produced nearly as large an average yield and the highest yield in 4 tests, indicating that the omission of potash from the fertilizer did not greatly affect results. Acid phosphate used alone gave a very marked increase in yield in all tests and produced the highest yield in three. Since 250 pounds of acid phosphate contains twice as much phosphorous as the mixed fertilizers, this result is not surprising. The indications are that phosphorous is by far the most important single element in fertilizing tomatoes in Missouri.

In 1920 four cooperative experiments were made, with the formulas of fertilizers changed in the direction indicated by the previous year's results,

namely, reduction in percentage of nitrogen and potash, and increase in phosphoric acid. In all cases 200 pounds was the amount applied per acre. The results, given in Table 4, agree well with those of the previous year.

In 1921, cooperative demonstrations‡ on fertilization of tomatoes included three in St. Louis County and three in Jasper County. The results are shown in Table 5. The general results of the 1921 experiments are similar to those of the two preceding years. In three of the six tests, acid phosphate alone produced a greater increase in yield than did an equal weight of the mixed fertilizers, emphasizing the predominating need for

TABLE 4.—RESULTS OF 1920 COOPERATIVE FERTILIZER WORK.

Cooperator	Kind of soil and previous treatment	Fertilizer used	Yield lbs.	Gain lbs.	Percent gain
G. A. Pfieffer Marshfield, Mo.	Badly worn gravelly clay loam; tomatoes grown previous year	3-12-3*	4,270	3,990	1425.0
		3-12-0†	3,745	3,465	1247.0
		Acid phosphate	3,220	2,940	1050.0
		Check	280	----	------
R. H. Moore Marshfield, Mo.	Fairly rich black loam, creek bottom. In pasture previous year	3-12-3	8,560	4,750	124.0
		3-12-0	8,410	4,590	120.0
		Acid phosphate	8,390	4,570	119.0
		Check	3,820	----	------
J. Tucker Fordland, Mo.	Gravelly clay loam, clover sod and stable manure plowed under preceding fall	3-12-3	16,016	984	6.1
		3-12-0	15,510	410	2.7
		Acid phosphate	15,650	550	3.6
		Check	15,100	----	------

*Containing 3% nitrogen, 12% phosphoric acid, and 3% potash.
†Containing 3% nitrogen, 12% phosphoric acid, but no potash.

phosphorous in soils of this section. This indicates, that in soils as deficient in phosphorous as the soils of this section generally are, if only 200 to 250 pounds of commercial fertilizer is applied per acre, in the majority of cases the most enonomical increases in yield will be obtained by the use of acid phosphate. However, this might not be the case if considerably larger amounts of mixed fertilizers were applied—furthermore, the grower must consider the effect of fertilization over a series of years.

Net Returns from Fertilizers on Tomatoes.—Does it pay to grow a larger crop with the aid of fertilizers? Rent on land, the cost of plants, setting and cultivation are the same whether or not fertilizer is used. The extra expense includes the cost of the fertilizer, cost of application and of picking the extra fruit produced. These items have been estimated on the basis of current (fall 1921) prices for fertilizers, allowing $1.00 per acre for application and 5 cents a bushel for picking the extra fruit. The price

‡This work was carried on by Mr. E. M. Page, extension specialist in truck crops. Credit is due him for the 1921 data herein.

TABLE 5.—RESULTS OF 1921 COOPERATIVE FERTILIZER TESTS,
(In lbs. per acre.)

Cooperator	Kind of soil and previous treatment	Fertilizer used	Yield lbs.	Gain lbs.	Percent gain
J. I. Ferris, Webb City, Mo.	Gravelly silt loam, prairie soil. Grain farming, no manure.	2-12-2	3,100	2,635	738.0
		2-12-0	3,690	3,365	923.0
		Acid phosphate	3,885	3,520	968.0
		Check	365	----	------
F. L. Myers, Alba, Mo.	Fine sandy loam upland soil.	2-12-2	9,030	5,340	145 0
		2-12-0	7,950	4,260	115 0
		Acid phosphate	7,820	4,130	111.8
		Check	3,690	----	------
Geo. Fuchs, Jefferson Barracks, Mo.	Brown loess hill soil; in vegetables previous year.	2-12-2	8,130	1,510	22.8
		2-12-0	9,900	3,280	49.2
		Acid phosphate	10,135	3,515	52.8
		Check	6,620	----	------
S. E. Mo. State Teachers' College Cape Girardeau, Mo.	Clay loam, hill land. In pasture previous year.	2-12-4	12,760	5,620	78.7
		2-12-0	13,500	6,360	90.4
		Acid phosphate	11,160	4,020	55.3
		Check	7,140	----	------
R. E. Dressel, Sappington, Mo.	Loess silt loam, heavily manured. (Tomatoes staked and pruned.)	2-12-2	18,570	2,430	15.0
		2-12-0	16,740	600	3.7
		Acid phosphate	20,970	4,830	29.9
		Check	16,140	----	------
C. L. Wright, Webb City, Mo.	Dark silt loam, bottom land, grain farming.	2-12-2	22,575	4,655	34.5
		2-12-0	24,885	6,965	38.9
		Acid phosphate	21,490	3,570	19.9
		Check	17,920	----	------
Average for six tests		2-12-2	12,391	3,745	43.4
		2-12-0	12,772	4,126	47.7
		Acid phosphate	12,543	3,897	45.1
		Check	8,646	----	------

of the fruit is placed at $15 per ton. Table 6 gives the averaged results for the 1919 experiments.

Table 6 shows, after deducting the cost of fertilizer, of application, and of picking the extra amount of fruit produced, that the plots treated with the 5-8-7 mixture, the acid phosphate, the 5-8-0 mixture and the stable manure afforded substantial net gains per acre, in the order named. Nitrate of soda and sulphate of potash when used alone, resulted in a loss. It seems that a high grade complete fertilizer is the most economical, though in many cases when the amount of fertilizer used is small, 16 percent acid

phosphate used alone may give the greatest net returns upon the investment.

The work in 1921 dealt with tomatoes grown for shipment or for sale on local market. The results based on the average of two sets of experiments on early market tomatoes in St. Louis County are shown in Table 7. The price ranged from 5 cents per pound for the earliest fruit to 1.3 cents per pound at the end of the season. The net returns from use of commercial fertilizers are much greater in the case of the early market crop

TABLE 6.—EXTRA COST PER ACRE OF GROWING TOMATOES WITH FERTILIZERS AND NET RETURNS.
(Average of ten tests in 1919.)

Kind of Fertilizer	Amount applied per acre	Cost of fertilizer	Cost of application	Cost of picking	Total extra exp.	Yield per A. (tons)	Value of yield	Net gain from fert.
Stable manure	8 tons	$12.00	$2.00	$5.82	$19.82	5.77	$86.60	$23.88
5-8-7	250 lbs.	6.31	1.00	5.62	12.93	5.67	85.00	29.57
5-8-0	250 lbs.	5.00	1.00	5.08	11.08	5.40	81.00	27.42
Acid phosphate	250 lbs.	3.06	1.00	4.75	8.81	5.29	79.40	28.09
Sulphate of potash	150 lbs.	3.75	1.00	0.30	5.05	3.10	46.50	-1.05
Nitrate of soda	150 lbs.	5.02	1.00	0.18	6.20	2.93	44.00	-4.70
None	------	----	----	----	----	2.86	42.50	----

than were indicated in the preceding year's work on the cannery crop. In the 1921 experiments, acid phosphate used alone produced the greatest increase in yield and by far the greatest net returns. As the land used in both of these experiments had recently been manured for other market garden crops, it is not surprising that the acid phosphate gave larger returns than the mixed fertilizers. Since these tests were located on fertile market garden soil, it is particularly significant that the applications were very profitable—a total investment of $8.80 in acid phosphate yielding a net return of $121.00. The increased value of the crop from fertilized plots is due partly to increased yield and partly to increased earliness.

Effect of Fertilizers on Earliness.—One of the most important effects of fertilizers observed in these tests is the rapid early growth of the plants and the early date at which fruit begins to ripen on the fertilized plots.

TABLE 7.—COST PER ACRE AND NET RETURNS IN FERTILIZER TESTS WITH EARLY TOMATOES, ST. LOUIS COUNTY, 1921.

Fertilizer	Amount applied, per acre	Cost of fertilizer	Cost of application	Cost of picking	Total extra exp.	Yield per A. (tons)	Value of yield	Net gain from fert.
2-12-2	250 lbs.	$4.43	$1.00	$1.95	$7.38	13,350	$348.95	$44.32
2-12-0	250 lbs.	4.06	1.00	1.95	7.01	13,320	347.65	43.39
16% acid phosphate	250 lbs.	3.07	1.00	4.73	8.80	16,145	427.05	121.00
Check	0	----	----	----	----	11,380	297.25	----

The differences in total yield and earliness of fruits are shown graphically in figure 5. This is based on the average weekly yields of the untreated plots, in three of the 1919 tests. The check plots began heavy bearing the week of August 23-30, while the complete fertilizer plots came into bearing four weeks earlier, and the acid phosphate plots three weeks earlier. Both complete fertilizer and acid phosphate plots reached the peak of production a week before the plots that had no fertilizer. After September 6, there

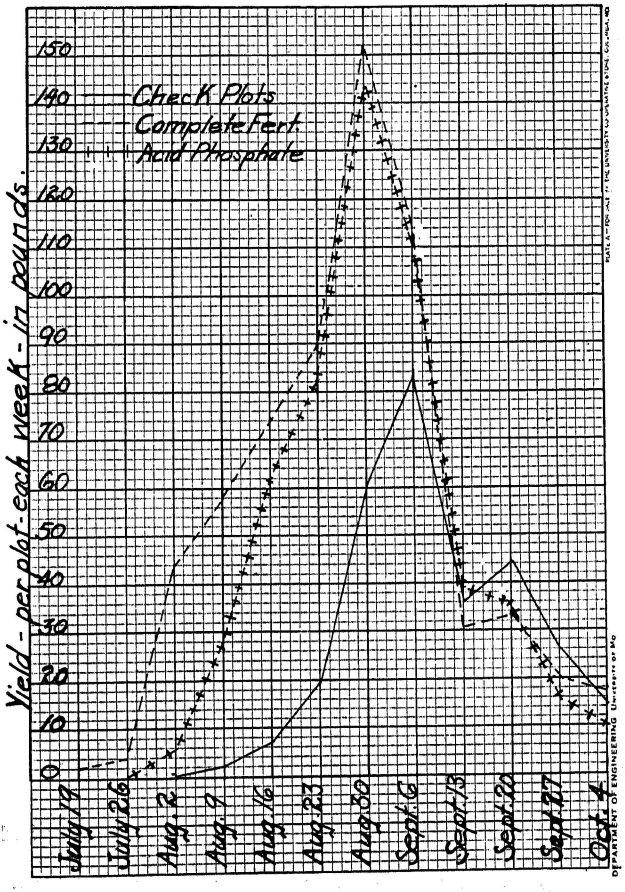


Fig. 5.—Effect of fertilizers on date of ripening and yield.

was little difference between fertilizer and check plots, as both declined rapidly. Similar results, showing a great increase in yield and a larger percentage of early fruit have recently been obtained in Indiana*, from applications of acid phosphate and mixed fertilizers containing a high percentage of phosphorous.

In several experiments where the total yield has been large because

*Market Growers Journal, 30: p. 72, Feb. 1, 1922.

of favorable growing conditions and natural high productivity of the soil, fertilizers have produced only a slight increase in yield, considering the season as a whole. However, in most of these cases, the production of early fruit has been much greater on plots receiving fertilizers than on the checks. A case of this sort is illustrated by figure 6, constructed from data obtained at Fordland, Mo., in 1920. The land for all plots had been in clover the previous year and a coat of stable manure was applied. The plot fertilized with 200 pounds per acre of 3-12-3 fertilizer started heavy bearing earlier than the check and produced a much larger yield of fruit the first three weeks, the yields being reversed the latter part of the season. Up

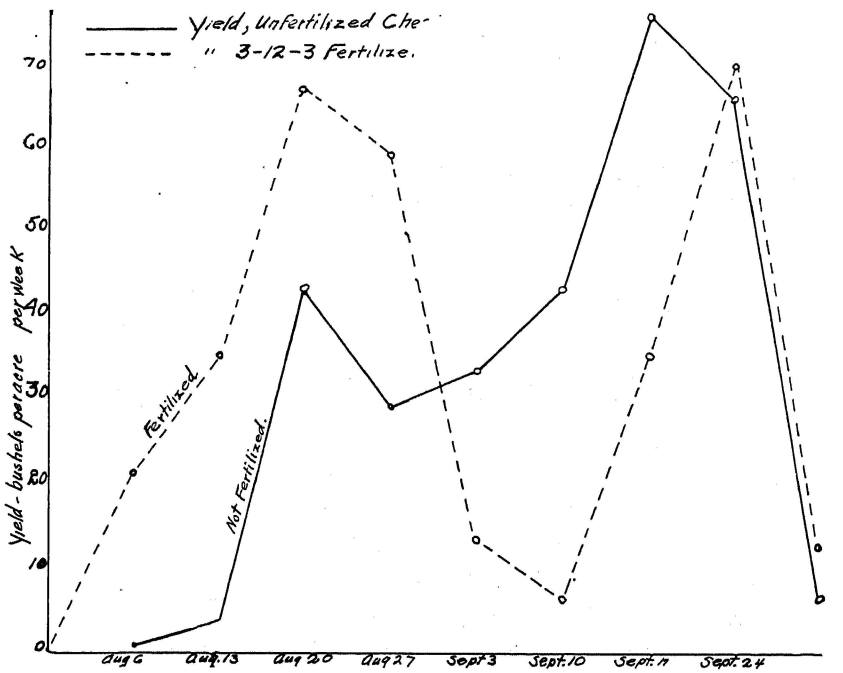


Fig. 6.—Difference in earliness where the increase in total yield is small.

to August 27, the check plot ripened 25.5 percent of its total yield for the season, the acid phosphate 47.5 percent and the 3-12-3 plot 57 percent.

The general effects of fertilizers in favoring early maturity are due probably to a more rapid development of the plant in its early stages rather than to any specific stimulation of fruit development and ripening. In the early part of the season, the root system is limited, therefore if a large supply of available plant nutrients is present, as it is if commercial fertilizer has been drilled in the row before the plants are set, they are enabled to start rapid growth at once. As in the case of total yield, phosphorous seems to be the most important element favoring earliness, but small percentages of nitrogen and potash are also helpful along this line.

Increased earliness of the crop is important to the market grower, for

the early fruit usually has the highest market value. To the cannery grower, increased earliness is an advantage for it distributes the season of heavy picking over a period of about six weeks, instead of three weeks, as in the case of the unfertilized crop. This would permit both the grower and the cannery to handle more tomatoes.

Method of Applying Fertilizers.—Tests have been made during the past three years to determine the most effective and economical method of applying commercial fertilizers to the tomato crop, when they are used in small quantities. Table 8 summarizes the results.

TABLE 8.—YIELDS WITH DIFFERENT METHODS OF APPLYING FERTILIZERS.

Year	Fertilizer used	Amount per acre	How applied	Pounds per acre		Per-cent gain
				Total yield	Gain over check	
1919	2-12-2	250 lbs.	In row, 5 days before setting.	14,860	3,820	34.6
1919	2-12-2	250 lbs.	Top dressing 10 days after setting.	12,200	1,260	11.4
1920	4-12-0	250 lbs.	In row same day plants were set.	25,700	4,500	21.2
1920	4-12-0	250 lbs.	Top dressing 10 days after setting.	23,600	2,860	13.7
1921	2-12-2	400 lbs.	In row same day plants were set.	15,550	5,910	61.0
1921	2-12-2	400 lbs.	Broadcast before setting plants.	15,050	5,410	56.0
1921	2-12-2	400 lbs.	Top dressing 10 days after setting.	13,000	3,360	35.0

It seems clear that for immediate results the best way to apply commercial fertilizer is by drilling it into the row and mixing with the soil before the plants are set. This might not hold true if very heavy applications were made, though as much as 1,200 pounds per acre applied in a single drilling has not injured tomato plants. It is important to supply fertilizers at the time and place the plant can use them most efficiently. Ordinarily there is plenty of moisture in the soil early in the season, but this is often lacking during midsummer so that fertilizers are ineffective if the roots do not reach them until then. When fertilizers are broadcasted, only a small part becomes available to the plant until the root system has spread out through the whole soil mass, too late for the plant to use them efficiently. When applied as a top dressing, a large part of the fertilizer is not reached by the roots until too late to be very effective, indeed a considerable portion may never become actually available to the plant because of the drying out of the surface soil as the season advances.

It should be added that the difference between the three methods of application is not fully apparent from the figures in Table 8. In 1921, fertilizer drilled in the row caused an increase in early fruit of 118 percent

over the unfertilized check; the same amount broadcasted, 35 percent and when applied as a top dressing, 45 percent. The increased yields due to top dressing and broadcasting fertilizers came principally during the latter part of the season.

Amount of Fertilizers to Use.—Some data are available as to the effects of various amounts of commercial fertilizer on tomatoes. Table 9 gives a summary of two years' tests at Columbia.

TABLE 9.—EFFECT OF VARIOUS AMOUNTS OF COMMERCIAL FERTILIZER ON YIELD OF TOMATOES.

(In pounds per acre)

Amt. of fertilizer per acre	1920			1921		
	Total yield	Gain	Percent gain	Total yield	Gain	Percent gain
	lbs.	lbs.		lbs.	lbs.	
None	21,050	----	----	9,640	----	----
125 lbs.	24,700	3,650	17.3	12,280	2,640	27.4
250 lbs.	25,710	4,660	22.1	13,550	3,910	40.6
500 lbs.	27,400	6,350	30.1	15,080	5,440	56.4
1000 lbs.	27,350	6,200	29.4	17,260	7,620	78.1

In 1920, the test was on Knox silt loam of rather high natural productivity and the fertilizer used was a 4-12-0 formula; in 1921, on a Putnam silt loam of low productivity and the fertilizer was a 2-12-2 formula. In 1920, maximum yields were produced by 500 pounds per acre and the application of additional amounts was apparently useless. In 1921, when the crop was grown on poorer land, the yield increased regularly with the amount of fertilizer and the increases were large enough to justify the heavier applications even if the tomatoes were sold for a low price to a cannery.

HARVESTING THE CROP

The tomato crop requires frequent pickings during a long season. When intended for immediate use or for sale to a canning factory, the fruit should ripen on the vines. Underripe fruits, if taken to a cannery, have to be culled out and kept for several days until they ripen. They require a longer period of cooking and they result in a lighter-colored product than is obtained from fruit ripened on the vine. The canneries are caused much loss and inconvenience because growers so frequently deliver them tomatoes unevenly ripened. When fruit is to be shipped some distance, it is desirable to gather it slightly underripe. Sando* found that tomatoes picked "on the turn", compared favorably to vine-ripened fruits both in composition and in taste, when ripened with free access of air. However, such tomatoes ripened without ventilation, as well as tomatoes gathered from the plants while still quite green, developed very poor flavor. These are facts of great importance to growers and shippers. Growers in general need to pay

*Department Bul. 859, U. S. Dept. Agriculture.

closer attention to the condition of the fruit when gathered, with reference to the use for which it is intended.

Preventing a Market Glut.—It is important to avoid as far as possible periods of over-supply on the markets. This condition is due to a large number of growers having crops approaching the height of their yield at approximately the same time. As a consequence the growers are taxed to harvest the crop, retail markets become "draggy" and the canneries are unable to handle all the tomatoes delivered. As a rule, a field which is planted early will ripen fruit more uniformly throughout the season than one which is planted late. Furthermore, there is a better seasonal distribution of the crop on soils that are well fertilized. It is also advisable to divide the tomato crop by planting two or three varieties which vary somewhat in season of maturity and period of heaviest yield, or to regulate the supply by varying the planting date, having a portion of the crop planted early and another portion two or three weeks later. The market demand for very late tomatoes in Missouri is sometimes nearly as good as for the extra early crop.

DISEASES OF TOMATOES

Blossom End Rot.—This trouble is common in dry seasons, causing the loss of most of the fruit formed during certain periods. The disease takes the form of a shrunken leathery brown or black decay at the tip ends of either green or ripe fruits. The decay usually advances slowly until the lower half of the fruit is shrunken in. The principal cause of this disease is lack of moisture; its prevention lies in controlling the moisture supply. Irrigation, either by flooding between the rows, or by the overhead spray method, has been found to reduce the amount of rot. Mulching with straw or other similar material checks this disease and is quite practical for small growers. On the other hand, losses from this rot are greatly increased in most seasons if the plants are staked, unless they are mulched also.

Shedding of Blossoms.—The dropping of blossoms without fruit setting is a frequent cause of loss. It is due probably to various unfavorable conditions. Anything that brings about abnormal growth or hinders the normal functioning of the plant is apt to cause shedding. If tomatoes are planted in soil very rich in nitrogen or if by the application of too much nitrogenous fertilizer (as stable manure) the plants are kept growing too rapidly, the fruit will not set. Rainy weather sometimes causes blossoms to drop, because of the rank vegetative growth resulting from excessive moisture. Very hot and dry weather also causes the blossoms to drop off before the fruit is set. The prevention of this trouble can be effected to a large extent by fertilizing judiciously, avoiding soils too heavily manured or too moist, and by planting early, so that fruit is set before hot dry weather.

Wilt.—This disease is common in most sections of Missouri and seems to be increasing rapidly in severity. It is caused by a *Fusarium* fungus, which is able to live in the soil for several years after a tomato crop. The fungus enters the roots and plugs the water-carrying vessels. Once the soil becomes infected, the tomato crop must be changed to fresh fields and every precaution taken to prevent spreading the disease by

manure, work tools, feet of animals or drainage water. Affected plants are characterized by the lower leaves and branches turning yellow, wilting and dying by degrees. The disease usually appears about midsummer and though the plants may not be entirely killed for some weeks, their yield is very poor and usually the latter half of the crop is a complete loss. Since this disease is so persistent in soils and is so easily spread to fresh lands, it has been thought especially important to develop resistant strains. Several experiment stations and the United States Department of Agriculture have introduced resistant strains which have considerable merit. At the Missouri Experiment Station, efforts are being made to develop resistant strains of vigorous growing, heavy yielding late varieties, such as suit best

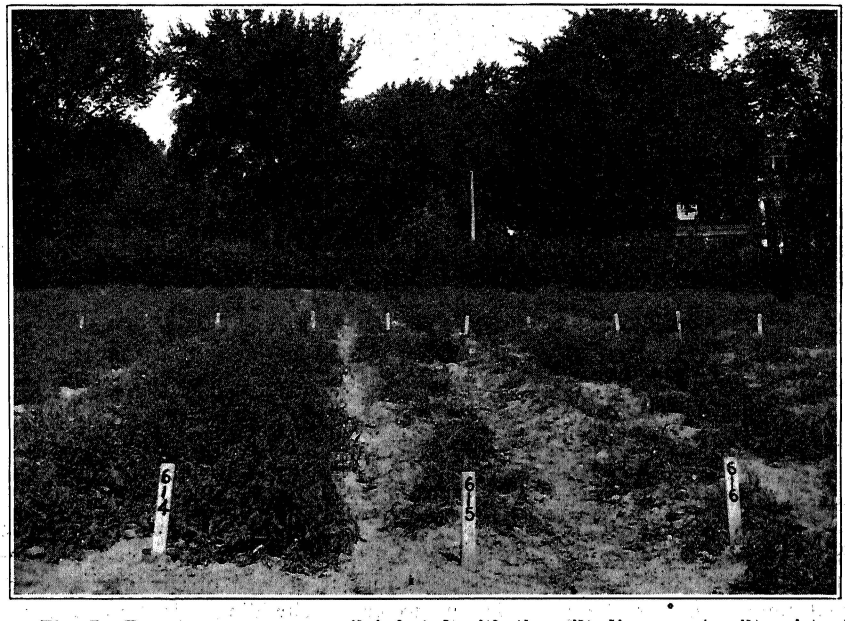


Fig. 7.—Tomatoes grown on soil infected with the wilt disease. A wilt-resistant selection in Row 614, and ordinary varieties in Rows 615 and 616. Columbia, Mo., August, 1921.

the cannery growers, as well as early sorts suitable for market growers. Figure 7 shows the difference between a resistant strain and an ordinary variety, when grown on wilt-infected soil. No variety has yet been developed which is immune to wilt, but a number of strains have been obtained which will succumb much more slowly than ordinary sorts and will therefore mature a much larger crop.

Leaf Spot or "Blight".—This is the most common disease of tomatoes, practically every field being more or less infected every year. It is a frequent cause of the premature death of the plants. The spores of the fungus causing this disease are spread readily by insects, by wind and rain and on the hands and clothes of pickers. The disease usually appears early in summer, beginning on the older leaves. It is first recognized in small water-

soaked specks on the under sides, which soon develop into larger brown dead spots. These brown spots increase in size rapidly if the weather is damp, the older leaves are killed and the disease spreads to the younger parts of the plant, frequently resulting in complete defoliation in August. This leaves a crop of partly grown fruits to ripen on the dead vines, these are of poor quality and the late crop is a total loss. In dry seasons, however, the disease spreads slowly and may do very little damage.

Spraying.—Efforts to control tomato leaf spot by spraying have been made by several experiment stations with varying results. Pritchard and Clark[5] in experiments in several eastern states, found considerable increase in yield from spraying, the benefit of the spray being greatest when the

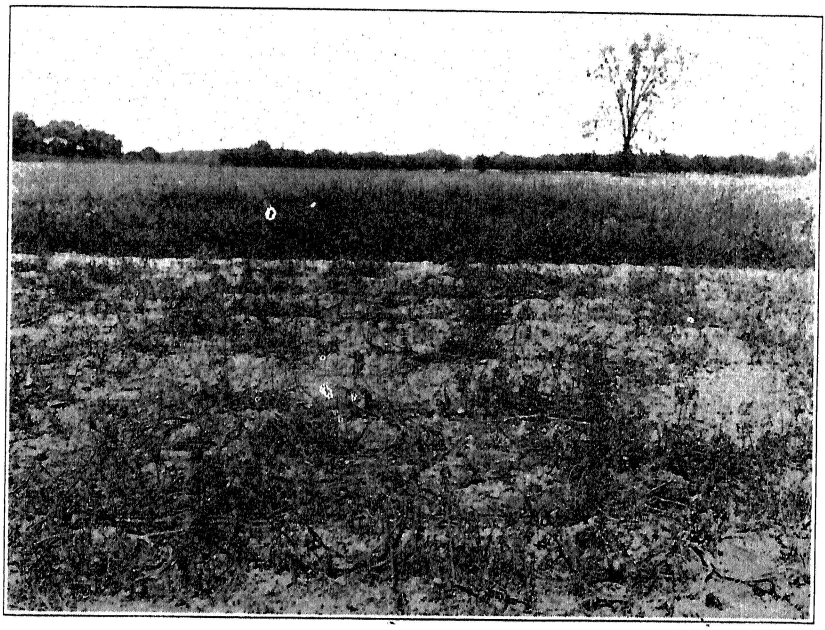


Fig. 8.—Unsprayed tomato field near that shown in figure 7. Leaf spot caused death of plants in late summer.—Courtesy of New Jersey Experiment Station.

disease became severe early in the season. On the average, a copper-soap mixture gave the best results. In New Jersey[6], it was found that spraying four times with bordeaux mixture increased the yield but did not control the disease to any great extent. Spraying with copper-soap mixture (½ pound bluestone, 3 pounds fish oil soap, 50 gallons water) gave good results and was recommended because it is much cheaper than standard 4-4-50 bordeaux. In Illinois[7], by spraying tomatoes with bordeaux the total yield was increased to a marked degree, but the amount of early fruit was reduced somewhat. Evidently sprayed plants remain alive longer and pro-

[5]Phytopathology, Vol. IX. Pp. 554-564. December, 1919.
[6]New Jersey Agr. Exp. Sta. Bul. 345, 1920.
[7]Illinois Agr. Exp. Sta. Bul. 144, 1910.

duce more late fruit. Pritchard and Clark[8] concluded, as a result of a large number of tests conducted in several states during three years, that spraying did not consistently affect the yield of early fruit but in the majority of cases the yield from the first three pickings was greater on sprayed plots.

From the rather extensive experiments in other states, it may be concluded that the leaf spot disease can be controlled fairly well by spraying, the effect usually being to increase the yield and quality of the latter part of the crop. In some localities the leaf diseases are so severe, that production of tomatoes is small unless thorough and timely spraying is practiced. The home gardener and the cannery grower especially may gain much by keeping the tomato vines in healthy productive condition throughout the season.

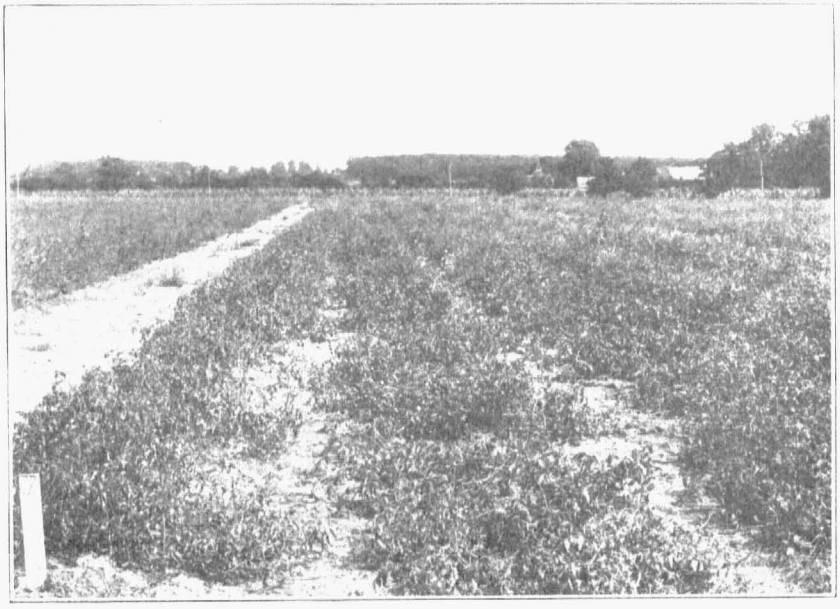


Fig. 9.—Tomato field sprayed with weak bordeaux mixture plus fish-oil soap. In healthy condition in late summer.—Courtesy of New Jersey Experiment Station.

In addition to spraying, there are other practices which will do much to prevent the leaf spot disease and are important for other reasons. First, since several diseases are harbored in the plant bed and frequently disseminated from it, fresh soil should be used in it each year. Second, plants should be sprayed thoroughly with bordeaux mixture before removal from plant bed to field. Third, the tomato crop should not be planted on the same land more frequently than once in three or four years. Fourth, tomato vines should be gathered and burned in the fall, instead of turning them into the soil or incorporating them with manure or compost where the chances of redistributing diseases would be excellent.

[8]Phytopathology, IX, pp. 289-301, July, 1919.

INSECTS

Fruit Worms cause some damage to the tomato crop each year and in some seasons are very destructive. They bore into the green or ripening fruit, rendering it unfit for use. There are a number of broods of this insect in Missouri each year, one emerging about the time early fruit is setting. Usually the late broods are most injurious, but sometimes much of the early fruit is destroyed. This pest passes the winter in the soil; consequently deep plowing in fall or winter will help protect the next year's crop. Planting a small quantity of sweet corn in or near the tomato field will serve to trap a great many of the worms, if it is planted so as to reach the silking stage about the time the tomato plants begin fruiting. The wormy corn must of course be gathered and destroyed to eliminate later broods. Late summer injury has been eliminated by gathering and destroying all wormy fruit the early part of the season.

That the loss of tomatoes from fruit worms can be reduced by proper spraying also is indicated by work in Virginia[9]. In 1919, sprayed plots had 16.25 percent of the fruits injured by worms, while in an unsprayed plot 25.23 percent were injured. In 1920, the sprayed plots had an average of 13.7 percent and an unsprayed plot had 21.39 percent wormy fruit. The spray material used was bordeaux mixture plus 2 pounds arsenate of lead powder to 50 gallons. The importance of thorough spraying and of high pressure is brought out in the Virginia experiments.

SUMMARY AND RECOMMENDATIONS

Profits in growing tomatoes for the canning factory and for market can be increased by adopting methods and practices which increase the yield per acre at small expense.

Varieties should be selected which are especially adapted to the purpose for which they are grown.

The best seed is the cheapest in the end—home selection and saving is the safest way to get it.

The yield and earliness of the crop depend largely on the size and vigor of the plants used. For the cannery grower, the coldframe method will probably give best results. The market and home gardeners' needs can be met most satisfactorily by the hotbed-transplanting method, unless a greenhouse is available.

Early setting of plants in the field is very desirable; it increases earliness and total yield, enables plants to make greater use of fertilizers, favors good growth before summer drouth and lengthens the picking season.

Phosphorous is the fertilizing element most needed by tomatoes on all soils of this region; it can be applied in mixed fertilizers, in acid phosphate, or in bonemeal.

Nitrogenous fertilizers and potash fertilizers used alone, are not likely to produce profitable increases in yields of tomatoes in Missouri. However, small amounts of these in mixed fertilizers will probably prove profitable under certain conditions. The good effects of nitrogen and potash are shown most on soils cultivated for years without the application of manures or turning under of green-manuring crops.

[9]Va. Truck Experiment Station, Bul. 33, 1921.

Rotted stable manure at the rate of 8 tons per acre increases the yields of tomatoes as much as 250 pounds of high grade commercial fertilizer but not as cheaply. Furthermore, stable manure may retard the early ripening of fruit. The following are general conclusions:

1. On very poor, badly worn, or sandy soils, a complete fertilizer having approximately the formula of 2-12-2 seems most desirable under present conditions.

2. On soils of medium productivity a mixed fertilizer without potash, such as 3-12-0, will probably give best results.

3. On soils of high productivity, or where stable manure or legume crops have recently been plowed in, 16 percent acid phosphate alone is probably the most economical material for fertilization.

Best results from commercial fertilizers may be expected when this is drilled into the row and mixed with the soil before the plants are set.

The most economical amount of fertilizer to use depends largely on the natural productivity of the soil—the poorer the soil, the more fertilizer profitably used by the crop. Applications up to 1,000 pounds per acre have given profitable increases on poor land, while on more fertile soil the use of 500 pounds per acre was most profitable. Light applications, 200 to 300 pounds per acre, have given very profitable increases, and perhaps until growers become more familiar with use of commercial fertilizers, the light applications are safest.

Tomatoes fertilized with 250 pounds per acre of complete fertilizer have usually ripened a much larger amount of early fruit than those receiving no fertilizer. Acid phosphate also has increased the earliness, but not as much as the complete fertilizer.

On rich or well manured land, commercial fertilizers may increase the earliness of the crop without increasing the total yield very much.

Mulching with straw or similar material retards earliness somewhat, but greatly increases the yields of late fruit; it is recommended for home gardeners and for market growers having a demand for late tomatoes.

Staking plants and pruning to a single stem is unprofitable. It does not increase the actual amount of early fruit and greatly reduces the yield of late fruit.

Staking plants without pruning does not affect the yield very markedly. This practice may be advisable for home gardeners, who wish to save space.

Tomato wilt can be prevented by growing the crop on fresh land. Resistant varieties are available which will produce a fair crop on badly infected soil.

Leaf spot or "blight" can be controlled by rotation of crops, use of fresh soil in the plant bed, spraying or dipping plants in bordeaux mixture just before transplanting to the field and by application of copper sprays to plants in the field.

Spraying for disease control is necessary in many localities where leaf diseases are serious. Usually, home gardeners and cannery growers can gain much by spraying, for the plants are kept in healthy vigorous condition until the end of the season.